Design and Implementation of PC-Based Prototype Electronic Stethoscope for Internet-Based Telemedicine System Application

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Abstract

This paper is a progress report on our recent experiments of the design and implementation of prototype PC-based portable electronic stethoscope for generating four types of auscultation mode that have better auscultation frequency and sound amplifier than acoustic stethoscope. This system has also the software to record the patients' identity and auscultation sound that useful for medical diagnosis. The four types of auscultation mode that can be selected i.e. normal mode (20 Hz – 2 kHz), respiratory mode (150 Hz – 2 kHz), cardiac mode (20 Hz- 660 Hz) and wheeze mode (60 Hz – 2 kHz). The auscultation sound is recorded by PC in digital form that can be transmitted to the other area/unit through the Internet using GSM/CDMA mobile phone as the telemedicine system application.

This prototype utilizes electrets microphone, pre-amplifier, wide band pass filter, mode selector circuit, 4 filter circuit, audio amplifier and dynamic speaker. This prototype is connected to the Personal Computer for recording patients' identity and auscultation sound in the database system.

The results of preliminary hardware test show that maximum audio amplifier is 38,8dB and the frequencies of auscultation mode have error 0.6%-0.7% from the design specifications. Therefore the auscultation sound can be heard clearly. The software has been tested and has succeeded to record and retrieve the patients' identity and auscultation sound files.

Keywords: *Ausculatation, database, electronic stethoscope, internet, PC-based, telemedicine system.*

1. Introduction

The Prototype of electronic stethoscope in this research consists of electronic circuits, i.e. electrets microphone, pre-amplifier, wide band pass filter, auscultation modes selector, four modes filter, audio amplifier and dynamic speaker. This prototype system is designed for four modes auscultation that can be selected through the auscultation modes selector. Four types of auscultation mode that can be selected are normal mode (20 Hz – 2 kHz), respiratory mode (150 Hz – 2 kHz), cardiac mode (20 Hz- 660 Hz) and wheeze mode (60 Hz – 2 kHz).

The output of electronic stethoscope prototype is connected to the Personal Computer for recording patients' identity and auscultation sound in the database system. The auscultation sound is recorded by PC in digital form that can be transmitted to the other area/unit through the Internet for diagnosing process that conducted by specialist medical doctor. This is one of methods in telemedicine system application for transmitting the several types' biomedical information. Figure 1 shows the system block diagram.

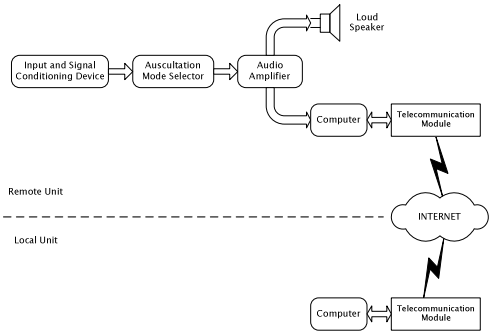

Figure 1. The simple block diagram of PC-based prototype electronic stethoscope for telemedicine system application

2. Telemedicine system

Telemedicine system is an application of communication, electronics and computer technology in order to provide medical information transfer from one place to another remote place[3]. The goal of telemedicine system is to assist medical procedure (data collection, data

analysis, diagnosis, theraphy and further actions) conducted by medical doctor.

Telemedicine system will convey the following medical information such as:

- Text (*alphanumeric data*), e.g., patient medical record
- Physiological signals, e.g., ECG, EEG, EMG, ERG, EOG signals
- Medical images
  - Still image, e.g., Bone *X-ray* image and *thorax* image
  - Moving / dynamic image, e.g., heart image taken from USG.
- *Voice* and *sound*, example Auscultation sound, *Doppler sound* and voice of the medical doctor.
- Combination of above medical information.

Telemedicine system is also developed for supporting several applications, such as: tele-diagnosis, tele-consultation, tele-health information system, tele-health education which are very important for improving community health care services. One key element of telemedicine system, which is very important in order to be able to transfer medical information, is the availability of the telecommunication network which is reliable, good quality of service, and wide coverage.

In order to implement telemedicine system, a health unit needs to have a telecommunication network in order to be able to communicate with other health unit (center health unit or referral hospital). Unfortunately, the availability of the wired telephone line (public switched telephone network) is very limited, not every health unit has telephone connection. To solve this problem, we propose an alternative to use many features of wireless telecommunication networks which have been developed very rapidly for supporting several telemedicine applications; they include both fixed wireless and mobile wireless telephone system.

3. Scope of research

The references data are applied for determining the auscultation sound frequency division of electronics stethoscope prototype in this research i.e. US Patent Office No.5.602.924[2] and official publication from Indian Academy of Clinical Medicine[1]. The ranges of auscultation sound frequency division for four type of auscultation mode i.e.

- Normal Mode, frequency range: 20 Hz – 2 kHz, for filtering cardiac sound and respiratory sound frequencies.
- Respiratory Mode, frequency range: 150 Hz – 2 kHz, for filtering only respiratory sound frequency.
- Cardiac Mode, frequency range: 20 Hz – 660 Hz, for filtering only cardiac sound frequency.
- Wheeze Mode, frequency range: 60 Hz – 2 kHz, for filtering the wheeze sound.

In designing and implementing process, system divided into 3 modules i.e. hardware module, software module, and telecommunication module. Hardware module includes microphone, pre-amplifier, wide band pass filter, mode selector, logic switch, buffer, high pass filter, low pass filter, audio amplifier, speaker, power supply and PC interface.

Software module that designed in this system consists of database system using Microsoft Access and GUI (graphic user interface) using Visual Basic 6.0 for displaying audio-visual auscultation data from recording process of the electronic stethoscope. And telecommunication module is designed using GPRS (General Packet Radio Services) or PDN (Packet Data Network) application in GSM or CDMA mobile phone technology. The system block diagram is showed in Figure 2.

In Figure 2, we can see that sound signal will be captured by microphone to be converted to electrical signal. Then, this electrical signal is amplified four times by pre-amplifier and filtered by wide band pass filter to yield only sound frequency that has frequency range i.e. 20 Hz – 2 kHz. The electrical signal will be conducted to one of four auscultation modes that appropriated with the mode selector position. Four types of auscultation mode consist of one electronic buffer circuit and three electronic filter circuits, which produce four different types of frequency range.

After filtering process, the signal will be amplified (26 dB) by audio amplifier circuit. The amplified signal can be connected to the loud speaker or to the Personal Computer through the line in of sound card device. If the system using the PC, we can record and retrieve the patients' identity and auscultation sound in the database system in digital form, as well as we can display the auscultation signal in the monitor.

The digital data can also be transmitted to the other area through the Internet for diagnosing process that conducted by specialist medical doctor using telecommunication modules. In this research, we use GPRS or PDN application to connect to the Internet in mobile phone technology through the one of several GSM or CDMA mobile phone operators. The mobile phone is connected to the PC through the USB port or serial port.

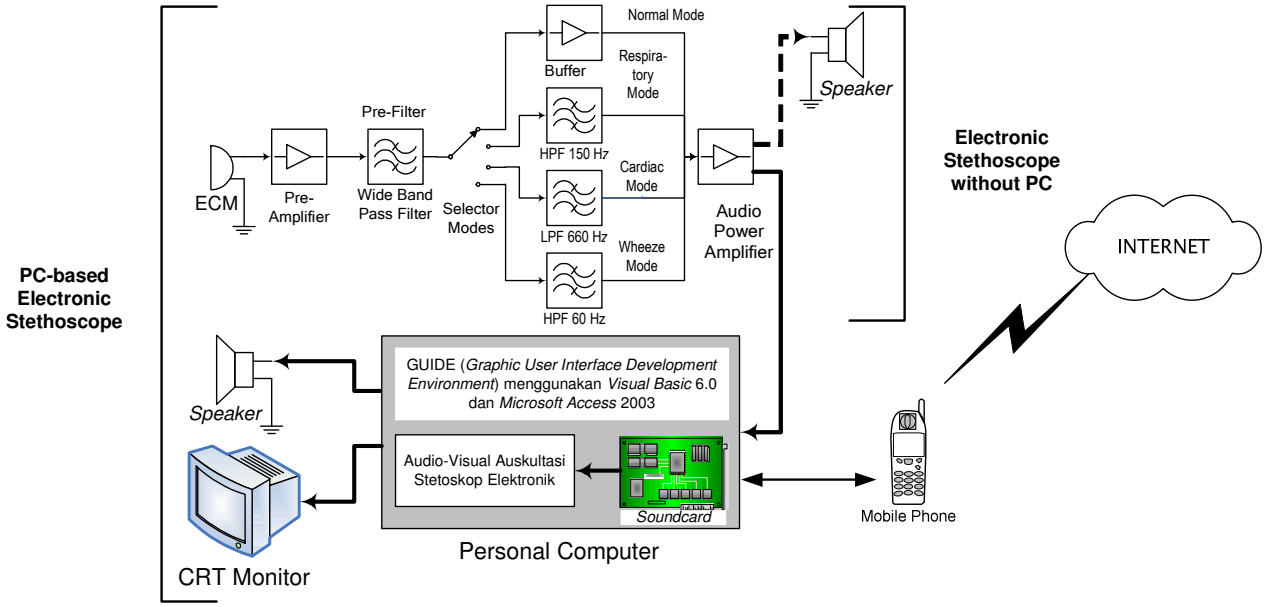

Figure 2.Block diagram system of hardware and telecommunication modules.

4. Preliminary results

After having built the system, then we have to do three different tests and measurements. We have run the following two different tests and measurements, i.e.: hardware module test and software module test. The telecommunication module as the fourth test is still performed now in Bandung area.

4.1. Hardware module test

The goal of this test is to measure the maximum gain of amplifier circuit, the form of output signal and the frequency range of four types of auscultation mode. In this test, we also measure the battery life time for this prototype. Speaker is used as the load for this measurement that connected series to the resistor. The block diagram of hardware test is illustrated in Figure 3.

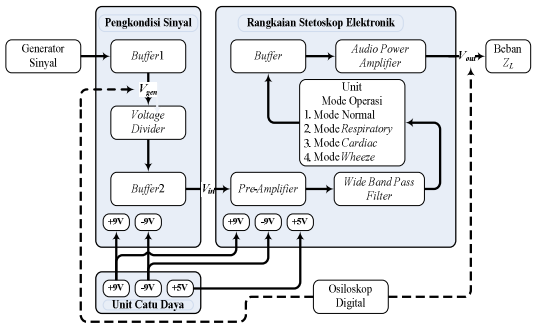

Figure 3. Block diagram of electronic stethoscope circuit test

The test is performed with giving sinusoidal input signal to the pre-amplifier and measure the output signal from the audio power amplifier. One of signal curve characteristics from the test results of electronic stethoscope circuit in cardiac auscultation mode is illustrated in Figure 4.

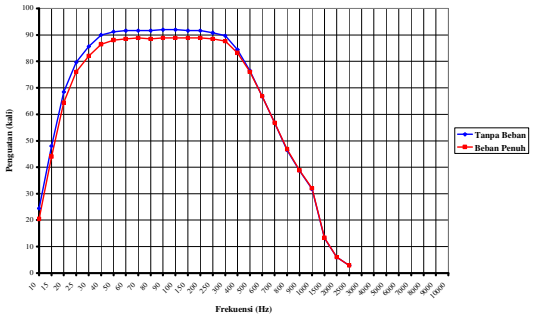

Figure 4. Signal curve characteristics of cardiac auscultation mode (20 Hz - 660 Hz)

The result recapitulation of cut off frequencies and gain tests for four types of auscultation mode can be seen in Table 1 and Table 2.

Table1. Cut-off frequency of four types of auscultation mode

Auscultation Mode	Lower *Cutoff* Frequency	Upper *Cutoff* Frequency
Normal	19,69 Hz	1,988 kHz
Respiratory	143,7 Hz	2,016 kHz
Cardiac	19,42 Hz	641,0 Hz
Wheeze	57,14 Hz	2,016 kHz

Table 2. Maximum gain of four types of auscultation mode

Auscultation Mode	Maximum Gain (times)	Maximum Gain (dB)
Normal	90,0 times	39 dB
Respiratory	88,0 times	38,89 dB
Cardiac	88,8 times	38,96 dB
Wheeze	88,4 times	38,92 dB

4.2. Software module test

This test includes recording and retrieving of the patients' identity and auscultation sound files. In this test, we also performed to display the auscultation signal and play the auscultation sound. We have performed this system to approximately 19 patients and the recorded signals have been consulted to the medical doctor. Figure 5 shows the registration form for new patient and Figure 6 shows the recorded patient signal.

Figure 5 Registration form for new patient

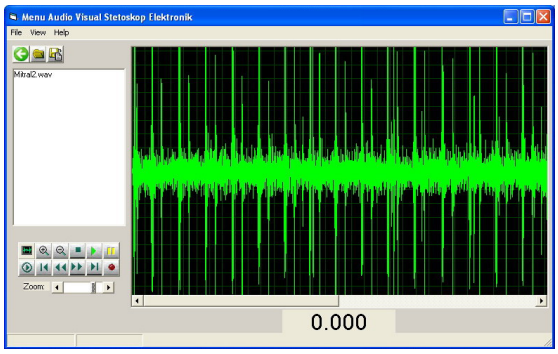

Figure 6 Recorded patient signal

5. Conclusion

According to the results of the experiment, we can draw the following preliminary conclusions:

- Design and implementation of hardware module and software module of the electronic stethoscope system has been tested successfully.
- The maximum audio amplifier is 38,8dB and the frequencies of auscultation mode have error 0.6%-0.7% from the design specifications.
- The auscultation data in digital form will be tested with transferring the data through the Internet using GSM (GPRS application) or CDMA (PDN application) mobile phone.

6. References

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