ELECTROCARDIOGRAM MONITORING USING WIRELESS LAN ECG

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1. Introduction

Electrocardiogram (ECG) is a physiological signal produced by electrical activity of heart. ECG is recorded using electrocardiograph device. There are three types of electrocardiograph device, categorized by different purposes of the ECG measurement. Standard clinical ECG uses 12 electrodes and paper chart to represent ECG signal. Monitoring ECG uses 1 or 2 electrodes and a cathode ray tube (CRT) to display the signals. In monitoring ECG, patient's ECG is recorded for a certain period to observe patient's heart condition. Sometimes, patient should be examined in other room so monitoring ECG will be interrupted because the ECG device can not be moved

To solve problem mention before, this paper proposes a design of portable ECG device connected with wireless data transmission module. Using portable device, if patient has to move to another room for other examination, monitoring ECG still can be conducted. It is made possible by the use of Wireless Local Area Network (LAN) 802.11b, chosen for data transmission because 802.11b protocol is common in Indonesia. For some computer, 802.11b devices is embedded, that allows PC or notebook to receive the data without additional devices. By transmitting ECG data that will be received by server, patient's ECG could be monitored every time even the patient mobile form one room to another room.

2. The ECG

ECG signal has voltage up to 5 mV and frequency from 0.5 Hz until 100 Hz. ECG signal has specific waveform, therefore it can be used to indicate the health of the heart. ECG signal is recorded using electrocardiograph. ECG waveform has several components such as: P wave, R wave, QRS complex, T wave, P-R interval, and R-T interval. Each component of ECG indicates specific activity of human heart. The relationship between ECG waveform with cardiac activity is as follow:

a. P wave is the electrical waveform that is caused by atrial contraction, i.e. the portion of the ECG tracing that represents depolarization of the atrial myocardium. Initial portion of the P wave is largely a reflection of right atrial depolarization, and the terminal portion reflects depolarization of the left atrium.
b. R wave is a portion of the ECG that represents the end of atrial contraction and the beginning of ventricular contraction.
c. QRS complex is a portion of the EKG tracing that represents depolarization of the ventricular myocardium. Normally the ventricles are activated simultaneously
d. T wave is a portion of the ECG that represents ventricular repolarization
e. PR interval: time interval from onset of atrial depolarization (P wave) to onset of ventricular depolarization (QRS complex)

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f. The isoelectric period (ST segment) following the QRS is the time at which the entire ventricle is depolarized and roughly corresponds to the plateau phase of the ventricular action potential.

A normal ECG waveform can be seen at figure 1.

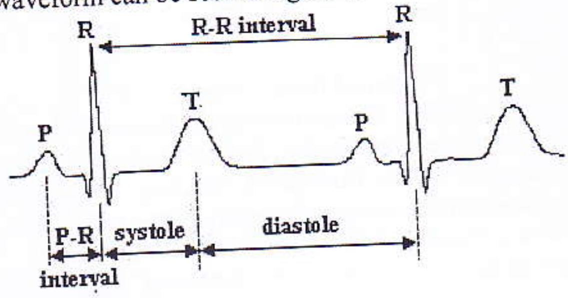

Figure 1: A Normal ECG

Table 1: Parameter of Electrocardiogram [1]

ECG Wave	Amplitude	ECG Interval	Duration
P	< 0.3mV	P-R	0,12 – 0,20 second
R	1,6 – 3mV	Q-T	0,35 – 0,44 second
Q	25% from R	S-T	0,05 – 0,15 second
T	0,1 – 0,5 mV	Q-R-S	0,06 - 0,10 second

The Interval between consecutive R indicates period of heart beat which can be converted to *Heart Rate*: (1)

$$HR = \frac{60000}{R-R} \quad (bpm)$$

R – R = interval between consecutive R wave, in millisecond.
Interval R-R is almost constant, the change of R-R interval indicate abnormal heart rate.

There are three methods to record ECG waveform [2]:

1. Standard Clinical ECG
   This method uses 10 electrodes (12 leads), and is used to diagnose the heart of patient.
2. Vectorcardiogram
   It is modelling human potential as 3 dimension vector by using bipolar Einthoven leads. It records ECG signal using 3 electrodes at body surface. Einthoven lead configuration can be seen at figure 2.
3. Monitoring ECG
   This method uses 1 or 2 electrodes which is attached at body surface, and is used to monitor the patient's heart in long time period.

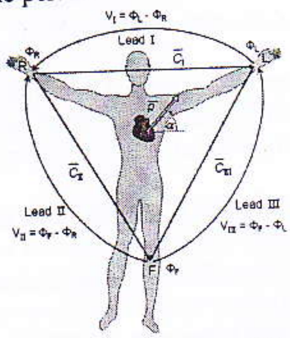

Figure 2: Einthoven triangle configuration [3]

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3. System Design

Design of proposed Wireless LAN ECG system can be seen at figure 3. ECG signal is recorded by use a single channel ECG then this signal is transmitted via wireless LAN network to server. At the server, this data will be recorded, displayed, and analyzed. The circuit of single channel ECG can be seen at figure 4.

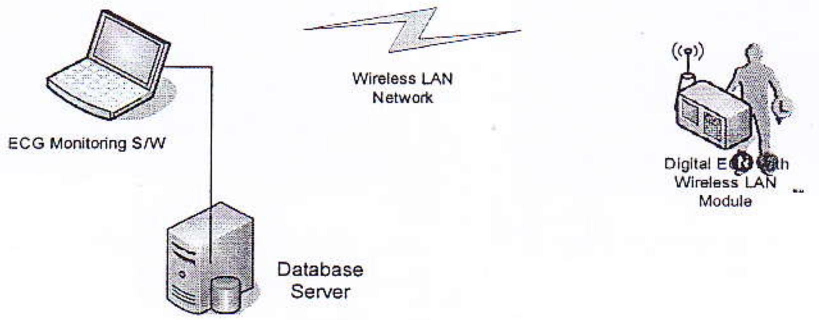


Figure 3: Wireless LAN ECG system

Single Channel ECG

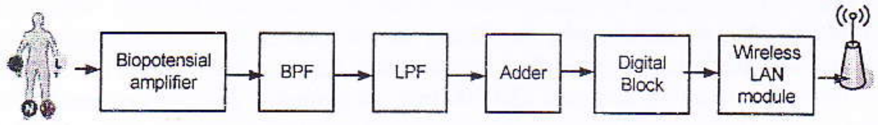
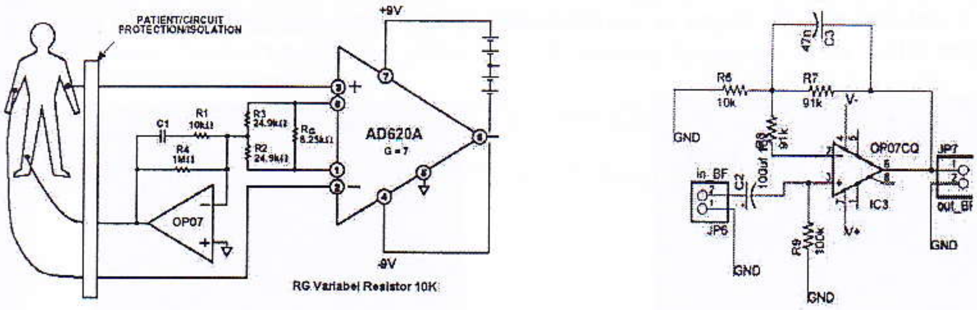


Figure 4: Single Channel ECG System with Wireless LAN Module

ECG signal is captured using electrode then it is amplified using bio-potential amplifier. Band pass filter (BPF) is used to limit signal in 0.5-40 Hz to remove low frequency noise and 50Hz power line interference. Low pass filter (LPF) is used to limit ECG signal under 20Hz. Adder will raise voltage level up to 1 volt to make ECG signal level suitable as input of analog digital converter (ADC). Analog process of ECG signal will produce signal within 0.5-20 Hz and 0-4 Volt. Figure 5(a) and Figure 5(b) show bio-potential amplifier circuit and BPF circuit respectively.



(a) (b)

Figure 5: (a) Bio-potential amplifier[4] (b) BPF 0.5 – 40 Hz

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Digital Block and Wireless LAN Module

Digital subsystem consists of 0804 analog to digital converter, AT89C51 microcontroller, and serial communication RS323. Circuit of wireless LAN ECG digital subsystem can be seen in Figure 6.

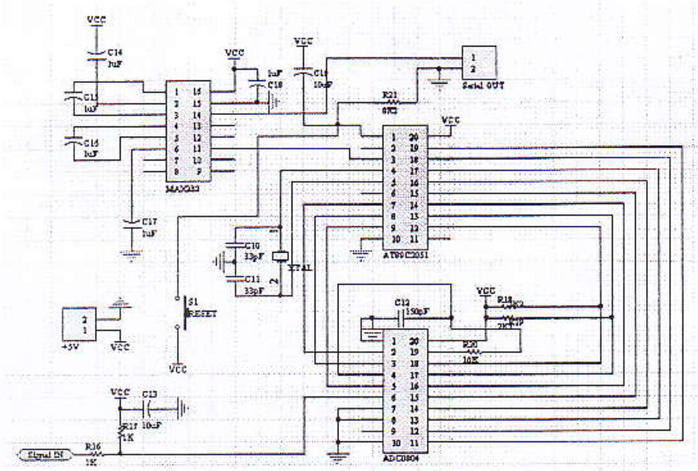


Figure 6: Digital subsystem

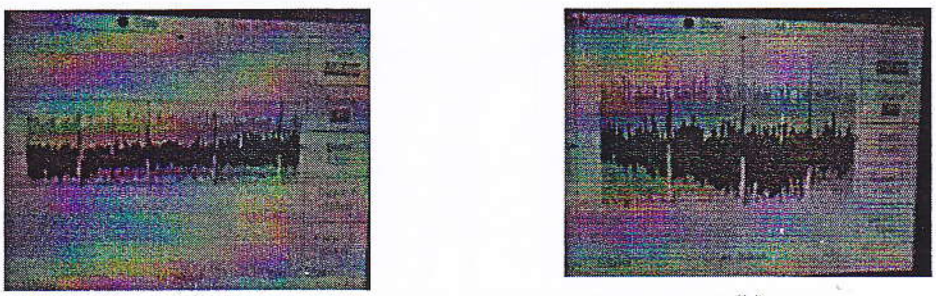
This design uses Wiz610wi, embedded wireless LAN module from WIZNET®[6] as transmitter module. This module works to change serial data communication to *wireless* LAN 802.11b standard data packet. This module has processor, data memory, 802.11b transceiver, and serial connection with maximum data rate 230.400 bps. This module can be connected to PC/laptop without access point. To connect the module with digital ECG, we connect data output of RS232 with pin number 2 DB9 of Wiz610wi.

Monitoring ECG Software

The software was developed using Borland Delphi 7. Generally, this software will check whether data transmitted by wireless LAN module exist. After the ECG data are received, ECG data will be displayed at PC monitor and saved to database.

4. Result & Discussion

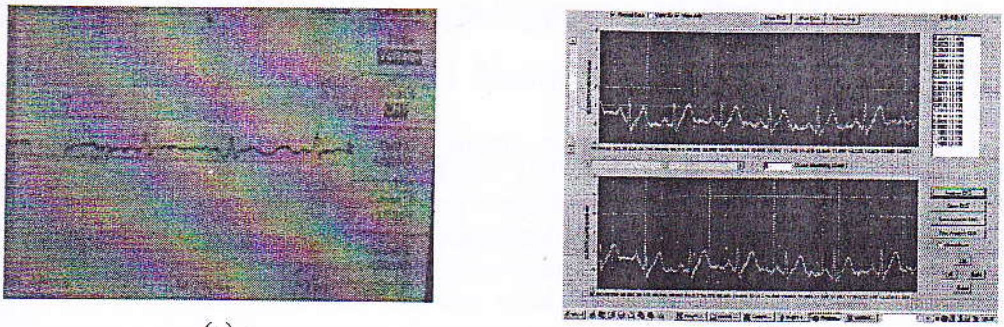
Output signal of bio-potential amplifier and output signal of BPF are shown in figure 7(a) and 7(b) respectively. Figure 7(a) and 7(b) show that ECG signal has higher level but noise is still exist. Noise is reduced in LPF output as shown in Figure 8(a) and signal ECG received by PC is shown in Figure 8(b).



(a) (b)

Figure 7: (a) Bio-potential amplifier output (b) BPF output

ECG signal received by PC shows that ECG had been transmitted properly and noise was reduced to tolerable level. In ECG recording process, patient's movement causes noise significantly. It therefore needs signal processing step to reduce patient's movement noise.



(a) (b)

Figure 8: (a) LPF 20 Hz output (b) ECG signal received by PC

5. Conclusion Remark

Wireless LAN ECG device has worked properly. Signal conditioning block is able to amplify ECG signal to level that can be transmitted by wireless LAN module and the receiver can receive the transmitted ECG signal. Some existing problems are stability of the device and the limitation that one server could access only one device. Patient's movement produces noise that significantly disturbs the received signal. Special filter is needed to minimize the noise. For next work, we still try to make server that can received ECG form some devices simultaneously.

Acknowledgments

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