

The Wireless Electrocardiography through the Computer Global Network

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Abstract

The electrocardiogram is a physiological signal as the key for assessing the public health. Our development of the electrocardiography (EKG) using two electrodes was designed upon the two-position measurement method. The electrodes sense the electrocardiography signals from the skin, and transfer to the amplifier unit. The amplifier was designed for high input impedance with lower noise (sound pitch). The amplified signal filters the sound reduction before digitizing to digital signal. The data signal is sent to the EKG Analyzer System via Bluetooth wireless communications and displays the EKG signal in real time. The Wireless and Cloud Electrocardiography (W&C EKG) is safe for human on electrical shock hazards as a result of the electrodes and measurement unit, the use of small batteries, and a completely isolated from electrical power source. The system provides the analysis functions of cardiac time intervals, PR interval, QRS interval, QT interval, RR interval, and ST segment in line with the medical device standards. The personal records stored on Cloud system can be displayed on the computer global network, personal computers, notebook computers and portable devices such as mobile phones or Tablets. The W&C EKG could be used for monitoring health applications and conditions to improve personal health life style and activities.

Keywords: electrocardiography; heart; computer global network; wireless; Cloud

1. Introduction

The current communication technology evolution has rapidly progressed. The communication over long distances can be done more conveniently through the computer global network such as personal computers or portable devices with an access into electronic mail (e-mail) for sending and receiving pictures and sounds. Additionally these devices have capability of intercommunication with various peripherals devices, divided into two main connecting wired signals, such as Universal Serial Bus (USB), Serial port RS232, HDMI and VGA, and the other is connected with wireless technologies like network access; Wireless

fidelity (Wi-Fi), Bluetooth (BT), Radio frequency (RF) communications equipment. An electrocardiogram (EKG) are used to record electrical changes in the myocardium during the cardiac cycle. Hence the electrocardiogram is an important physiological signal for assessing the health condition inquiries¹⁻⁴. As well as to send information of EKG signals online, it is possible to help the specialist preliminary to diagnose and give the suggestion to prevent heart disease. However, the conventional EKG instrumentations are large and very expensive, only found in a well-organized hospital. It's, still, difficult for someone to get such services except heart disease patients.

For this reason, to develop portable and low cost W&C EKG (Wireless and Cloud Electrocardiography) is to help people monitoring their EKG signal and become alerted when they have found an abnormal signal and get proper consultations from a Cardiology physician. Accordingly, the system design is proven to be safe for humans from electrical shock hazards and provides analysis on critical parameters. Therefore, without any trouble, technical results can be obtained via different types of portable devices.

The research of Pavlopoulos and team (1998)⁵ have developed a device that can help diagnosis via a long-distance by providing information to support primary care and the patient was advised by medical professionals. The device was developed by the team can send major signals and pictures of patients, for example, from the crime scene to the counseling center via mobile phone. This device helps medical professionals at the center and able to evaluate the patient's information and make recommendations to primary care appropriately. The research for development of these devices was similar to the work of Steven Green Hindenburg, Cardiologists of St. Frances C. York hospital; which has connected the heartbeat device to his heart patients at home via the Internet. It can detect abnormal rhythm of heart patients at home at any time. The critical information of the patient is automatically saved to the office to help to analyze and prevent of heart rhythm disorder in patients, and is easy to take care and quickly respond⁶. According to research in Thailand in 2006, development of recording EKG signal by using Bluetooth for EKG wireless measurement to detect basic signal of patients, such as heart rate and body temperature could be recorded in memory⁷. Later in 2008, the recording EKG data development using microconverters ADuC 8425 for main processor and digital sound filtering and minimizing, the analog filter circuits used a digital signal processing technique for heart rate analysis and displayed

the component of EKG signal⁸. In addition, it also included the design of a portable EKG recorder running on Windows with EKG signal program and the main server for inquiries⁹. The analysis and information process, EKG is capable of determining the positions of the QRS wave and heart rate. The data can be transmitted via the internet. However, the equipment is still not portable. From the previous studies, there were not much EKG development reported, also the available EKG equipment have not been able to analyzed or displayed clearly in critical values such as of the Cardiac intervals or the distances between waves (Inter-wave Segments).

2. Materials and Methods

2.1 Design principles

The changing of electrical-chemical reactions of the heart cause the cardiac contractions. Electrocardiography is a medical examination to observe the heart's electrical reactions that change over time. The electrical signals from electrodes attached on the skin of the chest area, the voltage at each position away from the heart will change according to the contraction and relaxation of the heart.

The EKG measurement used the conducting plate to sense the voltage at each point around the heart, an electrical potential based on the measurement and the distance from the heart. In general, the EKG electrodes are used to measure 12 leads but we have develop the electrocardiography (EKG), using two electrodes for two positions measurement method. The electrodes sense the electrocardiography signals from the skin, and transfer to the amplifier unit. The amplifier was designed for high input impedance and low impact of sound. The amplified signal was filtered for noise reduction using active filter before digitizing to a digital signal. The data signal is sent to the EKG Analyzer System via Bluetooth wireless communications and displays the EKG signal in real time. Consequently, the W&C EKG

(Wireless and Cloud Electrocardiography) is safe for human being on electrical shock hazards due to the electrodes and measurement unit, using small batteries, and completely isolated from electrical power source. The system provides analyzes functions, including the PR interval, QRS interval, QT interval, RR interval, ST segment in accord with the standard EKG signal. Moreover, the personal records stored on Cloud system can be displayed on a personal computer, notebook computers and portable devices such as mobile phones and Tablets Figure 1A.

2.2 The Development steps

Equipment

1. IC Instrument Amplified AD 620 (Analog Devices).
2. Electronic components, such as capacitor, resistor, battery, any cables.
3. Bluetooth transmitter
4. Bluetooth receiver
5. Electronic Circuit Box
6. ECG electrodes.
7. Notebook Computer
8. Cloud system (WD My Cloud, Western Digital).

Development of W&C EKG is composed of two major areas: the design of hardware and software components, are as follows,

2.3 The Hardware design

2.3.1 EKG Amplifiers Circuit.

Amplified Circuit was designed for the signal from the electrode plates on the skin near the heart. The voltage would be changed in according to the heart contraction cycle. The receiver circuit had high input impedance and low noise (sound pitch). IC Instrument Amplified AD 620 of Analog Devices was used for this circuit adjusted to low current and compliant with the design work. The Gain is related to resistance between pin 1 and pin 8 as equation below.

Gain = $1 + (49.4 \text{ kohms} / R \text{ across pin 1 and pin 8})$.

2.3.2 Filters circuit

EKG signal measured from the skin produced noise (high sound pitch) such as in electrical power and electromagnetic radiation. From previous reports that the system needs to filter out the unwanted signals, only the EKG signal in the frequency range between 0.03 to 70 Hz are allowed to pass¹⁰ Therefore, the circuit design was integrated with the filter in a range from 0.01 to 100 Hz frequency responses. The filters uses active filter types that could simply amplify and filter at the same time before sending the signals for processing via Bluetooth.

2.3.3 Design of the electrode points for the EKG measurement

The EKG measurement uses two signal electrodes from two positions with one ground point displaying clear EKG signals. The positive attached 2 inches away from the edge of left armpit and 1 inch below the collarbone (No.1), the negative attached next to the fourth right ribs under the breasts (No.2) and the ground attached to the right ribcage (No.3) as illustrated in Figure 1B.

2.4 The Software design

2.4.1 The EKG Signal input

The data signals input via Bluetooth used the subprograms "Sound Acquisition" on LabView program by setting the resolution = 16 bit, duration = 4 second and sampling rate = 11,025 Hz.

2.4.2 The Noise filter

Input data were collected by the subprograms "Configure Collector" then transfer to the subprograms filter, software filter in LabView as illustrated in Figure 1C

To filter out the low frequency and high frequency signals by using a Band Pass function. Setting the value of Low cut off frequency = 0.3 Hz, High cut off frequency = 38. Hz and selected a filter type to be Butterworth with the order = 30.

2.4.3 Record data signal

EKG signal after filtering would be clear and displayed on the screen in 60 second intervals for overall measurement and data

record. To view the EKG wave form in detail, the display 5 seconds interval was showed. All functions were controlled by main program.

2.4.4 EKG waveform Analysis

The recorded EKG signal could be analyzed to find the components and parameters of the EKG wave form by using measurement tools of LabView software including:

- Waveforms of interest (wave complexes) are a P-wave, QRS wave and T wave form.

- Wavelength (cardiac interval) are PR interval, QT interval and QRS interval.

- The distance between the wave form (inter-wave Segment), including PR segment and ST segment

All the important intervals on the recording are compared with the EKG standards as follows¹⁻²,

- PR-indicates that the atria are electrically stimulated (depolarized) to pump blood into the ventricles normally between 0.12-0.2 seconds.
- QRS-indicates that the ventricles are electrically stimulated (depolarized) to pump blood out normally between 0.06-0.1 seconds.
- QT- indicates the amount of time from the beginning of the QRS complex to the end of ventricle repolarization normally between 0.4-0.43 seconds.

ST-indicates the amount of time from the end of contraction of the ventricles to the beginning of the recovery period (repolarization) normally between 0.08-0.12 seconds.

3. Results and Discussion

The W&C EKG (Wireless & Cloud Electrocardiography) could be displayed, analyzed, and recorded online via a computer global network

3.1 The Functions of the W&C EKG

The EKG measurement unit uses a small battery for its power source, lightweight and mobile for comfortable use in different conditions and locations. Next, the unit is safe from electrical shock hazard that may be risky on other EKG equipment as a result the measurement unit is completely isolated from the electrical power source. In addition, the data from measurement unit were transferred to the computer via Bluetooth communication, and recorded on cloud medium storage which could be accessed in any place in the world using computer global network as illustrated in Figure 2.

Finally, the EKG signal can be recorded and set as a record on demand, typically set in 60-second intervals during measuring for the PR interval, QT interval, QRS interval, ST segment to use for interpreting EKG signal compared to the standard EKG signal as illustrated in Figure 3.

3.2 Performance test

Performance tests and measurement of EKG signal by W&C EKG were as follows,

3.2.1 Test the W&C EKG system by measuring in subjects (Groups 1)

Install the electrode on the test subject, the positive electrode attached away from the armpit to the left 2 inches and 1 inch below the collarbone, negative electrode attached next to the fourth right ribs under the breasts and ground electrode attached to the right ribcage. The results were illustrated in Table 1 and example of EKG signal from one subject was showed in Figure 4.

3.2.2 The satisfaction of individuals in the use of the W&C EKG in subjects (Group 2)

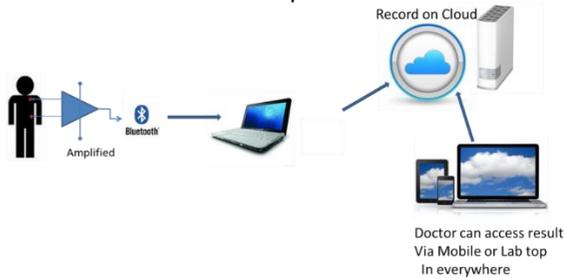
The satisfaction rating from the subjects in group 2, six male subjects were introduced to demonstrate how to use the equipment unit the subject understood, and were capable of using the equipment under supervision of researchers. According to Table 2, the feedbacks from the test group after using the equipment were shown.

3.2.3 The evaluation of the applications of W&C EKG by the experts

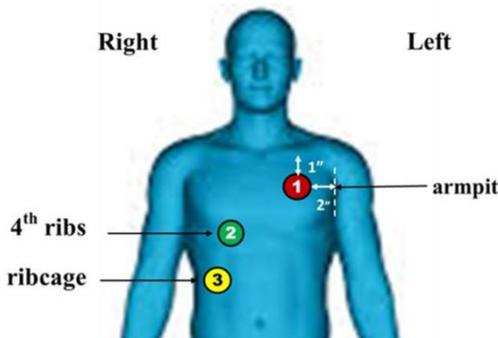
The evaluation result was conducted by interviewing expert's opinions in the field of medical instrumentation design. The experts tested the W&C EKG and made suggestions based on the questions and answers shown in Table 3.

A.

EKG wireless data communication Development



B.



C.

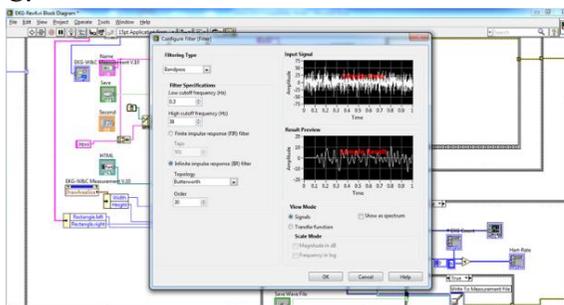
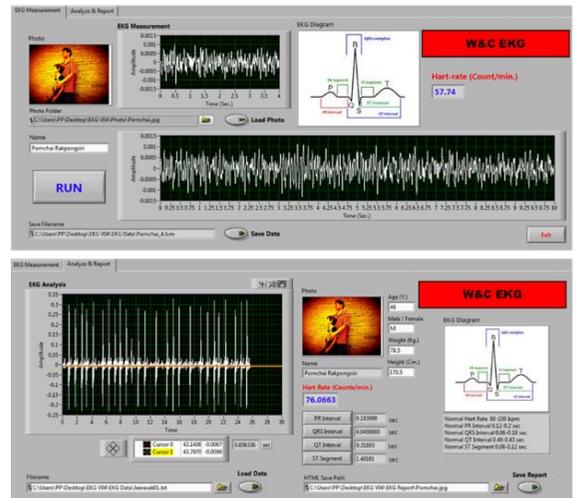


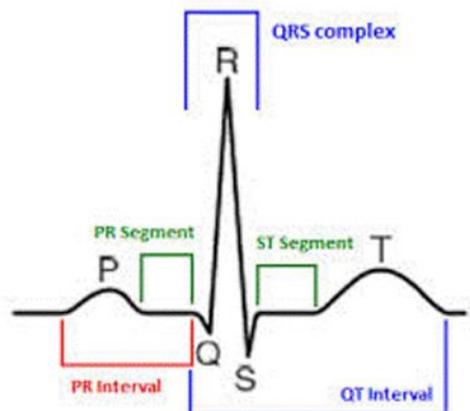
Figure 1. Diagram design and Cloud storage system (A), The position of the electrodes for EKG signal measurement (B) and The subprograms filter, software filter in LabView.



Figure 2. The W&C EKG components recorded and displayed the EKG signal via WD mycloud.



B.



C.



Figure 3. The W&C EKG control program (A), Standard EKG signal (B) and Example EKG signal from W&C EKG (B).

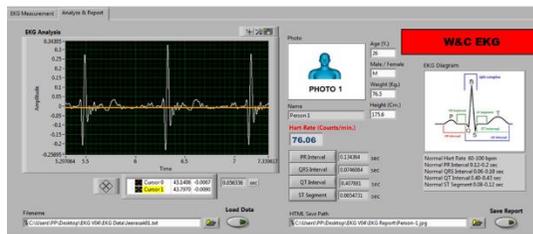


Figure 4. Example of EKG signal from W&C EKG & of one subject.

Table 1. Age (years), weight (kg.) Height (cm) and the major components of the EKG signal measured by W&C EKG test in 6 healthy male subjects.

Subject no.	Age (year)	Weight (kg.)	Height (cm.)	The major components of the EKG.					Results compared with the standard
				Heart Rate (b/min.)	P-R Interval (sec.)	QRS Interval (sec.)	Q-T Interval (sec.)	S-T segment (sec.)	
1	26	76.5	175.6	76	0.1343	0.0746	0.4078	0.0854	Normal
2	25	72.4	172	78	0.1859	0.0982	0.4078	0.1034	Normal
3	30	75.5	170.5	75	0.1655	0.0822	0.4080	0.1110	Normal
4	27	74.8	175.2	77	0.1724	0.0813	0.4023	0.1053	Normal
5	29	73.5	171.2	79	0.1341	0.0622	0.4071	0.1054	Normal
6	26	74.7	172.4	79	0.1520	0.0945	0.4011	0.0993	Normal

Table 2. The feedback opinion from 6 six male subjects in the group 2 after using the equipment.

W&C EKG system	least (%)	little (%)	moderate (%)	much (%)	most (%)
1. Comfortable of using				66.7	33.3
2. Comfortable of portability or mobility				33.3	66.7
3. Safety					100
4. Performance				66.7	33.3
5. Apply online on a daily lifestyle.					100
6. Overall satisfaction.				66.7	33.3
summary				58.35	61.1

Table 3. The 3 medical instrumentation design expertise opinion after using the W&C EKG system.

Question	Interview
1	Using of the W&C EKG is convenient or not ? and how?
2	To carry or move the W&C EKG easy or not ? and how?
3	The W&C EKG is safe or not ? and how ?
4	Using the program of W&C EKG is convenient or not ? and how?
5	The W&C EKG give an accuracy results or not ? and how?
6	What about the overall performance of the W&C EKG ?

Answer	Expert 1	Expert 2	Expert 3
1	Yes, it is convenient because users can use the equipment like using a personal computer, and simply click the icon in the program to measure the EKG signal.	Yes, it is convenient because user is familiar with the computer, and the program is not complicate.	Yes, the system is easy and convenient of using.
2	Yes, because the system is portable and easy to carry around for using any place.	Yes, it is compatible and portable devices .	Yes, it is convenient and portable, and works with a general computers
3	Yes, it is safe equipment with good design from electrical shock hazards with using of battery for measurement unit.	Yes, it is good design of safety concept.	Yes, it is good and safe equipment.
4	Yes, the program has functional tools to save, analyze and display the results easily.	Yes, it is easy to learn of using the program.	Yes, it is not difficult of running the functional programs.
5	Yes, it shows the results correctly in line with the standard EKG signals.	Yes. The program shows in line with the standard signals.	Yes, the result closed to the standard signal.
6	Overall performance rating is good.	Equipment's overall performance is good.	Good for overall performance.

4. Discussion and Conclusions

The W&C EKG (Wireless and Cloud Electrocardiography) has been developed to be safe for patients from electrical shock hazards by completely isolating the measurement unit from high voltage electrical power source, use only battery for power supply, and transmit the signal to main unit via Bluetooth wireless communications. Besides, the system provides analysis functions including the PR interval, QRS interval, QT interval, RR interval, ST segment in agreement with the standards EKG values. Not only the personal records stored on Cloud system but the W&C EKG can be displayed on a personal computer, notebook computers and portable devices such as mobile phones and Tablet.

According to the Table 1, performance testing and measuring the EKG signal by the equipment in 6 healthy male subjects, the results showed clear EKG components including of the PR interval, QRS interval, QT interval, RR interval, ST segment in step with the standards EKG values. The example of EKG signal from one subject was showed in Figure 4. In addition, the satisfaction rated from six male subjects was given and satisfied all aspects, and percent rating level of “most” and “much” are 61.1% and 58.35%, respectively Table 2. Illustration, Table 3 represented the results from the interview of 3 experts in instrumentation design were as follows:

- First Expert (48-year-old male senior Electrical Engineering Manager): using of the W&C EKG is convenient because users can use the equipment like using a personal computer, simply click the icon in the program to measure EKG signal.
- Second Expert (40-year-old male Computer Engineering): using of the W&C EKG is convenient because user is familiar with the computer.
- Third Expert (35-year-old female Computer Software): using of the W&C EKG is convenient, portable

and easily works with general computers.

In conclusion, our measurement unit, W&C EKG from 3 experts in instrumentation design interview, is also portable, and comfortable to use. Thus, this is able to analyze and show clearly the critical values such as the cardiac time intervals and the distance between waves (Inter-wave Segments). Additionally, the overall performance in terms of usability, mobility, safety, comfort and accuracy are at good level of satisfactions.

5. Acknowledgements

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