

Wireless ECG Monitor Using Labview

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Abstract: Electrocardiogram (ECG) is a diagnostic tool that is used to measure and display the heartbeat. Nowadays, hospitals still use the traditional ECG monitor machine. The traditional ECG monitor machine is still stationary. The hospital staff has to move the machine with its wires from one patient to another. The purpose of this work is to acquire, transmit and display the ECG signal. In this work, it can be divided into two stages. The first stage is how the ECG signal is acquired using electrodes. Electrode is a sensor that is used to collect electrical activity from the heart. Three limb leads, based on Einthoven's Triangle theory will be used in this work. The signal collected by electrode will be amplified using instrumentation amplifier INA118 with the gain amplification, $G = 9$. After the first amplification, the signal will go through a band pass filter, which allows frequency from 0.5Hz to 150Hz to pass through. The signal is then amplified, using 741 operational amplifier with gain, $G = 51$ to boost the signal into more readable signal. The total amplification for the first stage was 459. The signal is then send to ADC for wireless transmission via XBee. In the second stage, the USB port or Serial port of the laptop will be configured using LabVIEW software so that the ECG signal can be received. The LabVIEW software was programmed to receive, read, and display the ECG signal received. The ECG signal is successfully transmitted wirelessly via XBee to a laptop without it losing its characteristic (PQRST wave).

Keywords: Electrocardiogram (ECG); Labview; Op-Amp; ADC Converter;

1. Introduction

Electrocardiogram monitor machine is one of the healthcare that is widely used in hospitals and clinics in Malaysia [1]. An electrocardiogram is a diagnostic tool that is used to measure and record the rate of heartbeats. From there, the irregularity of heart activities can be detected, to see if there are any damage to the heart. The traditional and commonly used Electrocardiogram monitor machine is still using wire, and it is stationary [2]. The electrocardiogram (ECG) is a time-varying signal reflecting the ionic current flow which causes the cardiac fibers to contract and subsequently relax. The surface ECG is obtained by recording the potential difference between two electrodes placed on the surface of the skin [3]. A single normal cycle of the ECG represents the successive atrial depolarization or repolarization, and ventricular depolarization or repolarization which occurs with every heartbeat [4].

Anyone who has ever been to a hospital should know the Electrocardiogram monitor machine [5]. The problems can be viewed from a certain point of views. From patient's point of view, and from the hospital staff's point of view. From the patient's point of view, the ECG machine can be troublesome, cumbersome and uncomfortable [6]. Their movement was limited as the wires attached from the body to ECG machine. From the hospital staff's point of view, it is not user-friendly. Currently, the ECG monitor at the hospital is stationary [7]. The ECG machine with its wires needs to be moved for the staff to measure the patient's ECG signal, from one patient to another [8].

In this work, the ECG signal is to be acquired and amplified using the designed ECG circuit. From there the signal will be transmitted wirelessly. Signal received from the transmission was expected to have the same characteristic as the transmitted signal [9-10].

2. Background and Literature Review

The electrocardiogram, often referred to as an ECG is a graphic representation of the heart's electrical activity. The device that detects, measures and records the ECG is called an electrocardiograph [11-14]. The ECG provides healthcare professionals with valuable information [15-16]. It is used to identify irregularities in the heart rhythm and to reveal the presence of injury, death or other physical changes in the heart muscle [17-19]. It is used in the hospitals, clinics and other medical facility. It is used as both an assessment and diagnostic tool. It can also provide continuous monitoring of the heart's electrical activity during transport or in the contrary care unit [20]. Figure 2.1 shows a picture of a patient performing ECG. The ECG machine detects the electrical current activity occurs in the heart. It does this through electrodes placed on the patient's skin. These impulses which appear as a series of upward (positive) and downward (negative) waveforms. It is then transferred to the ECG machine and displayed on a monitor [21]. As the impulse moves toward a positive electrode of the ECG, it produces a positive waveform. In this ECG tracing the waveforms (P, QRS, T) are positive, means that the impulses are travelling toward a positive electrode. When it moves away from a positive electrode, it produces a negative waveform. The sites for the placement of the electrodes vary depending on which view of the heart's activity is being monitored [22]. A normal ECG tracing is a straight line with upward and downward spikes (deflects), that indicate electrical activity within the heart [23].

2.1 Producing ECG Waveform

Electrical impulse that is produced by the human heart is measured with the ECG machine. The ECG machine interprets the impulses and produces the waveform. The waveform indicates how the heart is functioning, and the condition of one's heart. It is necessary to view the electrical impulse from different sides, since the heart is three-dimensional [24].

2.2 ECG signal

There are many kinds of shapes and signal's wave for ECG signal. Some people's ECG wave is different than others in term of the shape and the signal's amplitude [17].

2.3 Lead ECG

A 12 – lead ECG gives a complete picture of the heart's electrical activity. 12 – lead ECG records the electrical activity in 12 different views at a slightly different angles. It records the electrical impulses produced in the heart [17]. The 12 views provide information about how the electrical impulses travel through various part of the heart. The 10 lead wires produce 12 different lead circuits consisting of one or more wires from the electrodes to the electrocardiograph (ECG machine). The 12 circuits produce 12 different tracing. The electrodes identify each of the 12 leads [17]. The 12 leads are made up of three different types of leads. For this work, not all the leads will be applied. Only the three standard limb leads will be applied in this work. It is also known as bipolar leads, or as a three – lead ECG system. The electrodes placement will be based on Einthoven's triangle.

2.4 Standard Limb Leads

ECG leads are either bipolar or unipolar. Standard limb leads is also known as bipolar leads. Bipolar leads require two electrodes of opposite polarity (positive and negative). A bipolar lead records the flow of the electrical impulse between the two selected electrodes. Bipolar leads have the third electrode called the ground. The ground is used to help prevent electrical interference from appearing on the ECG. It has zero electrical potential when compared to the other two electrodes (positive and negative). The bipolar leads include lead I, II and III. The axes of these three bipolar leads form a triangle around the heart. It referred to as Einthoven's triangle [17]. Einthoven is the scientist credited with developing the first ECG machine. The Einthoven's triangle is formed by three of the limb electrodes; electrode on the left arm, right arm and left leg. The three electrodes will be placed on the patient's body based on this theory. The electrodes can be placed either on the patient's arm chest, as long as the electrodes form a trainable. The electrical current created by the heart is measured between the positive and negative electrodes placed on the body. If no current is flowing, the waveform is flat or isoelectric [17]. If the current move towards the positive electrode, the ECG waveform will be positive (upright) above the isoelectric baseline. If the current moves away from the positive electrode, the ECG will be negative (downward) below the isoelectric baseline [16].

2.5 Pervious work

The research on previous works will be focused on their method, hardware and software implementation. In this part, the method, hardware and software used on previous works will be briefly explained. In 2003, Ricardo Isais, Khoi Nguyen, Gabriel Perez, Roberto Rubio, and Homyoum Nazeran, "A Low-cost Microcontroller-based Wireless ECG-

Blood Pressure Telemonitor for Home Care” [1]. This work develops a combination of blood pressure and heart monitoring system, a device for homecare telemedicine. This device allows patients to check their own vital signs (blood pressure and ECG), and for the healthcare professionals remotely monitor the vital signs quickly. For the blood pressure, An Omoron HEM-609 blood pressure monitor was used to acquire the patient's blood pressure. For the ECG signal, 3 disposable monitoring electrodes were used to pick up the electrical activity, before being fed to the ECG amplifier. ECG amplifier was custom designed and implemented using AD624AD. The ECG signal was then amplified with a gain of 1000 and filtered. Both data from the blood pressure monitor and the ECG amplifier were then fed to the PIC 16C774A microcontroller. The data was then being processed in the microcontroller for wireless transmission. For wireless transmission, a high performance RF Module TXM-900-HP-II transmitter and receiver were used to wirelessly transmit and receive the vital sign data from the micro-controller to a personal computer at the receiving site. The operation frequency of the transmitter is 900MHz and its range is 1000 feet and it transmits the data using the frequency shift keying (FSK) transmission method [1]. The final part involved a development of a user-friendly graphical user interface using Visual Basic to receive the incoming patient data from the receiver, store them, process them and display [24]. In 2004, A. Vehkaoja and J. Lekkala, “Wearable Wireless Biopotential Measurement Device” [2]. This device was a 3-lead wireless ECG transmission system. This device shows the method that uses two amplifier stages before the wireless data transmission. The first amplifier stage was used by using an instrumentation amplifier INA118. After this amplifier, high pass filter was used for removing the dc-component from the biosignal. Cut-off frequency of the high-pass filter is 0.08 Hz [2]. The second amplifier stage is non-inverting, using AD8552 operational amplifier from Analog Devices. Before sampling, the signal is low-pass-filtered to avoid aliasing. Maxim MAX7414, 5th order switched capacitor filter having Butterworth-type frequency response and cutoff frequency of 192 Hz were used [2]. For the Analog-to-Digital Converter and wireless data transmission, this work uses CC1010 radio transceiver which operates at 868 MHz ISM (Industrial Scientific Medical) frequency band. The CC1010 also has an integrated 8051-based microcontroller whose 10-bit Analog-to-Digital Converter is employed for sampling the measured signal at 500 Hz frequency [2]. The signal is then processed and displayed in computer screen using a program made with LabVIEW software development tool. In 2013, N. M. Z. Hashim, M. S. Sizali, “Wireless Patient Monitoring System” [3], This work uses the actual ECG machine to collect and process the patient’s heart beat rate data. This system can be divided into three parts. The first part is developing a program for microcontroller, the second part is transmitting the data from microcontroller to the PC using XBee module and the last part is designing the GUI as the interface for the doctors. The data collected will be feed into the Peripheral Interface Controller (PIC) 16F877 microcontroller circuit. The microcontroller will determine whether heart beat is normal or abnormal via coding. The data from the microcontroller circuit will be transmitted wirelessly via XBee module. This paper states that the efficiency of data transferring led the XBee to be used in this study as to compare to the other wireless technology[3]. XBee module by Digi Corp. was chosen in this work. Visual Basic Net. 2010 Graphical User Interface (GUI) has been chosen for this work to display the heart beat reading. The authors T. K. Kho, Rosli Besar, Y. S. Tan, K. H. Tee, K. C. Ong, “Bluetooth-enabled ECG Monitoring System”[4] divided work into several parts. The parts were represented using block diagrams. In this work, the ECG sensor is connected to the ECG sensor circuit. The ECG sensor circuit is constructed to detect, amplify and filter the weak electrical signal acquired from the patient’s body. The signal from the ECG sensor circuit will then be fed to the signal processing circuit. At the signal processing circuit, the signal will be fed to the Analog-to-Digital Converter that was attached with the microcontroller. The 8051 microcontroller is responsible to control the data flow between ADC and the Bluetooth module. It sets the Bluetooth connection link and transmits the ECG data to the displaying device via Bluetooth. Bluetooth is a wireless technology based on radio waves. The Bluetooth module that is connected to the microcontroller acts as the slave. The microcontroller starts to send data over the wireless link upon it is notified. For the output, a graphical user interface (GUI) of the PC-based software is developed in Visual Basic 6.0. GUI is capable of receiving, processing and displaying the ECG signal. The software was programmed and designed so that the ECG signal can be displayed on the PC screen. The information can be stored in the PC for filing purpose [25].

3. Research Methodology

This work work can be divided into two stages as developing methodology. The first stage is where ECG signal from patient’s body will be measured, before amplification and being transmitted. The second stage is where the amplified signal is received by XBee Module. The LabVIEW will be programmed to read and display the signal. Fig. 1 shows the block diagram of the stages involved in this work.

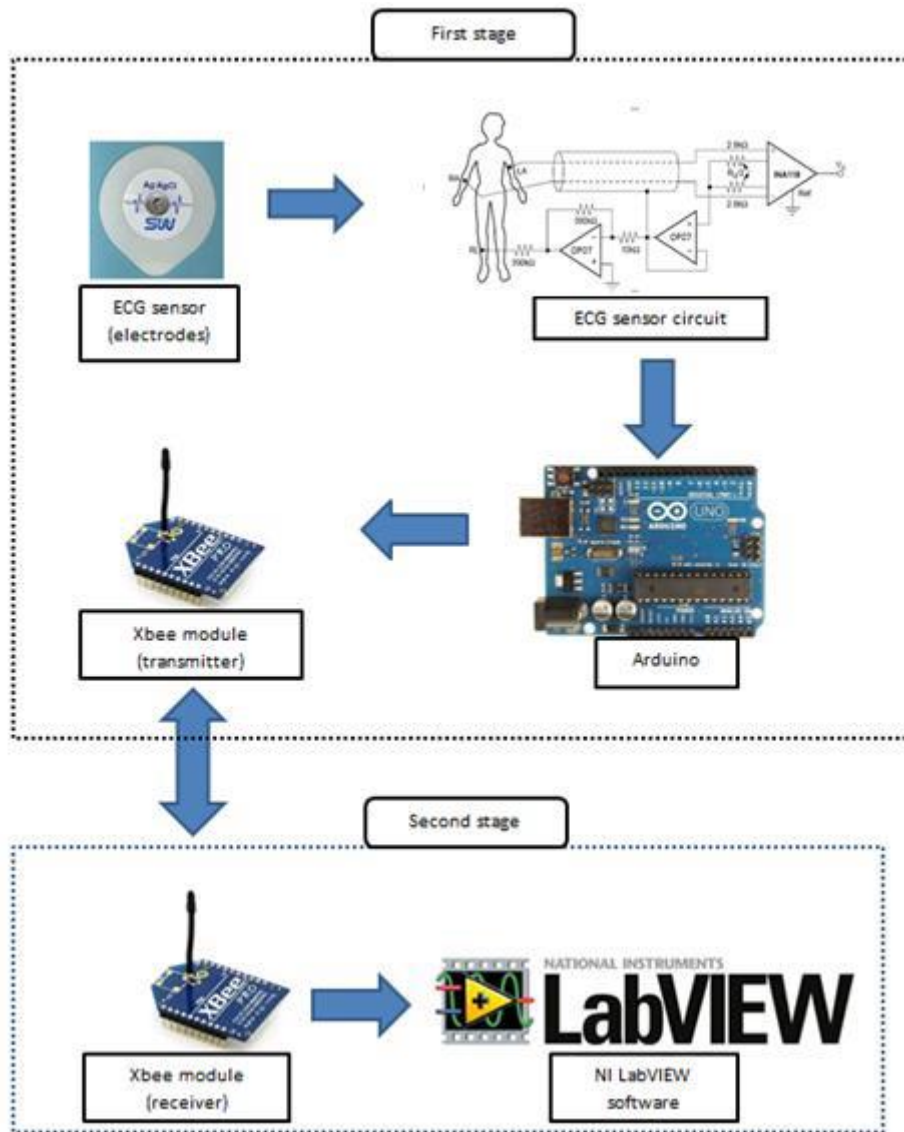


Fig. 1 - System design for ECG monitoring

3.1 Simulation of the Proposed Circuit

The ECG sensor circuit has been designed and simulated using Proteus software. The expected result from the simulation was the voltage will be amplified. For the input, a signal generator was used as replacement to actual ECG signal, as the ECG signal cannot be found in Proteus. The simulation shows that the ECG circuit that was implemented in the Proteus did amplified. Fig. 2 shows the circuit built in Proteus, and Fig. 3 shows the simulation result.

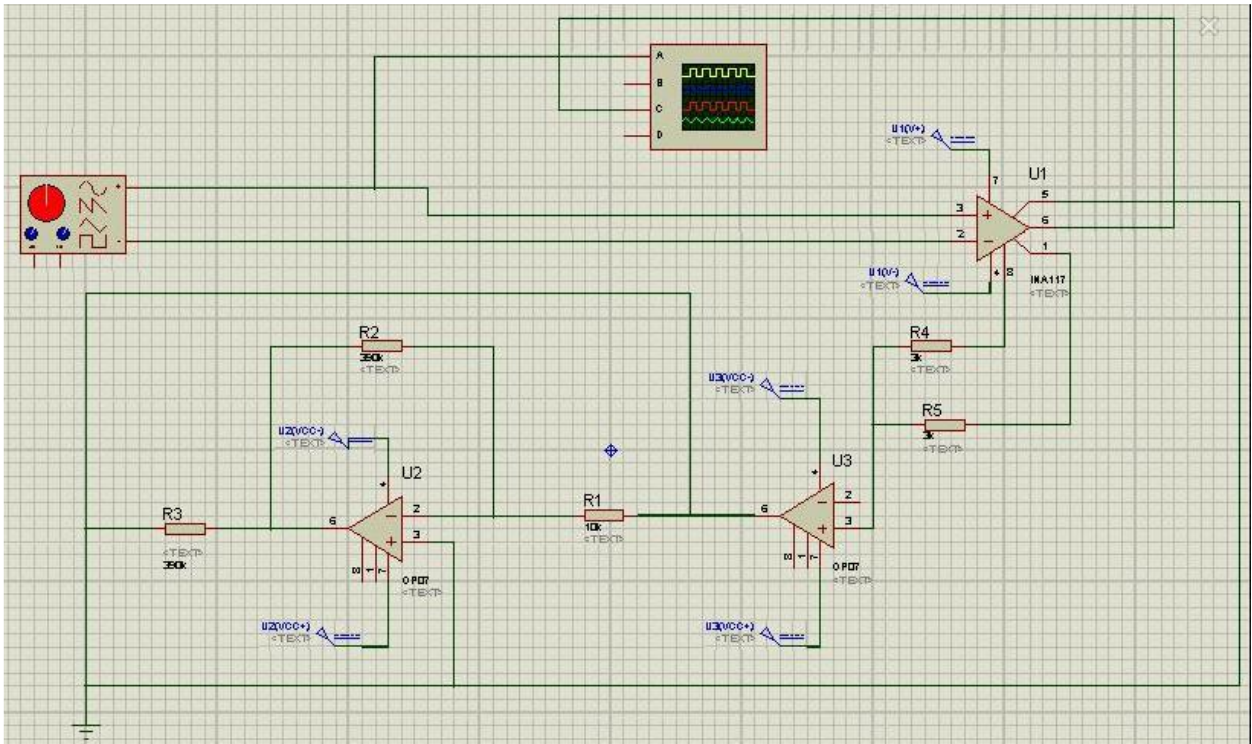


Fig. 2 - Circuit implemented into Proteus

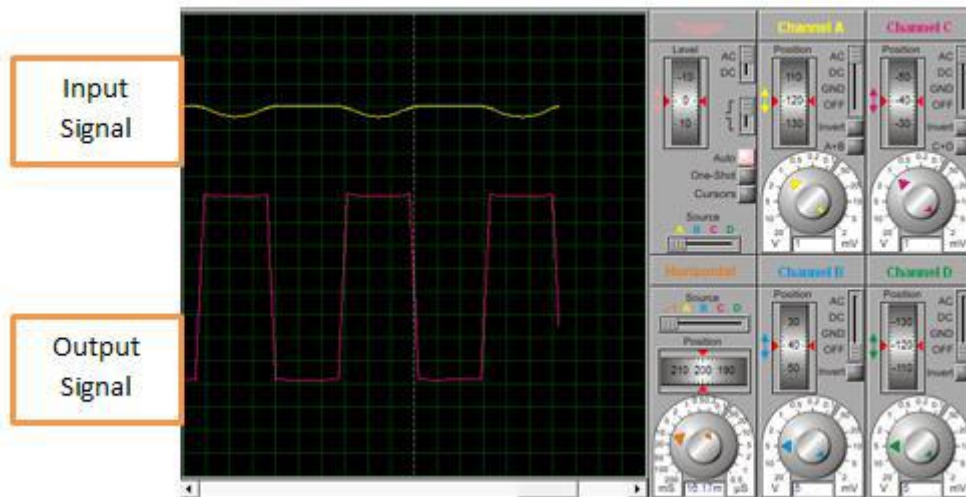


Fig. 3 - The sine wave before and after amplification

From Fig. 3, the simulation result shows that the signal has been amplified. The gain of the circuit was set to 9. Fig. 3 shows that the output signal's amplitude had increased 9 times.

3.2 LabVIEW as an ECG

There have been many research and study on using LabVIEW as an ECG. Some of them even used this software as an ECG[8][9]. The study shows that we can design an ECG acquisition and analysis system based on LabVIEW with the support of a DAQ board. This system can conduct the acquisition, display and saving the ECG signals and the calculation of heart rate, and accomplish signal's analysis and processing in VI[8][9]. LabVIEW has the ability to analyze the physiological signal, displays and stores data in the computer. User can operate the system for monitoring his physiological signal and understanding his health very easily. This software will be tasked to receive ECG signal via serial read, process for display on the laptop monitor. Fig. 4 shows the basic concept of what the LabVIEW software will do.

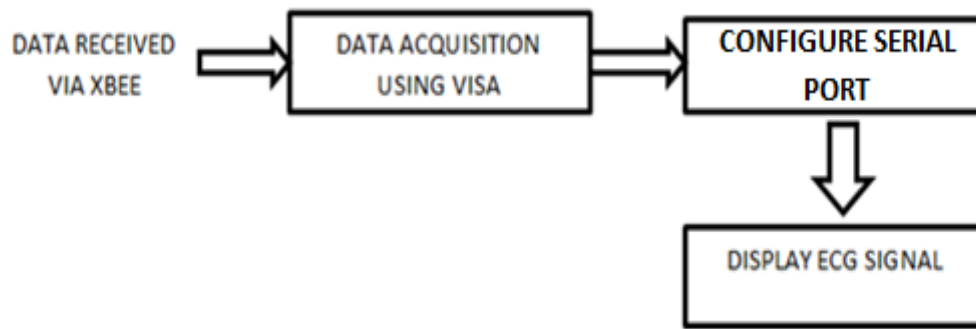


Fig. 4 - LabVIEW software basic concept as an ECG display

3.3 Data Acquisition using VISA

The Virtual Instrument Software Architecture (VISA) is a standard for configuring, programming, and troubleshooting instrumentation systems comprising GPIB, VXI, PXI, Serial, Ethernet, and/or USB interfaces. It provides the programming interface between the hardware and development environments such as LabVIEW. NI-VISA is the National Instruments implementation of the VISA I/O standard. NI-VISA includes software libraries, interactive utilities such as NI I/O Trace and the VISA Interactive Control, and configuration programs through Measurement & Automation Explorer. It is a standard across the National Instruments product line. DAQ device will not be needed in this work. By using VISA for data acquisition, the data received via XBee will be serially received by using serial port (USB port). This will cut the cost, as the cost for a DAQ device was around RM500 per device.

3.4 Serial Port Configuration

Fig. 5 shows the block used for port configuration using VISA. By using this block, serial port can be configured to receive data via USB port (serial port). The serial port will be configured to receive data via XBee.

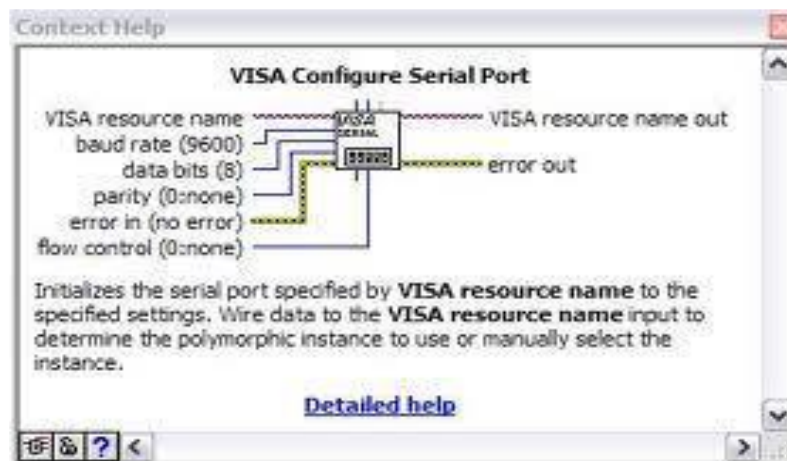


Fig. 5 - Port configuration using VISA

From there, the LabVIEW will be programmed so that it can read the data for display on laptop using graph. Programming the LabVIEW. Referring Fig. 6, the LabVIEW can be programmed step by step from reading the data, to displaying the ECG signal. Programming the program can be separated into two parts. The first part consist of the data being read, and the second part consist of the data being displayed. Fig. 6 shows the first part of the LabVIEW program.

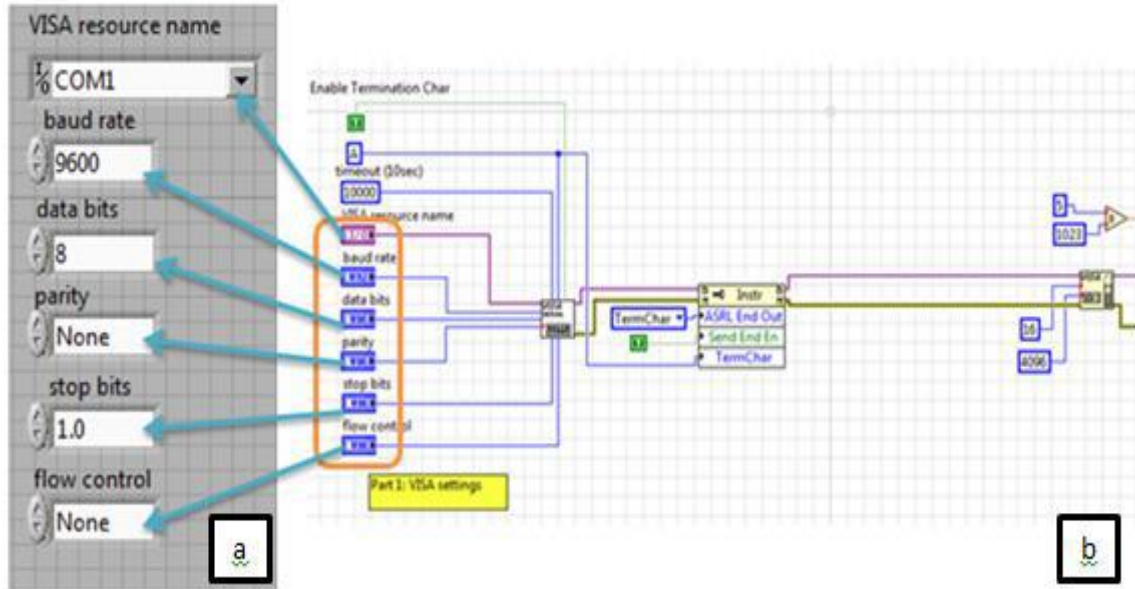


Fig. 6 - First Part of the LabVIEW program.

The first part of programming the LabVIEW consist of the VISA setting. VISA setting is where the serial port being configured to receive the data. In the circle, the symbol shows that the configuration can be controlled manually by any user. Looking at (a), VISA resource name is for the serial port. User can select which port will be used for the data to pass through. Baud rate is the data speed, which is to decide how fast the data will be transmitted serially through the selected port. For this work, baud rate of 9600 is used as ECG signal does not need to be too fast. The data bits is where user decides how many bits for the LabVIEW to read at one time, and for this work it is 8 bit. Fig. 7 shows the second part of the program. In this part, the data will be read by byte. At the data collected circle, the LabVIEW is programmed to read 15 byte before going through the next process. But usually it cannot read 15 bytes. The data collected will be read by LabVIEW as maximum as it can read.

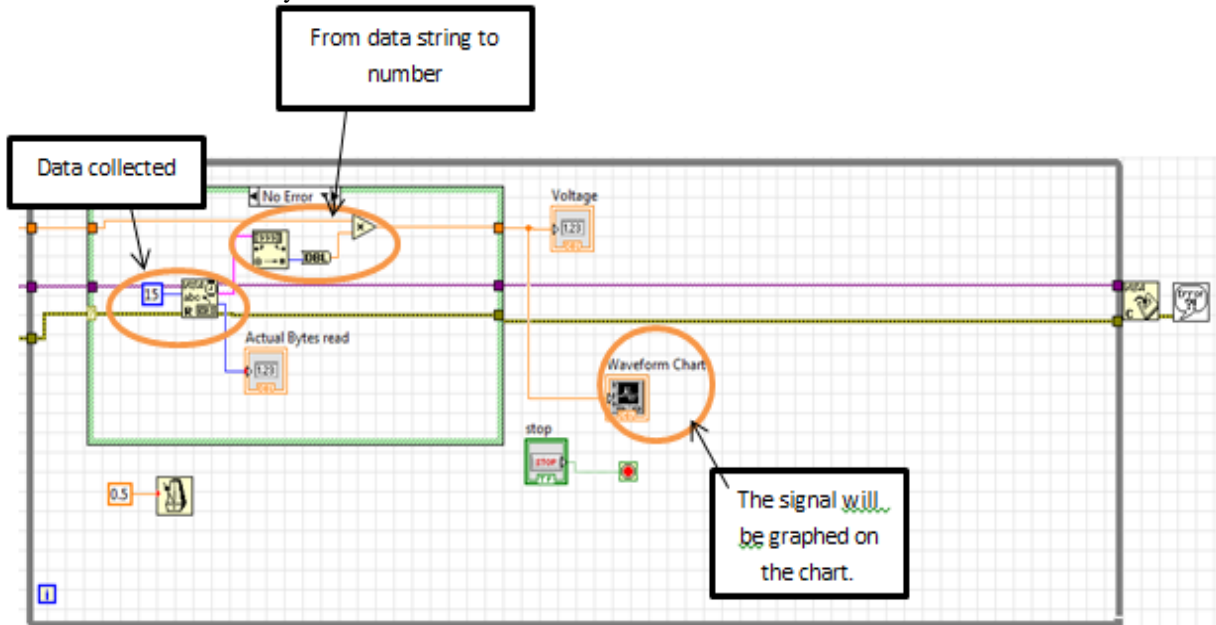


Fig. 7 - Second Part of the LabVIEW program.

After it read the maximum bytes available, the string of data will then be converted into numbers. The data which is now in numbers will be graphed on to the chart for display. The process will run over and over again until the user stops the program. Fig. 8 shows the full GUI for the LabVIEW program.



Fig. 8 - GUI of the program.

4. Results and Discussion

In this section, ECG signal that was measured from our body. In first stage, the ECG signals were measured from three different subjects or humans. The ECG signal that was measured from the subject's body will be calculated to ensure that it agrees well with the theory. Second stage will show the comparison of the signal transmitted wired and wirelessly. The results were compared and analyzed in this section to show that ECG live monitoring can be done wirelessly.

4.1 Stage 1: Measuring ECG Signal

The ECG signal amplitude is so small, as had been mentioned in literature review. The ECG signal's amplitude for human normally range between 0.5mV to 5mV. From the results measured, calculation was made to ensure that it agrees with the theory.

- For Subject 1

From the calculation, the actual ECG signal's amplitude that was acquired is 0.54mV. In theory, the ECG signal should be 0.5mV to 5mV. This proves that the ECG signal that was measured is approximately the same value.

- For Subject 2

From the calculation, the actual ECG signal's amplitude is 1mV. The amplitude is in correct range. But the ECG signal wave was a little different when compared to the first subject.

- For Subject 3

From the calculation, the actual ECG signal's amplitude is 0.8mV. The amplitude is according to the range of theory. This ECG signal wave has similarities with the first subject, but different when compared to the second subject.

4.2 Stage 2

The ECG signal measured from the first stage will be transmitted wirelessly using XBee module. In this stage, the results are focused on PQRST wave. In order to know either wireless transmission did lose PQRST wave or not, results are taken in two situations, where the situations when ECG circuit is wired directly to the laptop and ECG circuit is wirelessly to the laptop.

4.2.1 ECG Circuit Wired Directly to Laptop

The ECG circuit was wired directly to laptop via USB port. After the USB port has been configured to receive data, the results were displayed in LabVIEW software. Fig. 9 shows the ECG signal display when the circuit is wired directly to the laptop. Inside the circle, the PQRST can be seen. The signal shows P, QRS, and T waves that are of different sizes and shapes.

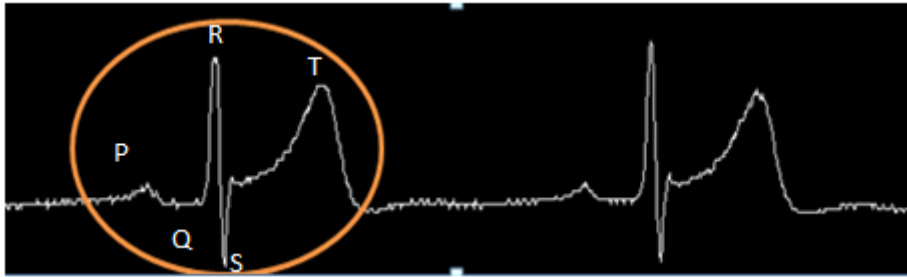


Fig. 9 - ECG signal when wired to laptop.

4.2.2 ECG Wireless transmission

It is crucial for the transmission not to lose the PQRST wave. Noises from any source can interrupt the signal. the noise that interfere the signal can make the signal loses the PQRST wave. In order to check if wireless transmission loses the PQRST wave, ECG signals are displayed before and after wireless transmission.

4.3 ECG Signal (Transmitter)

The XBee module has been installed to send signal wirelessly. The transmitter of the XBee module was installed with the ECG circuit as in Fig. 10.

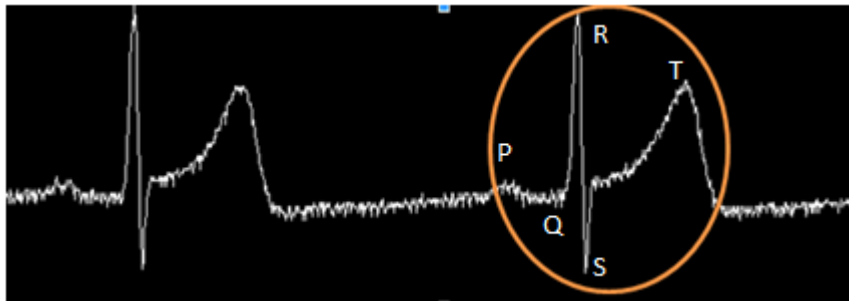


Fig. 10 - ECG signal at the transmitter

Fig. 10 shows the ECG signal at the transmission point (ECG circuit). PQRST wave can be seen inside the circle. This signal looks alike with ECG signal when wired directly to laptop.

4.4 ECG Signal (Receiver)

The XBee module for the receiver part has been installed at the laptop. It has been installed to USB port, where the USB port will be configured to receive data from the transmitter. The data that passes through the USB port was configured via LabVIEW software, processed and will be displayed. A few tests had been made. ECG signal from Fig. 10 was transmitted wirelessly several times, and the signals received were somewhat different compared to each other. Fig. 11 shows the different transmission points and the signals received.

Fig. 11 shows the ECG signals received. The measurements are taken from three different transmission points. From the figure, the small circles shows that the signal received was interrupted by noises. Noise from many source has intercept the signals transmission. The good thing is, the signal did not lose PQRST wave which is important for ECG signal.

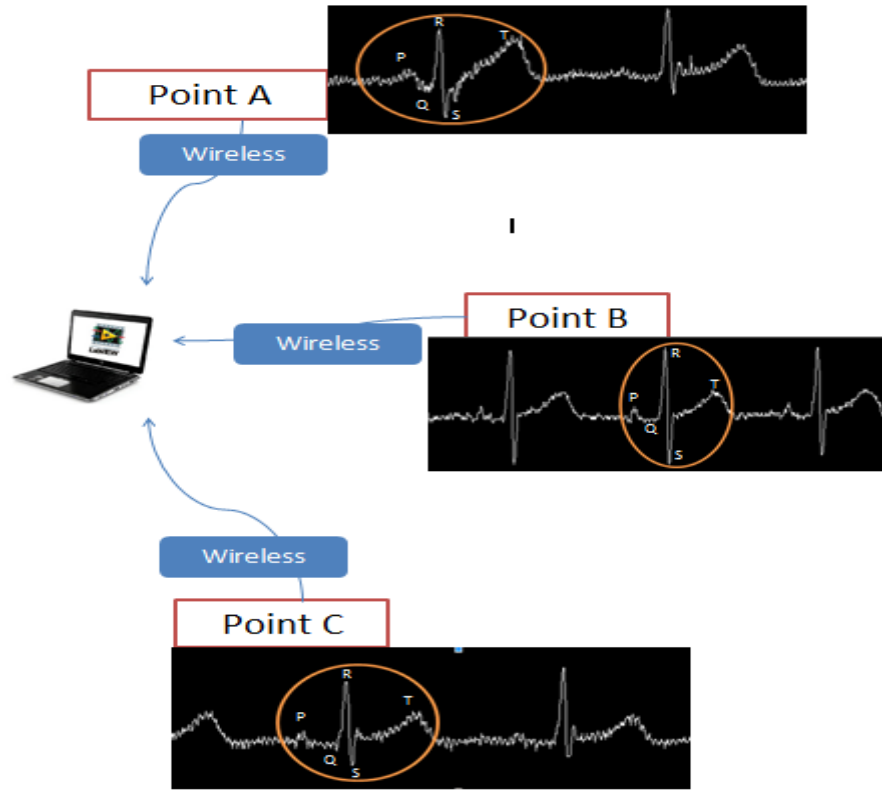


Fig. 11 - Different transmission points and the signals received.

4.5 Wireless Transmission Range

Transmitting continuous data is not the same as transmitting data in demand. Continuous data needs to be transmitted, even though there is no signal to be transmitted. For continuous data wireless transmission, the range needs to be considered as in the data transmitted contain information that may be vital. XBee ZB is used, because its maximum range was enough for this work. For this part, the results from three different ranges are taken. Fig. 12 shows the layout of the measuring set.

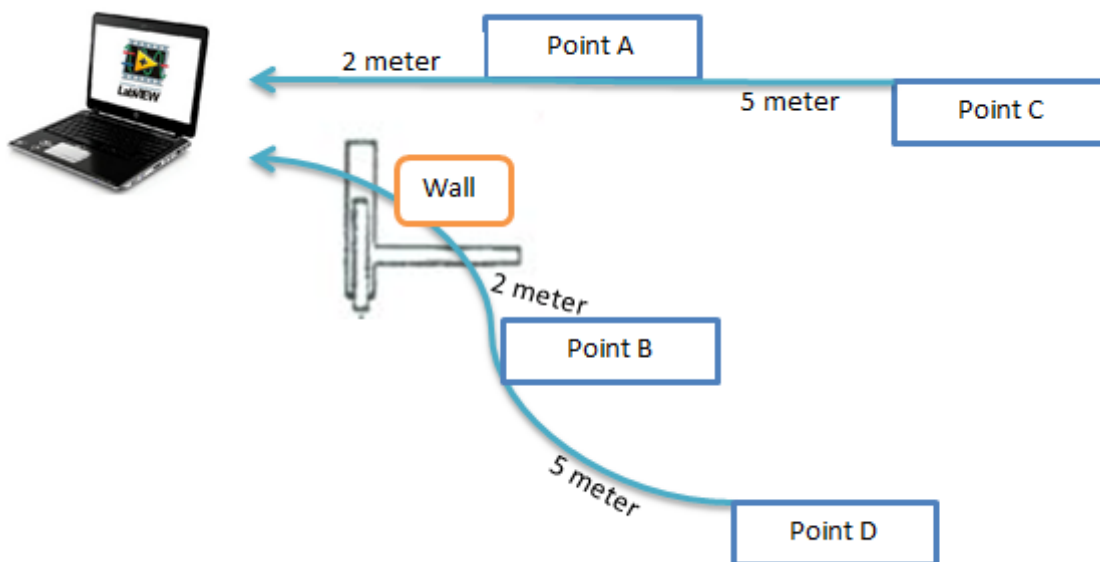


Fig. 12 - Measuring set layout for close range.

4.6 Close Range (0 to 2 meter)

Fig. 13 shows the ECG signal received when it is transmit from Point A. the range of the transmission is 2 meter, without anything to block the signal. The ECG signal still can be transmitted, and the result shows that it has not lose its important characteristic (PQRST wave).

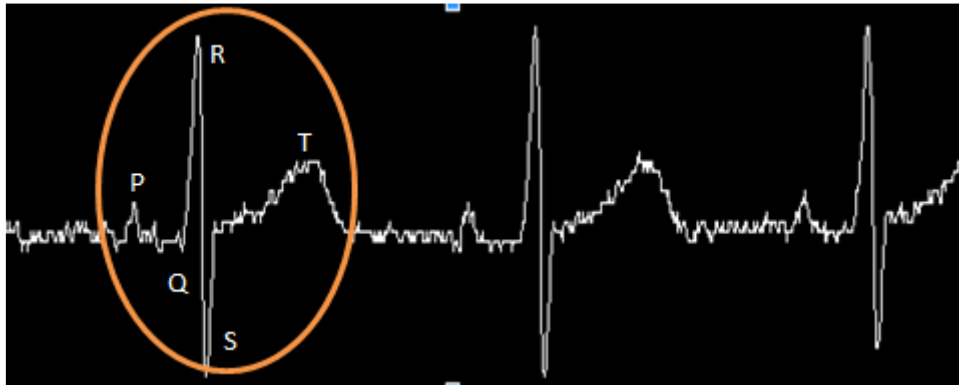


Fig. 13 - ECG signal (Point A)

4.7 Close Range (with wall)

A wall is set between receiver and transmitter, so that the transmission is not Line Of Sight (LOS). This shows that the device can still receive signal even if something solid was placed between the transmitter and receiver as shown in Fig. 14.

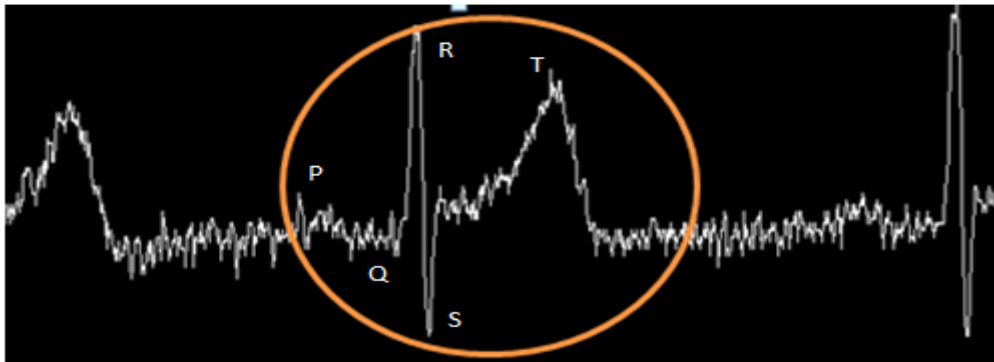


Fig. 14 - ECG signal (Point B).

Fig. 14 shows the ECG signal received from a close range, without LOS transmission. Results shows that the PQRST wave is still there, but the signal is somewhat noisy compared to LOS transmission. It may be due to block and noises that occurs during transmission.

4.8 Medium Range (with wall)

A wall is set between receiver and transmitter, so that the transmission is not Line Of Sight (LOS). This is to check whether the wall will affect the signals transmission as in Fig. 15.

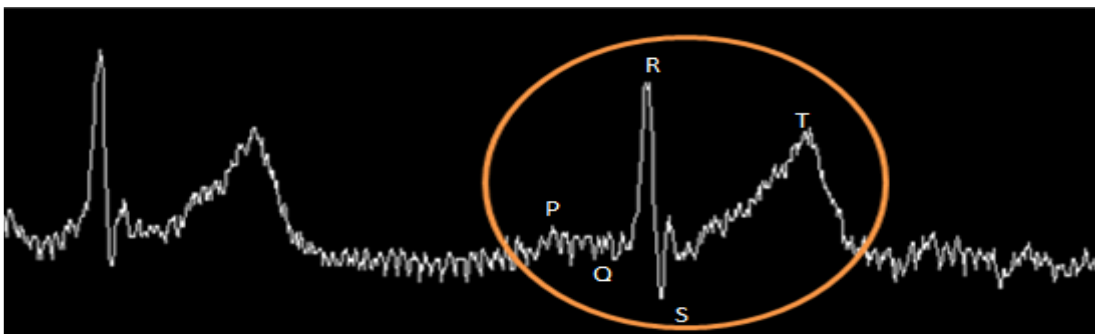


Fig. 15 - ECG signal (Point D)

Fig. 15 shows the ECG signal received when the transmission is not LOS. Inside the circle, the PQRST is nearly lost. It still has its characteristic, but almost lost it due to blocking and noises

4.9 Far Range (6 to 10 meter)

Fig. 16 shows the ECG signal received from far range, with transmission is LOS. Due to its far range, it may be the cause of noises that occur that interfere the signal. The ECG signal received is kind of noisy, but PQRST wave can still be seen inside the circle.

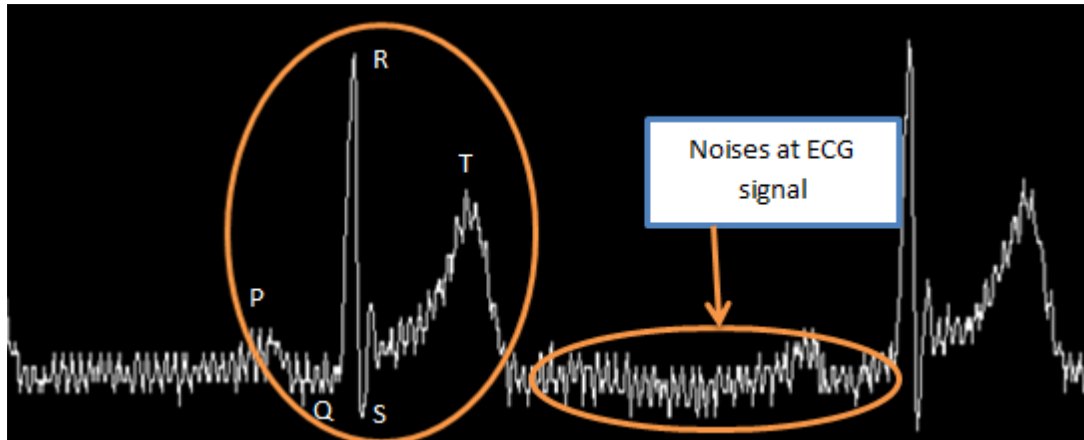


Fig. 16 - ECG signal

5. Conclusion

As for conclusion, the wireless ECG monitoring system has been developed for years. There are a lot of designs in term of hardware and software being used in previous works and researches. Regarding this work, the objective set has been achieved. An ECG circuit that managed to collect ECG signal has been developed. The ECG signal is wirelessly transmitted from the first stage of the system to the second stage. It is transmitted successfully without it losing the important characteristic (PQRST wave). The ECG signal also is successfully being displayed at the graph chart using LabVIEW software. For future upgrade regarding this work, filters can be implemented by using LabVIEW software. Filters can be programmed using LabVIEW software to remove and cleanse the noise for cleaner and clearer ECG signal. The type of filters that can be used are band pass filter with cutoff frequency 0.5Hz to 150Hz, as the ECG signal range is 0.5Hz to 150Hz. The other filter that can be implemented is notch filter, used to remove the power noise. Power noise's frequency normally ranges from 55Hz to 60Hz.

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