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WIRELESS TRANSMISSION OF ECG USING ZIGBEE MODULE

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Abstract— **Electrocardiography (EKG or ECG) is a transthoracic interpretation of the electrical activity of the heart over time captured and externally recorded by skin electrodes. The ECG works mostly by detecting and amplifying the tiny electrical changes on the skin that are caused when the heart muscle "depolarizes" during each heartbeat. At rest, each heart muscle cell has a charge across its outer wall, or cell membrane. Reducing this charge towards zero is called de-polarization, which activates the mechanisms in the cell that cause it to contract. This project aims at transmission of the ECG data from the patient to the doctor's computer wirelessly. This is done by the following steps: ECG signal is first acquired from the patient using Leads(Electrode). The converted signal is then filtered to get the required frequency using Filters. Then it is converted from Analogue to Digital form. Then it is transmitted using ZigBee module. The Receiver is connected to the computer by means of a serial port and the actual representation of ECG displayed by using Visual Basic software.**

I. INTRODUCTION

In the intensive care unit or during anesthesia, patients are attached to monitors by cables. These cables obstruct nursing staff and hinder the patients from moving freely in the hospital. However, rapidly developing wireless technologies are expected to solve these problems. To this end, this study revealed, problems in current patient monitoring and established the most important medical parameters to monitor. In addition, usable wireless applications in the hospital environment were studied. The most important parameters measured of the patient include blood pressures, electrocardiography, respiration rate, heart rate and temperature. Currently used wireless techniques in hospitals are based on the WMTS and WLAN standards. These techniques include Bluetooth, ZigBee and UWB. Other suitable techniques might be based on capacitive or inductive coupling. The establishing of wireless techniques depends on ensuring the reliability of data transmission, eliminating disturbance by other wireless devices, ensuring patient data security and patient safety, and lowering the power consumption and price. ECG monitoring is very important in the medical field. The monitoring of the ECG signals and an appropriate warning about the patient to the doctor at the appropriate time will save the patient. The integration of wireless communication into medical applications has immediate benefits. With wireless communications, monitoring of patients can be done remotely and efficiently. This would enable the intelligent monitoring of multiple patients concurrently. When a patient has alarming medical condition, the monitoring user can be informed to take appropriate action. This technology in hospitals is rapidly advancing. The potential is to have a totally monitored

hospital network, where each patient is constantly monitored via wireless telemetry. The application of wireless biomedical sensor extends past the hospital sitting. This technology could see its way into houses, cars and even workplace. Now the total condition of a person's health could be taken care of effectively and in a safe manner. This could be in the form of an intelligent car that could take control in the event that a driver experienced a heart attack. The number of possible applications of this technology is endless. ZigBee is one of the most prominent wireless protocols and we believe that transmitting real time ECG data can be good stress test in order to evaluate its capabilities.

II. THEORY OF ELECTROCARDIOGRAPHY

A. Definition:

Electrocardiography is a commonly used, non-invasive procedure for recording electrical changes in the heart. The record, which is called an electrocardiogram (ECG or EKG), shows the series of waves that relate to the electrical impulses which occur during each beat of the heart. The results are printed on paper of displayed on a monitor. The waves in a normal record are named P, Q, R, S and T and follow in alphabetical order. The number of waves may vary, and other waves may be present. This method causes no discomfort to a patient and is often used for diagnosing heart disorders such as coronary heart disease, pericarditis or inflammation of the membrane around the heart, cardiomyopathy or heart muscle disease, arrhythmia and coronary thrombosis.

B. Purpose

Electrocardiography is a starting point for detecting many cardiac problems. It is used routinely in physical examinations and for monitoring the patient's condition during and after surgery, as well as during intensive care. It is basic measurement used for tests such as exercise tolerance. It is used to evaluate causes of symptoms such as chest pain, shortness of breath, and palpitations. This technique will provide your doctor with a 24 hour record of the patient.

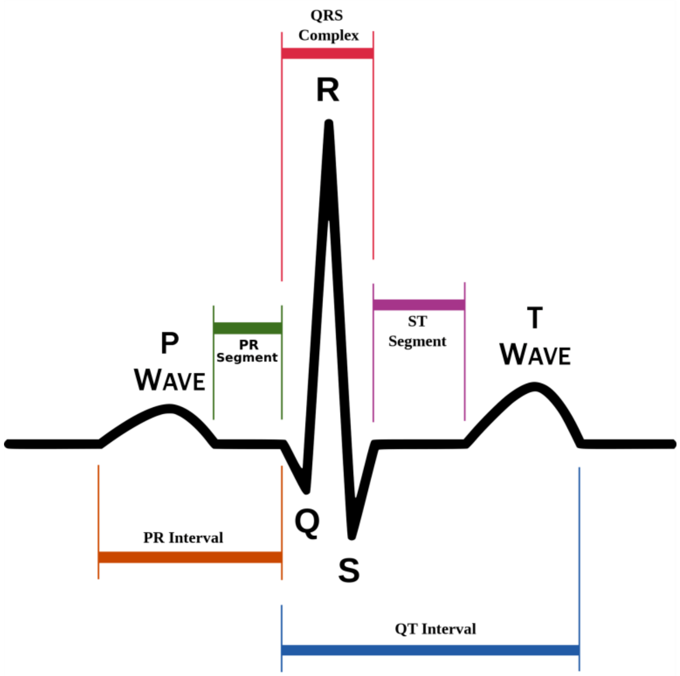

Figure 1. ECG Waveform

C. Description

The patient disrobes from the waist up, and electrodes are applied to specific sites on the arms, legs and chest. When attached the electrodes are called leads; 3 to 12 leads may be employed. When using this technique doctors will connect electrodes to the chest, wrist and ankles that are connected to a recording machine. This machine will display the electrical activity in the heart as a trace on a rolling graph or screen. This technique can be taken at a doctor's office, hospital or even at home and will provide your doctor with a 24 hour record of the patient's heart activity from a tape recorder that is worn by the patient.

If the contractions of the lower heart chambers are extremely irregular this could indicate ventricular fibrillation. When the upper and lower heart chambers are beating independently this could indicate a complete heart blockage. If the upper heart chambers are beating fast and irregular, this can indicate arterial fibrillation.

D. Procedure

The electrocardiography is a painless and quick procedure. Electrodes are placed on the skin of the patient to measure the flow and direction of the electrical currents in the heart during each heartbeat. Each electrode is connected by a wire to the machine which produces tracing for each electrode. This tracing represents a particular view or what is called lead of the heart's electrical patterns.

An electrocardiography produces waves that are known as the P, Q, R, S and T waves which gives each part of the ECG an alphabetical designation. As the heartbeat begins with an impulse, the impulse will first activate the upper chambers of the heart or atria and produce the P wave.. Then the electrical current will flow down to the lower chambers of the heart or ventricles producing the Q, R and S waves. As the electrical current spreads back over the ventricles in the opposite direction it will produce T waves. Using this technique doctors can determine where in the heart abnormal rhythms start which allows them to begin to determine the cause.

III. BLOCK DIAGRAM

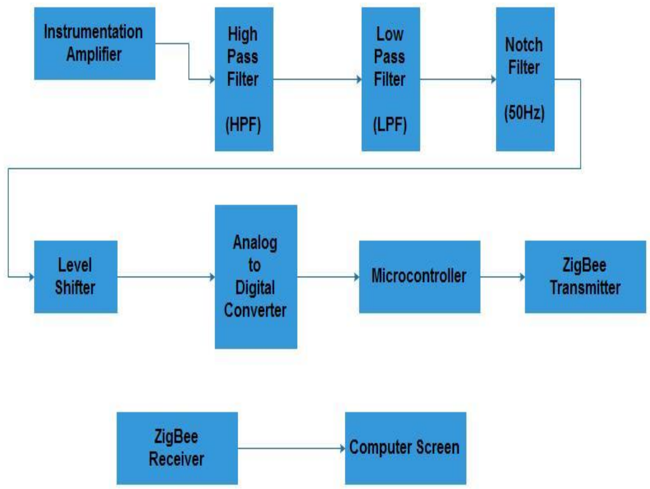

Figure 2. Block Diagram of Proposed System

IV. HARDWARE DESCRIPTION

A. Instrumentation Amplifier

The front end for the signal acquisition is an instrumentation amplifier. It has a very high common mode rejection ratio (CMRR) and high input impedance which is required for capturing ECG signals. The analog device AD620 was chosen for the implementation in the system. The AD620 is a high-precision, low-noise, instrumentation amplifier that requires only one external resistor to set gains of 1 to 1000. Furthermore, the AD5620 features 8-lead SOIC and DIP packaging that is smaller than discrete designs and offers lower power, making it good fit for battery powered, portable applications.

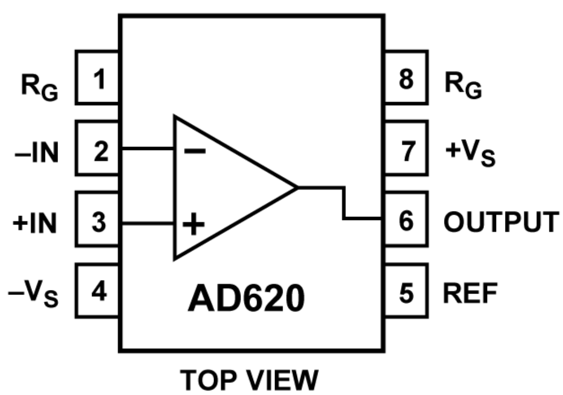

Figure 3. ADC 620 Instrumentation Amplifier

The AD620, with its high accuracy of 40 ppm maximum nonlinearity, low offset voltage of 50mV max and offset drift of 0.6 mV/ºC max, is ideal for use in precision data acquisition systems, such as weigh scales and transducer interfaces. Furthermore, the low noise, low input bias current and low power of the AD620 makes it well suited for medical applications such as ECG and non-invasive blood pressure monitors.

B. Filters

The ECG signals were amplified by the instrumentation amplifier and fed into the noise filtering circuits in different stages. The following are the filters used:

1. Low Pass Filter

The first stage was a low-pass filter designed at the cut-off frequency of 150Hz. The low pass filter was implemented as cascaded RC or passive filters.

$$f_c = 1/_2\ \pi RC$$

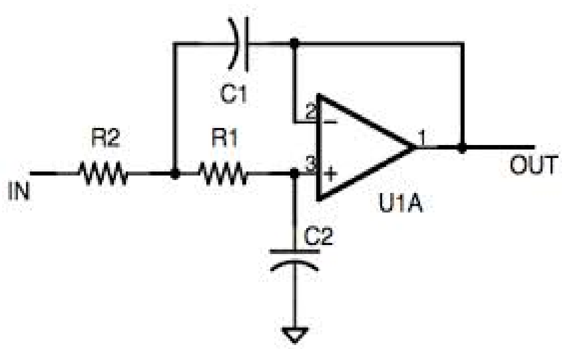

Figure 4. Low Pass Filter

2. High Pass Filter

The simplest circuit high pass filter circuit using an operational amplifier can be achieved by placing a capacitor in series with one of the resistors in the amplifier circuit as shown. The capacitor reactance increases as the frequency falls and as a result this forms a CR low pass filter providing a roll off of 6dB per octave.

$$X_c = 1/_2\ \pi f C$$

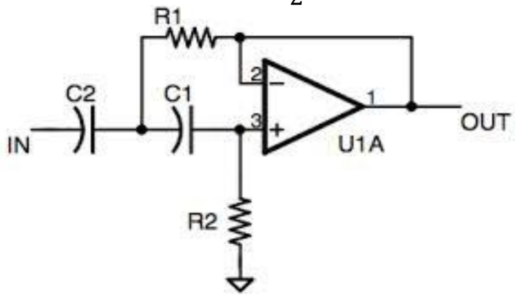

Figure 5. High Pass Filter

3. Notch Filter

The twin T circuit is very useful as a notch filter. Here the twin T provides a large degree of rejection at a particular frequency. This notch filter can be useful in rejecting unwanted signals that are on a particular frequency.

The circuit for the twin T notch filter is shown below and can be seen to consist of three resistors and three capacitors. It operates by phase shifting the signals in the different legs and adding them at the output. At the notch frequency, the signals passing through each leg are 180º out of phase and cancel out.

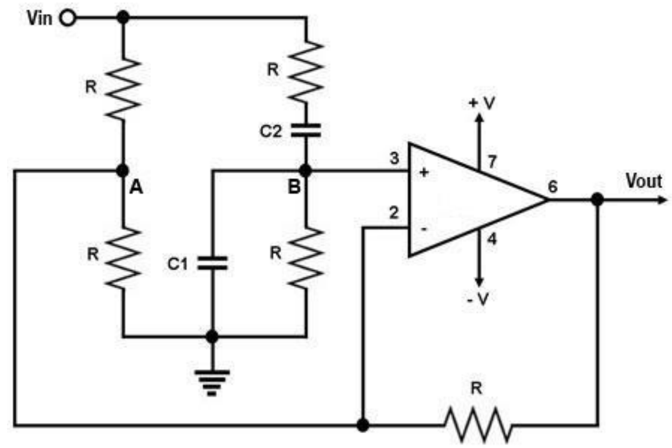

Figure 6. Low Pass Filter

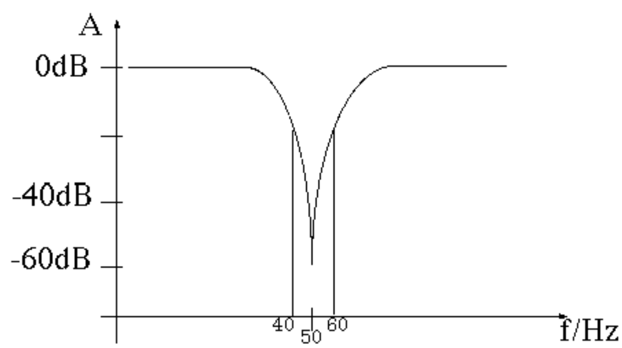

Figure 7. Frequency Response of Notch Filter

In common with other RC circuits, the RC twin T notch filter circuit has what may be termed as soft cut-off. The response of the notch circuit falls away slowly and affects a wide band of frequencies either side of the cut-off frequency. However very close to the cut-off frequency, the response falls away very quickly, assuming that close tolerance components have been used.

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C. Signal Amplification and DC Biasing

After amplification and filtering, signals are digitized by an analog-to-digital converter (ADC). The ADC requires the sampled values to fall "completely" within the positive voltage range. The summing amplifier ensures the containment in positive range

The DC voltage, which is added to signal values, is supplied by the voltage divider circuit made with two 3.9MΩ resistors. The other resistors set the gain of the amplifier to 1 and they don't influence the voltage division. In this way the output of the summing is the ECG signals transposed up by half of the supply voltage.

D. Digital Acquisition

The process of digitization and wireless transmission is controlled through the embedded software on ADC0809, ZigBee Module respectively. The on board software defines a protocol which synchronizes the acquisition, digitization and transmission cycles of the ECG signal among various modules.

1. Analog-To-Digital Conversion

Analog Devices ADC0809 data acquisition system was used to manage the digitization of the ECG signal and subsequently store it for transmission. The ADC0809 has a built-in 8-bit ADC which was used for digitization.

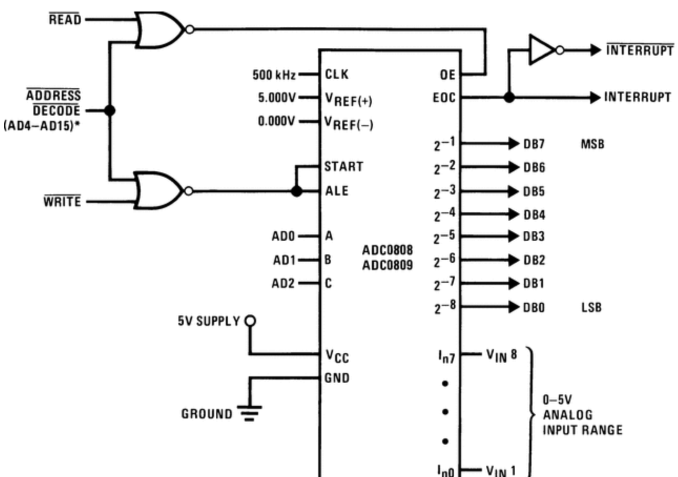


Figure 8. Pin Diagram of ADC 0809

2. Data Buffering

A buffer routine or storage medium used in telecommunications compensates for a difference in rate of flow of data, or time of occurrence of events, when transferring data from one device to another.

The transmission of data is done in packets. This results is severe distortion when recreating the original signal. Thus, it is of vital importance to design the system in a way that samples are not lost while the data is being transmitted on the network. Thus, a buffering strategy was designed to overcome this limitation.

V. ZIGBEE

One of the emerging standards in the move toward a wireless world is an approach called ZigBee. Pioneered by Phillips, it has formed into an alliance of companies working together to create a wireless communication protocol. The ZigBee stack unlike Bluetooth is relatively straight-forward, as can be seen in figure below.

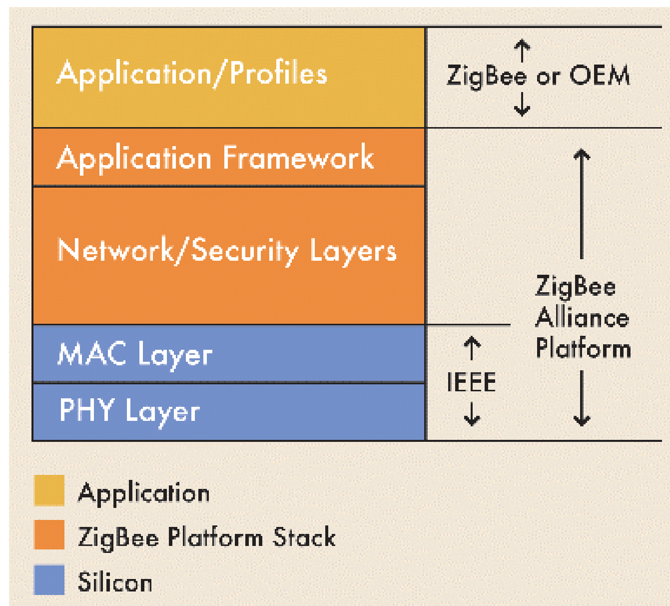


Figure 9. ZigBee Alliance & Standard

The main purpose of this standard is to provide its customers with three main features:

- Low data rate
- Low power consumption
- Low cost

A. Protocol Selection

ZigBee device is ideal for a static network, which comprises of a multiple devices communicating with smaller packets.

B. Data Rate

The ZigBee technology operates in the 2.4 GHz ISM band. The maximum data achievable on this technology is 250 kbps.

C. Power Consumption

The ZigBee is capable of a battery life of 6 months to 2 years with AA batteries.

D. Cost

The ZigBee Module cost's as low as Rs. 6000.

VI. Flowchart of Proposed System

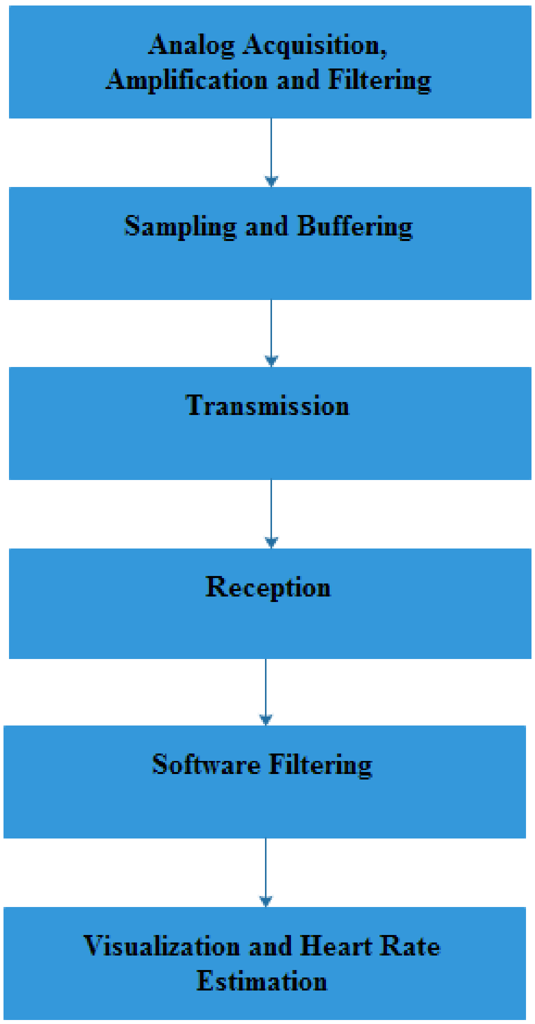


Figure 10. Flowchart of Proposed System

VII. Software Implementation

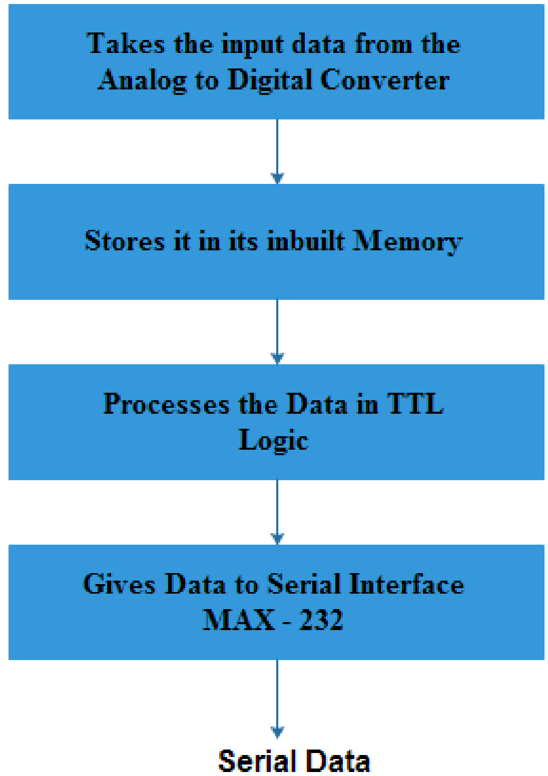


Figure 11. Flowchart of Microcontroller Logic

VIII. Hardware Implementation

A. Data Acquisition

Data acquisition is done using three electrodes namely RA, LA and LL. The LL lead is the reference point in the ECG whereas RA and LA are connected to the chest of patient. When the heart beats, the frequency is different than the reference point. These electrodes detect the analog frequency and give it to the Instrumentation Amplifier (AD620). The Instrumentation amplifier gives output related to the difference between the input analog frequencies and amplifies it.

It is then given to the Optocoupler (MCT2E). The output of the isolator is given to the High Pass Filter and then to the Low Pass Filter. This enables the output to be in a pre-determined frequency range. We use the OP07CP operational amplifier as a comparator where the outputs of the High Pass Filter and the Low Pass Filter are given as the input and the output of this operational amplifier is given to a Notch Filter which is constructed using a Twin-T network.

The output of the Twin-T Notch Filter is given to an Adder Circuit where we can see positive half of the ECG. This is done because the negative half of the ECG graph is negligible.

This completes the acquisition stage of the project.

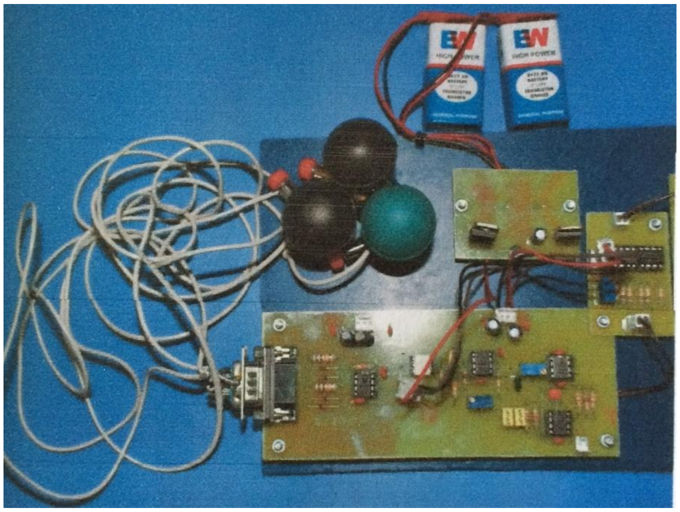


Figure 12. Data Acquisition

B. Digitization & Transmission

The output obtained from the adder or the Notch Filter is analog stage. For transmission of this data, it is necessary to convert it into digital format. For this we use an Analog to Digital Converter (ADC0809). This converts the analog input into 8-bit digital output. This is then given to a Microcontroller (AT89S51) which is used for data buffering. This ensures that the data is transmitted real time.

The microcontroller is of TTL logic based device. We connect the microcontroller to the MAX-232 because the microcontroller itself is not suitable for serial transmission. The output is then sent to a ZigBee Transmission Module which transmits the ECG Data real time.

This concludes the Digitization & Transmission part.

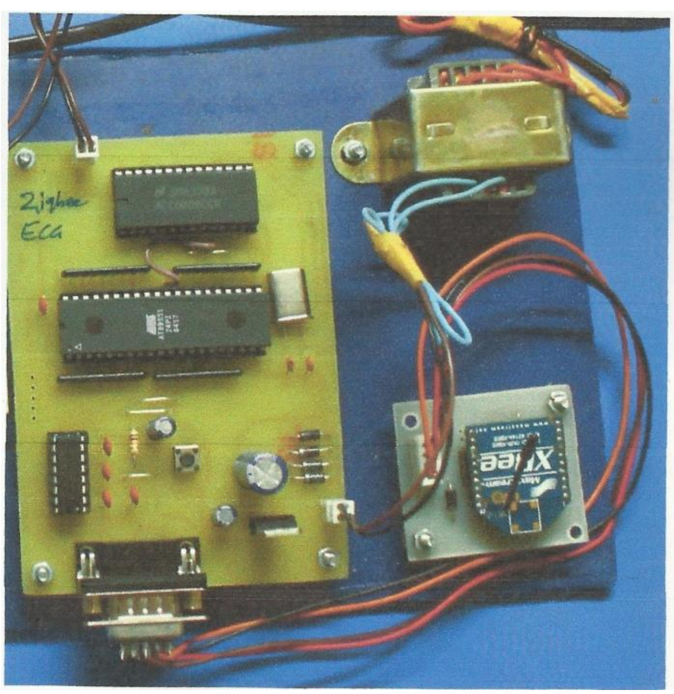


Figure 13. Digitization & Transmission

C. Receiver

At the receiver end the ZigBee Receiver module receives the real time data from transmission device and then makes it available at the serial port of the device. The Real Time data is then seen on the computer using serial port. For that we have designed a Visual Basic program through which we can plot the ECG graph and see the real time data.

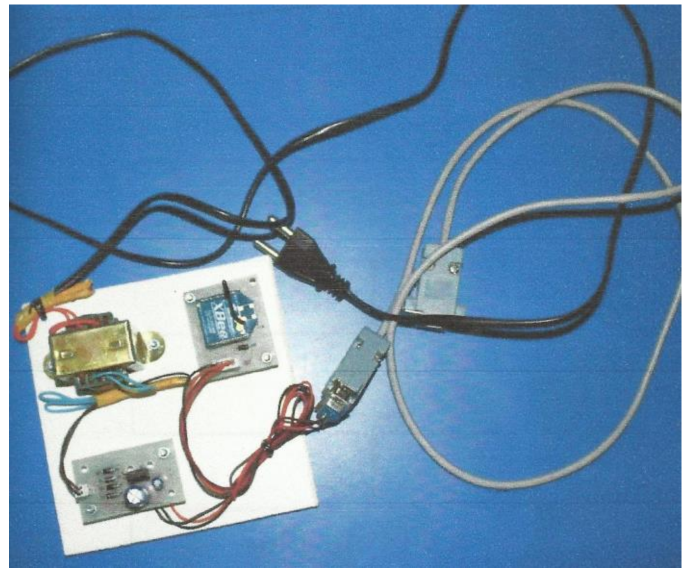
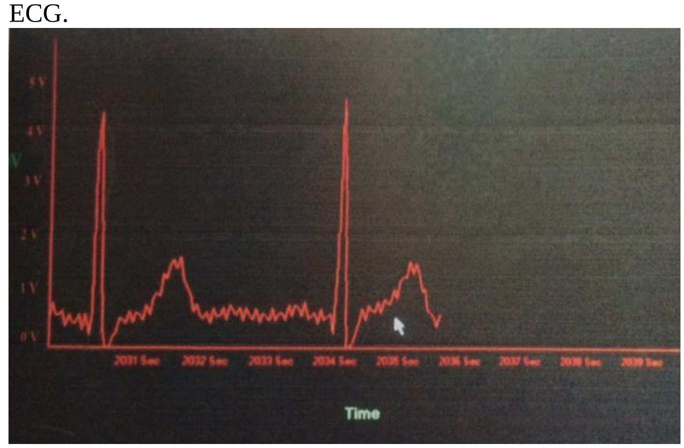


Figure 13. Receiver

IX. RESULT

The system is designed and implemented and works successfully. The ECG recorded using the electrodes, is filtered for any noise present in it through low pass, high pass and notch filter. It is followed by Analog to digital conversion and finally sampled and transmitted by the transmitter. A receiver at the other end receives such a signal which is plotted using VISUAL BASIC. The figure shows graph of ECG.



X. CONCLUSION AND FUTURE SCOPE

The presented system monitors the ECG and transmits it wirelessly to the personal computer. The signal is transmitted using microcontroller and ZigBee transmitter. It is received by the receiver and recorded on the computer using VISUAL BASIC.

Although visual basic is used to record the signal in this proposed system, the same can be done using MATLAB.Also isolation of the R wave and measuring the distance between the successive R waves would give an automatic arrthymia detector. Amplitude measurement of various waves encountered in the ECG would give an indication of heart disorders.Algorthims for the same can be designed and implemented in MATLAB

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