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System Design and Realization of Wireless ECG

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ABSTRACT

The objective of the project is to design ECG Monitoring system using Microchip PIC16f877 and transmit the ECG signal to the Personal Computer using Blue tooth technology. This Wireless ECG system is a low cost, low power portable system with wireless transmission for real time ECG acquisition, archiving and visualization in a PC and has become a more established technology. The natural step in this progress is to develop a reliable ECG system that contributes to the cable reduction in medical and physiotherapy environments. With the use of a microcontroller the analogue signal is digitally converted at a specific sample rate that based on the resolution of the ECG-signals and also to reduce noise level of the ECG signal, and give the perfect ECG signal of the patient.

INTRODUCTION

The recent Records shows that the heart disease affected patients are rapidly increased in India and around the world. In India 70,000 patients 45 years of age or older affected. The aim of this project is to develop a prototype of an electrocardiogram (ECG) sensor and to transmitting data via Bluetooth to a PC. It is also a low cost, portable system with wireless transmission capabilities for the acquisition, processing, storing and visualization in real time of the electrical activity of the heart to PC. Now they are using ECG systems in the hospitals are wired systems, it has several Electrical devises with long wires and cables which ideally has 12 cables connected to patients so the data collection is very antiquated. In old ECG devices it has 12 points to sense the electrical signal from the patients and it is also difficult to fix the patients body. In this wireless ECG system eliminate all the cables and reduced the points 12 to 3 (Right Arm, Left Arm, Right Leg) and make a system wireless with each node communicating wirelessly to the computer. Compare to old system this wireless ECG is low coast and less power consumption. Eliminating the long cables between nodes, the patient is comfortably able to move around without the hassle of wires, while also being able to place the electrodes on themselves without being impeded by leads. Similarly it provides the doctor or nurse with a trouble-free approach to the patient's ECG signal.

For this device Patients has more benefit, which will make data more accessible by cost and ease of use. Using a familiar computing environment, the patient can have on-hand ECG data. The storing of data on file, in conjunction with communication media like the Internet provides many options. This wireless ECG is reducing the hospital stops work burden and it is user Friendly device. Several groups has developed ECG system with reduce the noise using software's but this design will reduce the noise using high end filtering used in the ECG sensor circuit. So we get very good and quality of signal from the ECG sensor and also having the capabilities of wireless transmission for real time ECG signal visualizations of PC. This ECG system design has the Band width rang from 0.05 to 100 Hz

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A.ECG Signal:

An electrocardiogram (ECG) is a recording of the electrical activity on the body surface generated by the heart. ECG measurement information is collected by skin electrodes placed at designated locations on the body. The ECG signal is characterized by six peaks and valleys labeled with successive letters of the alphabet P, Q, R, S, T, and U shown in figure 1.

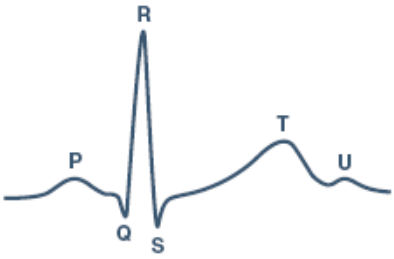

Fig. 1: ECG Signal.

From the Figure P wave is the sequential activation (depolarization) of the right and left atria, QRS complex is right and left ventricular depolarization (normally the ventricles are activated simultaneously); ST-T wave is ventricular depolarization. U wave indicate origin for this wave is not clear - but probably represents "after depolarization's" in the ventricles. PR interval is the time interval from onset of atrial depolarization (P wave) to onset of ventricular depolarization (QRS complex), QT interval is indicate duration of ventricular depolarization and depolarization, RR interval indicate duration of ventricular cardiac cycle (an indicator of ventricular rate) and finally PP interval is indicate duration of atrial cycle (an indicator or atrial rate).

II. System Description:

This ECG System consist of seven modules: Electrodes, Instrumentation Amplifier, Filter Section, Analog to digital section, Processor (microcontroller), Memory (100mb), Bluetooth section and personal computer software implementation.

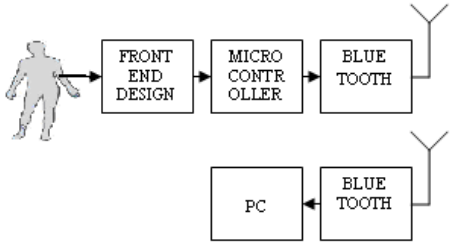

Fig. 2: System Description.

The figure 2 shows the Wireless ECG system Description. The ECG signal from the human body is sensed using Electrodes, then the ECG signal is send to front end design. In the front end design it consists of 2 stages: one is Instrumentation Amplifier and another stage is Filter Section.

Microcontroller is used for Analog to digital conversation and this processor has several advantages to use in this system. Bluetooth is using for wireless communication between microcontroller and personal computer. Bluetooth is a pure ad hoc networking protocol especially for short-range low-power wireless communication and it is allow secure and robust communication, apart from universally accepted standard.

III.Front End Hardware Design Description:

Front end design is the important hardware design part in the wireless ECG system. The front end design is dealing with the extremely weak signals amplitude is ranges from 0.05 mV to 3 mV resulting from electrodes-skin contact- plus common-mode- component from the potential between electrodes and ground. The useful Bandwidth of the ECG signal, depending on the application, for intensive care and ambulatory patient's bandwidth is ranges from 0.05 Hz to 50 Hz and normal frequency range is from 0.05 Hz to 100 Hz.
Figure 3 shows the front end design of the ECG system.

A. Instrumentation amplifier:

Instrumentation amplifiers are widely used in different measurement applications where it is necessary to suppress any unwanted common-mode signals. Typically, Instrumentation amplifiers are realized with three operational amplifiers.

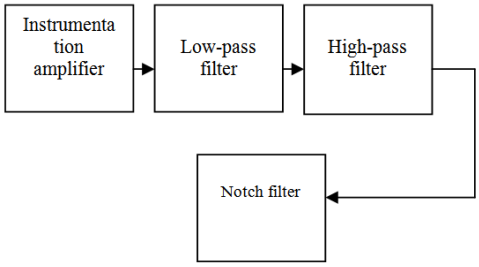

Fig. 3: Front-end Design Descriptions.

The proposed instrumentation amplifier has lower corner frequency of 0.05 Hz and upper corner frequency is 100 Hz. For the safety and production purpose the leakage current below safety standard limit of 10 μA. The common-mode rejection ratio (CMRR) is the ratio of amplification of the signal divided by amplification of the common mode input. A high common-mode value is recommended for ECG system.

This amplifier has the CMRR >> 123 db, which is Considered high for an electrocardiography. A CMRR of 100dB means the common mode signal will represent %1 of the output signal.

The signal should be amplified as close to the source as possible to alleviate loss of representation. However the gain of the signal should not be too high to prevent DC offsets and noise saturating the amplifier, so I fix the gain of the amplifier as 1000. in this the DC restoration amplifier that uses a feedback arrangement to eliminate the DC offset in the bioelectrical Signal amplifier and protection against high defibrillation voltages, also it has high input impedance and low output impedance.

B. Noise Cancellation In Ecg Signal:

ECG signals are corrupted by various kinds of noise. The following are the main source for creating noise in ECG signal Power line interference, Electrode contact noise, Motion artifacts, Muscle contraction, Base line drift, Instrumentation noise generated by electronic devices, Electrosurgical noise. For accurate detection on ECG signal, filtering the ECG signal and discard these noise sources. The following are the filters used to remove the noise from the ECG signal. Sallen-Key Low-pass filter is used for removing the high frequency noise. Sallen-Key high-pass filter is used is used for removing the low frequency noise and notch filter is used for removing the artifacts of the signal.

C. Sallen-Key Low-pass filter Design:

A low-pass filter is implemented to remove baseline wander of a patient. Baseline wander, or extragenoeous low-frequency high-bandwidth components, can be caused by:Perspiration (effects electrode impedance), Respiration and Body movements.

The low-pass filter used in this design is 4th order sallen-key low-pass filter. Properties of sallen-key is Simplicity of the design, Non-Inverting Amplifier (positive Gain), Replication of elements. The Limitations of Sallen-Key Filter is the Gain and Q are related; *Q* must be > ½, since *A* must be > 1.

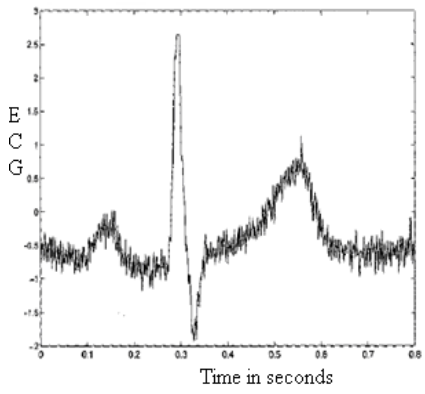

Fig. 4:

Figure 4 shows the ECG signal retrieved from the Instrumentation amplifiers it has noise.

Figure 5 is the output of the sallen-key low-pass filter.

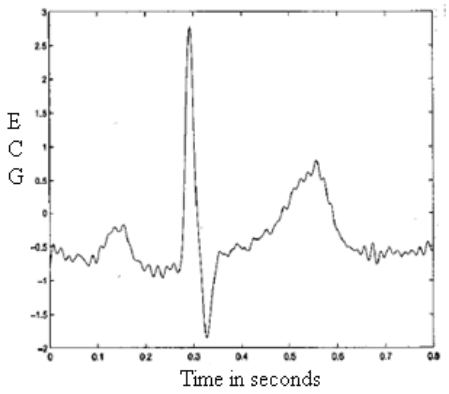

Fig. 5:

D. Sallen-Key High-pass filter Design:

The high-pass filter is used to remove frequencies higher than 100Hz. The electrode offset of 300mV to 500mV at the input to the instrumentation amplifier. Being a DC voltage, this can be removed by a high-pass filter. The High-pass filter used in this design is 4th order sallen-key High-pass filter.

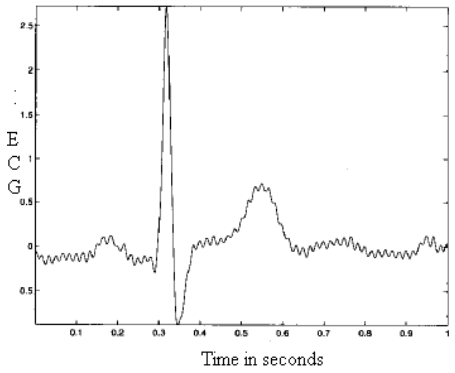

Fig 5:

Figure 5 is the output of Sallen-Key 4^{th} order High-pass filter. It removes DC voltage present in the ECG signal.

E. Notch Filter Design:

The notch filter rejects a narrow frequency band and leaves the rest of the spectrum little changed. The most common example is 60-Hz noise from power lines and other example is low-frequency ground roll. The amplitude response of a notch filter is flat at all frequencies except for the stop band on either side of the center frequency. Notch filter used in this design is 4^{th} 50 Hz notch. For the ECG signal the notch filter is used to reduce 50 Hz noise. A 50 Hz notch filter will attenuate signals at 50Hz, but not higher than, or lower than 50Hz.

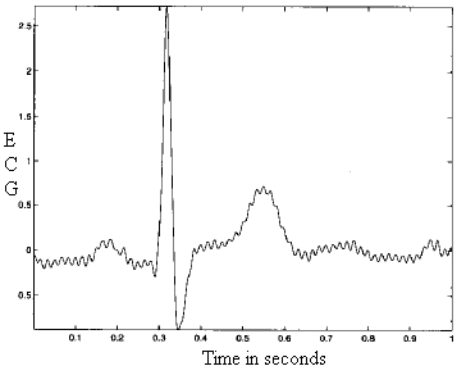

Fig. 6:

Figure 6 shows, the output of the high pass filter and it has 50 Hz noise.

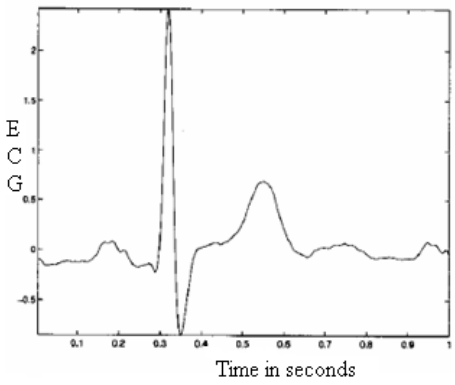

Fig. 7:

Figure 7 shows the output of the 50 Hz 4th order notch filter. It attenuates signals at 50 Hz.

IV. ECG SIGNAL Digitizing:

A PIC microcontroller is used for analog to digital conversion for ECG signal. This device is low coast and having modern features. In this device code can be assembler or C and it has 8-bit CMOS Flash Microcontroller based on RISC technology with 10-bit multi channel Analog to Digital Converter with 40MHz / 100ns per instruction (4 clocks). The signal frequency can reach 200 Hz, so we have selected a 500 Hz sampling frequency, with a 10 bit resolution, as provided by the microcontroller. Extension to 12 bits to fulfill the requirements of telematic emergency services is straight forward by choosing a microcontroller with a 12 bit converter.

Microcontroller also has More EEPROM for program (32K vs. 1K), More DATA RAM (1.5K vs. 36 bytes), More DATA EEPROM (256 bytes) and DATA EEPROM useful for lookup tables (e.g. 'sine wave') or to store state of the machine even when powered off.

The A/D module has four registers. These registers are: A/D Result High Register (ADRESH), A/D Result Low Register (ADRESL), A/D Control Register 0 (ADCON0), A/D Control Register 1 (ADCON1). The ADCON0 register controls the operation of the A/D module and The ADCON1register configures the functions of the port pins. Analog reference voltage is software selectable either the device's VDD and VSS, or the voltage level on the RA3/AN3/ VREF+ pin and RA2/AN2/VREF- pin. The A/D module is Able to operate while the device is in SLEEP mode and generates the result via successive approximation.

A. Software Description:

The microcontroller has been programmed to perform the following functions: capture and digitize the ECG signal, establish the connection to the Bluetooth and send the data to PC. The software used to perform those functions is MPLAB IDE.

MPLAB IDE is a software program that runs on PC to provide a development environment for embedded system design. It is called an Integrated Development Environment, or IDE, because it provides a single integrated "environment" to develop code for embedded microcontrollers.

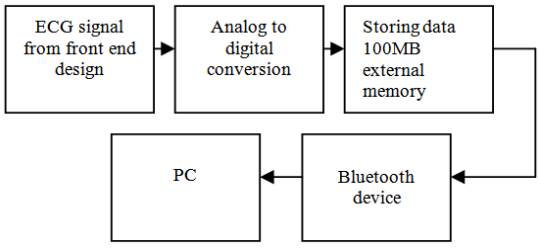

Fig. 8: Software Description.

Figure 8 is the software description of the system. Analog ECG signal is converted in to digital form and then the data is stored in to 100MB external memory. Then the stored data is send to the System using Bluetooth wireless communication device.

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Bluetooth Technology For Wireless Transmission:

Bluetooth wireless technology is a short-range communications system intended to replace the cables connecting portable and/or fixed electronic devices. The key features of Bluetooth wireless technology are robustness, low power, and low cost. The Bluetooth core system consists of an RF transceiver, baseband, and protocol stack. The system offers services that enable the connection of devices and the exchange of a variety of data classes between these devices. Both the microcontroller and the Bluetooth chip are involved in this process. Packets that contain signal information are sent to the chip, using their USART module as interface. Any device connected via Bluetooth and receive them in real-time.

Conclusion:

In this paper, the Developed Wireless ECG system has very less noise and low coast system. Acquisition and visualization of ECG signal in the personal computer is easy to install for a patient and Physician with little previous knowledge. This is patient and doctor friendly device. Comparatively the power consumption is very less. The Wireless ECG consists of reduced cables and reduced configuration. The data is stored in a computer file format. Pen and paper methods, along with the time associated with them, can now be reduced in the hospital environment. Work-load is reduced from the hospitals and Proliferation of ECG data by enabling its use at home. The wireless ECG is very useful and compact device for Hospital Environment.

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