Wireless ECG Monitoring System

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Abstract - **Second greatest killer in the world is the heart disease. Improvements in diagnosis and treatment tools are welcome by the medical community; one of the most useful diagnostic tools for heart patients is the electrocardiogram, which operates by measuring the tiny electrical signals emitted by the heart through chest electrodes. The goal of this project is to develop a device classified as a " Wireless ECG Monitor" which outperforms currently available devices, It is intended that this very product will go through medical approval and will in a year or two be found saving peoples lives. This device is designed to record single channel of full-spectrum ECG. It stores this enormous amount of information in the memory for further correspondence. Wireless technique is used to remove burden of holter monitor. It can monitor ECG of a patient, who is far apart. The device will analyze ECG for real time and will display Heart Rate, amplitude, and intervals of some critical components.**

Keywords: ECG, Wireless.

I. INTRODUCTION

An ECG is a measurement of the electrical activity of the heart (cardiac) muscle as obtained from the surface of the skin. As the heart performs its function of pumping blood through the circulatory system, the result of the action potentials responsible for the mechanical events within the heart is the generation of a certain sequence of electrical events.

A. ECG Measurement:

The electrical impulses within the heart act as a source of voltage, which generates a current flow in the torso and corresponding potentials on the skin. The potential distribution can be modeled as if the heart were a time-varying electric dipole If two leads are connected between two points on the body, electrical voltage observed between the two electrodes is given by the dot product of the two vectors.

B. System Functionality:

The key task is to design simple wireless ECG Monitoring system. It will be first electrocardiogram monitoring system to eliminate the wires and cables between patient's bedside monitors. RF technology will transmit data from electrode to system the system helps in giving early mobility to patients. The device component will be designed to make them appear less threatening and more comfortable to wear. Therefore, it has designed our solution with patient mobility in mind to facilitate mobile monitoring, which enables personalized home based monitoring where patient can access their health records anytime anywhere.

II. ECG – An Overview

A. Heart Signal:

The atria and ventricles work together, alternately contracting and relaxing to pump blood through your heart. The electrical system of the heart is the power source that makes this possible. Heartbeat is triggered by electrical impulses that travel down a special pathway through your heart. The impulse starts in a small bundle of specialized cells called the SA node (sinoatrial node), located in the right atrium. This node is known as the heart's natural pacemaker. The electrical activity spreads through the walls of the atria and causes them to contract. At rest, a normal heart beats around 50 to 99 times a minute. Exercise, emotions, fever and some medications can cause your heart to beat faster, sometimes to well over 100 beats per minute.

B. Electrocardiogram:

ECG is the electrical manifestation of the contractile activity of the heart's myocardium. The P, QRS and T waves characterize the ECG waveform (Figure 2.1). The most prominent feature is the QRS complex, where R denotes the peak of QRS complex.

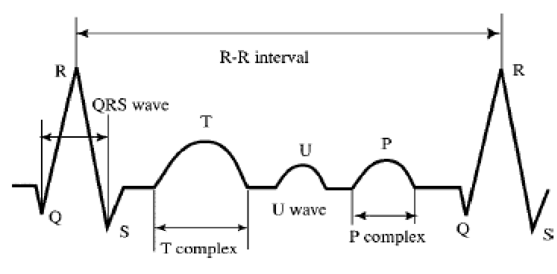

Fig 2.1 Typical cardiac cycle of an ECG

Any disturbance in the regular rhythmic activity of the heart (amplitude, duration and shape of rhythms) is known as arrhythmia. Cardiac arrhythmias may cause the heart to pump less effectively, causing insufficient blood to reach the brain another vital organ. When the body's blood flow is inadequate, the person can faint or suffer chest pain. Sometimes, sudden cardiac death can occur. Therefore, a continuous cardiac monitoring and online analysis system could detect these rare episodes of cardiac arrhythmias as they occur.

C. Standard ECG Lead System:

Two electrodes placed over different areas of the heart and connected to the galvanometer will pickup the electrical currents, resulting from the potential difference between them The resulting tracing of voltage difference at any two sites due to electrical activity of the heart is called a "lead". Most of the ECG machines use 12-lead system, whereas in this project a 3-lead system is used. Both feature 3 electrodes placed on the limbs. If the heart's electrical activity is viewed as a simple dipole, these three leads record the projection of this dipole onto the sides of the 'Einthoven Triangle'(figure 2.2), i.e. the equilateral triangle formed by the vectors of the limb leads .

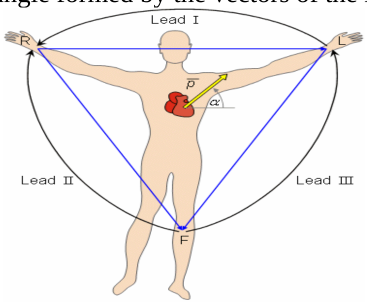

Fig 2.2: The Einthoven Triangle & 3-lead electrode placement.

D. Common Artifacts:

The electrical signals of heart obtained from the patient's body are of very low strength (2.5mV) & mixed with noise. The instrumentation amplifier and further Inverting amplify the low strength signals and non-inverting amplifiers to provide gain up to 2000. Three different types of noise are present in the signal.

- DC Electrode offset potential
- 50Hz AC induced interference.
- The electrodes pick up muscular noise.

III. SYSTEM DESIGN

The electrical signals of heart obtained from the patient's body are of very low strength (2.5mV), low frequency & mixed with noise. The instrumentation amplifier amplifies the low strength signals & filters eliminates the noise. Using notch filter eliminates the 50 Hz supply noise picked up by body. ADC then converts the amplified clean signal into digital samples. The micro controller takes care of acquiring the samples & storing them in memory. The data acquired from memory is converted into serial data & transmitted through Com1 port to transmission module. The reception module receives the data & transmits it serially to computer through Com1 port. The data is represented in graphical format on computer. Block diagram of the system is shown in fig 3.1. In practice three bipolar leads and nine unipolar leads are available. But for our application signals from unipolar lead are sufficient to detect arrhythmia because it is horizontal to the Einthoven triangle.

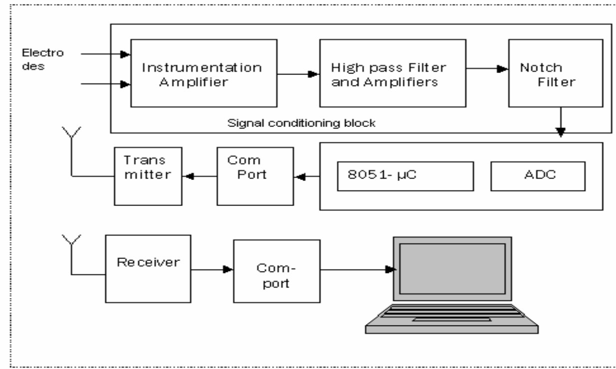

Fig 3.1 Block Diagram of the system

A. Instrumentation amplifier:

This is intended for low level signal amplification where low noise, low thermal and time drifts, high input impedance an accurate close loop gain are required. Besides, high CMRR and high slew rate are desirable for superior performance. As ECG signal is of very low amplitude, instrumentation amplifier is used to amplify it at initial level so that ECG signal will not get loaded. The two signals entering the differential amplifier are subtracted to cancel the common noise present in the signal. Because of instrumentation amplifier common noise gets cancel with advantage of strengthening the signal.

B High Pass Filter and Amplifiers:

In order to block DC offset present in the signal, we have to use High Pass Filter to block DC. If DC is not getting blocked at this level it will increase with gain of amplifiers connected after DC blocker, will induce noise .In order to provide gain of 2000 we have to use two amplifiers one is inverting and other is non-inverting.

C. Notch filter:

In order to reduce 50Hz power line frequency hum notch filter is very essential. It should be highly precise at 50Hz. It is composed of one low pass filter to blocks, and one high pass filter.

D. Microcontroller:

For Our project we are going to microcontroller AT 89C52. This controller is for controlling analog to digital converter operation, MAX232 that is used for serial interface and controlling the wireless communication through MR-96. Programming of the microcontroller is done in Assembly language code. Because it is easy and occupies less memory space compare to C.

E. Analog to Digital Converter:

For converting analog signals of ECG into digital in order to interface with the microcontroller analog to digital converter is needed. In order to get good accuracy 12- bit Analog to Digital converter AD574 is selected. It has several features, which are useful for us. Conversion time is very less

(35us). Due to its bipolar ability, it is very useful for digitalizing the bipolar ECG signals. It gives parallel 12bit output, makes it easy to interface with the microcontroller.

F. Wireless Communication Kit:

The system uses MR-96 Wireless Communication Kit for transmission of the digitally converted ECG signals. automatically .Dual serial port, 3 interface modes MR-96 provides 2 serial ports and 3 interfaces, with COM1 as the TTL level UART interface and COM2 as user defined standard RS-232/RS-485 interface Due to GFSK interference due to noise is reduced. Transmitter current drawn is very less in this case. Maximum data rate is 9600 bits/sec. The range of the module is about >300 meters. The low power consumption of the module makes it perfect for the portable devices.

G. Signal Display:

In practice paper recorder are used to display the variation in the electric activity of the heart. The ECG is printed on the graph paper. This system display ECG signal, on monitor of computer. Digital signals are captured from RS232 port and displayed on Command prompt by using software, which is written in C.

IV. HARDWARE DESIGN

A. Signal Conditioning block:

To amplify low amplitude ECG signals this system uses amplifiers. Gain of the amplifiers is adjusted according to the specifications of the analog to digital converter. AD574 has the analog input voltage for bipolar application is +5V to –5V. ECG signals have maximum voltage rage of 2.5mV. So the required gain of the system is

$$\text{Gain} = \frac{\text{Output (I/p of ADC)}}{\text{Input (O/p of ECG signal)}}$$

$$\text{Gain} = \frac{5V}{2.5mV} = 2000$$

This uses two stages to provide gain of 2000. It has been decided that instrumentation amplifier will provide of 66 and inverting amplifier will provide gain of 30. So the total gain provided by the system is

$$\text{Gain} = 66 * 30$$
$$= 1980.$$

B. Microcontroller and Interfaces:

Analog signals from signal conditioning block are given to AD574. Microcontroller is controlling AD574 using port3. Digital signal are given to Port 1 of microcontroller. Digital data is transmitted to max232 using RXD and TXD of microcontroller. Signals from RS232 are transmitted to MR96 wireless communication kit. MR-96 is used to transmit ECG signals at 334MHz.The wireless communication module operates at standard baud rates from 9600 to 115200. It has been decided to select 9600-baud rate for communication purpose. The serial data communication is carried out with the help of the UART present in the microcontroller. The communication used here is in mode 1. Timer 1 is used in Mode 2 as an auto load 8-bit timer that generates the baud frequency. The baud frequency selected for the serial communication is 9600 Hz. By loading this value of 0FDh in the TH1 register the 9600-baud rate is obtained. MR-96 Kit is used for wireless communication because of following features. Ultra low power transmission with the transmission power of 10mW. ISM frequency band: requiring on application of frequency point. Carrier frequency of 433MHz, also capable of providing 450MHz carrier frequency. High anti-interference and low BER (Bit error Rate) Based on the GFSK modulation mode, the high-efficiency forward error correction channel encoding technology is used to enhance data’s resistance to both burst interference and random interference and the actual bit error rate of 10-5 ~ 10-6 can be achieved when channel bit error rate is 10-2.Long transmission distance: Transparent data transmission: Transparent data interface is offered to suit any standard or nonstandard user protocol. Any false data generated in the air can be filtrated automatically

V. SOFTWARE DESIGN

A. Microcontroller Unit:

Software for the microcontroller is designed in assembly language. Before writing a program, modes of serial communication are decided, baud rate is selected. Conversion is initialized by sending pulse of Start Of Conversion. After waiting up to Conversion time and accepting End Of Conversion, 8-bit MSB is read and 8-bit LSB is read from ADC. 16 bit data is converted into 12 bit data. 12 bit data is transmitted to SBUFF register. Here system is transmitting two * then transmitting 12-bit data 600 times. Two * are used at the receiver for checking the sequence of data. Count of 600 is chosen because it is easy to display the data on desktop, which has pixels of 640 x 480. Data transmission is checked by interrupt TI. Software tool used to debug a program is RIDE-IDE. Hex Code generated by the RIDE-IDE is burned in to 89C52 using the Flash Magic Software. This program will continuously collect the values from ADC and transmit to the wireless module. Wireless module converts it into 434.233GHz frequency using GFSK technique.

B. PC Serial Port:

The RS-232 serial communication standard is the most popular serial communication scheme in the world. Although it suffers from many drawbacks, speed being the primary one, it use is widespread and there are literally thousands of devices you can connect to a PC using an RS-232 interface. Manipulating the serial port is not difficult. However, the 8250 SCC contains lots of registers and provides many features. Therefore it takes a lot of code to control every feature of the chip. The UCR Standard Library provides an excellent set of routines that control the 8250. They even an interrupt service routine allowing interrupt driven I/O. For software that goes directly to the hardware, especially interrupt service routines for the serial ports, needs to deal with hardware addresses, not logical addresses. Therefore, we will always mean I/O base address 3F8h when we discuss COM1.

VI. RESULT AND CONCLUSION

This wireless device is designed to record single channel of full-spectrum ECG. It can monitor ECG of a patient, who is far apart. The device analyzes ECG for real time and will display Heart Rate, amplitude, and intervals of some critical components. The system consist of two section

1. Transmitter
2. Receiver

1. Transmitter: ECG signals captured by Electrodes are processed and filtered by signal conditioning block. Filtered signals are given to AD574 for conversion into 12-bit digital data. Digital data is transferred to the max232 using microcontroller. MR-96 Wireless Communication Kit collects data from Max232, which then modulates it using GFSK technique and transmit at a frequency of 434.23MHz.

2. Receiver: At the receiver side we have receiver of MR-96 Wireless Communication Kit and PC to display waveform. MR-96 will receive data at 434.23MHz, demodulate it transfer it to the COM I port of PC. Registers of 8250 collect data. Collected data is processed further for display on screen (640 X 480 pixel). At receiver Heart rate, R-R interval, R-Wave amplitude, Q-wave amplitude is calculated and displayed on screen.

A. Results:

Wireless ECG Monitoring System is tested on ten persons. ECG signals are observed on Digital Storage Oscilloscope and on monitor of computer. It is observed that they are comparable. Comparison of parameters obtained from ECG Machine and Wireless ECG Monitoring System:

Sr. No.	Parameter	Observation using		% Error
		ECG Machine	Wireless ECG	
1	R-R interval	0.560 msec	0.536 msec	4.4
2	Heart rate	107 per minute	111 per minute	3.6
3	R wave amplitude	0.9 mV	1 mV	4.4

Table 6.1: Comparison of parameters

B. Conclusion:

Based on the result presented above it is concluded that:

- Wireless ECG monitoring system is designed and implemented successfully.
- The performance of the system is satisfactory and it's validity is certified by clinician.
- This system can acquire ECG signals of a patient present at remote place (200m) and the signals can be recorded and analyzed at receiver side.
- The system is tested for 10 normal persons and results are compared with ECG machine results and accuracy found in 89%.
- Accuracy is limited due to conversion time (35 usec) of ADC (AD574) used.
- The system can measure ECG parameters like R-R interval, Heart Rate, R-wave amplitude in real time.

C. Future Enhancement:

- Application of mobile communication: The ECG captured in memory can be transmitted by the use of GSM module, which can be incorporated in the transmitter part.
- Internet communication in telemedicine: The ECG can also be transmitted to any part of the world via Internet. The doctors or team of specialists can thus analysis the data and take the decisions accordingly.
- Self explanatory remedies by the device: Additional software & circuitry can be added, so as to enable the device to analysis the acquired waveform on itself & provide the best possible remedy immediately.
- Different Lead Configuration: ECG waveform can be taken with different lead configurations i.e. Lead 1, Lead 2, Lead 3,Av, Ar, Al, etc. these all waveform are important for diagnosis Four electrodes are connected to the patient's body.

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