Real Time ECG Signal Transmission for Remote Monitoring

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Abstract - **Our main objective is to implement a monitoring system which monitors the heart pulse of a patient. This work presents a novel easy-to-use system intended for the fast and non invasive monitoring of the Lead I electrocardiogram (ECG) signal by using a wireless steering wheel. The steering wheel used here is a prototype model. A novel heart rate detection algorithm based on the continuous wavelet transform has been implemented, which is specially designed to be robust against the most common sources of noise and interference present when acquiring the ECG in the hands. Skin Electrodes were used to record the nerve voltages for monitoring the heart pulse. The voltages recorded will be sent to an instrumentation amplifier which amplifies the signal, and then to a filter which filters the noise. Thus, analog signal is given to Analog-to-Digital Convertor (ADC) of Arduino. There, analog voltages are been converted to digital and that digital values will be stored in the EEPROM of Arduino. The values stored in EEPROM will be sent to PC via XBEE (IEEE 802.15.4) wirelessly and a serial port will be opened in the MATLAB by using a serial object. GUI is programmed to make the user interface interactive and simple. Using the real time plot, I've plotted the values received by XBEE module and making a running waveform which displays when the MATLAB sent a query to Arduino.**

Keywords - **ECG, Arduino Uno, Zigbee.**

I. INTRODUCTION

At present, heart disease is one of serious diseases that may threaten human life. The electrocardiogram (ECG) is important role in the prevention, diagnosis the abnormality of patients and rescue of heart disease. In progress has been made in the development of a remote monitoring system for ECG signals, the deployment of packet data services over telecommunication network with new applications. The tele-transmitting and receiving of ECG signal is the key-problem to realize the tele-diagnosis and monitoring of ECG signals.

Background

Telemedicine is the use of medical information exchanged from one site to another via electronic communications to improve patients' health status. Telemedicine is a newest technology which combining telecommunication and information technology for medical purposes [1]. It gives a new way to deliver health care services when the distance between the doctor and patient is significantly away. Rural area will get the benefit from this application. Patient monitoring is one of the telemedicine, which always needs improvement to make it better. It is vital to care in operating and emergency rooms, intensive care and critical care units. It is also important for respiratory therapy, recovery rooms, out-patient care, radiology, ambulatory, home and sleep screening applications.

The advantages of a patient monitoring system are it can reduce the risk of infection and other complication in order to make the patients comfortable. Furthermore, implement of patient monitoring in hospitals might reduce the costs in terms of installation and also maintenance of wiring [2].

Since many critical patients need a high attention in intensive care unit (ICU) and cardiac care unit (CCU), thus the bedside in the hospitals over the limit as provided to the patients. Otherwise, this creation will helpmore elderly patients who need constant monitoring, both in the hospital or home environment.

Previously, the available medical monitoring system is generally bulky and thus uncomfortable to be carried by patients. Patient monitoring using wireless sensor network has a greater potential in the future in order to achieve the best performance health care services and also to avoid from cost pressure in the hospital.

II. GLOBAL ARCHITECTURAL

The structure of global system is shown in Figure1. It consists of three parts: ECG Sensor circuit, Wireless network, and Personal monitor. Among them, Portable ECG Sensor circuit check status of the heart of the patient and record the analog ECG signal. This analog ECG signal is digitized by 10 bit ADC of the ATMEGA 328 microcontroller in Arduino Uno Board. This digitized ECG signal is send to the remote location using ZigBee module, At remote location the data is received from serial port and displays the ECG wave form using GUI application from mat lab.
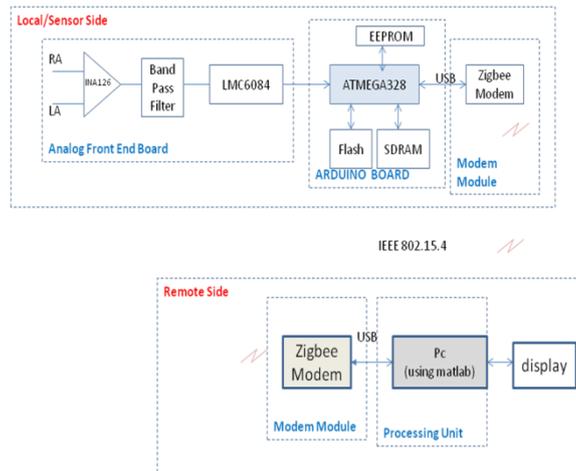
Figure 1. Block diagram of the circuit

III.   ECG CIRCUIT DESIGN

The ECG circuit

We started to build the first ECG prototype circuit after doing a lot of research and studying about the requirements of the ECG system. We wanted the ECG circuit to be as simple as possible and yet give us the desired output required for primary diagnosis of heart. The simplest circuit ever possible to detect ECG is built with a single instrumentation amplifier, filter circuit and output stage amplifier.
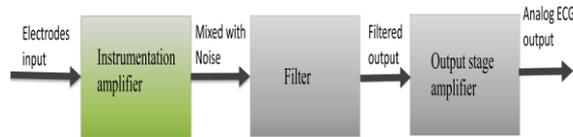
Figure 2 :Block diagram of ECG Sensor

Instrumentation Amplifier

The signal acquisition is the first consideration when an HRM is implemented. But the signal is too small and contains a lot of added noise. As we said above the signal extracted from the heart has amplitude of approximately 0.5mV.Since, it is necessary to amplify the signal and filter the noise, and then extract the QRS complex. An instrumentation amplifier is usually the very first stage in an instrumentation system. This is because of the very small voltages usually received from the probes need to be amplified significantly to be proceeding stages. We can summarize the reasons to use instrumentation amplifier:

1.   Get differential signal
2.   High input impedance
3.   High CMRR
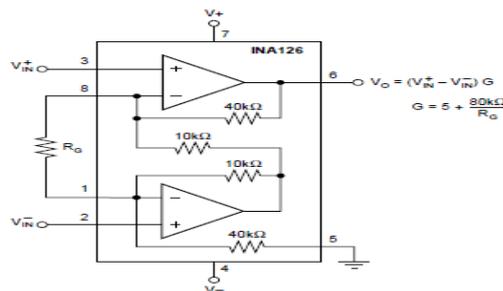
Figure 3. Internal circuit of INA126U

The INA126 is precision instrumentation amplifier for accurate, low noise differential signal acquisition. Their two-op-amp design provides excellent performance with very low quiescent current (175µA/channel). This, combined with a wide operating voltage range of ±1.35V to ±18V, makes them ideal for portable instrumentation and data acquisition systems.

Gain can be set from 5V/V to 10000V/V with a single external resistor. Laser trimmed input circuitry provides low offset voltage (250µV max), low offset voltage drift (3µV/°C max) and excellent common-mode rejection.

Filter

A further stage in this is to use band pass filter. The reason for using band pass filter is to avoid the DC voltages created by the muscles and to avoid the high frequency component which is not of any use to us. The high pass filter section has a cut off of 0.5Hz and the low pass filter has cut off of 35Hz approximately. Since the low pass cut off is must lower than 50Hz, it helps in suppressing some of the 50Hz noise as well, which is a good thing. We preferred passive filter topology i.e. using only capacitor and resistors to filter out the signal. Passive filters of 2nd order are implemented and they require around 10 seconds of settling

time. That means you need 10 seconds for the circuit to settle down and start showing you correct signal. Active filters if at all used would yield better result and the settling time for them is less than a second.
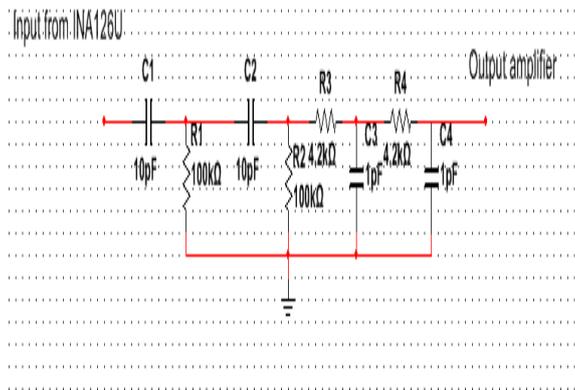
Figure 4. Filter circuit

The above figure shows the filter schematic with values calculated using the equation:
F = 1 / (2*pi*RC)
This stage receives the signal from the first stage i.e. INA126.

After the filter stage comes the final amplification stage in which the filtered ECG signal is amplified using non-inverting operational amplifier with a gain of 100 to 220. This stage is necessary to bring the ECG signal's peak-to-peak amplitude to around 2V approximately. Bringing the voltage level to 1-2V will yield a better resolution when given to the ADC of the microcontroller in later stage.

A low amplitude signal given to ADC would require high resolution (>12bits) to be recognizable which would increase the cost and components. To avoid adding another ADC IC, we preferred to amplify the voltage level of the signal.

The stage successive to this is where we will give the final ECG signal from the circuit to the analog-digital converter of the microcontroller. We will discuss about the microcontroller later in this book.

Once the data is digitized, we can transmit this information to the computer where we can digitally filter the signal and plot it in real-time, or do whatever we want with it.

Output Stage Amplifier
The LMC6084 is a precision quad low offset voltage operational amplifier, capable of single supply operation.

Performance characteristics include ultra-low input bias current, high voltage gain, rail-to-rail output swing, and an input common mode voltage range that includes ground.

These features, plus its low offset voltage, make the LMC6084 ideally suited for precision circuit applications.
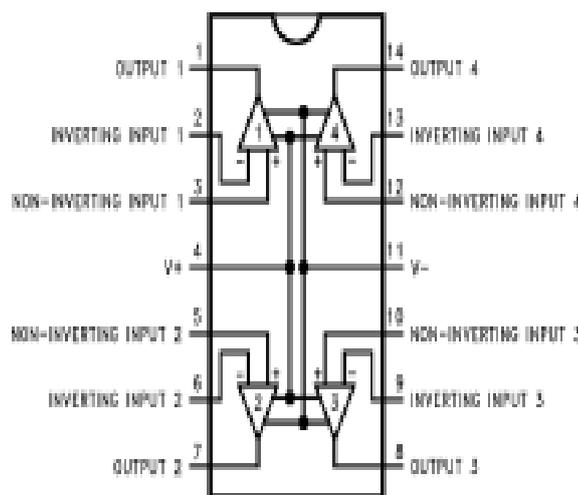
Figure 5. Internal circuit of LMC6084
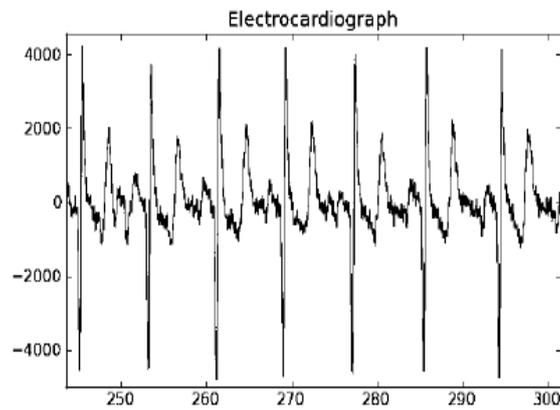
Figure 6. Final stage output
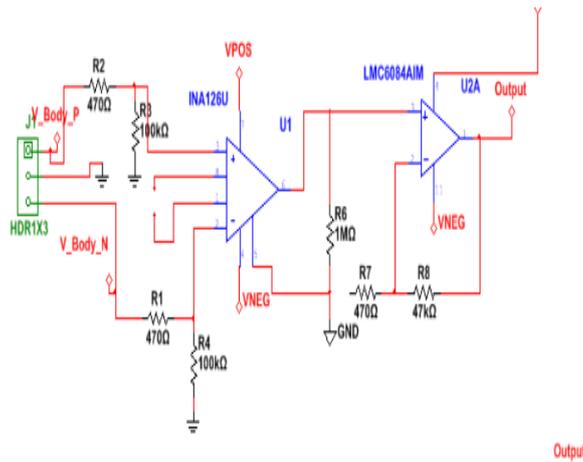
Figure 7.ECG sensor circuit

IV.   ARDUINO UNO BOARD

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins which 6 can be used as PWM outputs, 6 analog inputs, a 16MHz crystal oscillator, a USB connection, a power jack and a reset button. It contains everything needed to support the microcontroller which simply connect it to a computer with a USB cable or power it with a AC to DC adapter or battery (5V) to get started. Arduino is an open-source electronics prototyping platform based on flexible and easy to use hardware and software.

The Uno is differs from other boards because it features at ATmega 16U2 (Atmega8U2 up to version R2) which programmed as a USB-to-serial converter. The microcontroller on the board is programmed using the Arduino programming language which based on wiring and the Arduino development environment which based on processing. It can receive input from variety of sensors and can affect the surrounding by controlling lights, motors and other actuators. Arduino project can be stand alone or they can communicate other software running on the computer such as Lab view, Flash, Processing or MaxMSP. Figure 8below shows the front view of Arduino Uno Rev3.

Figure 8. Arduino Uno Rev3-Main Board

The Arduino Uno can be powered via the USB connection or with external power supply. The adapter can be connected by plugging a 2.1 mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin

header of the power connector. If supplied with less than 5V, the board maybe unstable. The power pins are as follows:

V_{in} – The input voltage to the Arduino and supply voltage can used this pin. 5V – This pin output a regulated 5V from the regulator on the board.

3.3V – A 3.3V supply generated by the on-board regulator. Maximum current draw is 50mA.

GND – Ground pin

Arduino 0023 Software

Arduino software need to be install to programmed Arduino Uno board which can be downloaded from Arduino main website. Different Arduino needs different software. Arduino Uno board can be displayed in Arduino 0023 software as shown in Figure 8 below.

Figure 9. Arduino 0023 Software.

Arduino Uno board is main function in the system because it read and interpreted the data from the ECG circuit output. Software Arduino 0023 could be downloading directly through the internet from the Arduino main page in order to build a specific programmed. Then, installed the software in the laptop to ensure the Arduino Uno board can operate nicely with the system.

In order to program coding in the Arduino Uno, Arduino 0023 software should be install first. Then, programming for ECG circuit is burned in the Arduino Uno board. In the Arduino Uno board Atmega328 microcontroller was used . To our concern the ADC and serial port of the atmega328 was of the maximum use. So we will focus clearly on this ADC of atmega328 which helps us in digitizing the analog signals.

Analog to Digital converter

ADC of atmega328 has a resolution of 10bits. In our circuit we used the internal reference voltage of +5V which results in step size of approximately 5mV. Using a lower reference voltage will give us smaller step size. A smaller step size means we can digitize smaller voltage levels. But 5mV step size is sufficient for our application.

The atmega328 contains a 10-bit successive approximation ADC with sampling frequency ranging from 10 kHz to 200 kHz. It is said that as we increase the sampling frequency the error rate increases because the circuit is unable to sustain high speed switching because of the poor noise performance.

The ECG signal lies in frequency spectrum of 0.5Hz to 35Hz (this is the range for monitoring purposes and our circuit is meant for monitoring) therefore, the sampling frequency of the ADC can be kept as low as 100SPS. For better results we have kept the sampling frequency at 1kSPSs.

The analog input channel is selected by writing to the MUX bits in ADMUX. Any of the ADC input pins, as well as GND and a fixed band gap voltage reference, can be selected as single endedinputs to the ADC. The ADC is enabled by setting the ADC Enable bit, ADEN in ADCSRA. Voltage reference and input channel selections will not go into effect until ADEN is set. The ADC does not consume power when ADEN is cleared, so it is recommended to switch off the ADC before entering power saving sleep modes.

The ADC generates a 10-bit result which is presented in the ADC Data Registers, ADCH and ADCL. By default, the result is presented right adjusted, but can optionally be presented left adjusted by setting the ADLAR bit in ADMUX.If the result is left adjusted and no more than 8-bit precision is required, it is sufficient to read ADCH. Otherwise, ADCL must be read first, then ADCH, to ensure that the content of the Data Registers belongs to the same conversion. Once ADCL is read, ADC access to Data Registers is blocked. This means that if ADCL has been read, and a conversion completes before ADCH is read, neither register is updated and the result from the conversion is lost. WhenADCH is read,ADC access to the ADCH and ADCL Registers is re-enabled.

The ADC has its own interrupt which can be triggered when a conversion completes. When ADCaccess to the Data Registers is prohibited between reading of ADCH and ADCL, the interruptwill trigger even if the result is lost.

USART

The USART has to be initialized before any communication can take place. The initialization process normally consists of setting the baud rate, setting frame format and enabling theTransmitter or the Receiver depending on the usage. For interrupt driven USART operation, theGlobal Interrupt Flag should be cleared (and interrupts globally disabled) when doing

theinitialization.Before doing a re-initialization with changed baud rate or frame format, be sure that there are noongoing transmissions during the period the registers are changed. The TXCn Flag can be usedto check that the Transmitter has completed all transfers, and the RXC Flag can be used tocheck that there are no unread data in the receive buffer. Note that the TXCn Flag must becleared before each transmission (before UDRn is written) if it is used for this purpose.The following simple USART initialization code examples show one assembly and one C function that are equal in functionality.

V. ZIGBEE

ZigBee is one type of bidirectional wireless network technology. Zigbee is easy to use and need low power consumption [14]. This is a new communication technology that based on the IEEE 802.15.4 standards and a new appropriate MAC control. Zigbee is suitable to bear operation of small data quantity and it may insert into a variety of equipments and support geography localization function simultaneously. The important characteristic of Zigbee is a network function. The advantages of using zigbee are short distance, low complexity, low power consumption, low data rate, low cost, high fault tolerance, flexibility and autonomy, security high, and very small equipment volume [15]. Zigbee radio frequency module is shown in Figure 9

Figure 10. Zigbee RF Module [15].

Zigbee Series 1 is used in this project to transfer the data wirelessly. The connection will involve four main legs with Arduino Uno board which are RXD, TXD, Gnd and Vcc [19]. Both Zigbee are same but depend on the programming which one is transmitter or receiver. Figure 11 and Figure 12 showed the correct connection with Arduino Uno board and USB Connector.
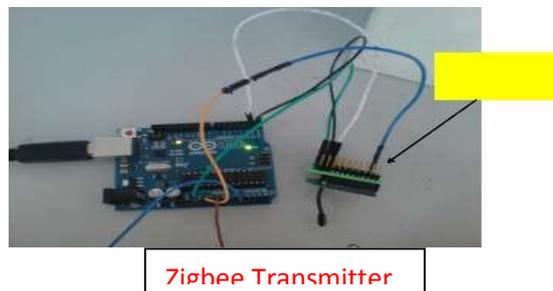
Figure 11. Zigbee Connected to the Arduino Uno board.
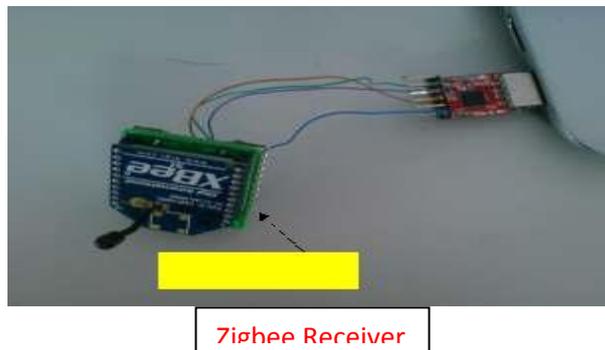
Figure 12. Zigbee Connected with USB Connector

VI. MONITORING SECTION

The ECG signal coming from the Zigbee receiver is shown in the pc by using GUI (graphical user interface) application in mat lab and we are calculating the heart beat of the person based on the ECG wave which is shown in the below fig

Figure 13. Zigbee Connected with USB Connector

VII.   CONCLUSION

As a conclusion, a prototype of patient monitoring system using wireless sensor network has been successfully developed. Based on the results obtained from the project, it showed that the project achieved the first objective. A wireless communication is successfully created between Zigbee modules and Arduino Uno board to process the data information and able to displayed in the monitor . ECG signal collected from the patient simulator used to reduce a noise. The ECG signal and heart beat can be monitored through laptop or personal computer wirelessly. The patients' ECG signal and heart beat can be monitored remotely anywhere and anytime.

REFERENCES

[1] Matthew D'Souza, Montserrat Ros, Adam Postula, "Wireless Medical Information System Network for Patient ECG Monitoring" Digital System Design: Architectures, Methods and Tools, 2006, DSD 2006, 9th EUROMICRO Conference, 2006, pp.617-624.
[2] Yuce, M. R. and H. Chee Keong, "Implementation of body area networks based on MICS/WMTS medical bands for healthcare systems", Engineering in Medicine and Biology Society, 2008, EMBS 2008, 30th Annual International Conference of the IEEE, 2008, pp.3417-3421.
[3] Arun E, Marimuthu V,Marimuthu V, Pradeep E, Karthikeyan M, "Remote Patient Monitoring-An Implementation in ICU Ward", Software Engineer, Department of Electrical and Electronics Engineering, Value Source Technologies, US Technologies, Kathir College of Engineering, Anna University, 2011, pp.1-5.

BIOGRAPHIES

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