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IoT Based Health Monitoring System by Using Raspberry Pi and ECG Signal

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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 noninvasive monitoring of the Lead I electrocardiogram (ECG) signal by using a wireless steering wheel. The steering wheel used here is a prototype model. As the World-Wide Web (WWW) continues to evolve, it is clear that its underlying technologies are useful for much more than just browsing the web. Web browsers have become the de facto standard user interface for a variety of applications including embedded real time applications. The embedded web server technology is the combination of embedded device and Internet technology. Through this embedded web server user can access their equipment's remotely. The equipment mentioned here could be home appliances and factory devices. 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 serial (RS232) wired interface 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, Python language, SSL encryption

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. 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, and 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].

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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 willshelp more 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.In this modern era of automation and advanced computing the social and commercial needs of mankind are changing very frequently. To keep up with these changes, we need to develop systems which are capable of performing different functions within some specified limits of time, accuracy and cost. Automation can be very effective to reduce human effort and involvement in different areas. This can be a boon for those fields which need a lot of skilled employees and also in areas where it is dangerous for lives of people involved in that job. Now-a-days in medical field there is a need of data monitoring and control, for this application embedded web server can prove to be a very good system which may be capable of reducing the need of skilled workers. An embedded system is a device that has computer intelligence and is dedicated to performing a single task, or a group of related tasks. An embedded system often performs monitoring the medical parameters of a patient. A web server is a system which hosts websites and provides services for any requesting clients. The general purpose web server composes of an operating system, web pages or web applications and a huge amount of memory and sometimes a special hardware. The embedded web server is the combination of embedded device and Internet technology, which provides a flexible remote device monitoring and management function based on Internet browser and it has become an advanced development trend of embedded technology. An embedded web server is an ARM processor that contains an internet software suite as well as application code for monitoring and controlling machines/systems.

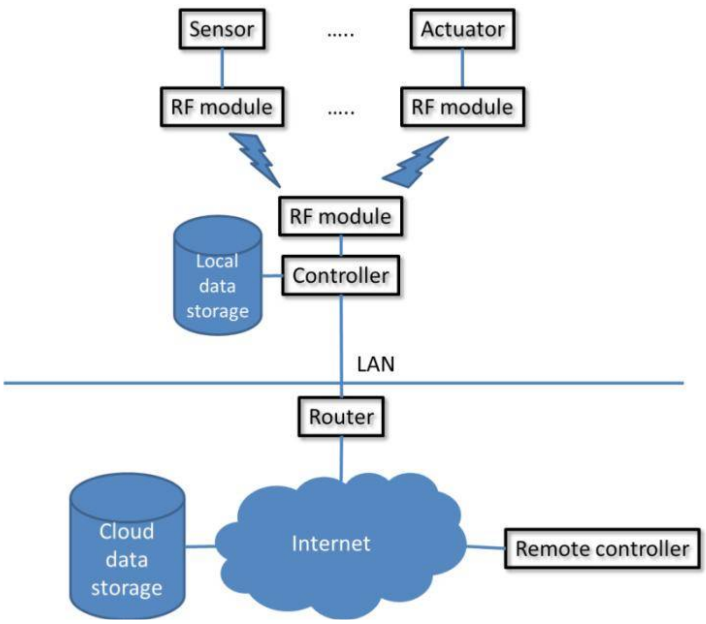

Figure No 01: IOT Architecture

Using an Ethernet shield, you can make an Arduino into a Web server.By equipping an Arduino with an Ethernet shield you can turn it into a simple web server, and by accessing that server with a browser running on any computer connected to the same network as the Arduino, you can:

1. Control hardware from the webpage (using Javascript buttons).
2. Read the state of a switch (using simple HTML).
3. Read value of a sensor (using simple HTML).

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II. SYSTEM ARCHITECTURE

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.

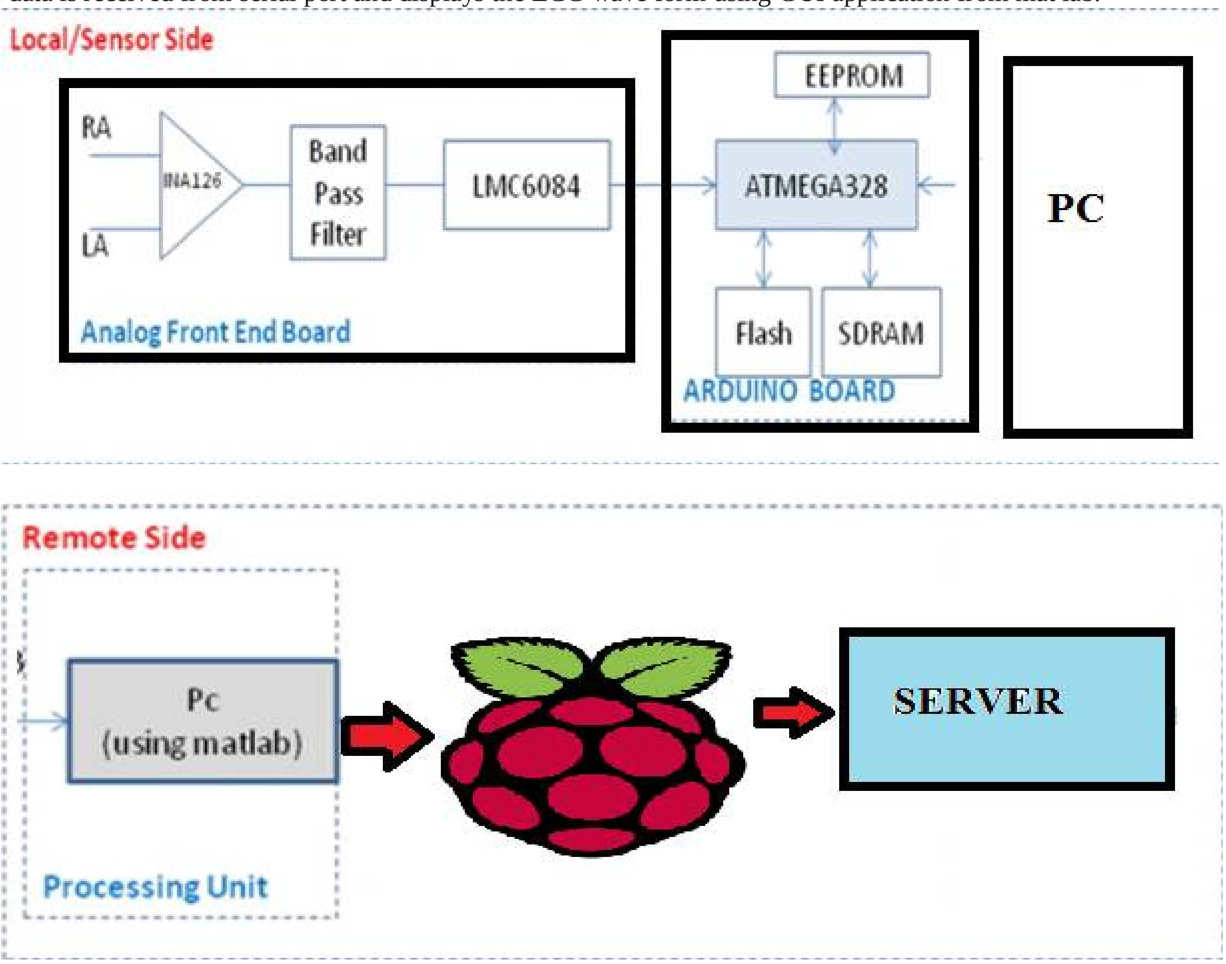

Figure No 02. Block diagram of the circuit

The raspberry pi installed with Raspbian wheezy real time operating system (Flavour of Linux). An Embedded web server is developed in that Raspbian OS to monitor the medical parameter of every patient. Through the Embedded web server the medical parameters like ECG, Body temperature and accelerometer values are displayed in the embedded web server with encryption algorithm. The ECG sensor and body temperature shows the patient health conditions and the accelerometer shows the body movement of patients. The embedded web server is protected with encrypted password for security. The encryption technique used here is SSL Encryption method.

SSL Algorithm

SSL is the short form for Secure Sockets Layer, a protocol developed by Netscape for transmitting private documents via the Internet. SSL uses a cryptographic system that uses two keys to encrypt data − a public key known to everyone

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and a private or secret key known only to the recipient of the message. Both Netscape navigator and Internet Explorer support SSL, and many web sites use the protocol to obtain confidential user information, such ascredit card numbers. By convention, URLs that require an SSL connection start with https: instead of http. Another protocol for transmitting data securely over the World Wide Web is Secure HTTP (S-HTTP). Whereas SSL creates a secure connection between a client and a server, over which any amount of data can be sent securely, S-HTTP is designed to transmit individual messages securely. SSL and S-HTTP, therefore, can be seen as complementary rather than competing technologies. Both protocols have been approved by the Internet Engineering Task Force (IETF) as a standard. The Secure Sockets Layer protocol is a protocol layer which may be placed between a reliable connection-oriented network layer protocol (e.g. TCP/IP) and the application protocol layer (e.g. HTTP). SSL provides for secure communication between client and server by allowing mutual authentication, the use of digital signatures for integrity and encryption for privacy. The protocol is designed to support a range of choices for specific algorithms used for cryptography, digests and signatures. This allows algorithm selection for specific servers to be made based on legal, export or other concerns and also enables the protocol to take advantage of new algorithms. Choices are negotiated between client and server when establishing a protocol session.

III. HARDWARE DESCRIPTION

To implement this embedded web server we used different hardware, which are described in this section.

1. Arduino

The Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

2. Accelerometer sensor

The accelerometer sensor used here is ADXL335which is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

The user selects the bandwidth of the accelerometer using the CX, CY, and CZ capacitors at the XOUT, YOUT, and ZOUT pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis.

3. ECG sensor

MOD-EKG is digital heart-rate monitor based on TI's MSP430FG439 microcontroller. The heartbeat rate per minute is displayed on the LCD. In addition, the application outputs a digital data stream via an RS232 serial port to allow EKG waveform display on a PC. The only way to do this is via board's UEXT connector, where RS232 signals are leaded. The connection between the PC and MOD-EKG can be made by using our adapter – MOD-USB-RS232 that converts the RS signals into USB signals, and vice versa.

An electrocardiogram (ECG), also called an EKG, is a graphic tracing of the voltage generated by the heart muscle during a heartbeat. In this application, the EKG waveform is used by the MCU to measure the heartbeat rate. Because heartbeat calculation is the major focus the electrodes are simplified to two connections, one to a right hand and the other to the left hand.HTML pages and connecting /communicating with new users etc., The RTOS manages all the required tasks in parallel and in small amounts of time. Web based management user interfaces using embedded web server have many advantages: ubiquity, user-friendly, low-development cost and high maintainability. Embedded web server has different requirements, such as low resource usage, high reliability, security, portability and controllability for which general web server technologies are unsuitable.

4. Ethernet

Ethernet is the networking technology used in many offices and homes to enable computers to communicate and share resources. Many Ethernet networks also connect to a router that provides access to the Internet. IEEE 802.3 supports a LAN standard originally developed by Xerox and later extended by a joint venture between Digital Equipment Corporation, Intel Corporation and Xerox. This was called Ethernet.

IV. SOFTWARE DESCRIPTION

RTOS

A real-time operating system (RTOS) is an operating system (OS) intended to serve real-time application requests. It must be able to process data as it comes in, typically without buffering delays. Processing time requirements (including any OS delay) are measured in tenths of seconds or shorter. A key characteristic of an RTOS is the level of its consistency concerning the amount of time it takes to accept and complete an application's task; the variability is jitter. A hard real-time operating system has less jitter than a soft real-time operating system. The chief design goal is not high throughput, but rather a guarantee of a soft or hard performance category. An RTOS that can usually or generally meet a deadline is a soft real-time OS, but if it can meet a deadline deterministically it is a hard real-time

OS.

The Apache HTTP Server, commonly referred to as Apache is a web server application notable for playing a key role in the initial growth of the World Wide Web. It is an open-source web server platform, which guarantees the online availability of the majority of the websites active today.Apache is developed and maintained by an open community of developers under the auspices of the Apache Software Foundation. The server is aimed at serving a great deal of widely popular modern web platforms/operating systems such as Unix, Windows, Linux, Solaris, Novell NetWare, FreeBSD, Mac OS X, Microsoft Windows, OS/2, etc. Apache 2.2 came out in 2006 and offers new and more flexible modules for user authentication and proxy caching, support for files exceeding 2 GB, as well as SQL support. Apache 2.2 version was used for creating Web server for this project.

PHP

The PHP Hypertext Pre-processor (PHP) is a programming language that allows web developers to create dynamic content that interacts with databases. PHP is basically used for developing web based software applications. PHP is a recursive acronym for "PHP: Hypertext Preprocessor". PHP is a server side scripting language that is embedded in HTML. It is used to manage dynamic content, databases, session tracking, even build entire e-commerce sites. PHP Syntax is C-Like.

MySQL

It is the most popular Open Source Relational SQL database management system. MySQL is a small, compact database server ideal for small and not so small applications. In addition to supporting standard SQL (ANSI), it compiles on a number of platforms and has multithreading abilities on UNIX servers, which make for great performance. For non-Unix people, MySQL can be run as a service on Windows NT and as a normal process in Windows 95/98 machines.

Python Language

Python is a widely used general-purpose, high-level programming language. Its design philosophy emphasizes code readability, and its syntax allows programmers to express concepts in fewer lines of code than would be possible in languages such as C. The language provides constructs intended to enable clear programs on both a small and large scale. Python supports multiple programming paradigms, including object-oriented, imperative and functional programming or procedural styles. It features a dynamic type system and automatic memory management and has a large and comprehensive standard library.

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V. ECG CIRCUIT DESIGN

1. 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.

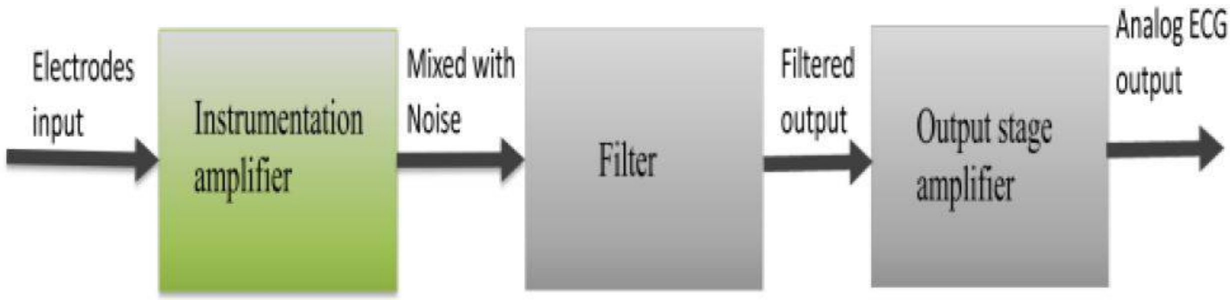

Figure No 3: Block diagram of ECG Sensor

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

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.

1. 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 settlingtime. 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.

F = 1 / (2*pi*RC)

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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.

2. 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.

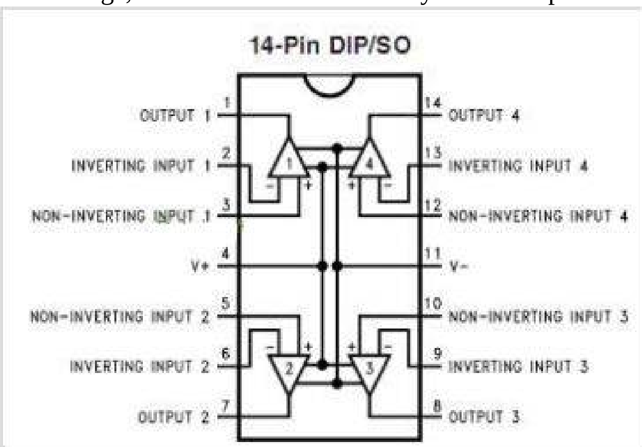

Figure No 04: Output Stage Amplifier

VI. 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.

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Figure No 05. 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 pinheader of the power connector. If supplied with less than 5V, the board maybe unstable.

The power pins are as follows:

Vin – 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

1. 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. 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.

2. 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 ended inputs 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 interrupt will trigger even if the result is lost.

3. 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) .

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.

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