International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Microcontroller Based Heart Rate Monitor

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Abstract: ***This project is designed to measure heart beat (pulse count), by using embedded technology. In this project simultaneously it can measure and monitor the patient's condition. This project describes the design of a simple, low-cost controller based wireless patient monitoring system. Heart rate of the patient is measured from the thumb finger using IRD (Infra Red Device sensor). Pulse counting sensor is arranged to check whether the heart rate is normal or not. So that a SMS is sent to the mobile number using GSM module interfaced to the controller in case of abnormal condition. A buzzer alert is also given. The heart rate can be measured by monitoring one's pulse using specialized medical devices such as an electrocardiograph (ECG), portable device e.g. The patient heart beat monitoring systems is one of the major wrist strap watch, or any other commercial heart rate monitors which normally consisting of a chest strap with electrodes. Despite of its accuracy, somehow it is costly, involve many clinical settings and patient must be attended by medical experts for continuous monitoring.***

Keywords: Microcontroller, heart rate, patient, sensor

1. Introduction

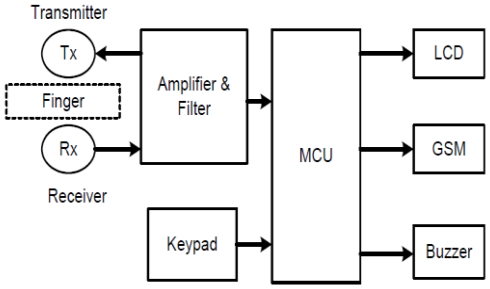
This project is useful in medical applications and offers less cost and size than ECG (Electro cardiogram). In the case of emergency, for people who are suffering with heart diseases continuous monitoring of the patient are required which is sometimes not possible in the hospital or the patient location is far away from the hospital. In such case this prototype circuit is useful to measure the heart rate and the information is transmitted to the medical advisory for the preliminary precautions so that patient can be under control, prevented from serious situation before reaching to the hospital.

2. Photoplethysmography

Photoplethysmography is the process of optically estimating the volumetric measurement of an organ. Pulse oximetry, cardiovascular monitoring, heart rate monitoring etc are few common applications of photoplethysmography. Let us have a look at the application of photoplethysmography in heart rate monitoring from the finger tip. When the heart expands (diastole) the volume of blood inside the finger tip increases and when the heart contracts (systole) the volume of blood inside the finger tip decreases. The resultant pulsing of blood volume inside the finger tip is directly proportional to the heart rate and if you could somehow count the number of pulses in one minute, that's the heart rate in beats per minute (bpm). For this an IR transmitter/receiver pair placed in close contact with the finger tip. When the heart beats, the volume of blood cells under the sensor increases and this reflects more IR waves to sensor and when there is no beat the intensity of the reflected beam decreases. The pulsating reflection is converted to a suitable current or voltage pulse by the sensor. The sensor output is processed by suitable electronic circuits to obtain a visible indication (digital display or graph).

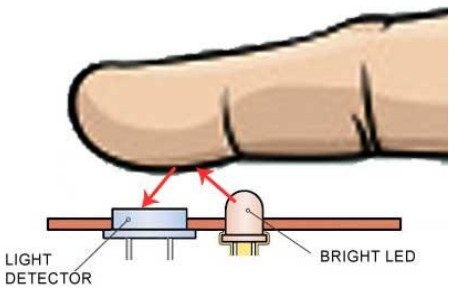
3. Working Principle

The system majorly consists of three components like heart rate sensor circuit, GSM modem and MCU. Let us see the brief explanation of circuitry.



Heart Beat Sensor

The Heart Beat signal is obtained by LED and LDR combination. Pulses form hands interrupts the light reaching the LDR and this signal is read by microcontroller, The RF signal is transmitted by transmitter in a digital format. This circuit uses Manchester encoding to avoid a long trail of one or zero. The protocol is well defined for different device types ensuring compatibility with your whole entertainment system 5 bit address and 6 bit command length. Constant bit time of 1.778ms bits are of equal length of 1.778ms in this protocol, A logical zero is represented by a pulse in the first half of the bit.

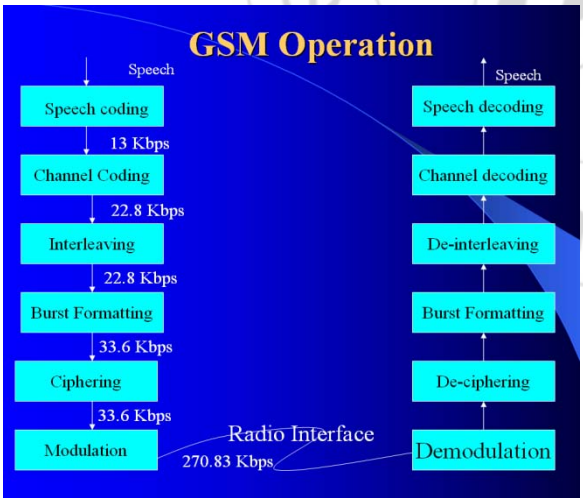


GPS Receiver System

This is a high gain GPS Receiver (5V Serial) with 4pin. Receiver is made with third generation POT (Patch Antenna on Top) GPS module. The built in 3V to 5V level convertor enable us to interface with normal 5V Microcontrollers. The 4 Pins are 5V, TX, RX, and GND. Yes, there is no setting required, just plug in to the power (5v), your data (NMEA 0183) is ready at TX pin. This is a standalone 5V GPS Module and requires no external components. It is built with internal RTC back up battery. It can be directly connected to Microcontroller's UART. With the use high gain GPS engine providing a solution that high position and speed accuracy performances as well as high sensitivity and tracking capabilities in urban conditions & provides standard NMEA0183 strings in "raw" mode for any microcontroller. The module provides current time, date, latitude, longitude, speed, altitude and travel.

GSM Modem

TTL (5V is built with Tri-band GSM/GPRS engine, works on frequencies EGSM 900 MHz, DCS 1800 MHz and PCS 1900 MHz It is very compact in size and easy to use as plug in module. The Modem is coming with 5V TTL interface, which allows you to connect directly to 5V microcontroller. The baud rate is configurable from 9600-115200 through AT command. The GSM/GPRS TTL Modem is having internal TCP/IP stack to enable you to connect with internet via GPRS. It is suitable for SMS as well as data transfer application in M2M interface. You need only two wires (Tx, Rx) except Power supply to interface with microcontroller. Using this modem, you can send SMS, data and read SMS through simple AT command. Inbuilt Powerful TCP/IP protocol stack for internet data transfer over GPRS.



Signal Conditioning

Signal conditioner converts the output of the sensor /transducer into an electrical quantity suitable for operation of the display or recording system. Signal conditioner may vary in complexity from a simple resistance network or impedance matching device to multi-stage amplifiers and other complex electronic circuits. Signal conditioning usually include functions such as amplification, filtering (analog or digital), analog to digital and digital to analog conversion or signal transmission circuitry. They help in increasing the sensitivity of instruments by amplification of the original signal or its transuded form. The buffer amplifier, which is usually an instrumentation amplifier, is proposed in this paper which provides impedance buffering, signal gain and common mode rejection. It has high input impedance, 100Mohms or more to reduce the effects of any signal distortion.

IR Sensor

The sensor consists of an IR light emitting diode transmitter and an IR photo detector acting as the receiver. The IR light passes through the tissues. Variations in the volume of blood within the finger modulate the amount of light incident on the IR detector. IR transmitter and receiver placed on the same plane and the finger functioned as a reflector of the incident light. The IR receiver monitors the reflected signal. Here, an infrared LED (OPB100EZ) and phototransistor (OPB100SZ) is used as sensor device.

Amplifier and Filter Design

Filtering process is required to remove the undesirable noises. The weak nature of the IR signal and the noise affecting on it, requires the implementation of a range of filters and differential amplifiers. The signal conditioning circuit consists of two identical active low pass filters with a cut-off frequency of about 2.5 Hz. Cut Off Frequency $=1/2\pi RfCf = 1/2\times3.1416\times68K\times1uF=2.34$ Hz; where, Rf=R1=R4=68KΩ and Cf=C1 =C3=1µf. This indicates that the maximum measurable heart rate is about 150 bpm. The gain of each filter stage is set to 11, giving the total amplification of about 121. Gain of each stage=1+Rt/Ri =1 + 680KΩ/ 68KΩ=11; where, Rt=R2=R5=680KΩ and Ri=R3=R6=68KΩ. A 1 uF capacitor at the input of each stage is used to block the dc component in the signal. The equations for calculating gain and cutoff frequency of the active low pass filter. The two stage amplifier/filter provides sufficient gain to boost the weak signal which is 3-4 mV and coming from the IR sensor unit, and convert it into a pulse. This pulse is counted by microcontroller. Then an LED is used which blinks each time when the heart beat is detected.

Microcontrollers

Microprocessors and microcontrollers are widely used in embedded systems products. *Microcontroller is a programmable device*. A microcontroller has a CPU in addition to a fixed amount of RAM, ROM, I/O ports and a timer embedded all on a single chip. The fixed amount of on-chip ROM, RAM and number of I/O ports in microcontrollers makes them ideal for many applications in which cost and space are critical.

The Intel 8051 is Harvard architecture, single chip microcontroller (µC) which was developed by Intel in 1980 for use in embedded systems. It was popular in the 1980s and early 1990s, but today it has largely been superseded by a vast range of enhanced devices with 8051-compatible processor cores that are manufactured by more than 20 independent manufacturers including Atmel, Infineon Technologies and Maxim Integrated Products.

8051 is an 8-bit processor, meaning that the CPU can work on only 8 bits of data at a time. Data larger than 8 bits has to be broken into 8-bit pieces to be processed by the CPU. 8051 is available in different memory types such as UV-EPROM, Flash and NV-RAM. The present project is implemented on Keil µvision. In order to program the device, Preload tool has been used to burn the program onto the microcontroller.

The AT89s52 is a low-voltage, high-performance CMOS 8-bit microcomputer with 8K bytes of Flash programmable memory. The device is manufactured using Atmel's high density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set. The on chip flash allows the program memory to be reprogrammed in system or by a conventional non volatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89s52 is a powerful microcomputer, which provides a highly flexible and cost-effective solution to many embedded control applications.

A/ D Convertor

The A/ D convertor carries out the process of analog to digital conversion. An A/ D convertor is a single chip integrated circuit having a single input connection for the analog signal and multiple pins for digital output. It may have 8, 12, 16, or even more output pins, each representing an output bits. The higher the number of bits the higher the precision of conversion. Each step represents a change in the analog signal: 8-bits gives 256 steps, 12- bits provides 4096 steps and we get 32768 steps with 16 output bits. Speed of an A/D convertor is generally expressed as its conversion time, i. e. the time elapsed between application of a convert command and the availability of data at its output. The speed of A/ D Convertor are measured by its settling time for a full scale digital input change.

PIC Controller

The PIC 16F877 is an 8-bit microcontroller, which has an on-chip eight channel 10-bit Analog-to-Digital Converter (ADC).First we detect fall down using accelerometer and fed to the I2C ports. The amplified and conditioned Heart Rate signal is fed to input port RB0 (INT) of the microcontroller. Also, upon command, the microcontroller reads the temperature sample stored in the RAM of the LM35 through the ADC port RA0. It is then converted and stored in the PIC16F877 memory as two 8-bit unsigned integers (0-255). After completion of signals acquisition, the microcontroller constructs the SMS messages and packs the data samples in these messages to the desired length, then communicates with the mobile phone using at-commands on its GSM modem port to send the message(s). A complete system can therefore be built using one MCU chip and a few I/O devices such as a keypad, display and other interfacing circuits. Most of the pins are for input and output, and arranged as 5 ports: PORTA (5pins), PORTB (8pins), PORTC (8pins), PORTD (8pins) and PORTE (3 pins), total of 32 I/O pins.

LCD Display

The Model JHD 162A Series LCD is the typical standard HD44780 type of LCD with 16characters x 2 row LCD module. Since this project the Heart Rate, temperature, adders and contact no to display; therefore, a LCD module is necessary.

KEIL Software

Keil is an IDE (Integrated Development Environment) which is used to develop an application program , compile and run it Even the code can be debugged .It is a simulator where we can check the application code even in the absence of the hardware board. Keil is also a cross compiler The process of development of the soft code on a processor for a particular application and which can be implemented on the target processor is known as Cross Development. In our design the main heart of the hardware module is the micro controller which is the programmable IC .The programming language used for developing the software to the micro controller is Embedded C /Assembly. The KEIL cross compiler is used to edit, compile and debug this program Micro Flash programmer is used for burning the developed code on Keil in to the micro controller Chip.

Wireless Monitoring

Monitoring and control is the core of the real- time monitoring system for patient physical states, and it can dispose , display , save ,query and analyze the data from each patient. To know the physical states of inpatient, the physical parameters need to be monitored real –time. With the increase in the number senior citizens and chronic diseases, the number of elderly patients who need constant assistance has increased. One key point of all critical care for elderly patient is the continuous monitoring of their vital signs. The results prove that the mobility, usability and performance of our proposed system have impacts on the user's attitude, and there is a significant positive relation between the user"s attitude and the intent to use our proposed system. This proposed system is expected to monitor the electrical activity of heart of the patient under critical care more conveniently and accurately for diagnosing which can be interfaced with PIC 16F877 to bring it under a network system widely for the doctor to monitor the patient's condition sitting in his own office without being physically present near to the patients bed. Wireless – networked embedded device includes signal conditioning circuitry, sensors and a PIC controller with a wireless Transceiver module. To measure or monitor human movements or activities, a graphical LCD display is selected for its low price, small size, capability of continuous measurement, and ease of integration.

4. Expected Outcome of the Project

This project is initiated to alert the family members about patient's heartbeat via SMS. It fulfills the objective to detect and monitor patient's heartbeat rate using PPG technique, interfaced with GSM modem and sends alert to the family or/and medical experts via SMS.

The connection between microcontroller and HyperTerminal is successfully established before the system can be interfaced to the GSM modem. At the moment, ongoing test on sending alert directly from PIC circuit to mobile phone is still carry out to get a stable system. For future development, this project can be properly designed. It can be modified to become very light, portable, smart and elegant. E.g. like a watch or embed with i-POD.

By using the value of heart rate, we also can know the ages, oxygen contents in human body and patient's weight. By using this prototype circuit containing AT89S52 MCU, GSM Modem, LCD and other hardware circuit so that the page messages can be transferred at fixed time intervals to the corresponding medical expert to give necessary precautions to take care about the patient.

This system has the following features:
AT89S52 MCU consumes low power with suitable devices for interconnection, auto alarm system is provided which sounds only when the reading exceeds or reduces than the normal level, Continuous monitoring of patients is done which is simple by using GSM network.

Application of the Project
The Health care industry is responding to the increasing popularity and availability of technological innovations, such as tablets and Smartphone. Utilizing Smartphone and employing it in the field of health care and medicine is helpful as it simplifies the operation of medical devices to enable lightly trained individuals whether patients or medical practitioners to reliably collect medical data for diagnosis and prognosis. This Phone Accessory Heart Rate Monitor is therefore a part of a greater project that intends to make health monitors used in clinical practices compact and available to the public with straightforwardness to use and no consideration of time or place. Having the data on the phone, it can be used as a health monitor or sent to a physician elsewhere for remote evaluation so the patient can seek advice from his physician without having to book for an appointment.

5. Conclusion

The instrument has simple structure stable and reliable operation, high Accuracy, low power consumption, good portability full featured function, and extensive application occasion. The real time monitoring system for cardiac patient physical state is based on wireless transceiver module technology. It can be taken by patient and keep the patient moment intact because it is miniature and portable .The system can monitor and record the physical states and moment parameters real time, and the provide auxiliary means for the correct diagnosis of doctor. With intelligent transreciver module , the sign of acute disease for patient can be found early, and then the patient can be helped in time, the sudden death of patient can be avoided. The wireless transreciver module technology can be suited for short distance communication, and the transmission distance is limited only about 10 meters, and then It can be suitable for in- patient monitoring. The system is important to be applied to patient care.

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