An Embedded, GSM based, Multiparameter, Realtime Patient Monitoring System and Control – An Implementation for ICU Patients

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***Abstract*— Wireless, remote patient monitoring system and control using feedback and GSM technology is used to monitor the different parameters of an ICU patient remotely and also control over medicine dosage is provided. Measurement of vital parameters can be done remotely and under risk developing situation can be conveyed to the physician with alarm triggering systems in order to initiate the proper control actions.**

In the implemented system a reliable and efficient real time remote patient monitoring system that can play a vital role in providing better patient care is developed. This system enables expert doctors to monitor vital parameters viz body temperature, blood pressure and heart rate of patients in remote areas of hospital as well as he can monitor the patient when he is out of the premises. The system in addition also provides a feedback to control the dosage of medicine to the patient as guided by the doctor remotely, in response to the health condition message received by the doctor. Mobile phones transfer measured parameters via SMS to clinicians for further analysis or diagnosis. The timely manner of conveying the real time monitored parameter to the doctor and control action taken by him is given high priority which is very much needed and which is the uniqueness of the developed system.

The system even facilitates the doctor to monitor the patient's previous history from the data in memory inbuilt in the monitoring device. Also data can be sent to several doctors incase a doctor fails to respond urgently.

Keywords- Wireless, Remote patient monitoring, Body temperature, Heart rate, Blood pressure, SMS, GSM,ICU.

1. INTRODUCTION

Patient Monitoring System is a process where a surgeon can continuously monitor more than one patient, for more then one parameter at a time in a remote place.

The technical brilliance and development in different fields has led to a drastic change in our lives, one among them is embedded systems and telecommunications. Telecommunications has the potential to provide a solution to medical services to improve quality and access to health care regardless of geography. The advances in information and communication technologies enable technically, the continuous monitoring of health related parameters with wireless sensors, wherever the user happens to be. They provide valuable real time information enabling the physicians to monitor and analyze a patient's current and previous state of health. Now a days there are several efforts towards the development of systems that carry out remote monitoring of patients.

Although many wireless standards can be used, there are important considerations such as range, throughput, security, ease of implementation and cost. The patient monitoring involves handling of sensitive data. These data should be transmitted securely without any intrusion [1].

2. PROBLEM DEFINITION

The problem found in most hospitals is that continuous monitoring of vital parameters is done for ICU patients, but the monitors are local to the room in which the patient is admitted. Physician has to frequently visit the patient and asses his/her condition by analyzing the measured parameters such as temperature, blood pressure, drip level etc. In case of emergencies, the nurse intimates the doctor through some means of communication like mobile phone. A growing selection of innovative electronic monitoring devices is available, but meaningful communication and decision supports are also needed for both patients and clinicians. There has to be a mechanism by which the physician can remotely measure the vital parameters himself at any instant of time and update himself of the patient's health status and also take control action remotely if he desires.

A. Implemented System

The Implemented system provides mobility to the doctor to a certain extent. Measurements of vital signs and behavioral patterns can be translated into accurate predictors of health risk, even at an early stage, and can be combined with alarm triggering systems in order to initiate the appropriate actions for the physician [2].

An advanced technique "An Embedded GSM based Real Time Multi parameter Patient Monitoring System and Control" is used for ICU patients. In case of emergency and critical situations we have to alert the doctor immediately. For this we are using a GSM based network for doctor to patient communication in the hospital and even to communicate and indicate the status of the patient through SMS.

The uniqueness of the developed system is that, in addition to real time monitoring and conveying of data,

978-1-4673-4805-8/12/$31.00

control action is provided wherein, the doctor can even take preliminary action remotely because of the feedback system provided. This way of communication is actually done with the GSM network and a feedback motor connected to the saline.

In this way just by knowing the patient's biomedical parameters, the doctor can remotely control the flow of medicine.

3. SYSTEM DESIGN

A Block Diagram Representation of the System

The system design consists of both hardware and software. Firstly as per the block diagram the hardware components required were assembled.

The code is written in embedded C, and is burnt into the microcontroller using flash programmer.

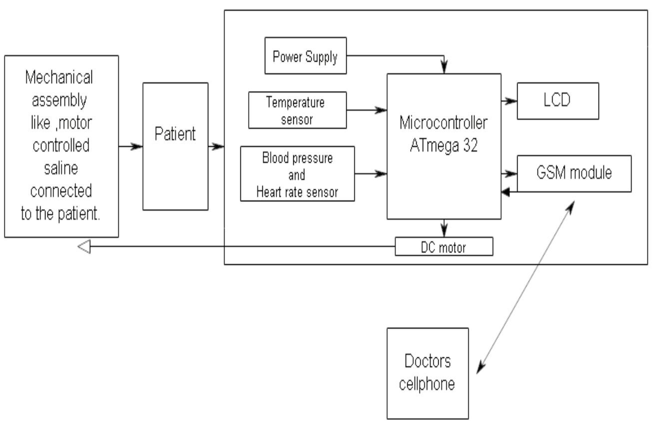

Figure 1: Block Diagram of the Implemented System.

B. Pressure Sensing Mechansim

For the blood pressure and heart rate measurement the Oscillometric method is used. The following diagram explains the mechanism.

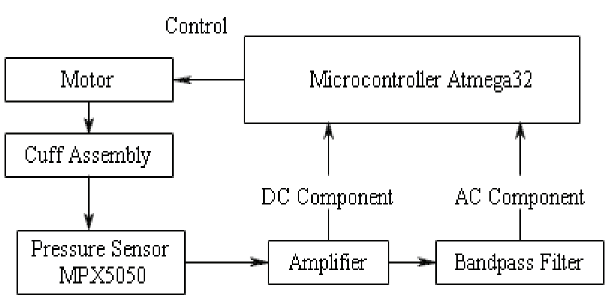

Figure 2: Blood Pressure and Heart rate Sensing Mechanism.

Oscillometric Method:-To perform a measurement, we use a method called oscillometric.The air is pumped into the cuff to be around 20 mmHg above average systolic pressure. After that the air will be slowly released from the cuff causing the pressure in the cuff to decrease. As the cuff is slowly deflated, we measure the tiny oscillation in the air pressure of the arm cuff. The systolic pressure is the pressure at which the pulsation starts to occur. We use the MCU to detect the point at which this oscillation happens and then record the pressure in the cuff. Then the pressure in the cuff will decrease further. The diastolic pressure will be taken at the point at which the oscillation starts to disappear.

C. The Analog Circuit Design

Analog Circuit: - It is used to amplify both the DC and AC components of the output signal of pressure transducer so that we can use the MCU to process the signal and obtain useful information about the health of the user. The pressure transducer produces the output voltage proportional to the applied differential input pressure. The output voltage of the pressure transducer ranges from 0 to 40 mV. But for our application, we want to pump the arm cuff to only 160 mmHg (approximately 21.33 kPa). This corresponds to the output voltage of approximately 18 mV. Thus, we choose to amplify the voltage so that the DC output voltage of amplifier has an output range from 0 to 4V. Then the AC signal from the amplifier will be passed on to the band-pass filter.

The filter is designed to have large gain at around 1-4 Hz and to attenuate any signal that is out of the pass band. The AC component from the band-pass filter is the most important factor to determine when to capture the systolic/diastolic pressures and when to determine the heart rate of the user. The reference voltage is maintained constant at 2.5 volts.

D. Pressure Sensor MPX 5050

We use the MPX5050 pressure transducer from Motorola to sense the pressure from the arm cuff. The pressure transducer produces the output voltage proportional to the applied differential input pressure. It provides max pressure of 50KPA, and output voltage proportional to it is 40mVdc.

The transfer characteristic is shown in figure below.

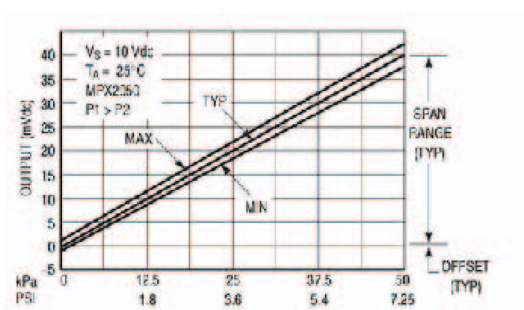

Figure 3: Pressure versus Output voltage characteristics for MPX5050

E. Amplifier

Since the output voltage of the pressure transducer is very small, we have to amplify the signal for further processing.

We use the instrumentation amplifier INA129P from Analog Devices. The resistor Rg is used to determine the gain of the amplifier. Since we need the gain of approximately 100, we choose the resistor Rg to be 1.2K. This will give us the gain of 40.

F. Bandpass Filter

The band-pass filter stage is designed to provide a range between 1-4Hz. Band pass filter designing i.e. the lower and higher cutoff frequencies are found using the formula

$$f = 1/2\text{pi}RC \quad (1)$$

$$f_l = 1/(2\text{x}3.14\text{x}3.3\text{Kx}47\mu\text{F}) = 1.2\text{Hz}$$

$$f_h = 1/(2\text{x}3.14\text{x}120\text{Kx}330\text{nF}) = 4.1\text{Hz}$$

The AC output from this stage will be passed on to the analog-to-digital converter in the Mega32 microcontroller.

G. Heart rate Measurement

After the program finished calculating the systolic pressure, then it starts monitoring the pulse rate of the patient. We choose to determine the pulse rate right after determining the systolic pressure because at this point the oscillation of the waveform is strongest.

The program stars counting the pulses from the systolic pulse for 15 seconds and that value when multiplied by 4 gives the number of pulses in 1 minute. The heart rate value is available at the output of ADC2.

H. Body Temperature Measurement

In the system RTD PT 100 is used for body temperature measurement .PT100 offers 100ohms resistance at zero degree celcius.The output of PT100 is approx 10mV,at 37^o C. LM 358 is used as current mirror which gives current output of 1mA.RTD output is fed to ADC0 of ATmega32 which is used to measure temperature values.

4. Interfacing GSM module and AT Commands Used

A GSM module has an RS232 interface for serial communication with an external peripheral. HyperTerminal is a Windows application. The AT commands are sent by the HyperTerminal to the GSM module. The Information Response and/or Result Codes are received at the microcontroller and retransmitted to the HyperTerminal by the controller. The microcontroller is programmed to receive and transmit data at a baud rate of 9600.

A. AT Commands Used

The AT commands used in the implemented system to communicate between the physician and the GSM module are as follows:-

- AT+CMGF:-Used to set SMS format.
  Here text format is used.
- AT+CMGW:-Used to store message in the SIM.
- AT+CMGS:-Used to send message to a phone no.

B Various Case Studies for message Pasing

Message Protocol for the Physician

- Type "1", and send SMS on to the GSM module attached to the designed system, to get current status of patient remotely.
- Type "2MHn", where n=any 1 digit number ,and send SMS to move motor attached to saline, , this is to move motor in forward direction i.e. clockwise direction, to increase current medicine flow remotely
- Type "2MLn" and send SMS, to move motor in reverse direction i.e. anti clockwise direction, to decrease medicine flow remotely.
- Type "3" and send SMS to get previous history readings of patient's biological parameters.

C Normal Condition

- Measure biological parameters at fixed interval of time.
- Store data in memory as history.
- In between doctor can check current status by sending option "1".
- Monitor patient temperature continuously.

D Temperature Crosses Threshold Condition

- Body temperature crosses normal value.
- System immediately takes current reading and sends SMS to two physicians simultaneously, out of which is a main doctor and other is subordinate doctor.
- Waits for main doctor to acknowledge, within 3 minutes.
- If main doctor does not acknowledge in 3 minutes, a buzzer will ring and alert message is sent to subordinate doctor.
- If any one or both of them acknowledges messages, they can ask for history of patient by sending message as "3".

After diagnosing history, main doctor can revert back by sending option "2" to change medicine dosage remotely, if required as a preliminary action under critical situation.

5. WORKING OF THE SYSTEM

The patient's all 3 biomedical parameter's viz blood pressure, heart rate and temperature are measured at a fixed time interval and stored in memory if they are within limits. Mean while the system will also continuously measure temperature using RTD and feed to ADC .It compares the measured temperature with the predefined value, and checks if the value is above or below a set range.

If the temperature exceeds beyond the set value the module immediately starts measuring heart rate and blood pressure by a micro pump, valve, and pressure sensor and cuff assembly. The air will be pumped into the cuff using the motor and pump about 120 -160mmHg (average for human) .Then we will slowly release the pressure using the valve and measure, the pressure, at a point when we start getting the oscillations this is our systolic pressure ,the pressure value from the transducer at this point is our systolic pressure.

Now we go on deflating the cuff, the point when the oscillation damp is our diastolic pressure.

The pressure transducer will convert it into a range of 0-40mV which we will amplify using operational amplifier to 4v. The value of systolic and diastolic is measured using adc1 and adc2 respectively.

The value is put in a buffer and sent to two physician's simultaneously, using our GSM module and wait for 3 minutes for any one to response If any of the doctor does not respond in three minutes a buzzer will ring .

If any of the doctor acknowledges the messages, he can send back a message asking for last history details. Thereafter he can diagnose those parameters and revert back a message to the GSM module. The GSM module message will be read by the microcontroller to generate a signal which will drive a dc motor connected to the saline unit, whose rotation will control the flow of medicine. GSM provides for longer distance communication [3]. Figure 4 shows the flowchart of the implemented system.

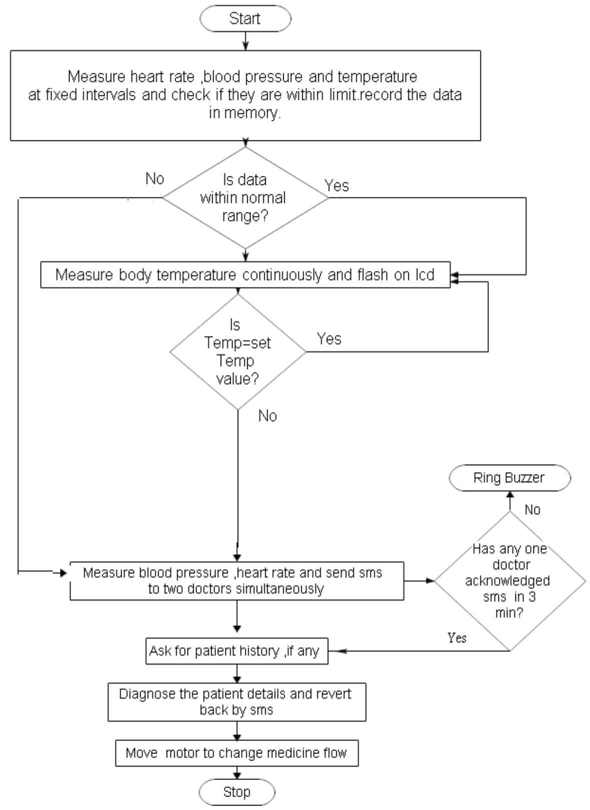

Figure 4: Flowchart of the implemented system

6. COMPARISON WITH ANALOGUES SYSTEMS

The physician can receive biomedical information on GSM network only if a nurse sends data manually via SMS .Also according to talks with various physicians, systems are rarely seen which allows them to take measurement from any place directly by just sending an SMS.Also care has been taken in the development that if one physician does not acknowledge in three minutes the SMS will be sent to subordinate doctor immediately as well as hospital staff will be informed via buzzer. The control of medicine flow via SMS is done only as a preliminary action in case needed. Also the system provides history data to the physician remotely; such facility is also not yet seen in any devices.

7. CONCLUSION AND RESULTS

The remote patient monitoring system is one of the major improvements in the hospitality because of its advanced technology. A wireless patient monitoring system to measure heartbeat, body temperature and blood pressure by using embedded technology is discussed. An embedded technology is used instead of DSP technology to develop this system so that it is easy to operate and available at an affordable cost.

This is a convenient process to monitor the patient's health conditions from any distance. Since we are using GSM technology, this makes the user to communicate for longer distances. This work provides real-time update of the patient's health to the doctor along with necessary preliminary action taken by physician in case of his absence. It reduces the frequent visits of the doctors to the patient in person and assistance to the patient in case of biomedical parameter change.

A.Results

The system was tested rigorously in the presence of a physician on many patients as well as healthy people, the results found to be same as the one's measured by the physician and with the implemented system. A validity report was thus prepared. During the execution of the system snapshots of the display were taken. The system being a complete hardware design the data available on cell phone and LCD display have been captured. The system's prototype is successfully implemented and can be demonstrated. A few test results of the system are put down below, which show successful implementation of the system. Figure5 shows the actual implemented system. Figure 6 shows a sample reading of BP and heart rate of patient onto the LCD attached to the module on the patient's side. The readings were matched with the readings taken by physician and found to be same. Figure 7 shows a patient's reading onto the doctor's cell phone. It consists of the patient's ID, date, time body temperature, BP values and heart rate. Figure 8 depicts the message to be sent by physician to control the flow of medicine as a preliminary action to change biological parameters. Figure 9 shows that since option 2 have to be typed to control medicine flow, the acknowledgement message also shows ACK 2, that control has been taken. If option 1 or 3 was sent then it sends ACK 1 or ACK 3 respectively. Figure 10 shows message sent by physician to retrieve patient's history readings. The history readings will be same like the SMS received in figure7.

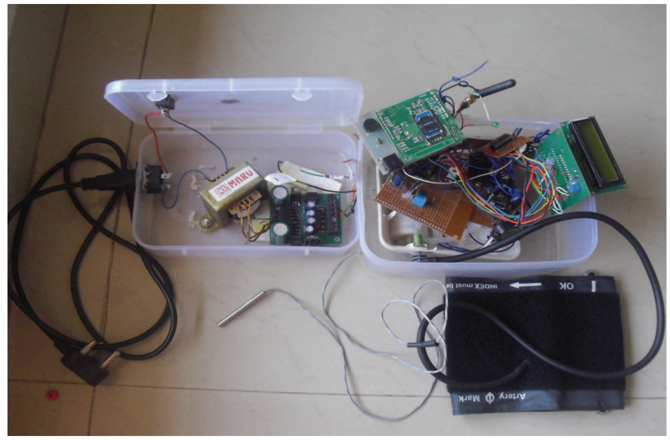

Figure 5: Hardware Module of the Implemented System

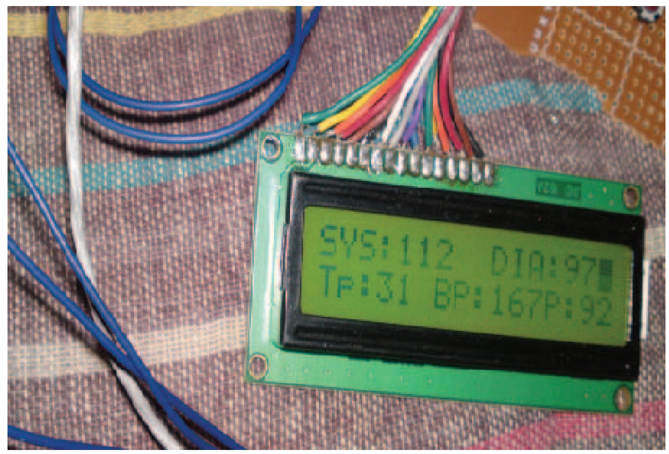

Figure 6: LCD displaying patient's Blood Pressure Values.

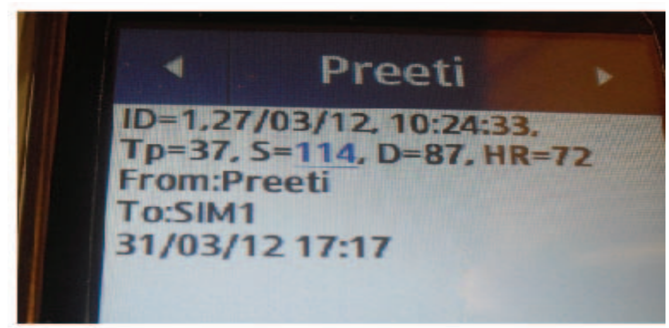

Figure 7: SMS received on doctor's cell phone

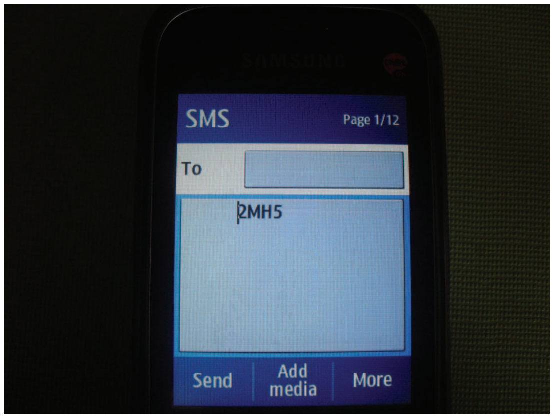

Figure 8: Message format sent by doctor to control medicine flow

Figure 9: Acknowledgement message received by physician after he sends an SMS to control medicine flow.

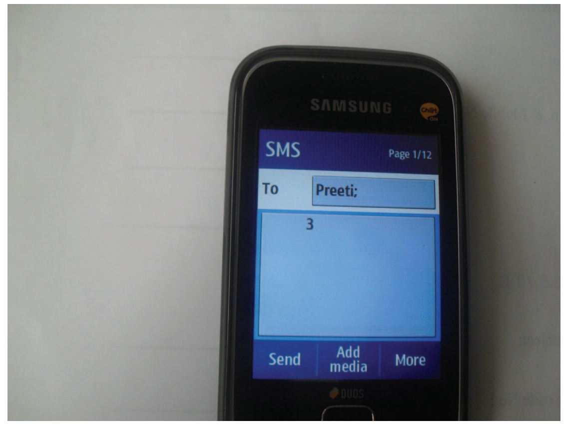

Figure 10: Message sent by physician to retrieve patient's history readings.

References

[1] Arun E,Marimuthu V,Pradeep E and Karthikeyan M on"Remote Patient Monitoring-An implementation in ICU Ward", International Conference on Information and Network Techonology IPCSIT,Vol 4, 2011 pages 260-264..

[2] Pedro Girao,Fernando Santiago,Pena A ,"Enabling Telecare assessment with pervasive sensing and Android OS smartphone",IEEE 2011,page289-293.

[3] Sukanesh R,Rajan S.P ,Vijayprasath S.S Prabhu ," GSM based tele alert system", IEEE 2010,pages 1-5.

[4] Kamel M, Fawzy S.,"Secure remote patient monitoring system" IEEE Feb 2011, pages 339-432.