Multichannel Biotelemetry for Transmitting the Medical Data of Infants

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***Abstract*--This project represents an infant monitoring system to reduce the potential risks for Sudden Infant Death Syndrome (SIDS), which can be used at home or in hospitals. This system consists of Carbon Dioxide (CO_2) sensor, temperature sensor and heart rate sensor. The CO_2 concentration in the exhaled air, temperature and heart rate is regularly and frequently sensed. It also includes a GSM module to transmit the data. Besides the alarm signal, all sensor signals are multiplexed and transmitted along with the infant's ID for diagnosis purposes. The transmitter is in sleeping mode until there is an initiation from PIC controller. The alarm signal of each infant is the ID designated for the incubator. At the receiver end, an SMS will be received as soon as alarm signal is sent by the identified transmitter while the server starts to record the data and the doctor is informed via a mobile.**

Keywords: *Infant monitoring system, Sudden Infant Death Syndrome (SIDS), Carbon dioxide sensor, GSM, SMS, alarm signal, infant.*

I. INTRODUCTION

Healthcare cost is an urgent issue globally. In the U.S., the cost for healthcare has reached 16% of the Gross National Product in 2004, equating to US$1.88 trillion [1]. The costs for infant care are high due to the facts that the work is highly labour intensive. For healthy infants, Sudden Infant Death Syndrome (SIDS) is the most critical problem needed to be addressed. SIDS is defined as any sudden and unexplained death of an apparently healthy infant aged one month to one year [2-3]. According to the National SIDS/Infant Death Resource Center, SIDS is responsible for roughly 50 deaths per 100,000 births in the U.S. in 2004 (Fig. 1). Although the SIDS rate has been reducing, due to the awareness in parents and nurses, it is still too high for any family that suffers trauma and loss. Reducing the sudden death rate in infants by an effective monitoring and alarm system is a challenge for researchers.

Although the causes of SIDS have not been explained thoroughly in literatures, trouble with breathing has been known as the most common reason. Inborn factors such as disorders in the lungs
or glands, respiratory infections, and improper sleeping positions are possible causes [2-3]. SIDS may happen to healthy infants without any identifiable physiological preconditions and it

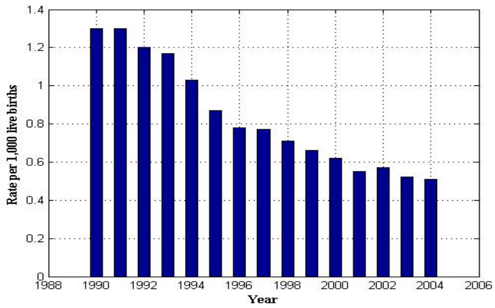


Fig 1. The SIDS rate in the U.S. from 1990 to 2004 [3].

usually happens during sleeping without any warning signs, such as crying, struggling or suffering. Therefore, an effective respiratory monitoring system may be a good way for early warning to reduce SIDS risk.

There were some proposed infant monitoring systems, such as cardiopulmonary monitoring [4-7], vision monitoring [8], oxygen consumption monitoring [9] and multi-purpose monitoring [10]. Some approaches are invasive [4-7, 9-10], making both the infant and his/her parents uncomfortable. Some are not as effective as expected such as baby monitoring cameras due to the unrecognized signs of SIDS [8].

We propose a new method using CO_2 sensors, temperature sensor, and heart beat sensor placed in the crib around an infant to non-invasively monitor the exhaled air concentration, temperature, and heart beat variation from him/her. By monitoring the outputs of CO_2 sensors, we can detect if there is anything wrong with the infant's respiration. The output data can be used to activate an alarm or logged for further diagnoses. With GSM integration, our system can be used to monitor a large number of infants in the nursery room of a hospital.

II. METHODOLOGY

A. System design

1) Crib design

Infants may take various sleeping positions and theexhaled air may spread in many directions due to aircirculation. Thus, an array of CO_2 sensors is placed aroundthe crib on the bars to provide sufficient information. Acircuit board connected to the sensors is placed outside thecrib to process the data. The circuit board includes awireless module for transmitting and receiving data. Themodule is away from the infant to ease parents' concern ofelectromagnetic waves from the wireless module. A drasticvariation of CO_2 concentration will produce an abruptchange in sensor outputs and the processor will be activatedto send out an alarm signal. With the GSM approach, anidentification (ID) signal of the infant will be sent out tocorrelate the sensing/alarm signals with the ID. This willsignificantly reduce the labour costs and time. The sensor data and ID can be pulled periodically for monitoring and calibration. The stored vital sign data can help doctors to identify or diagnose any potential health problems in infants.

2) System Overview

Fig. 2 shows the functional block diagram of the system hardware. The system has been designed to take several inputs to measure physiological parameters of human such as temperature, heart rate, $CO_2$and detection of any fall. The inputs from the sensors are integrated and processed by the PIC controller. The results are sent through GSM module as SMS to the physician.

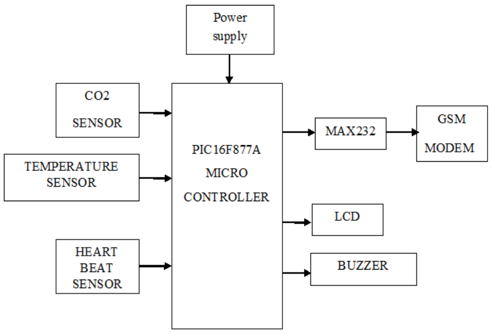


Fig. 2 block diagram

The sensors mounted in the crib will send the signals to the PIC controller which is programmed. If any of the values become abnormal the system provides the alarm and sends SMS via GSM modem to the physician. The GSM is interfaced with PIC by using serial communication driver MAX 232. The LCD is placed to continuously monitor the infant.

B. CO_2 sensor

Human's exhaled air roughly consists of 79.5% nitrogen(N2), 16.5% oxygen (O2) and 4% CO_2 [11]. The CO_2 is thendiffused quickly to a much lower concentration between2000ppm and 5000ppm in the air [12]. Therefore, theworking range of our CO_2 sensor has to cover the range from2000 to 5000ppm of CO_2. The exhaled air has a saturatedhumidity, even after diffusion, the relative humidity (RH) ofthe air composition is still high. This might introduce errorsin the sensor performance, requiring us to design the systemto work in a wide range of humidity. Furthermore, a shortresponse time sensor is needed for real time monitoringpurposes.

There are commercial off-the-shelf CO_2 sensors in themarket with various sensing principles, such aselectrochemical based, infrared based and metal-oxide basedsensors. According to our previous sensor review results[13], we found that electrochemical based sensors give thebest performance but the short lifetime prohibits the use.

Infrared based sensors are sensitive but bulky in size andmore costly [14]. With the goal to achieve a low-cost andlong-term system, we chose metal-oxide based CO_2 sensors.We do realize the shortcomings of metal-oxide sensing, suchas humidity and temperature dependence. We have carriedout testing and calibration experiments that will be describedin later sections.

C. Heart Rate Sensor and Temperature Unit

It consists of LED (light emitting diode) and LDR (lightdetection resistor) which are placed parallel to each other. LEDemits IR (Infrared) rays so that, when the finger is placed inbetween LED and LDR so that there exists some systolicpressure [15, 16]. LED emits IR rays which are travelled throughfinger and blood flows with arteriole pressure. Wheneversystolic pressure is applied, normal pressure of blood flow isdisturbed at fingertip which is high and IR rays penetratethrough blood and are received by LDR. The signals are analogwhich are converted into digital by the PIC. LM35 temperature sensor [17] isused to measure the temperature and connected to PIC. Thissensor unit works under low power DC input of 5V which iscontrolled by a mini transformer.

D.MAX232

Since GSM supports digital data transmission,MAX232 is used to convert the digital data in the serial formusing parallel-in-serial-out shift registers suitable for wireless communication. UART IC chip allows the digital datatransmission in the form of bits (bits per second) inasynchronous manner (characters transmission). RS232standards are used for serial communication [18], which are notTTL (Transistor-Transistor-Logic) compatible.

E.GSM

GSM is abbreviated as Global System for MobileCommunication [19]. GSM modem has a slot for inserting SIM(Subscriber Identity Module). GSM network contains MobileStation, Base station subsystem and Network subsystem. Mobilestation contains IMEI number and SIM has IMSI number. Basestation subsystem contains Base Transceiver Station which hasantennas for communication and Base Station Controller whichcontrols multiple base stations. Network subsystem containsVLR (Visitor Location Register), HLR (Home LocationRegister), AuC (Authentication Center) and EIR (Equipment
Identity Register). MSC (Mobile Switching Center) is the majorpart which is the gate way for communication between mobilestation and PSTN. HLR stores the information about thesubscriber and the current location of subscriber. VLR providesthe services to the subscribers of HLR who are visitor users.AUC gives the security of the user and to identify the locationof the subscriber. EIR is also for security purpose and toidentify the mobile station. MAX232 is connected to GSMmodem so that it is useful

for serial data transmission. OSS(Operation Support System) is used to control the traffic ofusers.

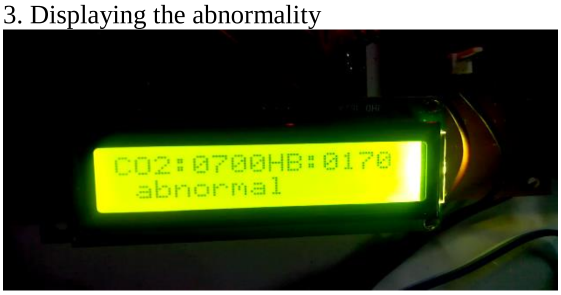
III. RESULT AND DISCUSSION

Heart rate sensor,CO_2sensorand LM35sensor senses the heart rate, temperature, exhaled $CO_2$of infant by taking the average of ten readings byfixing maximum and minimum values (normal range of heart beat is 60-150bpm and 98.6^{o} F) and the data is transferred to PIC controller. Crystal oscillator generates 11.0952MHz of signals usedfor operation and by enable input MUC works, stores the data inEPROM chip which is displayed on LCD. PIC stores thedigital data after converting the analog data from sensor unitby ADC in the PIC, for some delay unit of time and resets the reading in PIC as well as in LCD also. MAX232 receives the digitaldata and converts into serial form suitable for GSMcommunication so that data is received by the user (doctor) byverifying the IMEI number.The doctor advises precautions forthe temporary observation of the patient from serious condition.

1. Initializing and resetting all components

2. Display CO_2/HB/Temp

3. Displaying the abnormality



4. After sending the SMS to the Doctor/a person it will display as ‘SMS sent’ on the LCD display

IV. CONCLUSION AND FUTURE SCOPE

By using this prototype circuit containing PIC16F877,GSM Modem, LCD and other hardware circuit so that the pagemessages can be transferred at fixed time intervals to thecorresponding medical expert to give necessary precautions totake care about the patient. This system has the following features: i. PIC16F877 consumes low power with suitabledevices for interconnection. ii. Auto alarm system is providedwhich sounds only when the reading exceeds or reduces thanthe normal level. iii. Continuous monitoring of patients is donewhich is simple by using GSM network.

The device can be improved in certain areas aslisted below: i. A graphical LCD can be used to display a graphof the change of heart rate over time. ii. Sound can be added tothe device so that a sound is output each time a pulse isreceived. iii. Serial output can be attached to the device so thatthe heart rates can be sent to a PC for further online or offline analysis. iv. The Whole health monitoring system,which we have proposed can be integrated into a small compactunit as small as a cell phone or a wrist watch. This will help thepatients to easily carry this device with them wherever they go.The VLSI technologies will greatly come handy in this regard. v. The project can be implemented as complete patient healthmonitoring system by measuring B.P, Tumours etc., which canbe done by connecting corresponding sensors to the PIC.

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