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 (CO2) sensor, temperature sensor and heart rate sensor. The CO2 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 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 CO2 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 CO2 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 the exhaled air may spread in many directions due to air circulation. Thus, an array of CO2 sensors is placed around the crib on the bars to provide sufficient information. A circuit board connected to the sensors is placed outside the crib to process the data. The circuit board includes a wireless module for transmitting and receiving data. The module is away from the infant to ease parents’ concern of electromagnetic waves from the...
wireless module. A drastic variation of $CO_2$ concentration will produce an abrupt change in sensor outputs and the processor will be activated to send out an alarm signal. With the GSM approach, an identification (ID) signal of the infant will be sent out to correlate the sensing/alarm signals with the ID. This will significantly 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 the GSM module as SMS to the physician.

![Fig. 2 block diagram](image)

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 signals to the PIC controller which is programmed. If any fall. The inputs from the sensors are integrated and processed by the PIC controller. The results are sent through the GSM module as SMS to the physician.

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 between 2000 ppm and 5000 ppm in the air [12]. Therefore, the working range of our $CO_2$ sensor is to cover the range from 2000 to 5000 ppm of $CO_2$. The exhaled air has a saturated humidity, even after diffusion, the relative humidity (RH) of the air composition is still high. This might introduce errors in the sensor performance, requiring us to design the system to work in a wide range of humidity. Furthermore, a short response time sensor is needed for real-time monitoring purposes.

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

Infrared based sensors are sensitive but bulky in size and more costly [14]. With the goal to achieve a low-cost and long-term system, we chose metal-oxide based $CO_2$ sensors. We do realize the shortcomings of metal-oxide sensing, such as humidity and temperature dependence. We have carried out testing and calibration experiments that will be described in later sections.

C. Heart Rate Sensor and Temperature Unit

It consists of LED (light emitting diode) and LDR (light detection resistor) which are placed parallel to each other. LDR emits IR rays so that, when the finger is placed in between LED and LDR so that there exists some systolic pressure [15, 16]. LED emits IR rays which are travelled through finger and blood flows with arteriole pressure. Whenever systolic pressure is applied, normal pressure of blood flow is disturbed at fingertip which is high and IR rays penetrates through blood and are received by LDR. The signals are analog which are converted into digital by the PIC. LM35 temperature sensor [17] is used to measure the temperature and connected to PIC. This sensor unit works under low power DC input of 5V which is controlled by a mini transformer.

D. MAX232

Since GSM supports digital data transmission, MAX232 is used to convert the digital data in the serial form using parallel-in-serial-out shift registers suitable for wireless communication. UART IC chip allows the digital data transmission in the form of bits (bits per second) in asynchronous manner (characters transmission). RS232 standards are used for serial communication [18], which are not TTL (Transistor-Transistor-Logic) compatible.

E. GSM

GSM is abbreviated as Global System for Mobile Communication [19]. GSM modem has a slot for inserting SIM (Subscriber Identity Module). GSM network contains Mobile Station, Base station subsystem and Network subsystem. Mobile Station contains IMSI number and SIM has IMSI number. Base station subsystem contains Base Transceiver Station which has an MEI number for communication and Base Station Controller which controls multiple base stations. Network subsystem contains VLR (Visitor Location Register), HLR (Home Location Register), AuC (Authentication Center) and EIR (Equipment Identification Register). MSC (Mobile Switching Center) is the major part which is the gate way for communication between mobile station and PSTN. HLR stores the information about the subscriber and the current location of the subscriber. VLR provides the service to the subscribers of HLR who are visitor users. AuC gives the security of the user and to identify the location of the subscriber. EIR is also for security purpose and to identify the mobile station. MAX232 is connected to GSM modem so that it is useful.
for serial data transmission. OSS(Operation Support System) is used to control the traffic of users.

III. RESULT AND DISCUSSION
Heart rate sensor, CO2 sensor, and LM35 sensor senses the heart rate, temperature, exhaled CO2 of infant by taking the average of ten readings by fixing maximum and minimum values (normal range of heart beat is 60-150 bpm and 98.6°F) and the data is transferred to PIC controller. Crystal oscillator generates 11.0952 MHz of signals used for operation and by enable input MUC works, stores the data in EPROM chip which is displayed on LCD. PIC stores the digital data after converting the analog data from sensor unit by 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 digital data and converts into serial form suitable for GSM communication so that data is received by the user (doctor) by verifying the IMEI number. The doctor advises precautions for the temporary observation of the patient from serious condition.

1. Initializing and resetting all components

2. Display CO2/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 the corresponding medical expert to give necessary precautions to take care about the patient. This system has the following features: i. PIC16F877 consumes low power with suitable devices for interconnection. ii. Auto alarm system is provided which sounds only when the reading exceeds or reduces than the normal level. iii. Continuous monitoring of patients is done which is simple by using GSM network.

The device can be improved in certain areas as listed below: i. A graphical LCD can be used to display a graph of the change of heart rate over time. ii. Sound can be added to the device so that a sound is output each time a pulse is received. iii. Serial output can be attached to the device so that the 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 compact unit as small as a cell phone or a wrist watch. This will help the patients 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 a complete patient health monitoring system by measuring B.P, Tumours etc., which can be done by connecting corresponding sensors to the PIC.

V. REFERENCES


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