Wireless Baby Monitoring Device for SIDS prevention

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Abstract

This project report outlines the development and testing of a wireless baby monitoring device aimed at reducing the risk of Sudden Infant Death Syndrome (SIDS), a leading cause of death among infants. The device tracks two critical physiological indicators: breathing patterns and body temperature, to provide real-time monitoring and quick alerts to caregivers upon detecting abnormalities. Through comprehensive simulation results, the device shows a promising capability to identify critical changes in the indicators of interest, while having a relatively simple and accessible design. However, there are also limitations like reliability under environmental factors and long-range connectivity consistency. In addressing these challenges, there are discussions and potential future directions to enhance sensor precision and explore alternative wireless options and design in general. Overall, this project marks a nice step to interdisciplinarily advance passive infant monitoring, provide a dependable, efficient, and accessible solution for early detection of SIDS, and improve the well-being of infants and caregivers.

I. INTRODUCTION

Background

Sudden Infant Death Syndrome, or SIDS, is a subtype of Sudden Unexpected Infant Death that is responsible for the deaths of between three and four thousand infants per year in the United States. Risk factors for SIDS are numerous and highly varied, including low birth weight and smoke exposure, but it is still possible for SIDS to occur in any infant, most often when they are sleeping or in bed. Preventing these cases from occurring is an ongoing difficulty in childcare, as it is essentially impossible for parents to actively monitor a baby every hour of the day. Therefore, the ease and reliability with which parents can passively monitor their infants is directly related to reducing SIDS cases and helping parents of young children maintain peace of mind.

Current baby monitoring devices usually consist of a camera and microphone, more for notifying parents of activity, rather than its notable and dangerous absence. More advanced devices that track infants' heart rates, movement, and oxygen levels do exist but tend to be prohibitively expensive, often costing upwards of $500. Therefore, there is room in the market for a wearable device for infants under one year of age that will allow parents to passively monitor their babies for the most dangerous symptoms of SIDS and other forms of potential injury.

The majority of our research is the development of a wireless baby monitoring device designed to significantly reduce the risk of Sudden Infant Death Syndrome (SIDS) by meticulously tracking two crucial physiological indicators: breathing and body temperature. These parameters were identified as pivotal in the early detection and prevention of SIDS, as irregularities in an infant's breathing patterns and sudden changes in body temperature are often precursors to potential health issues. By incorporating advanced sensor technology, our device offers continuous, real-time monitoring, providing parents and caregivers with immediate alerts should any abnormalities arise. This surveillance system aims to bridge the gap in passive infant monitoring technologies, ensuring that critical signs of distress are not overlooked, thereby enhancing the safety and well-being of infants during their most vulnerable stages of development.

Ensuring the reliability of this device is crucial, given its role in safeguarding infant lives. To meet this essential requirement, our device incorporates multiple fail-safes, a sensor calibration process, and a comprehensive testing regimen to guarantee consistent performance under varying conditions. Battery life, signal integrity, and the system's resilience against common interferences have been carefully evaluated to ensure uninterrupted operation. Furthermore, user-friendliness and accessibility are prioritized to facilitate widespread adoption and ease of use; the integration of these reliability features underscores our commitment to providing a dependable, efficient, and user-centric solution in the fight against SIDS, promising peace of mind for parents and protection for infants.

II. METHODS AND DESIGN

Overview

The plan for our design is to create a baby monitor that is placed close to the oral area of the infants that includes a thermistor that can adjust the resistance of the potentiometer through temperature changes and a breathing gap detector that can count the infant moments of stopped breathing up to 20 times/seconds which will trigger an Alarm and send a signal to Arduino that pairs with the Smartphone devices.

Theoretical Calculation

For the thermistor design, we plan to use a Wheatstone bridge that connects a potentiometer that is connected to an OP Amplifier connected to a buzzer. To calculate the potentiometer trig the Gering resistance at the Temperature Threshold of 39° we use to set the resistance parameters on the left side of the Wheatstone bridge botWheatstonems. We are setting the potentiometer to the upper limit of 5 k Ohms with a 20° temperature limit and a lower limit at 2.423k Ohms with a 40° temperature limit. From the equation below we can calculate the threshold temperature resistance as 2558 Ohms and sensitivity of -136 Ohms/ Celcius.

$$Sensitivity = \frac{\Delta R_T}{\Delta T} = \frac{5000\,Ohms - 2423 0hms}{20° - 40°} =- 136 0i$$

$$R_T(39°) = R(25°) + Sensitivity \cdot \Delta T$$

$$R_T(39°) = 5000 + - 1360 \cdot (39° - 20°)$$

$$= 2558\,Ohms$$

Using all of the parameters in the Wheatstone bridge and voltage input of Vcc that has a value of 5 volts. Assuming that the voltage across the thermistor (Vth) is equal to Vref (the output voltage from the Wheatstone bridge at the temperature threshold) we can use the following equation to calculate the output voltage from the thermistor.

$$V_{out} = V_{cc}\left(\frac{R_{Th}}{R_{Th}+R_2} - \frac{R_{12}}{R_{12}+R_{11}}\right) = 2.55V$$

For the breathing gap detector. We use an AC Signal Source with a peak voltage of 2Vpk and a frequency of 10Hz to mimic the baby breathing effect. Connect to a DIP switch that can close and open mimicking the breathing effect and none breathing effect. Connecting to a High Pass filter that blocks the DC component (0Hz) and passes the AC component of the signal to an OP Amplifier with a gain of 1.01 sending to a Schmitt Trigger inverter that connects to two Monostable Multivibrators output single pulse duration of 11.1ms and 25.8ms. All of that connects to an OR Logic gate with the Thermister sending a signal to another Monostable Multivibrators with a pulse duration of 11.1ms that connect to two inverters leads to a 200Hz buzzer and Arduino output.[7][8][9]

$$f_c = \frac{1}{2\pi R_{12} C_9} \approx 99.5\,Hz$$

$$Gain = 1 + \frac{R_{feedback}}{R_{Input}} = 1.01$$

$$T_1 = 1.1 \times R_7 \times C_4 = 11.1ms$$

$$T_2 = 1.1 \times \frac{1}{\frac{1}{R_8} + \frac{1}{R_9}} \times C_5 = 25.8ms$$

$$T_{output} = 1.1 \times R_1 \times C_8 = 11.1ms$$

Circuit Design

We used a Wheatstone bridge along with an R12 potentiometer that can adjust resistance based on the temperature detected. If the temperature is high, then the resistance will decrease, and if the temperature is lower the resistance will increase.[3] We set the trigger temperature to be 39°, significantly higher than normal human body temperature. If the temperature increases to 39 degrees, the resistance increases to 5kΩ, and the Wheatstone bridge sends a non-inverting signal to OPA27A that amplifies the signal to the Arduino and the alarm.

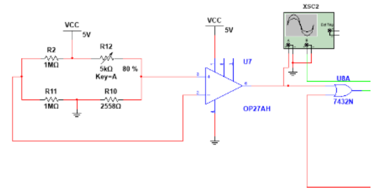


Figure 1: The general system circuit diagram for the thermistor.

For the breathing gap detector, we use an AC signal source with a peak voltage of 2V and a frequency of 10Hz. This is connected to a DIP switch triggered when the infant breathes, which feeds into a high-pass filter from 2 OPA27s with a cutoff frequency of 1.6µF. This sends the AC signal to a feedback resistor and an input resistor with a gain of 1.01, then sends the amplified signal to an inverter with a threshold of 2V. It is then connected to two 555 timers that generate high pulses with durations of 11.1 milliseconds and 25.85 milliseconds. The way this design functions is that a one-timer triggers at the onset of breathing in, and the other timer triggers at the onset of breathing out, so the output is high whenever either one has happened recently, and when one resets the other will as well. This way, the output should remain continuously high as long as a new trigger comes in at least every 20 seconds. The overall signal output is connected to an OR gate with thermistor input that can determine the temperature of the infant so that when either requirement is satisfied, it triggers the alarm.[4][5]

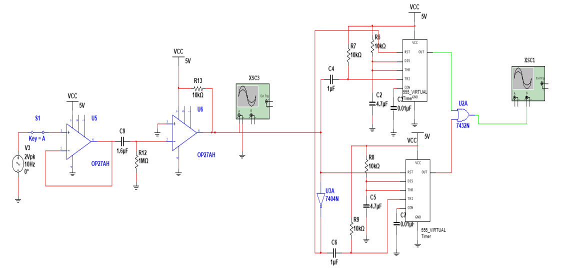


Figure 2: The general system circuit diagram for the breathing gap detector.

The signal that is sent from the thermistor and breathing detector is directed to an OR gate that is connected to a 555 timer with a duration of 11.1 ms that generates a single pulse to the alarm through 2 inverters and then to a 200 Hz buzzer that makes noise when the thermistor or breathing detector reach their threshold values of 39C or 20s, respectively. [6]

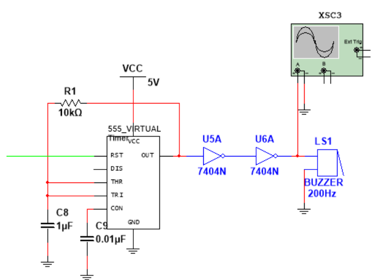
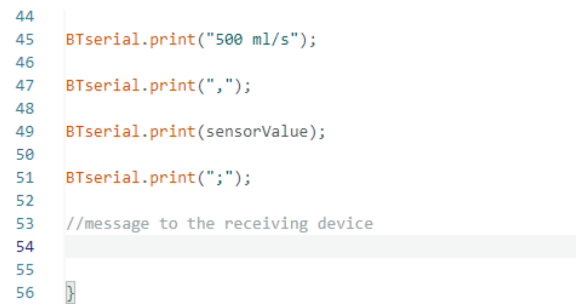


Figure 3: The general system circuit diagram for the Alarm.

Arduino Design

When the buzzer alarm is activated, some of the voltage is also sent to an Arduino R3 that's paired with HC05 to our phone which receives the signal once the Arduino is activated. Our App of choice is Serial Bluetooth Terminal, which can receive Arduino Messages far away from the monitor.[1]

```
/*Developer: Frederik Hauke

Important Notices:

This Arduino-Code is written for Visualizating measurement data from a microcontroller via Bluetooth.

Before starting this application, the Bluetooth-Modul (HC-05) has to be coupled to the Smartphone.In the special case of the HC-05 the default Pi

Wiring: GND of HC-05 to GND Arduino, VCC of HC-05 to VCC Arduino, TX HC-05 to Arduino Pin 10 (RX) RX HC-05 to Arduino Pin 11 (TX) */

#include <SoftwareSerial.h>

SoftwareSerial BTserial(10, 11); // RX | TX

int sensorPin = A0;

int sensorValue = 0;

void setup() {

BTserial.begin(9600); }

void loop() {

sensorValue = analogRead(sensorPin);

//IMPORTANT: The complete String has to be of the Form: 1234,1234,1234,1234;

//(every Value has to be seperated through a comma (',') and the message has to

//end with a semikolon (';'))

BTserial.print("1234");

BTserial.print(",");

BTserial.print("1234.0");

BTserial.print(",");

BTserial.print("1234 hPa");
```



```

BTserial.print("500 ml/s");

BTserial.print(",");

BTserial.print(sensorValue);

BTserial.print(";");

//message to the receiving device


}
```

Figure 4: This is the image of the signal-sending Arduino code that will generate specific messages once the voltage signal is sent through the signal design.

Overall Circuit

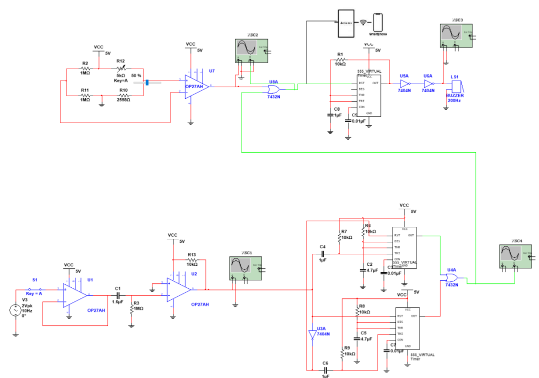
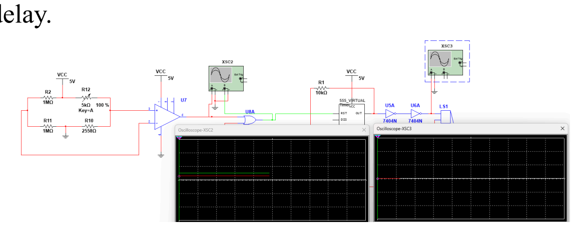


Figure 5: The general system circuit diagram for the baby monitor.

III. RESULTS

The simulation results that are shown on Multisim are promising including that when the thermistor detected infant temperature below 39°, the top of Figure 6 indicates that the potentiometer is around 5k Ohms with a temperature of 25°, both Oscilloscope of the thermistor and the Alarm showing no output from the thermistor. However, as soon as the temperature is detected around the 39° temperature threshold, there is an output of the thermistor going through the amplifier and sending signals to the Alarm and Arduino. Both values of the voltage output and the time duration match our calculations and proceed with continuity with zero delay.



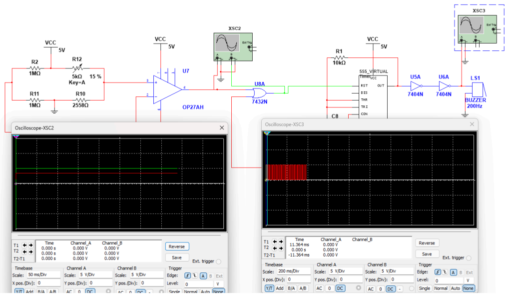


Figure 6: The graph showing the thermistor detector design on Multisim. The top of the image indicates the thermistor doesn't reach to 39° temperature threshold, so there isn't any voltage output. The bottom image indicates as soon as the thermistor reaches 39°, the output shows a square wave with matching time duration in the Analysis section and sends a buzzer and Arduino alarm.

The breathing gap monitor shows another consistent result: the DIP switch mimics the breath detector which triggers the AC signal sending the peak voltage to the high pass filter and the OP Amplifier. On top of Figure 7, the breathing detector senses input of the breath which opens the DIP switch to stop sending signals to the following circuit's components. Both the output of the Amplifier and the two Monostable Multivibrators have zero output since there aren't any AC signal inputs. When there is no breath detected the signal will keep sending through the DIP switch as no breathing is detected, the switch will remain closed. Below Figure 7, we can see that as soon as the breath stops over 20 seconds, the signal from the OP Amplifier will be sent through the two Monostable Multivibrators and generate a matching time duration square wave from expectations to the Alarm and the Arduino.

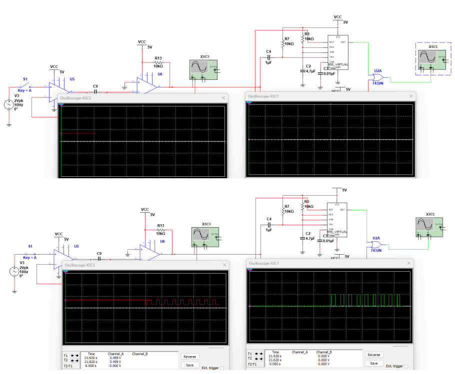


Figure 7: The graph showing the breathing gap detector design on Multisim. The top of the image indicates continuous breathing detected, which resulting no voltage output. The bottom image indicates no breath detected over 20 seconds, showing square wave output with matching time duration in the Analysis section.

IV. DISCUSSION

Limitations

One main limitation of the device is that the readings from the temperature sensor may be affected by environmental factors, such as the surrounding air. This is most likely to happen if the device is not properly secured to the infant or not close enough in proximity, the readings could be faulty. Also, since the breathing detector uses a sonic input, surrounding noises could also affect its readings, making it somewhat unreliable.

Another main limitation is the Bluetooth component. Bluetooth is not reliable over long distances, so the parent may not be notified by the device if they are not close enough, or the signal to their phone could lag behind to a significant degree. Also, it is worth noting that similar devices with affordable prices and reliable functionality already exist on the market, so our device may not be able to compete with others on the market.

Applications:

The primary application of this wireless baby monitoring device is in real-time health monitoring of infants in order to prevent SIDS. It is designed to be used in domestic settings, providing care through continuous surveillance of the child's breathing patterns and body temperature. The device's utility is demonstrated through the simulation results, in that when the device detects abnormality, it promptly alerts caregivers, allowing for quick reaction. This capability is particularly valuable for nighttime or different-room caring.

Industry Significance:

The most notable bioengineering industry significance that this device has is its accessibility and affordability. One aim of its development is to make life-saving technology more accessible and affordable since it can be modeled with very inexpensive parts. It also leverages the precision of bioengineering to detect critical changes in infants' physiological parameters.

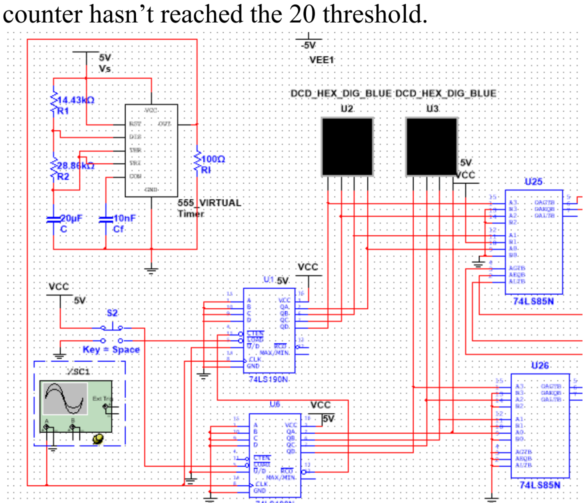
Also, the design of this device embodies the interdisciplinary nature of bioengineering, combining electronics, sensors, and healthcare to address an important medical challenge. Lastly, this device in its ideal form aims to advance pediatric care across the board.

Future Directions

There are multiple directions and functions that can be further implemented. One possible future improvement is to improve the reliability and signal integrity. The aim is to allow the usage of the device in diverse environments while keeping reliability, and so considering factors like temperature fluctuation, humidity, interference, noises, etc. Also, the wireless implementation using Bluetooth can be replaced, considering its limited range and inconsistent signal overall, and options like Wi-Fi, LoRa can be used to implement the ranged communication function of this device for better consistency. On top of that, more user interface and just general external design of the device can be improved and re-implemented with convenience and domestic scenario in mind, as the current choices are still prototypic.

V. ALTERNATIVE SOLUTION

As we mentioned in the discussion, the breathing gap detector could be affected by noise and other environmental issues which will stop the timer and reset the DIP Switch which could lead to unrecognized apnea of the infants through the monitor. To solve the issue we propose an alternative design that serves as a counter that can add up the non-breathing moment over a set of no breathing detected counts.[] By continuing using a DIP switch to mimic the breathing detector that is set to send four hex inverters that each two one set of the counting decimals that will add up continuously if no breath is detected. The 555 timers on the top act as an authorization to time the non-breathing gap values that add up over 15 to 20 and send the signal to the Logic gate that connects to the buzzer and the Arduino. Although the design shows a lot of functionality, no delay is added to the timer which leads to possible other noise overriding the non-breathing detection which may continue to open the DIP switch. This could cause the signal to continue sending to the buzzer, even though the counter hasn't reached the 20 threshold.



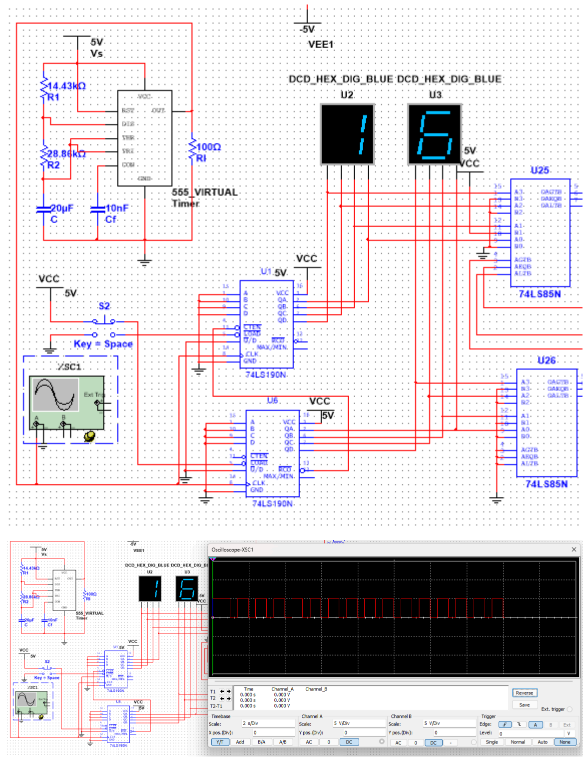


Figure 8: The graph showing a Multisim counter design that serves as a breathing gap detector that will trigger once 20 times of non-breathing detected in the infant which will send the signal to the Arduino and the Alarm. On the second and below of the graph, we can see that the timer isn't reaching to threshold of 20 counts but continues sending out square wave signals.

ACKNOWLEDGEMENT

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