A Noble Approach To Detect Sudden Infant Death Syndrome (SIDS) And Monitor Environmental Parameters

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ADVANCED PROJECT I

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A Noble Approach To Detect Sudden Infant Death Syndrome (SIDS) And Monitor Environmental Parameters

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Abstract: *SIDS, or Sudden Infant Death Syndrome, is a rare phenomenon in infants under one year of age. This project aims to detect the stoppage of the breathing motion of a baby and also to measure the temperature, humidity, CO2, LPG, and smoke level of the environment near the infant using commonly used microcontrollers and different types of sensors such as heart rate monitoring sensor, flex sensor, temperature, and humidity sensor and gas sensor.*

1. Introduction: Sudden infant death syndrome (SIDS), sometimes known as "Cot death," is a pediatric phenomenon seen in infants less than a year old. Where unexpected death happens to a healthy-looking baby, usually during its sleep. According to the National Health Services of the United Kingdom, around 200 babies die yearly from SIDS [1]. Although the number might seem alarming, the cases are rare. So, not much emphasis is given to its prevention or detection.

In this project, we have developed a microcontroller-based solution that could monitor a baby's vitals and alarm the parents if there is an anomaly in the vital of the child or the surrounding environment.

2. Project Overview: The project is an amalgamation of four parts.

I. Breathing Cycle Monitoring Unit
II. Environmental Parameter Monitoring Unit
III. Central Processing Unit
IV. Data Visualization, Connectivity, and Notification Unit

2.1 Breathing Cycle Monitoring Unit: This unit consists of the heart rate monitoring sensor AD8232 for monitoring the heart rate and showing the output as an ECG (Electrocardiogram) and the Long Flex Sensor used to monitor the chest movement to detect apnea.

2.2 Environmental Parameter Monitoring Unit: The HTU21D-F sensor measures the environmental parameters such as temperature and humidity of the surrounding environment. We also used an MQ-2 Gas sensor to detect CO2, LPG, and Smoke in the environment at the ppm (Parts Per Million) level.

2.3 Central Processing Unit: This unit is considered the brain of the whole project. For this project, Arduino Mega 2560 microcontroller board is used, which processes all the data sent from the breathing cycle monitoring unit and the environmental parameter monitoring unit. Suppose the unit detects any anomaly in the reading. In that case, the central processing unit will generate a signal invoking the notification unit to send a notification to the infant's parents or caregiver. Also, in terms of regular reading, the output data generated by the breathing cycle monitoring unit and the environmental parameter monitoring unit is displayed.

2.4 Data Visualization, Connectivity, and Notification Unit: In this project, the illustration of the ECG graph and the environmental parameters is done through a 3.5-inch TFT LCD is used. For connectivity and sending notifications through mobile carriers, the system utilizes a SIM900 GSM module. The system also utilizes a buzzer to alert people nearby if the microcontroller detects any anomaly.

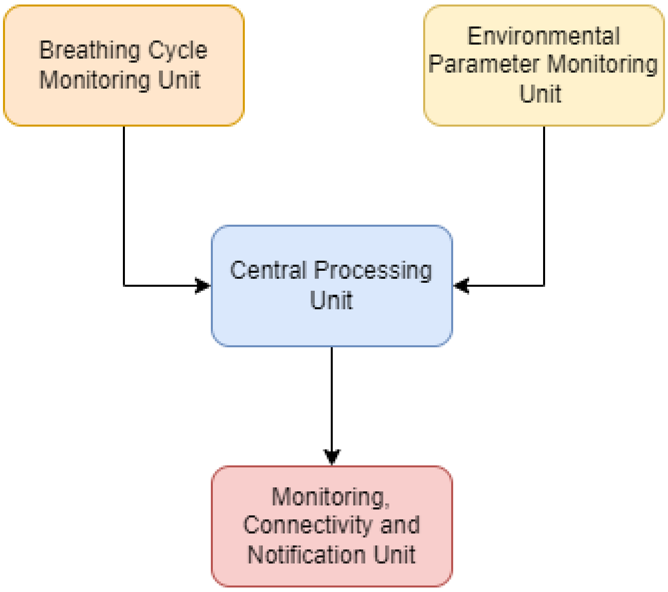

Fig 2.1: Project Overview.

3. Working Principle: The system developed for this project works in the following manner:

At the beginning of the system, the microcontroller unit power-ups all the sensor modules and screens and starts polling for data from both the breath cycle monitoring unit and the environmental parameter monitoring unit.

After receiving the data, the microcontroller starts to analyze the data to see if there is any anomaly. As the main purpose of this system is to detect the stoppage of the breathing cycle or apnea, the microcontroller analyses the data of both the heart rate monitor sensor and the long flex sensor to see if the data is constant over ten seconds. If both data streams are constant for more than 10 seconds, then the microcontroller sends a notification via SMS. The microcontroller unit also sounds the buzzer to notify the people nearby.

Now even if the data stream from the flex sensor is not constant but the heart rate monitor data stream is constant, the microcontroller unit will sound the alarm and send a text-based notification to the people to alert them about the current situation.

For the case of only the flex sensor data being constant, the system sends only text notifications.

As the system also monitors the surrounding environmental parameters such as temperature and humidity, CO_2, LPG, and Smoke, the system also polls these data from the environmental parameter monitoring unit and the data from the breathing cycle monitoring unit. According to Environmental Protection Agency (EPA), it is better to keep the relative humidity

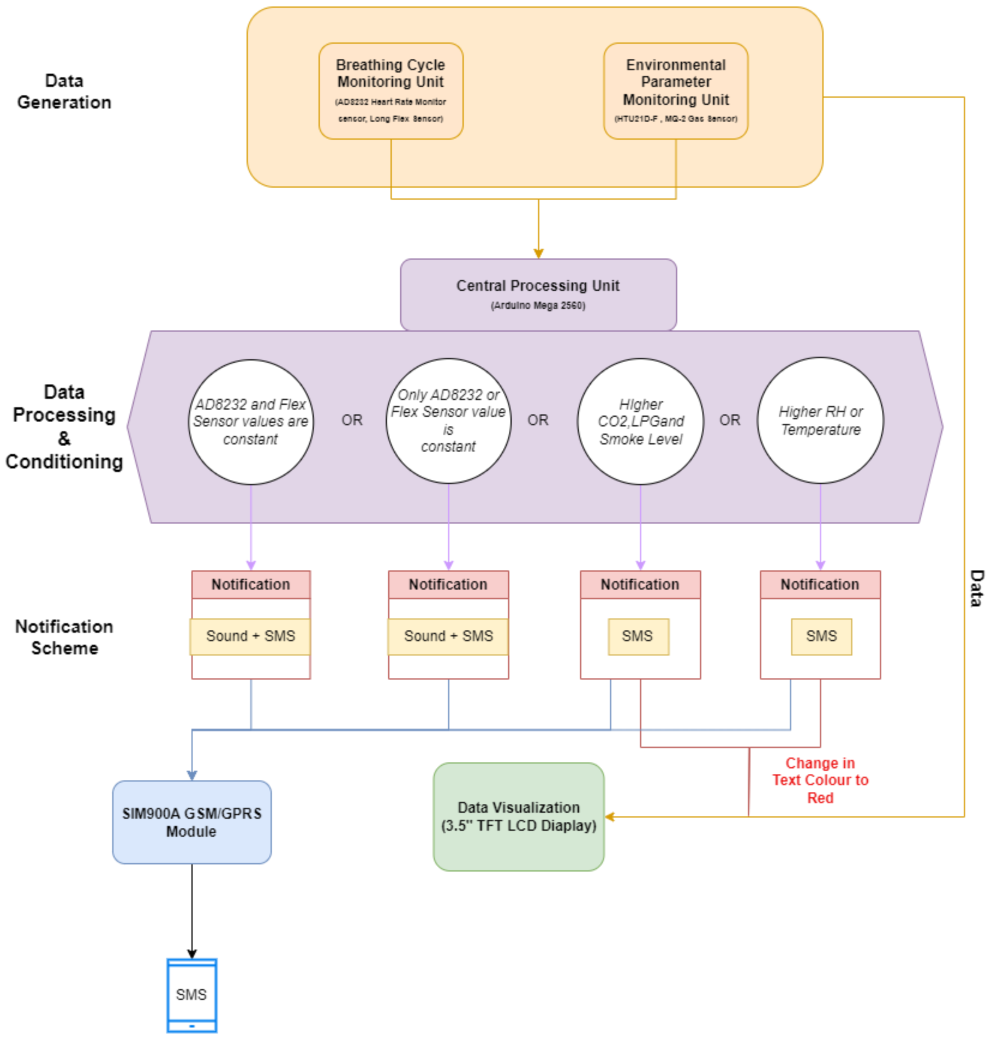

Fig 3.1: Diagrammatic overview of the working principle of the system.

(RH) of the house at 40% to 60%, some pediatrics recommend 55% relative humidity for infants and young children [2]. The ambient temperature for a baby to sleep is around 68°F to 72°F (or 20°C to 22°C) [3]. In this system, we have set the threshold value for the temperature and humidity to be 28°C and humidity to 65%. So, if the temperature and the humidity value is more than or equal to that, the system will send an SMS about the anomaly. Also, the text color of the temperature and humidity will become red from white.

For a child, a healthy environment will need to have CO_2, LPG, and Smoke levels less than 1000 PPM. Thus, if the value received from the MQ sensor is greater than 1000 PPM [4-5], the system will throw an SMS as a notification and change the text color from white to red for the values crossing the threshold level.

In case of anomalies and no anomalies, the system displays the sensor output values on the LCD screen and the ECG graph.

4. Equipment Specifications and Pricing:
For this project, the following equipment was utilized:

4.1 Microcontroller Module: For this project, the selection of the microcontroller was made based on the factors such as price point, availability, a higher number of GPIO ports, and the capability of reading both analog and digital signals. Considering the abovementioned criteria, the Arduino Mega 2560 microcontroller board was the obvious choice. The specification for the Arduino Mega 2560 is given below [6]:

Table 4.1: Arduino Mega Specifications

Board	**Name**	Arduino® Mega 2560 Rev3
Microcontroller	ATmega2560	
USB connector	USB-B	
Pins	**Built-in LED Pin**	13
	Digital I/O Pins	54
	Analog input pins	16
	PWM pins	15
Communication	**UART**	Yes, 4
	I2C	Yes
	SPI	Yes
Power	**I/O Voltage**	5V
	Input voltage (nominal)	7-12V
	DC Current per I/O Pin	20 mA
	Supported battery	9V battery
Clock speed	**Main Processor**	ATmega2560 16 MHz
	USB-Serial Processor	ATmega16U2 16 MHz
Memory	**ATmega2560**	8KB SRAM, 256KB FLASH, 4KB EEPROM
	Width	53.3 mm
	Length	101.5 mm

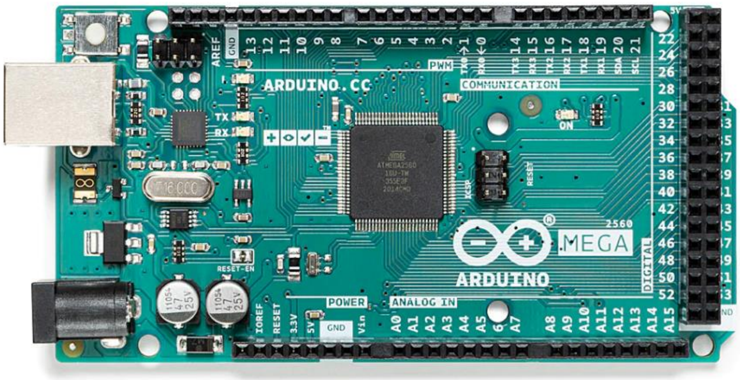

Fig 4.1a: Arduino Mega (Source)

4.2 AD8232 Heart Rate Monitoring Module: We used the Sparkfun Single Lead Heart Rate Monitoring module using the AD8232 chip for the project. The Ad8232 is an integrated signal conditioning block for Electrocardiogram (ECG) and other bipolar measurement applications. The absolute maximum ratings for AD8232 are given in the table below [7]:

Parameter	***Rating***
Supply Voltage	3.6V
Output Short-Circuit Current Duration	Indefinite
Maximum Voltage, Any Terminal	+Vs + 0.3V
Minimum Voltage, Any Terminal	-0.3V
Operating Temperature Range	-65°C to +125°C
Maximum Junction Temperature	140°C

Table 4.2: Absolute Maximum Ratings for AD8232

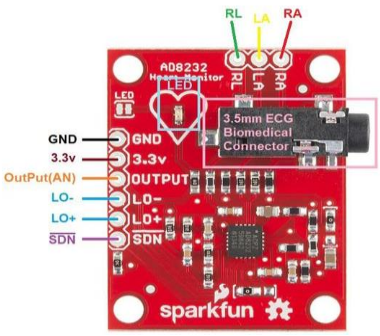

Fig 4.2a: AD8232 Module (Source)

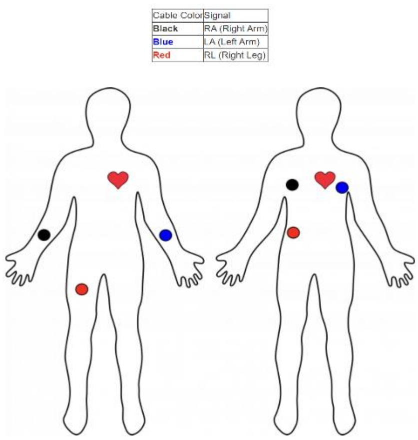

Fig 4.2b: Sensor Probe Placement(Source)

The sensor needs to be connected to a separate voltage source to reduce the noise in the output. Therefore, a 9V battery was added to a 9V to 3.3V converter (AMS1117), which was used to power the sensor.

4.3 Long Flex Sensor: We have used the long flex sensor to monitor the infant's breathing cycle. The sensor was sewn to a strap attached to the infant to detect its breathing cycle. For the long flex sensor to work properly, the sensor used a resistor to voltage converter, which converts the long flex sensor output (the resistance value) to a voltage value using an Op Amp (LM358).

Fig 4.3a: Long Flex Sensor (source)

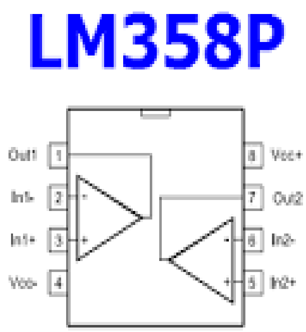

Fig 4.3b: LM358 Pinout (source)

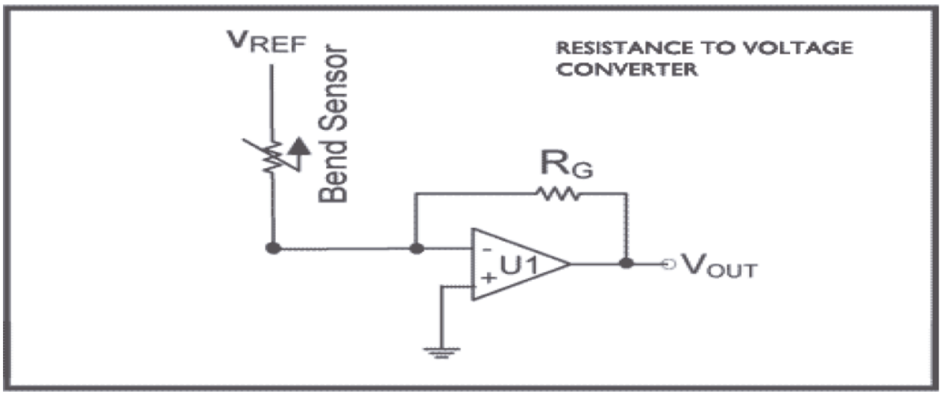

Fig 4.3c: Resistance to voltage converter configuration for long flex sensor [8].

As the sensor's resistance increases with the increase of degrees, the sensor is bent. Thus the output voltage increases with the increase of its bending. The specification for the long flex sensor is given below:

Parameters	***Rating***
Flat Resistance	10K Ohms
Resistance Tolerance	+-30%
Bend Resistance Range	60K to 110K Ohms
Power Ratings	0.5W to 1W(Peak)

Table 4.3: Specifications of long flex sensor [6].

4.4 HTU21D-F Temperature and Humidity Sensor: The HTU21D-F sensor provides accurate values for humidity and temperature. The maximum rating for the HTU21D-F Temperature and Humidity Sensor is given below [9]:

Fig 4.4a: HTU21D-F Temperature and Humidity Sensor(Source)

Parameters	***Rating***
Storage Temperature (Tstg)	(-40 to 125) °C
Supply Voltage (Peak)	3.8V Vdc
Humidity Operating Range (RH)	(0 to 100) %RH
Temperature Operating Range (Ta)	(-40 to +125) °C
VDD to GND	(-0.3 to 3.6) V
Digital I/O pins (DATA/SCK) to VDD	(-0.3 to VDD + 0.3) V
Input current on any pin	(-10 to +10) mA
Communication protocol	I2C

Table 4.4: Specifications of HTU21D-F Temperature and Humidity Sensor

4.5 MQ-2 Gas Sensor: The MQ Gas sensor can detect multiple pollutants in the surrounding environment. For this system, we are utilizing the sensor's CO2, LPG, and Smoke level values. The MQ gas specification is given below [10]:

Parameters	Ratings
Using Temperature, T_{ao}	-20°C to 50°C
Relative Humidity, R_H	<95%
Circuit Voltage, V_C	5V±0.1
Heating Voltage, V_H	5V±0.1
Standard Detection Condition	Temp: 20℃±2℃ Vc:5V±0.1 Humidity: 65%±5% Vh: 5V±0.1
Detecting Concentration	Scope 0 to 5000 ppm

Table 4.5: Specifications of MQ-2 Gas Sensor.

Fig 4.5a and 4.5b : MQ-2 Sensor Front & Back Side

4.6 SIM900 GSM/GPRS Module: This module gives cellular connectivity to the system. And over this connectivity, text messages will be sent to alert the caregivers if there is an anomaly in the data. The module uses AT commands to send messages.The feature for the module is given below [11]:

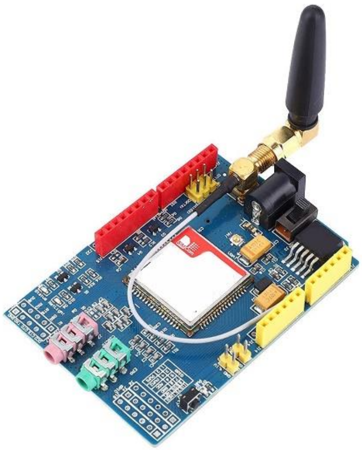

Fig 4.6a: SIM900 GSM/GPRS Module (Source)

Features	***Rating/Protocol/Dimensions/Size***
GSM	Quad-Band 850/900/1800/1900 MHz
GPRS Data	GPRS Class 10: max 85.6 kbps (Downlink)
SMS via GSM/GPRS	Point to Point MO and MT, SMS Cell Broadcast, Text, and PDU Mode
Voice	Half Rate, Full Rate, Enhanced Full Rate Codec, Echo Suppression
Internet Protocols	Embedded TCP/UDP, FTP, HTTP
Power Supply Voltage	5V
Power Supply Current	2A

Table 4.6: SIM900 GSM module features.

One thing that needs to be noted here is that for this project we needed to find an operator that still operates in 2G. Otherwise the SIM900 module will not work. For operators that work in 3G it is better to use SIM5320A.

4.7 LCD Display module: For data visualization, we have used a 3.5" TFT 320x480 + Touchscreen Breakout Board w/MicroSD Socket - HXD8357D. The specification of the module is given below [12]:

Parameters	***Rating/Protocol/Dimensions/Size***
Diagonal Length	3.5 inch
Resolution	320x480
Communication Protocol	SPI
Voltage compatibility	3.3V or 5V
Screen	56mm x 85mm x 4mm / 2.2"x3.4"x0.2
Weight	52g
Number of pins	40

Table 4.7: LCD Module Specifications.

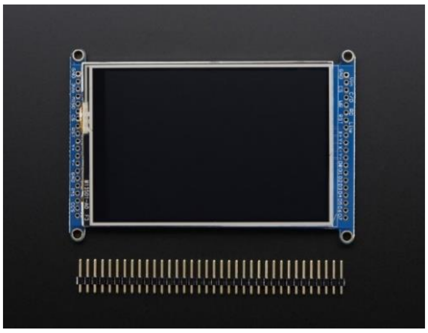

Fig 4.7a: Adafruit 3.5" (320x480) TFT LCD Display Breakout Board.

For this project, we have also used a buzzer to generate sound alerts while detecting specific sorts of anomaly.

The overall cost for the whole project is shown in the table below:

Component Name	No of units	Price (in USD)
Arduino Mega	1	48.20
AD8232 Module	1	21.50
Long Flex Sensor	1	12.95
HTU21D-F Module	1	10.95
MQ-2 Gas Sensor	1	3.00
SIM900 GSM Module	1	17.09
LCD Display Module	1	39.95
Miscellaneous	-	15.00
Total Cost	168.64	

Table 4.8: Cost Calculation.

5. Results: After multiple dedicated trials and vigorous observation, it can be said that the system worked as planned. For description purposes, we can divide the results into two categories:

5.1 Under Normal Condition: The normal condition for the system means ECG and Flex sensor output values are not constant for more than 10 seconds, and all the environmental parameter data are within their threshold limit. Under regular condition, the project worked perfectly. Showing all the values on the LCD monitor for the ECG, Flex Sensor, Temperature, Humidity, CO2, LPG, and Smoke level.

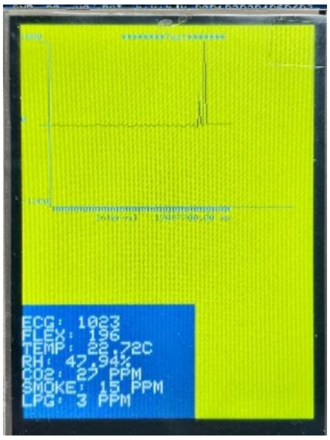

Fig 5.1a: System Under Regular Condition

In normal conditions, we also get an ECG graph. The ECG graph generated by AD8232 and plotted in Arduino's Serial Plotter is illustrated below:

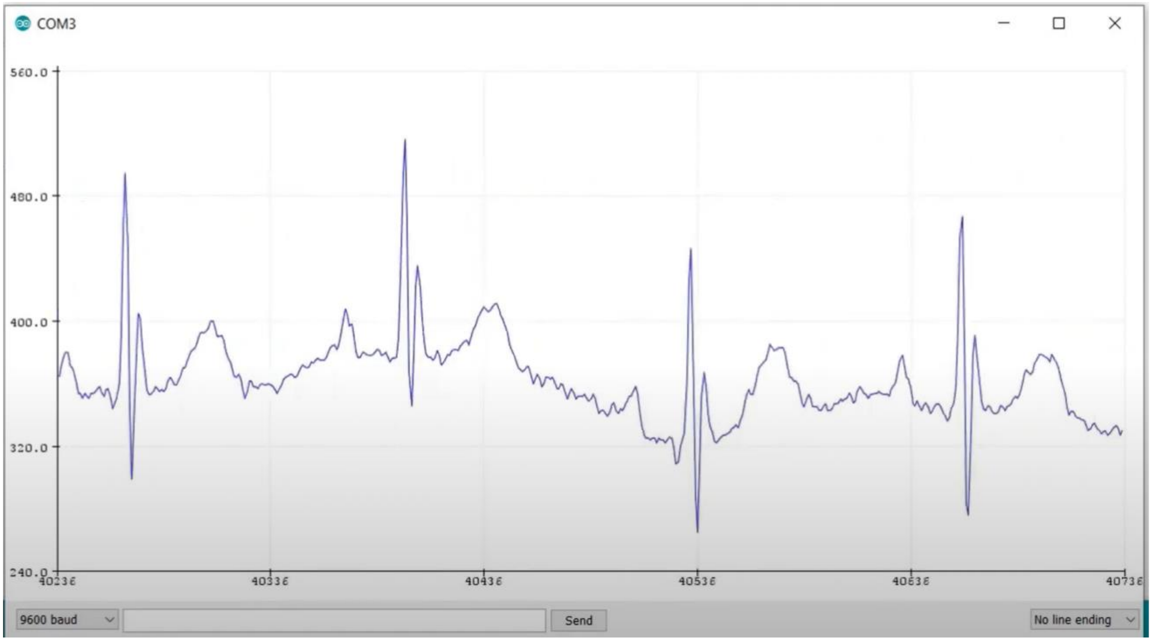

Fig 5.1b: ECG graph on Arduino IDE's Serial Plotter.

5.2 System Under Abnormal Condition: There can be two types of abnormalities in the system:

5.2.a. Abnormality in Breathing Cycle Monitoring unit: This anomaly means that the data from either the ECG or the Long Flex Sensor are constant. This infers that the child or the infant is not breathing for 10 seconds or more. As a result, the buzzer will start ringing, and an SMS will be sent to the selected number. The picture below shows the SMS sent by the system to notify the caregiver that the flex sensor has stopped, which means that the child has stopped breathing.

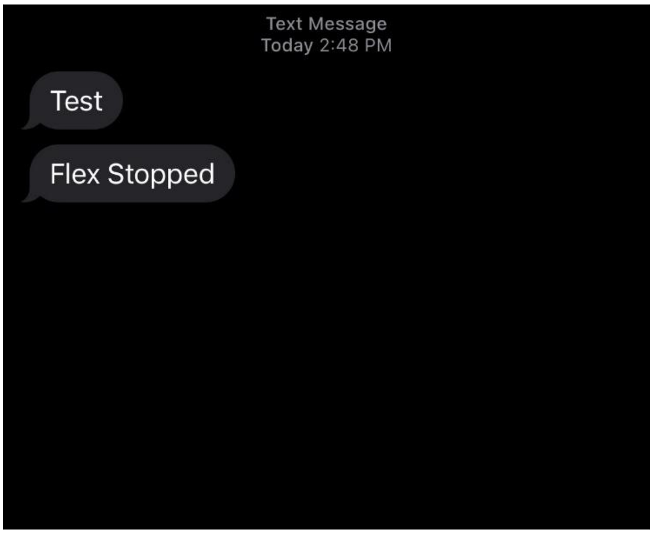

Fig 5.2.a.1: Text Message Sent By The System

5.2.b. Abnormality in Environmental Parameter Monitoring Unit: This kind of abnormality occurs when parameters monitored by the sensors cross their threshold value. If the threshold value is crossed, then on display, the digits representing the values from the sensor become RED from its regular white-colored text. And also, the system sends a text notification to the caregiver mentioning which parameter has crossed its threshold. In the system, the threshold value for the CO2 was set to 1000 ppm. Thus any value greater than 1000 ppm will trigger the SMS and turn the value red on the LCD.

Fig 5.2.b.1: Abnormality In CO2 Level

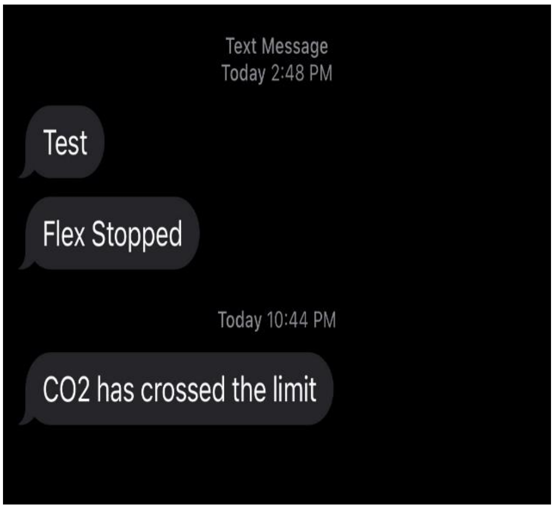

Fig 5.2.b.2: SMS Sent Due To The Abnormality In CO2

Similarly, for other parameter data sent by sensors crosses the threshold value, the system will send an SMS and turn the value red on the LCD.

The actual connections between the microcontroller unit, sensors, and display unit are shown below:

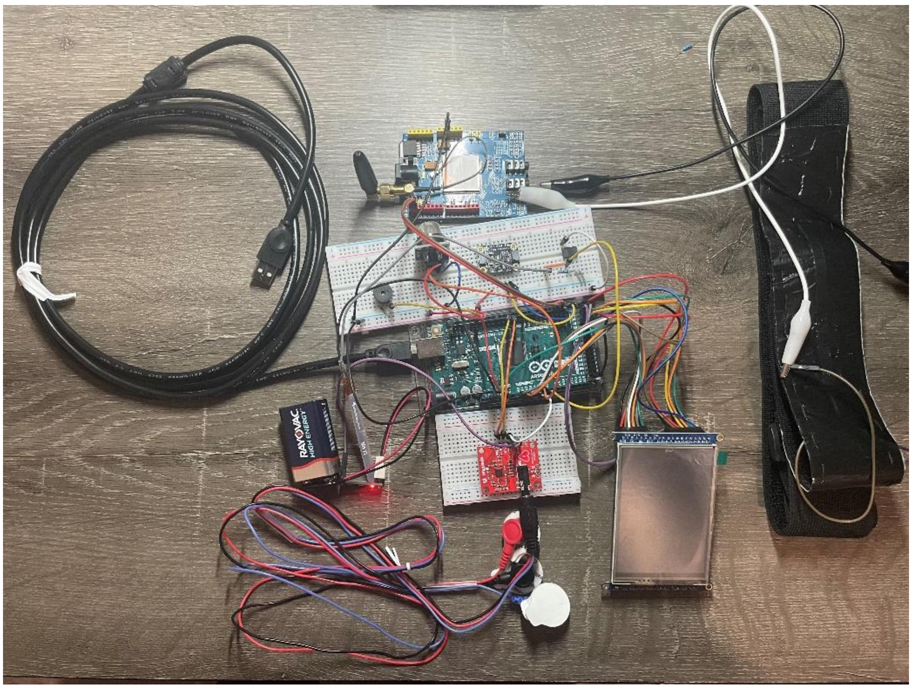

Fig 5.2.1: System Setup

For better understandability of the connection of the modules of the system, a table containing the pinouts of the module and their connection to the Arduino mega is given below:

	LCD Module Connection	
Module Pins	- -	*Arduino Mega Pins*
D0 to D7	- -	22 to 29
CS	- -	A3
CD	- -	A2
WR	- -	A1
RD	- -	A0
GND	- -	GND
3V to 5V	- -	5V
	AD8232 Sensor	
	AD8232 Connection with ASM1117 voltage converter	
Module Pins	- -	*ASM1117 Pins*
3.3V	- -	Vout
GND	- -	GND
	ASM1117 voltage converter connected to a 9V battery	
ASM1117 Pins	- -	*9 Volt Battery*
Vin	- -	+ ve
GND	- -	- ve
	AD8232 Connection with Arduino Mega	
Module Pins	- -	*Arduino Mega Pins*
LO+	- -	4
LO-	- -	5
OUTPUT	- -	A4
	HTU21D-F Sensor	
Module Pins	- -	*Arduino Mega Pins*
VIN	- -	5V
GND	- -	GND
SCL	- -	21
SDA	- -	20
	MQ-2 Sensor	
Module Pins	- -	*Arduino Mega Pins*
A0	- -	A5
GND	- -	GND
VCC	- -	5V
	SIM900 GSM Module	
Module Pins	- -	*Arduino Mega Pins*
TX	- -	18 (TX1)
RX	- -	19 (RX1)
Yellow Connector 9	- -	GND

For the Long flex sensor to work properly, the sensor needed to be added to a Resistance to Voltage Configuration. For that, we have used LM358 Dual Op-amp. The output of the Op-amp is connected with the A6 of the Arduino Mega. For the flex sensors, one part is connected to 3.3V, and the other is connected to pin 2 (Negative terminal) of the Op-amp. Resistor Rg= 330ohm is connected with pin 1 (OUTPUT) and pin 2 (Negative terminal). Pin 3 (Positive terminal) and Pin 4 (VCC-) are connected to GND. Pin 8 (VCC+) is connected to 5V.

6. Future Works: Although the current prototype works properly. There are always scopes for improvement. For this prototype, the following improvements can be considered:

1. For this prototype, to reduce the noise in AD8232 output, we have provided the sensor with a different DC input source so that the 50Hz noise from the regular power supply does not induce any noise. But still, there is noise in the signal. Thus we will add filtering to the system.
2. In this system, multiple tasks need to run at the system, which is why in the future, we will be using multi-threading to reduce the delay in the system.
3. In the future, we shall add internet connectivity to the system such that the sensor values can be seen in real-time via mobile apps.
4. Finally, in the future, the system will be placed in a compact and user-friendly ergonomic cover.

7. Conclusions: The developed prototype has successfully detected apnea or stoppage of breathing in an infant and can notify the caregiver via SMS and buzzer sound. Which fulfills the main purpose of this project of preventing SIDS. Along with that, the prototype could monitor and notify any anomalies in the surrounding environmental parameters such as temperature, humidity, CO2, LPG, and smoke levels.

Acknowledgment: This project stands upon the knowledge gained throughout the tenure of the Masters in Electrical Engineering program. Therefore, I would like to thank each and every professor and teaching assistants who have mentored me throughout my journey here at NYU Tandon School of Engineering.

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