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Wearable device for Air Quality monitoring with disease prediction system

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Abstract: Today, air pollution exists to be a major concern around the world. Industrial emissions, greenhouse gases, automobile emissions, incinerations, etc., increase the air pollutants and release toxic substances into the air. This in turn affects human beings and other living beings with respiratory ailments and climatic changes on a large scale. According to WHO seven million people die every year due to airborne diseases. Also,14 states in India have been identified with an average of 2.5 PM (particulate matter), which is 17 times higher than that of the recommended WHO limit. This paper delivers a solution to monitor, track, detect and indicate an individual about the air quality index of the surrounding (AQI), amount of particulate matter (PM), and also the individual's heart rate, breathing rate, and temperature. The solution is a compact, smart and user-friendly wrist device that is also capable of predicting the respiratory diseases that the individual may be affected with. The real-time data can be computed with cloud assistance and monitored through a mobile application by the user or remotely. This device will also serve as a great tool for monitoring a patient's respiratory and environmental health by them or their medical support.

Index terms: IoT, Smart Wearable, Embedded systems, Air Pollution, Air Quality Monitoring, Disease prediction

I. INTRODUCTION

According to WHO's new estimates, it is revealed that '9 out of 10 people breathe air containing high levels of pollutants' and' both ambient and household air pollution are responsible for about 7 million deaths globally per year'. Under these circumstances, an individual has to be highly alert to the surrounding air quality and their respiratory health. Existing solutions include smartwatches for measuring air pollution, public air purifiers, and air quality monitoring systems. But a smart, personalized, and effective solution is needed for the respiratory safety of an individual. This paper proposes the idea of a flexible skin attachable device that serves as a smart and personal respiratory health monitoring system as well as an atmospheric air quality monitoring system. This device shows the data on how much time the user exposure to the pure air and pollutant air. Based on these data the device will also be capable of predicting the possible respiratory health risks of the user and alerts accordingly. This wearable air quality monitoring and disease prediction device is made to provide accurate data to the user.

II. PROPOSED APPROACH:

2.1 Methodology:

This wearable air quality monitoring device is made technically viable with the help of sensors and processors. In this proposed system, the wearable device consists of various sensors for measuring air quality index, atmospheric temperature, humidity, pollutants in the atmosphere (PM 2.5, PM 10, NO2, Ozone, Chlorines, SO2, H2S, and odorous gases), and the user's heart rate, spO_2 levels, temperature and eventually the breath rate. The measured parameters will be transmitted through a Bluetooth communication to the user's mobile application. The acquired data is analyzed for the user's healthy exposure levels to atmospheric pollution. Accordingly, the user will be alerted through mobile application and user interface of the device. Further, the measured data can be used to predict if the user is affected by any respiratory ailment or other diseases through analysis. The User's Real-time Air Quality data will be uploaded to the cloud and it will used for future analysis. The following is the table of the components proposed with their model and specifications:

S.no	Components	Model	Specifications
1	Temperature & Humidity Sensor	DHT22	Power supply: 3.3V – 6V DC Output signal: Digital signal via single-bus Sensing element: Polymer humidity capacitor & DS18B20 Operating range: Humidity 0-100% RHH (Max +-5%RH); Temperature -40°C – 125°C Accuracy: humidity ±2%; temperature ±0.2°C Sensing period: ~2s
2	Respiratory Irritant Sensor	RESP IRR20	Screen Printed Electrochemical sensor Detection of respiratory irritant gases: NO2, Ozone, Chlorines, SO2, H2S, and odorous gases. Operating Temperature Range: -10 to 40 C (0 to 40 C continuous) Operating Humidity – non-condensing: 0 to 100% RH (15 to 95% continuous) Power Consumption < 50 µW circuit & ambient gas dependent Measurement Range: 0 to 20 ppm (calibrated as NO2 equivalents) Response Time to 90%: < 60 seconds typical Sensitivity: -50 +/- 25 nA/ppm (NO2 equivalents)
3	Pulse oximetry and heart rate monitor	Max30100	Operating Voltage: 1.8v – 5.5v Operating Temperature Range: -40°C to +85°C Ultra-Low Shutdown Current (0.7µA, typ) Integrated Ambient Light Cancellation Ultra-Low-Power Operation (< 1 mW)
4	PM2.5 and PM10 Particle Sensor	TIDA-00378	Analog front-end design for PM2.5 (<2.5µm) and PM10 (<10µm) particle detection and count Zero-volt bias to minimize photodetector noise and stabilize performance over temperature Instrumentation amplifier topology to reject external noise sources Low noise, low input bias current

Table 2.1: Components & Specifications

2.2 Block Diagram:

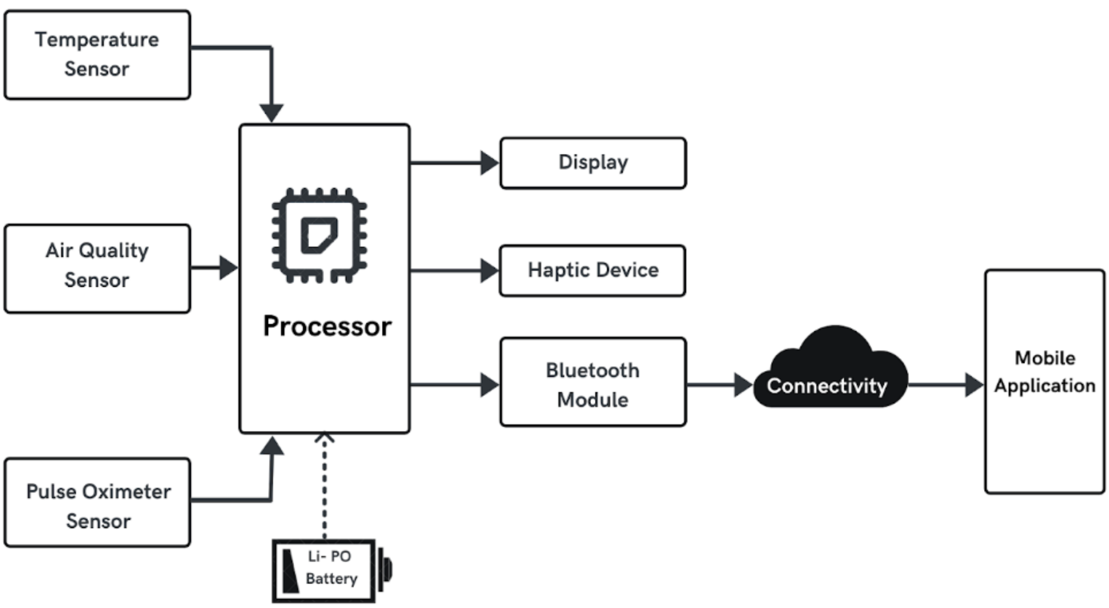

Figure2.1: Block diagram

2. 3 Parameters to be measured:

- **User's biological parameters**
  1. Heart rate
  2. Breathe rate
  3. SpO_2

- **Atmospheric parameters**
  1. Temperature
  2. Humidity
  3. Pollutant levels (CO, NO2, O3, SO2, NH3, PM 10.PM 2.5)

2.4 Calculation of breathing rate:

Since breath rate cannot be measured directly through sensors, it has to be calculated from the collected data such as pulse rate and SpO_2 level. The breath rate is calculated using a Photoplethysmography (PPG) method which can be found using a pulse oximeter sensor. This method was analyzed using wavelet transform so this will generate an accurate determination of breath rate. The pulse oximeter data will be sent to mobile applications and the PPG wavelet will be plotted and processed in the application. By doing some research we find that the PPG method will give an accurate breath rate by using pulse oximeters.

III. WORKING:

3.1 Work flow and prediction charts:

When the device is placed on the user's wrist, various parameters will be sensed and recorded by the integrated sensors. Temperature & Humidity Sensor will measure the user environment's temperature and humidity. PM stands for Particulate Matter which are atmospheric aerosol particles. They are suspended into the atmosphere through combustion and various other factors and cause serious respiratory problems when inhaled.pm 2.5 are particulate matter with a particle diameter of 2.5 microns. This is one of the most dangerous air pollutants and a particulate matter (PM) sensor is used to detect and measure it. A respiratory Irritant Sensor is used to measure the levels of atmospheric gases in the surrounding air like NO2, Ozone, NH3, SO2, CO, and odorous gases. Hence, all the major affecting pollutants will be measured and their levels will be indicated.

The air quality index (AQI) indicates the quality of the breathing air and is determined by measuring the amount of pm 2.5, pm 10, and other pollutants in the air. AQI. According to National Ambient Air Quality Standards (NAAQS), AQI is calculated with eight pollutants that are pm 2.5, pm 10, nitrogen dioxide, Sulphur di oxide, carbon monoxide, ground-level ozone, ammonia. Supposedly, if the exposure levels to certain air pollutants are higher than the safety standards for more than the specified time period, then the user will be immediately alerted about the severity of the air quality. The following table is used to calculate the air quality:

AQI Category	AQI	Concentration Range (CO in mg/m3 and other pollutants in µg/m3) *2h-hourly average values for PM10, PM2.5, NO2, SO2, NH3, and Pb & 8-hourly values for CO and O3.							
		PM 10	PM 2.5	NO2	O3	CO	SO2	NH3	Pb
Good	0-50	0 - 50	0 - 30	0 - 40	0 - 50	0 - 1.0	0 - 40	0 - 200	0 - 0.5
Satisfactory	51 - 100	51 - 100	31 - 60	41 - 80	51 - 100	1.1 - 2.0	41 - 80	201 - 400	0.5 - 1.0
Moderate	101 - 200	101 - 250	61 - 90	81 - 180	51 - 100	2.1 - 10	81 - 380	401 - 800	1.1 - 2.0
Poor	201 - 300	251 - 350	91 - 120	81 - 180	169 - 208	10 - 17	381 - 800	801 - 1200	2.1 - 3.0
Very Poor	301 400	251 - 350	121 - 250	281 - 400	209 - 748*	17 - 34	801 - 1600	801 - 1200	3.1 - 3.5
Severe	401 - 500	430 +	250+	400+	748+*	34+	801 - 1600	1800+	3.5+

Table 4.1: Air Quality Index chart

3.2 Flow diagram:

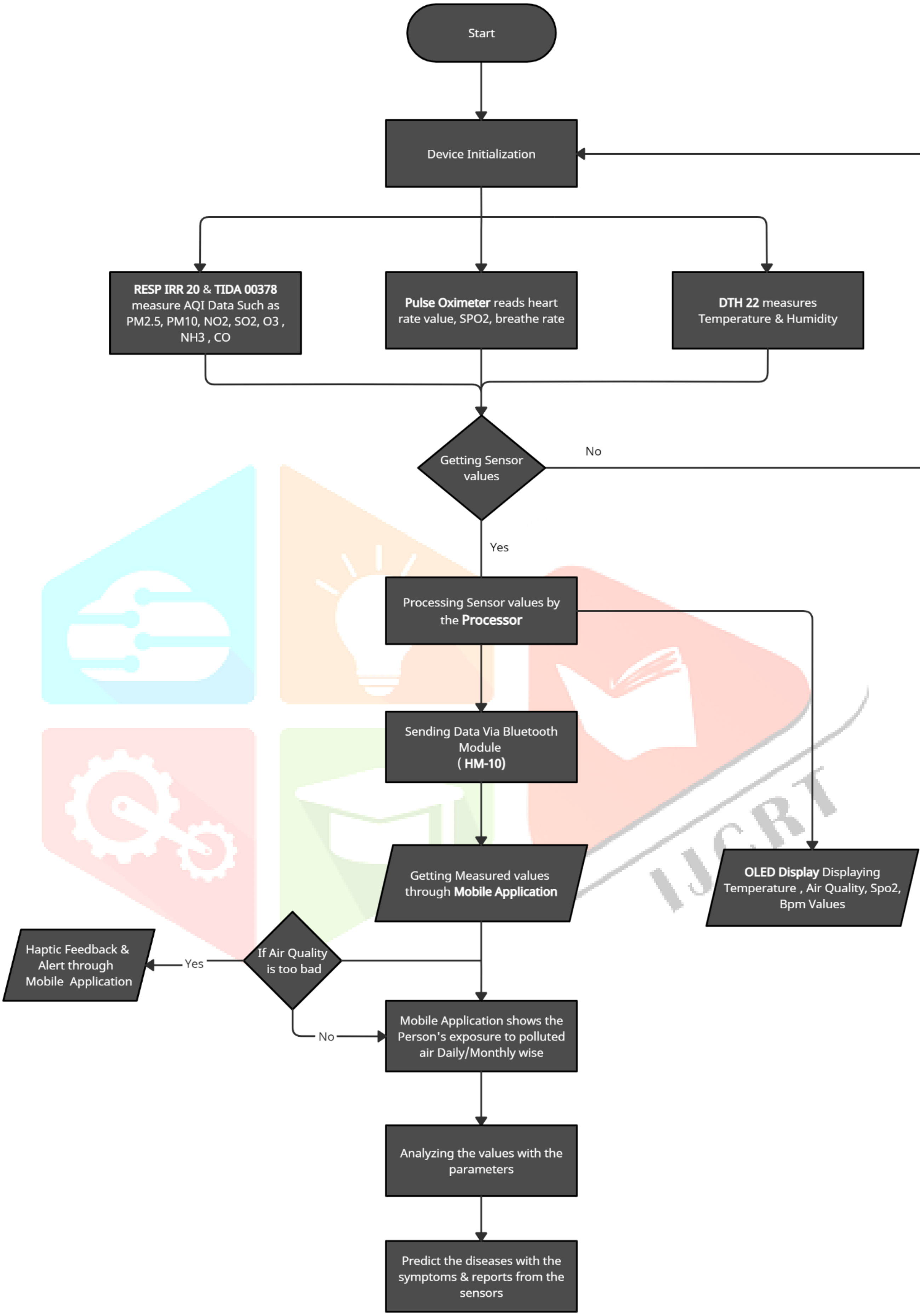

Figure 3.1: Flow diagram

3.3 The air quality history and further prediction:

The recorded data is also pushed to the cloud for storage and further computation. The user will be able to view the past data history for further insights. Hence, it also helps in tracking the respiratory health of the user/ patient. From the sensed data, the respiratory symptoms can be identified. Further, the collected data can be computed to find or predict if the user has been affected with any cardiac/respiratory disease. The prediction is done based on the following criteria:

Table 3.2: Predictions of diseases

S.no	Prediction to indicate	Symptoms	Normal body specifications	Parameter
1	COVID -19	Raise in temp above 100f, Drop in SpO_2 value below 90%	Body temp: 97.8f-99f, SpO_2: >90 (greater than 90) Normal heartbeat rate: 60 to 100 bpm	Temperature, Heart Rate
2	Hypothermia	A drop of body temp below 95f	Body temp: 97.8f-99f	Temperature
3	Pneumonia, Bronchitis	Breathing rate above 40/min	Normal breath rate: Birth to 1yr - 30 to 60 1 to 3 year - 24 to 40 3 to 6 year - 22 to 34 6 to 12 year - 18 to 30 12 to 18 year – 12 to 1	
4	TTN Transient Tachypnea	Breathing rate Above 60/min		Breathing
5	Asthma	Pulse 100 to 125 per min (children older than 5) 2. Pulse rate <140 (2 to 5) 3. Respiratory rate of 20 to 30 /min (older than 5 yrs)	Normal heartbeat rate: 60 to 100 bpm	Breathing, Heart Rate
6	Heart diseases	Less than 60bpm, more than 100 to 200 BPM	Normal heartbeat rate: 60 to 100 BPM	Breathing, heart rate

IV. OUTPUT:

4.1. The user interface on the device:

The acquired real-time data will be constantly updated on the OLED display of the device. Any abnormalities in the parameters will be immediately indicated to the user through the haptics indication from the device and the user will be instructed to breathe pure air.

4.2 User's mobile application:

The real-time data will also be updated on the user's mobile application simultaneously. Through the mobile application, the user's respiratory health and surrounding air quality can be easily monitored remotely by others. The application shall also display the history of the recorded data. In this way, the user's data can be accessed at any time. Here, any abnormalities in the parameters will be immediately indicated to the user through a notification. Adding to this, the available real-time data is processed to predict the respiratory health of the user. If there is a prediction of any respiratory ailment, the user will be immediately alerted and would be advised to seek medical assistance.

4.3 Computer aided design model of the proposed solution:

The figure shows the developed CAD model of the wrist device. It was developed using Solidworks. Solidworks software is used to model and develop a computer aided design virtually. The modelled design consists of a sensor layer that is fabricated with the temperature sensor, Pulse oximeter and air quality sensor. It contains an OLED display to displayed the data to the user. Its band material is made of rubber which has comparatively high sweat resistance and comfort that makes it more suitable for the user. The figure shows the OLED display of the device, which displays the following data:

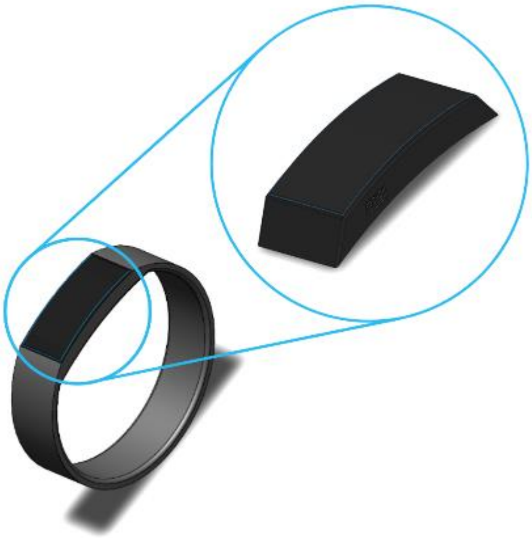

Figure 4.1: Wrist device.

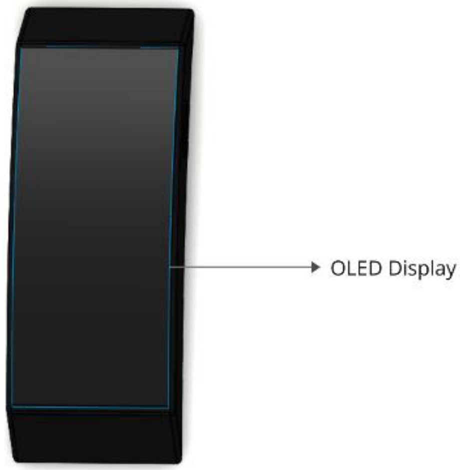

Figure 4.2: OLED Display

Figure 4.3: Side view

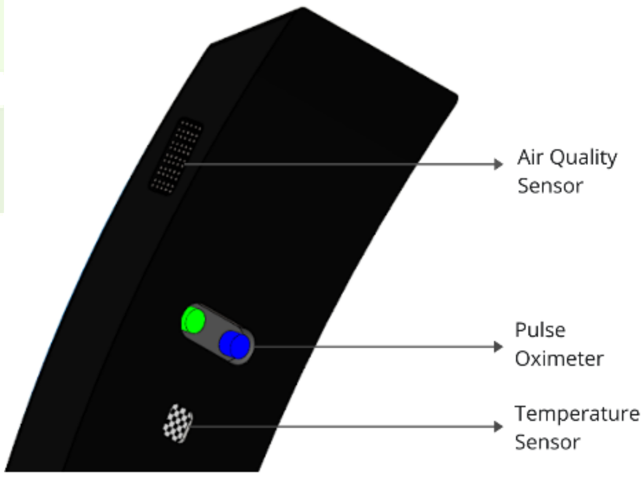

Figure 4.4: Sensor layer

4.4 Circuit and Simulation results:

The proposed solution is simulated for various use cases using Proteus 8 software including Arduino and Blynk libraries. Proteus 8 is a software for generating schematic designs of circuits and virtually simulate the microprocessors. Here, Arduino UNO was chosen as the microcontroller for simulation. Arduino UNO is an ATmega328P based microcontroller. For the purposes of simulation, only selective sensors and parameters were able to be tested in software. Hence, DHT22 and Max30100 sensors were simulated which measured the parameters such as temperature, heart rate and SpO_2levels of the user. The simulated results are shown below:

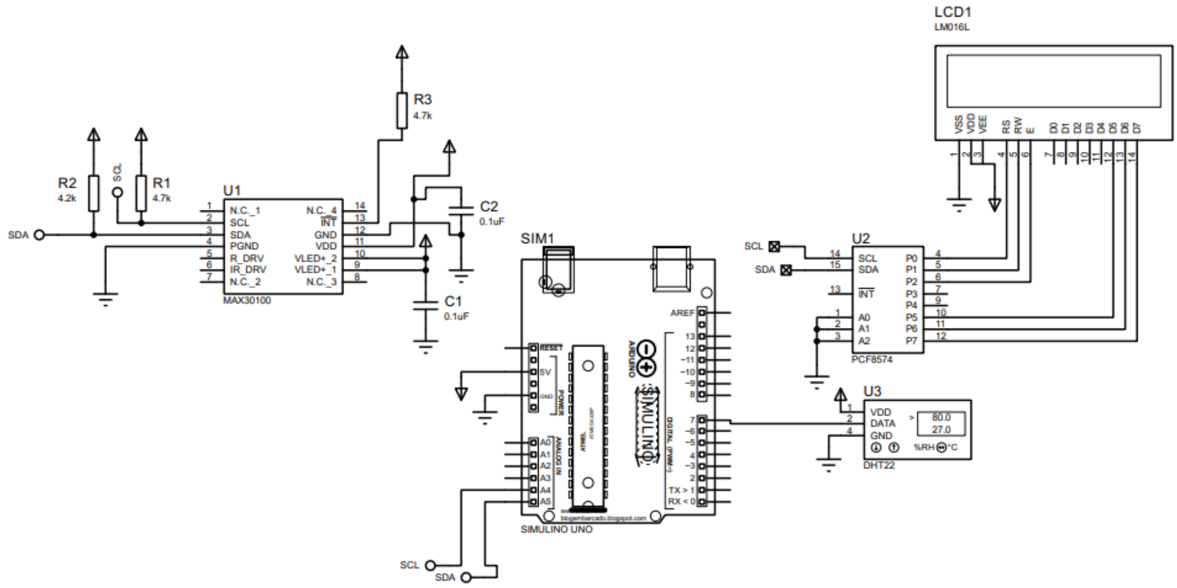

Figure 4.5: Simulated Circuit

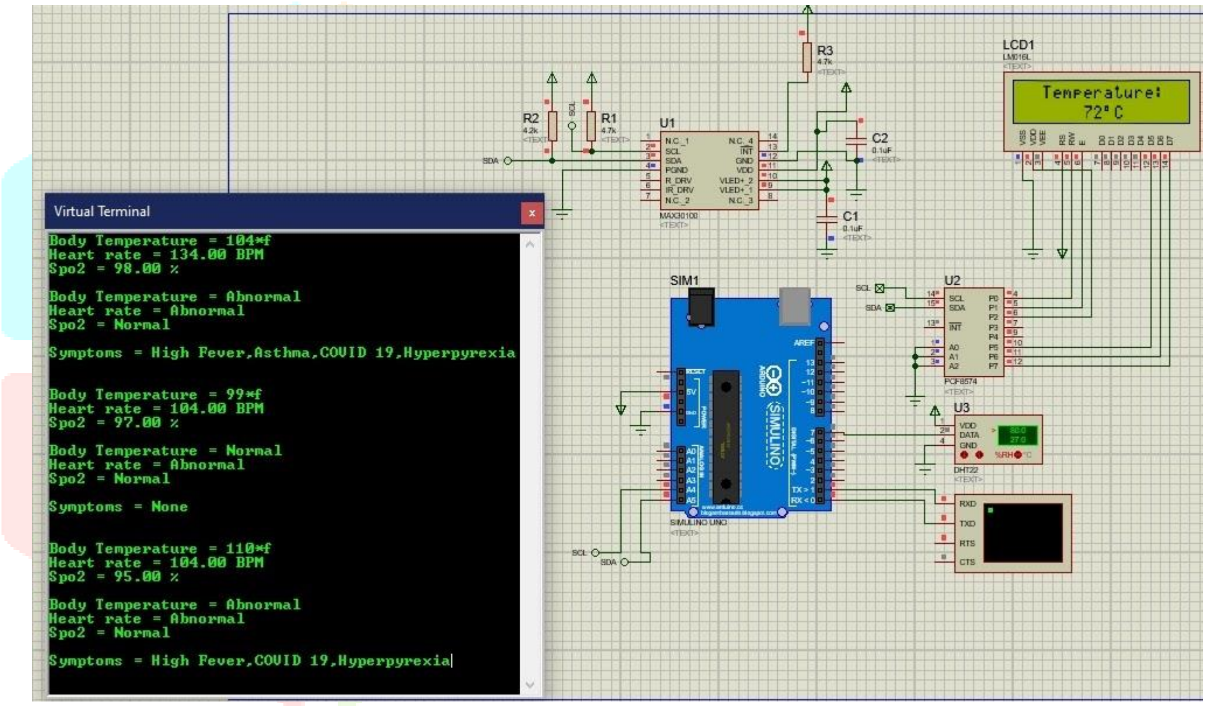

Figure 4.6: Simulation of the circuit in Proteus 8

V. RESULTS AND DISCUSSION:

5.1 Virtual Terminal of Proteus:

The simulation was conducted for various use-cases and the results were compared. Each use-case involved different values of the user's heart rate (in BPM), SpO_2 levels (in %) and body temperature (in F). Based on that, the symptoms were classified and the possible health risks were predicted and displayed on the terminal.

5.2 Mobile Application

Figure 6.2 shows the developed and simulated android mobile application that displays the real-time data obtained from the sensors using Proteus 8 software and Arduino IDE. Blynk is an IoT platform for storing data in private clouds and develop mobile applications. Blynk platform was used to build the application which also involves the sensor data being pushed to the Blynk cloud for storage and further prediction of ailments. Hence, in addition to the wrist device’s display, the data can be remotely monitored from anywhere and at any time which also makes it a great medical tool for monitoring patients too.

Figure 5.1: Virtual terminal of Proteus

Figure 5.2: Mobile Application

5.3 Analysis Report:

A study was conducted among candidates from various cities to record their responses regarding air quality and its effects on the environment. 66.7% of them reported that their city was highly polluted with poor air quality. Out of 60 surveyee , 29.6% of them were living in an air polluted locality, 11.1% of them were suffering from respiratory ailments and 9.3% of them live near highways/industries. The following graph indicates the survey's use of various existing air quality-related devices:

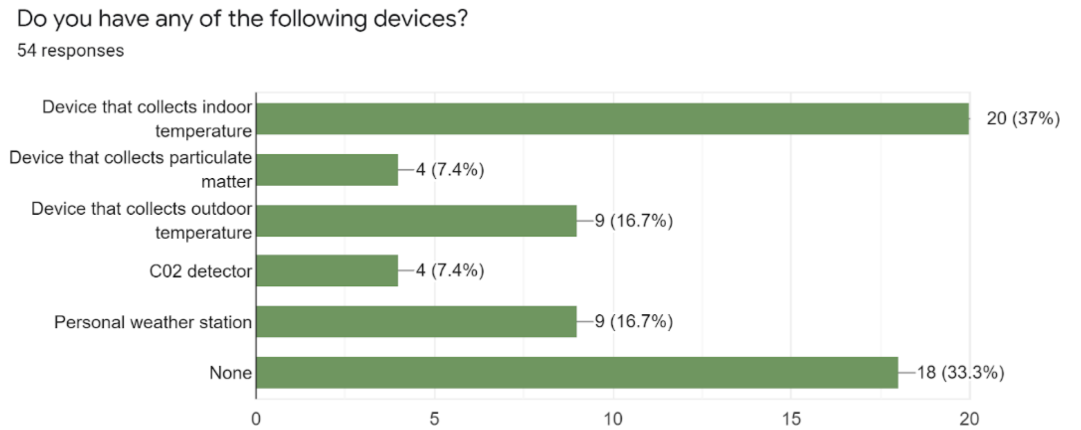

Figure 5.3: Analysis report

5.3 Future scope:

As wearable devices are playing a major role in continuous health and environment monitoring, there has been a tremendous development in bringing new forms and features to it. With advancements in electronics, conductive nanomaterials, and energy devices like supercapacitors, flexible skin attachable devices raise to be a promising solution. Hence, with suitable elastomer substrate, miniaturized wearable sensors, and self-powering technology, a skin attachable device will be the future scope of this proposal. Being a bioelectronic device, it tends to sense the bio-signals of the user including temperature, cardiovascular signal, etc. With high accuracy, sensitivity, and stability.

VI. CONCLUSION:

Now a days, air pollution is a major concern for most of the people's respiratory health. Therefore, this wearable wrist device with air quality monitor can help the individual in various polluted scenarios. However, the user's heart rate, respiration rate, and temperature are also monitored through flexible sensors and the data is send to the user's mobile application and cloud. Based on the algorithms the statistics of the user's exposure to atmospheric gases on a daily and monthly basis, the Air Quality Index data, and other user's biological parameters will be displayed in the mobile application. Additionally, the air borne diseases are also predicted based on the reports and diagnosis, thus helping in tracking the individual's respiratory health.

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