Low Cost Bedside Patient Monitoring for the Clinical Community Battling COVID-19

Team Name: CORPHOREOS

Team Number: 52

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Problem Overview / Motivation

- The primary motivation ⇒ **shortage** of medical equipment and supplies during any outbreak
- Availability of equipments ⇒ depends on the cost of procurement and presence of local manufacturers; government has walk the **tightrop**e keeping in view equally conflicting priorities like education, transportation, defense etc.
- Clinical community battling for COVID-19 requires **effective and contactless** monitoring of vital signs to identify and treat at-risk patients in an affordable manner, **not all need ventilation/ICU care** but **many will require constant monitoring** and admission for **medium** symptoms (**in-room care**)
- The availability of bedside patient monitors remains limited, given the **surge in demand** and the **cost of acquiring** such a device. An anecdotal evidence is **non-availability of air beds for preventing pressure ulcers** during prolonged care.
- We **need monitoring systems** which are
    - Low cost (our research found an entry level monitor from a leading Netherland health care device maker costs **Rs 3,00,000**. Can we make one at **1/10** of the cost?
    - Indigenously manufactured
    - Contactless or involve minimum contact with the care providers
    - Rugged
    - Technically sound
    - Ubiquitous (like a thermometer, bp monitor)

The 5 W's and 1H

Who is this problem for?	The solution is for the clinical community battling COVID-19 and similar scenarios. The solution can be extended for all other kind of patient monitoring including home care.
What is it?	The solution is a low-cost bedside patient monitoring system for monitoring the vital signs of patients (respiration rate, pulse rate, body temperature, oxygen saturation). The solution also sends the collected data to a central dashboard equipped with intelligent alerts. The central console will allow the nursing station to monitor the vitals of patients in a contactless manner.
When and Where does this problem exist?	We find that the availability monitoring equipment is limited in our overstretched health care facilities like nursing homes, hospitals, even during regular times. Based on our experience, we noticed that even modern tertiary hospitals have a small monitor to bed ratio for in-room patients. However, the scarcity becomes actute during a pandemic like COVID-19 when the patient flow increases dramatically.
Why does it need to be addressed?	The shortage of monitoring systems results in reduced patient care and worse health outcomes. The ability to scale up when the demand for such monitors arises is also a key consideration. Centralized monitoring with alerts will allow proactively detecting (in a contactless manner) early warning signals that require immediate intervention.
How can we solve it?	The proposed solution provides a low-cost bedside patient monitoring system with central monitoring. The cost to locally manufacture and set up one is a fraction of what an imported device costs.

Relevant Clinical Background (Patient Monitoring)

- Patient-Monitoring Systems, Reed M. Gardener and M. Michael Shabot, http://eknygos.lsmuni.lt/springer/56/585-625.pdf.
- Top 10 Remote Patient Monitoring Companies for Hospitals, https://mhealthintelligence.com/news/top-10-remote-patient-monitoring-solutions-for-hospitals.
- Next-Generation Patient Monitor Promotes Proactive Care, https://www.hospimedica.com/critical-care/articles/294780177/next-generation-patient-monitor-promotes-proactive-care.html
- Philips patient monitoring products related to COVID-19 care, https://www.usa.philips.com/healthcare/medical-specialties/covid-19/patient-monitoring-and-diagnostic-cardiology-bundles.
- Vital Signs (Body Temperature, Pulse Rate, Respiration Rate, Blood Pressure), https://www.hopkinsmedicine.org/health/conditions-and-diseases/vital-signs-body-temperature-pulse-rate-respiration-rate-blood-pressure.
- Managing Emerging Infectious Diseases: Should Travel Be the Fifth Vital Sign?, Trish M. Perl, MD, MSc; https://annals.org/aim/fullarticle/2762507/managing-emerging-infectious-diseases-should-travel-fifth-vital-sign.
- Coronavirus disease 2019 (COVID-19), https://bestpractice.bmj.com/topics/en-gb/3000168/monitoring.

Relevant Clinical Background (Measuring Vital Signs)

- Theory and application of the infrared temperature sensor, https://www.omega.co.uk/technical-learning/infrared-temperature-measurement-theory-application.html

- S. Dash, K. H. Shelley, D. G. Silverman and K. H. Chon, "Estimation of Respiratory Rate From ECG, Photoplethysmogram, and Piezoelectric Pulse Transducer Signals: A Comparative Study of Time–Frequency Methods," in IEEE Transactions on Biomedical Engineering, vol. 57, no. 5, pp. 1099-1107, May 2010. https://ieeexplore.ieee.org/document/5447592

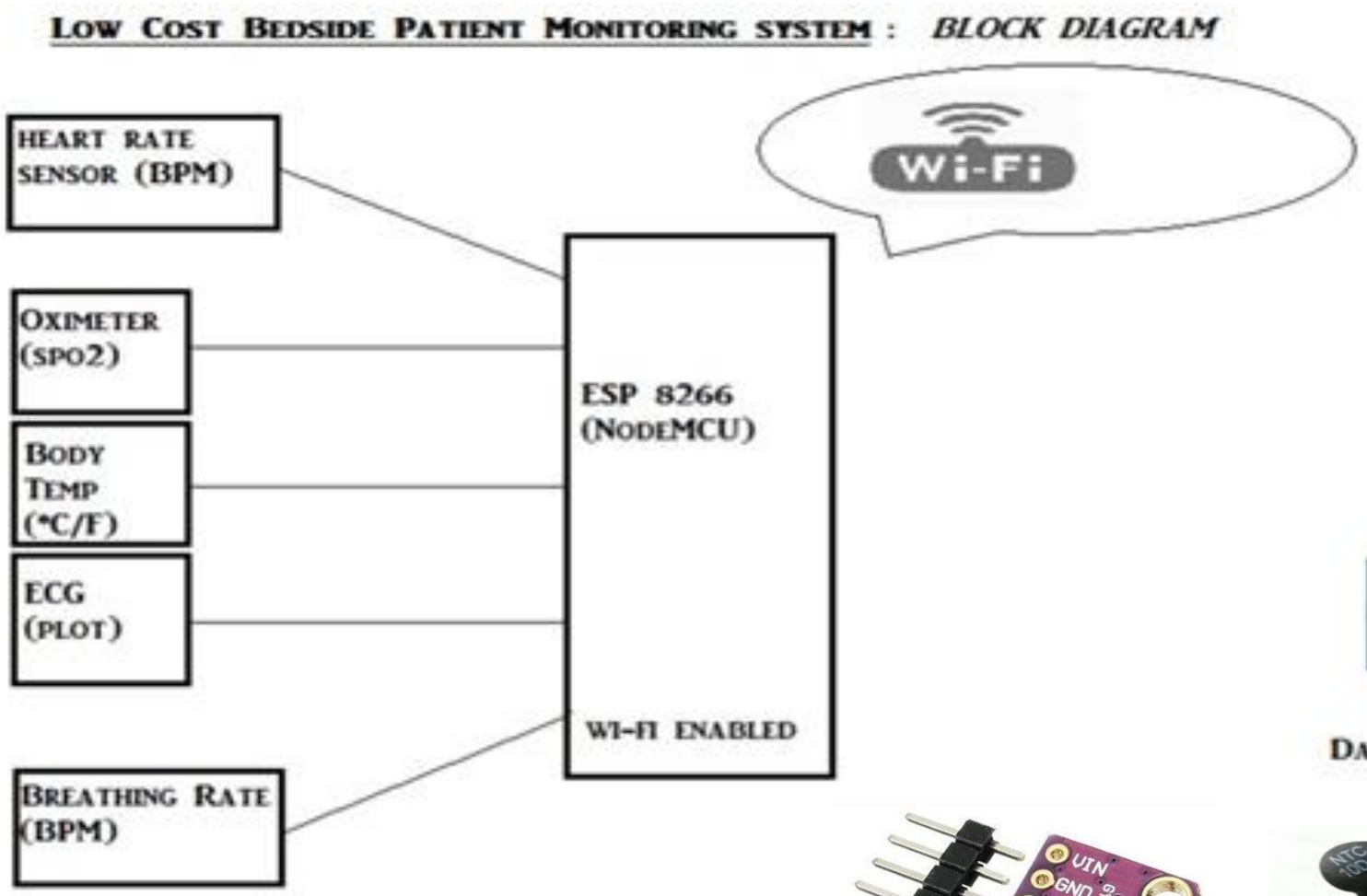
- Tarak Das ; Sayanti Guha ; Nisha Banerjee ; Piyali Basak, Development of thermistor based low cost high sensitive respiration rate measurement system using audio software with audio input, 2017 Third International Conference on Biosignals, Images and Instrumentation (ICBSII)

- Robert Scholz ; Boris R. Bracio ; Michael Brutscheck ; Peter Trommler, Non-invasive respiratory rate detection in spontaneous respiration by humidity measurement, 2017 28th Irish Signals and Systems Conference (ISSC)

Proposed Solution

- A **low cost portable patient bedside monitoring system** with **contactless monitoring** using a **central dashboard** at the nurses station. (it is less than 1/10th of the cost which can be further optimized)
- Continuous monitoring of **vital signs** like **body temperature, blood pressure, respiratory rate, lung compliance, SpO2 or oxygen saturation, and ECG.**
- The monitoring system will send the collected data to a **central console** for **visual depiction** and **alerting** when required. Central console developed using Open Source.
- **Complex** and **expensive** sensors have been replaced with low cost active components and amplifiers
- Based on scientific theory like pressure to temperature conversion using **Masco's** formula.
- Leverages **IOT**, plan to integrate **Machine Learning** for alerting

Proposed Solution



DATA AQUISITION AND REMOTE MONITORING

* Lung compliance is being explored

Use Cases

Connected and contactless monitoring platform

Connecting medical devices into intelligent systems has the potential to deliver **better quality of care** with **lower costs** and **improved patient outcomes**.

Proactive & Intelligent Monitoring Saves Lives

In medical emergencies, faster response times lead to better outcomes. Data sent from emergency services to hospitals helps teams to prepare in advance, shortening time to treatment through proactive planning.

IoT: Data Delivery & Synchronization

A realtime messaging solution needs to delivers an event-driven integration platform that offers doorstep information, can intelligently distribute only necessary data, and ensures connections are secure.

Remote Patient Monitoring (Home, Hospital or on the Move)

Remote patient monitoring is the transmission of data from patients at home, in the hospital or while on the move. The goal is to leverage the proliferation of tablets, smartphones and cloud to improve care; patients receive better outcomes.

Evidence for Functionality/ Efficacy [it is a working prototype]

ECG Measurement: (Ideal wave + Patient's wave -> Final wave (on comparison)

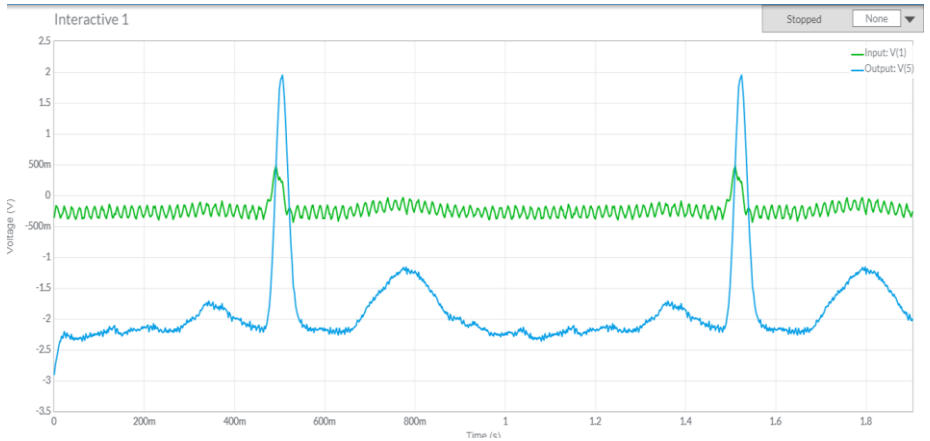


Figure1 : Ideal Wave (Designed with alternative of sensor)

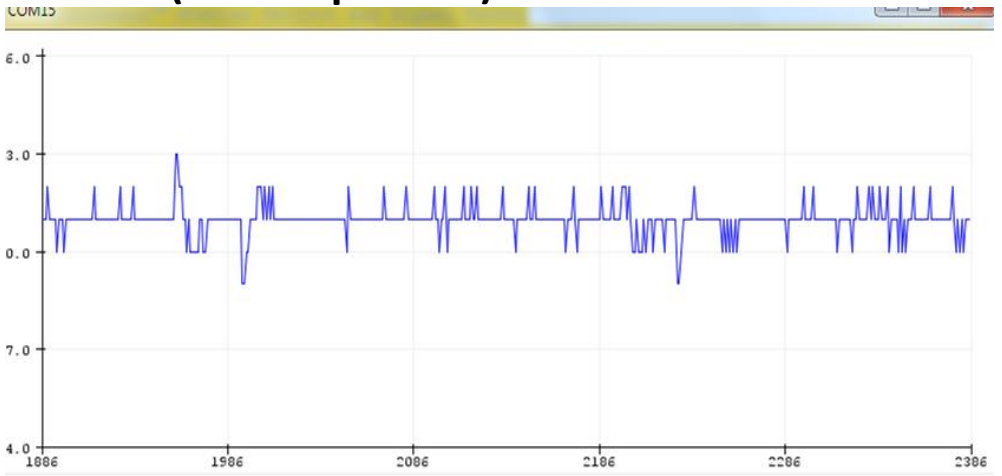
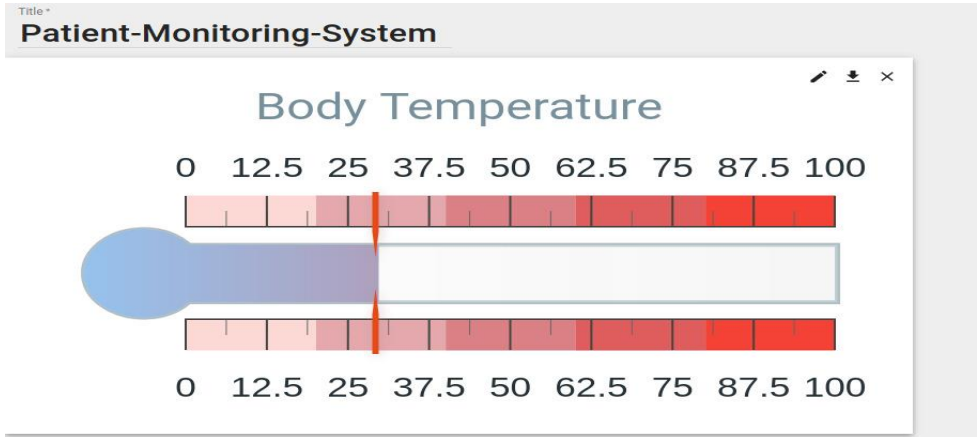


Figure 2 : The final output after Comparison

Measurement of Body Temperature using IR temperature sensor and WIFI module



* Compliance and SpO2 measurements are yet to be tested. Simulation Results are Obtained.

Evidence for Functionality/ Efficacy [it is a working prototype]

Respiratory Rate Measurement (Using Pressure - Temperature conversion and Masco's Law):

Figure 3: Nebulizer mask for patient to breathe which already has the sensor fixed in.

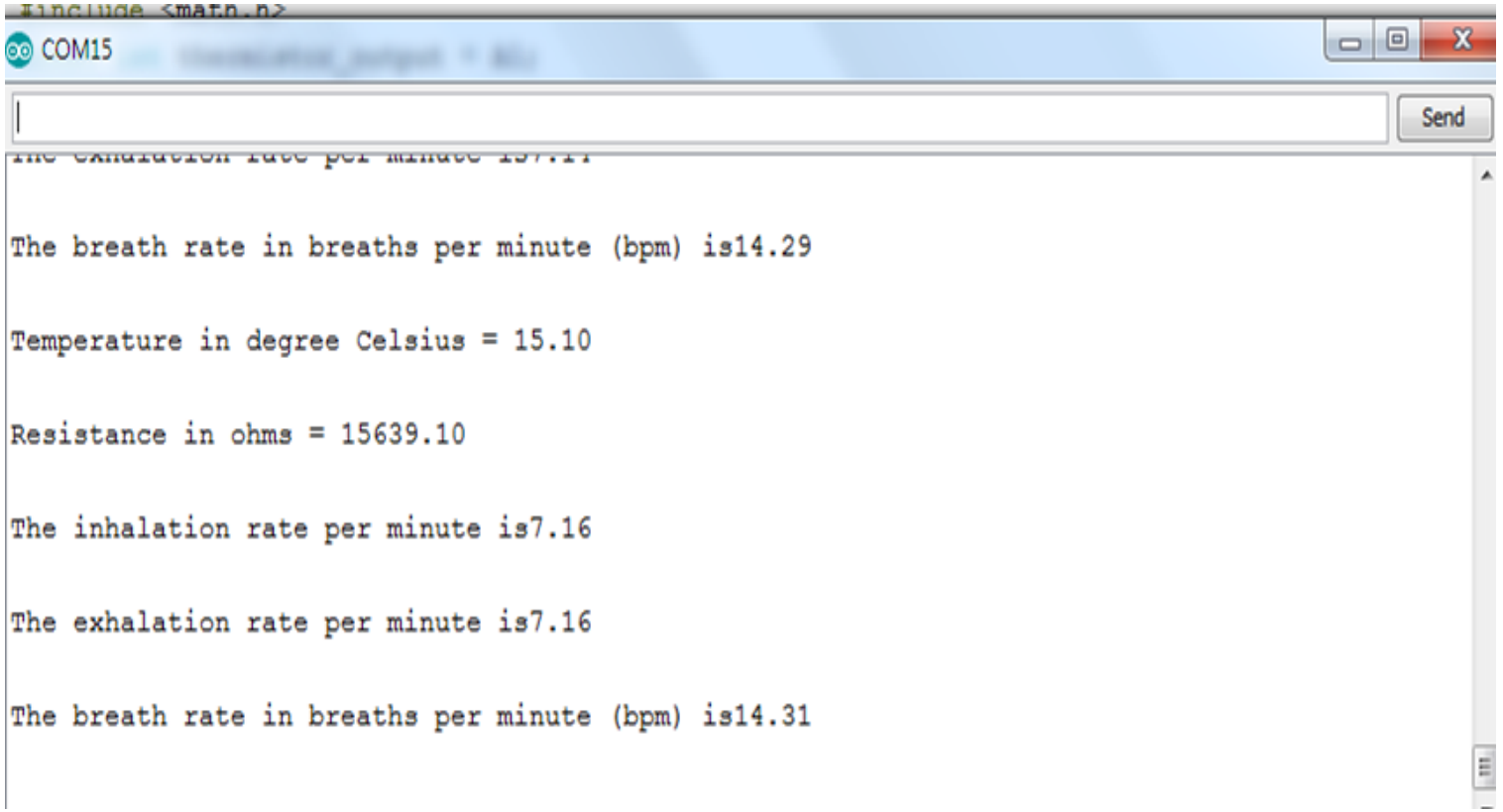
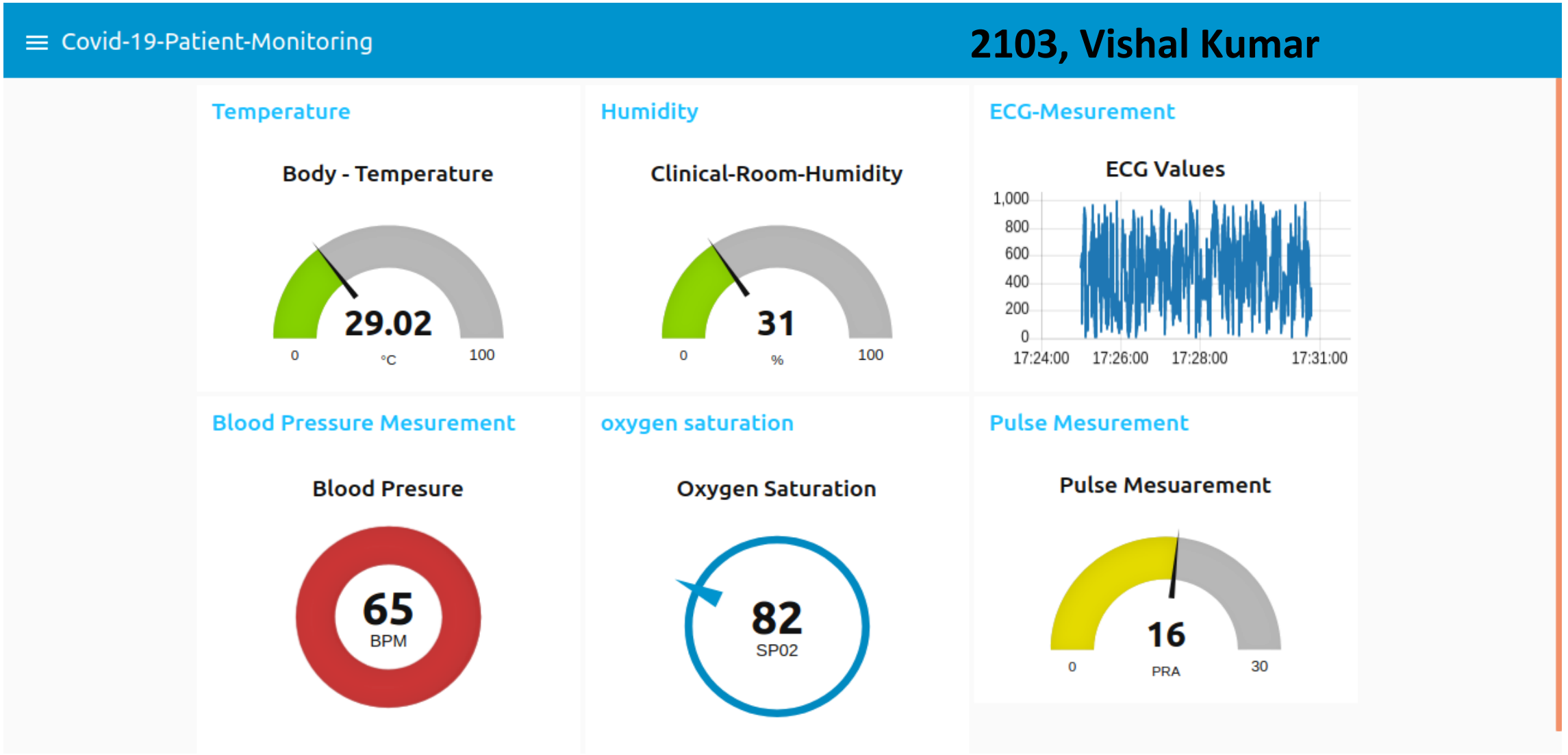


Figure 4: The breath rate is measured in terms of pressure _ temperature conversion.

Evidence for Functionality/ Efficacy [it is a working prototype]



Monitoring Platform : Developed on Open Source tool - Node-Red (data is coming from real time sensors and some parameters are just emulated due to unavailability of the sensor at present.

Evidence for Functionality/ Efficacy [it is a working prototype]

Further Design/Testing Required

- The solution has been implemented using a mix of **hardware** and **simulation** tools to understand the technical feasibility, theoretical background, and cost analysis.
- Next step is to convert into a lab prototype housing all the components, developing the central console, integrating the same ⇒ **Working Prototype**
- The working prototype will be assessed on volunteers and results compared with a standard monitoring system.
- The reliability of the components will also be assessed.
- The result will be a **Field Prototype** which will be subject to field tests.

Implementation Plan

- We are open to both kind of business models **self manufacture** (own venture) or **collaboration** with a bio-medical device manufacturer (private or public sector).

- For a **field prototype (2-3 pieces)**, team will use their own funds and collaborate with a small scale bio-medical device manufacturer. It is expected to take around 4-6 weeks which includes a central monitoring control. There will also be a need to move to HL7 messaging standards.

- For scaling up manufacture, we will have to look for funding from external sources.