Journal of Academic Research Vol 30, Issu 02, 2026 "133-142"

Design, Implementation, and Preliminary Validation of an Integrated Electro-Mechanical Patient-Monitoring Unit

Fares M. Ibrahim Benour[1], Akram Almabrouk Aleiah[2], and Walid T. Shanab[3]

[1]Higher Institute of Industrial Technology–Angela, Mechatronics Engineering Department, Libya
[2]Higher Institute of Industrial Technology–Angela, Mechanical Engineering Department, Libya
[3]Higher Institute of Engineering Technology–Tripoli, Communication Engineering Department, Libya,

DOI: https://doi.org/10.65540/0sr33t92

Article information

Key words

Remote Patient Monitoring; Internet of Medical Things; MAX30100; ESP8266; Pulse Oximetry; Preliminary Validation

Received 17 05 2026,
Accepted 21 08 2026,
Available online 22 08 2026

Abstract

Remote patient monitoring can support the follow-up of patients with chronic diseases, but low-cost prototypes often present ambiguous controller architectures, duplicated sensors, and qualitative validation. This paper reports the design, implementation, and preliminary bench validation of an integrated electro-mechanical patient-monitoring unit based on a single NodeMCU ESP8266 controller. A MAX30100 optical biosensor measures heart rate (HR) and peripheral oxygen saturation (SpO_2), while an OLED provides local display. The controller communicates with LabVIEW over USB-UART and with the UBIDOTS platform over Wi-Fi for visualization, logging, and automated email alerts. The final architecture excludes the previously listed Arduino Uno and auxiliary pulse sensor because the ESP8266 performs the control and communication tasks and the MAX30100 measures both target variables. Six paired readings were compared with a commercial Beurer pulse oximeter. SpO_2 bias, mean absolute error, and root-mean-square error were −0.83, 0.83, and 1.22 percentage points; the corresponding HR values were −0.33, 1.67, and 2.08 bpm. These results indicate close numerical agreement within a small normoxic sample, but they do not constitute conformity testing to ISO 80601-2-61. The SolidWorks respiratory-assist element is retained only as a non-clinical bench concept; no automatic or patient-connected ventilation is claimed.

I. Introduction

Remote patient monitoring (RPM) uses digitally transmitted health information to support follow-up beyond conventional face-to-face encounters. Systematic reviews show that RPM can improve access and continuity for patients with chronic diseases, while also emphasizing that clinical effectiveness depends on appropriate device selection, workflow integration, and evidence quality [1,2]. The engineering value of a low-cost prototype therefore lies not only in acquiring a signal, but also in documenting a coherent architecture, a reproducible data path, and the limitations of the measured evidence.

Photoplethysmography (PPG) is the optical principle used by pulse oximeters to estimate pulse rate and peripheral oxygen saturation. Although compact PPG sensors are suitable for connected health applications, their performance is affected by motion, sensor placement, tissue perfusion, ambient light, and skin pigmentation. Reviews of wearable PPG technology consequently recommend explicit validation procedures and cautious

Faresbanoor78@gmail.com

interpretation of prototype readings [3,5].

Published low-cost Internet-of-Things systems frequently combine a MAX30100-class sensor with a Wi-Fi-enabled controller and a local display [6,7]. This combination is therefore not, by itself, a sufficient scientific contribution. The present revision focuses on four defensible contributions: a single-controller architecture with unambiguous task allocation; removal of duplicated sensing and processing components; quantitative analysis of the available paired readings; and an explicit separation between the implemented monitoring subsystem and the non-clinical electro-mechanical concept.

The resulting prototype is a portable bench-top monitoring unit rather than a body-worn ventilatory device. The finger is placed on the optical sensor during measurement, while the controller, display, and communication electronics remain off-body. The system displays HR and SpO_2 locally, forwards data to LabVIEW and the UBIDOTS cloud, and issues an email notification when configured abnormal conditions are detected. No diagnostic decision, treatment recommendation, or automatic respiratory actuation is made by the prototype.

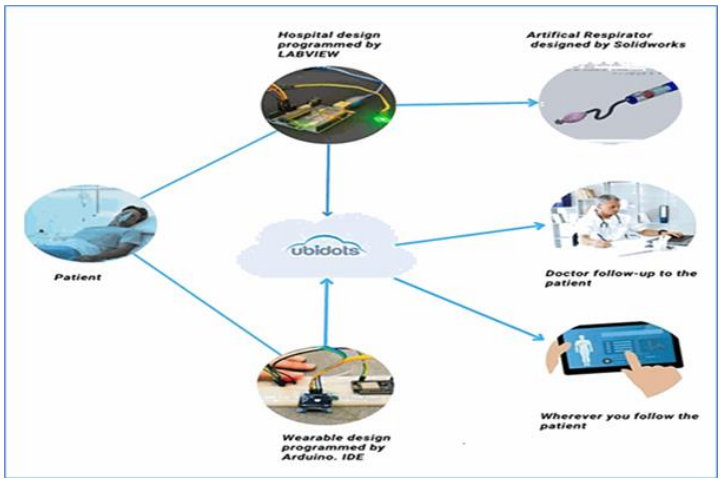

Figure (1): Revised block diagram of the implemented monitoring prototype and the separately scoped electro-mechanical concept.

II. Problem Statement and Research Objectives

Patients who require repeated observation of HR and SpO_2 may not always have continuous access to hospital-based monitoring. A low-cost connected unit can assist data collection and remote supervision; however, an ambiguous dual-microcontroller design, redundant pulse sensors, unsupported wearable claims, and an unqualified ventilation claim weaken technical validity. The engineering problem addressed here is therefore to define and evaluate a coherent monitoring prototype whose implemented functions, communication paths, statistical evidence, and safety boundaries are stated precisely.

The revised work pursues the following objectives:

- Implement HR and SpO_2 acquisition using one MAX30100 sensor and one NodeMCU ESP8266 controller.
- Provide local OLED display, PC-based LabVIEW visualization, cloud logging, and automated email notification through a clearly defined communication architecture.
- Quantify agreement with the available commercial-oximeter readings using bias, mean absolute error, root-mean-square error, standard deviation, mean absolute percentage error, and maximum absolute error.
- Reclassify the SolidWorks respiratory-assist model as a non-clinical concept and identify the engineering and medical requirements that must be met before any patient-connected ventilation study.

III. Related Work and Research Gap

RPM reviews report broad use of home and mobile monitoring for chronic disease management, but also show substantial heterogeneity in sensors, outcome measures, communication platforms, and validation quality [1,2]. For a prototype paper, this places particular importance on transparent task allocation, traceable measurements, and a distinction between functional demonstration and clinical effectiveness.

Wearable PPG reviews identify heart rate and oxygen saturation as common outputs, while warning that numerical agreement in a small number of resting measurements does not establish accuracy across motion, low perfusion, hypoxemia, or diverse skin pigmentation [3,5]. The MAX30100 integrates pulse-oximetry and heart-rate sensing

in one optical device; consequently, a separate pulse sensor duplicates the measured HR function rather than adding an independent clinical variable [8].
Several IoT prototypes have already demonstrated MAX30100-based HR/SpO_2 acquisition with an OLED and web connectivity [6,7]. The research gap in the present work is therefore not the existence of this hardware combination. It is the need for a consistent single-MCU implementation, explicit local/serial/cloud interfaces, a quantitative preliminary comparison, and a scientifically bounded electro-mechanical scope. These elements define the revised contribution.

IV. System Architecture and Methodology

A. Measurement Scope

The implemented subsystem measures two variables: heart rate in beats per minute and peripheral oxygen saturation in percent. It also reports measurement availability and alert status. The prototype is intended for engineering demonstration and preliminary comparison; it is not presented as a certified medical device, a diagnostic instrument, or a substitute for clinical assessment.

B. Single-Controller Hardware Architecture

The NodeMCU ESP8266 is the sole microcontroller. It acquires MAX30100 data, updates the OLED, exchanges serial data with the computer, and manages Wi-Fi communication. The Arduino Uno previously listed in the component section is removed from the operational architecture because no second processor is required. Likewise, the auxiliary pulse sensor is removed because the MAX30100 already provides both HR and SpO_2. This revision eliminates the dual-MCU ambiguity and the duplicated HR channel.

Table (1): Final architecture and task allocation.

Component	Interface
MAX30100 optical biosensor	I^2C
NodeMCU ESP8266	I^2C, USB-UART, Wi-Fi
1.3-inch OLED	I^2C
LabVIEW / Excel	USB-UART
UBIDOTS / Gmail	MQTT / HTTPS over Wi-Fi
Arduino Uno and auxiliary pulse sensor	Not connected

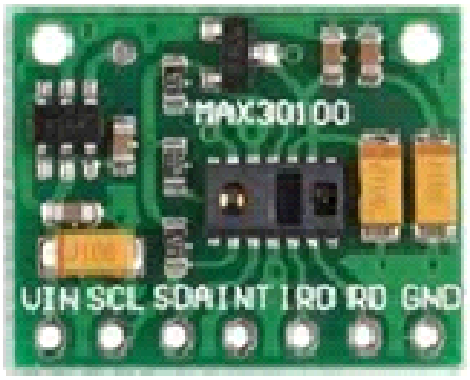

Figure (2): MAX30100 optical biosensor [8].

Figure (4): OLED display used for local presentation.

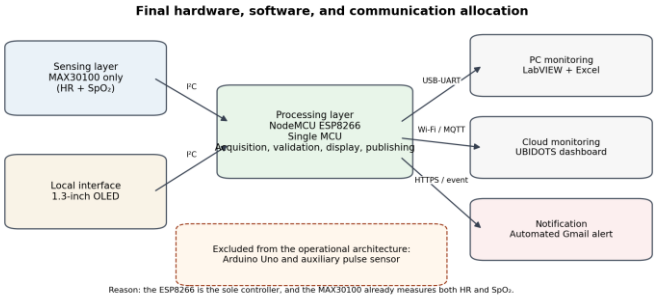

Figure (5): Final single-controller hardware, software, and communication allocation.

C. Communication and Software

The MAX30100 and OLED share the I²C bus and are supervised by the ESP8266. The NodeMCU USB interface provides UART serial communication with LabVIEW for graphical monitoring and Excel export. Wi-Fi connects the controller to the UBIDOTS service using a lightweight publish/subscribe data path consistent with MQTT-based IoT communication [10]. The Arduino development environment is used only to compile and upload ESP8266 firmware; it is not evidence of an Arduino Uno processor in the final hardware.

SolidWorks is used to document the enclosure and electro-mechanical concept. LabVIEW provides local plots and data acquisition, while UBIDOTS provides remote visualization and event handling. Gmail notification is treated as an alerting demonstration only. Alert thresholds must be configured by an authorized healthcare professional for any future supervised study; the prototype does not independently diagnose hypoxemia, arrhythmia, or respiratory failure.

D. Monitoring Algorithm

After initialization, the ESP8266 checks the I²C devices, acquires the red/infrared optical data through the MAX30100 library, calculates HR and SpO_2, and rejects unavailable readings. Valid measurements are shown on the OLED and transmitted over USB-UART and Wi-Fi. When a configured abnormal condition is detected, the system records the event and requests an email notification. The revised algorithm does not activate the electro-mechanical concept, because the available work does not include a clinically validated respiratory controller, airway-pressure feedback, tidal-volume control, or respiratory-rate control.

E. Preliminary Validation and Statistical Method

The available dataset contains six anonymized paired records labelled Persons A–F. Each record compares the MAX30100 prototype with a commercial Beurer pulse oximeter. Participant demographics, the commercial-device model number, controlled desaturation conditions, motion conditions, and skin-pigmentation measurements were not available for this analysis. The experiment is therefore categorized as a preliminary bench comparison rather than clinical validation.

For each pair, x_i denotes the prototype reading, r_i denotes the commercial-oximeter reading, and e_i denotes their difference. Agreement was summarized using the following descriptive metrics. Because the sample is very small

and the SpO_2 reference range is narrow, correlation and inferential hypothesis tests were not used; correlation can be misleading when assessing agreement between measurement methods [11].

$$e_i = x_i - r_i \quad (1)$$

$$\text{Bias} = (1/n)\,\Sigma_{i=1}^{n}\, e_i \quad (2)$$

$$\text{MAE} = (1/n)\,\Sigma_{i=1}^{n}\, |e_i| \quad (3)$$

$$\text{RMSE} = \sqrt{[(1/n)\,\Sigma_{i=1}^{n}\, e_i^2]} \quad (4)$$

$$SD_e = \sqrt{\{[1/(n-1)]\,\Sigma_{i=1}^{n}\, (e_i - \text{Bias})^2\}} \quad (5)$$

$$\text{MAPE} = (100/n)\,\Sigma_{i=1}^{n}\, |e_i/r_i| \quad (6)$$

Bias indicates the mean signed difference, MAE and RMSE quantify average error magnitude, SD_e describes the dispersion of paired errors, MAPE provides a relative error measure, and $\max|e_i|$ reports the largest observed difference. These calculations strengthen the quantitative analysis but do not replace a formal pulse-oximeter conformity study.

V. System Implementation

A. Final Assembly and Wiring

The final wiring connects the MAX30100 and OLED directly to the NodeMCU ESP8266 through the common I²C bus. The assembly drawing and separate sensor/display diagrams in Figures 6–8 are consistent with this single-controller architecture. No Arduino Uno-to-ESP8266 communication link is required or claimed.

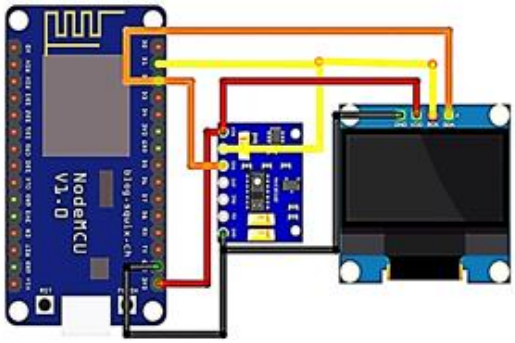

Figure (6): Final NodeMCU, MAX30100, and OLED assembly.

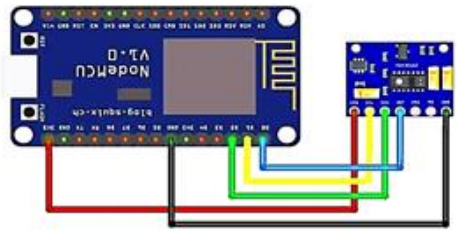

Figure (7): MAX30100-to-ESP8266 I²C connection.

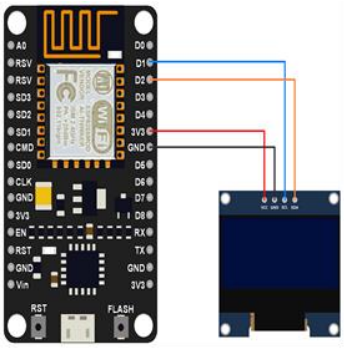

Figure (8): OLED-to-ESP8266 I²C connection.

B. Bench-Top Deployment and Data Flow

The electronics are arranged as a bench-top unit connected to a computer during the reported tests. The optical sensor is contacted by the finger for a measurement interval; the controller, wires, display, and computer remain off-body. Figure 9 provides visual evidence of the implemented prototype and LabVIEW acquisition. Accordingly, the manuscript no longer describes the entire electro-mechanical assembly as a lightweight wearable device.

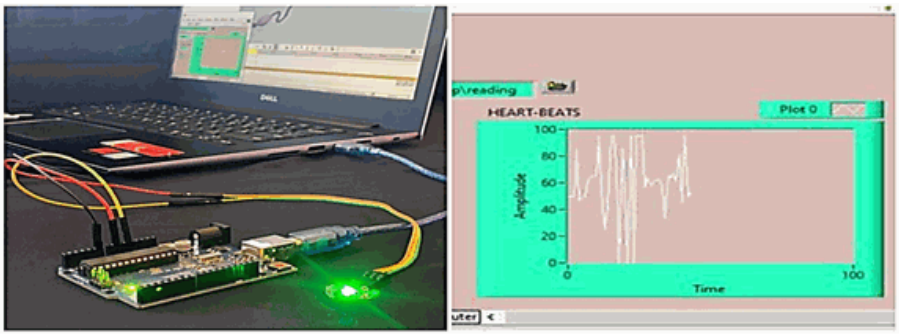

Figure (9): Bench-top MAX30100/NodeMCU prototype and LabVIEW acquisition display.

C. Electro-Mechanical Concept and Safety Scope

Figure (10) shows a SolidWorks model that represents an electro-mechanical respiratory-assist concept. The available design does not specify the actuator type, motor torque, displacement-to-volume relationship, breathing frequency, tidal volume, inspiratory/expiratory ratio, airway pressure, relief valve, patient circuit, alarm hierarchy, or failure-safe state. No patient-connected respiratory test data are presented. The model is therefore not called a respirator or ventilator in the implemented-system description and is not activated from HR or SpO_2 measurements.

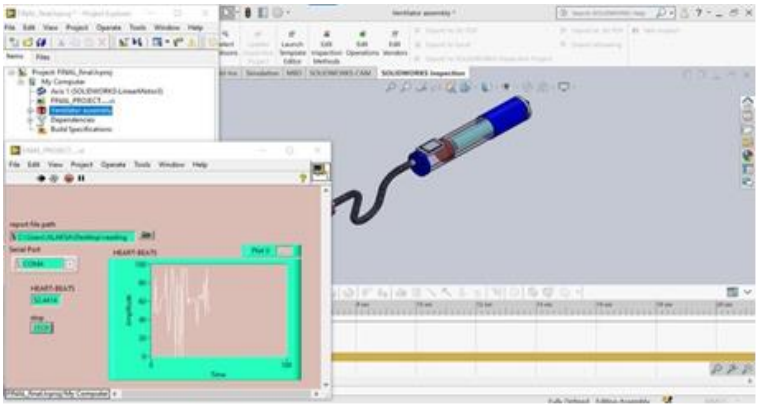

Figure (10): SolidWorks model retained as a non-clinical respiratory-assist concept; no patient-connected ventilation is claimed.

A future clinical ventilator would require an independently engineered closed-loop respiratory system with validated actuator dynamics, measured pressure and flow, controlled respiratory rate and tidal volume, redundant alarms, risk management, and compliance assessment against the applicable ventilator requirements. The current ISO catalogue identifies ISO 80601-2-12:2023 for critical-care ventilators [13]. Such work is outside the tested scope of the present prototype.

D. Local and Cloud Monitoring

LabVIEW displays the acquired waveform and values, while data can be exported for later analysis. UBIDOTS provides remote visualization and event processing. Figure 11 documents the local front panel together with a Gmail notification. This evidence verifies data presentation and notification functionality, but it does not establish clinical response time, cybersecurity performance, or service availability.

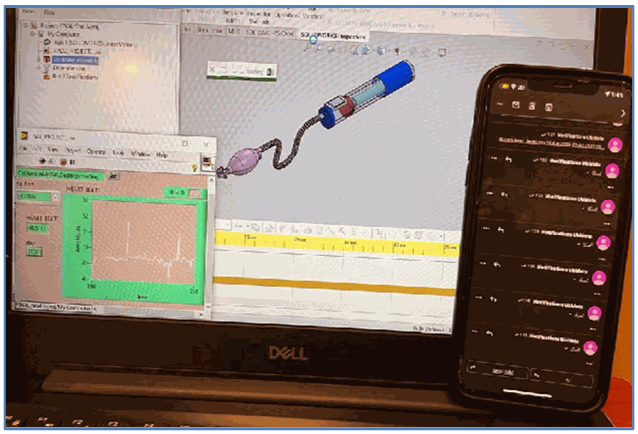

Figure (11): LabVIEW front panel and Gmail notification generated during the functional demonstration.

VI. Results and Discussion

Tables 2 and 3 retain the six paired readings reported in the original experiment. The SpO_2 reference values lie between 98% and 99%, so the dataset represents a narrow normoxic range. The HR reference values range from 75 to 96 bpm. The tables are followed by an error analysis that quantifies the observed differences rather than relying on raw visual comparison alone.

Table (2): Paired SpO_2 readings.

Sample No.	MAX30100	Commercial Oximeter
Person A	97%	99%
Person B	97%	99%
Person C	99%	99%
Person D	99%	99%
Person E	98%	99%
Person F	98%	98%

Table (3): Paired heart-rate readings.

Sample No.	MAX30100 (bpm)	Commercial Oximeter (bpm)
Person A	82	81
Person B	98	96
Person C	71	75
Person D	84	84
Person E	85	87
Person F	96	95

Table (4): Descriptive error metrics for the six paired records.

Parameter	Bias	MAE	RMSE	SD_e	MAPE	Max |e|
SpO_2 (pp)	-0.83	0.83	1.22	0.98	0.84%	2
HR (bpm)	-0.33	1.67	2.08	2.25	2.00%	4

pp = percentage points. Negative bias means that the prototype reading was lower on average than the commercial-oximeter reading.

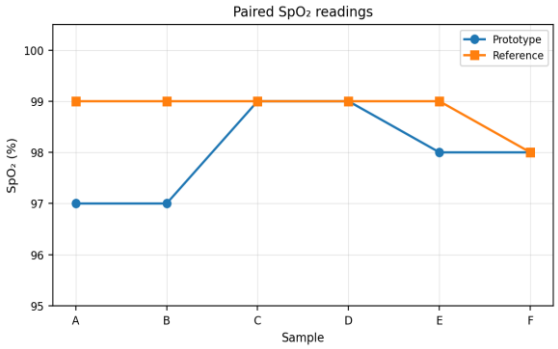

Figure (12): Paired SpO_2 readings for the prototype and commercial oximeter.

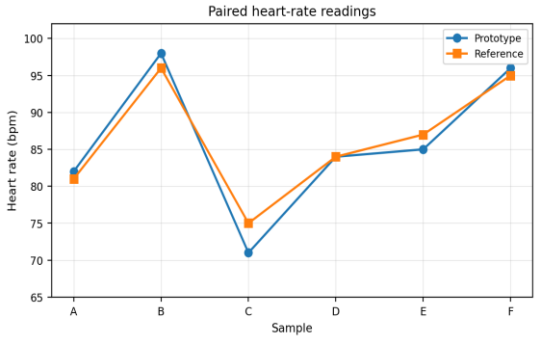

Figure (13): Paired heart-rate readings for the prototype and commercial oximeter.

A. SpO_2 Agreement

The prototype SpO_2 readings showed a mean signed difference of -0.83 percentage points, an MAE of 0.83 percentage points, and an RMSE of 1.22 percentage points. The maximum absolute difference was 2 percentage points. These results show close numerical agreement in the available resting, normoxic records, but the constant or near-constant reference values do not test performance in clinically important low-saturation ranges.

B. Heart-Rate Agreement

The HR comparison produced a bias of -0.33 bpm, an MAE of 1.67 bpm, and an RMSE of 2.08 bpm. The maximum absolute difference was 4 bpm. Person C produced the largest HR difference, with the prototype reading 4 bpm below the commercial device. The small overall errors support continued prototype development, but they do not demonstrate interchangeability across activity, arrhythmia, or poor-perfusion conditions.

C. Interpretation Relative to Medical-Device Testing

ISO 80601-2-61:2026 addresses the basic safety and essential performance of pulse-oximeter equipment intended for human use [12]. The present comparison does not claim conformity because it includes only six paired records, no controlled desaturation protocol, no arterial co-oximetry reference, no documented repeated-measures design, and no stratification by motion, perfusion, or skin pigmentation. The correct interpretation is therefore "preliminary bench agreement," not "medical accuracy certification."

Functionally, the revised architecture demonstrates acquisition, OLED display, LabVIEW visualization, cloud transfer, data logging, and email notification. Its scientific contribution is the documented integration and quantitative preliminary evaluation of those functions. The electro-mechanical respiratory concept was not evaluated as a therapeutic subsystem and contributes no clinical ventilation result to the present paper.

VII. Limitations and Future Work

The main limitation is the small dataset and its narrow SpO_2 range. The commercial oximeter model, participant characteristics, sampling synchronization, motion state, ambient-light condition, finger temperature, perfusion state, and skin-pigmentation measures were not available. These factors prevent generalization and preclude a formal method-comparison analysis with reliable limits of agreement. The MAX30100 is also an older device; the manufacturer recommends MAX30101 or MAX30102 for new designs [8].

Future work should use a documented reference device, synchronized repeated measurements, a larger and diverse participant sample, controlled motion and perfusion tests, and ethics approval with informed consent for any human-subject protocol. The communication subsystem should be evaluated for packet loss, latency, authentication, encryption, power consumption, and failure recovery. A migration to a currently recommended optical sensor and an updated Wi-Fi controller should also be considered.

Any respiratory-assist development must be conducted as a separate medical-device project. It should define the patient population and intended use, select and characterize the actuator, measure airflow and airway pressure, regulate respiratory rate and tidal volume, provide independent over-pressure protection and alarms, and undergo risk management and standards-based verification before any patient connection. Automatic actuation based solely on a low heart-rate reading is not part of the revised design.

VIII. Conclusion

This paper presented a revised, coherent implementation of an integrated electro-mechanical patient-monitoring prototype. The operational system uses one NodeMCU ESP8266 and one MAX30100 sensor, eliminating the

previously ambiguous Arduino Uno and redundant pulse-sensor paths. HR and SpO_2 are displayed locally, transferred to LabVIEW, published to UBIDOTS, and used to generate an email notification. The available six-record comparison yielded SpO_2 bias/MAE/RMSE values of −0.83/0.83/1.22 percentage points and HR values of −0.33/1.67/2.08 bpm.

The quantitative results support the feasibility of the monitoring and communication chain within a limited normoxic bench dataset. They do not establish clinical equivalence or ISO conformity. The SolidWorks respiratory element is explicitly limited to a non-clinical concept and is neither automatically actuated nor presented as a ventilator. This scope correction, together with the single-controller architecture, updated references, and statistical analysis, provides a more rigorous basis for future engineering validation and supervised clinical research.

Conflict of interest statement: "The authors declare no conflicts of interest."
Author Contributions: "All authors have made a substantial, direct, and intellectual contribution to the work and approved it for publication."
Funding: "This research received no external funding."
Data Availability Statement: "No data were used to support this study."

References

[1] F. A. C. de Farias, C. M. Dagostini, Y. de A. Bicca, V. F. Falavigna, and A. Falavigna, "Remote Patient Monitoring: A Systematic Review," Telemedicine and e-Health, vol. 26, no. 5, pp. 576–583, 2020, doi: 10.1089/tmj.2019.0066.

[2] M. Peyroteo, I. A. Ferreira, L. B. Elvas, J. C. Ferreira, and L. V. Lapão, "Remote Monitoring Systems for Patients With Chronic Diseases in Primary Health Care: Systematic Review," JMIR mHealth and uHealth, vol. 9, no. 12, Art. no. e28285, 2021, doi: 10.2196/28285.

[3] S. Knight, J. Lipoth, M. Namvari, C. Gu, M. Hedayati, S. Syed-Abdul, and R. J. Spiteri, "The Accuracy of Wearable Photoplethysmography Sensors for Telehealth Monitoring: A Scoping Review," Telemedicine and e-Health, vol. 29, no. 6, pp. 813–828, 2023, doi: 10.1089/tmj.2022.0182.

[4] S. Ryals et al., "Photoplethysmography—New Applications for an Old Technology: A Sleep Technology Review," Journal of Clinical Sleep Medicine, vol. 19, no. 1, pp. 189–195, 2023, doi: 10.5664/jcsm.10300.

[5] R. Al-Halawani, P. H. Charlton, M. Qassem, and P. A. Kyriacou, "A Review of the Effect of Skin Pigmentation on Pulse Oximeter Accuracy," Physiological Measurement, vol. 44, no. 5, Art. no. 05TR01, 2023, doi: 10.1088/1361-6579/acd51a.

[6] K. V. S. S. Ganesh, S. P. S. Jeyanth, and A. R. Bevi, "IOT Based Portable Heart Rate and SpO_2 Pulse Oximeter," HardwareX, vol. 11, Art. no. e00309, 2022, doi: 10.1016/j.ohx.2022.e00309.

[7] O. Y. Tham, M. A. Markom, A. H. A. Bakar, E. S. M. M. Tan, and A. M. Markom, "IoT Health Monitoring Device of Oxygen Saturation (SpO_2) and Heart Rate Level," in Proc. 1st Int. Conf. Information Technology, Advanced Mechanical and Electrical Engineering (ICITAMEE), Yogyakarta, Indonesia, 2020, pp. 128–133, doi: 10.1109/ICITAMEE50454.2020.9398455.

[8] Analog Devices, "MAX30100: Pulse Oximeter and Heart-Rate Sensor IC for Wearable Health," product information and data sheet, accessed Aug. 16, 2026.

[9] Espressif Systems, "ESP8266EX Datasheet," ver. 7.1, Nov. 2025.

[10] A. Banks, E. Briggs, K. Borgendale, and R. Gupta, Eds., "MQTT Version 5.0," OASIS Standard, Mar. 2019.

[11] J. M. Bland and D. G. Altman, "Statistical Methods for Assessing Agreement Between Two Methods of Clinical Measurement," The Lancet, vol. 327, no. 8476, pp. 307–310, 1986, doi: 10.1016/S0140-6736(86)90837-8.

[12] ISO 80601-2-61:2026, Medical Electrical Equipment—Part 2-61: Particular Requirements for Basic Safety and Essential Performance of Pulse Oximeter Equipment, 3rd ed., International Organization for Standardization, Geneva, Switzerland, 2026.

[13] ISO 80601-2-12:2023, Medical Electrical Equipment—Part 2-12: Particular Requirements for Basic Safety and Essential Performance of Critical Care Ventilators, International Organization for Standardization, Geneva, Switzerland, 2023.

تصميم وتنفيذ والتحقق الأولي من وحدة كهروميكانيكية متكاملة لمراقبة المرضى

فارس محمد إبراهيم بنور[1]، أكرم المبروك عليّة[2]، ووليد الطاهر شنب[3]

[1]المعهد العالي للتقنية الصناعية–أنجيلة، قسم الميكاترونكس، ليبيا
[2]المعهد العالي للتقنية الصناعية–أنجيلة، قسم الميكانيكا، ليبيا
[3]المعهد العالي للتقنية الهندسية–طرابلس، قسم هندسة الاتصالات، ليبيا

الملخص

تسهم المراقبة الصحية عن بُعد في متابعة مرضى الأمراض المزمنة، إلا أن كثيرًا من النماذج منخفضة التكلفة تعاني غموضًا في معمارية المتحكمات، وتكرارًا في المستشعرات، واعتمادًا على مقارنة وصفية محدودة. تعرض هذه الورقة تصميم وحدة كهروميكانيكية متكاملة لمراقبة المرضى وتنفيذها والتحقق الأولي منها مختبريًا بالاعتماد على متحكم واحد من نوع NodeMCU ESP8266. يُستخدم مستشعر MAX30100 لقياس معدل ضربات القلب وتشبع الأكسجين في الدم، مع شاشة OLED للعرض المحلي، واتصال تسلسلي ببرنامج LabVIEW، واتصال لاسلكي بمنصة UBIDOTS لتسجيل البيانات وعرضها وإرسال تنبيه آلي عبر البريد الإلكتروني. أزيل متحكم Arduino Uno ومستشعر النبض الإضافي من المعمارية التشغيلية النهائية؛ لأن ESP8266 ينفذ مهام التحكم والاتصال، ولأن MAX30100 يقيس المتغيرين معًا. أظهرت مقارنة ست قراءات مزدوجة مع جهاز Beurer تجاري أن الانحياز ومتوسط الخطأ المطلق والجذر التربيعي لمتوسط مربع الخطأ لتشبع الأكسجين بلغت −0.83 و0.83 و1.22 نقطة مئوية، بينما بلغت القيم المقابلة لمعدل القلب −0.33 و1.67 و2.08 نبضة/دقيقة. تشير النتائج إلى تقارب عددي أولي ضمن عينة صغيرة وفي المجال الطبيعي للتشبع، ولا تمثل اختبار مطابقة للمعيار ISO 80601-2-61. كما حُدد نموذج SolidWorks لمساعدة التنفس بوصفه مفهومًا مختبريًا غير سريري، من دون ادعاء تشغيل تلقائي أو توصيله بالمريض.

استلمت الورقة بتاريخ 2026/05/17، وقبلت بتاريخ 2026/08/21، ونشرت بتاريخ 2026/08/22

الكلمات المفتاحية: المراقبة الصحية عن بُعد؛ إنترنت الأشياء الطبية؛ مستشعر MAX30100؛ المتحكم ESP8266؛ قياس التأكسج النبضي؛ التحقق الأولي