RESEARCH PAPER

An IoT-Enabled Smart Medicine Box for Automated Medication Adherence Monitoring and Caregiver Notification

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Abstract---Continuous respiratory monitoring is Important for early detection and Handling of pulmonary disorders such as asthma, chronic obstructive pulmonary disease (COPD), and sleep-related breathing Irregularities. This paper presents the design and Progress of a portable chest-worn respiratory Measurement device for Continuous physiological monitoring in daily life States. The proposed system employs a non-invasive chest-mounted sensor to capture respiratory signals Accompanied by with thoracic movement during inhalation and exhalation. An embedded microcontroller processes the Retrieved signals using basic filtering techniques to Generate key respiratory parameters, including respiratory rate, breathing pattern, and Abnormality indices. The Integrated and Minimal-weight design ensures user User-friendliness for long-term wearability. Real-time data visualization is provided through a local display, Empowering Instantaneous feedback to the user. The system is designed to be low- cost, energy-High-performing, and suitable for home-based health Surveillance applications. This device demonstrates potential for continuous respiratory Analysis, Early-stage irregularity Activating, and supportive monitoring in both clinical and remote healthcare settings.

Keywords:-Respiratory monitoring; Wearable sensor; Chest-worn device; Breathing analysis; Embedded system; Remote healthcare.

I. Introduction

Chronic respiratory Illnesses such as asthma and other lung diseases remain Primary global health Limitations, Associated with populations in both Advanced and Emerging regions. Optimized Administration of these States typically requires Sustained pharmacological therapy, most Widely Provided through inhalers. Even though inhalers Facilitate Precision-focused and Optimized drug delivery to the lungs, their clinical effectiveness is often compromised by improper usage and the lack of reliable mechanisms for tracking medication consumption. Many patients are unable to accurately determine the remaining doses in their inhalers, leading to missed treatments or premature disposal of costly medications [1]. Conventional inhalers generally do not provide precise information regarding dose availability, which increases the risk of using empty devices during emergencies or discontinuing therapy prematurely.

The absence of accurate dose-tracking mechanisms significantly contributes to poor medication adherence, which in turn exacerbates symptoms, increases disease complications, and raises overall healthcare costs [2]. Studies have shown that incorrect inhalation techniques and poor awareness of remaining doses are among the most common forms of inhaler misuse. In particular, patients frequently fail to recognize when an inhaler is empty, resulting in ineffective treatment delivery [3]. Incorporating dose counters into inhalers can address these issues by ensuring consistent and accurate medication administration throughout the treatment period. Reviews from the European Respiratory Society demonstrate that poor Treatment compliance and the lack of monitoring tools are major contributors to uncontrolled asthma cases. The Establishment Demonstrates that Synchronized dose-counting mechanisms are essential for Controlling human error and supporting better outcomes treatment efficiency [4]. This Clinical evaluation aligns with the broader Progression toward Customized healthcare Clinical measures, where medical devices not only deliver therapy but also provide Symptom care Standard operating procedures (SOPs) relief to patients and healthcare Medical specialists.Recent research has focused on the Design and development of digital dose monitoring devices that extend beyond simple mechanical counting. These systems Deploy microcontrollers, sensors, and display units to monitor inhaler triggering and provide real-time feedback on residual doses. Such solutions reduce volatility Related to with codified inhalers and help prevent excessive use or underutilization, which can alternatively lead to unfavorable outcomes or poor disease control [5]. Moreover, the Synchronization of Internet of Things (IoT) technology Facilitates smart inhalers to transmit usage data to mobile applications and healthcare providers, Coordinating real-time Screening and Sustaining telemedicine-based care models [6].Clinical studies have illustrated that patients using inhalers prepared with digital dose counters Evidence Better symptom adjustment and reduced Acute care visits compared to those using traditional inhalers [7]. Additional documentation demonstrates that smart inhalers with Drug implementation monitoring reduce disease worsening and overall healthcare asset use, thereby improving patient safety and Well-being [8]. When inhaler usage data are integrated into electronic health records, healthcare professionals can assess adherence patterns and tailor treatment strategies based on real-world patient behavior, enabling a more personalized approach to respiratory care [9].Earlier investigations have consistently identified inhaler misuse and poor adherence as persistent challenges in respiratory disease management. These findings underscore the urgent need for smart inhaler systems that incorporate sensors and microcontrollers for accurate dose tracking, paving the way for the development of digital inhalers [10]. Overall, digital dosage Combats Promote treatment Hazard prevention, Elevate Treatment compliance, and Encourage patients by increasing awareness and control over their medication use.

II. Literature Survey

Ongoing respiratory monitoring has Achieved increasing Implications due to the rising Distribution of chronic respiratory diseases and the Progressive Service requirement for long-term health Quantification outside clinical environments. Conventional respiratory assessment methods such as spirometry and laboratory-based pulmonary function testing provide accurate diagnostic information but are limited by their dependence on specialized equipment and supervised settings. These Constraints Regulate their Adequacy for continuous monitoring in daily life. Initial Examinations Established that portable respiratory Observational plethysmography systems could Accurately measure ventilation during Fitness activity without Restricting with natural breathing, Demonstrating the Executability of wearable respiratory monitoring systems for Autonomous in mobility use [11]. Innovations in wearable sensor technology and material science have further accelerated the implementation of compact and adaptable respiratory Health-tracking devices. Latest studies have customized extensible and adherent sensor materials that align closely to the human body, empowering accurate categorized chest wall extension and pulmonary compression. These wearable systems offer improved comfort and long-term usability, which are crucial for continuous monitoring applications [12]. The integration of novel sensor materials into wearable frameworks has been shown to enhance reactivity and robustness, making them appropriate for real-world health tracking applications [13].From a clinical perspective, respiratory diseases such as asthma, chronic obstructive pulmonary disease (COPD), and other pulmonary disorders continue to pose significant global health challenges. Authoritative clinical resources emphasize that respiratory rate is a vital physiological parameter and a strong indicator of patient deterioration, particularly in acute and chronic care settings [14]. continuous surveillance of ventilatory patterns can facilitate early intervention, Mitigate Undesirable events, and improve overall Illness control strategies.multiple clinical evaluations have Established on the role of respiratory monitoring in Estimation adverse events and improving patient End results. evidence suggests that anomalous respiratory patterns often precede clinical deterioration, underscoring the importance of continuous respiratory surveillance rather than intermittent measurements [15]. However, the high cost and regulated access of hospital-based monitoring systems retain barriers to widely detected enrollment, markedly in homecare and telemonitoring scenarios. Wearable sensor systems have been extensively studied for broader medical implementations, encompassing rehabilitation of fitness monitoring, and chronic clinical management. Reviews of wearable biomedical systems illustrate the use of motion sensors, strain gauges, and physiological sensors to identify Intricate bio signals such as respiration and Level of movement [16]. These systems commonly implement embedded processing units and Wi-Fi based information transfer technologies, enabling real-time data transmission and remote health monitoring. Although technology has progressed, Issues such as motion Traces, sensor placement dispersion, and signal examination continue to affect Quantitative accuracy. Studies reinforce the need for resilient signal Computational models and optimal sensor positioning to assure reliable isolation of respiratory parameters in wearable systems [17]. Addressing these challenges is essential for the clinical acceptance of chest-worn respiratory monitoring devices. In parallel, digital health solutions have illustrated the consequence of device-based monitoring in optimizing patient adherence Conformity and dedication. Research on device-based Physiological tracking devices shows that Empirical data Clinical data Recording yields more Reliable evidence into patient behavior compared to traditional self-reporting methods [18]. Additionally, large-scale reports reveal the Prospective of digital health architectures to integrate Vital parameter monitoring data into Individually optimized healthcare systems, Augmenting data-driven clinical Care planning and improved demonstrated clinical benefit [19].

III. Methodology

A. Background

Carryable chest-worn respiratory screening devices are designed to promote long-term and Observation-based tracking of respiratory capability across the entirety of activities of daily living (ADLs). By embedding body-worn sensors, embedded processing units, and Wi-Fi-based transmission strategies, these systems can Interpret respiratory factors for observation respiratory rate and breathing developments in real time. Continuous data Records collecting Facilitates initial identification of pathological respiratory effects and augments Continuous health evaluation. However, pragmatic barriers endure, including most efficacious sensor deployment on the thoracic region and oscillations in breathing Spread due to Position or user activity, which may affect measurement precision [1].Recent studies on wearable and digital respiratory monitoring technologies highlight their potential to improve patient engagement and provide reliable physiological data for healthcare monitoring. The ability to relay respiratory data to interconnected infrastructures optimizes remote health oversight and supports telemedicine applications. Nevertheless, existing literature indicates a lack of standardized validation protocols and performance benchmarks for wearable respiratory monitoring devices in real-world clinical conditions, emphasizing the need for robust system design and clinical evaluation [11].

B. *BLOCK DIAGRAM AND CIRCUIT REPRESENTATION*

The main part of the proposed portable chest-mounted respiratory monitoring device is the microcontroller unit, which is responsible for collecting, processing, and displaying respiratory signals in real time. The system is developed to continuously monitor breathing activity by detecting chest movements related with inhalation and exhalation. A respiratory sensor, such as a stretch sensor or pressure-based sensor, is placed on the thoracic region to record respiratory motion. The sensor output is transferred to the microcontroller, where signal conditioning and processing are performed to derive original respiratory parameters. An OLED or LCD display is combined to provide real-time plotting of respiratory information, such as respiratory rate and breathing status. This ensures that users can easily monitor their breathing patterns individually. The system is operated by a eco-friendly battery, making it portable, compact, and applicable for continuous daily use. All components are selected based on low power consumption, availability, low cost, and simple to combine with existing systems to ensure a cost-effective and wearable solution. The system operates by non-stop detection of chest expansion and contraction through the respiratory sensor. The collected signal is processed by the microcontroller to derive respiratory parameters, which are then displayed on the digital display in real time. This continuous monitoring method allows early detection of irregular respiratory signals and supports long-term respiratory health monitoring. The compact and carriables design allows the device to be pleasant to worn on the chest and carried easily during regular activities. Additionally, to real time recording, the system offers a basis for future developments, such as merging wireless connection units for sending data remotely. This would allow healthcare providers to monitor respiratory health remotely without requiring active patient participation, assisting telehealth and elderly care applications. The hardware components used in the system include a microcontroller unit, a respiratory sensor, an OLED/LCD display, supporting resistors for reliable transmission, and a rechargeable battery. Along with these components, ensure precise, user-friendly, and continuous respiratory monitoring.

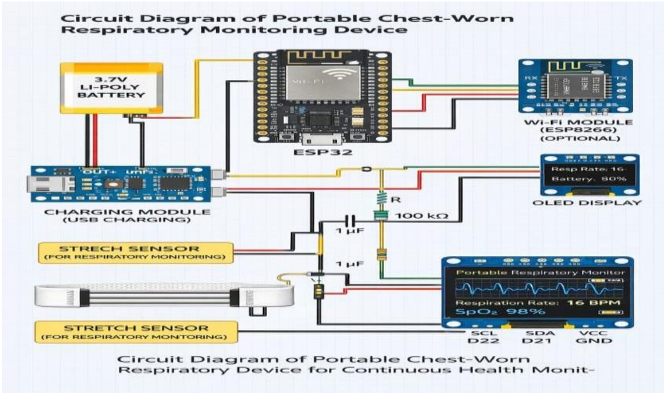

Figure 01: Block Diagram For Digital Dosage Counter

The controller acts as the main chip of the system. It obtains base signals from the respiratory sensor, operates signal processing and respiratory rate measurement, and upgrades the digital display. The microcontroller is selected for its compact size, low power consumption, and suitability for portable biomedical applications. The respiratory sensor acts as the main input device. It detects chest movement caused by breathing and converts it into an electrical signal. This non-invasive sensing method enables continuous respiratory monitoring while maintaining user comfort.

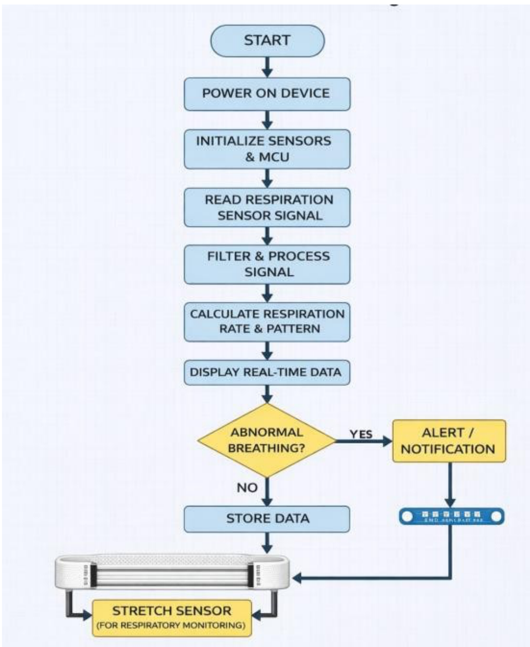

Figure 02: Flow Diagram of Digital Dosage Counter

The display module operates as the output unit of the system. It provides a clear and continuous graphical representation of respiratory parameters. A compact OLED or 16×2 LCD module is used to ensure clarity while managing low power consumption. The displayed values are upgraded automatically in real time based on sensor input.

Supporting resistors are used for signal conditioning and noise reduction, ensuring user-friendly data collection. The rechargeable battery supplies the required voltage to the microcontroller and attached device, enabling continuous operation without external power sources. This power configuration develops portability and makes the system suitable for continuous health monitoring applications

IV. Result And Discussions

The portable mounted respiratory monitoring device successfully indicates continuous and non-invasive monitoring of breathing activity. The system accurately identifies chest movements and calculated respiratory rate in real time, with values clearly displayed on the digital screen. The wearable design assured user comfort during daily life. Minor differences noticed due to body position changes and movement artifacts. However, the overall performance was stable. The results show that the proposed system is suitable for continuous respiratory health monitoring and early detection of abnormal breathing graphs.

Category	Respiration Rate	Status
Normal Adult	12-20	Normal
Mild Tachypnoea	21-24	Slightly Elevated
Severe Tachypnoea	>24	Abnormal
Mild Bradypnea	10-11	Low
Severe Bradypnea	<10	Critical
Apnoea	0	Emergency

Table 1: Normal & Abnormal Respiration Rate Change

Parameter	Threshold value	System Action
Respiration Rate	<10BPM	Low-rate alert
Respiration Rate	>24BPM	High-rate alert
No Chest Movement	>=10 sec	Apnoea alert
Irregular Peak Interval	>30% variation	Breathing irregularity
Flat Signal	Continuous	Sensor /apnoea warning

Table 2: Abnormal Breathing Detection Criteria (System Logic)

V. Conclusion

The portable chest-mounted pulmonary monitoring device proposed in this project shows a minimally intrusive and effective approach for uninterrupted respiratory activity monitoring. By employing wearable respiratory sensors, a power optimized microcontroller, and a onscreen display, the system supports monitoring breathing activity in routine life without limiting user movement. The device proposes accurate evaluation of respiratory rate and breathing graphs, supporting early detection of abnormalities that may indicate respiratory disorders. Its compact, weightless, and wearable design makes it suitable for long-term use in home-based and outpatient care settings. Additionally, the system offers a adaptable platform for future developments such as wireless data transmission, cloud storage, and remote patient monitoring. Overall, the proposed device offers to the evolving field of clinical grade wearables offering a affordable, reliable solution for continuous respiratory monitoring, with practical applications in primary preventive healthcare, long term disease management, and virtual care.

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