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# SLEEP STAGING AND APNEA MONITORING THROUGH SMART WEARABLES

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***Abstract:*** Sleep disorders such as sleep Apnea significantly impact overall health and quality of life, necessitating efficient and non-intrusive monitoring systems. This study presents a novel approach to sleep staging and Apnea detection using smart wearables, integrating real-time health parameter monitoring with advanced data analytics. The proposed system continuously tracks key physiological indicators, including pulse rate, oxygen saturation ($SpO_2$) levels, snoring sounds, and skin resistance, without disrupting the user's natural sleep cycle. These parameters serve as critical biomarkers for detecting abnormal breathing patterns associated with sleep Apnea. The integration of a mobile-based interface through the Blynk application enhances user experience by offering real-time visualization of recorded data, enabling users to monitor their sleep health remotely. The non-invasive nature of the wearable design ensures maximum comfort, promoting adherence to long-term monitoring without affecting sleep quality.

**Keywords***:* Sensors, IoT Platform, Sleep Apnea, Pulse rate, Wearable design

## 1. Introduction

Sleep disorders, particularly sleep apnea, pose significant health risks, including cardiovascular diseases, cognitive impairments, and metabolic disorders. The early detection and continuous monitoring of sleep patterns and related physiological parameters are crucial for effective intervention and management. Traditional methods for diagnosing sleep apnea often involve polysomnography (PSG), which requires patients to spend the night in specialized sleep laboratories connected to multiple sensors and monitoring equipment[10]. This process is not only inconvenient but also expensive and disruptive to natural sleep patterns. Therefore, there is a growing demand for non-intrusive, cost-effective, and user-friendly sleep monitoring solutions that can be used in real-world settings. The system continuously tracks essential health parameters, including pulse rate, oxygen saturation levels, snoring sounds, and skin resistance. These metrics are monitored in real time, ensuring minimal discomfort and allowing for seamless data collection without disturbing the patient's sleep. This data-driven approach enhances the accuracy of sleep disorder detection while offering a practical and convenient alternative to traditional diagnostic methods[2]. One of the key advantages of this approach is its integration with a mobile application using the Blynk platform[11]. The application provides real-time data visualization, enabling users to monitor their sleep quality and receive alerts for abnormal readings. This feature ensures timely intervention and facilitates proactive health management[8].

### 1.1. Problem Statement

Sleep disorders, including sleep apnea, significantly impact health, leading to conditions such as cardiovascular disease, cognitive impairment, and fatigue. Traditional sleep monitoring methods, such as polysomnography (PSG), are expensive, require clinical settings, and are intrusive, limiting their accessibility for continuous, real-time monitoring. There is a need for a cost-effective, non-intrusive, and easily accessible solution for sleep staging and apnea detection[3]. Smart wearables equipped with biosensors and machine learning algorithms can provide an alternative approach to monitoring sleep patterns and detecting apnea events in real time, enabling early diagnosis and improving sleep health management[14].

## 2. Block Diagram

The ECG sensor continuously monitors the patient's pulse rate and heart rhythm, which are key indicators of health during sleep[15].

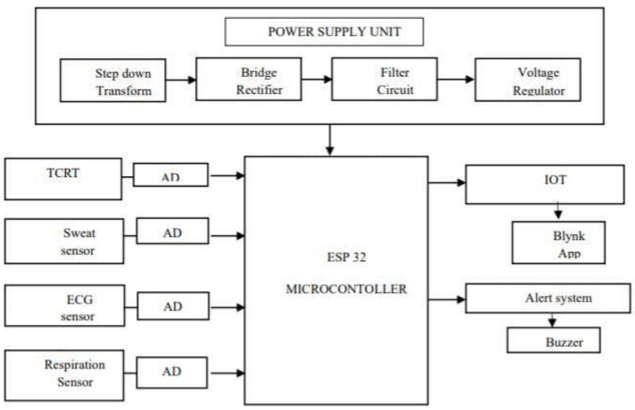


***Fig.1*** *Block diagram of sleep staging and Apnea monitoring System*

The sound sensor is used to capture snoring sounds, which are often linked to sleep apnea[7]. The TCRT sensor measures skin resistance, which can provide indirect insights into oxygen saturation levels. The sweat sensor measures changes in skin. moisture, which can be indicative of stress or changes in respiration rate during sleep. The ESP32 microcontroller processes the data from these sensors in real time, ensuring continuous monitoring without interrupting the patient's sleep. The Blynk app displays the health data on a user-friendly interface, allowing real-time monitoring of the patient's health metrics. It also provides instant alerts in case of abnormal readings, such as irregular pulse rate, low oxygen saturation, or excessive snoring, allowing for timely intervention.

## 3. Literature Survey

**Kadhim Kadhim, Melissa, E. Middeldorp.., "Prevalence and Assessment of Sleep-Disordered Breathing in Patients with Atrial Fibrillation:** A Systematic Review and Meta-analysis" in 2021. Sleep-disordered breathing (SDB) is increasingly recognized as a significant risk factor for atrial fibrillation (AF), yet its prevalence and impact on AF patients remain incompletely understood. This systematic review and meta-analysis aim to determine the prevalence of SDB in AF patients and assess its association with AF burden, severity, and recurrence.

**Daniel M Roberts, Margeaux M Schade, Gina M Mathew, Daniel Gartenberg, Orfeu M Buxton.., "Detecting sleep using heart rate and motion data from multisensor consumer-grade wearables, relative to wrist actigraphy and polysomnography" in 2022.**

Multisensor wearable consumer devices allowing the collection of multiple data sources, such as heart rate and motion, for the evaluation of sleep in the home environment, are increasingly ubiquitous[7]. However, the validity of such devices for sleep assessment has not been directly compared to alternatives such as wrist actigraphy or polysomnography (PSG).Eight participants each completed four nights in a sleep laboratory, equipped with PSG and several wearable devices.

**Zilu Liang, Mario Alberto Chapa-Martell.., "A Multi-Level Classification Approach for Sleep Stage Prediction with Processed Data Derived from Consumer Wearable Activity Trackers"** in 2021. Consumer wearable activity trackers, such as Fitbit are widely used in ubiquitous and longitudinal sleep monitoring in free-living environments. However, these devices are known to be inaccurate for measuring sleep stages. In this study, we develop and validate a novel approach that leverages the processed data readily available from consumer activity trackers (i.e., steps, heart rate, and sleep metrics) to predict sleep stages.

**Shan Wu, Mingjing Chen, Keming Wei, Guanzheng Liu.., "Sleep apnea screening based on Photoplethysmography data from wearable bracelets using an information-based similarity approach"** in 2021. Sleep apnea (SA) is a common sleep disorder in daily life and is also an aggravating factor for various diseases[4]. Having the potential to replace traditional but complicated diagnostic equipment, portable medical devices are receiving increasing attention, and thus, the demand for supporting algorithms is growing. This study aims to identify SA with wearable devices.Static information-based similarity (sIBS) and dynamic information based similarity (dIBS) were proposed to analyze short-term fluctuations in heart rate (HR) with wearable devices. This study included overnight photoplethysmography (PPG) signals from 92 subjects obtained from wearable bracelets[13].

## 4.Methodology

### 4.1 Existing Methodology

Obstructive Sleep Apnea (OSA) is a condition characterized by repeated episodes of partial or complete blockage of the upper airway during sleep, leading to breathing interruptions[6]. PSG involves overnight monitoring in a clinical setting, where a wide range of sensors and equipment track brain activity, eye movement, oxygen levels, airflow, respiratory effort, heart rate, and body movement.Portable home sleep apnea testing (HSAT) systems have emerged as an alternative to traditional polysomnography.These devices are typically worn by the patient at home and measure fewer parameters than PSG but focus on key indicators of sleep apnea[12].

### 4.2 Proposed Methodology

In this proposed method, essential health parameters related to sleep apnea are monitored, including pulse rate, oxygen saturation levels, snoring sounds, and skin resistance[1].These vital metrics are collected in real time without disturbing the patient,allowing for a seamless monitoring experience.The system employs advanced algorithms to analyze the data, providing insights into sleep patterns and potential apnea events.Additionally, the data is displayed simultaneously on a mobile application via the Blynk app, enhancing accessibility and convenience for ongoing health management.The data is displayed simultaneously on a mobile application via the Blynk app, enhancing accessibility and convenience for ongoing health management.Users can receive alerts for abnormal readings, enabling timely intervention.The method also allows for historical data tracking, helping users and healthcare providers identify, trends over time, ultimately improving overall sleep health and quality of life. Users can receive alerts for abnormal readings, enabling timely intervention.The method also allows for historical data tracking, helping users and healthcare providers identify trends over time, ultimately improving overall sleep health and quality of life.

## 5. Hardware Implementation

This circuit diagram represents[fig.2] an IoT-based sensor system powered by an ESP32 microcontroller. It integrates multiple sensors and power management components to collect real-time data and transmit it wirelessly. The circuit includes a 230V AC to 24V AC transformer, a bridge rectifier, and voltage regulators to provide stable DC power for the components.The system is designed for applications such as smart agriculture, environmental monitoring, or health tracking, where sensors measure parameters like soil moisture, water level, or bio-signals.

### 5.1 Circuit Diagram

The circuit starts with a 230V AC to 24V AC step-down transformer, which reduces the high-voltage mains supply to a lower AC voltage suitable for the system. This AC voltage is then converted to DC using a bridge rectifier consisting of four diodes arranged in a bridge configuration. A capacitor is placed after the rectifier to smooth the DC voltage by filtering out ripples.

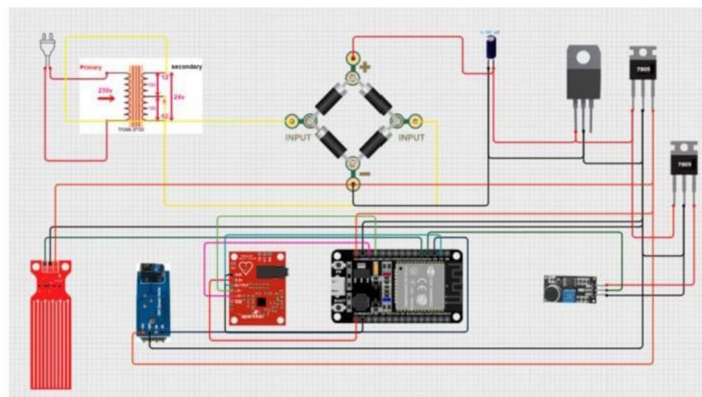

***Fig.2*** *Circuit Diagram for sleep staging and Apnea monitoring System*

To provide a stable 5V DC supply, the circuit includes two 7805 voltage regulators, which ensure a constant voltage for the connected components. These regulators are essential for powering the ESP32 microcontroller and various sensors, preventing voltage fluctuations that could affect their performance.The ESP32 microcontroller serves as the central processing unit, receiving data from multiple sensors. It is capable of wireless communication, allowing real-time data transmission to an IoT cloud platform[9]. Connected to the ESP32 are various sensors, including a soil moisture sensor, which detects the water content in the soil, and a water level sensor, which measures liquid levels. Another connected module appears to be a heart rate or bio-signal sensor, which can be used for health monitoring applications. Additionally, a voltage sensor module is included, possibly for monitoring power variations within the circuit.The wiring in the circuit ensures proper connectivity between power sources, sensors, and the ESP32. Red and black wires are used for power distribution, while other colored wires carry signal data from the sensors to the microcontroller. The ESP32 processes the sensor data and can send it wirelessly to a remote server or display it locally on an LCD or another output device. This makes the system suitable for applications such as smart agriculture, remote health monitoring, and IoT-based automation systems.

## 6. Result

The project successfully monitors sleep stages and detects apnea events using smart wearables[3]. The TCRT sensor tracks respiration by detecting chest movements, helping to identify irregular breathing patterns. The sweat sensor analyzes hydration levels and biochemical changes, providing insights into factors affecting sleep quality. The ECG sensor records heart rate and rhythm variations, aiding in sleep stage classification and detecting abnormalities[16]. The respiration sensor continuously measures breathing rate and depth, identifying apnea episodes and irregularities. The voltage regulator ensures stable power supply for reliable sensor operation. The step-down transformer efficiently converts high voltage to a usable level for the wearable system. Overall, the system provides real-time data for accurate sleep monitoring and apnea detection.

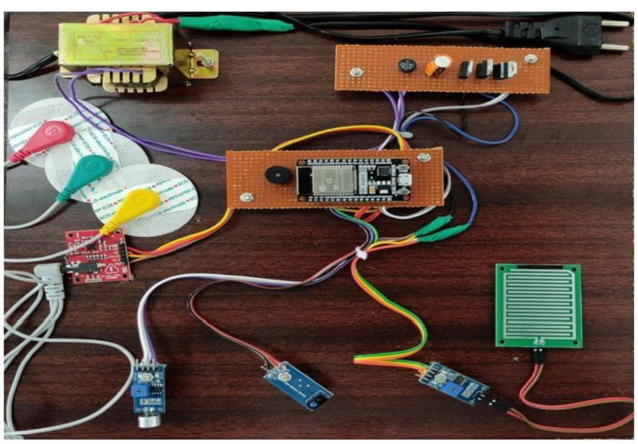

***Fig.3*** *Hardware of sleep staging and apnea monotoring through smart wearables*


***Fig.4*** *Output for Sleep staging and apnea monitoring through smart wearables*

## 7. Conclusion and Future Scope

### 7.1 Conclusion

The proposed Sleep Staging and Apnea Monitoring Through Smart Wearables system successfully enables real-time, non-intrusive monitoring of essential health parameters, including pulse rate, oxygen saturation levels, snoring sounds, and skin resistance. By leveraging advanced algorithms, the system effectively analyzes sleep patterns and detects potential apnea events, providing valuable insights for users and healthcare professionals.With seamless integration into the Blynk mobile application, users can conveniently access live data, receive alerts for abnormal readings, and track historical trends for better sleep health management. This innovative approach enhances early detection and intervention for sleep-related disorders, ultimately improving overall sleep quality and well being.

### 7.2 Future Scope

This project can be improved in many ways. Adding AI and machine learning can make sleep tracking and apnea detection more accurate. A mobile app can help users see their sleep data in real time and get alerts. Storing data in the cloud will allow doctors and users to track sleep health over a long time. The wearable device can be made smaller and more comfortable to wear for long hours. More sensors, like oxygen level and body temperature sensors, can be added to give better health insights. Finally, testing and getting medical approval can help make this system more useful in hospitals and clinics.

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