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Portable Low-Cost Home Sleep Monitor using Wemos D1 Mini

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Abstract. Sleeps disorders are a common disease overlooked by many people. Sleep disorder have many types and kinds and often associated with other severe illness such as diabetes, stroke, obesity and many others. Sleep monitors are one of many ways to read all parameters related to sleep and detect sleep disorders the subject has, however access to sleep monitor still expensive and tough to come by. Because of that accessibility, countless development of home sleep monitor occured around the world. However, most of that device still hard to operate and some of them gives error readings of parameters. Based on this, a portable low-cost home sleep monitor was developed using Wemos D1 mini as a microcontroller, MAX30102 as an oxygen level sensor, MPU6050 as an accelerometer, DS18B20 as a breathing flow sensor, and MAX9814 as a microphone. Each of the sensors read and give value to microcontroller and store the data to cloud and display the result in user's gadget. The aim of this development is to detect sleep disorders associated with each reading of sensors used and determine sleep quality as an early detection of symptoms before referring to professional relaled to sleep disorders or doctors.

Keywords: Sleep Monitor, Diagnosis, Portable, Wemos D1 Mini, MAX30102, MPU6050, DS18B20, MAX9814, Sleep Apnea, Willis-Ekbom.

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1. Introduction

Sleep less than 7 hours per night often associated with risk of obesity, diabetes, stroke, mental distress and impairs cognitive performance which indirectly increase the chance of many kinds of accidents and loss of productivity caused by hard to focus[1]. The cumulative of sleep loss stretch to physical and mental health problems such as reduced memory function, negative mood states, obesity, hypertension, and reduced immune response[2]. Lacks of sleeps only has negative effect to humans health which result in reduced quality of life, given that facts, total of sleep has spiked down compared to 50 years ago, approximately 20% adult around the world right now has nocturnal sleep disorders and it affects not only the healths but economicly, sleep disorder related treatment and expenditure in the United States costs around US$165 billion per year, in comparison treatment of heart failure, stroke, and asthma costs around US$20 to US$80 billion per year[3].

Sleep disorders are more common and problematic than many thought, many countries and researcher have tried to solve the problem and have come to a realization which is sleep study using sleep monitor. Sleep monitor as its name suggest is monitoring subject in sleep and collect data from all kinds of sensors after a few nights of sleep study at hospital or sleep center and professional will process the data and figure out any kinds of sleep disorders the subject has from all data collected and events happening when subject sleeps. Polysomnography or PSG for short is the current standard for measuring sleep, which measure all kind of parameters such as EEG, eye movements, muscle activity, heart rate, and breathing rate[4] to monitor individuals sleep, which the individuals typically spend the night in sleep laboratory to ensure effective sleeping environment and employed by numerous numbers of surface electrode to measure the parameter under the surveillance of sleep technician[5]. PSG has many restrictions to ensure correct monitoring of subjects which can affects subject's sleep in many ways and hinder the process of sleep study[6]. Sleep study without many restrictions are what many people try to invent to ensure as little as possible effect to subject sleeps. Now many inventions have emerged and sleep monitoring from home is possible with the main objective of this invention is the same as prologue to PSG, detecting early symptoms of common sleep disorder such as sleep apnea[7] and excessive daytime sleepiness[8], from there subject can be treated quickly according to symptoms or consult with professional such as sleep study center or doctor.

Early detection of any sign of sleep disorder such as sleep apnea and willi-ekbom disease are crucial[9] as the scope of this development heavily depend on that point and user friendliness for using the product at home as well as affordable. The significance of proposed device are detecting signs of sleep disorder at early stage without disturbing the sleep of user and more affordable than going to hospital or sleep center for diagnoses. The proposed device give affirmation to user about their sleep habits and the needs to go to hospital or sleep center for professional treatments or not.

2. Methods

2.1. Proposed System

Home sleep monitor need a few parameters values to determine any kinds of sleep disorders, such as breathing flow, movement of body parts, and sounds[10]. Shown in Figure 1, sleep monitoring system designed with sensing system to get the parameter values using accelerometer, oximeter, microphone, and thermometer with 2 microcontrollers divided as 2 unit. One of the units with breathing rate sensor and microphone as sound sensor with a microcontroller is called mask unit, and the other is called hand unit with heart rate sensor and accelerometer as motion sensor with a microcontroller. Data from all of these sensors will be sent to corresponding microcontroller which microcontroller 1 with accelerometer and heart rate sensor and microcontroller 2 with microphone and thermometer. After data transfer to microcontroller, all data will be sent to database as organized number in tables and displayed as graphics.

Each parameters have a sensors correspondent to each of them. Wemos D1 Mini as microcontrollers, MPU6050 for the accelerometer, MAX30102 for the oximeter, DS18B20 as the thermometer for breathing flow, and MAX9814 as the microphone. Battery 18650 with 3,7 Volt and 3000MaH for the power supply with 18650 chargers to replenish the power.

Wemos D1 Mini is a low-cost and low-power microcontroller that integrated with WiFi and Bluetooth based of ESP8266[11]. Chosen for this project because of its affordability and function.

MPU6050 is an accelerometer sensor which work with low voltage, makes it the suitable sensor to capture the acceleration of a body parts attached to it. The parameters to determine the acceleration of body parts is 3 axis of sensor positon which is X-axis, Y-axis, Z-axis, from the 3 positions change's the sensor calculates it against the time and gives out the acceleration per seconds[12]. Restless legs or hand syndroms are the sleep disorder which can be detected by data captured with MPU6050 as they measure movement of limbs attached to sensor[13].

MAX30102 is a high sensitivity pulse oximeter sensor able to capture many kinds of parameters such as heart rate, oxygen levels, and temperature. The parameters of oxygen level can indicate for hypoventilation sleep disorder which the oxygen levels drop and accompanied with episode of shallow breaths [14].

Microphone by MAX9814 used to capture noises around subject to determine parameters of noises that can affect sleep at certain levels. Noises from subject such as snoring can be captured too and included in sleep disorders and snoring sound can affects the sleeps as well[14].

DS18B20 is a low-cost 1-wire progammable temperature sensor operates within a wide temperature range from -55°C to +125°C with a decent accuracy of ±0.5°C. Communication with the sensor follows the 1-Wire method, and the temperature data is stored in a 2-byte register within the sensor[15].

Computer will be connected to the device through WiFi and read the data result from all the components mentioned above which all connected to Wemos D1 Mini to operate and gather all the parameters. The parameters will be transferred to Google Sheets as database and displayed as graph better for analyze and easier understanding. Google sheets is a free, cloud-based spreadsheet application provided by Google. It enables users to create and edit on spreadsheets seamlessly from any device[16]. It's used for data analysis, visualization, and record-keeping in real time for the proposed device.

2.2. Flowchart

The device utilizes the Arduino IDE as its application platform to program the device to read the parameters and connect to WiFi. The device's flowchart is shown in Fig. 2 and as shown the device will boot up and start initialization of the sensors, if the initialization is successful, all the sensors will start to boot up and will try to initialize again if the earlier initialization failed. The next in flowchart is to connect to network with WiFi and to database, if connected successfully the process will go on and the sensors will start to capture data to microcontroller and will send it to database through the network, if the device failed to connect to WiFi and database then the device need to be restarted and if the same problem keep occurring the code for WiFi SSID and password need to be double-checked. The process still going on and the data from database will be processed and displayed in the computers in the form of graph. The displayed data still need to be manually analyzed as the data don't have significant difference and hard to organize with automated process. Each sensor's data provides distinct indicators of various sleep disorders, with no inter-sensor correlations and calculated to provides user-friendly graph.

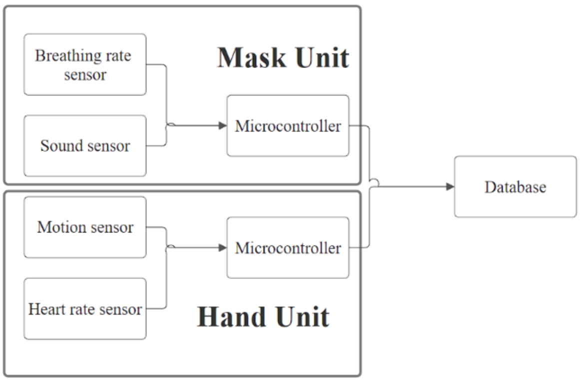


Figure 1. Diagram Blocks of Portable Sleep Monitoring System

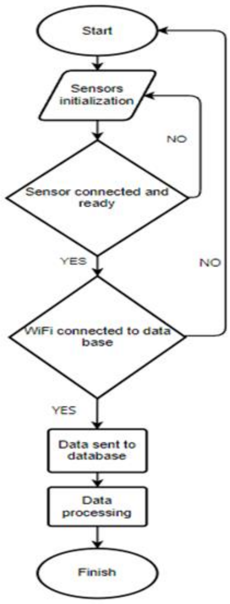


Figure 2. Device's Flowchart

2.3. Schematic

The schematics of the devices is two different unit, shown in Fig. 3, the corresponding sensors is the MPU6050 and MAX30102 and 3 pins of 2 which is battery, switch, and LED. The sensors will be connected to D1(SCL) and D2(SDA) as the communication pin. Battery connected to microcontroller through switch and LED as power indicator for the hand unit.

Mask unit accompanied with microphone and thermometer and the same battery, switch, and LED. As shown in Fig. 4, the microphone connected to A0 to capture analog inputs and thermometer connected to D1(SCL) and D2(SDA) as communication pin. Battery connected to microcontroller through switch and LED as power indicator for the mask unit.

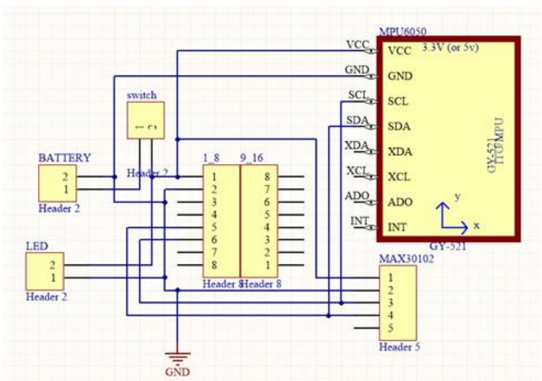


Figure 3. Circuit Schematic Hand Unit.

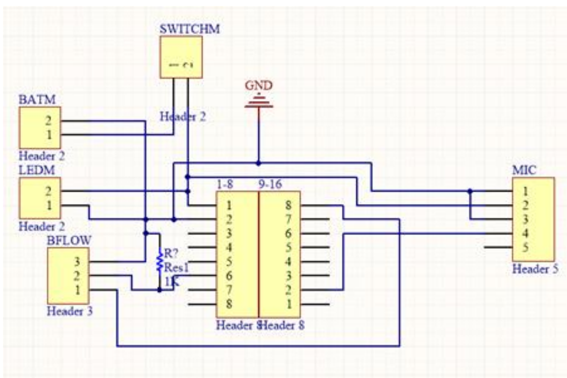


Figure 4. Circuit Schematic Mask Unit.

2.4. Design Implementation

The design of device is separated as 2 unit as shown in Fig. 5. Fig. 5 (a) is hand unit will be attached to around wrist like a watch and Fig. 5 (b) is mask unit in the form of oxygen mask with the device on its bottom and equipped as an oxygen mask should.

(a) **(b)**

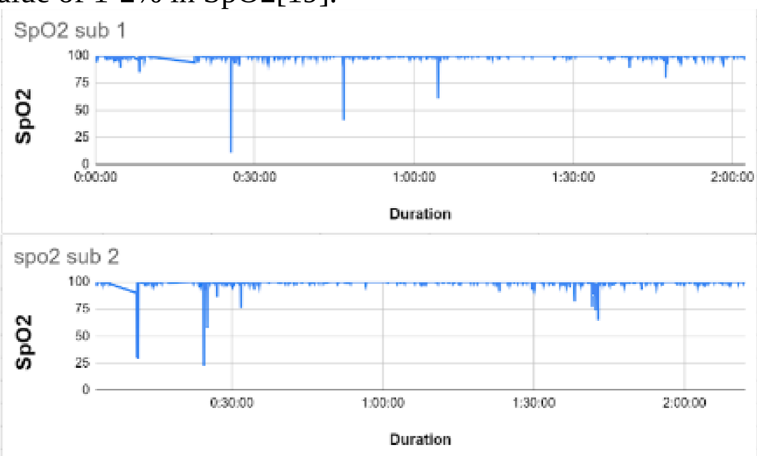
Figure 5. (a) Prototype Design Hand Unit, (b) Prototype Design Mask Unit.

2.5. Tool Installation
All unit will be worn according to each unit design as shown in Fig. 5, all unit designed to be easy to use and efficiently gather data from corresponding sensors. Hand unit has a housing of square for the wrist and has a housing for the MAX30102 sensor on the finger. Placement of MAX3012 sensor for reading need specific body part for the optimal readings, making the placement below finger the most suitable[17]. Mask unit has a housing for microcontroller and a mask for the sensors to read and gather data.

3. Results and Discussion

3.1. Oxygen Level Test
The device will be worn exactly shown before and all data from the sensors will be forwarded to microcontroller and will be send to database in the form of oxygen saturation will be send too with the same sensor as heartrate where the oxygen levels normaly stays within 95-100% for a healthy individual and considered dangerous if the reading stays at below 94%[18].

In Fig. 8, the measurement shows sometimes that the reading below 90% can be considered errors according to data only seconds of reading below 90% then back to around 95-100%. In the span of 2-4 hours of reading the sensors, the reading from sensors shows some error but overall stable reading of a healthy individuals. In Fig. 9 shown the validation of data between oxymeter and sensors MAX30102 measuring oxygen level and from 1 minute of data gathering, shows different value of 1-2% in SpO2[19].



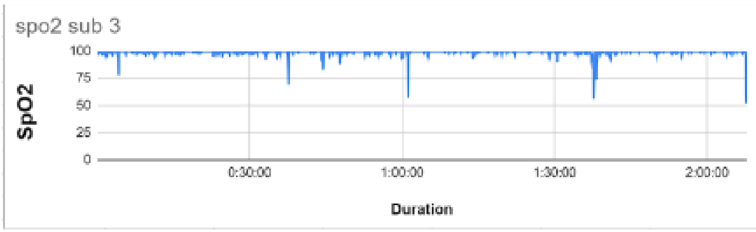


Figure 6. Measurement of Oxygen Levels from MAX30102.

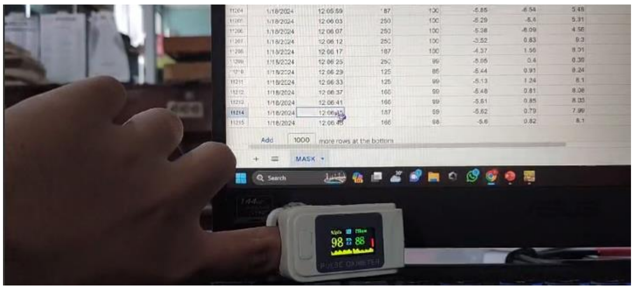


Figure 7. Data validation using Oxymeter.

3.2. Motions Test

The same unit as above, motion test uses MPU6050 as the sensor and transfer the data to microcontroller and then it forwarded to database in the form of x, y, and z axis value and determine the motion of subject's hand which wear the device. Many motions detected in sleeps considered as a sleep disorder where it can disrupt sleep quality[20]. The measurement shown in Fig. 10 shows almost no movement from 3 axises of subject 1 and 2, except for movement at early sleep and subject 3 shows more movement than 2 other subjects. 3 subjects move rarely according to data reading and can be inferred as no disruption to sleep quality [8].

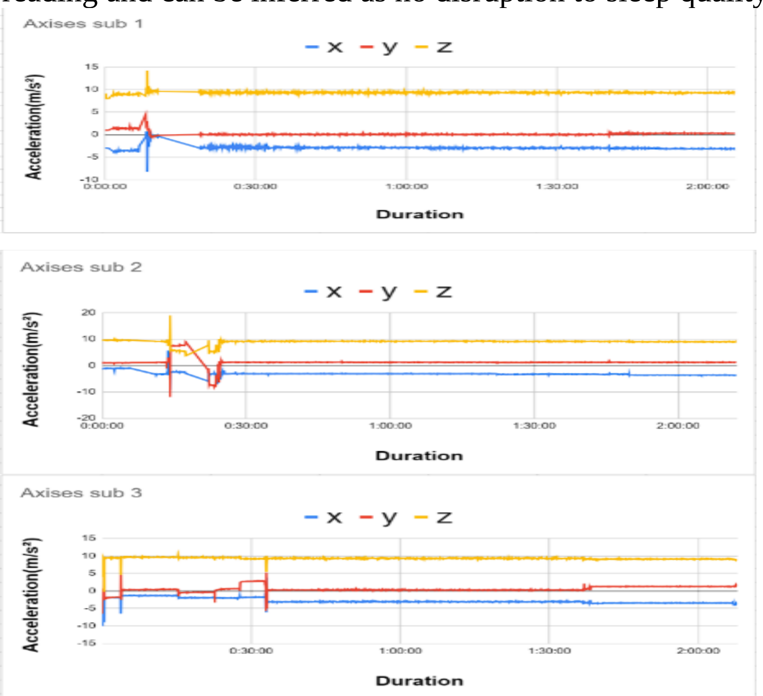


Figure 8. X, Y, and Z axises Measurement from MPU6050.

3.3. Breathing and Sound Test

This test consists of sound data from microphone of MAX9814 and temperature data from thermometer sensor of D18B20. The sound data just came in raw input, the louder the sound is, the sensor will read it as higher value. In Fig. 11, the sounds detected can shows loud noises especially over 200 and as shown in Fig. 11, the loud sounds can disrupt the sleep quality [8].

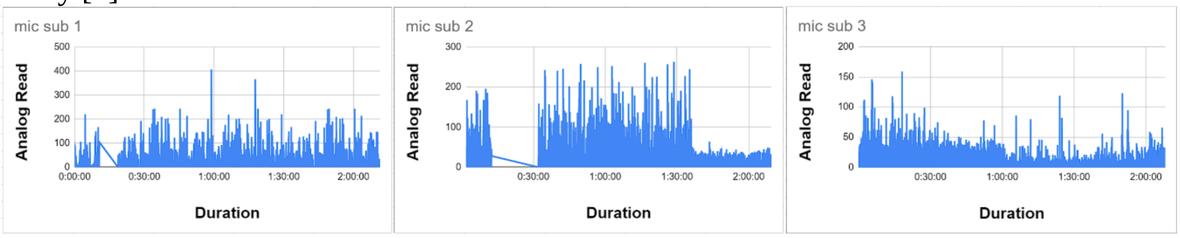


Figure 9. Measurement from MAX9814.

Breathing test uses thermometer to determine the pace of breathing of subject from the changes in value of sensors in reading the heat from breath. Shown in Fig. 11, the changes not really big and will stay around the same value if the pace of breathing is stable. The big changes in value show a change in pace of breathing as well but can't be determined if it change to rapidly taking a breath or stopping for a while.

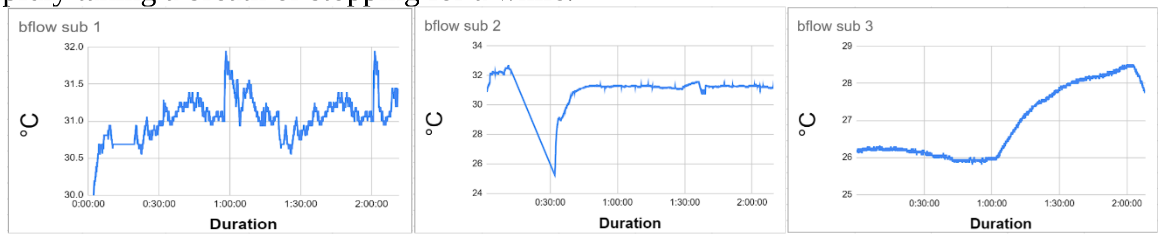


Figure 10. Measurement from DS18B20.

4. Conclusion

Sleeping disorders have many kinds and all types of symptoms. Early detection from these symptoms can prevent other illnesses to struck after countless night of bad quality sleeps. A device to address this issue to detects early symptoms before taking the matter to a professional or a doctor for more advance examination has been developed. The device consisted of 2 microcontroller and 4 sensors of MAX30102 oxygen levels sensors, MPU6050 accelerometer, MAX9814 microphone module, and DS18B20 thermometer. The experiment was conducted 3 times with same environment of sleep and 3 individuals. The results still shown signs of unstable reading which can be improved in the future by improvement in sensors qualities, more experiment conducted, and coordination with professional to calculate and compare more data to get higher accuracy and stable reading. Improvement of this caliber cannot be done as limitation of time and subject, expert to consult, and the objective itself to create affordable home sleep monitor became the main of many reasons.

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