Design and Fabrication of a Sleep Detector Modelling the Characteristics of a Mosquito

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Abstract- Incidences of Road traffic accident (RTA) have surged in recent years in spite of the sophistication and ingenuity of car manufacturers in building modern cars. This has fostered great concern for researchers to opt for better approaches to mitigate its increase. The conditions in which the driver feels most comfortable to take a nap while at the wheel are identical to the same conditions favouring mosquito attacks. Three mosquito attack conditions: low ambient temperature, low ambient light, and balancing were studied and used to design and fabricate a sleep detection device that detects sleep and alerts the driver by beep from the buzzer and vibration when sleep has been detected. The primary components used for designing the sleep detector includes: microcontroller, temperature sensor, light sensor, tilt sensor, passive buzzer, and vibration motor. The microcontroller is the brain of the device, as it processes and interprets the inputs from the sensors used and sends signals to the buzzer and the vibration motor at the incipient of sleep conditions. The device was built with a mobile app which is used to set or adjust the detector device to adapt to varying environmental conditions, displaying the ambient temperature and light intensity in real-time and records the time sleep was detected when connected. The average response rate of the device is 91% with an estimated accuracy of 67% which can be compared to its contemporaries available in the market, having response rates and accuracy ranging from 80% to 98% and 60% to 85% respectively. The device is portable, worn on the ear, and can be procured for an estimated price of ₦65,000 Nigerian Naira which is about $52 US dollars. The device case was modeled and printed in 3D using a 3D software and printer.

Index Terms: accident, detector, fatigue, mosquito, sleep

INTRODUCTION

Necessity has been said to be the mother of invention while mimicry has been its midwife. Humans have had most inventions borne from the mimicry of air, sea or land animals [1]. Most inventors have relied on imitating animal behaviors as inspiration for everything from fashion to architecture. This imitation in engineering is termed biomimicry. There are countless number of these inventions having bio-mimicked animal designs and characteristics.

Animals have been successfully adapted to their environment by evolving to meet the environmental challenges in their habitat. These adaptative behaviors have been keenly observed by humans who have thus translated these behaviors as models in technology and as inventions to address situations that threaten human survival as well as enhance the spheres of technological advancement and development. This research work thus mimics the characteristics of mosquitoes to provide an efficient sleep detector.

Sleep is a pivotal activity and a natural phenomenon for humans and animals that ensures their sustainability. However, the timing of sleep occurrence may be a factor determining the continual workability or inexistence of its victim. It is an important part of humans' daily routine, normally accounting for one-third of a human's day. Quality sleep, and getting enough of it at the right time, is pivotal to survival just as food and water. Without sleep, there would be difficulty in concentration and quick response.

Sleep is also important to a number of brain functions, including how nerve cells (neurons) communicate with each other. Contemporary research suggest that sleep plays a housekeeping role in removing toxins in the human brain that builds up while they are awake [2].

Research also reveals that a chronic lack of sleep, or getting poor quality sleep, increases the risk of disorders such as high blood pressure, cardiovascular disease, diabetes, depression, and obesity[3].
The Anopheles, Aedes, and Culex are mosquitoes that have a common feature, that of feasting on human blood, mostly accompanied by irritating buzzing

sounds. Balance during flight can directly affect their attack in terms of its ability to successfully land on and bite a host. Mosquitoes are highly adapted to flying and can stay in the air for long periods of time, but they require a stable position in order to land on a host and feed.
A mosquito's inability to maintain balance during flight, for example, due to a strong wind or turbulence, may cause difficulty landing on a host and feeding. Similarly, if a mosquito is disoriented or unable to maintain balance due to a physical injury or illness, it may also have difficulty biting a host.

One of the primary mechanisms is their ability to sense and respond to changes in airflow and air pressure. Mosquitoes have tiny sensory hairs on their antennae and other body parts that help them detect changes in airflow and air pressure. By using this information, they are able to adjust their wingbeat frequency and wing position to maintain stable flight.

In addition to sensing airflow and air pressure, mosquitoes also use their vision to help maintain balance during flight. They have highly specialized compound eyes that allow them to detect movement and perceive visual cues such as edges and contrasts. By using both their sensory hairs and vision, mosquitoes are able to maintain balance and navigate through complex environments, such as dense vegetation. Other environmental factors such as temperature and humidity can also affect a mosquito's ability to fly and maintain balance.

Illumination can condition mosquito attacks in several ways. Mosquitoes are most active during the hours of dawn and dusk, which are periods of low light. However, they can also be active during the daytime, particularly in shaded areas or indoors. The amount of illumination in an environment can affect the behavior of mosquitoes and their ability to find and attack hosts. One way in which illumination can affect mosquito attacks is by influencing their host-seeking behavior. Mosquitoes are attracted to their hosts by a combination of visual, olfactory, and thermal cues. The visual cues that mosquitoes use to locate their hosts include contrast, movement, and color. Illumination can influence the visibility of these cues, determining the success of failure of mosquitoes to find their victim. For example, mosquitoes may be less likely to attack in areas with bright light, as the contrast and movement of potential hosts may be more difficult to detect.

This is particularly true for species that are more active during the daytime, as bright light can make it arduous for them to find shaded areas in which to rest and seek out hosts.

Finally, illumination can also affect the behavior of hosts, which can indirectly influence mosquito attacks. For example, hosts may be more active during periods of bright light, which can make it more difficult for mosquitoes to land on and feed.

Temperature can affect mosquito attack in several ways, as it directly influences the development, behavior, and survival of mosquitoes [4]. Mosquitoes are ectothermic, meaning that their body temperature is regulated by the ambient temperature. Therefore, changes in temperature can also indirectly affect mosquito attacks by influencing the behavior of hosts. Hosts may be more active during periods of cooler temperatures, which can make them more vulnerable to mosquito attacks. Alternatively, hosts may use protective measures such as long clothing or insect repellents during periods of high mosquito activity, which can reduce the likelihood of mosquito bites.

In general, mosquitoes are most active and likely to attack hosts in temperatures ranging from 25°C (77°F) -28°C (82°F). At these temperatures, mosquitoes are able to fly and seek out hosts efficiently, and their metabolisms are optimized for maximum activity and energy expenditure. However, this temperature range can vary depending on the mosquito species, with some species being more active at slightly cooler or warmer temperatures [5].

Overall, the effect of temperature on mosquito attack depends on a combination of factors, including the species of mosquito, the behavior of the host, and the specific temperature conditions in the environment [6].

Detectors are usually paired together with an antitheft alarm system that automatically goes off when the

signal for activation has been received with the aid of specifically designed sensors.
A sleep detector is a device or system that is aided with sensors and algorithms to monitor and analyze sleep patterns, the duration and quality of sleep, the number of times a person wakes up during the night, as well as the different stages of sleep [7].

Most sleep detectors depend on machine learning algorithms to analyze the data collected by the sensors and provide understanding into sleep quality and quantity. These algorithms use a combination of statistical and mathematical models to identify patterns and trends in the data and make predictions about sleep stages and other sleep-related factors. Furthermore, sleep detectors can also assist in gathering information on the driving habits of individuals, avoiding accidents, minimizing loss of human life and financial losses, and enhancing connectivity on highways due to a reduced number of accidents resulting in traffic jams.

Most sleep detection methods such as wrist actigraphy or mobile apps consider a binary function, where the state can be classified as Awake/Sleep. Current actigraphs provide a fairly reliable measurement of when, and for how long, an individual sleep. They use an accelerometer to collect body movement data and often incorporate other sensors to measure body temperature, heart rate, respiratory rate, or even the galvanic skin response.

Contact-based sleep detection devices are all those devices that use sensors to be placed in contact with the body. Contact sleep detection devices are portable gadgets often attached to the wrist, ankle, chest, or head. They are often called actigraphs.
Contactless sleep detection methods are based on one or several of the following technologies: the use of a video camera, the use of a microphone, the use of echo-based devices, and other no-skin contact devices. Various studies have suggested that around 20% of road accidents are fatigue-related. The sleep detector is used in a vehicle for detecting the circumstances suggesting the onset of sleepiness of a driver and for alerting the driver. In some designs, an eye blink sensor is used to keep track of the driver's eyelid motion [8]. If the predefined safety conditions are not met, then the driver is alerted by producing an alarming sound from the inbuilt car speakers primarily. With others, a vibrating device is incorporated within the driver's seat which activates when the conditions are not satisfied.
There have been different approaches to the development and eventual design of a sleep detector using the fusion of different kinds of sensors or methods. One common method was the fatigue-detection method based on computer vision. This method leveraged eye state as an indicator of facial expressions, such as blinking frequency, yawning, and so on, which are helpful in detecting fatigue, and conversely, sleep. The eye state could be identified by analyzing the vertical and horizontal projection intensity of the facial image [9].
[10] designed a sleep detector device that concentrates on reducing road accidents in the country. This device facilitates the timely detection of a car driver's drowsy state, alerts him, and prevents the occurrence of any accident.
Another approach made use of templates applied when the eyes are opened or closed and a zero-mean normalized cross-correlation template as well and compared them in order to get their analytic basis. The combination of these technologies seemed to have given off a more accurate basis but it was limited to grayscale images and therefore was easily affected by ambient factors [11].
[12] proposed a 3-stage computer vision technique that included: face and eye detection based on eye equalization using a Hat transformation, pupil position detection following integral projection techniques and a Gaussian model, and a PERCLOSE (Percentage of Eye Closure) estimation. [13] tried to factor in consideration for drivers that make use of glasses when driving which seemed really difficult as the glasses were perceived as being eyebrows and so he decided to use pupil dilation and erosion which did not turn out positively. [14] based his research on the Hough transform and tried to study the complex properties of the eye as well as to detect round or circular objects in order to detect the position and movement of the pupil. Furthermore, edge detection technology was used to study the different eye forms and patterns as well as the numerous edge pixels of the eye [15]. [16] made use of the Euclidean distance technique to develop a system that could detect the behavior of the iris patterns. The aforementioned technologies are limited by ambient factors and hence they make use of image enhancers which gave rise to

an increase in the cost of materials, vis-a-vis, affordability.

[17] made use of infrared sensors to determine the driver's facial expressions by observing the eyebrows, the mouth positions, and the eye closure. This method gave positive feedback even for drivers using glasses or wearing a mustache. The design proposed by [18] focuses on the eye closure rate and the head positioning by pre-recording the images of the actual position and comparing it with the real-time results. [19] proposed a design based on some physical human gestures such as yawning and blinking by making use of a camera mounted at the top of the roof in front of the driver. This design gave a better output in drivers without beards or glasses. [20] based their design on the analysis of the eye blinking. [21] made use of a webcam video monitoring system and a laptop to determine or detect sleep in drivers. The software for the webcam was designed using the Viola-Jones algorithm and Ada-Boost classifier. [22] created a model that was more accurate and precise by using the Raspberry Pi camera and Raspberry Pi 3 model B to detect eye and head positions.

[23] designed a sleep detection model that was based on the fusion of Lane detection technology using the Hough transform and the Viola-Jones algorithm to detect eye and head movements.

[24] came up with a design that sought to analyze the steering wheel's angular velocity by taking note of the initial driving condition or position of the steering wheel and making sure they maintained some level of consistency throughout the trip. Sensors were also attached to the steering wheel and using warping distance, the steering angle was calculated and was monitored for consistency by Li and his colleagues. They were able to show that steering feel represented by maneuverability and lane-change ability of drivers correlated with physiological features such as mental or physical workload which could be pointers to fatigue.

[25] designed a detector based on Heart Rate Variability whose main function was to identify sleep using the wavelength transformation in brief periods. [26] proposed a design that made use of pulse sensors or infrared heart-rate sensors. [27] did propose a method that made use of wearable-type sleep detectors which contained galvanic skin response sensors in order to get their readings; such as heart rate, respiratory rate, stress level, pulse rate variability, and adjustment counter. [28] proposed an idea using wearable biosensors known as Bio-harness.

In consideration of the conditions that lead to mosquito attacks, attention is not only given to the primary sensors of the mosquito which detect light, temperature, and the excess carbon dioxide in the environment, but also to the position in which the mosquito attacks.

When these factors are put together, the mosquito model sleep detector can be said to be a device that explores the attacking characteristics or factors that affect the attacking probabilities of a mosquito, and uses the information garnered to measure or detect sleep in real time and warn or awake the user in time in order to avoid damage to life and property and mitigating roadside accidents.

The defining parameters sought for in the development of the mosquito model sleep detector are;

- The intensity of the ambient light
- The Temperature
- The position of the head (because the device is worn on the ear which is part of the head).

Several research has shown that 20% of road accidents are caused by fatigue or drowsiness of the driver. In 2020, the Federal Road Safety Corps (FRSC) in Nigeria, disclosed that about 2,656 road traffic crashes were recorded [29]. Africa is mostly hit by the incidence of road traffic accidents in tandem with its negative effects. The mortality rate in Africa (25.3% of its population) is almost three times that of Europe, where the number of road fatalities represents 31% of the relevant global figure. According to the National Highway Traffic Safety Administration (NHTSA) report in 2023, drowsiness caused 1.8% of fatal crashes from 2017 to 2021 [30]. However, the most disturbing concern is the fact that the disparity in road traffic accident results seems to be increasing. More specifically, according to the World Health Organization (WHO, 2015), road fatality rates in Africa are soaring. As far as Africa is concerned, road trauma is expected to worsen further, with fatalities per capita projected to double from 2015 to 2030 [31].

In many factories and industries where work activities are carried out at night, workers are likely to fall asleep on duty resulting to some negative effects such as: an increase in the risk of accidents, loss of production hours, increase in cost of health care, loss of job and even loss of life. In 2010, an Air India Boeing 737 crashed in southern India, killing 158 people on board. According to the official inquiry reveal that the pilot had been asleep for nearly three hours of the flight and woke disoriented just before the landing [32].

In other to improve the efficiency of existing sleep detectors, the need to pattern a design having established similarities of conditions favorable to mosquito attack and sleep became necessary.

The study will thus design a sleep detector device using the mosquito model by designing a portable sleep detector device that mimics the conditions favoring mosquito attacks using an infrared (IR) sensor, temperature sensor, and gyroscope. Next, algorithms and computer programming would be used to interpret the input/stimulus from the sensors and finally a 3D printing would be used to model and achieve the design.

2.0 METHODOLOGY

The device design involved both hardware and software components. The hardware components include sensors such as: *the light sensor, temperature sensor, tilt sensor, microcontroller, voltage regulator, buzzer, vibration motor, LED indicator, etc*. The software component is the Arduino and Visual Studio Code.

2.1 Materials

2.1.1 Hardware Components

The ambient light sensor is essential in this project and is majorly focused on the use of the product at night time and this sensor is what helps in determining the daytime from night time.

This function is synonymous with the specialized cells in the retinas of the eye which process light and tell the brain whether it is day or night and can in-turn advance or delay an individual's sleep cycle.

As regards the relation to the mosquito model, it is known that mosquitoes like to attack in the dark because sunlight dehydrates and weakens them thereby killing them or making them easily visible to prey. Thus, the ambient light sensor helps distinguish between daytime and nighttime (see Fig. 2a)

Thermoregulation plays an important role in the sleep-regulating mechanism of the body. When the thermal environment is comfortable, sleep seems more enjoyable and this is because the body is in a dynamic state of homeostasis.

As in relation to the mosquito model, mosquitoes like to attack at humid temperatures. They do not like very cold areas as it makes them inactive and they eventually die (below10ºC). They are lethargic in hot areas, but the disease they carry at this point is very potent. Thus, a temperature sensor, namely Ds18B20 is built in the device to alert the driver when a temperature seeming to induce sleep is reached. (see Fig. 2b)

The microcontroller, Esp8266-07 is coded in an open-source electronics platform that is based on its easy-to-use hardware and software. The boards are able to read inputs from sensors and turn it into an output signal by the use of the code on the software. The Esp8266-07 microcontroller is much simpler to use and quite easy to comprehend. (see Fig, 2c)

The breadboard provides a platform for connecting the electronic components together without needing to solder them. Printed circuit board (PCB) also known as printed wiring board (PWB) was used when making the final design. (see Fig. 2d)

Resistors are passive two-terminal electrical components that implement electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, divide voltages, bias active elements, and terminate transmission lines, among other uses. (see Fig. 2e)

Tilt sensors are also known as inclinometers. They are a type of position sensor used to measure angles or the slope of an object; in this case the position of the head of the user. (see Fig. 2f)

The TP4056 is a complete constant-current/constant-voltage linear charger for single-cell lithium-ion batteries. Its small outline package (SOP) and low external component count make the TP4056 ideally suited for portable applications. (see Fig.2g)

The PC817 is an optocoupler that includes a phototransistor and an IR diode. The circuit is simply appropriate wherever the incoming signal includes some data. However, when we need to transmit the signal from one element of the circuit to the other element even though the signal includes noise, the blend of IR Tx & Rx has to be utilized. From the circuit of the PC817 optocoupler, the IR gets the noisy signal from one part and transmits it to another using the IR signal so that it performs based on the design of the circuit. This IC has several uses because of its tiny size & control operation. (see Fig. 2h)

Humans enjoy sleep best when the environment is dark, cool, and ‘quiet’. So, from time to time, we need a sound component, *a passive buzzer*; that can help them become awake and alert when it gets too quiet or when the parameters in the project are breached.

This reaction is in tandem with mosquito bite in the sense that as the sharp piercing of the proboscis of the mosquito into the human skin is felt, the human quickly reacts by consciously locating wherever the mosquito may have bitten, the sound component would also bring back the driver into consciousness perhaps if he was drifting away. (see Fig. 2i)

To make the device portable, a *power source* is provided by the use of a Li-ion battery, which has about a 5V DC supply to power up the buzzer and microcontroller on which the sensors operate or are integrated. (see Fig. 2j)

The slide switch is used to power the device on and off. (see Fig. 2k)

The vibration motor is used to improve the output or response of the device by vibrating the device alongside the buzzer when sleep is detected by the sensors. (see Fig. 2l)

The figure (see Fig. 2m) is the *3D print* of the device protective case. The case is modeled to the required dimension and design in 3D modeling software and printed with a 3D printing machine. This component makes up the device and gives the device an aesthetic finish. As the design is based on a wearable or contact assessment type of device, the casing would look like that of an earpiece that is worn around the ear.

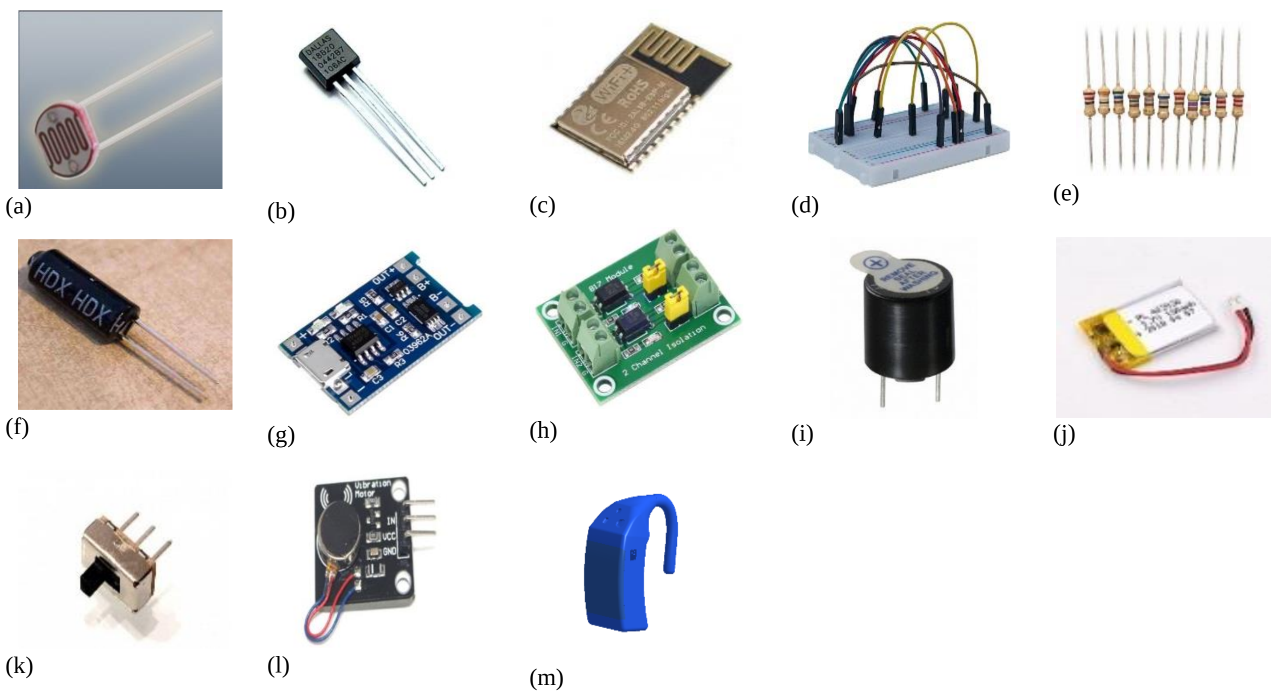

Figure 2 $a - m$: Hardware components used for the device design

2.1.2 Software Components

Most of the work done on the software aspect involves the use of different computer software (Arduino program, Visual Studio code software, etc.) to write computer code in C++ programming language to help the microcontroller receive input from these sensors, interpret the input accurately and give the required output using buzzer and vibration motor (output signals).

The use of 3D modeling software helped in achieving the overall design of the device. The device is designed in the form of a Bluetooth earpiece, using Onshape online software. Thus, the portable device is worn on the ear for optimum performance and comfort.

2.1.2.1 Arduino

The software development section deals with the use of the Arduino program to write code suitable for the intended project in C++ programming language and would be test run on the Arduino hardware component before soldering on a circuit board.

The Arduino integrated development environment (IDE) is a cross-platform application (for Microsoft Windows, macOS, and Linux) that is written in the Java programming language. It originated from the IDE for language processing and wiring.

The Arduino IDE is used because it supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, which is compiled and linked with a program sub main () into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program avenue to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

The Arduino Software (IDE) was used in writing the code used in programming the microcontroller used in this project using C++ programming language. (This can be available on request).

2.1.2.2 Visual Studio Code

The Visual Studio Code software is used to program a mobile application to be able to control the intensity of the light and temperature variant for the detector. It would also give feedback as per the time in which the device was used in order to be able to track sleep build-up patterns.

Visual Studio Code is a code editor redefined and optimized for building and debugging modern web and cloud applications. It is used because it is a source code editor that can be used with a variety of programming languages which include C#, Java, JavaScript, Python, C++, C, etc. Visual studio code was used to program and build the mobile app used for this project.

2.2 Methods

2.2.1 Hardware Connections

The ambient light sensor is connected in parallel to the 330k resistor to form a voltage divider. This is connected to the analog pin of the Esp8266-07 to sense the ambient light of the environment.

The temperature sensor has a 4.7k resistor connected between its data and a 3.3V terminal to read temperature data through one wire communication protocol.

The tilt sensor is connected as digital input on the Esp8266-07 voltage regulator but positioned in a way to measure if the tilt angle is higher than 30 degrees.

The Opto-switch is used to switch the buzzer when the device is activated, while the voltage regulator helps to regulate the battery volt to 3.3v for the Esp8266-07 for safe working mode.

The charging module helps to charge and monitor the li-ion battery effectively. The complete schematic diagram is displayed in Figure 2n.

2.2.2 Software Development

The embedded software is made up of C and C++ language written using Arduino IDE to program the esp12e via FDTI cable.

The mobile app is written in HTML, CSS, and JavaScript.

2.2.2.1 Installation and connection of the device mobile app:

- The APK version of the app is installed on the smartphone.
- The device is turned on from the slide switch (the red LED indicates that the device is on)
- After the installation, the Wi-Fi of the smartphone is turned on and connected to the device SSID.
- After successful connection, the smartphone data is turned off and the app is launched on the smartphone. The mobile will display the ambient temperature and the ambient light intensity in real-time.
- The mobile app also provides for adjusting the ambient temperature and ambient light intensity of the device suitable to the geographic location of use, which makes the device work well during the day and at night.

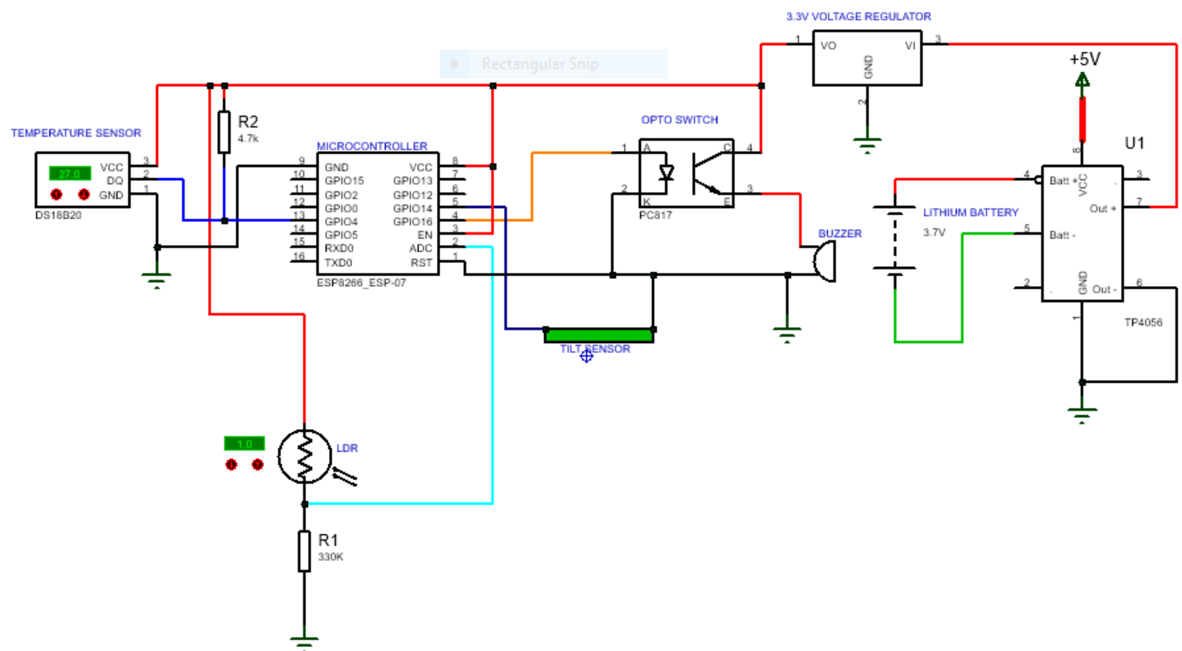

Figure 2 n: Circuit diagram of components assembly and its connections to the microcontroller.

3.0 RESULTS AND DISCUSSIONS

Various tests were conducted using the sleep detector device to ascertain the usability and accuracy of the device. Series of the tests were conducted during night times and as well as day time. The device's mobile app displayed the ambient temperature and ambient light intensity in real-time. The values of ambient temperature displayed on the mobile app were compared with standard measuring instruments like the thermometer and other sleep tracking devices like the Apple watch. The results showed high precision and accuracy.

In each of the tests conducted, the response rate of the device at different ambient light intensities was obtained and recorded. The response rate is the measure of how fast the sleep device is able to raise an alarm when there is a tilt.

Table I shows the result obtained during the night (11:00 p.m. to 1:00 a.m.) and Table 3.2 table shows the result obtained during the day (1:00 p.m. to 3:00 p.m.) *in Nigeria*.

$$\text{Response rate} = \frac{\text{Time it takes the device to detect sleep}}{\text{Time it takes to raise alarm}} \times 100\% \quad (3.1)$$

Table I: Test conducted at night time (11:00 p.m. – 1:00 a.m.).

S/N	Ambient temperature (°C)	Ambient light intensity (%)	Response rate (%)

1	29	10	90
2	30	20	92
3	28	30	89
4	30	40	90
5	29	50	93

Table II: Test conducted at day time (1:00 p.m. – 3:00 p.m.).

S/N	Ambient temperature (°C)	Ambient light intensity (%)	Response rate (%)
1	35	60	90
2	34	70	88
3	35	80	93
4	34	90	92
5	34	100	93

Tables I and II respectively displays results obtained from the device in recording data obtained in varying temperatures as well as light intensities. The response rate the device shows the dependability of the use of the device as it recorded an average of 91% with respect to the night time and day time respectively. It is noteworthy that this temperature ranges are peculiar to the average night time and daytime temperatures respectively as applicable in Nigeria. The device can be preset to a range of temperature peculiar to the location of its use using the mobile app.

Table III below displays the data obtained in the usage time, time required to fully charge the device when the battery is less than 5% as well as the weight of the device.

Table III: Sleep detector device information

Tests	**Values**
Usage time	About 3 hours of continuous use at full charge.
Charging time	20 – 25 minutes
Weight of device	65 grams

It can be deduced that the device can be used for up to 3 straight hours when turned on. It is also equipped with an android type charging port to recharge. The weight of the device is 65g which makes it wearable without causing strain or inconvenience to the user when worn on the ear.

The figures below, Fig. 3a and Fig. 3b show some head positions while using the sleep detector device. When the user's head is held straight, the sleep detector device is in neutral mode hence, no sleep is detected, no buzzing or vibration. see Fig. 3a. When the user's head is tilted forward during driving, the sleep detector device raises alarm and vibration, see Fig. 3b.

(a) (b)

Figure 3: Demonstration of the head position (a) at erect, the device is in neutral mode

(b) when tilted, the detector device raises alarm and vibrates

4.0 CONCLUSION

During driving, concentration of the driver is required, and sleeping at that moment can be very dangerous. This sleep detector device can help drivers to keep awake in this situation. The sleep detector is portable and it is worn on the ear. It has been designed to function optimally at night by default. However, it can be adjusted or reset by using the mobile app to suit the required environmental condition.

The sleep detector device is built with a mobile app to improve the usability of the device. When the mobile app is connected to the device, it displays real-time ambient temperature with the help of the temperature sensor built into the sleep detector device. When the temperature of the environment is low (below 30℃ on the mobile app) the sleep detector device becomes active to detect sleep just as mosquitoes become more active at relatively low temperatures.

The mobile app also displays real-time ambient light intensity transmitted from the light sensor in the sleep detector device. When the ambient lightening is lower than 40% on the mobile app, the device becomes more active for sleep detection just as mosquitoes are more active at night or in low-light environments.

When the device detects tilt and other conditions above are true, the device raises a beep alarm and vibration to indicate that sleep has been detected, just as mosquitoes are less active when it is unable to balance well in an environment. The detection times are recorded on the mobile app.

The mobile app can also be used to set the suitable ambient temperature and ambient light intensity which the sleep detector device should use as a threshold to sense sleep. This is a result of different ambient temperatures for different locations and environmental conditions (e.g. rainy, sunny, night, etc.). In other to make the app work well and be used in any location, the suitable temperatures are set using the sleep detector mobile app. (The sleep detector mobile app codes as well as the microcontroller coding can be made available on request).

The radiation emission of the device was investigated and it is safe for use. The radiation that can be emitted by the individual component of the device is negligible. The microcontroller emits 0.6W/kg which is very safe compared to mobile phone which emits between 1.2W/kg to 1.9W/kg. The safe dose of radiation exposure must be less than 2W/kg. Any amount more than 2W/kg is no longer safe for humans.

The average response rate for the sleep device is about 90%. The sleep-detecting accuracy of the device has been estimated to be around 67%. Other sleep tracking device available in the market has accuracy ranging from 65% to 90%, thereby making the device competitive in the market at an affordable rate since the device is made with affordable components. The cost of building the device with the component enlisted was about ₦65,000 ($52) which is relatively affordable and also finds applications for students, drivers at night, bakers, factory workers, night-shift workers, security personnel etc.

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