Easy wake up Device

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1. Introduction

1.1 Objective and Background

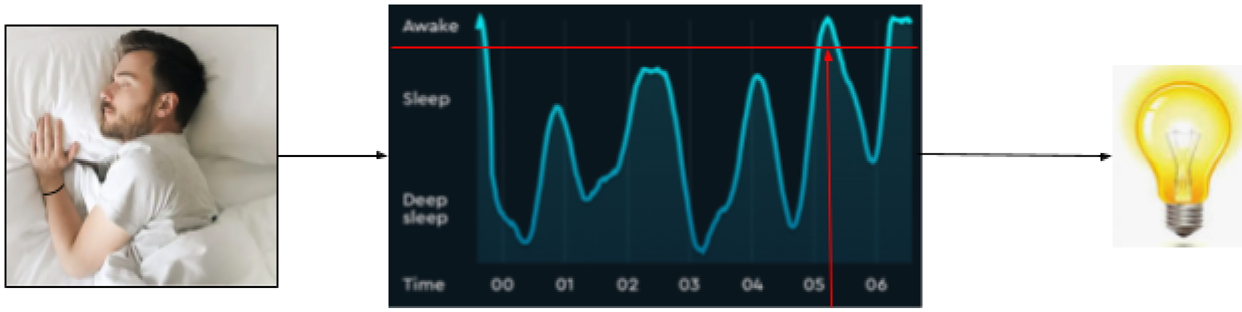
Many people are struggling to wake up in the morning. And many people just press snooze button on their alarm even though they are going to be late for work, according to a survey of almost 20,000 people done by the French tech firm Withings, more than 57% of the Americans are snoozers [1], and many people reported feeling tired or fatigued even when they slept for 7 to 8 hours, which is the suggested amount by experts [2]. Therefore, we are trying to find a way to help people wake up easily and feel energetic.

Currently, the most common way to wake up is to set an alarm, either using a cell phone or a clock. The problem with this is that people wake up abruptly in the morning from the loud sound of the alarm clock, smartphone, or other electronic device, and the majority of respondents to a survey (79%) said that a bad wake up experience will ruin their day [3].

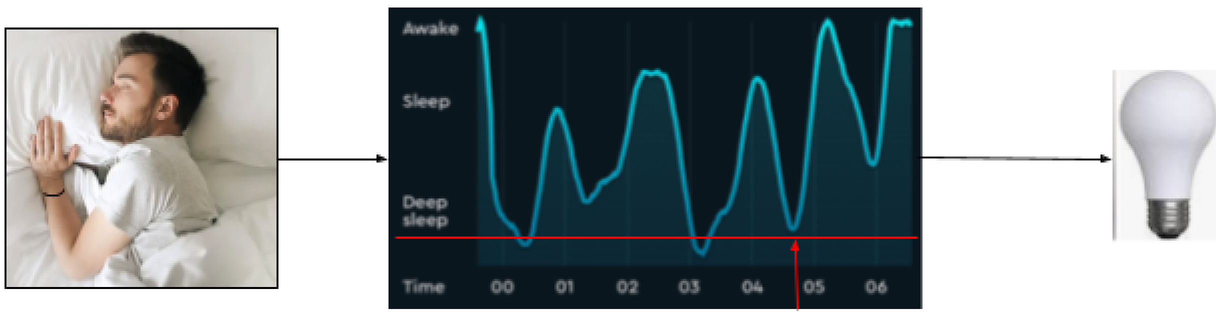
Some new technologies are attempting to track a user's sleep cycle to know the optimal time to wake them up [4]. According to an article by MedicalNewsToday, the best time to wake up is at the end of a sleep cycle, when the sleep is the lightest [5]. Other studies also show that using light can help your body prepare to wake up [6]. Our plan is to combine these technologies to create a device that will track your sleep cycle and then trigger a lightbulb to turn on. This will allow us to leverage the benefits of both technologies to help people wake up in the morning.

We plan to make this device fit on a band/watch which a user will wear on their arm. We will use a microphone, pulse sensor, and accelerometer to measure the user's noise, heart rate, and movement respectively. These data measurements will help us determine what sleep cycle the user is in. Additionally, we plan to use a bluetooth module to communicate between the band and the lightbulb, which will signal the light bulb when to turn on. We expect that this will require users to buy these specific lightbulbs to use with the band.

1.2 Visual Aid



when user is at awake state in sleep cycle, turn light up



when user is at deep sleep state in sleep cycle, turn light off

Figure 1 Visual Aid

1.3 High-level Requirements

- The device should have two modes for the user to select, the first is manual mode, in manual mode, the device will wake up the user according to the time the user set. the second is smart mode, in smart mode, the alarm will wake the user up according to the sleep cycle of the user and the range of time the user gave to the device
- The band system should be able to gather data using microphone, pulse sensor and accelerometer, and calculate the sleep cycle of the user using the data and transmit a signal to the lightbulb system.
- The light system should use light range from 0 to 2000 lumens to wake the user up gradually

2. Design

2.1 Block Diagram

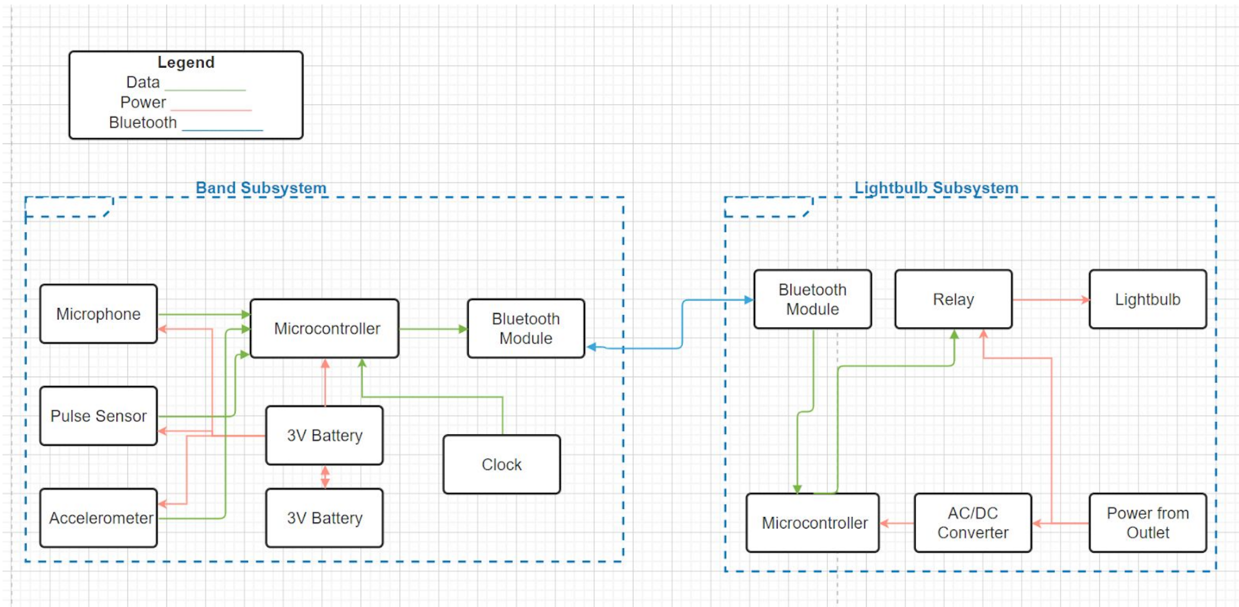


Figure 2 Block Diagram

For our design, we will two use subsystems: one for the band on the user's wrist and one for the light bulb to be turned on. The band subsystem will use the three sensors to collect data and program the microcontroller to interpret the data and detect whether the user is sleeping and what state of sleep they are in. We also use a real-time clock to keep track of the time so the light will not turn on before the user needs to wake up in the morning. Then the microcontroller in the band subsystem communicates the user's status to the microcontroller in the lightbulb subsystem which will subsequently signal the lightbulb to turn on or off.

2.2 Software Flow Chart

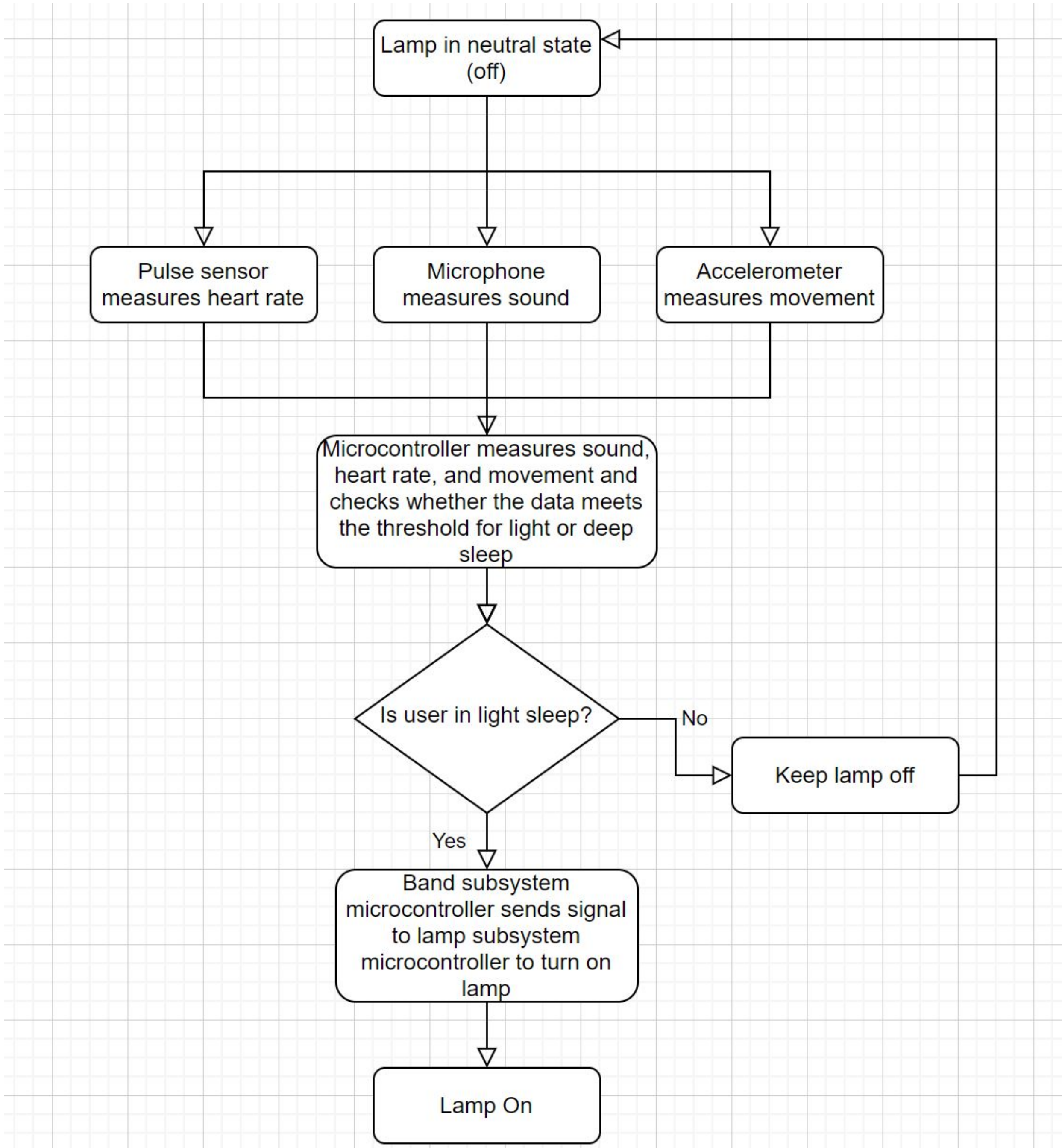


Figure 3 Software Flow Chart

2.3.1 Band Subsystem

Microphone

We plan to use an Adafruit MAX9814 Electret Microphone Amplifier to measure the sound the user is making. We will use it to send data to the microcontroller to figure out what stage of sleep the user is in.

Requirements	Verifications
1. Should have an operating voltage of 4-6 Volts	1. Connect a 5+-1 volt supply to the VCC of the microphone and then read the voltage from the output pin while speaking into microphone to see if the microphone works

Clock

We will need a clock chip to keep track of time so that the light will only turn on near the wake up time.

Requirements: We need a clock chip that has and is real-time clock that is self-powered via battery. It also must have I2c interface and have documentation for interfacing with the ATmega328 microcontroller

Pulse Sensor

We will be using a pulsesensor.com standard pulse sensor to measure the heart rate of the user to help determine the state of sleep the user is in. This data will be sent to the microcontroller to help determine whether to turn on the light.

Requirements	Verifications
1. Should have an operating voltage of 4-6 Volts 2. Should have supply current of less than 20 mA	1. Connect a 5+-.5 voltage supply to the pulse sensor and the green LED should turn on 2. When 5+-.5 volts is supplied to the pulse sensor, the ammeter measures a supply current of less than 20mA

Accelerometer

For an accelerometer, we are choosing to use an ADXL343 accelerometer. It will interface with our arduino and report movement of the user while they sleep, giving us more information to help determine what stage of sleep they are in.

Requirements	Verifications
1. Should have an operating voltage of 4-6 Volts	1. Connect a 5+-1 volt supply to the VCC of the accelerometer and then read the voltage across the SDA pin when we move the chip.

Microcontroller

For our band’s microcontroller, we plan to use a PCB we print ourselves that will use an Atmega328 microcontroller as it’s small size will be easier to fit in a band on the user’s arm. It also has enough I/O ports to take in data from all three sensors and we will program it to use that data to determine what state of sleep the use is in.
Requirements: Has at least 8 analog and digital input pins and is small enough to fit in a band on someone’s wrist (<2x5cm). Must also have a significant amount of memory (2KB RAM and 32 KB of Flash) to store data from the user.

Bluetooth Module

We have decided to use an Hc-05 bluetooth module to communicate between our band and lightbulb subsystems. They will allow us to send signals to the lightbulb subsystem to turn on or off the bulb.

Requirements	Verifications
1. Should have an operating voltage of 4-6 Volts 2. Current drawn must be less than 40mA.	1. Connect a 5+-1 volt supply to the VCC of the module and then check that the LED turns on 2. Measure the current drawn when above voltage is supplied to the module and ensure it is below 40mA

Batteries

We plan to use two Lithium ion button batteries to power our band as they are small and compact and can produce the necessary voltage for the microcontroller and sensors.
Requirements: Relatively small (<4cm^2) and can produce 5-6 volts total.

2.3.2 Lightbulb Subsystem

Microcontroller

For our band’s microcontroller, we plan to use a PCB we print ourselves that will use an Atmega328 microcontroller as it’s small size will be convenient. It will control the bluetooth module and send the signal to turn on the light.
Requirements: Has at least 4 analog and digital I/O pins and is relatively small (<3x5cm).

Bluetooth Module

We have decided to use a second Hc-05 bluetooth module to receive signals from the bluetooth module in the band subsystem to turn on or off the bulb.

Requirements	Verifications

1. Should have an operating voltage of 4-6 Volts 2. Current drawn must be less than 40mA.	1. Connect a 5+-1 volt supply to the VCC of the module and then check that the LED turns on 2. Measure the current drawn when above voltage is supplied to the module and ensure it is below 40mA

Relay

We need a relay switch to control whether to allow the 120VAC to power the lightbulb or not.

Requirements	**Verifications**
1. Should be able to handle 120VAC and be controllable by 5VDC	1. When 120+-1 VAC is connected to the relay interfaces, with no VCC, the measured load voltage will be less than 1 volt. When 5 volts are applied to the VCC terminals, the measured load voltage will be 120+-1 VAC.

AC/DC Converter

We will use an AC/DC converter to connect the outlet to the microcontroller

Requirements	**Verifications**
1. Should be able to convert 120VAC to 5VDC 2. Must produce at least 200mA.	1. Connect 120+-10VAC to the input terminals and measure the voltage across the output terminals which should be 5+-1 VDC. 2. Measure the current produced from the output terminals when above voltage is supplied and ensure it is above 200mA

Lightbulb

We will need a light source to be connected to our microcontroller to light up when the user is in a lighter sleep cycle.

Requirements	**Verifications**

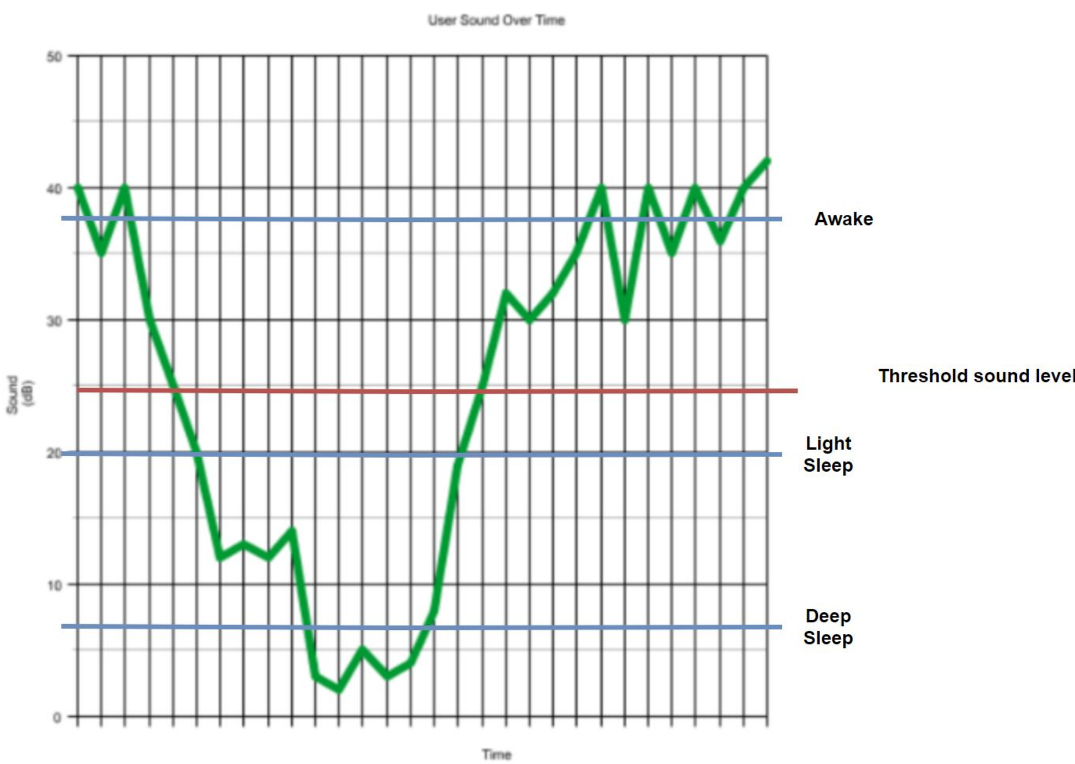
1. Should turn on when supplied with 120VAC	2. Connect 120+-5 VAC to the lightbulb and check that the lightbulb turns on.

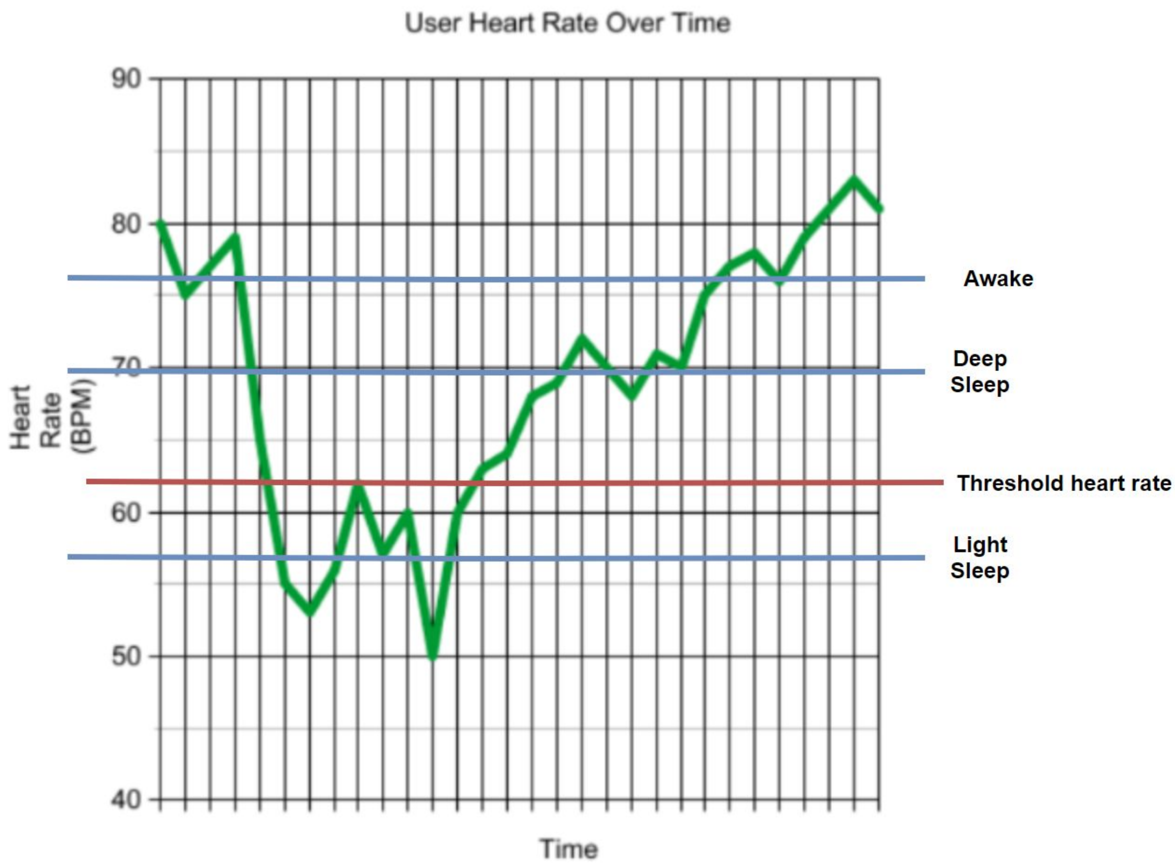
Power Supply

To power our Lightbulb subsystem, we plan to use a standard wall outlet or power generator to power up our Arduino and the rest of the components.

2.4 Tolerance Analysis

Given that our product will be recording user data and attempting to wake up a user based on their sleep cycle, we will need to create an algorithm that effectively detects the stage of sleep the user is in. To make this work, we will need to be able to differentiate between awake, deep sleep, and light sleep so as to avoid false positives and the light turning on at the wrong time. To do this, we plan to measure the normal movement, sound and pulse of a person when they're awake and make sure that the trigger for the light occurs at levels lower than that.





User Heart Rate Over Time
90
80
70
60
50
40
Heart Rate (BPM)
Time
Awake
Deep Sleep
Threshold heart rate
Light Sleep

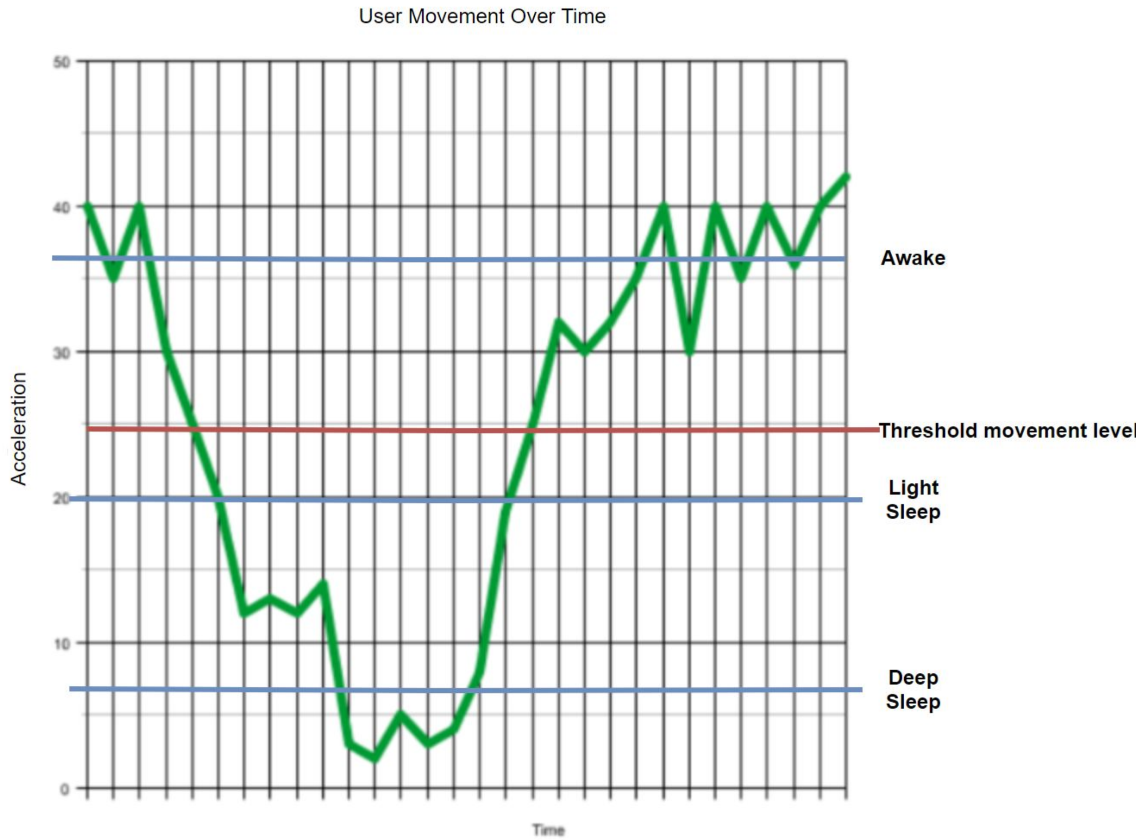


Figure 4 Sample Data Thresholds

We will calculate these threshold values by tracking user data and establishing the average sound, movement, and heart rate levels of the user while awake. According to research [7], a person's movement, heart rate, and sound decrease during sleep. When a user enters deep sleep, the user's movement and sound decrease further, but their heart rate increases, nearing the heart rate levels during wake hours. We can therefore measure the fluctuations in movement, sound and heart rate during a user's sleep cycle and use that to find the thresholds for when the user is in light or deep sleep.

We will also need to prove that our design works. To do this, we are prepared to volunteer to use the band and record it working properly or at least supply data to the band and show that it responds correctly.

3. Cost and Schedule

3.1 Cost

Part #	Manufacturer	Description	For	Price	Qty	Total
ATmega328	Microchip	8 bit controller	Both subsystems	$2.00	2	$4.00

Hc-05	HiLetGo	Bluetooth chip	Both subsystems	$7.99	2	$13.98
Max9814	Adafruit	microphone	band	$7.95	1	$7.95
ADXL343	Analog Devices	Accelerometer	band	$5.95	1	$5.95
	PulseSensor.com	Pulse sensor	band	$9.95	1	$9.95
CR2032	Maxell	Lithium batteries	band	$0.95	2	$1.90
2963	HiLetGo	Relay	lightbulb	$3.23	1	$3.23
	HENGRC	Mesh Milanese Loop band	band	$7.80	1	$7.80
OSMPW2-5	OSM Inc.	AC/DC Converter	lightbulb	$22.50	1	$22.50
L125A23N25UNV27K	TCP	Lightbulb	lightbulb	$8.59	1	$8.59
DS3231	Adafruit	Clock	band	$7.99	1	$7.99
Total						**$90.34**

3.2 Schedule

time	Han	Melech	Weipeng
2/22 - 2/27	work on design document & CAD assignment	work on design document & CAD assignment	work on design document & CAD assignment
2/28 - 3/6	work on design document	work on design document	work on design document
3/7-3/13	do researches on bluetooth module connection on Arduino	purchase parts & Prepare PCBs	purchase parts & do research on sensor
3/14-3/20	soldering assignment & simulation assignment & continue the research	soldering assignment & simulation assignment & finish PCB designs	soldering assignment & simulation assignment & continue the research
3/21-3/27	set up arduino simulator for testing	hardware assembly and testing (unit testing)	set up github repo for code sharing

3/28-4/4	start to work on algorithm for data exchanges (bluetooth module)	start to work on algorithm to acquire data from pulse sensor	start to work on algorithm to acquire data from accelerometer
4/5 - 4/11	algorithm to acquire the data from microphone and work on algorithm for the automatic mode	start working on algorithm for automatic mode which combines the user data and requested wake up time to tell us when to wake up the person	Work on algorithm for the manual mode & algorithm to control the light
4/12 - 4/18	system testing for the combined software	final assembly	system testing for the combined software
4/19 - 4/25	demo	demo	demo
4/26 - 5/2	work on final paper	work on final paper	work on final paper

4. Safety and Ethics

Before developing our project, we have taken into account the safety of our users as we include many electrical parts in our product. There are two major safety and ethics concerns for the end users. The first concern is the data manipulation, because the device is constantly measuring biological data of the user. Therefore, it is very important to use the data correctly and prevent it from leaking, as stated in the 8th rule of IEEE Code of Ethics. To comply with this, we promise our users that we won't record the data measured from them in any means, and the data is only transmitting to the smart light bulb subsystem.

The second concern is safe use of the batteries. We are using 3 Volt Lithium ion batteries to support the band which could create hazards of overheating and exploding. Following the first rule of IEEE Code of Ethics, we will follow the general battery safety documents and ensure the battery is stored in a secure location in our subsystem with terminals covered by insulating material to ensure that there are no short circuits. Additionally, during usage, we will ensure our users avoid swelling the batteries by adding documentation instructing them on how to charge the batteries correctly to avoid overcharging.

5. Citations

[1] Roitmann, E. (2017, June 16). To snooze or not to Snooze: The truth about the snooze button. Retrieved March 03, 2021, from https://blog.withings.com/2017/03/16/to-snooze-or-not-to-snooze-the-truth-about-the-snooze-button/

[2] McCarthy, N., & Richter, F. (2015, June 08). Infographic: Americans are tired most of the week. Retrieved March 03, 2021, from https://www.statista.com/chart/3534/americans-are-tired-most-of-the-week/#:~:text=45%20percent%20of%20Americans%20sleeping,or%20more%20days%20per%20week.

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