Rooster Band
The Wristband That Keeps You Awake

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ECE 445 Project Proposal - Fall 2019
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Introduction:

Objective:

Everyday life has become fast paced and with so much work to do or unexpected events, getting a good night's sleep can be hard to come by. Some people also have sleeping disorders which make them want to sleep at random times. People being drowsy can lead to sleeping in class, in meetings, behind the wheel, or on transportation. This will lead to them missing their stop, information, or even fatal accidents.

With the wristband we are creating, people will be kept awake within 5 minutes of entering the first stage of sleep. It will use an accelerometer, pulse, and muscle sensor that will collaborate to accurately tell if the user has entered the first stage of sleep. Once the sensors send a positive single that the user is in stage 1 of sleep, then the wristband will use a small vibration motor, small shocker, and a speaker to get the user back to being alert.

Background:

A large sleep census conducted by Sealy and the Loughborough University in 2016 showed that in the 5 countries where the census was conducted, an average of around 23% percent of people suffer from insomnia, and only 24% of people get the recommended 8+ hours of sleep. Clearly many people around the world have sleep problems and can’t get enough sleep. The study further shows that around 47% of people take naps during the day which disrupts their work and school day.[1] People are clearly having trouble staying awake and our device should be a simple solution that requires minimum effort for the user to take advantage of.

At first this project may just seem to be as simple as adding a vibrating function to one of the popular smartwatches or wearable sleep monitors but there are clear differences. The aforementioned devices’ main goal is to track a person's sleep, using an accelerometer to record the movements of the wearer and determine the wearer’s sleep status by the stillness of his/her body.[2] The problem with this is twofold. Firstly, the movement of a body during sleep will only completely stop after stage 2 of NREM sleep, meaning that by the time the user has been detected sleeping, he/she has already been asleep for 10-20 minutes and the damage will have already been done. The second problem is that it won’t be able to detect people falling asleep in other settings besides laying down on a bed making it useless for drivers and the like.

High-Level Requirements List:

1. Accurately detect if the subject is entering sleep state (hopefully detect sleep stages
2. Once sleep is detected, alert the subject to wake.
3. Minimum of 30 mins of continuous runtime(long enough to chase off sleep) while activating all waking peripherals. 6 hours of continuous silent runtime.

Design:

Block Diagram:

There are a total of 4 subsystems that we plan to implement for this project. Each one of these subsystems will fulfill or help fulfill one or more of our high-level requirements. The sleep detecting subsystem will be comprised of the 3 sensors we will be using to detect sleep without 3-5 minutes of stage 1 non-rem sleep. Every sensor will be able to send information to the control subsystem which will process everything through a programmable microcontroller that can use a bluetooth transceiver to connect to a smartphone app. When it gets positive signals from the sleep detecting subsystem, it will send signals to the wake up subsystem which deploys one or more of the 3 stimulation devices to wake up the user. Everything will be powered by our power subsystem which will have a 3.3v lithium ion battery that goes through a voltage regulator to maintain a steady voltage that will power all of our individual parts.

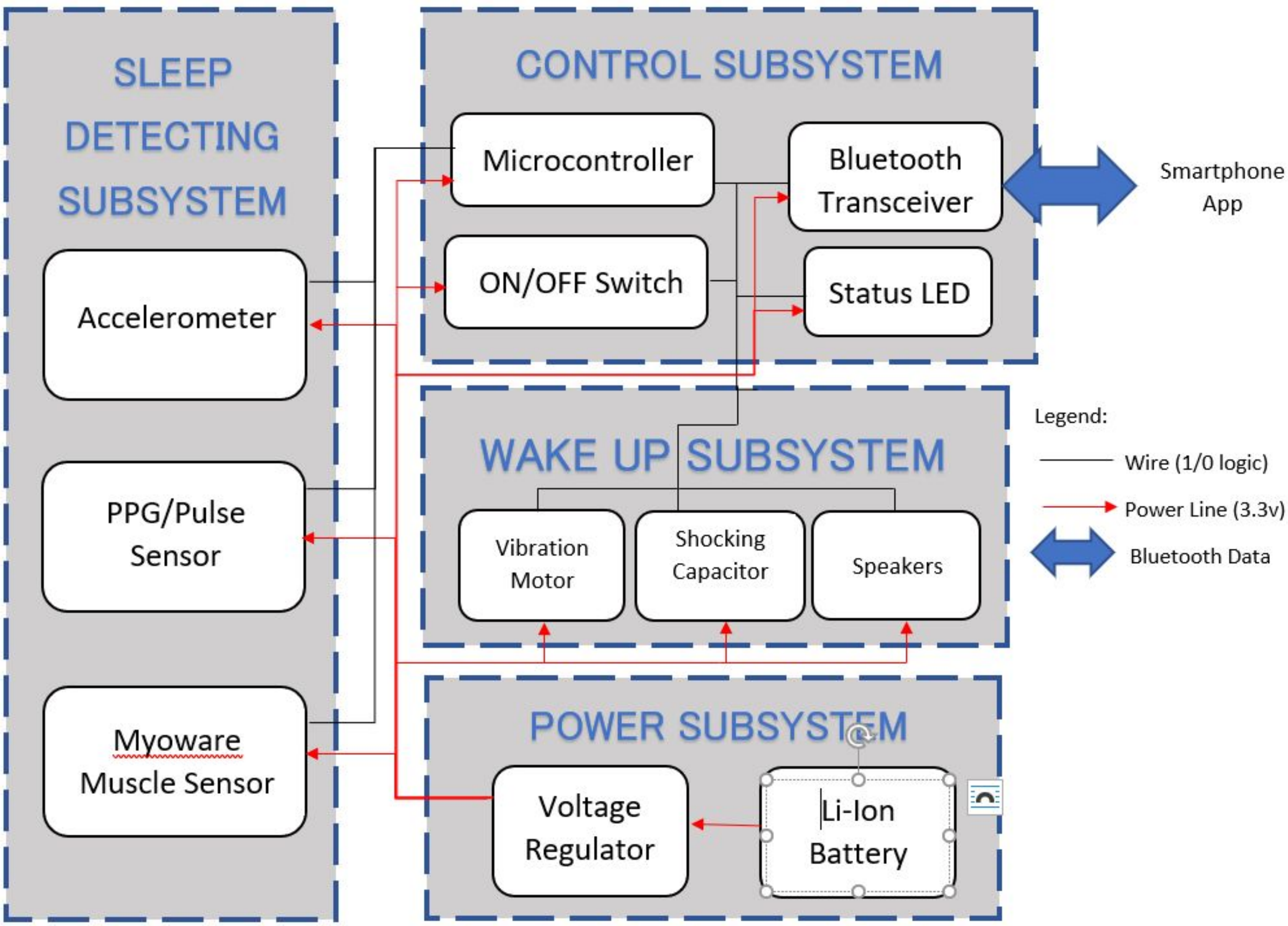

Figure 1

Physical Diagram:

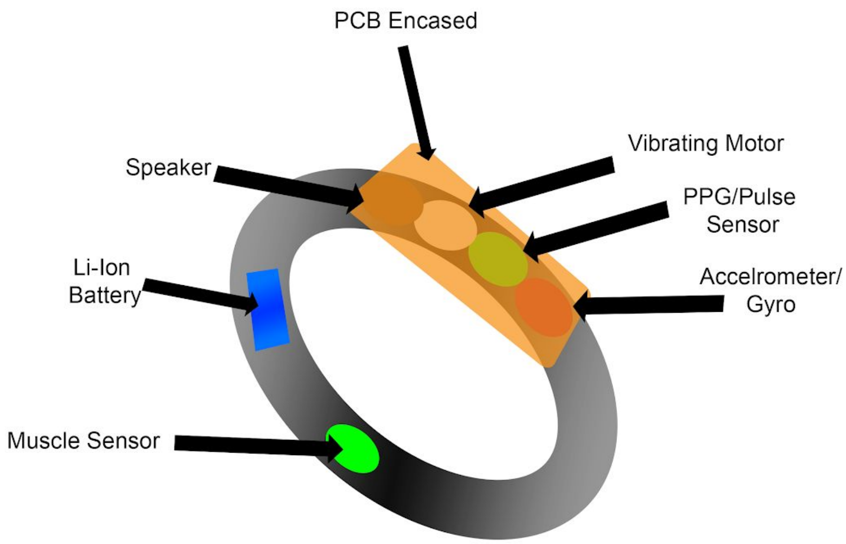

Figure 2

Our ideal form for this wearable device is that of a wristband. Wristbands are commonly used wearables that are convenient and compact. They are casual enough to wear in any situation making it very accessible. Figure 2 is a physical design prototype is similar to a watch where instead of a watch face, we will have a solid box that will hold the pcb and most of the internals including the pulse sensor and accelerometer. This box is represented by the orange rectangle in the diagram and the two dots underneath are the pulse sensor and accelerometer. The pulse sensor will be placed in a way to effectively read the user's pulse. The muscle sensor will be placed somewhere in the band to spread out the sensors to save space on the pcb and will be connected by a wire that runs through the band. Other parts such as the battery and speakers could also be placed in the band in a similar way to save space in the box. The material for the band is largely undecided. Possible options are a stretchable rubber ring so that the band will be tight enough for the sensors to have close contacts with the skin or a cloth wristband with stretchable fibers to make it more comfortable. So far there are no real physical requirements for the wristband besides being able to fit on a human wrist. An alternative will be an armband which functions as a larger wristband that will give us enough space to implement all the electronics but has the downside of being not as compact and casual as a wristband.

Functional Overview:

1. Sleep detecting subsystem: All the sensors will be connected and interpreted by the microcontroller. When a sensor readings fit a criteria, they will send a positive signal to the microcontroller. They will be connected directly to a power switch that will let the user control when the sensors are on or off.
    1. Accelerometer:This sensor will measure how much the user is moving. When the sensor is measuring low amounts of movement from the user, it will send a positive signal to the microcontroller.
    2. PPG/ Pulse sensor: This sensor will measure the pulse of the user. The sensor needs to measure a consistent heart rate that is lower than the user's resting heart rate. This sensor will have to be calibrated to each unique user's resting heart rate.
    3. Myoware Muscle Sensor: This sensor measured the voltage across a muscle. When the sensor measures a low voltage a positive signal will be sent to the microcontroller. Muscles relax in stage 1 of sleep and will give off a smaller voltage than someone who is at a resting state.
2. Control Subsystem:
    1. Microcontroller: This unit will take the positive signals sent from each sensor and weigh according to reliability. If the sensor is more reliable, the positive signal will have a bigger weight and the unit will send the appropriate signals to the Wake up subsystem.The unit will also interact with a bluetooth transceiver, which will let the user interact with the wristband through a mobile app. A constant signal will be sent to an LED light which will show that all subsystems are working.
    2. On/Off Switch: This unit will let the user turn the wristband on or off. No power will be supplied to any subsystem when the switch is in the off position.
    3. Bluetooth Transceiver: This unit will act like a bus for information the user sends from a mobile app to the microcontroller. The user will be able to turn the sensors off and see if there is an issue within the wristband that will require maintenance.
    4. Status LED: This LED will indicate whether all the components of the wristband are working properly. If a component is malfunctioning then the microcontroller will turn on the LED light, indicating maintenance on a component.
3. Wake up Subsystem: This subsystem will be controlled by the microcontroller and only active when the sensors combined signals are strong enough to indicate that the user is in stage 1 of sleep. There will be 3 attempts to wake the user up and they will be attempted in a certain order to be discreet.
    1. Vibration Motor: This unit will be the first attempt to wake up the user by using an imbalanced motor to vibrate. The wristband will vibrate on the user's arm.
    2. Shocking Capacitor: This unit will be the second attempt to wake up the user. This will charge a capacitor and the capacitor will discharge using the user's body

to complete the circuit and send a shock. The current through the user must be under 10 mA.

3. Speakers: This will be the final attempt to wake the user. The user will be able to control what the speaker sends out. This will be the least discreet form of waking up a user.

4. Power Subsystem: This subsystem will supply power to the wristband components.
    1. Voltage Regulator: This unit will take the power supplied by the Li-ion battery and send the appropriate power to each component according to their power ratings. Too much voltage will break the component and little voltage will not let the component work properly.
    2. Li-ion Battery: This unit will send power to the wristband. A set voltage sent to the voltage regulator.

Block Level Requirements

Component	Requirement
Accelerometer (MMA8452Q)	1. $1.95V < V_{DD} < 3.6V$ 2. $1.62V < V_{out} < 3.6V$ 3. $I_{max} = 1mA$ at $2.5V$ V_{DD} 4. SPI capable 5. Can detect a motion of head dozing
Pulse sensor	1. $3V < V_{in} < 5V$ 2. $3mA < I_{in} < 4mA$ 3. SPI capable 4. Reliably send pulse info while the user moves
Muscle sensor	1. $3.1V < V_{in} < 6.3V$ 2. $I_{max} < 14mA$, $I_{rms} = 9mA$ 3. SPI capable 4. Detects when the muscle on the attached site activates, differentiate flinch and moving of the muscle
Micro Control (stm32)	1. $1.8V < V_{in} < 3.6V$

	2. I_{VDD} < 120mA, I_{IO} < 25mA 3. SPI capable 4. Bluetooth capable
Vibration motor(10B27.3018)	1. 2.5V < V_{in} < 3.8V 2. I_{max} = 75mA at 3V 3. Test if capable of waking from a dozing state(no data found)
Speaker	1. Output > 65dB to wake user 2. P_{max} = 2W
Voltage regulator	1. Vout = 3 V ± 0.3 V at 100 μA
LED	1. I_{max} = 25mA 2. V_{max} = 3.5V, 3. Indicate Bluetooth connection 4. Indicate sleep state, device power on

Table 1

Risk Analysis

The critical element of this device is the algorithm for detecting sleep. Our objective is from the readings of the sensors, detect within 1 ~5 minutes since the user goes into drowsy state. Since the device is proposed to be worn, the sensor readings will be unstable due to user movement. It is a hurdle to handle the extremes and prevent as much false positives as possible. By increasing the length of each timeframe which we will process to categorize sleep/wake state, we can rule out outlying readings, but also the response time of our device will be longer. Also since the device will be worn for long durations, it is crucial to prevent false positives. Much like modern antivirus software companies balance false positive rate and false negative rate, we must find the balance that presents reliability without annoying the user.

Briefly mentioned above, maintaining proper contact for all sensors will be another risk for the device. Even when the User undergoes heavy activities, the sensors must function correctly. Also when one of the sensor loses proper contact, algorithm should recognize and ignore readings. Device should be water resistant to prevent electrocution of the user. If these goals are not reachable, the device should be targeted for stationary use only.

Safety and Ethics

The user should not have to take off the wristband when they go outdoors, so the wristband must be water resistant to keep the device safe from a potential short.

The components will have to be stable and have strong connections so that they are not broken when the vibration motor turns on. If they do not then the wristband connections can break and can overload the capacitor causing it to explode or create a short in the wristband. Therefore we will follow code #6 of the IEEE code of ethics and promise “to maintain and improve out technical competence,”[3] and create a complete and safe device with no technical defects that may harm the user.

There are safety hazards around the shocking capacitor that attempts to wake the user up. This is in danger of violating code #9 of the IEEE code of ethics, “to avoid injuring others, their property, reputation, or employment by false or malicious action.”[3] To avoid this, the current will have to be less than 10 mA with a fixed voltage capacitor and a variable resistance depending on the person. A factor for resistance is moisture, which can come from the user sweat or from moisture in the air due to weather. This function is also optional and can be turned off via the app if a user is uncomfortable using it.

This device can use shocking as in attempt to wake up the user. This function will be at the user’s consent if they choose to active the function on the mobile application “to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment” [3].

Resources:

[1] Morgan, Kevin. (2016, Nov) The Sealy Sleep Census. Sealy Corp, TX[Online]. Available: http://www.sleep-census.com/media/PDF/Sealy Sleep Census final report.pdf.
[2](2019, July 27)How Do Sleep Trackers Work? Understand Sleep Tracking Tech. Tuck Sleep.[Online]. Available:
https://www.tuck.com/how-sleep-trackers-work/
[3] Ieee.org. (2006). *IEEE IEEE Code of Ethics*. [online] Available at: http://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 9 Sep.. 2019].