SMART PILLOW

ECE 445 Senior Design Project Proposal

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1 Introduction

1.1 Problem

As technology advances, more people tend to use devices such as their phones or laptops right before going to bed. Studies have shown that sleep is affected drastically due to the use of technology in the hour before going to bed. This is mainly due to the blue light that is produced by the screens of these smart devices. The blue light produced has been known to interfere with the production of melatonin (the sleep hormone) in the body. This can result in less satisfactory sleep which causes people to be sleepier and more fatigued during the day. Some studies have also shown that bright screens can have an impact on alertness which can lead to users having disrupted sleep more often. Repeated dissatisfactory and disrupted sleep can lead to conditions such as sleep apnea. This is a growing concern due to the increase in the use of technology and can be dangerous.

The signs that a person is not having satisfactory sleep can be loud snoring and frequent changes in sleeping positions. One way that can improve sleep is by listening to relaxing music or some peaceful podcasts. However, you cannot be sure when you would be having disrupted sleep. Smartwatches do a good job of detecting your sleep cycle but they must be charged very often and they are not able to help you improve your sleep.

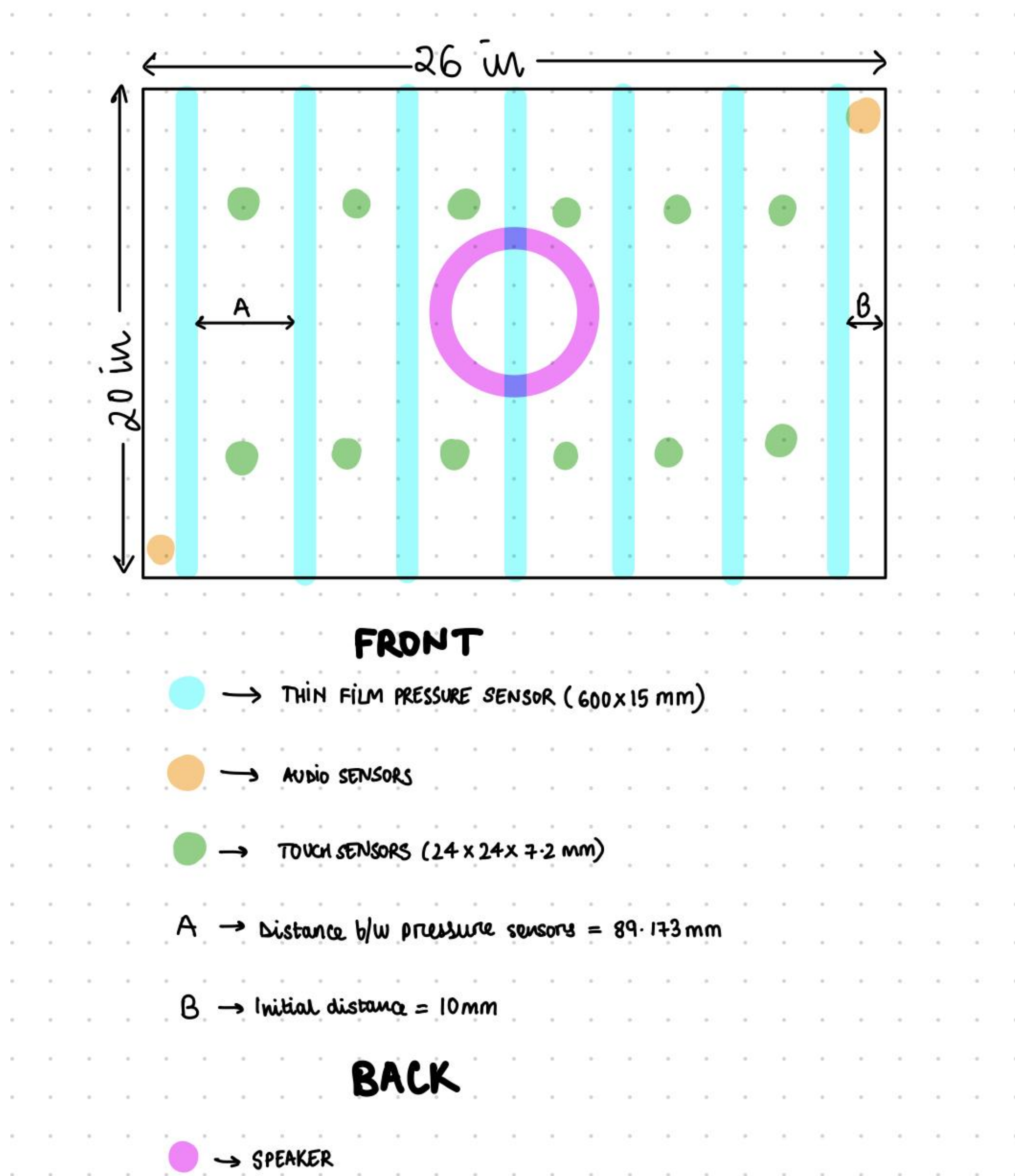
1.2 Solution

To fix the above-stated problems, we propose the implementation of a smart pillow. Through this smart pillow, we aim to not just track sleeping habits, but also improve them. We will track the sleeping habits of the user through the following sensors: touch sensor, audio sensor, and pressure sensor. In addition to these sensors, we will also use a Bluetooth speaker that can play white noise or any other sounds/music that the user feels comfortable with to aid sleep.
The audio sensor will be used to detect snoring which will provide us with insight on the quality of sleep of the user and potentially also detect sleeping disorders like sleep apnea. The touch sensor will be used together with the pressure sensor to determine the various sleeping positions of the user. This will then help us determine the quality of sleep of the user at each sleeping position.

We believe that our idea stands out from what is already available today through the usage of the Bluetooth speaker system and the fact that this is more cost-effective. Most devices that are currently available include mattresses and smartwatches. We believe that this is the feature that sets us apart from the other technology that is currently available in the market such as smartwatches and mattresses.

We will be using a power system to regulate the power of each sensor subsystem. Hence we will have to use a PCB since it will contain all the logic related to the sensors and the power modules. We believe that our product is a cost-effective and more versatile alternative to the current products available on the market.

1.3 Visual Aid

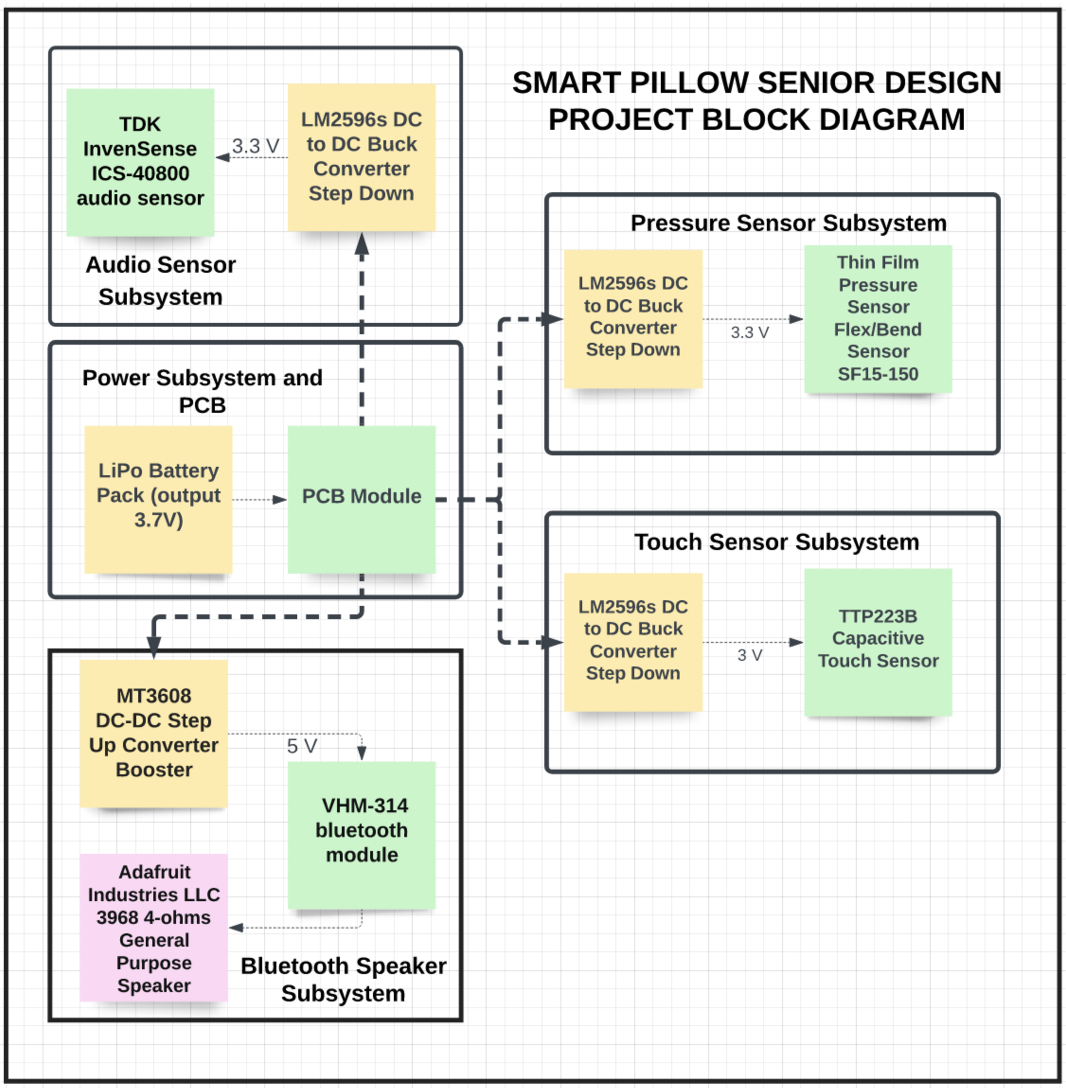


1.4 High-Level Requirements

1. The pillow should be able to detect motion when the person is in contact with the surface of the pillow.
2. The pressure sensor and the audio sensor readings should be used in combination to detect sleep problems.
3. There should be no interference in the data collected by the sensors from other components of the pillow (example: the bluetooth speaker should not interfere with the working of the audio sensor).
4. The pillow should be comfortable, which means that the user should not be able to feel the sensors when they touch their head to the top of the pillow
5. The front and back of the pillow should be clearly differentiated so the data from the pillow is actually usable.

2 Design

2.1 Block Diagram



2.2 Subsystem Overview

2.2.1 Power Subsystem

For the power subsystem, we will consider 4 parts that may require different power sources. These parts are (but are not limited to):

1. The pressure sensor subsystem
2. Touch sensor subsystem
3. The speaker (power here will be provided to the Bluetooth module and through that to the stereo amplifier unit and speakers)
4. The audio sensor subsystem

To ensure that the pillow remains light and comfortable we have decided to consider using Lithium Batteries. These are usually lightweight and are used in a variety of medical devices ensuring that they will be safe for use. Additionally, they have good capacity, and sufficient voltage for the sensors we plan on using (thin film pressure sensors and audio sensors). Doing some further research into flexible batteries we noted that most of the reported flexible batteries are based on flammable organic or corrosive electrolytes, which suffer from safety hazards and poor biocompatibility for devices (Stapleton)[1]. Hence, we have gone for the more rigid lithium-ion batteries as alternative sodium-powered batteries are too expensive for a project of this scale. To ensure that we can make the system as modular as possible we plan on using Lithium Polymer batteries.

2.2.2 Pressure Sensor Subsystem

This subsystem will mainly detect changes in pressure when a person is sleeping on the pillow. Usually, the pressure due to one's head can be used to determine the quality of sleep. People that tend to have poor sleep tend to put higher pressure on the pillow. Along with this, changing head positions very often can be a sign of bad sleep. Thin Film Force or Thin Film Pressure sensors SF15-150 Resistance will be used to detect changes in pressure and changes in head positions. One Thin Film Pressure sensor is 3.9 inches long, 0.4 inches wide, and 0.25 mm thick. Given the length and width of each sensor, we would be using 5-6 such sensors and placing them vertically across the pillow as shown in the visual aid. Each sensor would require around 3.3V to run. Since our power supply is 3.7V, we would be using LM2596s DC to DC Buck Converter Step Down Converter to get the desired voltage for the pressure sensor.
The use of multiple sensors will help us detect the different head positions of the person (which will be calibrated beforehand). The multiple sensors will also ensure the accurate detection of pressure applied to the pillow while sleeping.

Requirement:

- *The sensors must be cost-effective*
- *Should be extremely thin to ensure comfort while sleeping*
- *Must be placed at appropriate distances to ensure accurate reading of the head position*
- *Must be used to detect the amount of head pressure while sleeping*

2.2.3 Touch Sensor Subsystem

This subsystem will work in conjunction with the pressure sensors. Since the pressure sensors are strips, they would not cover the entire pillow. We will be using multiple small touch sensors that would be placed between two pressure sensors. The main aim of using the touch sensor is to detect the location of the head on the pillow because as mentioned earlier, head positions can help determine if a person is having bad sleep. Along with this, our goal is to try to use the touch sensors as a way to activate and deactivate other sensors to save power for our entire device. The dimensions of the touch sensor that we would like to use would be 24x24x7.2 mm. Each sensor would require around 3 volts to run. Since our power supply is 3.7V, we would be using LM2596s DC to DC Buck Converter Step Down Converter to get the desired voltage for the touch sensor

Requirements:

- *Small in size to ensure the comfort of the pillow*
- *Able to detect head positions*
- *Can be used to activate or deactivate other sensors which can help save power for the whole device*

2.2.4 Audio Sensor Subsystem

This subsystem will be used to detect sounds such as snoring. Snoring is the most common sign of disturbed sleep and sleeping disorders such as sleep apnea. For the use case of this project, we will be making use of two audio sensors so that we are able to detect any sounds produced by the user. We will be utilizing the TDK InvenSense ICS-40800 audio sensor for our device. It has a sensitivity of -38dBV and Signal to Noise ratio of 70dBA. We believe that these specifications will be adequate enough to detect sounds such as snoring which typically range from 45-60dB. The dimensions of each sensor are 4x3x0.97mm and require 155uA to run. Since our power supply is 3.7V, we would be using LM2596s DC to DC Buck Converter Step Down Converter to get the desired voltage for the audio sensor. (“ICS-40800 TDK InvenSense | Mouser”)

Requirements:

- *Small in size to ensure the comfort of the pillow*
- *Must be able to detect sounds such as snoring*

2.2.5 Bluetooth Speaker Subsystem

This subsystem can be broken up into 3 main parts: The connection from the power subsystem, the Bluetooth module, and the speakers. To ensure that the speakers get the right amount of power to function at a higher level, a voltage booster will be required. Hence we plan on using a step-up converter to convert the incoming 3.7V from the power source (the LiPo batteries) to the 5V that the system can utilize. To accomplish this, an MT3608 DC-DC Step Up Converter Booster (Electronic Co, Ltd.) will be used. The potentiometer on the booster will allow us to adjust the output voltage to 5V. The next step is to find and use the correct Bluetooth module. This means one that combines a Bluetooth receiver with a stereo amplifier and decoder, enabling us to both receive and play the song using only one chip. The choice for this is the VHM-314. This Bluetooth board offers Bluetooth 5.0 connectivity and comes in at a small size of 3cmx3cm which is something that we can easily fit into our design. The board will receive power from the PCB connection and will only be powered when the audio sensor is not in function. Finally, this Bluetooth board will be connected to a single speaker. The Adafruit Industries LLC 3968 4-ohms General Purpose Speaker is an ideal choice because it has a lower power rating of 3W and an ideal size (40mm diameter). To summarize, the main components of the design will be in the middle of the pillow with the speaker being at the back to all for comfortable hearing.

Requirements:

- *Small in size to maximize space for more important sensors*
- *Ability to work with the audio sensor, switching it off when it is on*
- *Good connectivity to any device*
- *Acceptable sound quality, ability to decipher what is being played*

2.3 Tolerance Analysis

The batteries we have chosen have a voltage of 3.7V and a power rating of 150mAh. This would work perfectly as a battery pack would allow us to power all the sensors. The calculations to prove this can be shown by using the specifications of an audio sensor:

- A typical audio sensor has voltages ranging from 3.3V to 5V.
- The operating current is usually 4mA to 5mA (Jadhav).
- Taking the upper limits, we get the power as 25mW. Running for 10 hours, the maximum power is 250mW.
- Run at 5V for the entire period of time (using a voltage converter) the maximum value comes to 50mAh which is well below the rating of a single lithium polymer battery.
- The voltage ratings for the thin film pressure sensor (3.3V), the Bluetooth module and speaker (5V), and the touch sensor (3V) all lead to similar calculations, telling us that a pack of batteries will be more than capable of providing power to run the 3 subsystems.

- Additionally, as the speaker and audio sensor subsystems cannot run at the same time, the power converted there will be enough to account for longer battery life in case the user forgets to switch the system off the previous night or has any other such problems.

3 Ethics and Safety

This project does not breach any ethical guidelines. This product is designed for those interested in improving their sleep quality. Throughout the development of this product, we plan to strictly adhere to the IEEE and ACM Code of Ethics. Safety will be the top priority of everyone involved in this project. Since our project is utilized in close proximity to the user's face and neck area, we will be using low-voltage components to ensure safety. In addition to this, during testing, we will not be collecting or storing any personal information of those involved. As engineers, we also have a commitment to sustainability. Through the development of this product, we will attempt to optimize the part list as best as possible. This will be accomplished by comparing different components and seeing which will give us the superior performance and the longest life span.

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