

Screening Habit Correction Headband

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1. Introduction

1.1 Problem

In the modern digital era, the widespread use of desktop computers and personal devices has led to a large increase in daily screen exposure. As people spend long periods seated in front of a monitor, they often fall into poor posture habits. According to Brown University Health, modern posture is often characterized by sitting at a computer with a tilted pelvis, slumped shoulders, and a forward head position [1]. This lack of proper posture is a major cause of the back and neck pain experienced by millions of people.

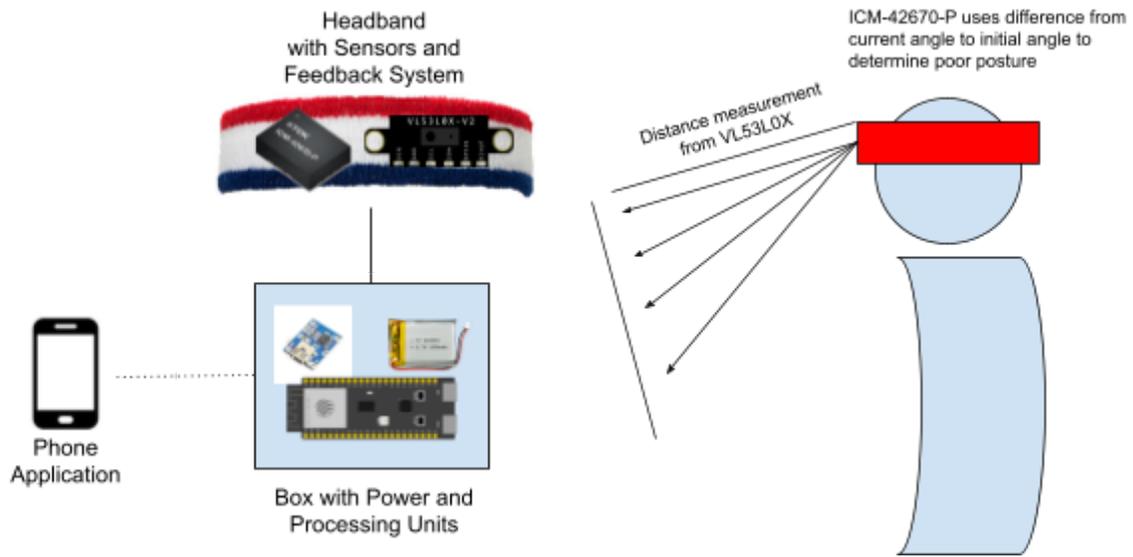
Poor posture causes imbalances in the body where some muscles get stretched and weakened while others become shortened and tight. Over time, this causes the body to get tired and wear down, leading to stiffness and pain. Additionally, increased shoulder tension from bad posture can lead to headaches [1]. Regarding eye health, looking at digital screens for long periods can cause digital eye strain. When using these devices, people tend to blink only 5 to 7 times a minute, compared to the normal rate of 15 times a minute. This lack of moisture can cause vision to blur and eyes to become dry, achy, or stinging [2]. Addressing these habits is critical for maintaining physical well-being and preventing daily discomfort.

1.2 Solution

Our solution, the Screentime Habit Correction Headband, is a wearable system designed to correct posture habits through real-time feedback. The system consists of a lightweight headband worn by the user and a stationary control box placed on the desk. The headband uses sensors to continuously monitor the user's position relative to their workstation. Specifically, an Inertial Measurement Unit (IMU) tracks the angle of the head to detect slouching or looking down, while a Time-of-Flight (ToF) sensor measures the exact distance between the eyes and the screen.

To correct the user, the device compares sensor data against a baseline set when the device is powered on. If the user leans closer than the recommended distance, has bad posture, or sits for too long, the system triggers immediate feedback via a vibration motor, a buzzer, and LED lights. To keep the headband light, most of the electronics, including the battery, power management, and the main microcontroller (ESP32), are inside the stationary desktop box. This box connects to the headband via a cable. Additionally, the microcontroller sends data via Bluetooth to a mobile app. This allows users to see their habits, track improvements over time, and view past data regarding their posture and screen time.

1.3 Visual Aid

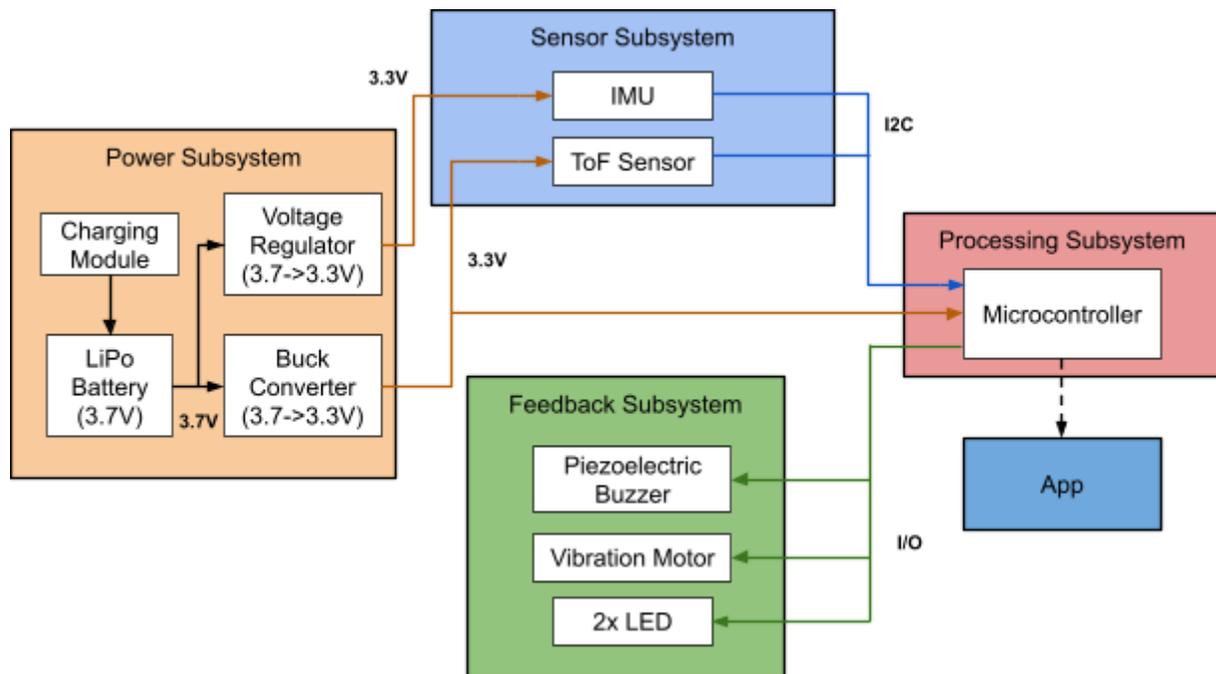


1.4 High-level Requirements

- The device must measure the distance from the user to the screen with an accuracy of ± 0.5 inches and detect head angles greater than 15 degrees.
- The system must trigger the vibration and audio alarm within 3 seconds when the user is too close to the screen (less than 12 inches), has bad posture (head angle greater than 15 degrees), or has been sitting still for 60 minutes.
- The power subsystem must allow the device to operate continuously for at least 2 hours on a single battery charge while maintaining Bluetooth connection and collecting sensor data.

2. Design

2.1 Block Diagram



2.2 Subsystem Overview

2.2.1 Power

Our power subsystem will be in charge of regulating and directing power to the rest of the components in the device. Completely residing in the box, it will contain a 3.7-volt lithium-polymer battery as well as a TP4056 charging module, allowing the battery to be rechargeable. The power subsystem will also be able to regulate and step down voltages using a voltage regulator and a buck converter. By using the LDL1117-3.3 voltage regulator, 3.3 volts can be sent to the IMU in the sensor subsystem with minimal noise. The buck converter will also direct 3.3 volts efficiently to the ToF sensor and the microcontroller. For the power subsystem to function correctly, the battery must supply at least 500mA to the voltage regulator and buck converter at 3.7V +/- 0.1V. The voltage also must be stepped down to 3.3 +/- 0.1V in order to support the components in the system.

2.2.2 Sensors

There are two sensors in the system which are both inside of the headband. The first sensor is the ICM-42670-P, which is an inertial measurement unit that is able to sense position and orientation in order to tell the microcontroller to send feedback when the user's posture is bad. This sensor is powered by 3.3 volts coming from the voltage regulator with little noise. The second sensor is the VL530X time-of-flight sensor, which is able to detect the distance from the user to a screen in order to tell the microcontroller to send feedback when the user is too close to their screen. This sensor is powered by 3.3 volts coming from the buck converter. For the sensor subsystem to be sufficient for our device, the

time-of-flight sensor must have a screen distance error less than 0.5 in and the inertial measurement unit must be able to detect head posture angle with accuracy within +/- 2 degree for an hour.

2.2.3 Feedback

The feedback subsystem consists of a vibration motor, speaker (Piezoelectric Buzzer), and two LEDs. The feedback components all will be driven by 3.3 volts sent by the microcontroller. There are two cases when the feedback subsystem will activate: one case is when the user is either slouching or too close to the screen, and the other case is when the user has been sitting in front of the screen for too long. Each case will turn on a separate LED, while both cases will activate the vibration motor and speaker. The LEDs and the speaker will reside inside the box so that the feedback is less intrusive but still noticeable, and the vibration motor will be in the headband. For the feedback subsystem to function correctly, the motor and buzzer must activate when the microcontroller detects the head posture angle at over 15 degrees or the screen distance is closer than 12 inches. Only one LED is turned on for each case. The feedback must turn off when the microcontroller detects that the user is in a good position.

2.2.4 Processing

The processing subsystem consists of the microcontroller, which is powered by 3.3 volts coming from the buck converter in the power subsystem. The microcontroller that we will be using is the ESP32. It will use sensor data as well as its own timer to determine when to send feedback to the user based on time of exposure to a screen, distance to a screen, and posture. The microcontroller will also manipulate the sensor data so the two cases' feedback won't interfere with each other. In addition, the microcontroller will have Bluetooth capabilities that will be able to communicate with the app and allow it to track data. For the processing system to function properly, the microcontroller must accurately activate the alarm in 3 seconds when poor head posture or low screen distance is detected, as well as when the user has been sitting for an hour. It should also be able to connect to the phone app via bluetooth.

2.2.5 App

The app will display the data of the sensors from the microcontroller using Bluetooth in a user-friendly way. The app will display the time it takes before the user's posture deteriorates or the screen gets too close to the user, the amount of times this occurs, and the general data such as daily screentime. The app will also have a graph of all these statistics that it can track over the course of a week. For the app to work, the microcontroller must be able to connect to the app and display the correct data. The app must store enough data points to track over a week. The app also must display accurate graphs for screen distance and posture times.

2.3 Tolerance Analysis

A potential risk of using the ICM-42670-P IMU is the possibility of drift over a long period of time. Because the position is being measured as a double integral of the acceleration, small errors can compound for a large position error. To resolve this issue, we will rely a bit on the sensor's tilt angles (pitch/roll) to determine the angle difference from where the IMU began. At power on, the initial angle is used as a reference point and when the angle differs from this reference by over 15 degrees, the alarm is activated by the MCU. Additionally, the angle is calculated using gravity as a reference to ensure the accelerometer can always determine which direction is down. Furthermore, to reduce the drift of our measured position, we will use a voltage regulator as opposed to a buck converter to power the IMU with less noise, as well as having the user recalibrate after a certain amount of time has passed.

3. Ethics, safety, and societal impact

In developing the Screentime Habit Correction Headband, we are committed to upholding the IEEE Code of Ethics, Section I, Item 1, which mandates that we hold paramount the safety, health, and welfare of the public [3]. Since our device is a wearable health monitor that provides physical feedback, our primary ethical responsibility is ensuring the user's safety. To prevent harm, the feedback mechanisms (vibration and audio) will be calibrated to non-intrusive levels to avoid startling the user or causing hearing damage. Furthermore, we must address the safety risks associated with our power subsystem, specifically the Lithium-Polymer (Li-Po) battery. Li-Po batteries can pose fire hazards if compromised. To mitigate this, we are utilizing a TP4056 charging module with built-in protection against overcharging and short-circuiting. We are also housing the battery in a rigid, stationary desktop enclosure rather than on the user's head.

We also adhere to the ACM Code of Ethics, Section 1.6, which requires us to respect privacy [4]. As our device collects data regarding user posture and screen time habits, we are responsible for handling this information securely. The companion app will only collect data necessary for functionality, specifically distance metrics and posture states, without storing unnecessary personal identifiers or sharing data with third parties without consent.

Finally, we recognize the societal and environmental impact of our project. Societally, our device aims to alleviate the widespread public health issue of musculoskeletal disorders and digital eye strain. This has the potential to improve workforce productivity and long-term quality of life. Environmentally, we are conscious of e-waste. By designing a durable, rechargeable system rather than one dependent on disposable batteries, we aim to minimize our environmental footprint. We will also encourage responsible recycling of the electronic components at the end of the device's lifecycle.

References

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