Screentime Habit Correction Headband

By

Colin Moy

Jake Chen

Zhiyuan Chen

Contents

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 soldiers, 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.
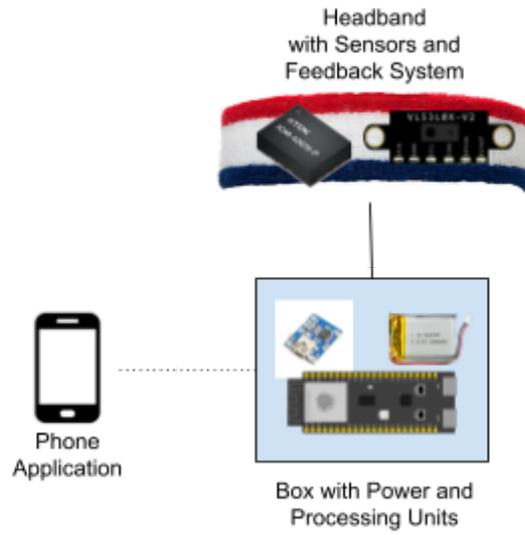
1.3 Visual Aid

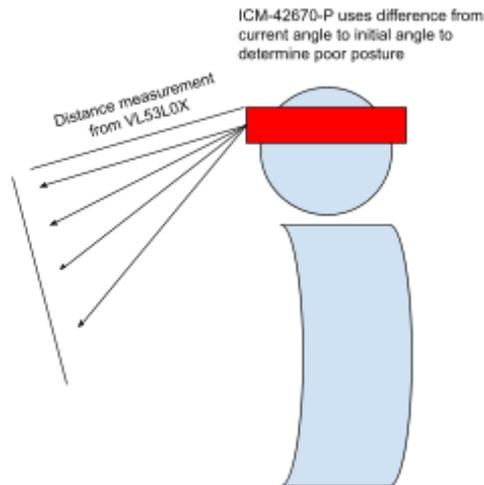Figure 1: General placement of main components.

Figure 2: Visual aid of sensor functions and headband use.

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.
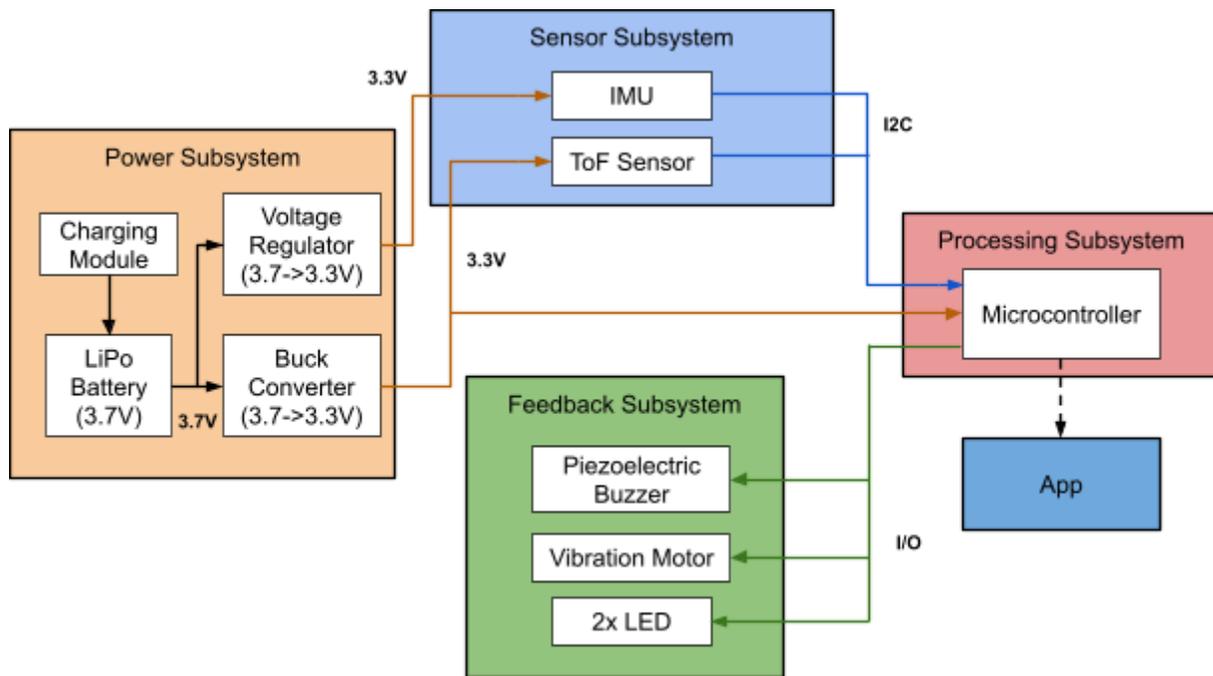
2. Design

2.1 Block Diagram

Figure 3: Block diagram of entire system

The design is divided into five main subsystems: Power, Sensor, Feedback, Processing, and App. The Power Subsystem utilizes a 3.7V LiPo battery, a charging module, and dual regulators (a voltage regulator and a buck converter) to supply a stable 3.3V to the device. The Sensor Subsystem collects real-time user data using an IMU for head pitch angle and a Time-of-Flight (ToF) sensor for screen distance. This data is transmitted via I2C to the Processing Subsystem, where an ESP32 microcontroller evaluates the inputs against calibrated thresholds. If poor posture or inadequate distance is detected for a sustained period, the microcontroller triggers the Feedback Subsystem, activating specific LEDs, a piezoelectric buzzer, and a vibration motor to alert the user. Concurrently, the Processing Subsystem transmits the posture data via Bluetooth to the App Subsystem for long-term user tracking and visualization.
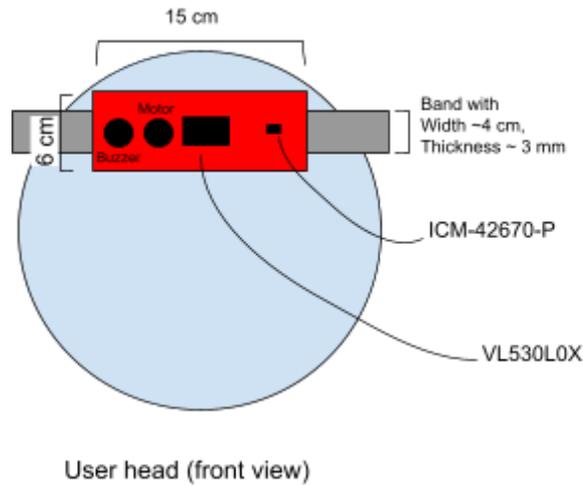
2.2 Physical Design

Figure 4: Front view of the headband with feedback and sensors.
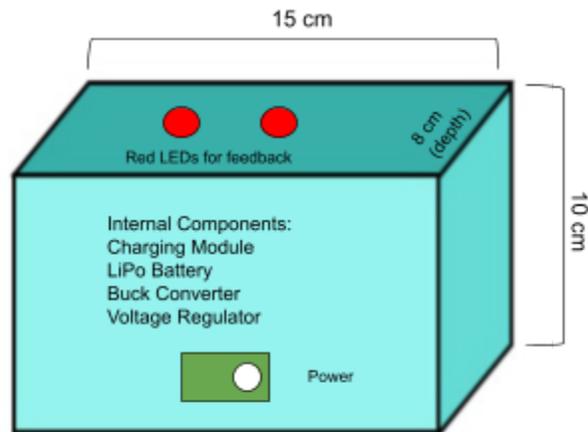
Figure 5: Physical dimensions of box containing power and processing systems, and 2 feedback LEDs.

The Screentime Habit Correction system consists of two primary physical components connected by a flexible cable. A 3D printed board (15 cm x 6 cm) is attached to an adjustable band with the board being mounted at the forehead. The VL53L0X sensor is mounted on the middle of the board to measure the distance to the screen. The ICM-42670-P is mounted to measure head tilt and is calibrated at power-on to detect head tilt. The desktop control box sits on the user's desk and contains all power electronics along with the ESP32-S3 microcontroller for processing and sending bluetooth data to a smartphone device. The box will also contain two status LEDs, a power switch, and a USB-C charging port. The box connects to the headband via cables carrying 3.3V power, 12 C datalines, and GPIO.

2.3 Subsystem Overview

2.3.1 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 3.7V 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 LP2950CZ-5.0 voltage regulator, 3.3V can be sent to the IMU in the sensor subsystem with minimal noise. The buck converter will also direct 3.3V 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 $\pm$ 0.1V. The voltage also must be stepped down to 3.3 $\pm$ 0.1V in order to support the components in the system.

Table 1: Power Subsystem – Requirements & Verification

Requirement	Verification
The voltage regulator and buck converter must step down the battery voltage to supply a stable 3.3V ± 0.1V to the sensors and microcontroller for a current load up to 500mA.	1. Connect the fully charged 3.7V LiPo battery to the input of the power subsystem. 2. Connect a programmable DC electronic load to the 3.3V output pins and set it to draw a constant 500mA. 3. Probe the 3.3V output pins using a Digital Multimeter (DMM). 4. Record the measured voltage in a data table to verify it remains between 3.2V and 3.4V.
The 3.7V LiPo battery must power the device continuously for at least 120 minutes while maintaining a minimum output voltage of 3.3V under a standard operating load.	1. Fully charge the battery to 4.2V. 2. Connect the battery to the assembled system and power it on. 3. Connect a DMM across the battery output terminals. 4. Use a stopwatch to measure the time elapsed until the battery voltage drops to 3.3V. 5. Record the total elapsed time as a single numerical value to verify it meets or exceeds 120 minutes.

2.3.2 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. The sensor is powered by 3.3V coming from the voltage regulator with little noise. Figure 6 shows the application schematic for a circuit with the sensor using I2C to communicate to the host, which has less noise compared to using SPI. The second sensor is the VL53L0X 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 3.3V coming from the buck converter. Figure 7 shows the application schematic for the VL53L0XFor 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.

Table 2: Sensor Subsystem – Requirements & Verification

| Requirement	Verification
The VL53L0X Time-of-Flight sensor must measure the user's screen distance with an accuracy of ±0.5 inches for distances ranging from 10 to 20 inches.	1. Mount the ToF sensor on a fixed stand facing a flat monitor. 2. Use a yardstick to place the monitor exactly 10.0, 12.0, 15.0, and 20.0 inches away from the sensor. 3. Read the calculator distance output via the serial monitor on a connected laptop. 4. Record the physical distance and the sensor output in a comparison table to verify the error margin.
The ICM-42670-P IMU must detect head pitch angles with an accuracy of ±2 degrees for angles up to 30 degrees from the calibrated baseline.	1. Secure the IMU to a digital angle gauge. 2. Establish a 0-degree baseline and zero the system. 3. Physically tilt the assembly to 10, 15, 20, and 30 degrees. 4. Read the computed angle from the ESP32 serial output. 5. Plot the measured angle versus the true angle on a graph to verify accuracy falls within the ±2 degree tolerance.
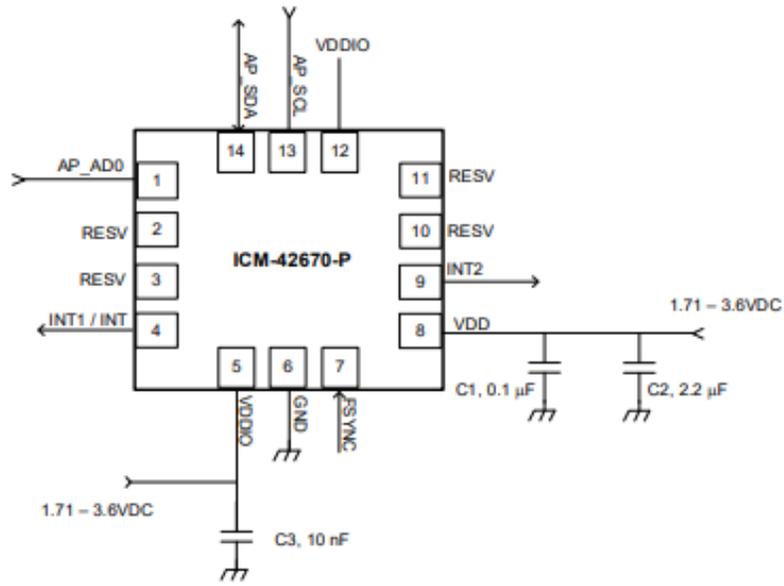
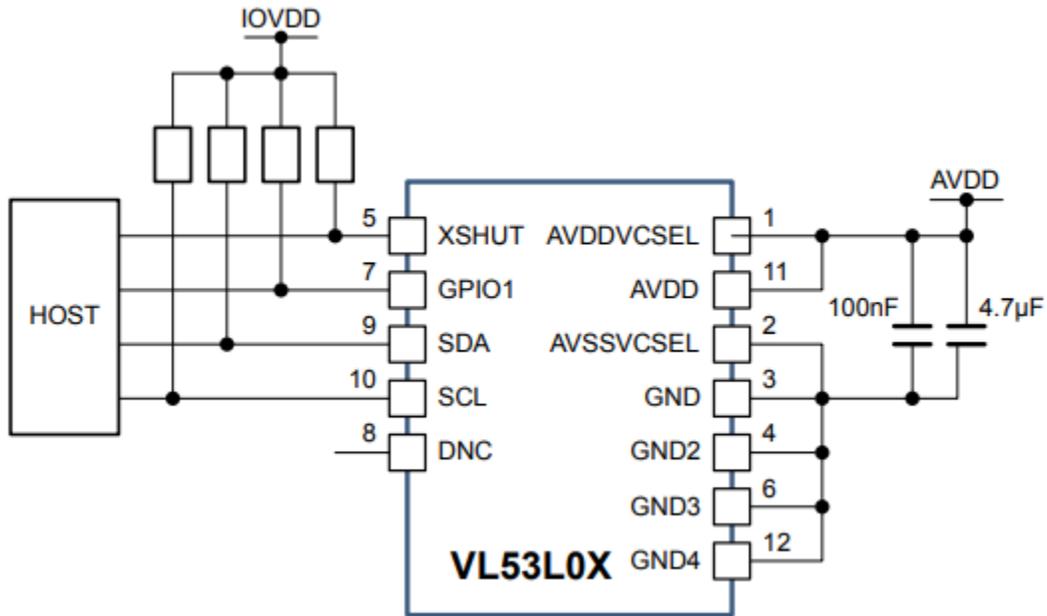Figure 6: ICM-42670-P Application Schematic (I2C Interface to Host) [5]

Figure 7: VL53L0X Application Schematic [6]

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2.3.3 Feedback

The feedback subsystem consists of a vibration motor, speaker (Piezoelectric Buzzer), and two LEDs. The feedback components all will be driven by 3.3V 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.

Table 3: Feedback Subsystem – Requirements & Verification

Requirement	Verification
The feedback components are powered by 3.3V from the microcontroller.	1. Connect LEDs, speaker, and vibration motor to the microcontroller. 2. Power on system, drawing power from the batter. 3. Use a multimeter in parallel to measure the voltage going into the system. 4. Ensure stable 3.3 V with ±0.1 V fluctuations.
One LED turns on within 3 seconds of head posture angle over 15 degrees.	1. Connect LED to microcontroller 2. Position IMU sensor with an angle of 20 degrees from initial horizontal. Verify angle with a protractor. 3. Time 3 seconds with a timer. 4. Ensure LED continuously lights up without fluctuations until sensor is brought back to horizontal. Test for at least one minute.
Other LED turns on within 3 seconds of screen distance less than 12 inches.	1. Connect LED to microcontroller 2. Position ToF sensor at 10 inches from screen. 3. Time 3 seconds with a timer. 4. Ensure LED continuously emit light without fluctuations until sensor is brought back to horizontal. Test for at least one minute.
Motor and buzzer activate when head posture angle and screen distance alarms are both detected.	1. Connect motor and buzzer to microcontroller 2. Position IMU at an angle of 20 degrees

	from horizontal and ToF sensor at 10 inches from the screen.
	3. Time for 5 seconds to ensure that both sensors activate alarms.
	4. Ensure both LEDs continuously emit light while the motor and buzzer activate. Test for at least one minute.
Feedback system turns off within a second of good position detected.	1. Test for all three cases: only IMU alarm activated, only ToF alarm activated, Both activated 2. With all three, when conditions are no longer present, LEDs turn off and motor+buzzer turn off

2.3.4 Processing

The processing subsystem consists of the microcontroller, which is powered by 3.3V 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 Low Energy (BLE).

Table 4: Processing Subsystem – Requirements & Verification

Requirement	Verification
The ESP32 must enforce a 3.0-second continuous threshold (±0.2 seconds) of poor posture or low distance before triggering the HIGH alarm signal on its output pins.	1. Connect an oscilloscope to the alarm output pin of the ESP32. 2. Programmatically feed a simulated IMU angle of 20 degrees into the ESP32 logic. 3. Start a stopwatch exactly when the simulated data transmission begins. 4. Start the stopwatch when the oscilloscope detects a rising edge on the output pin. 5. Record the elapsed time as a single numerical value to verify it is between 2.8 and 3.2 seconds.

2.3.5 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.

Table 5: Power Subsystem – Requirements & Verification

Requirement	Verification
The mobile application must successfully receive data packets via Bluetooth at a transmission rate of 1 Hz with a packet loss rate of less than 5%.	1. Program the ESP32 to transmit 100 consecutive dummy data packets at 1 Hz. 2. Run the mobile application and log the incoming packets. 3. Count the total number of successfully received packets. 4. Record the success rate as a percentage to verify it is 95% or higher.

2.4 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 head angle is calculated by integrating the gyroscope's angular velocity, small baseline errors compound rapidly over time. The head pitch angle, $\theta(t)$, is calculated by integrating the gyroscope's angular velocity, $\omega(\tau)$, over time:

$$\theta(t) = \theta_0 + \int_0^t \omega(\tau)d\tau$$

Due to the gyroscope's inherent bias, denoted as ω_{bias}, the integration error grows linearly:

$$\theta_{error}(t) = \omega_{bias} \times t$$

According to the ICM-42670-P datasheet, the typical Initial Zero-Rate Output (ZRO) tolerance is ±1°/s. Without correction, the drift over a 5-minute (300 seconds) period is calculated as:

$$\theta_{error} = 1°/s \times 300\,s = 300°$$

This 300° error completely invalidates the 15° posture threshold. To resolve this issue, our software will rely on the sensor's tilt angles (pitch and roll), calculated using the accelerometer's gravity measurements as an absolute reference to determine which direction is down. At power on, the initial angle is recorded as a reference point and the alarm is only activated when the current angle differs from this reference by over 15 degrees. Furthermore, to reduce the electrical noise that contributes to the drift of our measured position, we will power the IMU using a dedicated LP2950CZ-5.0 voltage regulator as opposed to a buck converter. Finally, if minor drift still accumulates over extended use, the system will allow the user to manually trigger a recalibration to reset the baseline angle.

3. Cost and Schedule

3.1 Cost Analysis

Labor costs are calculated using the course guideline: Hourly Salary x 2.5 x Hours to Complete. Assuming a $50/hour rate and an estimated 50 hours of remaining work per team member, the labor breakdown is as follows:

- Colin Moy: $50/hr x 2.5 x 50 hours = $6,250
- Jake Chen: $50/hr x 2.5 x 50 hours = $6,250
- Zhiyuan Chen: $50/hr x 2.5 x 50 hours = $6,250
- Total Labor Cost: $18,750

The cost of parts so far adds up to $34.51, and the total cost adds up to $18,784.51 for both labor and parts.

Table 6: Itemized list of Components and Costs

Description	Manufacturer	Quantity	Extended Price	Link
ESP32-S3-WROOM-1-N16R8	Espressif	1	$6.56	link
BATTERY LITH-ION 3.7V 2AH	Adafruit Industries LLC	1	$12.50	link
Lithium Battery Charger and Protection Module	NanJing Top Power ASIC Corp.	1	$1.25	link
IC REG LINEAR 5V 100MA TO92-3	Texas Instruments	1	$1.15	link
IC REG BUCK ADJ 1A SOT563	Diodes Incorporated	1	$0.21	link
IMU ACCEL/GYRO/TEMP I2C/SPI	TDK InvenSense	1	$2.25	link
SENSOR OPTICAL 24CM I2C	STMicroelectronics	1	$5.18	link
VIBRATION ERM MOTOR 3V	Seeed Technology Co., Ltd	1	$1.20	link
BUZZER PIEZO 3V 12.2MM TH	TDK Corporation	1	$0.57	link
LED RED DIFFUSED 5MM ROUND T/H	Würth Elektronik	2	$0.30	link
TRANS NPN 25V 1.5A SOT-23-3	Comchip Technology	2	$0.48	link
CAP CER 10UF 50V X5R 0805	Murata Electronics	2	$0.60	link
CAP CER 4.7UF 25V X5R 0805	Samsung Electro-Mechanics	1	$0.11	link
CAP CER 2.2UF 50V X5R 0805	Samsung Electro-Mechanics	1	$0.24	link
CAP CER 1UF 50V X7R 0805	Samsung Electro-Mechanics	2	$0.24	link
CAP CER 0.1UF 50V X7R 0603	Stackpole Electronics Inc	3	$0.30	link
CAP CER 10000PF 50V X7R 0805	Stackpole Electronics Inc	2	$0.20	link
RES SMD 100K OHM 1% 1/4W 0805	Vishay Dale	3	$0.57	link
RES SMD 10K OHM 1% 1/4W 0805	Vishay Dale	4	$0.40	link
RES SMD 1K OHM 1% 1/4W 0805	Vishay Dale	2	$0.20	link

3.2 Schedule

Table 7: Schedule for Project Progression

Week	Task	Person
2/22 - 2/28	Organize and order parts for prototyping	Everyone
	Work on PCB design	Jake
	Research bluetooth communication	Colin/Zhiyuan
3/1 - 3/7	Finish and audit PCB design	Jake
	Order missing parts	Everyone
	Prepare for breadboard demo	
	Design review	
	Second round PCB orders	
3/8 - 3/14	Start processing	Colin
	Start app	Zhiyuan
	Modify PCB design if needed	Jake
	Breadboard Demo	Everyone
	Third round PCB orders	
3/15 - 3/21 (Spring Break)	Continue working on programming and PCB design	Everyone
3/22 - 3/28	Continue working on app and bluetooth comm.	Zhiyuan
	Complete processing	Colin
	Build physical design	Everyone
	Fourth round PCB orders (**last PCB changes**)	
3/29 - 4/4	Debug subsystems	Everyone
	Individual progress reports	
4/5 - 4/11	Debug processing	Colin
	Complete app	Zhiyuan

	Start assembly	Jake
	Debug subsystems	Everyone
	Team contract assessment	
	Progress demo	
4/12 - 4/18	Complete assembly Testing Debugging	Everyone
4/19 - 4/25	Last minute debugging	Everyone
	Mock demo and presentation	
	Last-minute touches to demo and presentation	
4/26 - 5/2	Work on final paper	Everyone
	Final demo and presentation	
5/3 - 5/9	Submit final paper by Wednesday	Everyone
	Turn in lab notebooks by Thursday	
	Lab checkout	

4. 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.

5. References

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