ECE445 SENIOR DESIGN
FINAL REPORT
THE ANTI-SEDENTARY CHAIR

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Abstract

This paper discusses the design and results of the anti-sedentary chair, a lifestyle device designed to combat sedentary behavior. The device is comprised of a seat which senses when a user is sitting, a motion tracking device to be worn on the wrist, and a chair mounted interface with controls and display. The anti-sedentary chair senses how long a person has been sitting for and sounds an alarm when sitting for longer than the user-set time. The user can sit back down once the wearable device detects enough movement and then shuts off the alarm. The results of its completed design indicate that the device is functional and achieves its main design goals with a few areas still left for improvement.

Contents

1 Introduction

1.1 Problem and Solution

Sedentary behavior is a largely overlooked and underestimated issue in today's world. Sedentary behavior is an independent risk factor which elevates a person's risk factor for multiple health conditions, such as coronary artery disease, strokes, heart failure, hypertension [1], mood disorders, and depression [2].

To combat Sedentary behavior, our team has developed the anti-sedentary chair. The device is comprised of 3 main physical components. The seat sensor which detects if and how long a person is sitting for, a chair-mounted box with an alarm and a user interface for setting time between alerts and viewing the status of the device, and a wearable device that can go on the wrist which monitors a person's movement and sends data to the chair-mounted box indicating if a person is moving or not. The physical components just mentioned can be viewed in Figure 1 for further reference.

This report will go further in depth on the design, goals, requirements, verification methods, and results of this device, breaking it down into the main subsystems and components that comprise the device. Overall, the device has managed to achieve its high-level requirements and has been mostly successful in achieving the specific requirements for each subsystem. There are a few improvements that can still be made to this project, but such discussions will be further elaborated upon in the conclusion section of this report.

Figure 1 From left to right: seat sensor, chair mounted device, wearable device

1.2 High Level Requirements

To objectively lay out the major design requirements for the device, we have set four main design requirements which can be seen below.

1. The seat sensor must reliably detect when a user is sitting or not sitting; does not mistakenly toggle between states.
2. The movement tracker correctly identifies movement and reliably sends information to chair mounted board; system does not complete exercise state if user is still seated while shaking the sensor.
3. The alarm sounds when a user is sat for longer than the set time; alarm will continue to sound if user is seated and exercise has not been complete.
4. The wearable device and chair mounted device receive reliable power and can operate off rechargeable batteries or USB-C connection.

1.3 Deviations from Initial Plan

The previous high-level requirements served as the basis for the requirements of each individual subsystem and the main considerations when designing the subsystems and the components of each subsystem

The project goal and main objectives have remained largely the same throughout the course with a few modifications to ensure greater success and reliability of the final product. For reference, we have laid out the main design changes along with the reason for doing so in Table 1, below.

Original Plan	Final Design	Reasons for Change
Load cells mounted to bottom of chair legs to determine user sitting status.	Load cell mounted inside a cushion that sits atop the chair seat.	Made it easier to transport and simplified the manufacturing process.
Vibration sensors mounted on the back of chair legs to determine user movement.	Wearable device with IMU that monitors acceleration to determine if a user is moving.	More reliable and accurate at determining if a user is moving or not.
Display would use a seven-segment display, showing time between required movement.	16x2 Character LCD screen to display time, system state, and other statuses.	Allowed for more information to be displayed to the user.

Table 1 Design changes and reasonings for changes

2 Design

2.1 Overview

The anti-sedentary chair is comprised of two main systems that work together and communicate wirelessly. The chair mounted component receives information over BLE from the wearable for the purpose of detecting if a person is moving or not. Each system has the same power subsystem that consists of a rechargeable battery for power with the ability to also use power directly from a USB-C port if necessary. The chair mounted system has a seat detection subsystem that is composed of load cells which feed into an analog to digital converter to then be analyzed by the microcontroller to evaluate if a person is sitting or not. It also has a user controls and display subsystem that consists of two buttons which can increase and decrease the set time between mandated movement, an alarm that beeps when movement is required, and an LCD display which outputs information for the user such as the current state, timing information, and other status information for the user. The wearable has a movement detection subsystem which is comprised of an inertial measurement unit (IMU) which uses its accelerometer data to determine if someone meets the threshold for adequate movement. The block diagram in Figure 2 gives a visual representation of the previously described subsystems and components, along with basic information on the methods for signal transmission.

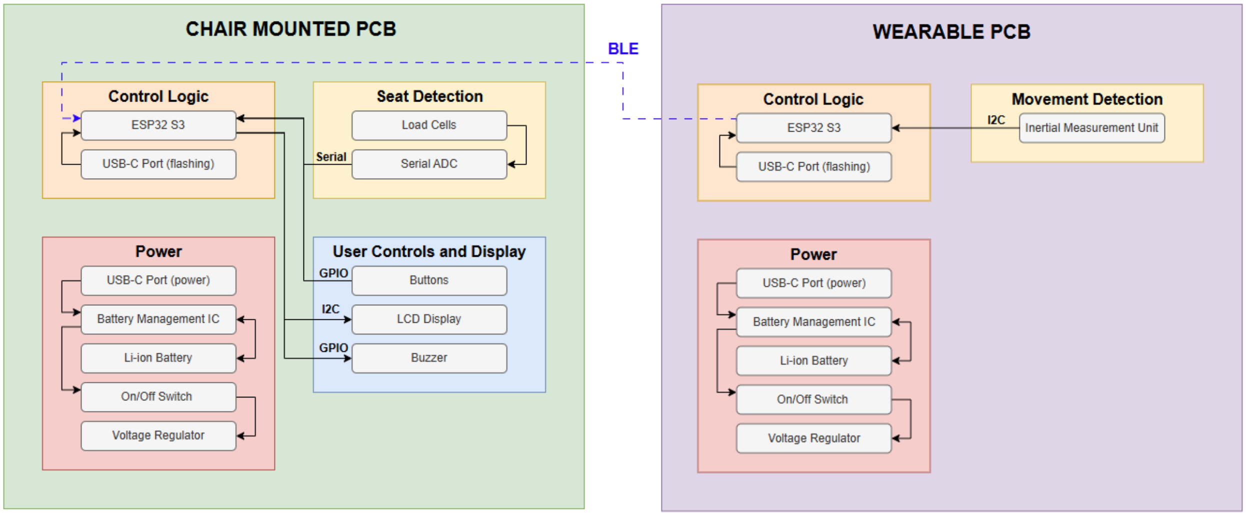


Figure 2 Block diagram of entire device

2.2 Control and Logic

The control and logic subsystem is implemented as a finite state machine on the chair-mounted ESP32. The finite state machine is responsible for combining the seat sensor result, sitting timer, BLE connection status, wearable movement result, and alarm behavior into one control flow. As shown in Figure 3, the main states are Waiting, Sitting, Standing Idle, Alarm, Exercising, and Cooling Down.

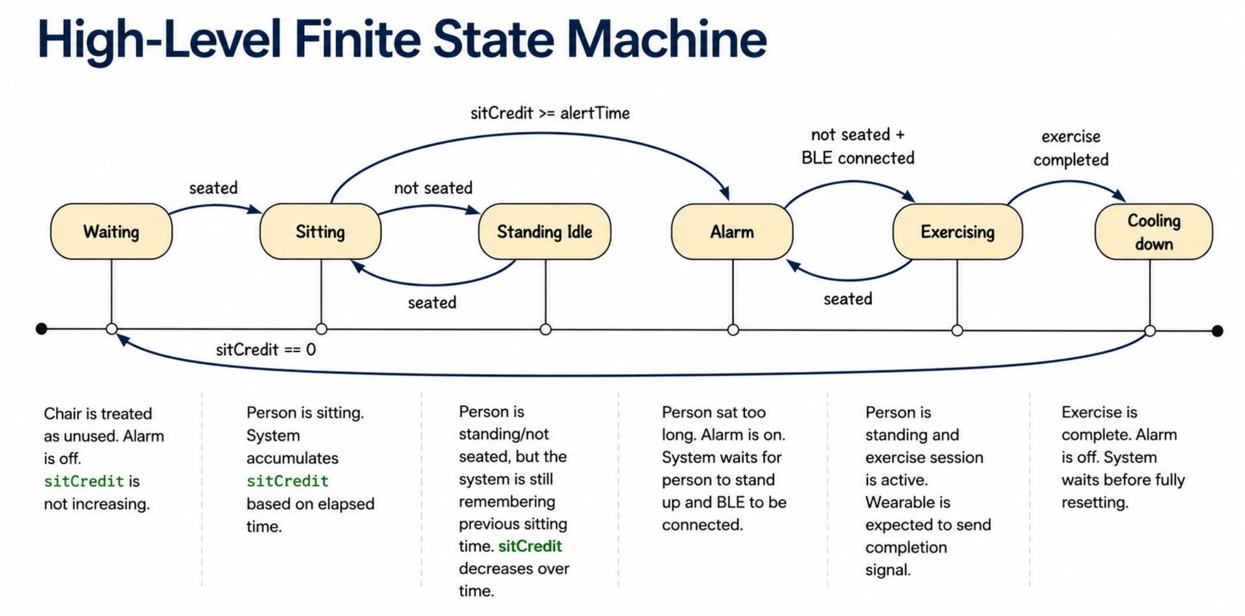
The system begins in the Waiting state. In this state, the chair is treated as unused, the alarm is off, and the sitting timer, called sitCredit, does not increase. When the seat sensor detects that the user is seated, the system transitions to the Sitting state. In the Sitting state, the system accumulates sitCredit based on elapsed sitting time. If the user stands up before the alert time is reached, the system enters the Standing Idle state. In this state, the system still remembers the previous sitting time, but sitCredit gradually decreases over time until it reaches zero and returns to the Waiting state or the user sits back down, returning to the Sitting state.

If sitCredit reaches or exceeds the user-set alertTime, the system transitions to the Alarm state. In the Alarm state, the buzzer is active and the system waits for the user to stand up. The alarm cannot be cleared only by sitting back down or briefly leaving the chair. Once the user is not seated and the BLE wearable is connected, the system enters the Exercising state. During this state, the wearable device is expected to send a completion signal after detecting enough movement. If the user sits down before exercise is complete, the system returns to the Alarm state.

After the wearable reports that the exercise requirement has been completed, the system enters the Cooling Down state. In this state, the alarm is off and the system waits briefly before fully resetting. Once the cooldown is complete and sitCredit returns to zero, the system returns to the Waiting state. This finite state machine ensures that the user cannot bypass the alarm by briefly standing up or shaking the wearable without completing the required movement.

The main objectives for this subsystem are:

- Correctly complete all tested FSM transitions for normal and edge-case workflows.
- Trigger the alarm whenever sitCredit reaches or exceeds the selected alertTime.
- Prevent the alarm from being cleared if the user sits back down before completing the required movement.
- Return to the normal waiting/timing behavior only after the wearable device reports movement completion and the cooldown state finishes.



Chair is treated as unused. Alarm is off. `sitCredit` is not increasing.

Person is sitting. System accumulates `sitCredit` based on elapsed time.

Person is standing/not seated, but the system is still remembering previous sitting time. **sitCredit** decreases over time.

Person sat too long. Alarm is on. System waits for person to stand up and BLE to be connected.

Person is standing and exercise session is active. Wearable is expected to send completion signal.

Exercise is complete. Alarm is off. System waits before fully resetting.

Figure 3 High-level finite state machine for the chair-mounted control system

2.3 Power

The power subsystem consists of a USB-C port, a battery management system, a Li-ion polymer battery, a switch, and a voltage regulator. The main objectives for this subsystem are:

- Charge the battery to its correct voltage at a safe C rate.
- Delivery stable and reliable power at the required 3.3V needed.

We used a BMS (MCP73871) with status pins for indicating charge complete and low battery along with a regulator (AP63203) capable of outputting 3.3V given a 3.8 to 42V input [5]. Both components required additional circuitry and tuning to get both chips functioning with their desired behavior. The BMS had programming resistors for setting current behaviors. PROG1 sets the maximum current which can be drawn and follows equation 1 from the BMS datasheet [3] where I_{REG} is the max current and R_{PROG1} is the programming resistor.

$$I_{REG} = \frac{1000V}{R_{PROG1}}$$

Equation 1 Max current draw [3]

The battery has a capacity of 350mAh and is designed for a C rate below 1 [4]. To comply, we set $I_{REG} =$ 350mA for a C rate of 1, meaning at a minimum, R_{PROG1} must be 2.857kΩ or greater. Since this is not a standard resistor value, 3.3kΩ was used instead. This results in a C rate of 0.866, a safe charging rate for the battery.

The BMS also requires the charge termination current to be set, which sets the current threshold that the BMS uses to determine when the battery has completed charging. The Li-ion battery datasheet does not specify a termination current, but since most Li-ion batteries have termination currents around 5-10% of the 1C rate, we used a termination current of 35mA. Equation 2 lays out the calculation for the programming resistor [3], where $I_{TERMINATION}$ represents the termination current.

$$I_{TERMINATION} = \frac{1000V}{R_{PROG3}}$$

Equation 2 Charge termination current [3]

Setting $I_{TERMINATION}$ to 35mA, R_{PROG3} comes to 28.571kΩ. Since this is also not a standard resistor value, we approximated R_{PROG3} to be 27kΩ.

The BMS outputs current which goes into the input of the regulator. In addition to this, the BMS also has a low battery output which we have tied to the enable pin of the regulator. This is so that when the battery is low, the regulator shuts off and prevents the battery from being over discharged.

Now, in reference to Figure 3 which displays the board layouts for the chair mounted device and wearable device, further design of the power system can be seen in the locations and positions of components. Coupling capacitors are in close proximity to the chips they're intending to aid, traces responsible for carrying more current are larger in size or are swapped for fills (such as in the wearable), and the entire front layer is set to 3.3V and the back is set to ground to allow for easy access to power and ground for each component on each board.

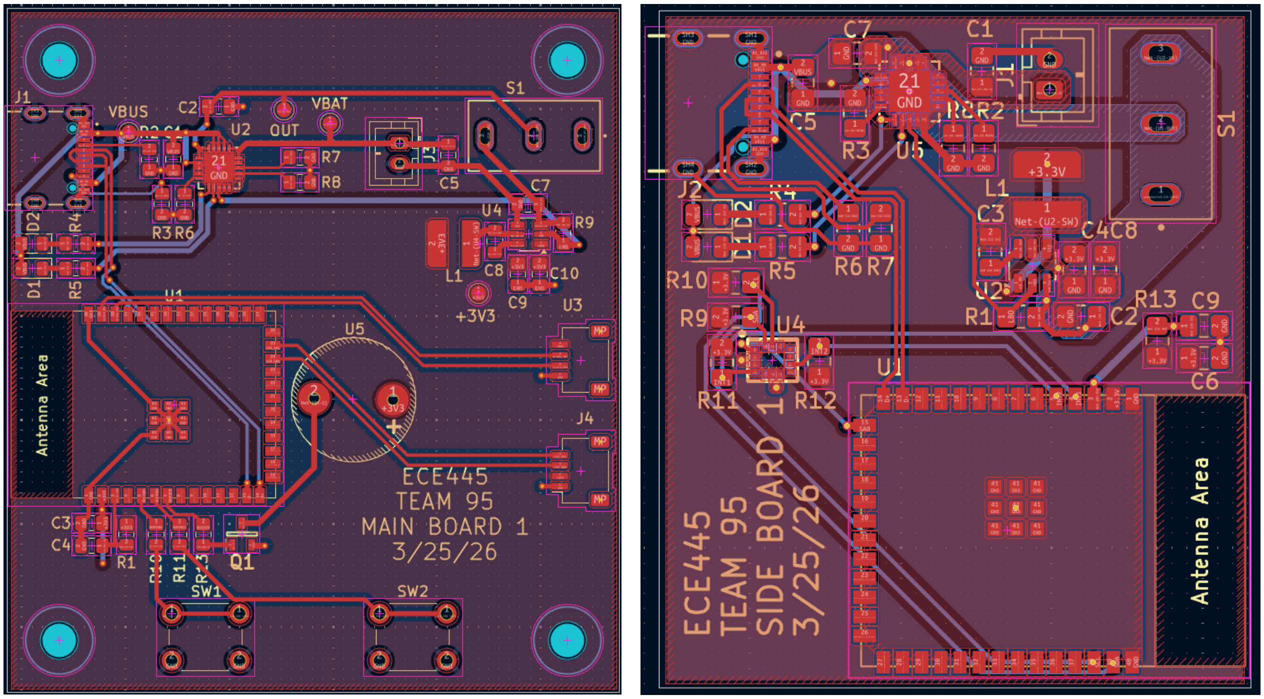


Figure 3 PCB for chair mounted device (left) and PCB for wearable device (right)

2.4 Seat Detection

The seat detection subsystem determines if a user is sitting on the chair. This is done using four load cells in a Wheatstone bridge configuration. The load cells are connected to a serial ADC with an on-chip programable gain amplifier (the HX711), which converts the differential voltage from the load cells into digital values that can be read by the ESP32. The main objectives for this subsystem are:

- Accurately detects if a person is sitting or not, does not mistakenly toggle between states
- Makes accurate transition between states <1 second >95% of the time

To communicate with the HX711, we wrote a software driven synchronous serial interface based off the timing diagram provided in the HX711 datasheet as seen in Figure 5.

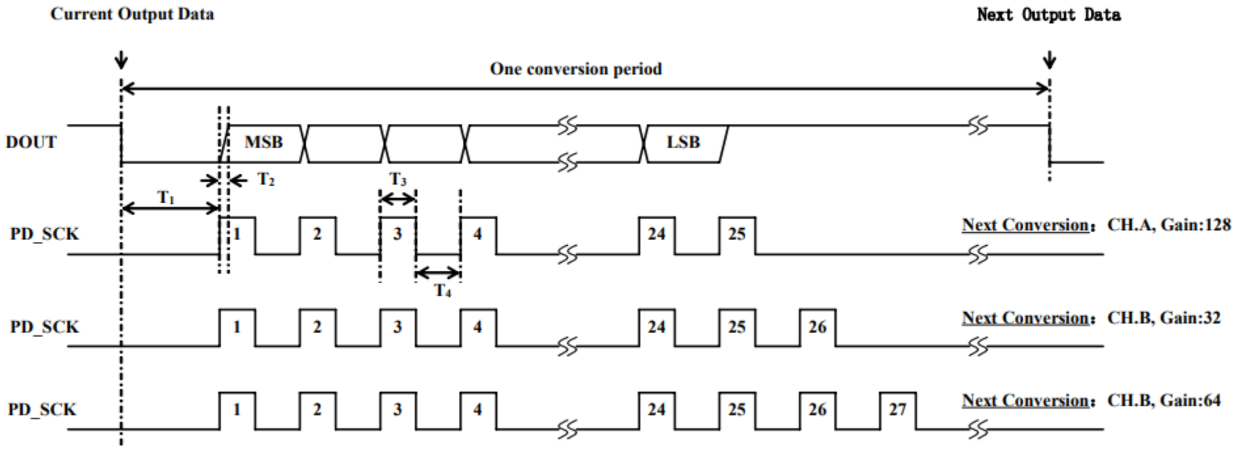


Figure 4 HX711 data output, input, and gain selection timing and control [6]

We used the 128 dB gain selection to have a wider range of output data and because we knew that most users would not be reaching the 200kg rated limit for the four load cells.

When the system powers on, a calibration process executes where the MCU records multiple readings and averages them to get a baseline value for the unloaded chair (during this process, the user is instructed to not sit). Then the system continuously samples the ADC data and compares the readings with the baseline. If the difference is greater than a predefined threshold, the system determines the chair is occupied. If not, the system determines the chair is empty.

To reduce false detections, the system uses an average of previous readings to evaluate if a person is sitting. This helps reject noise caused by small chair movements, sensor drift, or temporary shifts in the user's sitting position. The seat detection result is then used by the MCU in determining transitions between states such as Waiting, Sitting, and Standing idle.

In implementing the load cells into the physical design, we used 3D printed mounts that were slightly augmented from a publicly available 3D model [8]. Once printed, they were screwed to the bottom of a 1'x1' wooden board. Wires were incased in heat shrink tubing to ensure a robust design, and a cushion with memory foam was sewn together and affixed to the top. A second board was placed underneath the loadcells, and plywood was used to cover the side so the design would be completely enclosed.

2.5 Controls and Display

The controls and display subsystem is comprised of three main components: the buttons, the character LCD, and the alarm. The main objectives of this subsystem are:

- A single button press toggles a single increment or decrement of the timer.
- Alarm is disruptive to the user and triggers when sitting time has elapsed and user is seated. Alarm should turn off once standing but turn back on if user sits before movement is complete.

The buttons do not feature an analog debounce circuit. Adding debounce circuits was considered in the schematic design process but was discounted due to the ability to implement this feature using software, and because the ‘one-shot’ nature of the button would already need to be implemented in software. Once implemented in software, the timing information on the LCD was able to increase or decrease one time per button press, regardless of how long or brief the button is held for.

The buzzer used for the alarm was chosen for its ability to output 85dB at 10cm [7], which was found to be loud enough to be disruptive to a user who is close to the device. Its height was a small issue in designing the case for the chair mounted device, given that it was the tallest component on the board, however this was solved by making a hole for the buzzer to jut out from. This solved the height issue and made the buzzer more audible (and disruptive) to the user. It’s on/off behavior was resolved in the finite state machine discussed in chapter 2.1 which covers the control and logic subsystem.

Lastly, the 16x2 character LCD has was chosen for its ability to display a range of data to the user. A useful Adafruit library was used for controlling it, and we also utilized an LCD backpack to reduce the number of GPIO pins required to control the display and to make it compatible with I2C for ease of software development. This simplified its integration with other software components. Originally it had complications from updating too much, resulting in the screen flickering, but this was resolved by limiting how many times the screen can update per second.

2.6 Movement Detection

The movement detection subsystem consists of an ESP32-S3 microcontroller and an LSM6DSO IMU used to measure user motion. The main objectives for this subsystem are:

- Detect normal walking, speed walking, and running with at least 90% success over 10 trials for each movement type.
- Treat very low-intensity movement, such as slow walking, as a lower-confidence case for the current threshold-based method.
- Send a simple true/false activity packet to the chair-mounted ESP32 when the averaged acceleration magnitude exceeds the selected movement threshold.

The IMU measures acceleration along the x, y, and z axes. To simplify movement detection, the acceleration components were combined into a single linear acceleration magnitude, as shown in Equation 3. This allowed the firmware to compare user motion against one threshold instead of analyzing each axis separately.

$$a_{mag} = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

Equation 3 Linear acceleration magnitude

The LSM6DSO IMU communicates with the ESP32-S3 using the I^{2}C bus. I^{2}C was selected instead of SPI because the movement detection subsystem did not require high communication speeds, while I^{2}C simplified PCB routing and reduced the number of required GPIO connections. The IMU measures acceleration along the x, y, and z axes, with stationary measurements centered near 9.8 m/s^2 due to gravity. User movement produces additional acceleration above this baseline, allowing activity levels to be detected using threshold comparisons.

To improve measurement stability and reduce false detections caused by noise or sudden spikes, the IMU was configured to transmit 10 packets per second. The firmware averages these 10 samples to produce one acceleration value per second before comparing it against the movement threshold. An average acceleration magnitude near 11 m/s^2 was used to detect walking activity. Averaging the data produced more stable and reliable movement classification compared to using instantaneous samples.

3 Design Verification

3.1 Control and Logic

The control and logic subsystem was verified by testing the main finite state machine under normal and edge-case user behaviors. These tests checked whether the system could correctly transition between the main states based on seat detection, sitting time, alarm status, and movement completion. As shown in Table 2, each tested state transition produced the expected result.

Control Logic Test	**Expected Behavior**	**Result**
Empty chair at startup	System remains in EMPTY state after calibration	Passed
User sits on chair	State changes from EMPTY to SITTING	Passed
Sitting timer reaches alert time	State changes from SITTING to ALARM	Passed
User stands while alarm is active	State changes from ALARM to EXERCISING	Passed
User completes verified movement	Alarm clears and system enters cooldown/normal operation	Passed
User sits before completing exercise	Alarm is triggered again	Passed

Table 2 Control logic state machine transition verification result

Because every tested transition passed, the control and logic subsystem met its functional requirement for the tested workflows.

3.2 Power

To verify that our design could charge the battery to its correct voltage and at a safe C rate, we completely discharged a battery and then used a multimeter to measure its voltage as it charged. Since the battery charging cut-off voltage is 4.2V [4], charging was completed sometime between 3:29 and 5:45 AM, according to our recorded data in Table 3. This means that full charging took some time between 3.37 and 5.63 hours. This indicates a C rate between .18 and .30, which although an approximation, is well below the 1C limit and assures us the battery charges safely (albeit a little slow). It also indicates to us that the battery can charge to its correct voltage.

Time	12:07 AM	12:25 AM	12:48 AM	1:04 AM	3:29 AM	5:45 AM	6:07 AM
Voltage	3.334 V	3.542 V	3.672 V	3.793 V	3.902 V	4.262 V	4.265 V

Table 3 Voltage measurements of charging Li-ion battery

Lastly, we probed the voltage at multiple places on each board and found that the expected voltages were present. The output voltage from the regulator measured 3.313V, the Vin pin to the MCU measured 3.310V, the buzzer (positive lead) measured 3.308. All other pins measured close to 3.3V. This grants us confidence that the correct voltage is being received by each component requiring the use of 3.3V.

3.3 Seat Detection

To verify that our design could transition to the correct state within the desired amount of time (<1 second) we conducted 50 trials and read the output via a serial monitor. An example trial is given in Figure 6, which shows the seat sensor initially at its baseline, the estimated moment at which sitting took place, and a rise in the data (the slow rise is due to a 10 index wide sliding window average). In green it shows when the threshold is met, this is because we have a preset threshold of 100,000 and .8ms after sitting, that threshold was reached. The data continues to rise until it is stable at a higher value. This is by design, since it prevents fluctuations downward from mistakenly triggering a standing state. Following trials yielded similar results, and the results of our 50 trials can be viewed in Table 4.

```
[110188ms] Average of last 10 samples: 2440
[110288ms] Average of last 10 samples: 2486
[110388ms] Average of last 10 samples: 2572
[110488ms] Average of last 10 samples: 2730
[110588ms] Average of last 10 samples: 2968
[110688ms] Average of last 10 samples: 3554
[110788ms] Average of last 10 samples: 4653
[110888ms] Average of last 10 samples: 6773
[110988ms] Average of last 10 samples: 10893
[111088ms] Average of last 10 samples: 19291
[111188ms] Average of last 10 samples: 40921
[111288ms] Average of last 10 samples: 69555
[111388ms] Average of last 10 samples: 104674
[111488ms] Average of last 10 samples: 144871
[111588ms] Average of last 10 samples: 189286
```

```
[111688ms] Average of last 10 samples: 240637
[111788ms] Average of last 10 samples: 293525
[111888ms] Average of last 10 samples: 346514
[111988ms] Average of last 10 samples: 396985
[112088ms] Average of last 10 samples: 441772
[112188ms] Average of last 10 samples: 472373
[112288ms] Average of last 10 samples: 495890
[112388ms] Average of last 10 samples: 512630
[112488ms] Average of last 10 samples: 524384
[112588ms] Average of last 10 samples: 532108
[112688ms] Average of last 10 samples: 533066
[112788ms] Average of last 10 samples: 531947
[112888ms] Average of last 10 samples: 528873
[112988ms] Average of last 10 samples: 525942
[113088ms] Average of last 10 samples: 524454
```

Figure 5 Serial monitor output of HX711 readings over 3 second period when someone sits on seat sensor

Sitting Detected	Standing Detected	Correct Transition
50/50	50/50	50/50

Table 4 Results of 50 trials of seat sensor testing

3.4 Controls and Display

To verify that a single button press resulted in a single increment or decrement of the timer, we tested multiple cases to assure that function matched design intention. We took a handful of trials for different cases, as laid out in Table 5, and all tests managed to pass. Each normal button press resulted in a single increase/decrease to the time, and doing so at increased speed also yielded the same results. Holding the button down for a long period of time also only yielded one increment/decrement and holding one button down while pressing the other button resulted in the newly pressed button only incrementing/decrement once, which is the desired behavior.

Normal button press (3 sec between press)	Fast button press (<.5 sec between press)	Held button press (10 sec hold)	Another button pressed while other is held
Passes 10/10	Passed 10/10	Passed 10/10	Passed 10/10

Table 5 Button testing cases results

To ensure the robustness of the alarm, we tested multiple possible cases to ensure our intended behavior was occurring. We tested a normal use case of the alarm going off followed by the user standing (alarm turns off), two edge cases where the user either did not or only partly completed exercise before sitting back down (both of which retriggers the alarm), and a case of the user completing exercise after the alarm sounds (alarm is off, even after sitting). In each case, the alarm exhibited desired behavior and passed each test as outlined in Table 6.

NORMAL: alarm on, user stands, alarm off	Passed
EDGE CASE 1: alarm on, user stands, alarm off, user sits, alarm on	Passed
EDGE CASE 2: alarm on, user stands, alarm off, partially completes exercise, user sits, alarm on.	Passed
EXERCISE COMPLETE: alarm on, user stands, alarm off, user exercises, user sits, alarm remains off	Passed

Table 6 Alarm testing under multiple conditions results

3.5 Movement Detection

To verify the movement detection subsystem, acceleration magnitude data from the wearable IMU was recorded while the user performed slow walking, normal walking, speed walking, and running. This verification was designed around three objectives: detecting normal walking or stronger movement with at least 90% success over 10 trials, treating very low-intensity movement as a lower-confidence case, and sending a true/false activity packet when the average acceleration magnitude exceeded the selected threshold. As shown in Figure 7, the stationary acceleration stayed close to 9.8 m/s^2 due to gravity, while stronger movement caused the measured acceleration magnitude to repeatedly exceed the selected 11 m/s^2 threshold. This confirmed that the firmware could separate stationary behavior from sufficient user movement.

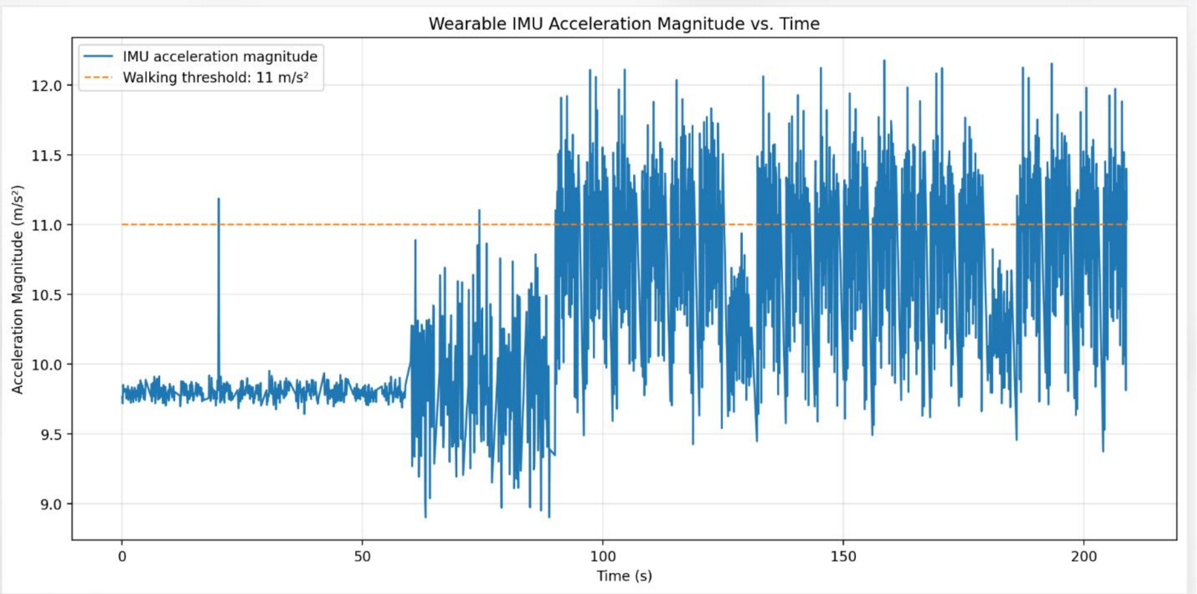


Figure 6 Accelerometer trials with walking threshold

The trial results in Table 7 show that the system met the main detection objective for normal walking, speed walking, and running. Normal walking passed in 9 out of 10 trials, while speed walking and running each passed in 10 out of 10 trials, meeting or exceeding the required 90% success rate. Slow walking only passed in 3 out of 10 trials, so it was treated as a lower-confidence movement case for the current threshold-based method rather than a reliable completion condition. In firmware, the averaged acceleration magnitude was compared against the 11 m/s^2 threshold shown in Figure 7, and each result was converted into a simple true/false activity packet sent to the chair-mounted ESP32. This allowed the main state machine to directly use the IMU output when deciding whether the user had completed enough movement before sitting back down.

Movement type	Slow walk	Walk	Speed Walk	Run
Pass rate	3/10	9/10	10/10	10/10

Table 7 Verification results under different speeds of walking

4 Costs

Part	Manufacturer	Unit Cost ($)	Quantity	Actual Cost ($)
ESP32 S3 WROOM 1	Espressif	$5.71	6	$34.26
BMS	Microchip Technology	$2.41	6	$14.46
Volt Regulator	Diodes Incorporated	$1.21	6	$7.26
IMU	STMicroelectronics	$5.32	4	$21.28
Switch	Same Sky	$0.74	6	$4.44
USB-C Port	GCT	$0.80	6	$4.80
3.9uH Inductor	Boums	$0.45	6	$2.75
Buzzer	VCC	$1.78	2	$3.56
NPN BJT	Diodes Incorporated	$0.28	4	$1.12
Push Button	Same Sky	$0.10	4	$0.40
Green LED	LITEON	$0.079	20	$1.58
100kΩ Resistor	YAGEO	$0.018	20	$0.36
27kΩ Resistor	YAGEO	$0.013	20	$0.26
10kΩ Resistor	YAGEO	$0.044	40	$1.76
5.1kΩ Resistor	YAGEO	$0.021	20	$0.42
4.7kΩ Resistor	YAGEO	$0.024	40	$0.96
3.3kΩ Resistor	YAGEO	$0.019	20	$0.38
1kΩ Resistor	YAGEO	$0.019	20	$0.38
22uF Capacitor	Samsung Electro-Mechanics	$0.088	20	$1.76
10uF Capacitor	KYOCERA AVX	$0.089	20	$1.78
4.7uF Capacitor	Samsung Electro-Mechanics	$0.036	20	$0.72
1uF Capacitor	Samsung Electro-Mechanics	$0.034	20	$0.68
100nF Capacitor	KEMET	$0.031	20	$0.62
Load cells + ADC Kit	ShangHJ	$11.99	1	$11.99
Li-Polymer Battery	Shenzhen PKCELL Battery Co.	$5.95	3	$17.85
16x2 LCD Display	Adafruit Industries	$9.95	1	$9.95
Pin Header	Adafruit Industries	$1.50	2	$3.00
Socket Header 10 Pack	Adafruit Industries	$3.50	1	$3.50
Wires	Unknown, provided by ECE department	$0.00	~10ft	$0.00
Heat Shrink Tubing	Unknown, provided by ECE department	$0.00	~3ft	$0.00
Screws & Nuts	Unknown, provided by ECE department	$0.00	16	$0.00
1x12x3’ Wood Board	Mastercraft	$7.99	1	$7.99
2’x2’ Plywood Panel	Bessemer Plywood	$5.15	1	$5.15
3D Printed Load Cell Mounts	Self-manufactured	$0.00	4	$0.00
3D Printed Cases	Self-manufactured	$0.00	2	$0.00
1 Yard Cloth	Waverly	$3.57	1	$3.57
Thread	Coats & Clark	$1.73	1	$1.73
Foam Cushion	Unknown, found as scrap material	$0.00	0	$0.00
Total				**$170.72**

Table 8 Parts, Quantities, and Costs

No labor costs were incurred since all labor was completed by members of the group project.

5 Conclusion

5.1 Accomplishments

Our team designed and built a functional sedentary detection chair system that combines chair-mounted seat sensing, BLE communication, wearable IMU movement detection, power management, PCB design, and user feedback through an LCD, buzzer, and LEDs. The final prototype detects when a user is sitting, starts a sitting timer, triggers an alarm after the alert interval, and requires verified movement before the alarm is fully cleared.

On the hardware side, our team completed the schematic design, PCB layout, component selection, soldering, and board bring-up for the chair-mounted control unit. The chair unit integrates the ESP32, HX711 load cell interface, power regulation circuitry, battery charging/protection circuitry, button inputs, LCD connection, and buzzer/LED outputs.

On the software side, our team implemented the main ESP32 control system, including the finite state machine, load cell calibration and thresholding, button debounce logic, LCD status display, buzzer/LED alarm behavior, and BLE communication with the wearable node. The wearable unit was used to send movement information to the chair unit so that the alarm could only be cleared after physical activity was detected.

The final prototype successfully demonstrated the main workflow of the project. The system was tested through sit/stand trials, button input tests, movement detection tests, power tests, and full state-transition tests. Overall, the project achieved the core goal of combining chair occupancy detection and wearable movement verification into one working sedentary reminder system.

5.2 Uncertainties

One uncertainty in our final prototype is the reliability of movement verification with only one wearable IMU. The current system can detect general movement, but it may not always distinguish between meaningful physical activity and simple sensor shaking. Because of this, the movement threshold may need further tuning for different users, different wearing positions, and different activity types.

Power stability is also an uncertainty in the current prototype. The battery capacity is relatively small, and when the battery level is low, the output voltage may not be high enough to reliably support the full system, especially when the ESP32, BLE communication, LCD, sensors, and alarm outputs are active at the same time. This could lead to unstable behavior or system resets.

5.3 Ethical considerations

The system uses seat occupancy and movement data, so privacy was considered during the design. Our prototype processes this information locally on the ESP32 and does not upload personal data to an external server. The system only uses the data needed to determine whether the user is seated and whether the required movement has been completed.

There are also safety and accessibility concerns because the device encourages the user to stand up and move. The system should be used voluntarily and should not be used to force users to exercise. It may not be appropriate for people with mobility limitations or certain health conditions, so users should decide whether the device is suitable for their own physical condition.

Another limitation of the current prototype is accessibility. Our alarm design mainly relies on sound from the buzzer and physical movement from the user. This means the system may not work well for users with hearing impairments or users with limited mobility. These users may not be able to hear the alarm clearly or complete the required movement task safely. Because of this, the current prototype should not be considered a universal solution for all users.

5.4 Future work

Future work could improve the system by adding a second wearable IMU device. Our current prototype only uses one wearable sensor, so adding another node on a different body location would make movement verification more reliable and reduce false clearing of the alarm.

The system could also be expanded to detect more complex activities, such as walking, squats, stretching, or leg raises. Instead of only checking for general movement, the device could guide the user to complete a specific exercise.

The user interface could be improved to support this feature. For example, the LCD could display instructions such as “walk for 15 seconds” or “complete 5 squats,” then show progress until the required movement is completed.

Another future improvement is to redesign the power system with a larger battery capacity. This would allow the chair unit and wearable device to operate for a longer time and reduce the risk of low-voltage resets when multiple components are active.

Future versions should also improve accessibility. For users with hearing impairments, the system could provide stronger visual feedback, such as brighter LEDs, LCD alerts, or phone notifications. For users with limited mobility, the system could allow customizable movement goals or alternative tasks based on the user’s physical ability. This would make the device safer and more inclusive for a wider range of users.

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Appendix A Requirement and Verification Table

Appendix A summarizes the main system requirements and the verification methods used to evaluate whether each requirement was met.

Requirement	Verification	Status
Control and logic correctly complete FSM transitions, triggers alarm at sitCredit >= alertTime, and prevents early alarm clearing	Tested Startup, sitting, timer expiration, standing during alarm, completed movement and early sitting cases, all passed, as shown in Table 2	Y
Power subsystem charges the battery safely and provides approximately 3.3 V to system components	Battery charged from 3.334 V to 4.265 V, and board voltage points measured close to 3.3 V, as shown in Table 3	Y
Seat detection identifies sitting/standing transitions within 1 second with at least 95% success	50 sit/stand trials were performed. Sitting, standing, and correct transitions were each detected in 50/50 trials, as shown in Table 4	Y
Controls and display register one timer change per button press and handle alarm edge cases correctly	Button tests passed 10/10 for each case, and alarm behavior passed all tested workflows, as shown in Tables 5 and 6	Y
Movement detection identifies normal walking, speed walking, and running with at least 90% success	Normal walk passed 9/10, speed walk passed 10/10, and run passed 10/10, as shown in Table 7	Y

Table 9 System requirements and verification summary

Appendix B Additional Figures

In this section, we have included additional figures that may be of use in better understanding the project and its functionality but were not referenced directly in the main text.

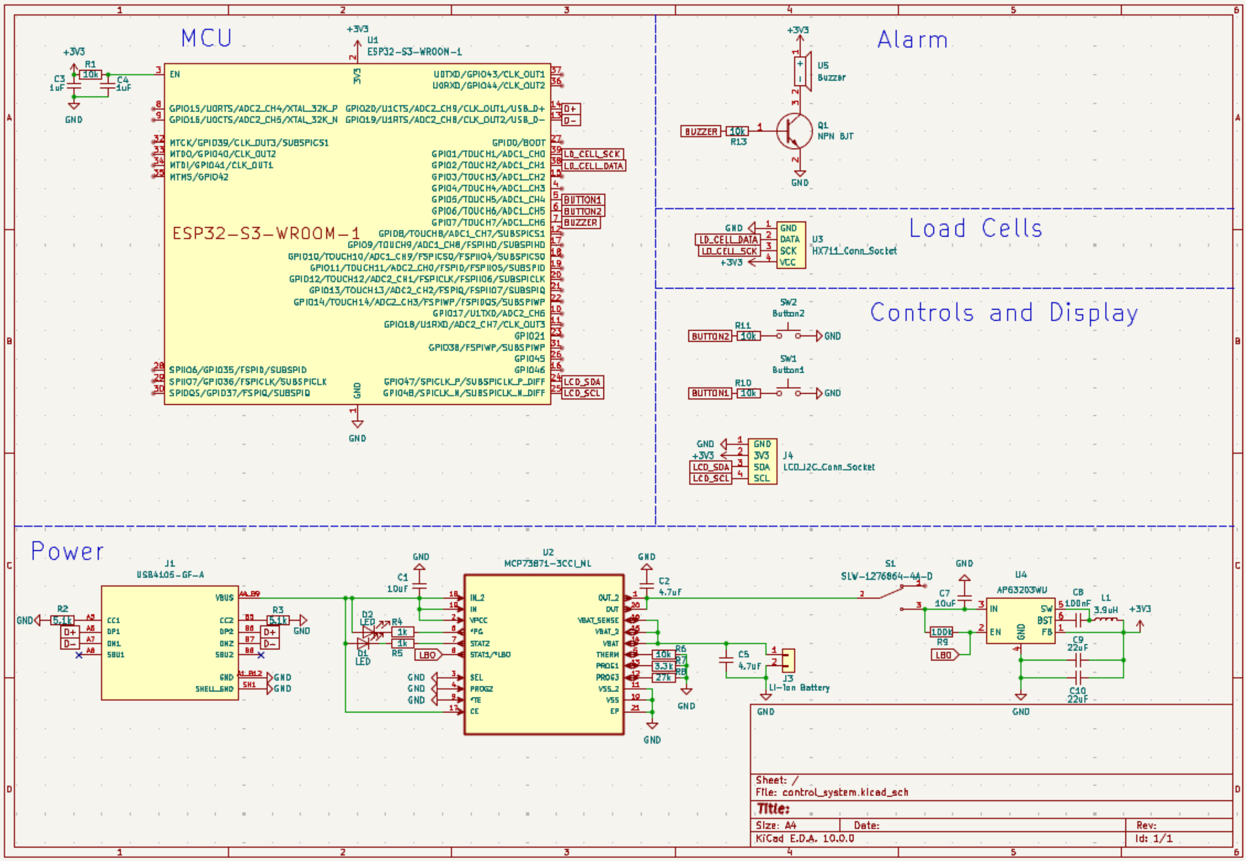

Figure 7 Schematic layout for chair mounted device

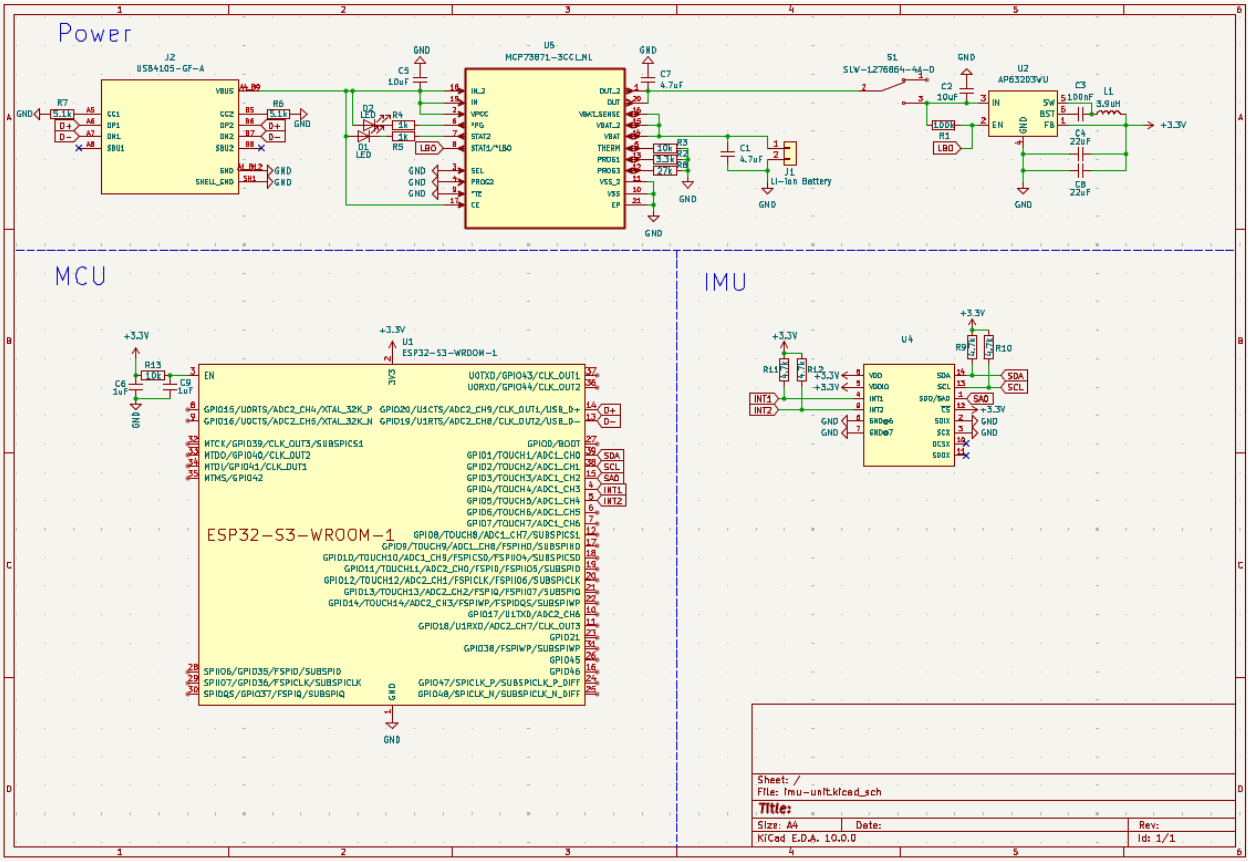

Figure 8 Schematic layout for wearable device

Figure 9 Augmented 3D print of the Load Cell (area for wires to pass though was expanded)

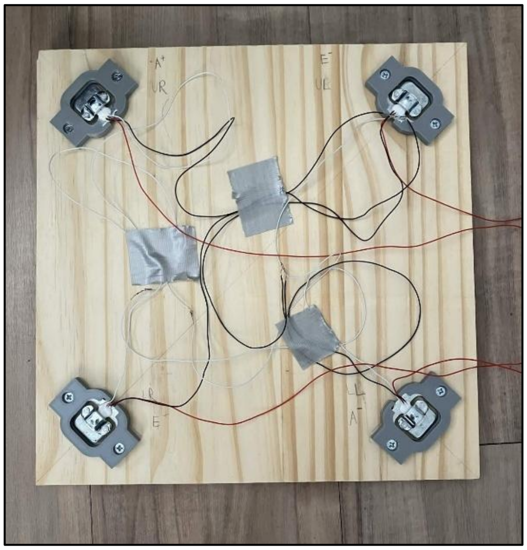

Figure 10 Configuration of the load cells mounted to the wooden board before being enclosed