ECE 445

Fall 2023

Senior Design Document

Bed Sensor Alarm

Colby King

Syed Ahmed

Ebaad Siddique

September 28, 2023

TA: Abhisheka Mathur Sekar

Introduction

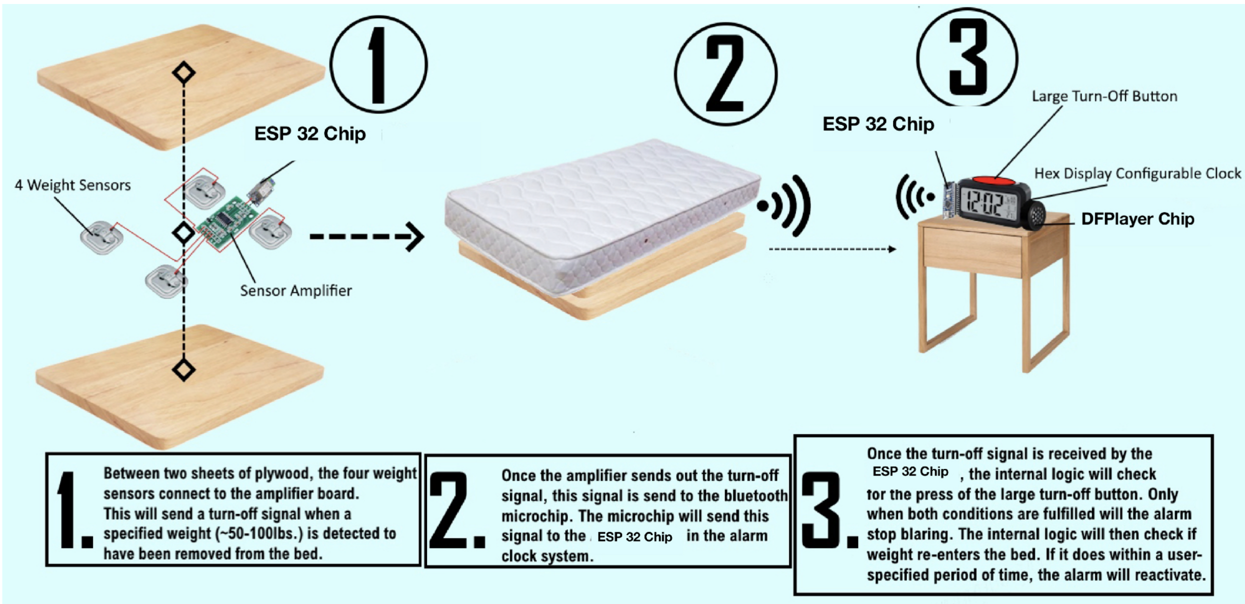
Problem: Most people wake up to an alarm in the morning. It is the easiest way to get the day started at the time you want. The problem is that it is too easy to see the alarm and go back to bed. With the snooze option or just general sleepiness, some people find themselves just going back to sleep regardless of the alarm system. There needs to be an alarm that can determine if someone is still in bed and not getting up at the correct time.

Solution: To stop the user from turning the alarm off and staying in bed, there should be a way to tell if the user has gotten out of bed and stayed out of bed. The solution to that problem is weight sensors. Using weight sensors this product can detect when weight has been removed from the bed and check to make sure the weight has stayed off the bed. The system will have an alarm function that the user can set and the weight sensing will be one of the ways to turn off the alarm. The sensor will fit between the bed frame and the mattress and the user can lay on the bed normally without any problems. This device will be able to sense the total weight of the bed and use that to make sure the user has not gotten back into bed. When the alarm goes off the user will have to press a button and the alarm will go off only if the weight on the bed has decreased by a set amount. Once the button has been pressed the user has 5 minutes to not get back into bed. If the bed senses another large weight increase within that time, the alarm will turn back on and they have to repeat the process. This will all occur without disrupting the stability of the bed.

High-level requirements list:

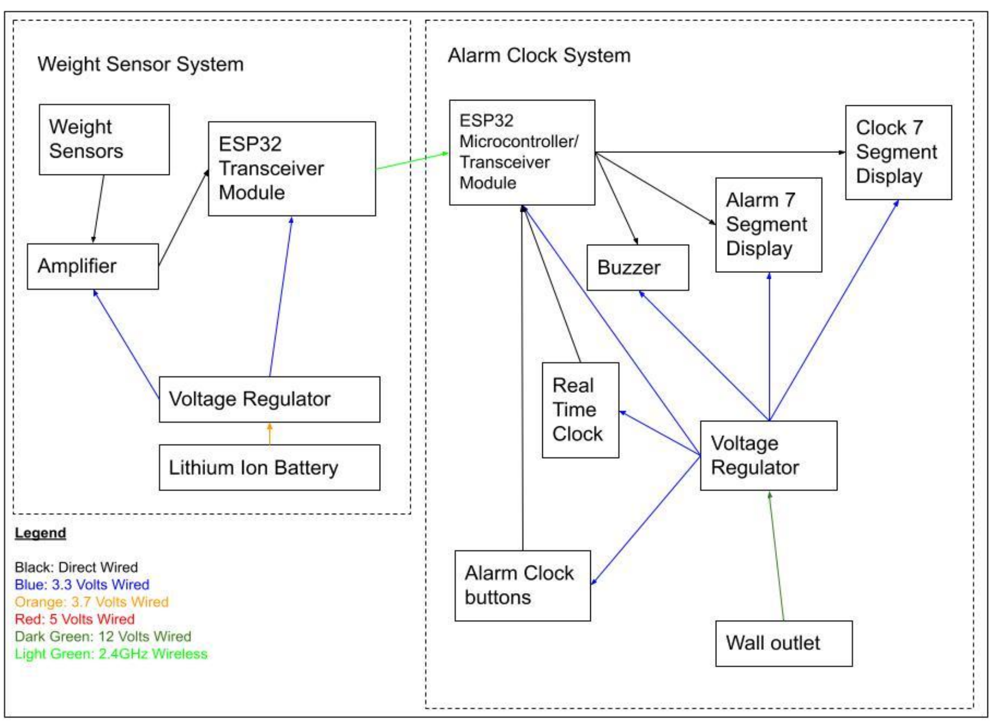
- The system should have 3 identifiable states
    - Regular standby mode: Normal clock operation
    - Alarm Mode: Alarm sounds and snooze button need to be pressed
    - Timer mode: The Snooze button has been pressed and the timer starts.
- The sensors should be able to wirelessly share the weight information with the central alarm and be able to sense when more than 50 lb of weight has been removed from the bed.
- After the snooze button has been pressed, the system will return to alarm mode if the 50 lb of weight has been added back onto the bed before the timer goes off.

Visual Aid



Design

Block Diagram



The bed sensor is designed to fit the size of a normal mattress but for this specific design, we scaled it down for proof of concept. Our small bed for the test will be 32” x 27” and our board for the sensors will also be the same size to properly cover the entire “mattress” area. The four sensors will go in each corner of the board approximately 2” from the edge on every side. This will help keep the sensors away from any potential splash while also covering the area of the board efficiently. In a larger-scaled version, more than 4 sensors would be used to ensure a larger weight can be held and the large area of the bed is accounted for.

The alarm clock does not need to have any specific physical dimensions beyond user accessibility.

Weight Sensing System

Power Subsystem: This entire system will be powered by two 18650 lithium-ion batteries that operate at 3.7 volts. Using a voltage regulator there will be a voltage step down to 3.3 Volts. It will power the wireless data chip and the weight sensors. There will be no microcontroller on this side as only the weight information needs to be passed on.

Requirements	Verification
The Power System must be able to supply 3.3 V to the weight sensors from a 3.7 V power supply.	Utilize a voltmeter with a DC power supply to confirm voltage to make sure it meets the requirements of the sensor.

Weight sensor subsystem: The weight sensors will be multiple half-bridge load cells connected to an amplifier. This will allow us to accurately get weight data from each sensor and pass it on to the alarm subsystem wirelessly. These weight sensors will be attached on both sides of a thin board that is the size of the bed. This will ensure all the weight is accurately on the load cells and getting the right values. Refer to the Visual Aid section of the design document for clarification.

Requirements	Verification
The weight sensor subsystem will need to successfully detect a difference in weight.	For the test, we will place the device under a mattress, and group members will lie down attempting to trigger the alarm clock at different moments.
Weight data passes to the alarm subsystem wirelessly.	Calibration and testing of each load cell using test cases so that we get accurate weight measurements.
The arrangement of load cells on the board ensures accurate weight distribution	Place known weights at different locations on the bed and observe if the system detects and responds to the weight distribution.
The sensor system consists of multiple load cells connected to an amplifier	Inspection and documentation of load cell and amplifier configuration.

Control subsystem: This control subsystem will take the total weight of the sensors and pass the bit information to the alarm clock system for the alarm logic. We will use an RN-41 Bluetooth chip to send the data to an ESP32 Bluetooth Chip. The signal will be sent using the standard Bluetooth at 2.4GHz. The RN-41 chip can operate from 3 to 3.6 V so that 3.3V power source will be sufficient to power the chip.

Requirements	Verification
The RN-41 shall operate within the voltage range: of 3 to 3.6 V.	Utilize a voltmeter to measure with the DC power supply to confirm it falls within the specified range.
Functionality of RN-41 Bluetooth to send data to ESP32 chip.	We can use a script to listen for incoming Bluetooth data (if it's connected, waiting for a connection, or it's been disconnected) from the RN-41 module. Use a mobile device or computer to connect RN-41 Bluetooth. Send the weight data from the terminal to Bluetooth. Then use the serial monitor to see the weight data being received and printed.

Alarm Clock System

Power subsystem: This entire system will be powered by a wall outlet with a voltage regulator that can step down the voltage to 3.3V. This will directly power every chip on the alarm clock system. Every chip on this system can handle a 3.3V power input.

Requirements	Verification
A power system with a voltage regulator will be used to power the ESP32 chip and everything else.	Utilize a voltmeter with a DC power supply to confirm voltage. Measuring output pins to confirm other components are powered like the speaker and display at 3.3V output.

Control subsystem: We will use an ESP32 to wirelessly accept the weight information from the weight sensor system. Using the Arduino IDE software we will check the weight before the alarm goes off and compare it to the current weight on the bed to ensure the user has gotten off the bed. When that happens and the snooze button is pressed, the alarm will turn off and a five-minute timer will start. Once no weight has been added back onto the bed within five minutes the alarm will stay off. The DS3231 chip will function as a real-time clock for the alarm. Using this clock we can wire the seven-segment display to show the time and set the alarm.

Requirements	**Verification**
The control system checks the weight before the alarm goes off and compares it to the current weight on the bed to determine if the user has gotten off the bed.	Testing control logic by simulating weight changes using group members and verifying the system accurately detects when the user gets out of bed even with a five-minute delay.
Functionality of the snooze button and how the five-minute timer starts. If no original weight is not back within 5 min, the alarm stays off.	Will test with group members lying down and simulating scenarios such as going to the bathroom.
Functionality of the clock we built with the seven-segment display. Make sure the wiring is correct and then it displays a clock from the Arduino chip.	Programming and debugging on board to set it, and making sure minutes and hours are moving accordingly.

User subsystem: This subsystem will consist of an alarm clock containing 4 control buttons, a buzzer, two LED seven-segment displays, and an additional snooze button. The four control buttons will allow the user to set the current time and set the time for the alarm they want. The first button will be a clock button. When held the user can change the time, first the hour then the minute. The second and third buttons will be a plus and minus button for changing the time. The fourth button will operate similarly to the first but it will be specifically to set the alarm. A quick press will turn the alarm on and off and a hold will change the time. There will be an LED indicator that will be illuminated when the alarm is on. The fifth button will be the snooze button which only functions to turn off the alarm. This will work with the weight sensor to only turn off the alarm after the weight has been removed.

Requirements	**Verification**
The functionality of each button in the user subsystem and of the alarm being set with LED lighting up.	Will use group members to simulate timings with sensors. This will help test buttons. Group members will test it out themselves. The actual demo will be with a smaller bed (dog bed). Verifying LED indicator turns on/off depending on alarm activation.
The snooze button turns the alarm off and turns back on when weight is added back on.	Testing snooze in conjunction with the weight sensor. We will make sure the wiring is correct and will simulate with a group member.

Tolerance Analysis:

The biggest risk for the successful completion of our project is the ability to accurately send the weight information from the weight sensors to the central alarm. This operation can be interrupted by multiple failures in our design. Primarily the inaccurate sending of Bluetooth data or the loss of battery on the sensor system.

To ensure accurate Bluetooth information is being sent, we plan on using specific weights in the building phase and using computer output to make sure the data is accurate. We will put known weights on the sensors and check the output data being sent to the second Bluetooth chip. We will ensure the data being sent is within 1% of the known weight.

The other concern was the battery life of the weight sensor system. To combat this we will test the input power required for the weight sensors and the voltage regulator. We will test both the operating power and the standby power so we can accurately see how much battery life is required to keep the power from running out. If we need more time for the amount of power provided by the battery, we will discuss putting the battery in a place that can be replaced by the user if necessary. We would have to ensure this location is safe from splashes or any short circuit issues.

Cost and Schedule

Labor Cost

Name	Weekly Hours	Hourly Pay	Weeks	Scaling Factor	Cost (USD)
Colby K.	**10**	**50**	**12**	**2.5**	**15,000**
Syed A.	**10**	**50**	**12**	**2.5**	**15,000**
Ebaad S.	**10**	**50**	**12**	**2.5**	**15,000**
Total	**$45,000**				

Table 1: Labor Cost

Cost Analysis

Bed Sensor		
Part Description with Link:	**Quantity**	**Cost**
Half bridge sensors *Includes amplifier	4	8.99
ESP32 Bluetooth Microchip (School provided) RN-41	1	0.00
18650 Lithium Ion Battery	1	10.99
Battery Holder	1	5.99
MCP1700 Voltage Regulator	10	5.00
Wooden Boards (plywood)	2	20
PCB	1	0.00
Total		50.97

Table 2: Bed Sensor Parts

Alarm Clock		
Part Description with Link:	**Quantity**	**Cost ($)**
7 Segment Display	2	3.50
ESP32 Microcontroller	2	23.97
Wall Plug	1	10.99
Wall Plug Adapter		
Voltage Regulator (12V to 3.3V)		
Buzzer	1	0.00
PCB	1	0.00
Buttons	5	0.99
Total		40.54

Table 3: Alarm Clock Parts

The total cost for parts as seen above including shipping and sales tax is $87.51. We will assume it took us 10 hours per week for 12 weeks. We can expect a salary of $50/hr (approximately the average salary of an electrical engineer in the US) ×2.5 (overhead factor) × 120 hours worked = $15,000 per team member. The total labor cost should account for all 3 members, therefore, $15,000 x 3 = $45,000.

Schedule

Week	Due	Colby	Ebaad	Syed
1		Initial Web Board Post	Initial Web Board Post	Initial Web Board Post
2		Web Board Post Approval	Web Board Post Approval	Web Board Post Approval
3		Early Project Approval	Early Project Approval	Early Project Approval
4		Project Approval (Approved)	Project Approval (Approved)	Project Approval (Approved)
5		Project Proposal and Team Contract (Done)	Project Proposal and Team Contract (Done)	Project Proposal and Team Contract (Done)
6	9/29	Design Document plus order parts	Design Document plus order parts	Design Document plus order parts
7	10/1	Design Review and Individual Peer Review	Design Review and Individual Peer Review	Design Review and Individual Peer Review
8		Assembling weight sensors to board, testing on actual bed	Assembling weight sensors to board, testing on actual bed	Assembling weight sensors to board, testing on actual bed
9		Programming: Communication to alarm clock from weight sensors	Assembling weight sensors to board, testing on actual bed	Assembling weight sensors to board, testing on actual bed
10		Building alarm clock using display segment	Building alarm clock using display segment	Building alarm clock using display segment
11		Testing alarm clock with sensors, checking functionality	Testing alarm clock with sensors, checking functionality	Testing alarm clock with sensors, checking functionality

12		Testing, checking for issues	Testing, checking for issues	Testing, checking for issues
13		Mock Demo (will make final touches afterwards)	Mock Demo (will make final touches afterwards)	Mock Demo (will make final touches afterwards)
14		Fall Break	Fall Break	Fall Break
15		Final Demo	Final Demo	Final Demo
16		Final Presentation and Paper	Final Presentation and Paper	Final Presentation and Paper

Discussion of Ethics and Safety

There are many ethical and safety concerns that we should consider when building the bed sensor alarm. As discussed in the IEEE Code of Ethics section II, to treat all people fairly and with respect and to not engage in discrimination based on characteristics such as religion, race, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression. And to not engage in harassment of any kind or bullying behavior. We will be open to any advice or criticism and make sure to prioritize safety when fixing issues and pay attention to the well-being of everyone.

Ethics Concerns

The only ethical issues we can see arising from this project are potential copyright or patent issues. Although this is an original idea for us, it is possible someone else had a very similar idea before us. We also will have to use some code for the alarm clock. This will probably require some external code from the internet. We as a group will make sure that if we use code we will use code that is for public use. As told in the IEEE Code of Ethics sections I and VI, we will honestly disclose any information and usage of code or data to any of the parties and at the same time maintain and improve our technical competence.

Safety Concerns

In the developmental stages of this project, the main safety issues will come down to assembly. There could be issues of getting burned soldering or getting electrocuted as it is being put together. With the finished project comes similar problems. If there is any exposed wire or loose components there could be an issue or electrocution. The biggest issue that could arise is the sensor catching on fire. This would lead to the bed probably catching on fire and this would pose the biggest risk to the user. The Alarm system will connect directly to a wall outlet which will produce a higher wattage than a typical battery. We will ensure any exposed metal directly to the wall outlet is properly covered and away from the user interface. As told in section I of the IEEE Code of Ethics we hold paramount, the safety, health, and welfare of the public to strive to comply with ethical design and sustainable development practices.

Citations

- Fliflet, Arne. “ECE 445 Parts Inventory.” *https://docs.google.com/spreadsheets/d/1pqk_fN6fMIju8Ngkg-_4KTQ6uj0hrlnuv49PCC0ijBk/edit#gid=1992434365.* Accessed 27 Sept. 2023.
- [1] IEEE. “”IEEE Code of Ethics”.” (2020), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (visited on 9/14/2023).
- Team, The Arduino. “Nano 33 BLE.” *Arduino Documentation Datasheet*, docs.arduino.cc/hardware/nano-33-ble. Accessed 27 Sept. 2023.