Design Document

Rithvik Kopparapu (rithvik6)

Allen Zhu (allenz2)

Zinovy Alecksandrovich (zinovya2)

Table of Contents

Introduction

Problem

In today's fast-paced world, for college students, industry professionals, and individuals from all walks of life, the ability to wake up on time has become a crucial skill for managing their daily responsibilities. Despite the universal need for sufficient sleep—a fundamental human necessity—modern life often forces us to sacrifice our time in bed in favor of meeting the demands of education, work, and personal commitments. Sleep, though essential for maintaining our physical and mental well-being, is frequently deprioritized due to the pressures of tightly packed schedules and looming deadlines. To keep up with these schedules, people have turned to a variety of methods to ensure they wake up on time. Traditional alarms remain the go-to for many, but their effectiveness tends to wane as individuals become accustomed to the routine. In response, some resort to setting multiple alarms at short intervals, hoping that the constant disruptions will eventually rouse them. Others experiment with specialized alarm apps that require the completion of specific tasks, such as taking a picture of a designated object or solving a puzzle, before the alarm shuts off. Smartwatches and fitness trackers have also introduced vibration-based alarms to offer a more discreet alternative to the jarring noise of traditional alarms. However, even with these technological innovations, the human body can adapt to repetitive stimuli. As individuals settle into the habit of snoozing or silencing their alarms without fully waking up, the effectiveness of these methods diminishes. People find themselves turning off their phones in their sleep, ignoring the vibration of their smartwatch, or otherwise bypassing the very systems designed to wake them. This phenomenon raises important questions about the limitations of current alarm systems and the biological and psychological factors at play in waking up. It highlights the need for more innovative, personalized solutions that account for human adaptability and the complex nature of sleep cycles.

Solution

To address the challenge of ensuring people wake up and stay awake when their alarm goes off, this project proposes the development of an innovative alarm clock system that integrates a series of physical challenges. The key to this solution is the use of simple, built-in sensors—such as a load cell, gyroscope, temperature sensor, and pedometer—that will prompt users to complete one of four randomly selected tasks each morning in order to disable the alarm. By varying the tasks and introducing an element of unpredictability, the system prevents users from falling into a routine where they can mindlessly snooze or turn off their alarm without fully waking up. The inclusion of these diverse challenges—ranging from requiring the user to apply pressure (load cell), perform specific movements or orientations (gyroscope), requiring active waiting time for the alarm to cool in the fridge (temperature) or engage in physical activity like walking (pedometer)—ensures that users engage both their bodies and minds in ways that naturally disrupt their sleep inertia. The random selection of the task by the alarm clock every morning keeps users alert and responsive, reducing the likelihood that they will adapt to a predictable routine and circumvent the system. The device will incorporate all necessary functionality into a single, easy-to-use product, eliminating the need for users to manage multiple devices or complicated setups. The randomness of the challenges enhances the effectiveness of the alarm system while minimizing the effort required from the user to configure it. Our project targets the core issue of adaptation that plagues traditional alarms, offering a practical and engaging method to ensure users are awake, alert, and ready to tackle their day.

Visual Aid and Physical Design

Figure 1: Example image describing our solution generated using Google Gemini

As shown in Figure 1, we intend our design to be a sensor deck above the clock. Our sensor deck will wake up when the selected time is reached and pick a challenge for the user to complete. After completion of the challenge, the sensor deck sends a signal to the alarm to stop ringing or making noise.

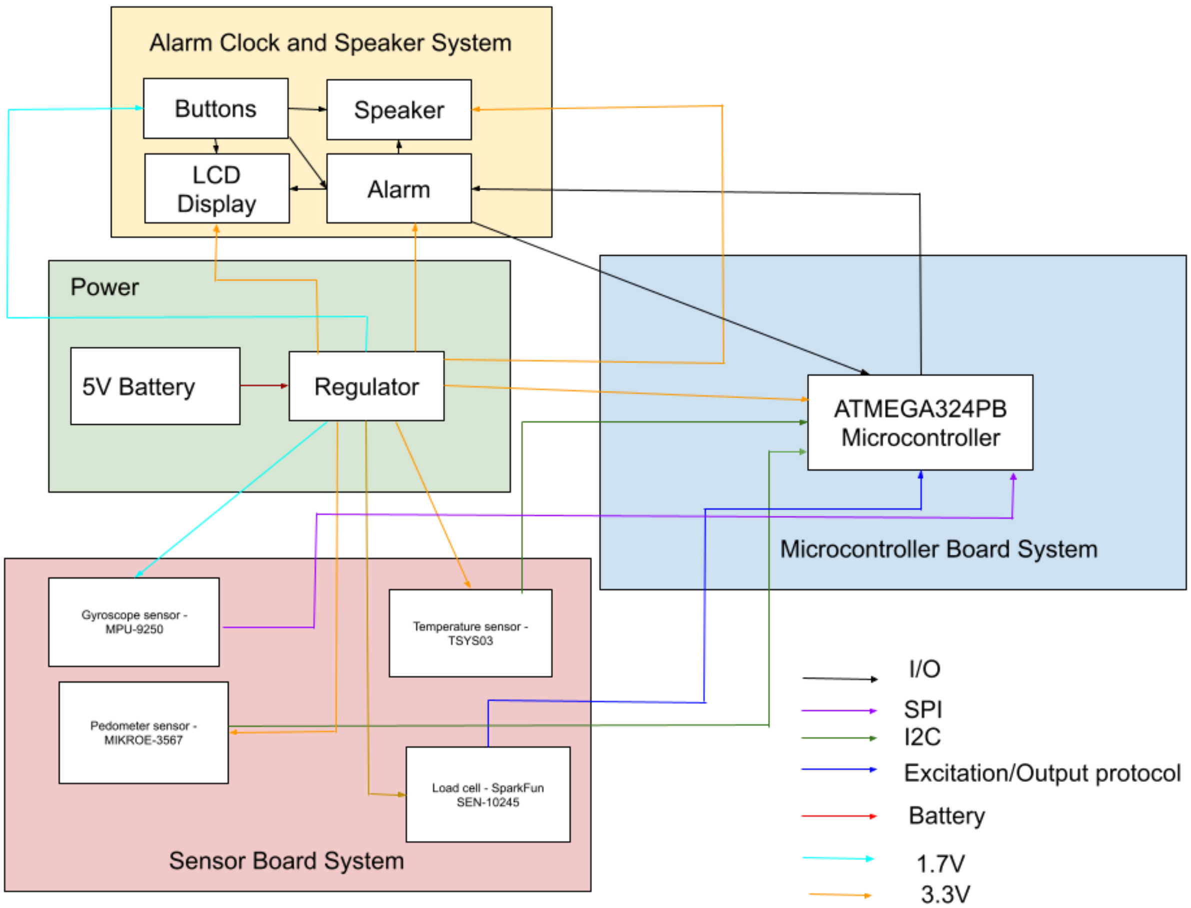
High-level Requirements

1. Challenge subsystem wakes up and decides which challenge to complete within five seconds of the wake-up time, and then stops ringing as soon as challenge is completed or within ten minutes, whichever comes first.

2. The active set of challenge sensors, the pedometer and gyroscope sensors, function as expected by indicating challenge completion within 250 steps walked and at least 2 minutes of shaking which results in an angular rate of 2 +/- 1 rad/s.

3. The passive set of challenge sensors, the temperature and force sensors, function as expected by indicating challenge completion within 5 +/- 2N of force applied for 3 minutes, and registering at least 2 mins of 37 +/- 3 deg F for 2 minutes.

Block Diagram



Subsystem Overview

Subsystem 1 - Alarm clock and speaker

The first part of our solution is the physical alarm clock that we will be modifying to add to our challenges. We wish to use a simple AA-powered alarm clock with a clear LCD display for the user to be able to easily program times in and use power efficiently. To inform the user what challenge is to be completed that morning, pressing the clock's snooze button will play an instruction on a separate speaker that we will add (i.e., "SHAKE CLOCK FOR ONE MINUTE"). This subsystem will send and receive required I/O signals to the Microcontroller subsystem via C. Each individual element of this subsystem will receive power from the regulator within the power supply and management subsystem. The Speaker, Alarm and LCD display will require 3.3v, and the buttons will require 1.7v.

Subsystem 2 - Challenge Deck with sensors

The second part of our solution is our challenge deck with the associated sensors:

1. *Gyroscope sensor* - MPU-9250 with built in gyroscope and accelerometer sensors. The challenge we want to incorporate here is to shake the clock for one minute, and we will use the data from the sensor to verify the shaking of the clock. This sensor will transfer its data via an SPI interface to the Microcontroller Subsystem. A supply voltage of 1.7v will be supplied via the power supply systems through the regulator.
2. *Temperature sensor* - TSYS03 temperature sensor. The challenge we want to incorporate here is to get up and put the clock in the fridge for two minutes while waiting there for the alarm to turn off. We will check to see if the clock holds a temperature below 40 degrees Fahrenheit (avg fridge temp is 37 degrees) for at least one minute, to consider the time it takes for the clock to cool. This sensor will transfer its data via an I2C protocol to the Microcontroller Subsystem. A supply voltage of 3.3v will be supplied via the power supply systems through the regulator.
3. *Pedometer sensor* - MIKROE-3567 pedometer sensor. The challenge we want to incorporate here is to get up and take 250 steps with the alarm clock. This sensor will transfer its data via an Excitation/Output protocol. A supply voltage of 3.3v will be supplied via the power supply systems through the regulator.
4. *Load cell* - SparkFun SEN-10245 load cell. The challenge we want to incorporate here is to apply an even and constant force for three minutes, to make it inconvenient enough time to be unable to do it in your sleep. This sensor will transfer its data via an I2C protocol to the Microcontroller Subsystem. A supply voltage of 3.3v will be supplied via the power supply systems through the regulator.

Subsystem 3 - Linkage to alarm clock

To link all the sensors, we will be using an ATMEGA324PB microcontroller. To make the alarm clock stop ringing when the challenge is completed, we will generate the signal that is usually generated by the "stop alarm" button to the alarm. Once the challenge is completed, we will also use the previously mentioned speaker to give the user simple audio feedback that they've completed the challenge, with a "ding" sound. This subsystem will act as the interface between the Alarm Clock and Speaker subsystem and the Sensor subsystem. The microcontroller will receive I/O data via the alarm subsystem. When a challenge is enabled, the microcontroller will receive and interpret the sensor data. If a challenge is active and if the challenge is completed, the microcontroller will send a signal to the Alarm and Speaker subsystem that will turn off the alarm and speaker. The microcontroller. If a challenge is not completed within 10 minutes of the challenge being set, then the microcontroller will send a signal to the Alarm and Speaker subsystem to turn off the alarm and speaker. The microcontroller will determine which challenge to complete via RNG and send this signal back to the alarm and speaker subsystem. These signals and conditions will be in C.

Subsystem 4 - Power supply and management

To power our alarm clock, we will be using a standard pair of AA batteries. This power supply and then the subsequent power regulator, the AZ1117CD-33TRG1, will be used to successfully power the display and alarm as well as the challenge deck with the appropriate step down voltage. The base supply voltage will be 5v. The regulator will send different voltages varying from 1.7v to 3.3v.

Subsystem Requirements

Subsystem 1 - Alarm Clock and Speaker System

Requirements	Verification

If no challenge/alarm is active, the clock will behave as a normal digital clock.	Verify the clock behaves normally without any input from user
The buttons on the clock will allow the user to change the time, as well as set an alarm/challenge.	Verify the clock behaves normally without any input from user The user will set an alternate time to set via buttons. Examine LCD display to verify if time has been set
If an alarm or challenge has been set, and the challenge has been completed, it must stop within 5 seconds of challenge completion.	Verify the clock behaves normally without any input from user The user will press snooze button to start a challenge User will complete the requirements of the challenge and observe if Speaker and LCD display will stop and update respectively
If the snooze button is pressed the speaker will notify the user which challenge has been chosen.	Verify the clock behaves normally without any input from user The user will press snooze button to start a challenge Verify to hear challenge notification from speaker
If an alarm or challenge has been set, and the challenge has not been completed within 10 minutes, it must stop.	Verify the clock behaves normally without any input from user The user will press snooze button to start a challenge Verify to hear challenge notification from speaker User will not complete the requirements of the challenge and observe if Speaker and LCD display will stop and update respectively after 10 minutes.

Subsystem 2 - Challenge Deck with sensors

Requirements	Verification
The gyroscope sensor accurately registers shaking (angular rate of 2 +/- 1 rad/s) and is able to interface with the microcontroller to communicate the completion of the 1 minute challenge requirement.	Verify the clock behaves normally without any input from user The user will press snooze button to start a challenge The user will continue to complete other challenges until they acquire the shaking challenge The user will complete the challenge and observe if speaker and LCD display notify and update respectively
The temperature sensor accurately registers cooling of the clock at the accurate average fridge temperature (37 +/- 3 deg F) and is able to interface with the microcontroller to communicate the completion of the 2 minute challenge requirement.	Verify the clock behaves normally without any input from user The user will press snooze button to start a challenge The user will continue to complete other challenges until they acquire the temperature challenge The user will complete the challenge and observe if speaker and LCD display notify and update respectively
The pedometer sensor accurately registers steps and is able to interface with the microcontroller to communicate the completion of the 250 +/- 25 step requirement.	Verify the clock behaves normally without any input from user The user will press snooze button to start a challenge The user will continue to complete other challenges until they acquire the step challenge The user will complete the challenge and observe if speaker and LCD display notify and update respectively

The load cell sensor accurately registers the force applied (5 +/- 2N of force) and is able to interface with the microcontroller to communicate the completion of the 3 minute challenge requirement.	Verify the clock behaves normally without any input from user The user will press snooze button to start a challenge The user will continue to complete other challenges until they acquire the step challenge The user will complete the challenge and observe if speaker and LCD display notify and update respectively

Subsystem 3 - Linkage to alarm clock

Requirements	Verification
The microcontroller is successfully able to send a signal to the alarm clock that the challenge is completed in order to turn off the alarm within 10 minutes or within challenge completion.	Verify the clock behaves normally without any input from user The user will press snooze button to start a challenge User will complete the requirements of the challenge and observe if Speaker and LCD display will stop and update respectively
The microcontroller is successfully able to read data from all sensors in order to register completion of the appropriate challenge within 5 seconds of challenge completion.	Verify the clock behaves normally without any input from user The user will press snooze button to start a challenge User will test the sensor corresponding to the given challenge and view terminal output of live C code.

Subsystem 4 - Power supply and management

Requirements	Verification
The regulator is successfully able to step the voltage down from 5V to 3.3V to interface with the challenge deck while also powering the clock.	Verify the clock behaves normally without any input from use Check continuity of each individual system and element

Tolerance Analysis

Components & Current Draw:

- ATMEGA324PB: 0.25 mA
- TSYS03: 400 µA (0.4 mA)
- SEN-10245: 1.5 mA
- MIKROE-3567: 60 µA (0.06 mA)
- MPU-9250: 0.2 mA
- Typical Digital Alarm: 260 mA

Total Current Draw:

- I_{out} = 262.41 mA

Parameters:

- $T_j(MAX)$ = 150°C
- V_{in} = 5V
- V_{out} = 3.3V
- $(\Theta_{jc} + \Theta_{ca})$ = 100°C/W

- Ta = 38°C

Junction Temperature Calculation:

Using the formula:
$Tj = Iout \times (Vin - Vout) \times (\Theta jc + \Theta ca) + Ta$

Substitute values:
$Tj = 0.26241 \times (5 - 3.3) \times 100 + 38$

$Tj \approx 82.61°C$

Since $Tj \approx 82.61°C$, it is below Tj(MAX) = 150°C.

TSYS03:

Temperature accuracy error = ± 0.5 °C.

Operating Temperature Range (°C) = -40 - 125

MPU-9250:

Gyro Full Scale Range(dps)= ±2000

Accel Full Scale Range(g) = ± 16

MIKROE-3567:

Pedometer error = ±3%

SEN-10245:

Output Sensitivity(mv/v) = 1.0±0.1

Cost and Schedule

Labor

($/hour) x 2.5 x hours to complete = TOTAL

The average starting salary of an ECE graduate is expected to be roughly $48/hr, which calculates to be $48/hr x 2.5 x 60 hrs = $7,200 for each student → $21,600 for all three students combined.

Including the costs of necessary parts, which is found in the table below adds up to $55.89. Subtract this from the labor cost and the total cost comes out to be $21,544.11.

Parts

Item	Manufacturer	Part #	Q	Cost	Description
Digital Alarm Clock	ECE Machine shop	N/A	1	N/A	Typical digital alarm clock
Gyroscope Sensor	TDK InvenSense	MPU-9250	1	$14.99	Sensor with built in accelerometer that detects motion
Temperature Sensor	TE Connectivity	TSYS-03	1	$0.70	Contains a built in thermometer that detects temperature and changes
Pedometer Sensor	MIKROE	MIKROE-3567	1	$28.00	Accurately records number of steps taken by a person
Load cell Sensor	Sparkfun Electronics	SEN-10245	1	$4.50	Used to measure pressure applied by user
Microcontroller	Microchip	ATMEGA-324PB	1	$2.29	Main unit of our system, used to link all sensors together
Regulator	N/A	AZ1117CD-33TRG1	1	$0.44	Used to step down voltage from 5V to 3.3V
AA Batteries	Duracell	N/A	2	$4.97	Standard 5V batteries

Schedule

Week	Task
10/7-10/11	Design schematics and order necessary parts
10/14-10/18	Start and continue board assembly
10/21-10/25	Start PCB Design and finish board assembly
10/28-11/1	Finish PCB Design, test components and begin soldering
11/4-11/8	Start programming board and test function
11/11-11/15	Finish programming board and link all components together
11/18-11/22	Finalize assembly and perform series of tests to ensure proper functioning
11/25-11/29	Add final touches and/or fix minor bugs
12/2-END	Demo

Ethics and Safety

The main ethical and safety concerns that arise from this project are in the form of disruption of the natural environment for unintended persons, such as companions or roommates of the user. In addition to this, another issue we potentially identified is the possibility of the challenges being excessively strenuous to our users. The IEEE code of ethics states that engineers should not injure others, whether that be mental or physical(*IEEE Code of Ethics, Section II no. 9*). For the case of disrupting anyone else, we prioritized having our challenges be as minimal time as possible in order to wake the user up but not be exceedingly long. In addition to this, we focused on making our challenges as easily accessible as possible, not involving any form of running or jumping to prevent excessive physical strain on the user and to not exclude or discriminate against those with disabilities(*IEEE Code of Ethics, Section II no. 7).*

A possible safety concern of placing the alarm clock in a refrigerator involves the use of alkaline batteries in frigid temperatures. A person may ignore or even forget about a ringing alarm clock in the refrigerator since the sound will likely be muffled and sleepiness can impair human judgment and decision making abilities. While refrigerators do not go below freezing temperatures, it is still possible for malfunctions to occur. Alkaline batteries are unsuitable for very low temperatures because the electrolytes may freeze, which can cause leakage or bursts. These batteries contain corrosive substances that are hazardous and can damage eyes and skin.