

ECE 445  
SENIOR DESIGN LABORATORY

## PROJECT PROPOSAL

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Moving Alarm Clock

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## Abstract

In comparison to the RFA, the proposal is a more detailed look into the project. High level implementation details, success requirements, and ethical considerations shall be discussed in the following proposal.

## Introduction

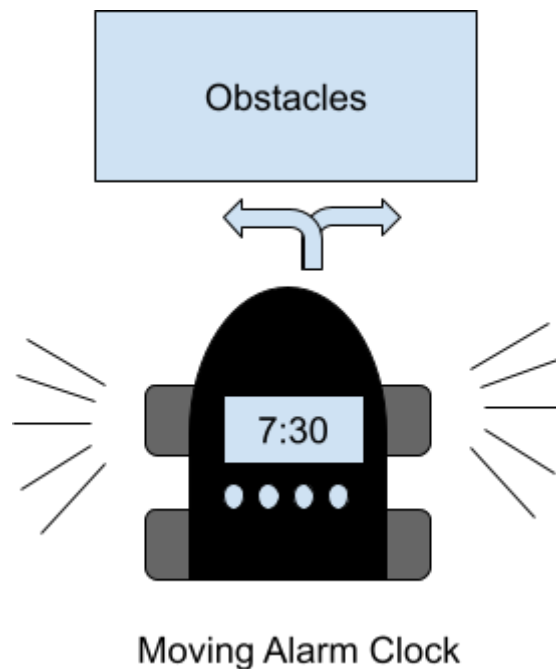
### Problem:

Many people find it difficult to wake up in the morning. Studies show that nearly 70% of people regularly press the snooze button on their alarms. This is a significant problem as it delays people's schedules and gives them less time in the day. Studies show that those who wake up earlier are less likely to develop mental health issues such as depression and anxiety. Those who are unable to wake up from their alarms may be putting their mental health at risk. Additionally those who keep ignoring alarms may disturb others nearby.

### Solution:

Our proposed solution to this issue is a moving alarm clock. This alarm clock will start playing the alarm sound at the same time that it starts moving. The user will have to chase the alarm clock in order to disable it. This will help them get exercise before turning off the alarm which will wake them up. Exercise raises core body temperature which helps wake people up in the morning, similar to a warm shower. It also gets the user away from their bed which can help decrease the urge to go back to sleep. The alarm will have a sensor that will detect obstacles in front of it and will turn away from them. It would be best if the user can't predict the path that the device will take so the device will randomly choose which direction to turn.

### Visual Aid:

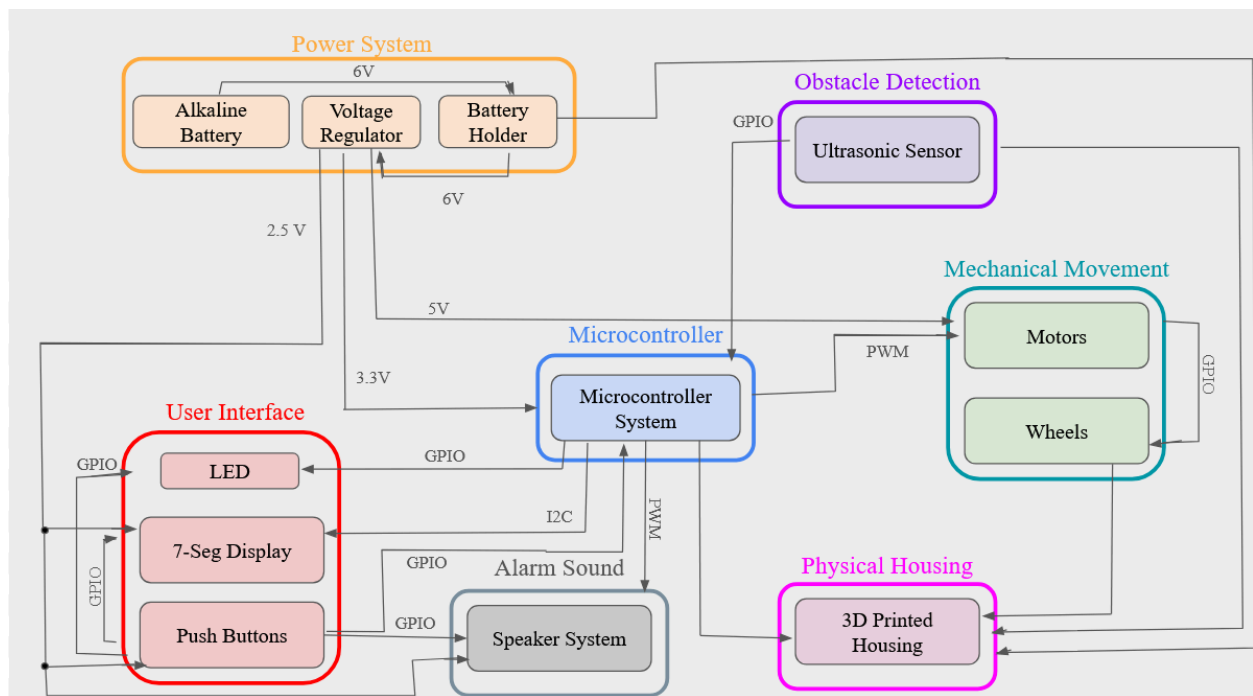


## High Level Requirements:

1. The first requirement is the alarm should ring within 10 seconds of the clock strikes the set alarm time. This is important because it is what causes the user to wake up.
2. The next requirement for success is the robot should start to move while the alarm is sounding. The robot should also be able to avoid crashing into walls and other obstacles using sensors. The sensors should be able to detect walls from 30 cm away and should randomly turn left or right after detecting a wall.
3. The alarm sound system should also be able to be turned off if the user manages to catch the robot. This gives the user an incentive to get up and catch it, waking them up in the process.

## Design

### Block Diagram:



The seven subsystems and the notable components within those subsystems are indicated in the block diagram above. The microcontroller interfaces with the rest of the system, obtaining power and push input and then providing the output to motors, displays, and speakers. The housing covers the entire system. The voltage regulator ensures that different voltages are transferred to different parts of the system. Different communication protocols are used, such as GPIO for simple I/O, I2C for more complex systems, and PWM for any time or frequency based aspects of the system.

## **Subsystem Overview**

The design is split into 7 different subsystems: Power, User Interface, Mechanical Movement, Obstacle Detection, Alarm Sound, Physical Housing, Microcontroller subsystems. The descriptions and requirements of each subsystem has been provided in this following section.

### **Power System**

The device will be powered by EN91 AA Alkaline batteries to enable untethered movement for the alarm actions to be performed, essentially removing a space constraint because no power cords are needed. There will be housing for the batteries which will help connect them to the voltage regulator and then the rest of the overall system. The batteries provide enough power to handle continuous motor operation, sensor activity, and the alarm sound for the necessary duration. A voltage regulator is included with the power system in order to provide different voltages for different subsystems. For instance, the microcontroller system would need 3.3V while the 7-segment display, with a lower  $V_f$ , would need 2.5V instead to accomplish the necessary functions.

### **User Interface System**

The user interface system consists of a 4 digit 7-segment display, 5 push buttons, and a LED. The 7 segment display has 4 digits in order to show time that is accurate to the nearest minute, helping it display the time for the user without including too many units. The 5 push buttons are used as follows: one for setting the hour, one for setting the minute, one to confirm the input time, one for changing alarm/clock modes, and one for turning the alarm on/off. The LED is present to indicate whether the alarm mode is currently on/off. All of these combined will help make the interaction user friendly and easy to understand while ensuring full functionality as well. The push buttons will send GPIO signals to the microcontroller system, with each button having a separate input in order to perform different functions. From the microcontroller, the output pins will lead into the 7-Segment display and the LED (corresponding to buttons 1,2, 3 and 5). Then the outputs from button 4 will be sent to the speaker for the alarm turn off mechanism.

### **Mechanical Movement System**

A motorized base with omnidirectional wheels is present in the vehicle, allowing for free movement in each direction. In addition to the ultrasonic sensor and obstacle detection, the combination of motors will enable smooth, dynamic movement, enhancing the effectiveness of the alarm by making it more challenging to deactivate. The motor will obtain instructions from code present in the microcontroller and will set the speed accordingly. Once the alarm time has been reached, the signal will be transferred to the microcontroller which will then provide instructions to the motor for movement.

## **Obstacle detection System**

Utilizing ultrasonic sensors to detect obstacles nearby and enable smoother and safer movement around obstacles. Real-time data will be provided to the microcontroller, enabling the device to adjust its movement path when obstacles are detected, preventing collisions or getting stuck. Detecting obstacles and moving around them form a necessary part of the overall system's function, thereby making it an important system.

## **Alarm Sound System**

There is a speaker controlled by the PCB and microcontroller to produce the alarm sound at a given user-specified time. The microcontroller will trigger the speaker based on the programmed alarm schedule, ensuring that the activation occurs on time. The sound system will be designed to produce a loud, attention-grabbing alarm, making it difficult to ignore. The sound of the alarm will continue until the user deactivates it.

## **Physical Housing system**

There will be a 3d printed durable housing that will make sure that the internal electronics are shielded from damage during movement and impact. The microcontroller, sensors, and motors are essential to the overall system and therefore needs to be protected. The housing will be designed in such a way in order to absorb maximum impact and still keep the product lightweight and usable.

## **Microcontroller System**

The microcontroller system will utilize an ESP32 microcontroller which will handle all core operations, including motor control, alarm activation, sensor input, and user interface interactions. It will also ensure smooth interaction between the LED / user interface and the functionality of the device, ensuring seamless integration while optimizing performance.

## **Subsystem Requirements**

### **Power System**

1. The power subsystem needs to provide 3.3V +/- 0.1V to the ESP32 microcontroller, LED, and ultrasonic sensor
2. To ensure continuous operation, the power subsystem needs to provide 5V +/- 0.1V to the motor
3. The power subsystem needs to provide 2.5V +/- 0.1V to the display, push buttons, and sound system

## **User Interface System**

1. The 7-segment display must maintain a brightness of at least  $125 \pm 10 \text{ cd/m}^2$  (obtained from typical screen brightness) to ensure visibility
2. All of the push buttons must be able to read input with a maximum response time of  $100 \pm 20 \text{ ms}$  to ensure smooth functionality
3. In a 6 hour period, the clock in the system should be accurate to the nearest  $\pm 1$  minute.
4. The alarm status LED must be visible from a 2 meter radius and change status within  $200 \pm 20 \text{ ms}$  of the push button press

## **Mechanical Movement System**

1. The vehicle must be able to move at a speed of  $7 \pm 2 \text{ mph}$  ( $3.13 \pm 0.83 \text{ m/s}$ ) on a flat smooth surface
2. The turning radius of the system must be  $30 \text{ cm} \pm 5 \text{ cm}$  to ensure 90 degree turns
3. Once the obstacle signal has been provided from the microcontroller, the wheels must turn within  $500 \pm 50 \text{ ms}$  of the signal

## **Obstacle detection System**

1. The obstacle detection system shall accurately detect obstacles within  $1 \pm 0.5$  meters
2. The sensor must have a field of view of  $120 \pm 10$  degrees to ensure large coverage for most indoor environments

## **Alarm Sound System**

1. The speaker must produce a sound with a volume of at least  $75 \text{ dB} \pm 5 \text{ dB}$  at a distance of 1 meters from the device
2. The alarm shall stop within  $200 \pm 20 \text{ ms}$  of the user pressing the button to deactivate it
3. The alarm sound must have a frequency between 2000 and 4000 Hz to match an attention grabbing alarm sound.

## **Physical Housing system**

1. The physical housing system must be able to protect internal components with no more than 2cm of surface deformation after being dropped from a height of 10m
2. After the internal components are mounted, the 3D printed housing must weigh no more than  $300 \pm 10\text{g}$
3. After exposure to around 20mL of water splashes in a span of 30 seconds, there should be no visible moisture in the internal components

## **Microcontroller System**

1. The ESP32 Microcontroller must execute major operations (time set, alarm activation, motor movement) within 100 +/- 10 ms for each task
2. After performing core tasks for 15 minutes, the temperature of the microcontroller temperature must not exceed 70 +/- 5C

## Tolerance Analysis

The average alarm clock is around 70-80 dBA. In order to be as loud as a regular alarm clock we would like our alarm clock to be at least 75 dBA. The speakers that we use have a sound level of 72 dBA with a margin of error of 3 dBA.

Since dBA is logarithmic we can't obtain the sound level by simply adding the dBA for each speaker together. The formula for a combination of sound sources is:

$$L_{tot} = 10 \cdot \log_{10}(10^{L_1/10} + 10^{L_2/10} + \dots + 10^{L_n/10})$$

where  $L_{tot}$  is the total sound level of all of the sources combined and  $L_n$  is the sound level of the nth sound source. The table below shows how, using this formula, the expected sound level increases as the number of speakers increases.

	1 Speaker	2 Speakers	3 Speakers	4 Speakers	5 Speakers
Expected sound level (dBA)	72	75.01	76.77	78.02	78.99

The table shows that just adding 2 speakers is enough to reach the desired sound level of 75 dBA. However we can't take these numbers as the actual value. Since there is a margin of error of 3 dBA we can't be sure that 2 speakers will actually produce enough sound. Below is a table that shows how the minimum sound level of the alarm clock changes as more speakers are added.

	1 Speaker	2 Speakers	3 Speakers	4 Speakers	5 Speakers
Min sound level (dBA)	69	72.01	73.77	75.02	75.99

As the table above shows, the device needs at least 4 of these speakers in order to guarantee a sound level high enough to compare to the average alarm clock. We would also like to set an upper bound of the possible sound level. If a sound is too loud it could cause hearing damage. We would like to have the sound level be under the sound level that causes hearing damage. Sounds 85 dBA or louder are attributed to causing hearing damage. The table below



shows how the maximum sound level of the alarm clock will change as the number of speakers increases.

	1 Speaker	2 Speakers	3 Speakers	4 Speakers	5 Speakers
Max sound level (dBA)	75	78.01	79.77	81.02	81.99

As the table above shows, using 5 speakers or less should not produce a sound that is loud enough to cause hearing damage. Based on this analysis using 4 speakers allows this product to perform properly. 4 speakers give the device a high enough minimum sound level and a low enough maximum sound level to both wake up the user and protect their hearing.

## **Ethics and Safety**

There are a few small ethical concerns with this product. The product could wake up people other than the intended user which may violate the IEEE Code of Ethics (I.1). This is also a concern with a regular alarm, although the motion of the alarm may move it within earshot of someone who wouldn't hear from a real alarm. This issue is not in control of our design as it is related to how the user uses the product. We would warn any user to be mindful of others around them as they use this. Another ethical and safety concern is the user may get hurt while trying to disable the alarm. This could violate the IEEE Code of Ethics (II.9). This may happen if their hand gets caught between the wheel and the frame, or if the device runs over a part of their body. In order to prevent issues like this we will make sure that the user can safely put a finger within the space between the wheel and the frame. We can do this by either putting a flexible/soft material, such as rubber, in this space or by making a large enough gap between the wheel and the frame to fit a finger or hand safely. Another way to do it is to have a very small gap between the wheel and the frame so there is no chance that anything will be able to get caught in the gap. We will also ensure that the device weighs less than 4 pounds so that the user does not get injured from having a part of their body run over.

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