ECE 445
SENIOR DESIGN LABORATORY

DESIGN DOCUMENT

Moving Alarm Clock

TEAM 31

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Abstract
In comparison to the RFA and the proposal, the design document 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

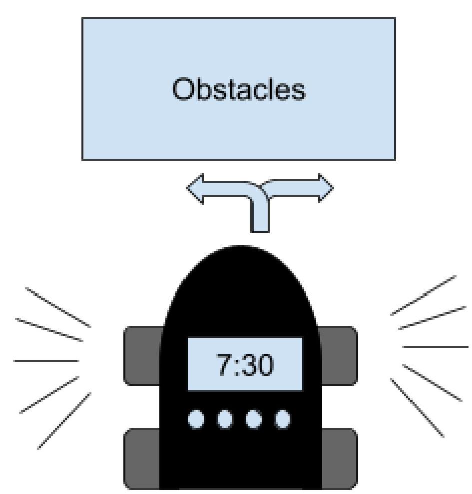
Problem:

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:



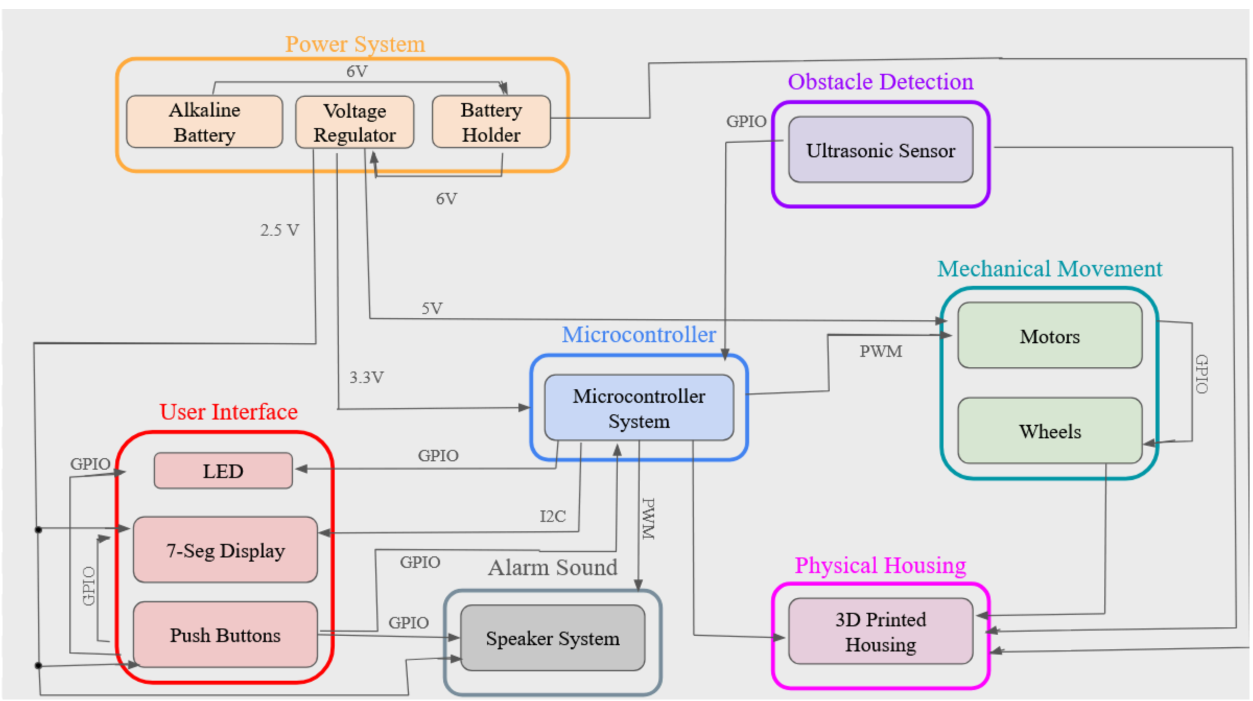
Moving Alarm Clock

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.

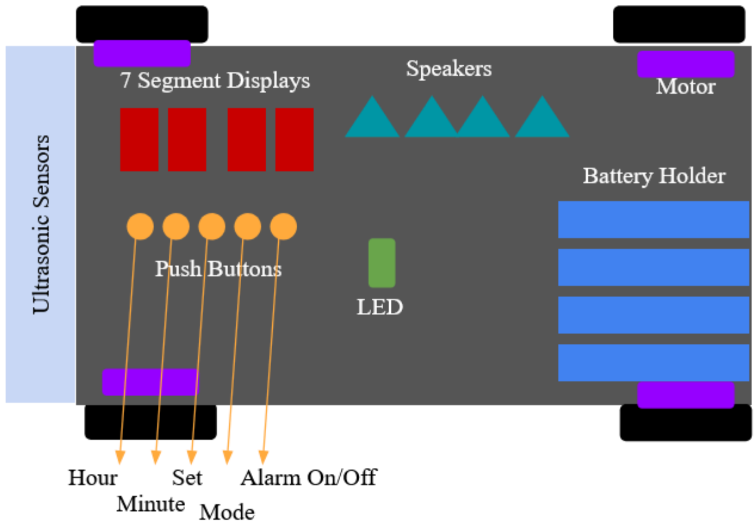
Design

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.

Physical Design

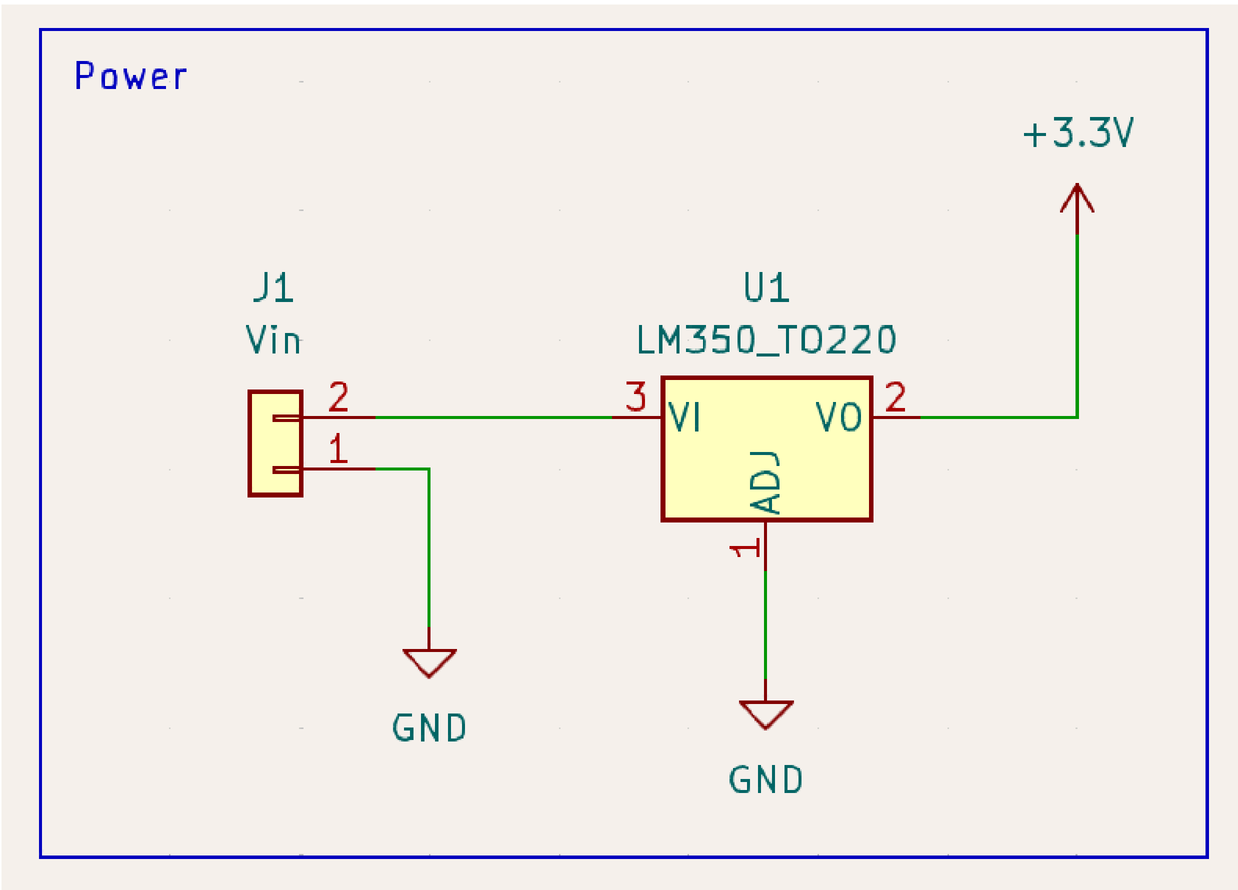


The following physical design provides a clear idea of the layout of the components within the moving alarm clock. With the physical housing, there is a location for the sensors in the front and the four wheels and motors on each side of the housing. Then, the battery holder is located in the back of the vehicle and the interface components in the front. The seven segment display displays hours (first two displays) and minutes (last two displays). The 5 push buttons work as indicated in the diagram and the LED is also present near the buttons. There are 4 speakers to obtain the required dB levels and they are located behind the time display.

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, requirements and verifications of each subsystem has been provided in this following section.

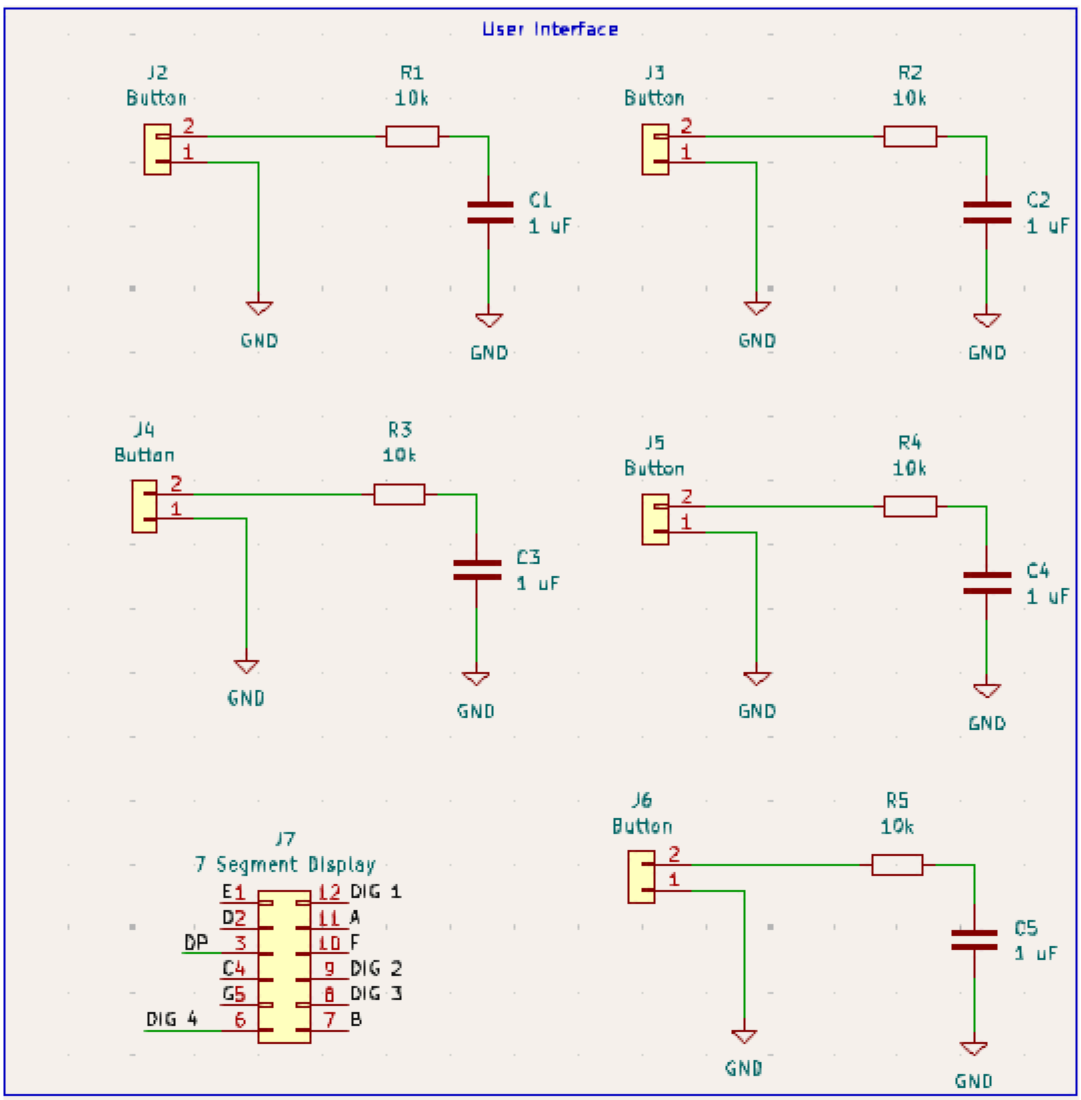
Power System



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 Vf, would need 2.5V instead to accomplish the necessary functions.

Requirements	Verification
The power subsystem needs to provide 3.3V +/- 0.1V to the ESP32 microcontroller, LED, and ultrasonic sensor	Utilize an oscilloscope to measure the output voltage of the regulator to all components and ensure that it is 3.3 +/- 0.1 V
To ensure continuous operation, the power subsystem needs to provide 5V +/- 0.1V to the motor	Utilize an oscilloscope to measure the output voltage of the regulator to all components and ensure that it is 5 +/- 0.1 V
The power subsystem needs to provide 2.5V +/- 0.1V to the display, push buttons, and sound system	Utilize an oscilloscope to measure the output voltage of the regulator to all components and ensure that it is 2.5 +/- 0.1 V

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.

Requirements	**Verification**
The 7-segment display must maintain a brightness of at least 125 +/ 10 cd/m^2 (obtained from typical screen brightness) to ensure visibility	Use a light meter and obtain the value of the brightness from the display and account for the brightness of the room when obtaining a figure
All of the push buttons must be able to read input with a maximum response time of 100 +/ 20 ms to ensure smooth functionality	Use a software program with the microcontroller to measure the speed at which the input is being provided and ensure it falls within appropriate range
In a 6 hour period, the clock in the system should be accurate to the nearest +/- 1 minute.	Record the time after setting the clock and check exactly 6 hours later. If there are large discrepancies in the time, modify the code in the microcontroller to account for those.
The alarm status LED must be visible from a 2 meter radius and change status within 200 +/- 20 ms of the push button press	Use a similar software program as requirement #2 to check status change and observe the LED from a distance of 2 meters and record whether it is visible to the naked eye

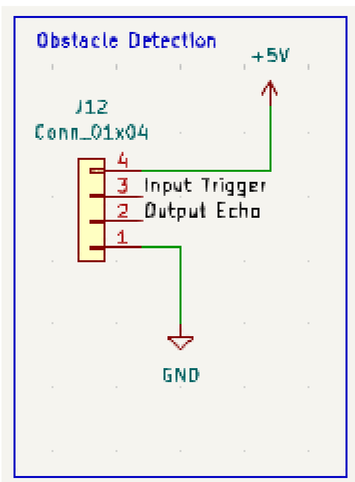
Mechanical Movement System

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.

Requirements	**Verification**

The vehicle must be able to move at a speed of 7 +/ 2 mph (3.13 +/- 0.83 m/s) on a flat smooth surface	To measure this, set a stopwatch and let the vehicle move in a straight line for 10m to determine the speed
The turning radius of the system must be 30 cm +/- 5 cm to ensure 90 degree turns	Set a predetermined location to turn and then measure out a circle with the radius depending on the wheel position to determine the radius of turn
Once the obstacle signal has been provided from the microcontroller, the wheels must turn within 500 +/ 50 ms of the signal	Run a software program to provide the 500ms indication and the tester can determine whether the vehicle has adequately turned within the time frame

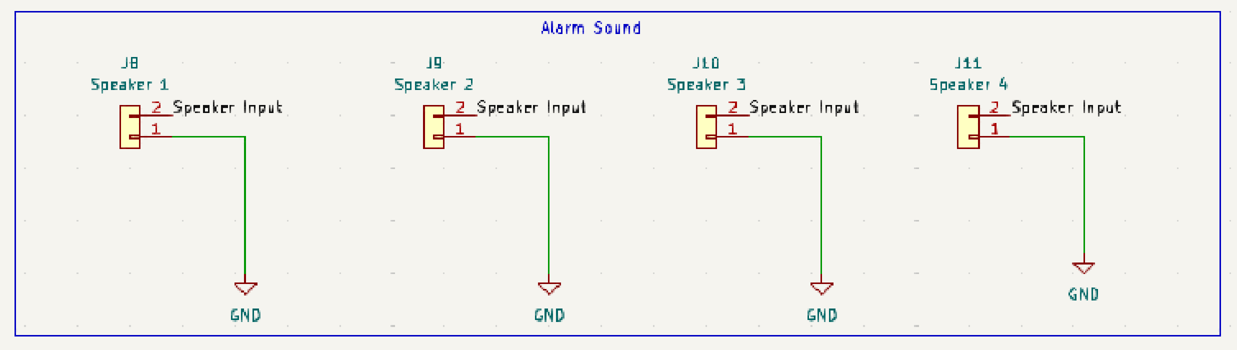
Obstacle detection System



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.

Requirements	Verification
The obstacle detection system shall accurately detect obstacles within 1 +/- 0.5 meters	Use the LED as a debug indicator and place obstacles in the direction of the vehicle and record if the LED turns on
The sensor must have a field of view of 120 +/- 10 degrees to ensure large coverage for most indoor environments	Different angles can be measured and the vehicle should be sent on a straight path with the LED indicator and then the detection will be recorded.

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.

Requirements	Verification
The speaker must produce a sound with a volume of at least 75 dB +/- 5 dB at a distance of 1 meters from the device	Utilize the sound level meter to measure the sound value from 1 meter away and record the measurement
The alarm shall stop within 200 +/- 20 ms of the user pressing the button to deactivate it	Use an oscilloscope and record the time from the button press to the sound system deactivation
The alarm sound must have a frequency between 2000 and 4000 Hz to match an attention grabbing alarm sound.	Use a signal generator to measure the frequency of the alarm sound and record the values

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.

Requirements	Verification
The physical housing system must be able to protect internal components with no more than 2cm of surface	Drop the housing apparatus on a hard surface from 10m and use the ruler to measure the size of damages on

deformation after being dropped from a height of 10m	every side of the physical housing
After the internal components are mounted, the 3D printed housing must weigh no more than 300 +/- 10g	Use a digital scale to weigh the system and record the measurements
After exposure to around 20mL of water splashes in a span of 30 seconds, there should be no visible moisture in the internal components	Conduct water splashes within the given timespan and the tester shall use their own discretion to see if there's moisture in the internal components

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.

Requirements	**Verification**
The ESP32 Microcontroller must execute major operations (time set, alarm activation, motor movement) within 100 +/- 10 ms for each task	Use online software tools or oscilloscopes to measure the time it takes from the code output to the actual execution of the task.
After performing core tasks for 15 minutes, the temperature of the microcontroller temperature must not exceed 70 +/- 5C	For testing, use an infrared thermometer to measure the temperature after 15 minutes of core tasks (motor, alarm sounds)

Subsystem Requirements

The following requirements will be rigorously tested to ensure that the requirements are met for project success. For more details on how these following requirements will be tested, please refer to the Requirements and Verifications table for the particular subsystem.

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 +/ 10 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 +/ 20 ms to ensure smooth functionality
3. In a 6 hour period, the clock in the system should be accurate to the nearest +/- 1 minute.
4. The alarm status LED must be visible from a 2 meter radius and change status within 200 +/- 20 ms of the push button press

Mechanical Movement System

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

Obstacle detection System

1. The obstacle detection system shall accurately detect obstacles within 1 +/- 0.5 meters
2. The sensor must have a field of view of 120 +/- 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 dB +/- 5 dB at a distance of 1 meters from the device
2. The alarm shall stop within 200 +/- 20 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 +/- 10g
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:

$$L_{tot}=10 \cdot log_{10}(10^{L1/10} + 10^{L2/10} + \ldots + 10^{Ln/10})$$

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.

Cost And Schedule

Cost Analysis:

Labor Cost: 55 ($/hour) * 2.5 * 20 (hours/week) *10 (weeks)= $27500
Parts Cost:

Part	Part Number	Quantity	Unit Cost ($)	Total Cost ($)
ESP32 Microcontroller	ESP32-S3-WROOM-1-N16	1	$3.48	$3.48
Speaker	665-AST03008MRR	4	$4	$16
Ultrasonic Sensor	HC-SR04	1	$6	$6
Motors	290-028	4	$7.22	$28.88
Wheels	1832-1038-ND	4	$3.95	$15.80
7 Segment Display	67-1450-ND	1	$5.67	$5.67
Push Button	E-SWITCH TL1105AF100Q	3	$0.51	$1.53
Batteries	EN91	4	$0.65	$2.60
Battery Holder	BH141	1	$3.39	$3.39
Voltage Regulator	LM350T	1	$2.93	$2.93

Total Cost: $27500 + $3.48+$16+$6+$28.88+$15.80+$5.67+$1.53+$2.60+$3.39= $27586.28

Schedule:

Week of 9/30	Complete Design Document and Circuit Schematic
Week of 10/7	Complete PCB

Week of 10/14	Order PCB, Order Parts
Week of 10/21	Soldering and assembly
Week of 10/28	Prototype Assembly
Week of 11/4	Prototype Assembly and Testing
Week of 11/11	Prototype Testing
Week of 11/18	Mock Demo
Week of 11/25	Fall Break
Week of 12/2	Final Demo
Week of 12/9	Final Presentation

Tasks and Teamwork

Since both team members have skills and experiences in similar aspects of the Computer Engineering curriculum (Software, Power circuits, and Data Science), skill based task delegation isn't an option that we have opted for. Instead, we have decided to delegate tasks based on technical vs. Documentation expertise. Since one of the team members is more well versed in circuit design and technical aspects of the project, more of the design tasks will be assigned to the member. On the other hand, the other member will be assigned more of the testing and documentation aspects of the project.

Ethics and Safety

Our project team takes ethical and safety considerations extremely serious and we ensure that any ethics or safety issues will be minimized. Therefore, this project team will act in accordance with the IEEE code of ethics present by the IEEE organization.

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.

To uphold the IEEE code of ethics section I.5, we will seriously consider any reviews provided by the course staff in regards to this product. In addition, we will ensure that the product is ready for consumers by seeking opinions from any potential consumers of the product and make any modifications as necessary. Ultimately, expert opinions and consumer opinions are of utmost importance and those will be accounted for in order to make this a more ethical product.

A possible safety issue that can arise from this product is the presence of Alkaline batteries, which on very rare occasions could catch fire or start leaking. In order to prevent these issues, we will provide instructions to the consumer to switch batteries more frequently. In addition, the physical housing will ensure that there is minimal contact between the user and the batteries unless necessary. The likelihood of Alkaline batteries catching fire is noticeably lower than that of Lithium ion batteries, which partially served as the motivation for choosing Alkaline batteries for this system.

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