

# **Voice-Activated Geographic Reference Globe**

## **ECE 445 Design Document - Spring 2026**

Project # 44

Mahathi Jayaraman, Rijul Roy, Varsha Mullangi

Professor: Joohyung Kim

TA: Chihun Song

13 February, 2026

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# **1. Introduction**

## **1.1 Problem**

Many American children and adults struggle with geography. Many of them cannot point out a country on a map or identify the locations of major world events. This lack of geographical knowledge can limit people's global awareness and make it more difficult to understand culture, current events, and international relations. We believe that this gap in knowledge starts at school, where students are not engaged enough to care about what they are learning. When geography is taught through memorization instead of connection, students may not retain the information in the long term.

In addition, many kids are spending a lot of time on screens and online, which is taking them out of the real world. While technology can be educational, learning centered around screens can be overwhelming and distracting. When all aspects of life are turning more and more digital, it may be a good idea to take a step back. However, traditional globes aren't always ideal. Globes often have very small words that are difficult for children to read clearly. It can also be challenging to locate specific countries, especially if a child is unfamiliar with that particular region of the globe. Clearly, a more interactive and intuitive approach to teaching and learning geography is needed.

## **1.2 Solution**

To solve this problem, our group wants to make an engaging product that can help students learn geography without being attached to a screen. That product is the Voice-Activated Geographic Reference Globe.

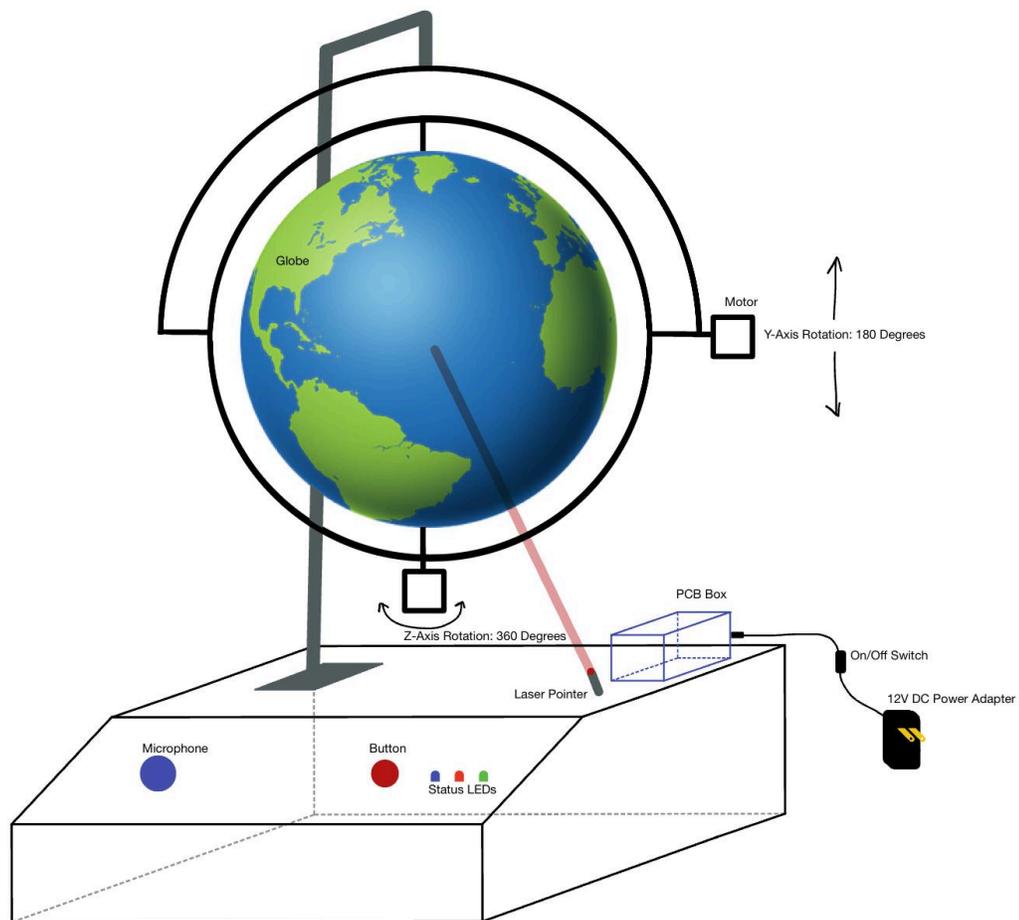
Our proposed voice-activated globe aims to solve this problem by making learning fun and interactive using a speech-detection mechanism. This mechanism will recognize a spoken country as input and automatically rotate the globe, ensuring that the specified location ends up at a pre-defined center point. This country will be lit up by a laser pointer, illuminating the region that the user wants to search for. This automated rotation makes it so that children do not need to do any manual searching for locations, letting them focus entirely on learning. The speech-based interaction means that the system is intuitive and easy to use for young children in a classroom setting.

Using this device, classrooms can help educate children on geography. Through a combination of the spoken aspect of naming a country and the visual aspect of the globe and laser pointer, the

country's name and location will be better absorbed by the user, which will help with recall later. Using a globe rather than just a screen that displays each country also helps with 3D spatial positioning of the countries in the user's mind, which lets them remember countries in relation to each other.

While engaging, this globe will not overwhelm children the way a computer program will. Instead, it will be just interesting enough to keep their attention and excitement about learning, without overexposure to screens.

### 1.3 Visual Aid



*Fig 1. Project Design*

Our design consists of two main elements: the globe and the base. The globe will be capable of 180° rotation on the Y-axis and 360° rotation on the Z-axis. The base will be built by

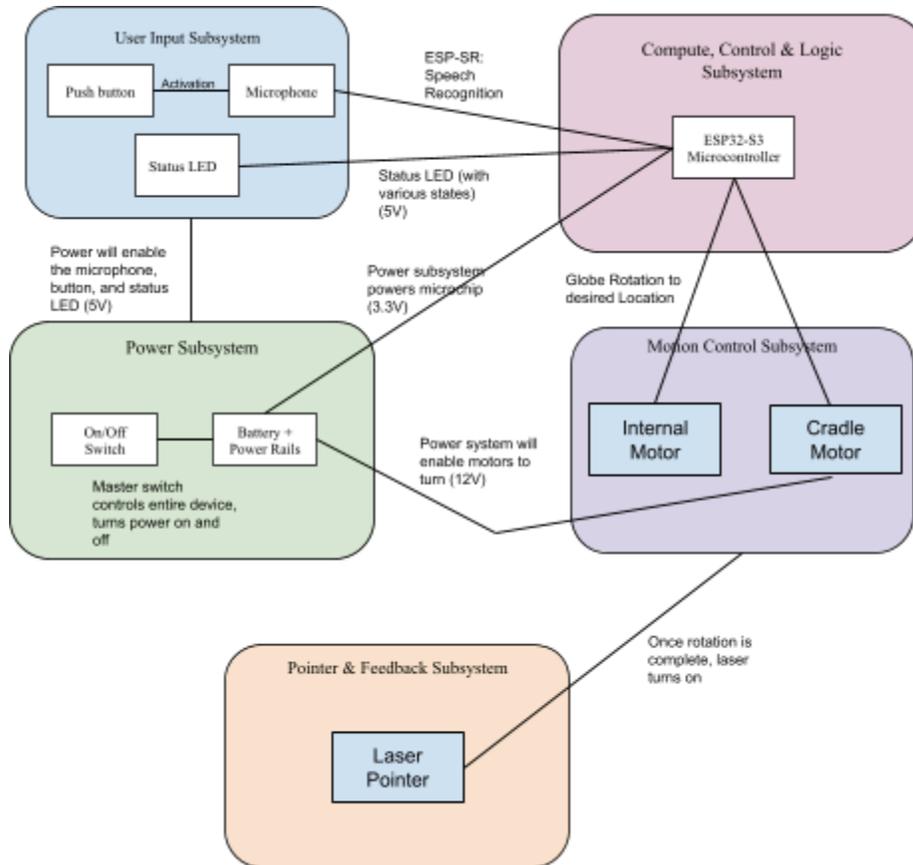
the machine shop and will hold the microphone and button that make up the User Input Subsystem (2.2.1). Additionally, it will contain the laser pointer that identifies the chosen country and the status LEDs, which comprises the Compute, Control & Logic Subsystem (2.2.2). The last item on the base is the PCB box containing our PCB. The 12V DC power adapter and on/off switch that belong to the Power Subsystem (2.2.5) are plugged into the pcb box.

## 1.4 High-Level Requirements

- Our vocabulary will be limited to the 195 countries on Earth, plus a “Reset” function. We will start with 50 countries, then move to 100, then 150, then all 196. Our target accuracy initially is a 75% detection rate.
- The status LED will light up:
  - Red if the word spoken is not a recognized country.
  - Blue while the button is being pressed and the microphone is accepting input.
  - Green when the country is recognized and matched with a known country in our country database.
- Once given a country as input, the globe correctly rotates to display, which ensures that said country ends up at the pre-defined center reference.
- The laser pointer accurately points to the pre-defined center reference point. It turns on automatically once the globe is done rotating. It will turn off when a new country is specified and remain off until rotation is complete to the new country.
- When reset, the globe will return to a neutral position with the laser pointing at a set location along the equator, and then the laser will not turn on again, essentially putting the globe into sleep mode.

## 2. Design

### 2.1 Block Diagram

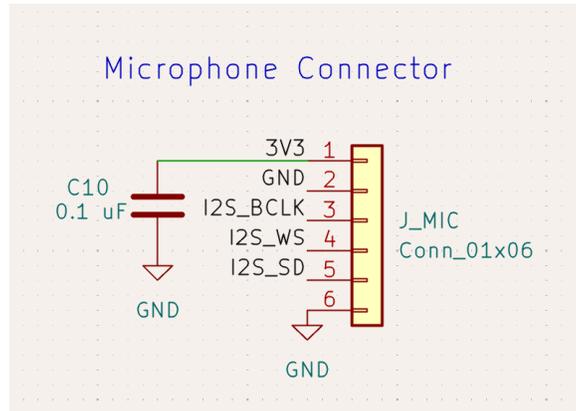


*Figure 2. Block Diagram for Overall Design*

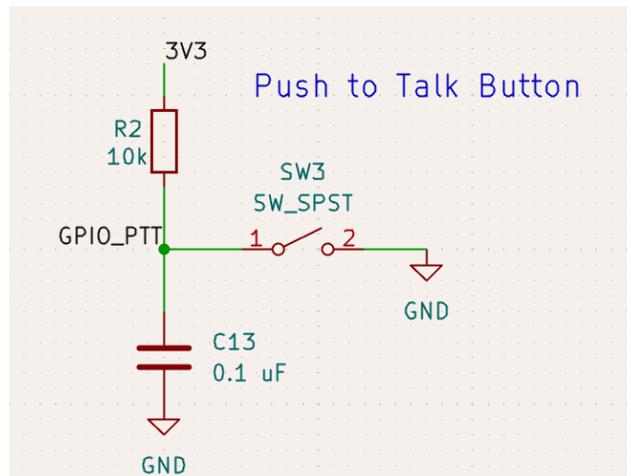
## 2.2 Subsystem Overview and Requirements

### 2.2.1 User Input Subsystem

This subsystem will implement the speech recognition mechanism of the globe. A simple push button (PS1024ALRED) and microphone (I2S Digital Microphone (INMP441)) will be connected to the GPIO pins of the ESP32-S3 MCU. While the button is pressed, the microphone will collect audio from the user, capturing the specified country the user wants to find. The microphone will stream audio to the ESP32-S3 over the I2S interface using a sampling format compatible with ESP-SR, which is a 16 kHz sampling rate and a mono channel format [4]. The MCU then processes this audio and transfers it to the Compute, Control, and Logic subsystem (subsystem 2.2.2), where it uses ESP-SR to help determine which country the user wants to find, motor logic, and status LED control.



**Figure 3.** INMP441 Microphone Module Connector Schematic



**Figure 4.** Debounced Push To Talk Button Schematic

**Table 1.** User Input Subsystem - Requirements and Verification

Requirements	Verification
<ul style="list-style-type: none"> <li>The user input subsystem will only capture audio while the push-to-talk button is being pressed, and will stop recording audio within &lt; 400 ms of the user not pressing the button</li> </ul>	<ul style="list-style-type: none"> <li><b>Equipment:</b> ESP32-S3 MCU, firmware with timestamps, microphone, PS1024ALRED Push Button</li> <li><b>Test:</b> Press and hold the push-to-talk button while speaking into the microphone and verify through</li> </ul>

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	<p>firmware output that audio capture begins only during the button press. Release the button and measure the time between button release and audio capture.</p> <ul style="list-style-type: none"> <li>● <b>Demonstration:</b> Firmware output showing that audio recording only happens while the button is being pressed and stops within 400 ms of the user releasing the button.</li> </ul>
<ul style="list-style-type: none"> <li>● The subsystem will accept spoken input from a user located 10 to 20 cm from the microphone under normal indoor audio conditions</li> </ul>	<ul style="list-style-type: none"> <li>● <b>Equipment:</b> Ruler, microphone, ESP32 MCU, status LED</li> <li>● <b>Test:</b> Stand at distances between 10 cm and 20 cm from the microphone and use a ruler to confirm the distance. Speak several country names under normal indoor room noise conditions. Verify through the status LED output from subsystem 2.2.2 that spoken input is recognized.</li> <li>● <b>Demonstration:</b> Status LED output showing successful spoken input capture and detection</li> </ul>
<ul style="list-style-type: none"> <li>● The push-to-talk input will be debounced such that a single physical press produces no more than one capture-start event and a single physical release produces no more than one capture-stop event</li> </ul>	<ul style="list-style-type: none"> <li>● <b>Equipment:</b> ESP32-S3 MCU, firmware, PS1024ALRED Push Button</li> <li>● <b>Test:</b> Press and release the button and monitor the firmware output for capturing the beginning and end of the recording. Verify that each press and release has exactly one start event and exactly one stop event.</li> <li>● <b>Demonstration:</b> Firmware output showing one start event and one stop event for each button press and release over multiple trials.</li> </ul>

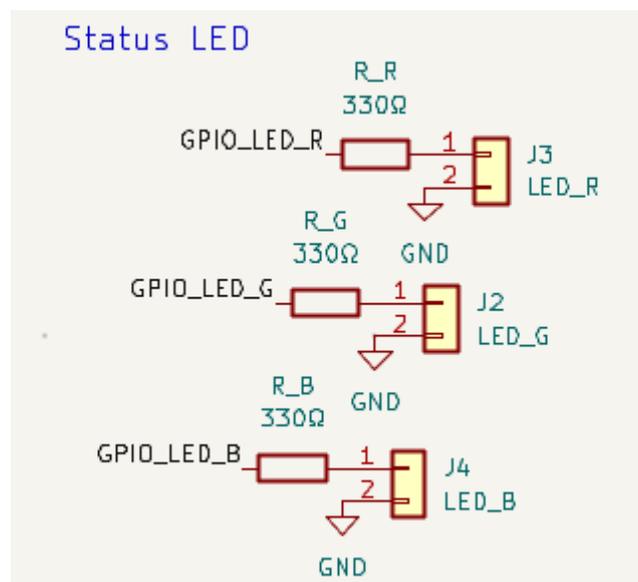
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### 2.2.2 Compute, Control & Logic Subsystem

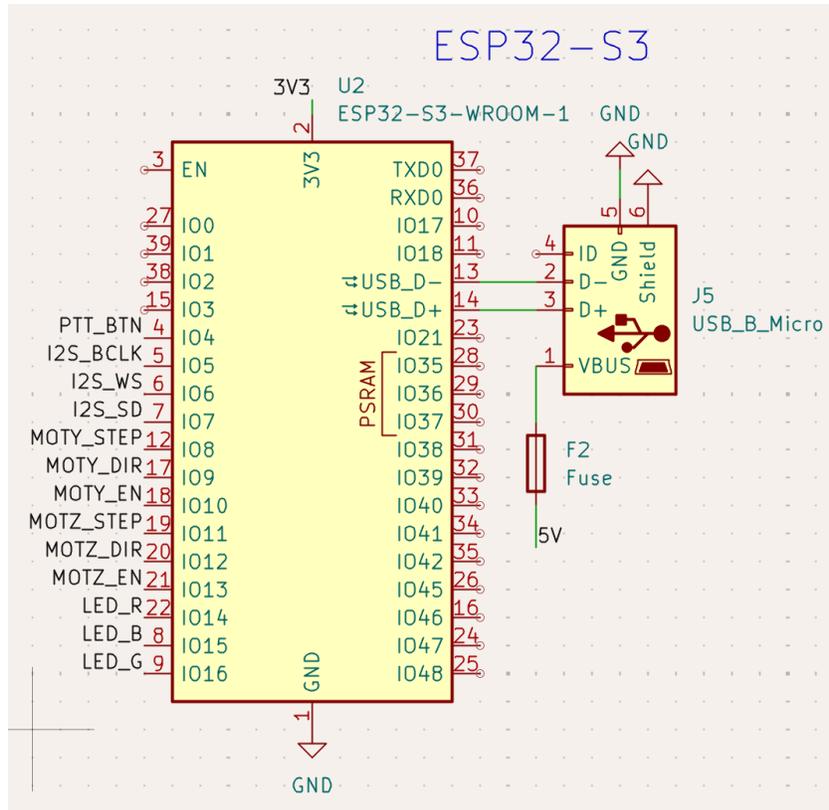
This subsystem is responsible for processing audio and calculating motor movements. It takes the audio input collected by the User Input Subsystem and extracts the country input using the

ESP-SR speech recognition framework. This subsystem will then match the given country input with our database of countries to find its location on the globe. We will be using a coordinate system similar to the latitude and longitude system to identify each country on the globe. After that, the subsystem will take the current position of the globe and the goal position and calculate the movement along each axis (in number of steps) needed to get the globe to its goal position, and send that information over to the Motion Control subsystem.

In addition to telling the Motion Control Subsystem how and where to move the globe, this subsystem provides real-time feedback to the user. Based on the current state in the speech recognition pipeline, it controls the status LEDs to communicate what the system is doing. While audio input is actively being collected, it turns on the blue status LED to indicate recording. If this subsystem fails to identify a country or fails to match the identified input with the country database, it turns the red LED on. When a country is correctly identified and matched in the county database, the green led is turned on to indicate a success. This will help the user understand if a country needs to be repeated or if the country was correctly recognized.



**Figure 5.** Status LEDs Schematic



**Figure 6.** ESP32-S3 MCU Schematic

**Table 2.** Compute, Control & Logic Subsystem - Requirements and Verification

Requirements	Verification
<ul style="list-style-type: none"> <li>The Compute, Control, and Logic subsystem will set the status LEDs accordingly, and the status LEDs must update to the correct state within 400 ms of any state change</li> </ul>	<ul style="list-style-type: none"> <li><b>Equipment:</b> ESP32-S3 MCU, INMP441 Microphone, firmware, camera</li> <li><b>Test:</b> Trigger each of the three states associated with the three status LEDs.</li> </ul>
<ul style="list-style-type: none"> <li>The Compute, Control, and Logic subsystem must process audio data from the User Input Subsystem using ESP-SR and output a single recognized country label or error within 2s of audio capture ending</li> </ul>	<ul style="list-style-type: none"> <li><b>Equipment:</b> ESP32-S3 MCU, INMP441 Microphone, PS1024ALRED Push Button, firmware</li> <li><b>Test:</b> Perform multiple trials of speaking valid country names while holding the push-to-talk button. Release the button and use timestamped firmware logs to measure the time from capture to final</li> </ul>

	<ul style="list-style-type: none"> <li>recognition.</li> <li><b>Demonstration:</b> Serial log showing recognition output and measured latency for each trial.</li> </ul>
<ul style="list-style-type: none"> <li>The subsystem must determine whether the recognized country exists in the country database. If it does not exist, the subsystem will generate an error state and set the red status LED within 400ms of the invalid recognition.</li> </ul>	<ul style="list-style-type: none"> <li><b>Equipment:</b> ESP32-S3 MCU, firmware, status LED hardware</li> <li><b>Test:</b> Speak a series of phrases that are not in the country database. Verify that the firmware flags “not in the database” and that the red LED is set within 400ms of the result.</li> <li><b>Demonstration:</b> Video and serial log showing invalid input detection and LED change timing.</li> </ul>
<ul style="list-style-type: none"> <li>If the recognized country exists in the database, the subsystem must retrieve the correct target (z, y) coordinates from the country database</li> </ul>	<ul style="list-style-type: none"> <li><b>Equipment:</b> ESP32-S3 MCU, firmware</li> <li><b>Test:</b> Select a fixed list of countries with known stored coordinates. Speak each one and compare the printed (z, y) values to the expected values from the database.</li> <li><b>Demonstration:</b> Table of expected vs. retrieved coordinates for each tested country.</li> </ul>
<ul style="list-style-type: none"> <li>The subsystem must compute the difference between the current globe position and the target position, convert it into motor steps for the z-axis and y-axis, and send step commands to the Motion Control Subsystem within &lt; 500 ms after coordinates are retrieved</li> </ul>	<ul style="list-style-type: none"> <li><b>Equipment:</b> ESP32-S3 MCU, firmware with timestamped step-command prints, Motion Control interface (GPIO outputs or command packets)</li> <li><b>Test:</b> Initialize the system to the neutral position, then input multiple countries. Confirm that the computed step counts match hand calculations for the same (current → target) coordinate pairs, and measure timing from coordinate retrieval to command output.</li> <li><b>Demonstration:</b> Serial log showing current position, target position, computed z-steps/y-steps, timestamps.</li> </ul>
<ul style="list-style-type: none"> <li>The subsystem must keep track of the current globe position after each</li> </ul>	<ul style="list-style-type: none"> <li><b>Equipment:</b> ESP32-S3 MCU, firmware, laser</li> </ul>

completed movement

- **Test:** Run a sequence of at least 10 country inputs. After each movement completion signal, verify that the stored “current position” equals the prior movement’s target position and that subsequent step calculations use the updated value.

### 2.2.3. Motion Control Subsystem

This subsystem will implement the motion control of the globe. This refers to the rotation of the globe, both along the globe’s axis as well as the cradle’s movement. The globe’s axis will control rotation around the z-axis (the actual Earth’s axis of rotation), while the cradle will control rotation around the y-axis (the axis perpendicular to the frame of view). When a desired country is recognized as an input (from the User Input subsystem and the Compute, Control & Logic Subsystem) and a desired destination is calculated, this subsystem will control the rotation of the globe to that location. The stepper motor embedded inside the globe will allow the globe to rotate around the z-axis precisely to the degree needed to point the desired country at the frame of view, and the stepper motor on the outside cradle track will rotate the entire cradle system around the y-axis to do the same. The GPIO pins of the ESP32-S3 MCU would be connected to the stepper motors, enabling rotation. The motors have the capability to calculate exact rotation, so we can use this to make sure the globe rotates to exactly the desired position.

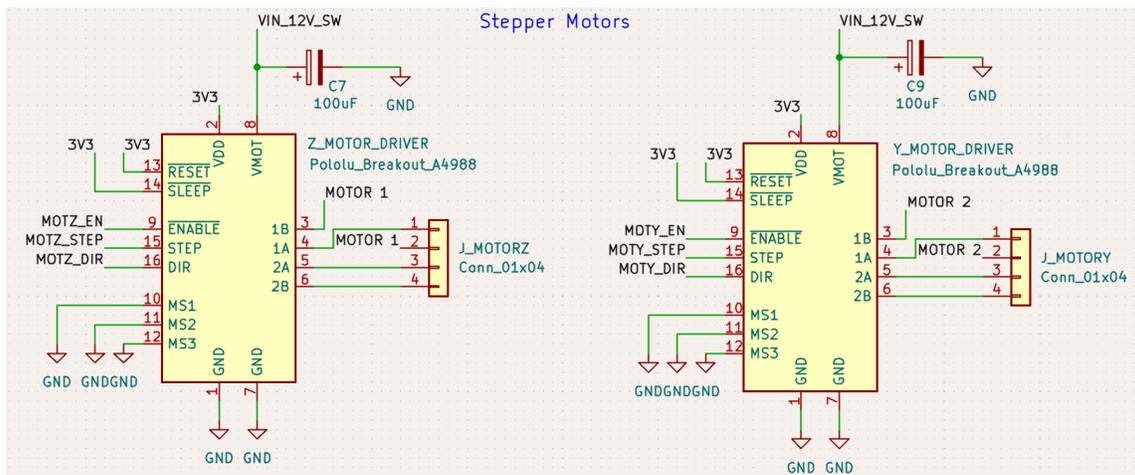


Fig 7. Motion Control Subsystem Schematic

Table 3. Motion Control Subsystem - Requirements and Verification

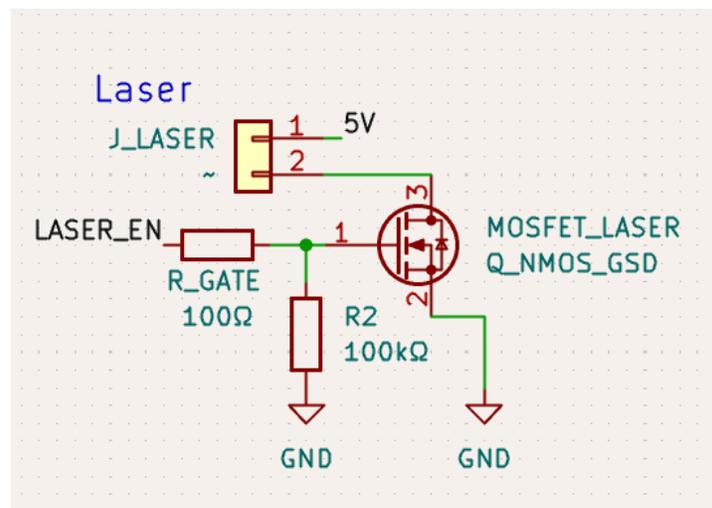
Requirements	Verification
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<ul style="list-style-type: none"> <li>• The motion system must rotate the globe on both axes to the location specified by the Compute, Control &amp; Logic Subsystem.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Equipment:</b> Camera, Ruler</li> <li>• <b>Test:</b> Enter a series of countries into the globe. Check the location the globe rotates to and compare this to the target location specified in the code.</li> <li>• <b>Demonstration:</b> A recording of these tests and a table of the target location and the actual location rotated to.</li> </ul>
<ul style="list-style-type: none"> <li>• The z-axis must have a full 360 degrees of motion available.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Equipment:</b> Camera</li> <li>• <b>Test:</b> Manually rotate the globe along the z-axis in both directions to ensure the globe has a total 360 degrees of motion available.</li> <li>• <b>Demonstration:</b> A recording of these tests.</li> </ul>
<ul style="list-style-type: none"> <li>• The y-axis must have 180 degrees of motion available.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Equipment:</b> Camera</li> <li>• <b>Test:</b> Manually rotate the globe along the y-axis in both directions to ensure the globe has a total 180 degrees of motion available.</li> <li>• <b>Demonstration:</b> A recording of these tests.</li> </ul>
<ul style="list-style-type: none"> <li>• The globe must rotate to the desired position within 10 seconds.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Equipment:</b> Camera, Stopwatch</li> <li>• <b>Test:</b> Enter a series of countries into the globe. Measure the time from the green LED activating to when the rotation of the globe is complete. This should be less than 10 seconds.</li> <li>• <b>Demonstration:</b> A recording of these tests and a time per trial table.</li> </ul>
<ul style="list-style-type: none"> <li>• Once rotation is complete, the system must send a signal to the Pointer &amp; Feedback Subsystem to turn on the laser within 1 second.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Equipment:</b> Stopwatch, Camera</li> <li>• <b>Test:</b> Set up the recording. Record multiple trials of giving a country to the globe. Once rotation to the country is complete, use the stopwatch to measure the time to laser activation.</li> <li>• <b>Demonstration:</b> A recording of successful laser activations and a time per trial log.</li> </ul>

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- Each motor has an operating voltage around 12 Volts, and an operating current around 2 Amps.
  - **Equipment:** Digital Multimeter
  - **Test:** Activate the motor, and use the multimeter to measure the voltage and current of the motor to ensure both values are around the accepted values.
  - **Demonstration:** A table of current and voltage values from the various trials.
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### 2.2.4 Pointer Subsystem

This subsystem will implement the pointer and feedback systems. This is the subsystem that controls when the laser pointer will turn on or off, which highlights the specified country. When the globe has rotated to the desired position (as calculated by subsystems 1 and 2 and reached by subsystem 3), the ESP32-S3 MCU will send a signal to the laser pointer to turn on. The laser pointer will remain turned on while the desired country is in the target position to face the frame of view, and will turn off as soon as the target is not in said position. This would be when a new country is recognized via the input subsystem 1, which would change the target country to another one that is not in the final location, thus turning off the laser.



*Fig 8. Pointer Subsystem Schematic*

*Table 4. Pointer System - Requirements and Verification*

Requirements	Verification
<ul style="list-style-type: none"> <li>The laser turns on within 1 second of completion of rotation (with the exception of the “Reset” function as mentioned below).</li> </ul>	<ul style="list-style-type: none"> <li><b>Equipment:</b> Stopwatch, Camera</li> <li><b>Test:</b> Set up the recording. Record multiple trials of giving a country to the globe. Once rotation to the country is complete, use the stopwatch to measure the time to laser activation.</li> <li><b>Demonstration:</b> A recording of successful laser activations and a time per trial log.</li> </ul>
<ul style="list-style-type: none"> <li>The laser turns off within 1 second of a new country being spoken and recognized (with the exception of use after the “Reset” function as mentioned below).</li> </ul>	<ul style="list-style-type: none"> <li><b>Equipment:</b> Stopwatch, Camera</li> <li><b>Test:</b> Set up the recording. Record multiple trials of speaking a new country with the laser on. Once the country is recognized and the green LED indicator turns on, use the stopwatch to measure the time to laser deactivation.</li> <li><b>Demonstration:</b> A recording of successful laser deactivations and a time per trial log.</li> </ul>
<ul style="list-style-type: none"> <li>The laser pointer either points directly within the specified country, or for countries with an area less than 0.25 cm<sup>2</sup> on the globe, the laser points within a distance range of 2.5 mm from the borders.</li> </ul>	<ul style="list-style-type: none"> <li><b>Equipment:</b> Ruler, Camera</li> <li><b>Test:</b> Speak a series of countries into the globe for the set of tests. Use a variety of countries, including big countries like Canada and China, and small countries like Panama and Croatia. For the big countries (above 0.25 cm<sup>2</sup>, the laser must be within the borders of the country. For smaller countries, the laser must be within 2.5 millimeters from the country’s borders.</li> <li><b>Demonstration:</b> A recording of these tests and a distance per trial log.</li> </ul>
<ul style="list-style-type: none"> <li>The laser pointer will be mounted on the base and will point directly at the equator when the globe is in a neutral position, and the desired country will rotate onto that spot.</li> </ul>	<ul style="list-style-type: none"> <li><b>Equipment:</b> Camera</li> <li><b>Test:</b> Use the “Reset” function to reset the globe to the neutral position. Manually activate the laser (as the neutral position will not activate the</li> </ul>

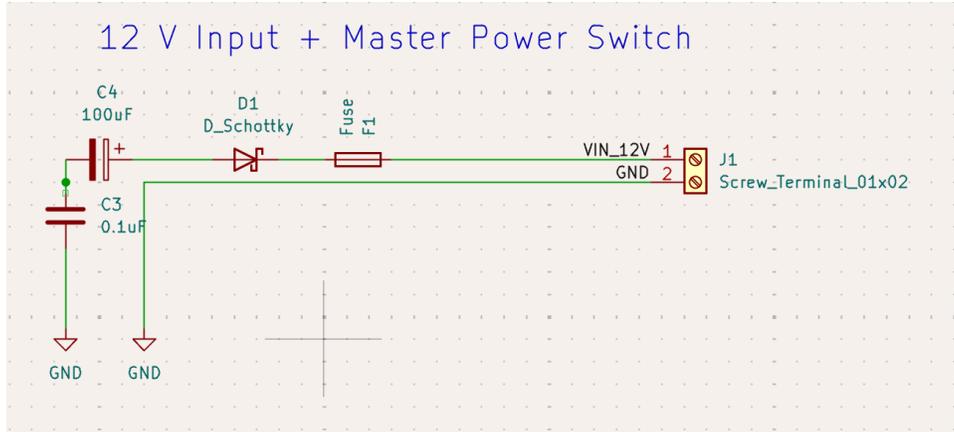
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	<p>laser. Check if the laser is pointing at the equator on the globe.</p> <ul style="list-style-type: none"> <li>● <b>Demonstration:</b> A recording of these tests.</li> </ul>
<ul style="list-style-type: none"> <li>● The laser pointer operates at a voltage between 2.6 to 6 VDC, and at a current less than 35 mA/50 mA (which is a power of less than 1 mW/2.5 mW).</li> </ul>	<ul style="list-style-type: none"> <li>● <b>Equipment:</b> Digital Multimeter</li> <li>● <b>Test:</b> Activate the laser, either manually or by speaking a country into the globe. Measure the voltage and current outputs of the laser. Make sure they are within the accepted range. Calculate the power from these two values.</li> <li>● <b>Demonstration:</b> A table of current, voltage, and power values from the various trials.</li> </ul>
<ul style="list-style-type: none"> <li>● The “Reset” function sets the globe into a neutral position (with the laser pointing at a predetermined spot along the equator) and <b>does not</b> activate the laser.</li> </ul>	<ul style="list-style-type: none"> <li>● <b>Equipment:</b> Camera</li> <li>● <b>Test:</b> Speak the reset word into the globe, and wait for the globe to reset into the neutral position. Ensure the laser does not turn on.</li> <li>● <b>Demonstration:</b> A recording of the globe successfully resetting with no laser activations.</li> </ul>

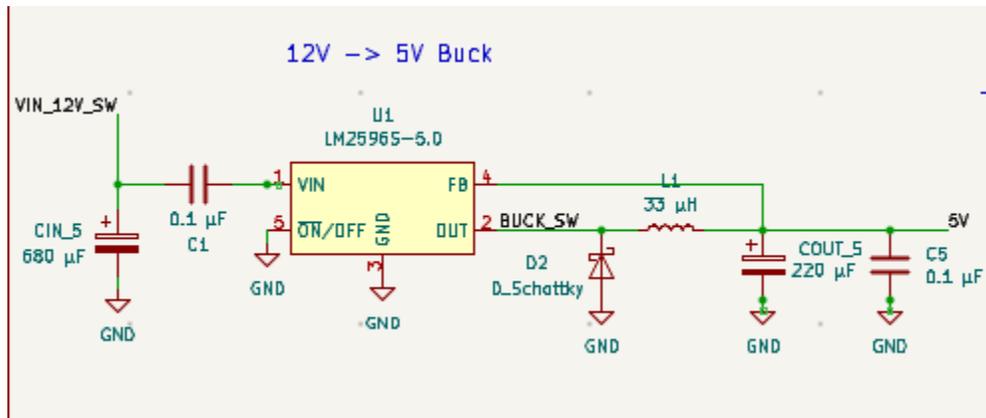
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### 2.2.5 Power Subsystem

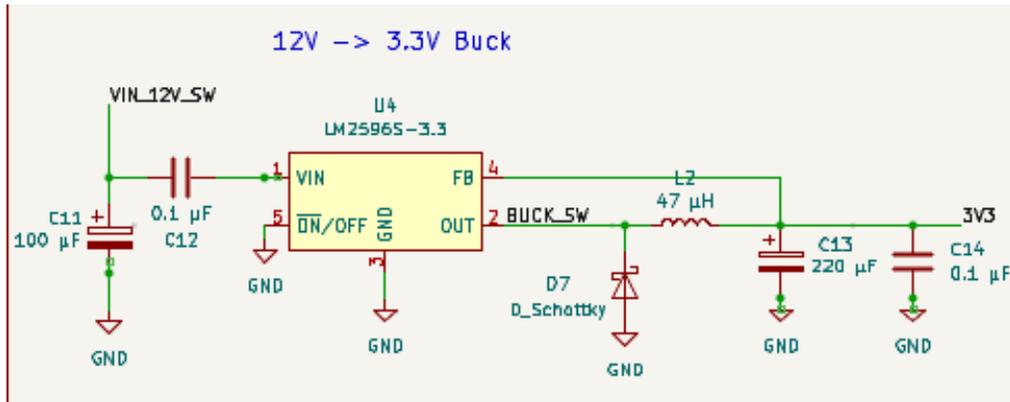
The power subsystem is responsible for powering the full system (MCU, microphone, LED, motors, laser) by providing regulated DC power using an external wall adapter. The wall adapter converts the AC power from the wall outlet to a regulated 12V DC power supply, which serves as the main input into the system. Voltage regulators will then convert the 12V power supply into 5V and 3.3V rails to power the various devices in our project. The 12V → 5V buck converter will generate a regulated 5V rail for components such as the status LEDs and the 12V → 3.3V buck converter will generate a regulated 3.3V rail for the ESP32-S3 MCU and other low-voltage components. This subsystem also includes a master on/off switch between the wall adapter and the PCB so that the user can safely turn the system on and off.



**Fig 9.** *V Input and Master Switch Schematic*



**Fig 10.** *12V to 5V Buck Schematic*



**Fig 11.** *12V to 3.3V Buck Schematic*

**Table 5.** *Power Subsystem - Requirements and Verification*

Requirements	Verification
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<ul style="list-style-type: none"> <li>• The power subsystem must accept a 12V DC input from the external wall adapter and distribute power to all subsystems</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Materials:</b> 12V wall adapter, multimeter</li> <li>• <b>Test:</b> Measure the voltage at the point where the power system connects to the PCB and confirm it is <math>12V \pm 5\%</math>.</li> <li>• <b>Demonstration:</b> Multimeter reading showing a stable 12V input while the system is plugged in.</li> </ul>
<ul style="list-style-type: none"> <li>• The power subsystem must generate a 5V power rail using a <math>12V \rightarrow 5V</math> buck converter</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Materials:</b> Multimeter</li> <li>• <b>Test:</b> Measure the output of the 5V rail with 0 load and full expected load and confirm voltage remains within <math>5V \pm 5\%</math></li> <li>• <b>Demonstration:</b> Multimeter reading showing a stable 5V input while the system is plugged in.</li> </ul>
<ul style="list-style-type: none"> <li>• The power subsystem must generate a 3.3V power rail using a <math>12V \rightarrow 3.3V</math> buck converter</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Materials:</b> Multimeter</li> <li>• <b>Test:</b> Measure the output of the 3.3V rail with 0 load and full expected load and confirm voltage remains within <math>3.3V \pm 5\%</math></li> <li>• <b>Demonstration:</b> Multimeter reading showing a stable 5V input while the system is plugged in.</li> </ul>
<ul style="list-style-type: none"> <li>• The 5V and 3.3V rails must operate simultaneously without causing voltage drop greater than 5% on either rail</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Materials:</b> Multimeter</li> <li>• <b>Test:</b> Measure both rails for a full cycle of taking input, processing input, setting status LEDs, running motor and turning on laser pointer. Confirm neither rail drops below specified tolerance.</li> <li>• <b>Demonstration:</b> Multimeter reading showing a stable 5V and 3.3V inputs while the system is plugged in for the 5V and 3.3V rails, respectively.</li> </ul>
<ul style="list-style-type: none"> <li>• The subsystem must include a master on/off switch that completely disconnects power from the rest of the circuitry</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Materials:</b> Multimeter</li> <li>• <b>Test:</b> Flip the on/off switch to off. Confirm system is not being powered.</li> <li>• <b>Demonstration:</b> Multimeter reading showing a stable 0V input while the system is plugged in.</li> </ul>

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- The power subsystem must operate with an efficiency of at least 80% at typical load conditions
  - **Materials:** Multimeter
  - **Test:** Measure input power ( $12V \times$  input current) and output power (sum of 5V and 3.3V rail power). Calculate efficiency and confirm it is greater than or equal to 80%.
  - **Demonstration:** Calculation sheet showing measured efficiency.
- 

## 2.4 Tolerance Analysis

For the rotation component, we will be using two stepper motors: one for the embedded rotation in the globe and the other on the external cradle. A stepper motor has up to 5% error per step in the motor's rotation. Each step rotates the motor by 1.8 degrees. However, because of the motor's design, after 200 steps, it is guaranteed to move exactly 360 degrees, which means that the error does not accumulate. This means that each step will cause a maximum of  $5\% * 1.8 = 0.09$  degrees. Our globe has a diameter of 10 inches, or 25.4 cm. Therefore, 0.09 degrees translates to 0.0199 cm. This value of 0.2 millimeters is small enough that on a large globe, it will not have much of an impact on our rotation for most countries, meaning that the country will still be able to be positioned correctly; however, it could have a slight impact on certain countries like Luxembourg or Vatican City, where the small size of the country requires the positioning of the globe to be extremely precise, which is why we have a tolerance level of 2.5 mm from the borders for small countries. We will be measuring the difference between the expected and actual positions every trial, and updating our error countering system accordingly.

## 3. Cost and Schedule

### 3.1 Cost

#### 3.1.1 Labor

The average starting salary for a Computer Engineering graduate from the University of Illinois Urbana-Champaign is \$103,222 [7]. This would mean that the hourly rate would be approximately \$49.63. Each team member spends approximately 15 hours a week for around 10 weeks, entailing that the total salary for one team member would be \$18,611.25. Since there are three of us, the total group labor costs would be \$55,833.75. Additionally, the Machine Shop is assisting with the development and assembly of our globe base and dual-axis cradle system. It

will take around a week for the construction of the globe system to complete. Assuming a total of ten hours for the total construction and assembly of the globe and an hourly salary of \$70, the cost for the machine shop labor would be \$1750. Therefore, the total cost of labor alone would approximately be \$57,583.75.

### 3.1.2 Parts and Materials

*Table 6. Parts and Costs List*

<b>Description</b>	<b>Manufacturer</b>	<b>Qty</b>	<b>Unit Price (USD)</b>	<b>Total Cost</b>	<b>Link</b>
Globe	Wizdar	1	\$30.97	\$30.97	<a href="#">Link</a>
Laser Module	Quarton	1	\$15.99	\$15.99	<a href="#">Link</a>
NEMA 17 Medium Stepper Motors	SparkFun Electronics	2	\$14.95	\$29.90	<a href="#">Link</a>
12 V Power Supply	AspenTek	1	\$9.99	\$9.99	<a href="#">Link</a>
INMP441 Microphone Modules	Teyleten	1	\$12.99	\$12.99	<a href="#">Link</a>
LM2596S-5.0/NOPB IC Buck	Texas Instruments	1	\$6.97	\$6.97	<a href="#">Link</a>
LM2596S-3.3 IC Buck	Texas Instruments	1	\$8.76	\$8.76	<a href="#">Link</a>
Power Inductors	Bourns	11	\$0.939	\$10.33	<a href="#">Link</a>
Push Button	E-Switch	2	\$1.30	\$2.60	<a href="#">Link</a>
ESP32-S3-WROOM-1	Espressif Systems	1	\$6.13	\$6.13	<a href="#">Link</a>
A4988 Stepper Driver Breakout Module	E-outstanding	1	\$4.44	\$4.44	<a href="#">Link</a>
A4988 IC	Allegro MicroSystems	5	\$2.96	\$14.80	<a href="#">Link</a>
Status LEDS, capacitors, resistors, misc.	—	—	—	\$5.00	—
<b>Total:</b>				<b>\$158.87</b>	

### 3.2 Schedule

*Table 7. Project Schedule*

Week	Task	Person
February 23rd – March 1st	Finalize ESP32 and microphone breakout board	Mahathi
	Finalize motor control breakout board. Provide machine shop reference diagram and parts	Rijul
	Finalize parts to order and finish buck regulator breakout board	Varsha
March 2nd – March 8th	Design Review with Instructors and TAs	Everyone
	Communicate with Machine Shop regarding progress of globe construction	Everyone
	Revise PCB based on feedback and submit second round PCB order	Everyone
March 9th – March 15th	Breadboard Demo with Instructors and TAs	Everyone
	Program ESP32 MCU Breakout board to test microphone, LEDs, and laser control	Mahathi and Varsha
	Test buck regulators to ensure safe voltage conversion	Rijul
March 16th – March 22nd	<b>SPRING BREAK</b>	
	Set up ESP32-SR and test its capabilities	Mahathi

March 23rd – March 29th	Pick up globe from Machine Shop and integrate it with the PCB	Rijul and Varsha
	Modify PCB based on testing and submit fourth round orders	Everyone
March 30th – April 5th	Testing and Debugging with globe integration	Everyone
	Individual Progress Reports	Everyone
April 6th – April 12th	Testing and Debugging with globe integration	Everyone
	Progress Demos	Everyone
	Team Contract Assessment	Everyone
April 13th – April 19th	Testing and Debugging with globe integration	Varsha & Mahathi
	Finalize assembling all components for the final globe system	Rijul
April 20th – April 26th	Mock Presentations	Everyone
	Mock Demos	Everyone
April 27th – May 3rd	Final Presentations	Everyone
	Final Demos	Everyone
May 4th – May 17th	Final Papers & Lab Notebooks Due	Everyone

## 4. Ethics, Safety, and Societal Impact

### 4.1 Ethics

There are several ethical considerations that need to be taken during the design and testing process. According to Principle 1.6 in the ACM code of ethics, one important consideration that will be raised is respecting privacy [3]. Since we are recording audio and using that to handle motor control logic, we need to ensure that the audio isn't being stored, collected or transmitted elsewhere without the consent of the user. Therefore, even though the audio processing is happening locally on the ESP32 MCU, we will discard audio data immediately after performing detection logic. Additionally, Principle 1.3 from the ACM code of ethics also states that we need to be honest and trustworthy [3]. One issue that can arise with this design is that it might not accurately pick up the words from users with accents or speech impediments, as the ESP-SR has limited speech recognition capabilities. Therefore, we must disclose this clearly in the instructions for usage to be transparent with the users about the limitations of the project's capabilities.

## **4.2 Safety**

Since this product is intended for younger kids, in a classroom setting, we need to heavily prioritize safety considerations. Since we are using a laser to illuminate the specified country, we need to ensure that there is no risk of eye damage or misuse of the laser. To combat this, we will ensure that the laser is mounted in the base of our globe system and the beam of light exits through a hole in the base. This will ensure that the laser position cannot be altered and has to point towards the surface of the globe. Additionally, we will be using a low-power Class 1 laser, which is safe even for long-term intentional viewing [1], or a Class 2 laser, which is used extensively in classroom settings. If we use a Class 2 laser, we will also ensure to have a warning label to guarantee compliance with IEC 60825-1, which is the FDA's standard for laser compliance [2]. Additionally, our design of the base will have no sharp edges and will use non-toxic materials to ensure the full safety of the users. Our design will also consider full electrical safety regulations, such as ensuring no wiring is exposed, ensuring proper insulation for motors, and more.

## **4.3 Societal Impact**

There are several societal or ethical issues that this voice activated globe helps impact. For example, since this is a screen-free and offline tool, this can be used in areas with limited internet or screen access. This helps promote educational equity, since schools are developing a higher reliance on screens and the internet for educational purposes, providing an offline interactive learning tool can help those with fewer resources have an equal opportunity to learn. In addition to reducing screen dependencies, this can also be more collaborative and engaging, using a physical globe to learn geography. This can help those who prefer hands-on learning methods by providing a hands-on learning tool.

## 5. References

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