Sunlight 360

ME102B Group 5
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Opportunity:

Our goal is to create an automated turntable for plants that will rotate them throughout the day, allowing equal exposure to sunlight for people with limited window space. Especially during cold winter months when there is little sunlight throughout the day, this product could be a great asset to those living in apartments, condos, or other smaller living spaces.

High-Level Strategy:

Our turntable consists of a start button, four pressure sensors, and a DC motor to rotate the table. When the button is pressed to commence operation, the first pressure sensor will check for the presence of a plant. If there is one there, the table will pause at that location for either 10 seconds or until the button is pressed again. The set time duration is easily changed, and can be manipulated based on the amount of sunlight available on a particular day. Then, the table will rotate to the position of the second plant spot, and repeat the process. Once the fourth plant has been checked, the table will rotate back to the initial position and restart the process. This system is controlled by one ESP32, located at the very bottom of the turntable. We utilized a timing belt transmission system to rotate the table and timed the duration required to rotate the table between each position.

In addition to this turntable, our original goal was to create a linkage controlled robotic arm that would descend upon the table, use a soil moisture sensor to measure the moisture content of the plant, and then water the pump using a peristaltic pump and tank. Due to time constraints we were unable to complete this implementation, so we pivoted the focus of our project to rotating the plants to equalize sunlight exposure. However, the design of our system allows for an arm to still be installed on the side, and future work would include reimplementing this system.

Integrated Device:

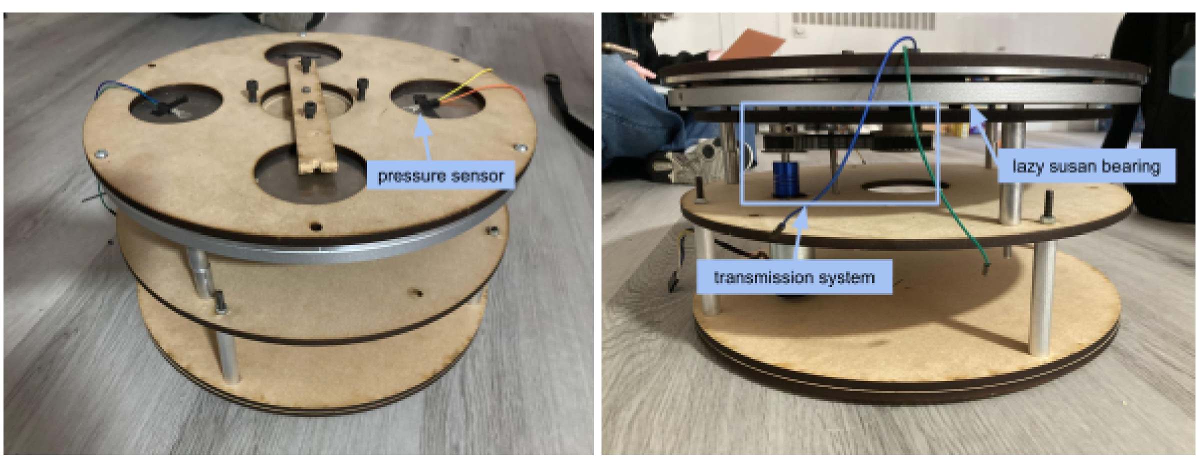


Figure 1: Integrated System

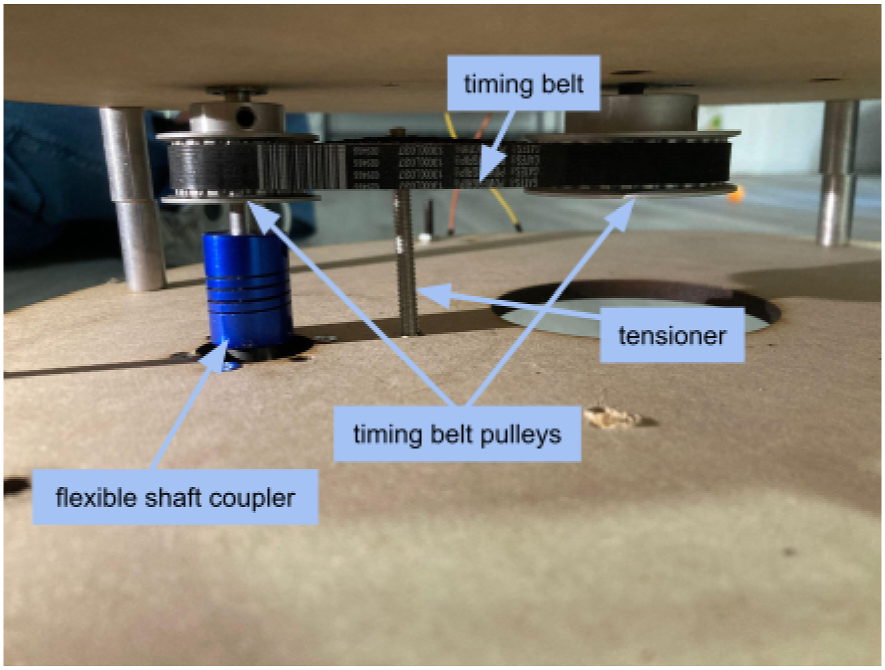


Figure 2: Transmission System

Critical Designs Decisions and Calculations

Based on our measured weight of 1.5lbs for a single plant, we can assume that the plants are four point masses located evenly around a circle of diameter 8.5in. Therefore, the moment of inertia for one plant is:

$$I_{plant} = mr^2 = m(8.5/2)^2 = 0.005289\, kg * m^2$$

The moment of inertia for the table, assuming it is a uniform disk, is:

$$I_{table} = \frac{1}{2}MR^2 = \frac{1}{2}M(14/2)^2 = 0.04244\, kg * m^2$$

Therefore, the total inertia of the system is:

$$4 * I_{plant} + I_{table} = 0.0636\, kg * m^2$$

Based on our desire for the system to have an angular acceleration of $1.4\, rad/s^2$, we can conclude that the required torque from the transmission system is:

$$\tau_{required} = I\alpha = 0.0636(1.4) = 0.08904\, N * m$$

Now we must determine what timing belt pulley ratio is required. Since the motor has a gear ratio of 90:1 and a continuous torque of $0.158\, N * m$, the ratio needed is:

$$ratio = \frac{\tau_{required}}{\tau_{motor}} = 0.56$$

Based on this minimum ratio, we decided to use an 18 and a 30 tooth timing belt, giving us a ratio of 0.6.

To determine the length of the timing belt required, we used an online timing belt calculator. Using the predetermined timing belt pulley ratio and distance between the motor shaft and the pulley drive shaft, we determined that we needed a 65 tooth timing belt.

Circuit Diagram and State Transition Diagram

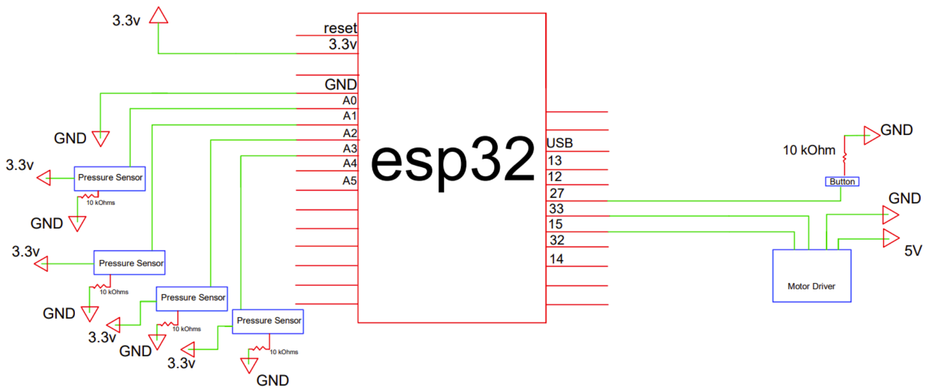


Figure 3: Circuit Diagram

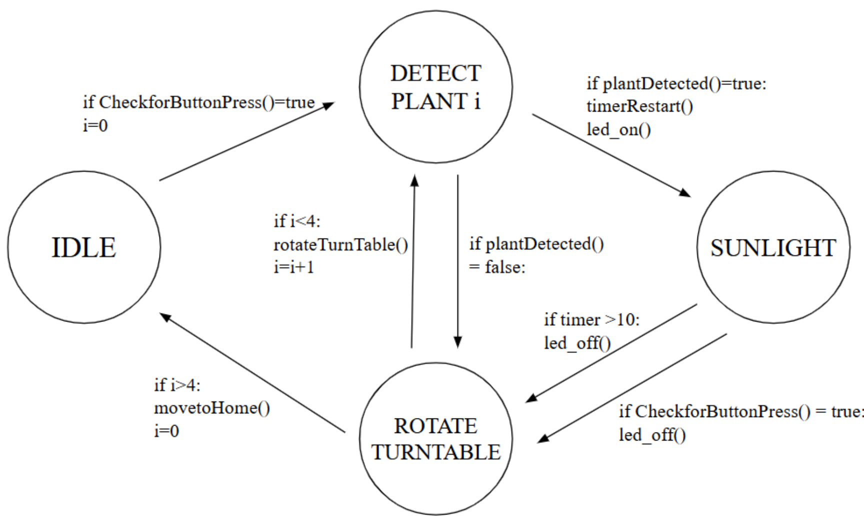


Figure 4: State Transition Diagram

Reflection

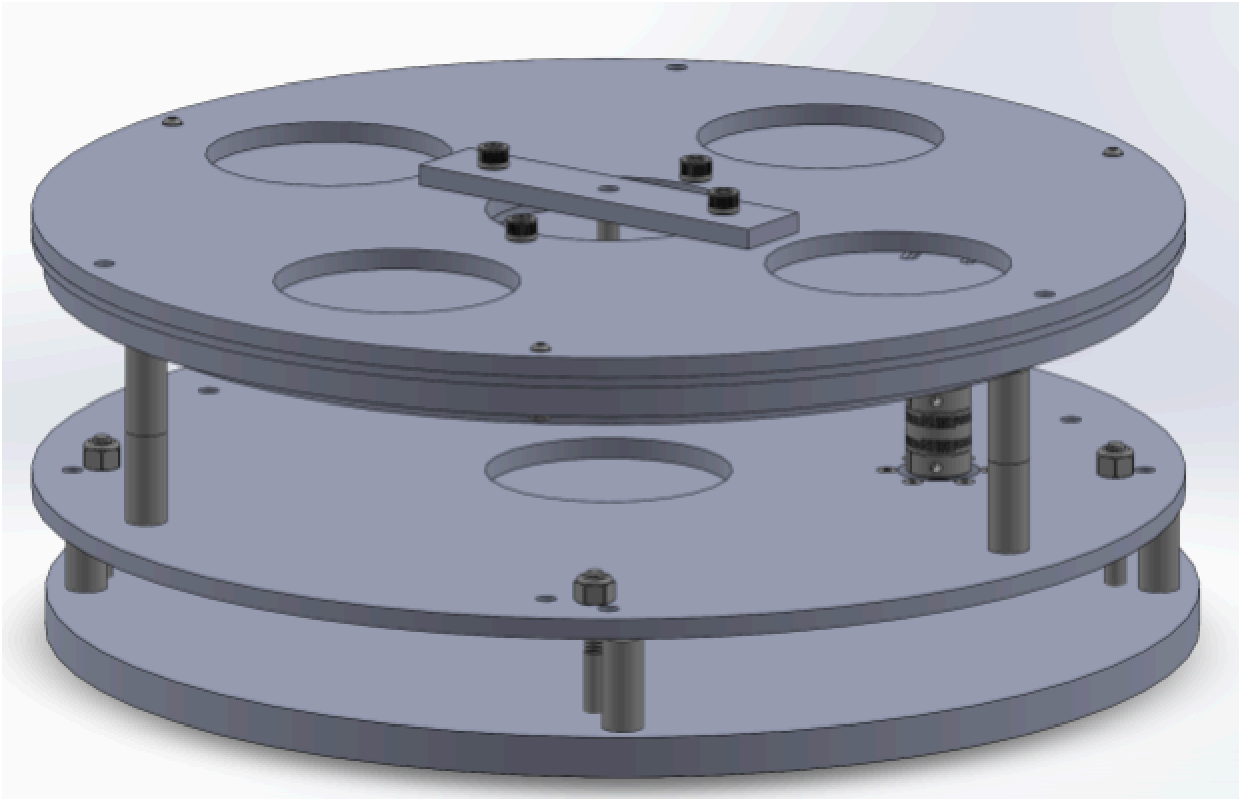
After many collaborative meetings this semester and quite a number of design challenges and setbacks, we successfully created our plant turntable. This project required hard work and resilience, and we went through a long iterative design process to redesign and fix our system when needed. If we were to do this project again, we would have a more extensive conversation about how to timeline our design and manufacturing process, and potentially even discuss if our ideas are manageable in the time given. However, this project still gave us a lot of opportunity to improve and refine our design, manufacturing, and software skills. To further this project, we would have implemented our robotic arm and water pump to enable this system to also maintain the plants on the turntable.

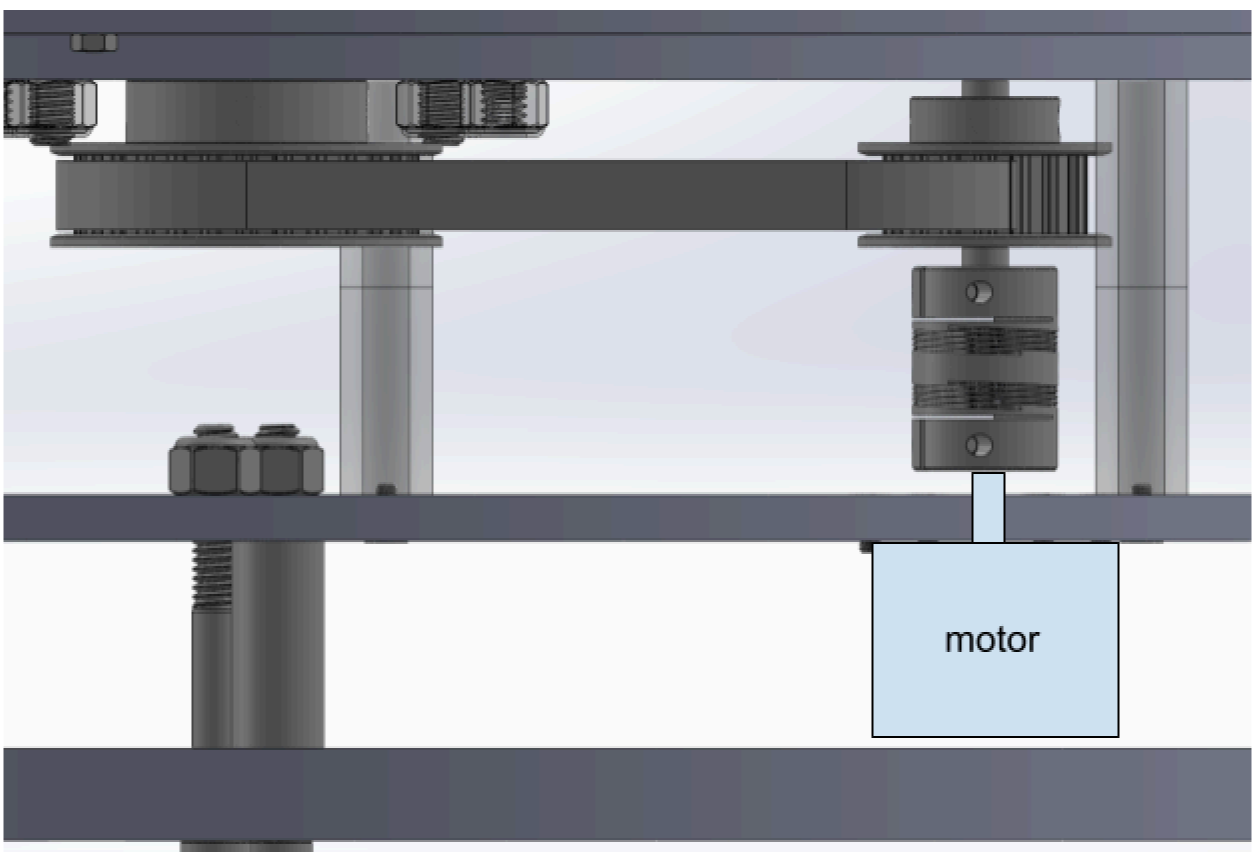
Appendix A: Bill of Materials

Item	Description	Purchase Justification	Price (ea)	Quantity	Vendor	Link
Thin Film Pressure Sensor	20g-2Kg high sensitivity force sensitive resistor	Used to determine position of plants	$ 11.99	1	Amazon	Amazon
Flexible Shaft Coupler	6mm to 6.35mm Aluminum Alloy Shaft Coupling L25xD19 Flexible Coupler with Screws Beam for motor shaft	Used to secure transmission shaft to motor	$ 5.49	1	Amazon	Amazon
Lazy Susan Bearings	14 in Lazy Susan Hardware Aluminum Bearing Metal Rotating Turntable Bearing	Rotate our lazy susan plate	$ 24.99	1	Amazon	Amazon
Aluminum Unthreaded Spacer	1/2" OD, 1-1/8" Long, for 1/4" Screw Size	Used to clear room between turntable plates for transmission design	$ 3.27	6	McMaster C	McMaster Ca
Linear Motion Shaft	1566 Carbon Steel, 1/4" Diameter, 3" Long	Used for transmission system since motor shaft is incredibly short	$ 5.78	1	McMaster C	McMaster Ca
Black-Oxide Alloy Steel Socket Head Screw	1/4" -20 Thread Size, 1-3/8" Long	Used to screw transmission system into turntable	$ 9.53	1	McMaster C	McMaster C
High-Strength Steel Nylon-Insert Locknut	Block-Oxide, 1/4" -20 Thread Size	Used to secure black-oxide alloy steel socket head screws	$ 5.08	1	McMaster C	McMaster C
Medium Density Fiberbc	1/4 2X4 MDF	Manufacturing Material for our turntable	$ 14.75	3	Home Depo	Home Depot
Countersunk Bolts	M5-0.8 x 70 mm Flat Head Socket Cap Screws	Used to secure turntable	$ 7.39	1	Amazon	Amazon
Aluminum Round Stock	Metal Magery Aluminum Round Stock 1/2" Diameter 3 Pack Bar 12" Long 6061 .5" Extruded Aluminum Rods	For custom spacers at the bottom of the turntable, enabling room for motor	$ 9.99	1	Amazon	Amazon
Timing Belt Pulley	Corrosion-Resitant Timing Belt Pully, XL Series for 3/8" Maximum Width, with Hub, 2 Flanges, 2-3/8" OD	Used for timing belt system to move turn table	$ 12.42	1	McMaster C	McMaster-Ca
Timing Belt Pulley, 2-1/8"	Corrosion-Resitant Timing Belt Pully, XL Series for 3/8" Maximum Width, with Hub, 2 Flanges, 2-1/8" OD	Used for timing belt system to move turn table	$ 20.11	1	McMaster C	McMaster-Ca
Timing Belt	XL Series Timing Belt	Used for timing belt system to move turn table	$ 9.39	1	McMaster C	McMaster-Ca
Stainless Steel Ball Bearir	Stainless Steel Ball Bearing, Flanged, Shielded, for 6 mm Shaft Diameter	Supports the shaft for stability	$ 8.77	1	McMaster C	McMaster-Ca
DC Motor with Encoder	12 V DC Motor	Used to rotate our timing belt system which in turn rotates the turn table	$ -	1	Lab Kit	
Shaft Collar	1/4" Shaft Collar Double Split Axle Collar Clamp of Carbon Steel Set Screw	Secure shaft required for rotation	$ 9.99	1	Amazon	Amazon

Sheet of Aluminum	6061 T651 Aluminum Sheet Metal 15 x 15 x 1/8 (0.125") Inch Thickness Rectangle Metal Plate Covered with Protective Film, 3mm Aluminum Sheet Plate Flat Stock, Finely Polished and Deburred	Used for one of the turntable plates	$ 31.99	1	Amazon	Amazon
M5 Socket Head Screws	M5-0.8 x 100mm Hex Socket Head Cap Screws	Used to connect bottom turntable plates to rest of system	$ 6.29	1	Amazon	Amazon
M5 Hex Nuts	M5-0.8 Stainless Steel Hex Nut 2-Pieces	Used to secure M5 nuts	$ 1.25	6	Home Depo	Home Depot
M5 Phillips Head Screws	#10-32 x 1 in. Phillips-Slotted Pan-Head Machine Screws (4-Pack)	Used to attach top plate to lazy susan bearing	$ 1.24	1	Home Depo	Everbilt #10-3
M5 Phillips Flat Head Scr	M5-0.8 x 100mm Flat Head Hex Socket Cap Screws Countersunk Bolts	Used to connect middle turntable plate to lazy susan bearing	$ 9.69	1	Amazon	Amazon
ESP32	Microcontroller	Used to control all parts of the system	--	1	Lab Kit	
		Total:	**261.5**			

Appendix B: CAD





Appendix C: Code

```
// Pin definitions
#define tableMotorPin1 33
#define tableMotorPin2 15
#define LED_PIN 13
#define button 27

const int pressureSensorPins[] = {26, 25, 34, 39}; //A0, A1, A2, A3 4 pressure sensor pins.


// motor speeds for PWM, choose 0-225
const int tableSpeed = 200;

// Constants
const int freq = 5000;
const int ledChannel_1 = 1;
const int ledChannel_2 = 2;
const int ledChannel_3 = 3;
const int ledChannel_4 = 4;
const int resolution = 8;
const int MAX_PWM_VOLTAGE = 255;

enum State {
  IDLE,
  DETECT_PLANT,
  SUNLIGHT,
  ROTATE_TURNTABLE
};

// Variables
int pressureValue;
int plantIndex = 0;
volatile bool buttonIsPressed = false;
volatile bool deltaT = false;
volatile bool interruptCounter = false;
bool timerRunning = false;
hw_timer_t*timer=NULL;
State currentState = IDLE;

```

```
//Initialization
void IRAM_ATTR isr() { //the function to be called when interrupt is triggered
  buttonIsPressed = true;
}

void IRAM_ATTR onTime() {
  interruptCounter = true;
  deltaT=true;
}

void setup () {
  Serial.begin(115200);
  ledcAttach(tableMotorPin1, freq, resolution);
  ledcAttach(tableMotorPin2, freq, resolution);
  attachInterrupt(button, isr, FALLING);

  // sensor pins
  for (int i = 0; i < 4; i++) {
    pinMode(pressureSensorPins[i], INPUT);
  }
  pinMode(button, INPUT);
  pinMode(LED_PIN, OUTPUT);

  timer=timerBegin(1000000);
  timerAttachInterrupt(timer, &onTime);
  timerAlarm(timer, 10000000, true, 0); //interrupt after 10 seconds
}

void loop () {
  if (plantIndex < 4) {
    switch (currentState) {
      case IDLE:
        if (CheckForButtonPress() == true) {
          currentState= DETECT_PLANT;
        }
        break;

```

```
case DETECT_PLANT:
  if (plantDetected(plantIndex)) {
    Serial.println('Plant Detected');
    led_on();
    timerRestart(timer);
    currentState = SUNLIGHT;
  }
  else {
   currentState = ROTATE_TURNTABLE;
  }
  break;

case SUNLIGHT:
//start timer, check for button push
  if (CheckForButtonPress() == true) {
    Serial.println('Button press - rotating');
    led_off();
    currentState = ROTATE_TURNTABLE;
  }
  if (deltaT) {
    deltaT=false;
    led_off();
    Serial.println('Timer interrupt - rotating');
    currentState = ROTATE_TURNTABLE;
  }
  break;

case ROTATE_TURNTABLE:
  rotateTurntable();
  plantIndex = (plantIndex + 1);
  Serial.println("Moving to Next Plant");
  if (plantIndex < 4) {
    currentState = DETECT_PLANT;
  }
```

```
          else {
            moveTableToHomePosition();
            plantIndex=0;
            currentState = IDLE;
          }
          break;
      }
  }

}


// Service Functions
void rotateTurntable() {
  // Code to rotate the turntable by TURNTABLE_STEP degrees
  Serial.println("Running motor slowly clockwise to rotate turntable 90 degrees");
  ledcWrite(tableMotorPin1, MAX_PWM_VOLTAGE);
  ledcWrite(tableMotorPin2, LOW);
  delay(1700); // Simulating rotation time
  ledcWrite(tableMotorPin1, LOW);
  ledcWrite(tableMotorPin2, LOW);

}


void moveTableToHomePosition() {
  Serial.println("Moving to home");
  ledcWrite(tableMotorPin1, LOW);
  ledcWrite(tableMotorPin2, MAX_PWM_VOLTAGE);
  delay(7000);
  ledcWrite(tableMotorPin1, LOW);
  ledcWrite(tableMotorPin2, LOW);


}

```

```
void led_on() {
  digitalWrite(LED_PIN, HIGH);
}

void led_off() {
  digitalWrite(LED_PIN, LOW);
}


// Event Checkers
bool plantDetected(int plantIndex) {
  int pressureValue = analogRead(pressureSensorPins[plantIndex]);

  if (pressureValue > 0) {
    Serial.println("Plant detected");
    return true;
  } else {
    Serial.println("No plant detected")
    return false;
  }
}

bool CheckForButtonPress () {
  if(buttonIsPressed == true) {
    buttonIsPressed = false;
    return true;
  }
  else {
    return false;
  }
}
```