University of Moratuwa

Department of Electronic & Telecommunication Engineering

EN2160 - Electronic Design Realization

Report

Self Stabilizing Spoon

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THIS REPORT IS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MODULE

EN2160 - Electronic Design Realization

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Abstract

The goal of this is to examine the use of an Arduino microcontroller to assist individuals with limited motor skills while they are eating. To complement humans, a stabilizing spoon prototype that would function in practical situations was created. who require help while they are eating. A sensor with gyroscopes and accelerometers was used to measure how quickly the device's position changed and in which direction the handle was tilted in order to make this feasible. To create a device with two degrees of freedom, two servo motors were positioned orthogonally to one another. The spoon was designed to keep its spoon basin horizontal with this configuration. The spoon's efficacy during testing was promising but had some drawbacks.

Scope

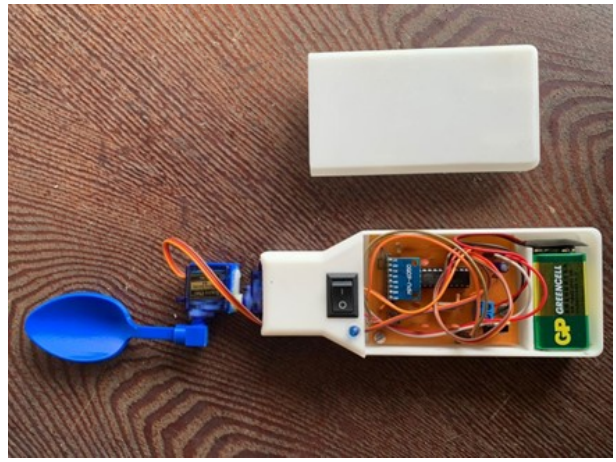
For a more detailed depiction, the spoon is designed to have two degrees of freedom: rotational movement around the x-axis, or roll, and rotational movement around the y-axis, or pitch. There won't be an engine to counteract motion on the z-axis, which is orthogonal to the x- and y-axes, because two degrees of freedom will suffice for this project.

Introduction

The self-stabilizing spoon is a revolutionary device designed to assist individuals with hand tremors or other motor impairments in their ability to eat independently. This report will provide an overview of the design and functionality of the self-stabilizing spoon, as well as its potential benefits for individuals with hand tremors and other motor impairments.

The goal of this project is to create a stabilizing spoon that can counteract unintentional movements like tremors. The objective is to create a prototype with a cheap budget that is primarily made up of a microcontroller and servo motors.

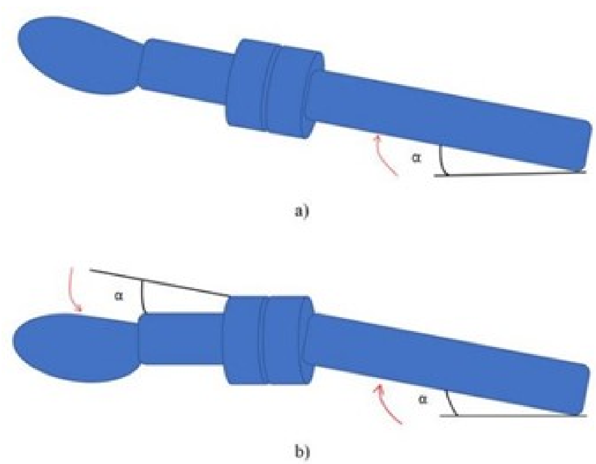
Today's market offers a variety of technological aiding spoons, but the items are unfortunately fairly pricey. The outcomes of this investigation may enable future research to produce stabilizing spoons that are more affordable and effective.



Method & Testing

The spoon is designed to have two degrees of freedom: rotational movement around the x-axis, or roll, and rotational movement around the y-axis, or pitch. There won't be a motor to counterbalance motion on the z-axis, which is orthogonal to the x- and y-axes, because two degrees of freedom will sufficient for this project.

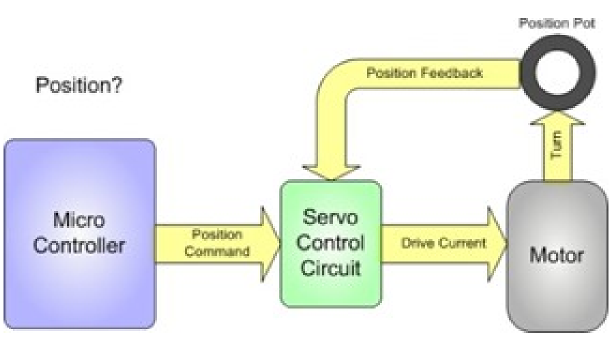
The spoon bowl will return to its initial horizontal position if the handle of the spoon tilts at an angle of α degrees, as shown in Figure below, thanks to actuators included into the spoon.



An electronic component known as an inertial measurement unit (IMU) is used in satellites, GPS systems, and aircraft. It gauges and records a body's precise acceleration and angular rate. According to invensense.com (2017), the IMU is made up of three gyroscopes and three accelerometers arranged orthogonality to one another to form a coordinate system. In reference to a randomly selected coordinate system, an accelerometer measures inertial acceleration and a gyroscope measures rotational position. Together, they can determine an object's location in space and if it is tilting.

Figure 1: Caption for Figure 1

This configuration creates a closed loop feedback mechanism inside the servo. The microcontroller is not included in the loop, which causes it to only send orders to the servo and not receive any information from it.



Initially we created a circuit using Arduino and a breadboard powering the servos through the Arduino output. Then we connected 9V battery externally and implemented a regulator circuit to power up. Then we moved to design a PCB including the ATMega328P as the standalone microcontroller. Then after the product was build test was done on various positioning of the hand and its stabilization in horizontal position.
In order to facilitate testing and assess its usefulness, the demonstrator was developed. The following issues needed to be resolved:

1. Reversing movements
2. The device's size should fit the user's hand

The counteracting of motions has been done separately using two different codes. The members of this project created one, and another stabilizing project used the other one. For a quick summary, refer to Figure below. Both algorithms have been using the IMU's output values to create rotational commands for the servo motors. The way the values from the IMU have been converted into rotational commands is the key distinction between the counteracting codes.

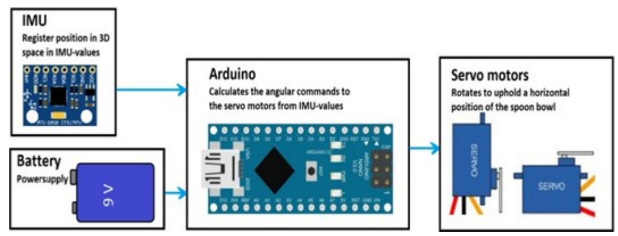


Figure 2: Overview of the involving components, created in Paint

1. IMU (MPU6050) Testing and Methodology

- Calibration: Before using the IMU, it needs to be calibrated to ensure accurate readings. This involves determining the bias and sensitivity of the sensors and compensating for any errors.

- Data Acquisition: The IMU continuously measures acceleration and angular rate along its three axes (x, y, and z). The MPU6050 communicates with the microcontroller (ATmega328P) via I2C to provide these sensor readings.

- Verification: During testing, the accuracy of the IMU's measurements is verified by comparing the sensor outputs with known reference values while the sensor is static.

- Motion Testing: The IMU is subjected to various controlled movements to assess its responsiveness and accuracy. For example, tilting the IMU at different angles and observing the corresponding pitch and roll values.

2. Microcontroller (ATmega328P) Testing and Methodology

- Code Testing: The code running on the ATmega328P is thoroughly tested and debugged. This involves verifying that the code accurately reads data from the IMU, processes it, and generates appropriate commands for the servo motors.

- Power Regulation: The regulator circuit that powers the ATmega328P and other components is tested to ensure it provides a stable and appropriate voltage.
- Communication with Servo Motors: The microcontroller communicates with the servo motors through PWM signals. The code is validated to ensure it correctly controls the servos' positions based on the IMU data.

3. Servo Motors Testing and Methodology

- Calibration: The servo motors need to be calibrated to map PWM values to specific angles accurately. This is usually done by finding the minimum and maximum PWM values that correspond to the desired range of motion for the spoon.
- Range of Motion: The servos are tested to ensure they can achieve the required range of motion for the spoon's stabilization. This includes checking the angle at which the spoon bowl returns to the horizontal position.
- Stabilization Testing: The servos are tested in conjunction with the IMU and microcontroller to observe how well they counteract tilting and maintain the spoon bowl in a horizontal position.

4. Mechanical Testing and Methodology

- Hand Fit and Ergonomics: The size and shape of the self-stabilizing spoon should be designed to fit comfortably in a user's hand. Various hand sizes are tested to ensure usability and comfort.
- Mechanical Robustness: The physical structure of the spoon should be robust and durable. Testing involves subjecting the spoon to various forces and stresses to ensure it can withstand normal usage.

5. Overall System Testing and Methodology

- Closed-loop Feedback: The entire closed-loop feedback mechanism is tested to evaluate how well the IMU, microcontroller, and servo motors work together to stabilize the spoon.
- Real-world Testing: The self-stabilizing spoon is tested in real-world scenarios with different users to assess its effectiveness and stability in practical use.

6. Algorithm Comparison

- Both algorithms used for counteracting motions are tested and compared to determine which one provides better stabilization performance.
- Parameters of the algorithms are fine-tuned and optimized to achieve the best results.

7. User Feedback

- User testing is conducted to gather feedback on the self-stabilizing spoon's usability, comfort, and effectiveness.
- Feedback is used to make any necessary improvements to the design and functionality.

Materials & Components

1. Microcontroller

The Atmel ATmega328P microcontroller is an excellent choice for use in a self-stabilizing spoon project because it has a number of features that make it well-suited for this type of application.

1. ATmega328P has a built-in Analog-to-Digital Converter (ADC) which can be used to convert the analog output of the accelerometer into a digital signal that can be read by the microcontroller. This allows the microcontroller to detect and measure the tremors in real-time.
2. ATmega328P has a built-in 8-bit timer/counter which can be used to control the frequency of the servomotor. This ensures that the spoon is moving in the opposite direction of the tremor with the appropriate speed and precision.
3. ATmega328P has a wide range of peripheral interfaces, including USART, SPI, and I2C, which can be used to communicate with other components in the system, such as the accelerometer, servomotor, and other sensors.
4. ATmega328P has a built-in watchdog timer, which can be used to monitor the system for errors and reset the microcontroller if necessary. This helps to ensure that the system is stable and reliable.

All of these features make the ATmega328P an excellent choice for use in a self-stabilizing spoon project, as it has the necessary capabilities to read and process the signals coming from the accelerometer, control the servomotor, and store the code and data needed to make the spoon stable.

1. Code Testing: The code running on the ATmega328P is thoroughly tested and debugged. This involves verifying that the code accurately reads data from the IMU, processes it, and generates appropriate commands for the servo motors.

2. Power Regulation: The regulator circuit that powers the ATmega328P and other components is tested to ensure it provides a stable and appropriate voltage.

3. Communication with Servo Motors: The microcontroller communicates with the servo motors through PWM signals. The code is validated to ensure it correctly controls the servos' positions based on the IMU data.

2. Servo Motor - Micro 9g Servo FS90

A micro 9g servo FS90 has a torque output of about 0.127 Nm and can spin about 180 degrees, making it a compact but potent servo motor. The servo motor is 23.2 x 12.5 x 22.0 mm in size and, as its name suggests, weighs 9 grams. The motor has a total of three pins: one for electrical ground, one for the input voltage (Vcc), which operates at a value of roughly 4.8 V or 6 V, and one for the signals (PWM).

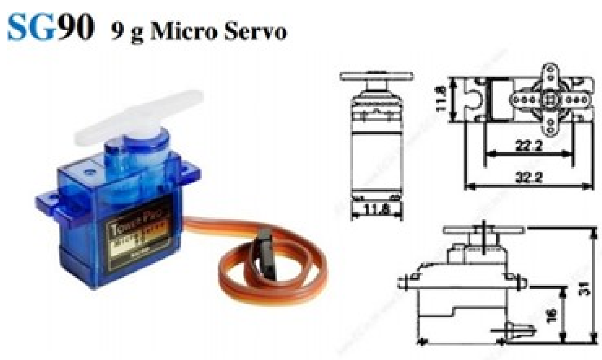


Figure 3: TowerPro SG90 Mini Micro Digital Servo 9g and its dimensions

- Calibration: The servo motors need to be calibrated to map PWM values to specific angles accurately. This is usually done by finding the minimum and maximum PWM values that correspond to the desired range of motion for the spoon.

- Range of Motion: The servos are tested to ensure they can achieve the required range of motion for the spoon's stabilization. This includes checking the angle at which the spoon bowl returns to the horizontal position.

- Stabilization Testing: The servos are tested in conjunction with the IMU and microcontroller to observe how well they counteract tilting and maintain the spoon bowl in a horizontal position.

3. IMU - MPU6050

The MPU6050 can precisely track human motions because it integrates a three-axis gyroscope and a three-axis accelerometer on the same board. It also has an integrated Digital Motion Processor. It can offer data on the boards' angular location and acceleration thanks to the gyroscope and accelerometer, both of which are triple axis Micro Electrical Mechanical Systems (MEMS) The MPU6050 was perfect for the project because of its compactness and readily available Open-source libraries.

1. Calibration: Before using the IMU, it needs to be calibrated to ensure accurate readings. This involves determining the bias and sensitivity of the sensors and compensating for any errors.

2. Data Acquisition: The IMU continuously measures acceleration and angular rate along its three axes (x, y, and z). The MPU6050 communicates with the microcontroller (ATmega328P) via I2C to provide these sensor readings.

3. Verification: During testing, the accuracy of the IMU's measurements is verified by comparing the sensor outputs with known reference values while the sensor is static.

4. Motion Testing: The IMU is subjected to various controlled movements to assess its responsiveness and accuracy. For example, tilting the IMU at different angles and observing the corresponding pitch and roll values.

Figure 4: The MPU6050

Methodology for Assembling the Self-Stabilizing Spoon

Assembling the self-stabilizing spoon is a technologically intricate process that requires careful integration of various components. This comprehensive methodology outlines the step-by-step process, starting from the bottom and building up the final product with advanced technological precision.

1. Preparation

- Acquire all the necessary components, including the precision-engineered spoon, high-torque servo motors, advanced IMU (MPU6050) with 3-axis gyroscopes and accelerometers, ATmega328P microcontroller, surface-mount resistors and capacitors, tactile switches with low actuation force, lithium-polymer battery with high energy density, high-speed PCB board, and precision manufacturing tools like pick-and-place machines and reflow ovens.

- Set up a controlled environment with an ESD-safe workstation to protect sensitive electronic components during assembly.

2. IMU Integration and Calibration

- Precisely mount the MPU6050 IMU on the spoon's handle using automated pick-and-place machines to ensure consistent alignment.

- Conduct a calibration process to compensate for sensor biases and align the IMU's axes with the spoon's reference frame using advanced calibration algorithms.

3. Servo Motors and Mechanism

- Utilize high-torque servo motors with closed-loop control for precise positioning of the spoon.

- Employ advanced 3D printing or CNC machining techniques to create the custom servo mounting mechanism for optimal torque transmission and minimal mechanical backlash.

4. PCB Fabrication and Assembly

- Design the high-speed PCB board with impedance-controlled traces and high-density routing to minimize signal interference and optimize performance.

- Employ automated assembly techniques, such as surface-mount technology (SMT), to populate the PCB with surface-mount resistors, capacitors, and the ATmega328P microcontroller with utmost precision and repeatability.

5. Wiring and Data Communication

- Use ultra-low capacitance and impedance wires for signal communication between the IMU, servo motors, and the microcontroller to minimize data loss and noise interference.

- Implement advanced data communication protocols, such as I2C or UART, for high-speed and reliable data exchange between components.

6. Firmware Development and Optimization

- Develop highly optimized firmware for the ATmega328P microcontroller using advanced programming languages and compiler optimizations to ensure real-time stabilization control with minimal latency.

- Implement advanced filtering and sensor fusion algorithms to process data from the IMU for precise stabilization calculations.

7. Closed-Loop Feedback Control

- Utilize advanced PID (Proportional-Integral-Derivative) control algorithms to maintain precise stabilization of the spoon's bowl in response to IMU sensor readings.

- Implement adaptive control techniques to continuously adjust control parameters for optimal performance in different usage scenarios.

8. Embedded Systems Testing

- Conduct extensive functional testing of the embedded system to verify proper communication between the IMU, microcontroller, and servo motors.

- Perform stress testing to assess system robustness and stability under various challenging conditions.

9. Mechanical Analysis and Validation

- Utilize finite element analysis (FEA) and simulations to evaluate the mechanical integrity of the custom servo mounting mechanism and ensure it can withstand operational forces without failure.

- Perform physical testing to validate the mechanical stability and durability of the assembled self-stabilizing spoon.

10. User Experience Enhancement

- Integrate user-friendly interfaces, such as touch-sensitive switches with haptic feedback, to enhance the user experience.

- Implement intelligent user profiles that adapt stabilization parameters based on individual preferences and motor control abilities.

11. Power Management and Efficiency

- Implement advanced power management techniques, such as sleep modes and power gating, to optimize energy consumption and extend the battery life.

- Utilize efficient voltage regulators and power delivery systems to ensure stable and clean power supply to all components.

12. Safety and Compliance

- Conduct rigorous safety testing to comply with international standards and regulations, ensuring the self-stabilizing spoon is safe for everyday use.
- Certify the product for electromagnetic compatibility (EMC) and electromagnetic interference (EMI) compliance.

By meticulously following this technologically advanced methodology, the self-stabilizing spoon can be assembled with cutting-edge precision and innovation, providing users with motor control difficulties a state-of-the-art assistive device that empowers them to eat independently and with utmost ease.

Algorithm

The code that was developed by the project's members has essentially three parts. The first part is bound to the declaration of each parameter used later in the code. The second part is the initial setup, establishing communication between the micro controller, servomotor and the IMU. The third part is retrieving the value outputs from the IMU, which it later transforms into rotational commands for the servo motors through a complementary filter. Figure below demonstrates the work flow through a flowchart, from the start of the code to the rotational commands of the motors.

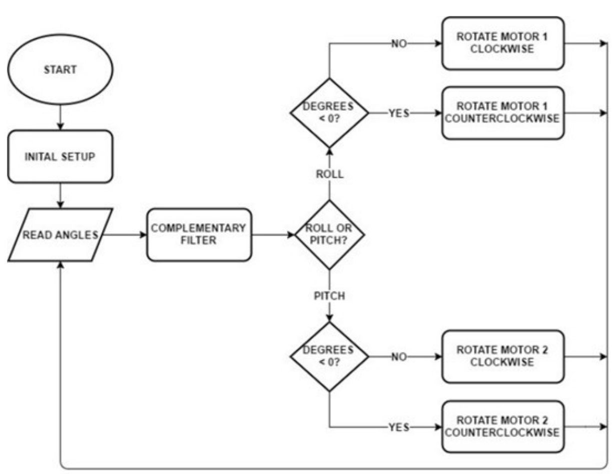


Figure 5: Flowchart over developed code

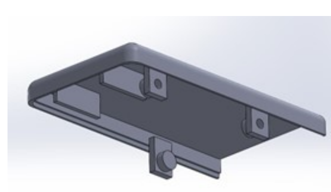
Table 1: **Bill of Materials**

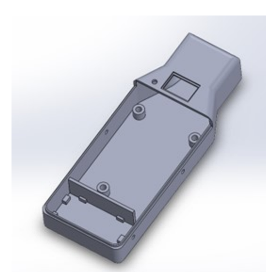
Item	**Quantity**	**Price (Rs.)**
Arduino Board	1	3320
PCB Printing	1	3500
Enclosure (3D Printing)	1	4200
Battery (9V)	1	950
Capacitors		
0.1 uf	3	60
22 pf	2	50
0.33 uf	1	30
Resistors		
10 K ohm	1	10
330 ohm	1	10
Oscillator 16MHz	1	50
Diode (Blue)	1	10
LM 7805 Regulator	1	40
Switch	1	40
Headers (Male, Female)	1	120
JST	1	90
Wires	1	150
Total		**12,360**

Enclosure and PCB Design

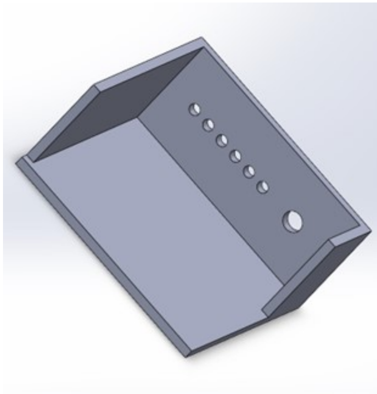
1. Enclosure

3*6mm threads were included in the top and bottom part of the enclosure to make it easier to remove and assemble again. Hole for LED and switch is placed in the top of the enclosure for easier accessing. Removable spoon bowl is included for easier replacement facility. Using Solidworks, all of the mounting components and the casing were created from PLA (hard plastic). The Prototype's casing, which is a hollow body with mounting details, is depicted below in Figure. The circuit board was positioned within the body on a rack above the battery while one of the servo motors was mounted with screws in the holes seen in the picture.

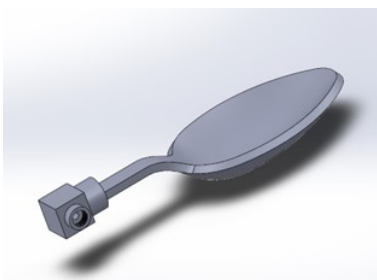




A standard servo rotor attached with screws to a straightforward container, Figure below, in which it was held, was used to attach the other servo motor to the described one.



The spoon bowl, Figure below, which was attached directly into the rotor of the outermost servo motor, is the third piece of enclosure.



2. PCB

The PCB design for this device was made using the software Altium Designer. Because we pur- chased the printed circuit board from a local manufacturer where holes do not contain copper, it is routed in a single layer (just the bottom layer). Components must be soldered on both sides if the PCB is routed on two layers. With some of the components, this is not possible.

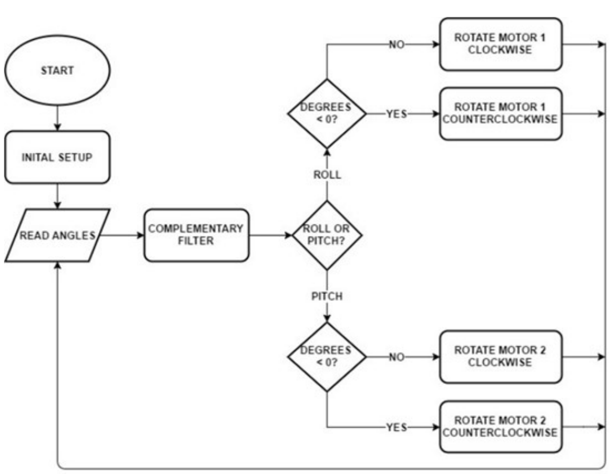


Figure 7: PCB Schematic

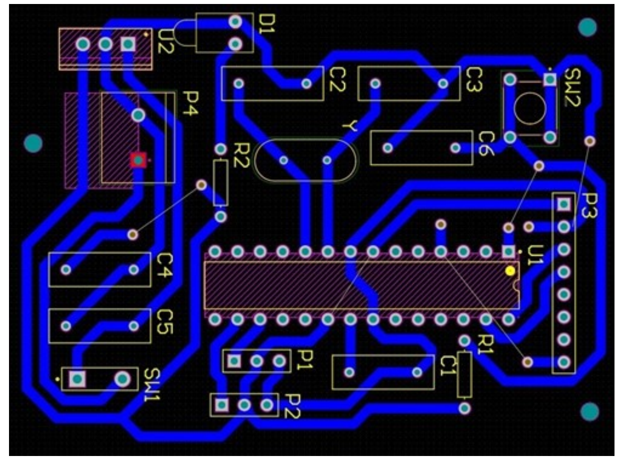
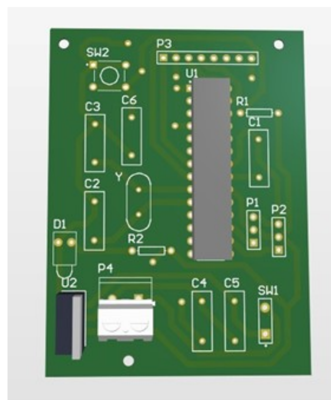
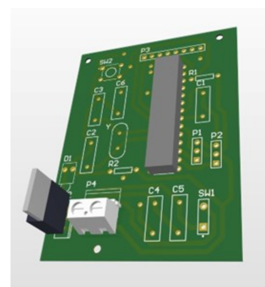


Figure 8: PCB Routing





Specifications and Extra Features

A self-stabilizing spoon is a type of utensil designed to help individuals with hand tremors or other motor impairments eat more independently and with greater ease. They can be a helpful tool for those with conditions such as Parkinson's disease, cerebral palsy, or multiple sclerosis ,Spinal Cord Injury, Post-stroke deficits, or Huntington's disease.

Some general features of a self-stabilizing spoon may include:

1. Weighted Handle: The handle of the spoon is often weighted to provide more stability and balance while eating. This can help reduce the effects of hand tremors or other motor impairments. The handle can rotate 360 degrees around stabilization can effectively offset more than 85% of hand shaking without worrying about the inconvenience and embarrassment caused by hand shaking. The use of safe medical grade materials is safe and harmless.

2. Angled Spoon: The spoon itself may be angled to help guide food into the mouth more easily. This can also help reduce spills and messes while eating. Suitable for right and left hand person. Portable and replaceable heads, multiple heads can easily deal with various foods, no worries when dining out, easy to remove the heads, cleaning without barriers.

3. ON-OFF switch: We can turn the switch on or off according to our use.

4. Non-Slip Grip: Many self-stabilizing spoons have a non-slip grip on the handle to help users maintain a firm hold on the utensil. Using non-slip material for the body.

5. Durable Material: Self-stabilizing spoons are often made from durable materials such as stainless steel or hard plastic to ensure they last for a long time.

6. Easy to Clean: Many self-stabilizing spoons are dishwasher safe or easy to clean by hand, making them convenient for daily use. (Dishwasher safe)

7. Versatile: It is interchangeable attachments or be designed to be used with other utensils, such as forks or knives, to provide greater versatility for users.

8. Batteries: We can use both rechargeable or changeable dry batteries.

Extra Features

1. Includes: Handle with spoon and fork attachments, battery with circuit

2. Handle Dimensions: 5 inches long, 2.5 inches wide, 2 inches high tapering to 1 inch high.

3. Spoon measures: 1.25 inches wide, 0.25 inches deep.

4. Materials: Medical grade durable plastic.

5. Weight: 260 g.

6. Color: White.

Preliminary Design

I am pleased to submit the comprehensive report on the design improvements made to the self-stabilizing spoon, as per your guidance. This report not only encompasses the enhancements implemented based on user surveys and feedback from friends but also incorporates additional improvements suggested by you to enhance the preliminary design. The report is organized into three sections: User Survey Analysis, Feedback from Friends, and Professor's Recommendations.

1. User Survey Analysis

During the initial phase of the project, extensive user surveys were conducted to identify the essential features and functionalities required for an optimal self-stabilizing spoon. The survey results revealed two key aspects that were integrated into the design:

1. Bluetooth Connectivity: Users expressed a strong desire to have the ability to monitor and control the self-stabilizing spoon using their mobile devices. To fulfill this requirement, a Bluetooth module was seamlessly incorporated into both the SolidWorks model and the Altium schematics. Moreover, a high-performance Bluetooth antenna was strategically placed to ensure robust connectivity and an extended range.

2. Heat Sensor: User feedback indicated a concern regarding food temperature while using the self-stabilizing spoon. In response, a heat sensor was intelligently positioned within the spoon component of the SolidWorks model. Corresponding modifications were made to the Arduino board schematics to accommodate this sensor. By connecting the heat sensor output to the mobile device via Bluetooth, users can now monitor and regulate the temperature of the food being consumed in real-time.

2. Feedback from Friends

To gather valuable insights and opinions from a diverse range of individuals, the self-stabilizing spoon was tested and evaluated by friends. Their feedback highlighted the need for improvements in the following areas:

1. MPU 6050 Improvements: Friends who tested the device identified the need for enhanced stability in the self-stabilizing feature. Based on their suggestions, comprehensive improvements were made to the MPU 6050 gyro sensor. These enhancements resulted in more accurate readings, leading to smoother movement and a significantly improved dining experience. The real-time gyro sensor data is seamlessly transmitted to the mobile device through the integrated Bluetooth module.

2. Battery Level Monitoring: The feedback received from friends emphasized the importance of providing users with a convenient way to monitor the battery level of the self-stabilizing spoon. As a result, sensors were integrated into the device to constantly monitor the battery level, ensuring that users are aware of the remaining charge. The battery status can be easily checked on the mobile device through the Bluetooth connection, allowing timely recharging when needed.

3. Recommendations from Professor

Throughout the design process, you provided valuable guidance and recommendations, further improving the self-stabilizing spoon. Based on your advice, the following additional improvements were implemented:

1. Enhanced User Experience: To optimize the user experience, you suggested incorporating extra features that would make the self-stabilizing spoon more versatile. One such feature was the addition of a weight sensor, allowing users to measure food portions accurately. This feature not only promotes portion control but also assists users in adhering to specific dietary requirements. Additionally, an adjustable handle was integrated into the design, ensuring ergonomic comfort and personalization for users with varying grip preferences.

2. Aesthetic Design: You emphasized the significance of an aesthetically appealing design to attract potential users. In response, the SolidWorks model was refined to include sleek contours and modern aesthetics, ensuring a visually pleasing appearance. The ergonomic grips were designed to provide a comfortable and secure hold while adding an element of sophistication to the overall product. The carefully chosen color scheme further enhances the visual appeal, making the self-stabilizing spoon an attractive choice for users.

3. Schematic Documentation and Wiring Complexity: Based on your teachings, the schematic documentation was meticulously updated to provide clear and comprehensive information. Detailed annotations were added to the Altium schematics, ensuring ease of understanding for users and future reference. Furthermore, in line with your recommendation, efforts were made to reduce the complexity of the wiring in the schematics, simplifying the overall design and improving the user-friendliness of the self-stabilizing spoon.

4. Draft Angle in SolidWorks: As per your guidance, draft angles were added to the SolidWorks part of the self-stabilizing spoon. By incorporating appropriate draft angles, the manufacturing process is facilitated, allowing for easier mold release during production. This optimization enhances the efficiency and quality of the manufacturing process, resulting in a more streamlined and cost-effective production.

In conclusion, the self-stabilizing spoon design has undergone significant improvements based on user survey analysis, feedback from friends, and your valuable recommendations. The incorporation of features such as Bluetooth connectivity, heat sensors, MPU 6050 improvements, battery level monitoring, weight sensors, an adjustable handle, schematic documentation, reduced wiring complexity, and draft angles in the SolidWorks part ensures that the final product caters to the needs and preferences of potential users while offering an enhanced and enjoyable dining experience.

Please find enclosed detailed screenshots of the updated SolidWorks model, showcasing the aesthetic design changes, draft angles, and ergonomic features. Additionally, the revised Altium schematics have been included, highlighting the modifications made to accommodate the sensor enhancements, reduced wiring complexity, and improved schematic documentation.

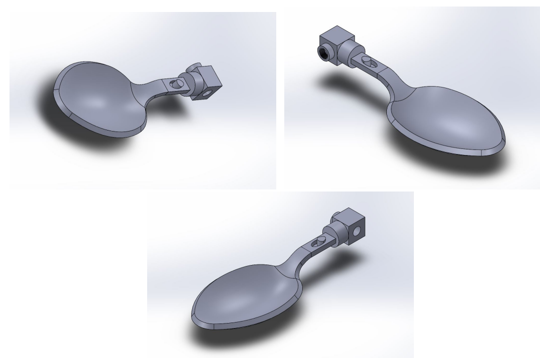


Figure 10: Sppon solidwork design

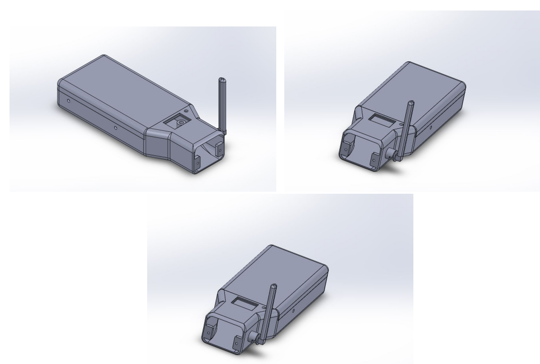


Figure 11: Spoon hand solidwork design

Thank you for your continued guidance and support throughout this design project. Your expertise and insights have been invaluable in shaping the self-stabilizing spoon into a compelling and user-centric product.

Conclusions & discussion

In conclusion, The final prototype that was built executed the movements that were intended by the project. However, after examining, it becomes clear that the device's outcomes and performance are insufficient to satisfy the project's initial requirements. The device can be significantly improved in terms of high frequency vibrations and smooth movements, and using quicker and

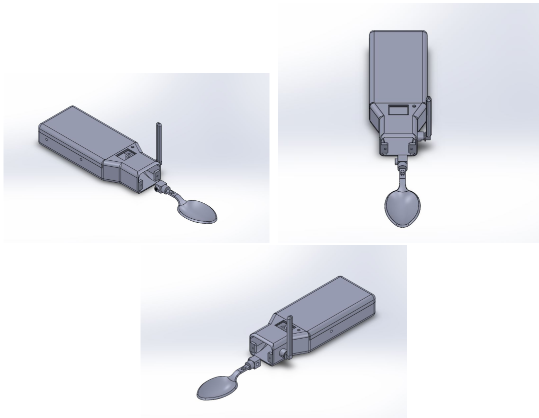


Figure 12: Assembly design of sppon and spoon hand

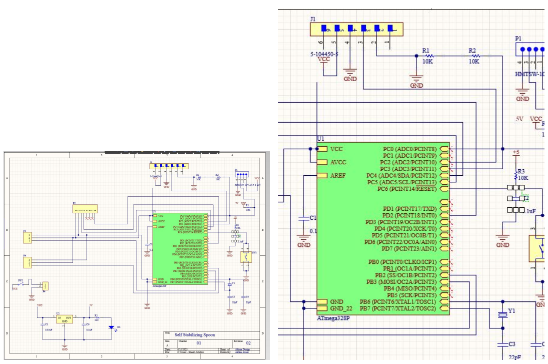


Figure 13: Added bluetooth schematic design

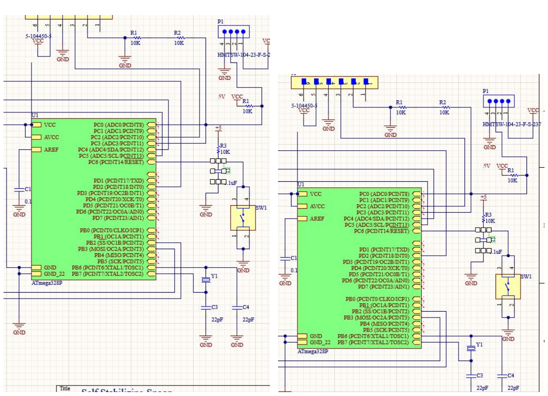
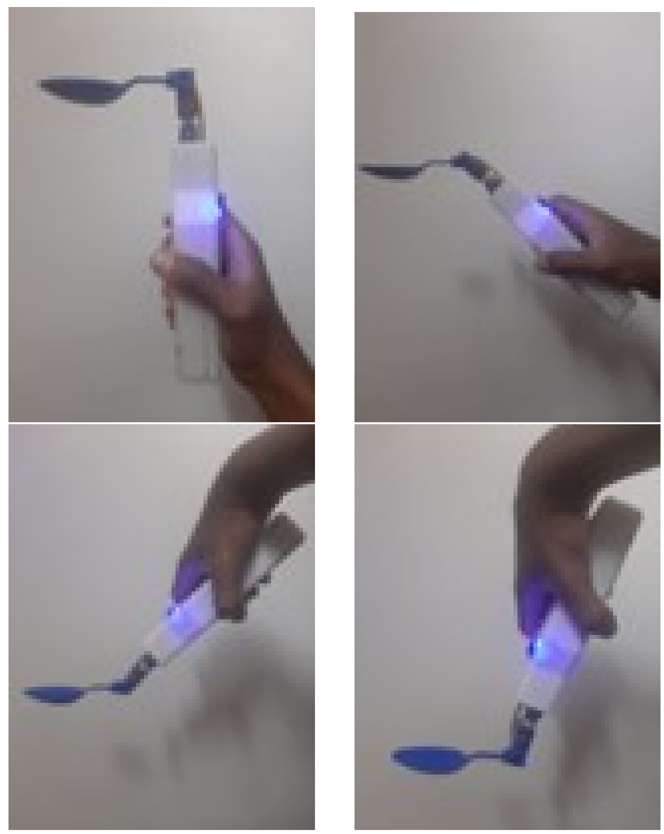


Figure 14: Added heat sensor schematic deisgn

high precision servo motors might be one way to address this issue.
The spoon was having difficulty maintaining a horizontal position, where slow motions were used; nonetheless, even while the spoon was not strictly maintaining a horizontal position, the deviation was not very serious. With that said, it is possible to talk about how well the gadget works for persons who have motor skill deficiencies. People with high frequency tremors would not benefit from the device, but others who have lost physical motor function might find it useful. These individuals may be physically challenged or older individuals with poor motor abilities. Considering what the spoon is meant to be used for, the device's total weight of 130 grams is fair.



Future Improvements

According to the conclusion and discussion chapter, the device doesn't react quickly enough for people with high frequency tremors to benefit from it. Other motors must be employed to fulfill this requirement; faster servomotors, DC motors, or maybe stepper motors would likely be the answer. MG90S servo motors could be used as an alternative. The MG90S is similar in size and weight to the SG90, but it rotates faster and has a higher operating torque. The item has a fair size, however it is quite enormous when compared to typical utensils.
Therefore, the user would benefit from a smaller gadget

in terms of comfort and discretion. Due to the hollowness in some sections, it may be possible to lessen the casing in some areas. The motors are overly huge, and an integrated rechargeable battery would reduce the amount of space needed to house the 9 V battery, which is now fairly bulky. The issue of changing batteries, which is extremely impractical with the current prototype, would also be resolved if an integrated rechargeable battery was chosen instead of a standard 9 V battery. Given the waste of batteries when they are exchanged, rechargeable batteries would also be advantageous environmentally.

User Manual

Self – Stabilizing Spoon

Contents

1 Introduction

The spoon is designed to automatically adjust its tilt angle to keep the spoon level, even if the user's hand is shaking or unsteady. The target audience for the spoon. The spoon is designed for individuals who have difficulty using a regular spoon due to hand tremors or other conditions. By using this spoon, it can help to reduce the difficulties and struggles of eating for people with tremors or unsteady hands, it can also provide them with more independence and dignity while eating. A list of the key features of the spoon are the tilt sensor, the power button, LED indication and the battery compartment.

WARNING:

Do not use the spoon as a medical device and should not be used as a substitute for professional medical care.

Remove the spoon head part and clean it separately after use.

2 Getting Started

The package includes three parts such as spoon head, intermediate servo, and spoon body. After assembling all the three parts spoon should be in a horizontal position as a reference.

9V batteries should be used to power the spoon. There is a separate compartment to place the battery in the body. Remove the top part of the body to replace the battery

Powering On and Off of the spoon is done by a switch on the top of the body. A blue LED mounted near the switch will indicate the state of power of the spoon. To reset the spoon to initial state there is a button mounted on the circuit board which can be done by removing the top part of the body.

3 Basic Operation

3.1 Functional Explanation

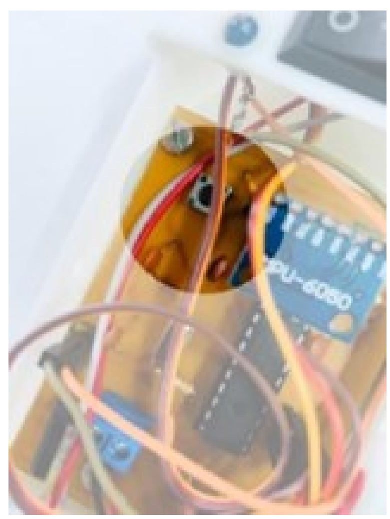
After powering up the spoon, the reference should be double checked. The spoon has two degrees of freedom. One for the translation movement along the spoon axis and the other for rotational movement. There are two separate servos for each degree of freedom.NOTE: Tilt sensor should be mounted statically all the time. If any malfunction occurs, please recheck the tilt sensor position.

3.2 Operational Instruction

Spoon is ready to use instantly after powering on. The way of using the spoon is common to all type of food. The way to use the spoon to scoop and eat food is like the ordinary spoon.

3.3 Troubleshooting

If the reference is not horizontal, reset button should be long pressed while the spoon is kept powered on. Reset button is the only trouble shooting method provided to the user.



4 Customized Options

The package only consists of ordinary spoon head, but spoon head can be replaced with any kind of spoon heads like fork. Other types of spoon head must be bought separately. User can select the color according to his preference. There are six color options available.

5 Warranty and Support

5.1 Warranty Information

Warranty will be covered for a period of six months from the date of purchase. Warranty will be provided only for internal circuit related damages. External damages will not be included in the warranty. Warranty can be claimed from the place you purchase the product or from the official manufacturer.

1. Technical Support : +94 76 010 43 14
2. Hotline/Fax : 011 226 61794
3. Mail : bioproductors@gmail.com

6 Disposal

All the electronic components can be disposed of as e-waste as there are many ways to dispose of e-waste nowadays.

Appendix: Developed Code

```
#include<Wire.h>
#include <Servo.h>
const int MPU_addr=0x68; // I2C address of the MPU-6050
int16_t AcX,AcY,AcZ,Tmp,GyX,GyY,GyZ;
float delta_t = 0.005;
float pitchAcc,rollAcc, pitch, roll, pitched;
float P_CompCoeff= 0.98;

// ============= INITIAL SETUP ==========================================
Servo myservo1, myservo2;
void setup() {
    // put your setup code here, to run once:
    Wire.begin();
    Wire.beginTransmission(MPU_addr);
    Wire.write(0x6B); // PWR_MGMT_1 register
    Wire.write(0); // set to zero (wakes up the MPU-6050)
    Wire.endTransmission(true);
    Serial.begin(115200);
    myservo1.attach(10);
    myservo2.attach(11);
}

// ============= MAIN LOOP =============================================
void loop(){
    Wire.beginTransmission(MPU_addr);
    Wire.write(0x3B); // starting with register 0x3B (ACCEL_XOUT_H)
    Wire.endTransmission(false);
    Wire.requestFrom(MPU_addr,14,true); // request a total of 14 registers
    AcX=Wire.read()<<8|Wire.read(); // 0x3B (ACCEL_XOUT_H) & 0x3C(ACCEL_XOUT_L)
    AcY=Wire.read()<<8|Wire.read(); // 0x3D (ACCEL_YOUT_H) & 0x3E(ACCEL_YOUT_L)
    AcZ=Wire.read()<<8|Wire.read(); // 0x3F (ACCEL_ZOUT_H) & 0x40(ACCEL_ZOUT_L)
    GyX=Wire.read()<<8|Wire.read(); // 0x43 (GYRO_XOUT_H) & 0x44(GYRO_XOUT_L)
    GyY=Wire.read()<<8|Wire.read(); // 0x45 (GYRO_YOUT_H) & 0x46(GYRO_YOUT_L)
    GyZ=Wire.read()<<8|Wire.read(); // 0x47 (GYRO_ZOUT_H) & 0x48(GYRO_ZOUT_L)
    //Complementary filter
    long squaresum_P=((long)GyY*GyY+(long)AcY*AcY);
    long squaresum_R=((long)GyX*GyX+(long)AcX*AcX);
    pitch+=((-AcY/40.8f)*(delta_t));
    roll+=((-AcX/45.8f)*(delta_t)); //32.8
    pitchAcc= atan((AcY/sqrt(squaresum_P))*RAD_TO_DEG);
    rollAcc =atan((AcX/sqrt(squaresum_R))*RAD_TO_DEG);
    pitch =(P_CompCoeff*pitch + (1.0f-P_CompCoeff)*pitchAcc);//pitch=P_CompCoeff*pitch +
    (1.0f-P_CompCoeff)*pitchAcc;
    roll =(P_CompCoeff*roll + (1.0f-P_CompCoeff)*rollAcc);
    /*
    if-statements to make the roll command go to where it is meant to go,
    i.e clockwise/counterclockwise rotation
    xi
    */
    if (pitch < -158)
    {
    pitched = abs(pitch + 158);
    pitched = pitched - 158;
    }
    else if (pitch > -156)
```

```
    {
    pitched = abs(156 + pitch);
    pitched = -156 - pitched;
    }
    //locked movement for upward direction of pitch
    if (pitched < -240)
    {
    pitched = -240;
    }
    //Servo commands, roll/pitch + nr, where nr is compensation for mountingto start
    horizontally
    myservo1.write((roll + 120));
    myservo2.write(pitched + 340);
}
```