# Design and Implementation of an Automatic Balance Tray with an Accelerometer, Four Servo Motors and a MCU

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***Abstract*—When people lift up a tray with trembling hands, it is easy for them to spill their drinks and soups. In this paper we design an automatic balance tray (ABT) which uses an accelerometer module, a MCU and four servo motors. This accelerometer module will automatically detect the angle of the tray and the MCU will control the servo motors and immediately rotate in the opposite direction of the tray to balance the tilting tray.**

***Keyword — Accelerometer; Servo motor; Balance control***

## I. INTRODUCTION (*HEADING 1*)

In a study where individual used simulation software programs in accelerometers with gyroscopes to control the stepper motor, these programs can calculate the tilt angle to obtain the current horizontal angle. They can modify the horizontality by means of compensation of the level. We hope the result of this study can be used on the cradle head of a camera [1]-[3]. In this paper we design an automatic balance tray that consists of an accelerometer, a microcontroller unit (MCU) and four servo motors. Fig. 1 shows this design which includes an accelerometer module which can be used to sense the acceleration data of roll, pitch, and yaw. The MCU will convert the acceleration data into an angle value. In addition, the MCU will drive four servo motors based on the sensed angles and then the servo motors will compensate the tilt angle of the tray, so that this design can ascertain a balanced tray.

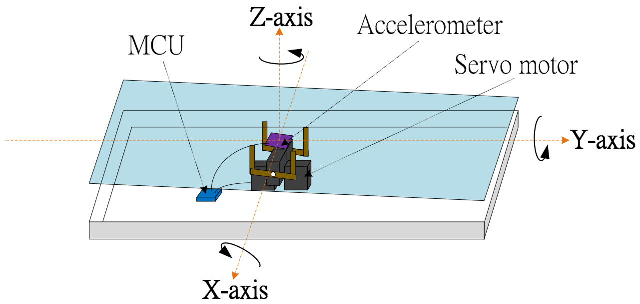


Fig. 1. The definition of roll, pitch, yaw in an automatic balanced tray.

## II. HARDWARE ARCHITECTURE

Fig. 2 shows the hardware architecture of the ABT which consists of an accelerometer module, an MCU and four servo motors. The accelerometer module communicates by means of an $I^2C$ serial bus. The system uses a data line (SDA) and a clock line (SCL) to make a link with the MCU. The four servo motors are cross placed under the tray. The accelerometer module is embedded between the tray and the servo motors. This design will directly measure the tilt angle of the tray and then control the servo motor to support the tray with four legs based on a joint activity. Therefore, the servo motor can quickly and easily either pull or push the tray in order that the tray will be balanced.

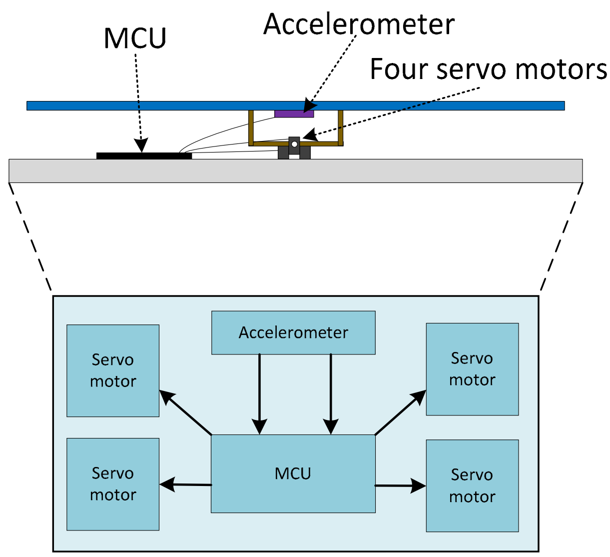


Fig. 2. ABT hardware architecture.

## III. SOFTWARE ARCHITECTURE

Fig. 3 shows the ABT software flowchart. When the user lifts up the balanced tray, the MCU will remember the first value of the accelerometer module in order to make a zero adjustment. When the tray is in a horizontal state the ABT with the accelerometer module will continue to send the X-axis, the Y-axis, and Z-axis acceleration values to the MCU. If the detected acceleration values of the three axes have not been changed, the MCU will continue to read the acceleration value. If not, that means the tray has been out of balance. The MCU will then calculate the value of the three-axis acceleration oblique angle and then convert those values into a compensatory angle so the four servo motors can automatically balance the tray in order that the tilt angle will return to the balanced level.

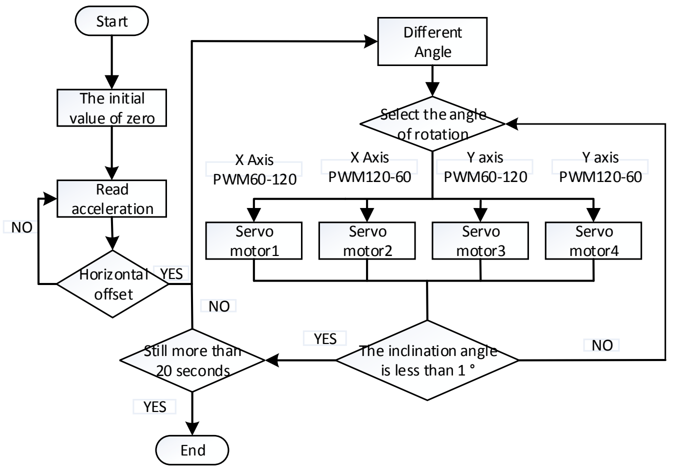


Fig. 3. The ABT software flowchart.

When the ABT is in the static stage, the system will obtain the balance through the zero adjustment procedure. Then the system will determine the angles value range between -180 to 180. As the servo motor is the continuous rotation type, the rotation angle of the servo motor ranges from about 1 to about 179 degrees. That means the ABT working angle ranges between -90 to 90 degrees.

## IV. Results of Experiment

Fig. 4 shows a schematic process that takes place after balancing the tray when the Y-axis tilt is compensated by the ABT if the tray is flat on the horizontal value which is taken up with the resulting Y-axis. When out of balance, the MCU will read the accelerometer module in order to read the acceleration values which will be calculated after the Y-axis servo motor drives the tilt compensation mode operation, in order to achieve an automatic balancing function of the tray.

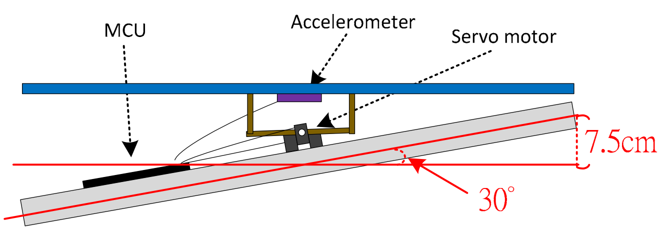


Fig. 4. The schematic process of ABT.

Table I shows this ABT specification that consists of a balanced angle range, a servo motor response time, and the accuracy of the control angle. This design is a prototype and in the next design we will enhance the balance angle range, the servo motor response time, and the accuracy of the control angle.

Table I ABT specifications

| ABT specifications | |
|---|---|
| Balanced angle range | ≤30° |
| Servo motor response time | <10ms |
| Accuracy of control angle | <1° |

Table II shows the power consumption of each module. The servo motor of the power consumption is the highest during the entire operation. When the system is in the static stage both the MCU and the accelerometer module still need to continually operate in order to sense the current angle of the tray. The MCU must constantly read the acceleration data and convert this data into a rotational angle in order to control the servo motors, in order to clearly determine the presence or absence of the tray level balance.

Table II The power consumptions of each ABT module

| | **Power consumption of each module** | |
|---|---|---|
| | ***Standby*** | ***Operation*** |
| Accelerometer module | 7.375 mW | 7.375 mW |
| Servo motor × 4 | 0 mW | 500 mW |
| MCU module | 27.1 mW | 27.1 mW |

## V. Conclusion

This design makes it easy to maintain a balanced tray for the elderly or for individuals with trembling hands. This design can be used anywhere, and will not be limited to the use of robots. In the future, the improvement design can enhance the acceleration filtering accuracy, and also can improve the mechanism design to attain the best equilibrium in order both to balance the tray quicker and to reduce the number of servo motors, which, as additional result, will significantly reduce power consumption.

## References

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