

# Microcontroller-based automatic Granule Weighing device with Human Machine Interface (HMI) integration

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## ABSTRACT

This research presents the design and development of an automatic granule weighing system based on a microcontroller, integrated with a TFT-based Human Machine Interface (HMI). The system aims to enhance accuracy and efficiency in the weighing process of granular raw materials, particularly in small- to medium-scale industries. It utilizes a load cell sensor and HX711 module for precise weight measurement, a vibrating motor to ensure consistent material flow, and a servo motor to control the dispensing valve. The HMI enables users to set target weights, adjust vibration speed, and monitor real-time data. Testing was conducted using rice granules with three different speed modes (low, medium, and high) and eight target weight variations. The system achieved an average error of 0.676% at low speed, 0.184% at medium speed, and 0.542% at high speed, with an overall accuracy of 99.533%. The integration of automated weighing mechanisms with an intuitive HMI demonstrates the system's potential for industrial applications requiring precise, reliable, and user-friendly material handling.

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## 1. INTRODUCTION

In the modern competitive industrial era, the implementation of production systems that are fast, precise, and reliable is essential to maintain product quality and production line efficiency [1], [2]. One of the critical processes supporting production continuity across various sectors such as food, pharmaceuticals, plastics, and chemicals is the weighing of raw granular materials [3]. The small size, irregular shape, and free-flowing nature of granules require careful handling methods to ensure accurate and consistent weighing results [4],[5]. However, many small and medium-sized enterprises (SMEs) still rely on manual weighing methods due to their low initial investment and simple implementation process [6]. While practical, this method depends heavily on the precision and consistency of human operators. As a result, it is prone to errors that can affect the accuracy of material dosing, disrupt production consistency, and compromise overall product quality [7],[8].

With the advancement of automation technologies, the development of automatic weighing systems using sensors and actuators has become increasingly common to address these issues [9], [10]. These systems typically incorporate load cell sensors for real-time weight monitoring, ensuring consistent and accurate measurements throughout the process. Additionally, flow control is managed through mechanisms such as gravity valves or vibrating feeders [11],[12]. Among these, vibrating feeders offer clear advantages by maintaining a stable and continuous flow of material, minimizing the risk of clogs and flow interruptions [13],[14]. To enhance usability, the incorporation of Human-Machine Interface (HMI) systems especially those based on TFT displays has become an integral part of modern industrial control systems [15]. These interfaces allow operators to view real-time data, monitor system performance, and adjust control parameters easily through a visual interface, thus simplifying local operation and system configuration [16].

Therefore, this study proposes the design and implementation of an automated granular weighing system that integrates a vibrating feeder as an adaptive flow control mechanism, controlled by an microcontroller. The system is equipped with load cell sensors and a TFT-based HMI for real-time display and user interaction. The proposed solution aims to improve weighing accuracy, reduce operator dependency, and enhance production efficiency—making it a practical automation option for industrial applications.

## 2. METHOD

The design and assembly of this tool are carried out by the requirements of the entire system. The system design determines the necessary components to ensure the final configuration aligns with the tool's functional needs. Figure 1 shows the block diagram of the system's working scheme, which includes three input components, two output components connected to actuators, and one HMI for user interaction. The ESP32 microcontroller serves as the central controller, processing all inputs and controlling outputs through drivers. Load Cell functions as a sensor to detect the weight of the object (granules) placed on the weighing platform. HX711 Module serves as a signal amplifier and ADC converter so that the data from the load cell can be read by the microcontroller. Pedal Switch acts as a manual input used by the operator to start the granule dispensing process. Push Button Reset, functions to manually reset or restart the process. ESP32 Microcontroller serves as the central controller of the system that processes all inputs and controls the outputs according to the programmed logic. TFT LCD (HMI), acts as a Human Machine Interface (HMI) to display weight information and system status in real time. Vibrating Motor functions to assist the flow of granules so they can fall smoothly into the weighing container during operation. Servo Motor functions as an actuator to open or close a mechanism, such as a gate for dispensing granules. The driver serves as a signal amplifier between the microcontroller and the motors to enable actuator movement.

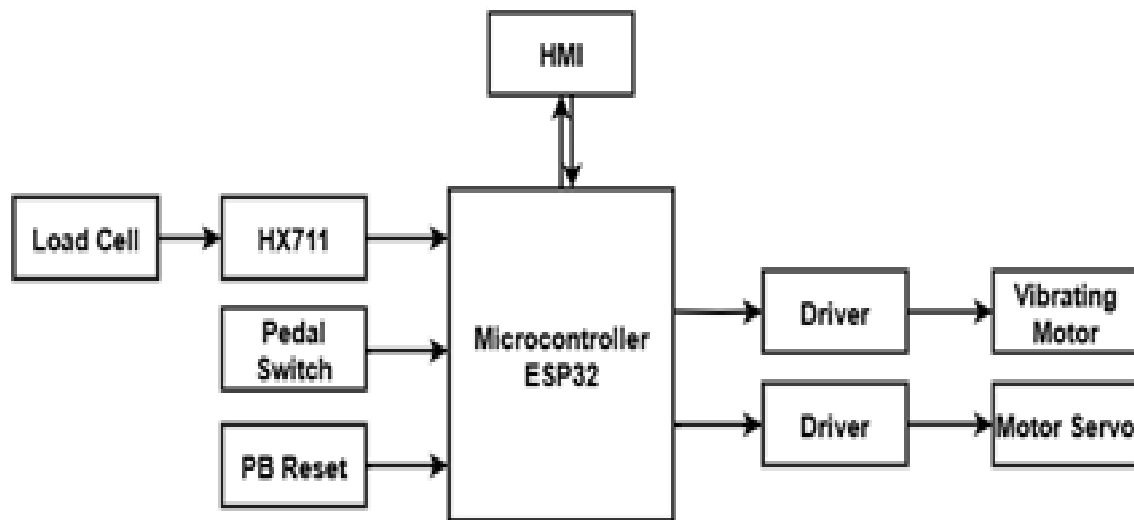


Figure 1. Diagram Block

The system operates by converting 220V AC to 24V DC using an SMPS to power the vibrating motor and then reducing it to 5V DC via a buck converter to supply the microcontroller and TFT-based HMI. Once powered, users can configure the target weight and vibration speed through the HMI, with settings stored in memory even after reset. This initialization process is illustrated in the flowchart in Figure 2, where 1 indicates active and 0 inactive states. Upon pressing the Start button, the microcontroller activates the vibrating motor, allowing granules to flow into a second hopper with a load cell. The microcontroller continuously monitors the weight, stops the motor once the target is reached, and allows the user to open the valve via a foot pedal to release the material. The cycle repeats automatically until the Stop button is pressed. These steps are clearly outlined in the system flowchart.

Additional features include a Clear function, which activates cleaning by running the motor and opening the valve and will stop once the stop button on the HMI is pressed. The Tare function resets the load cell to zero for more accurate measurements. These features are also shown in the flowchart, providing a clear view of the system's complete operation.

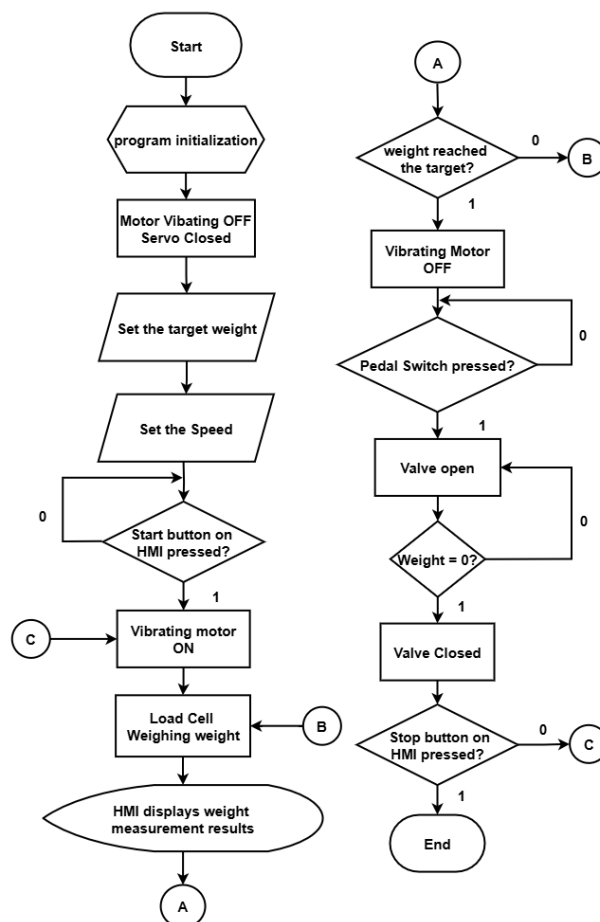


Figure 2. Flowchart System

In addition to the process workflow, the system's functionality depends on proper electrical connections between components. The circuit diagram ensures that the power supply, microcontroller, sensors, actuators, and interface are correctly connected according to their functions. Figure 3 illustrates the complete circuit design, providing a clear overview of the electrical structure supporting the system's operation.

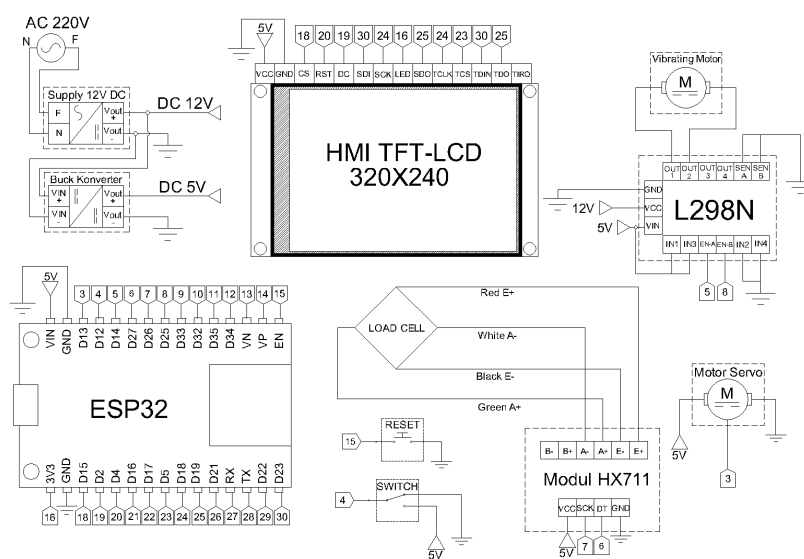


Figure 3. Circuit Scheme

Figure 4 illustrates the mechanical design of the tool, serving to clearly represent its physical structure and minimize the risk of errors during fabrication, ensuring that the final product aligns with design expectations.

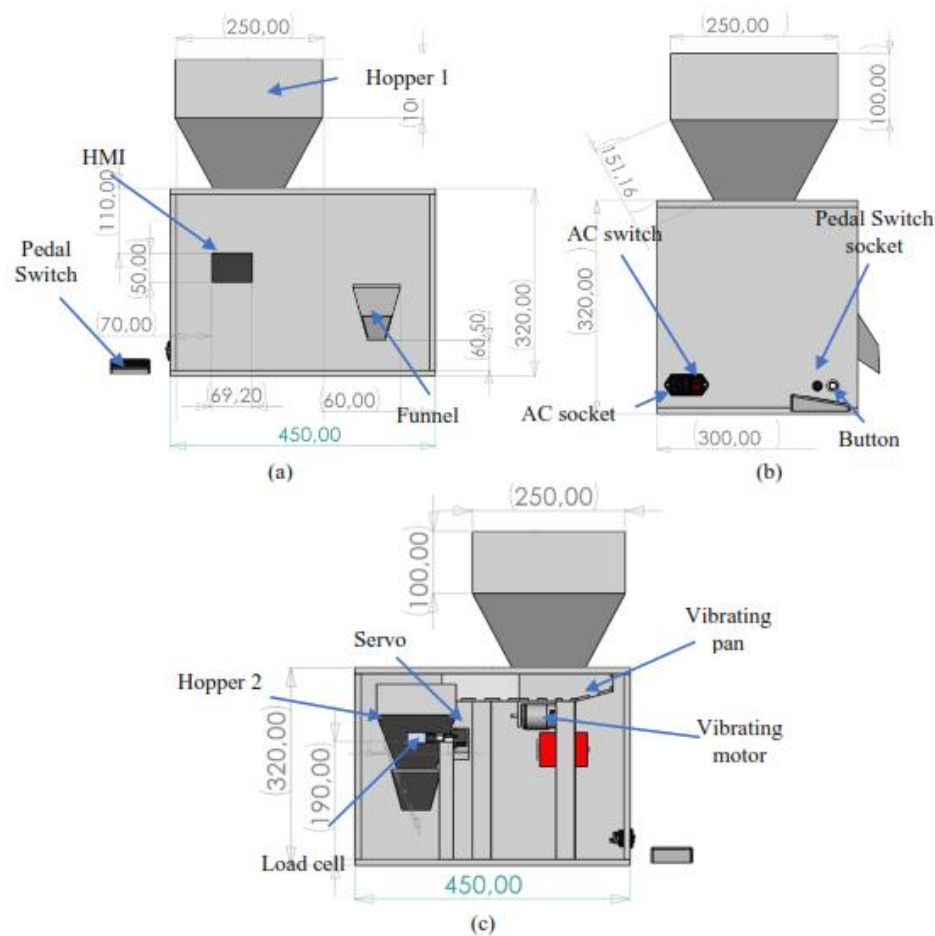
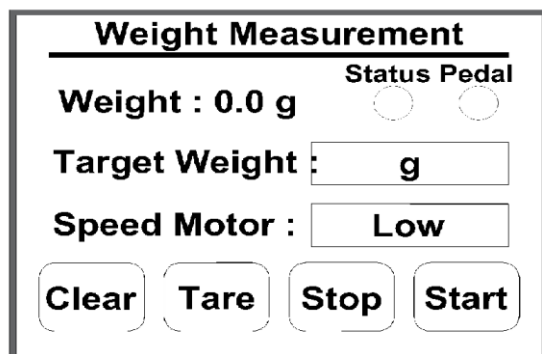
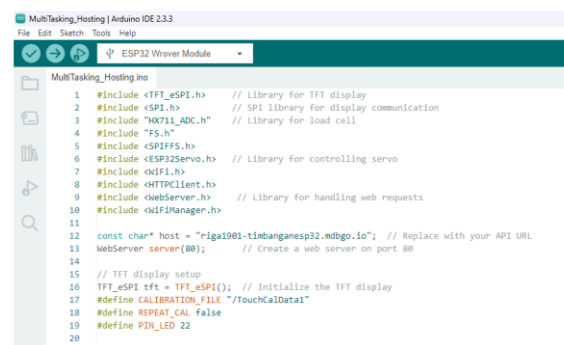


Figure 4. Hardware design. a) Front view design, b) Right view design, and c) Inside view design

The software design involved programming the microcontroller using the Arduino IDE to control the sensors, motors, and valves. A TFT LCD interface was also developed to display weight data and set parameters such as target weight and motor speed. Figure 5 shows the program implementation and display.



(a)



(b)

Figure 5. Software Design (a) HMI display, (b) Program view on Arduino IDE

### 3. RESULTS AND DISCUSSION

After the weighing system is complete, it is tested to determine the results of the device. Microcontroller-based Automatic Granule Weighing Device with Human Machine Interface (HMI) Integration test is shown in Figure 6.

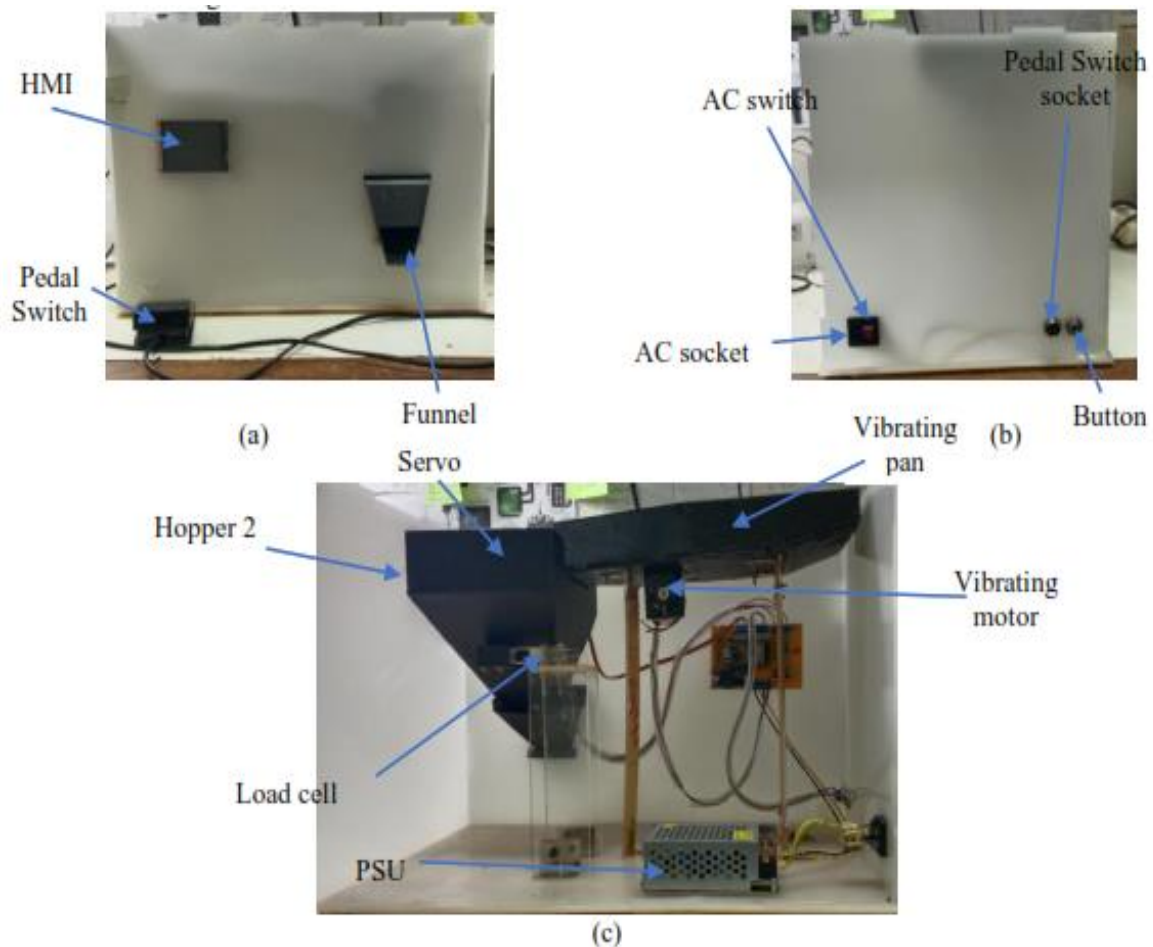


Figure 6. Tool View (a) Front view, (b) Right view, (c) Inside view

Figure 6 shows the device display from the testing of the Microcontroller-based Automatic Granule Weighing Device with Human Machine Interface (HMI) Integration. The working principle of this system begins when the weight of an object is detected by the load cell sensor, which then sends a signal to the weight amplifier. The amplifier amplifies the signal and converts it into high-resolution digital data, which is then sent to the microcontroller. The microcontroller processes the data and displays it on the HMI, allowing the weighing results to be monitored directly through the HMI screen.

Two types of testing were carried out. First, testing was conducted by weighing cat litter granules placed in containers with varying weights. During this stage, the output voltage from the load cell was measured, and the digital data converted by the weight amplifier was observed via the serial monitor for each measured mass. Second, testing was performed using rice granules with three speed modes and eight weight variations to determine the accuracy and error rate of the designed weighing system.

In the first test, data was collected by monitoring and measuring the digital output values from the HX711 module while weighing rice granules of a certain mass. This test was conducted to determine the relationship between the digital output and the mass, which must satisfy the linearity characteristic of the load cell sensor system [17]. The results of these digital value and mass measurements are presented in Table 1.

Based on Table 1 and the graph in Figure 7, it can be concluded that the working principle of the load cell sensor with the weight amplifier is that when a load is applied, the sensor generates a voltage that is then converted into digital data. This digital value is proportional to the applied weight. Voltage amplification is performed to ensure the signal can be accurately read by the microcontroller.

Table 1. Sensor linearity test results

| No | Weight (grams) | Digital weight amplifier output |
|----|----------------|---------------------------------|
| 1  | 0              | 0                               |
| 2  | 100            | 106498                          |
| 3  | 200            | 213022                          |
| 4  | 300            | 319501                          |
| 5  | 400            | 426028                          |
| 6  | 500            | 532517                          |
| 7  | 600            | 639040                          |
| 8  | 700            | 745571                          |
| 9  | 800            | 852030                          |
| 10 | 900            | 958526                          |

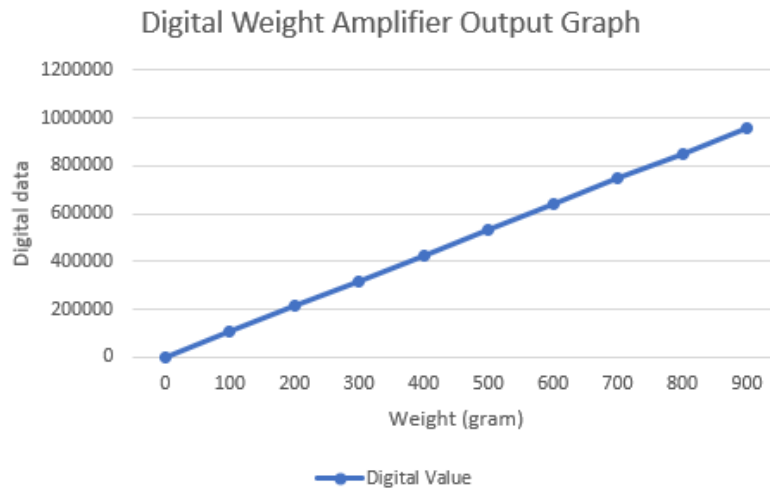


Figure 7. Digital weight amplifier output graph

The second test was carried out using three speed options and eight weight variations. The test object used was rice granules. This testing aimed to determine the average error and accuracy level of the Microcontroller-based digital weighing system. The monitoring display of the rice granule weighing process with a target weight of 250 grams at High speed is shown in Figure 8.



Figure 8. HMI display of 250 gram target weight measurement in High Speed

Figure 8 displays the HMI interface during the weighing process of rice granules with a target weight of 1000 grams at medium speed. The measured weight value is shown in real time on the HMI as a digital numeric display. The results weighing trials of rice granules at low speed can be seen in Table 2.

Tabel 2 Low speed testing

| Target weight | Weight at HMI (gram) | Error (%) | Information |
|---------------|----------------------|-----------|-------------|
| 50            | 51.0                 | 2         | Heavier     |
| 100           | 100.1                | 0.1       | Heavier     |
| 150           | 151.5                | 1         | Heavier     |
| 200           | 200                  | 0         | Heavier     |
| 250           | 250.7                | 0.28      | Heavier     |
| 300           | 301.3                | 0.43      | Heavier     |
| 350           | 350.6                | 0.17      | Heavier     |
| 400           | 400.1                | 0.02      | Heavier     |

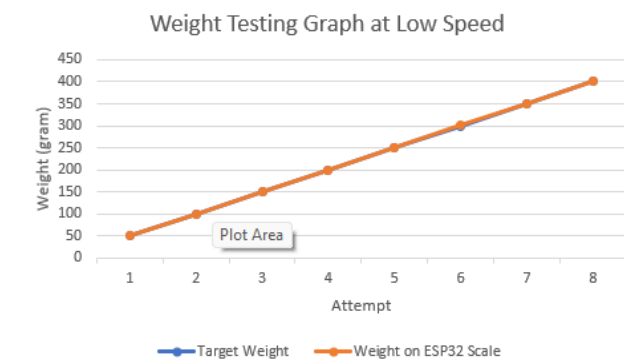


Figure 9. Weight Testing Graph at Low Speed

Table 2 and the graph in Figure 9 present the data obtained from low-speed rice weighing. The results show the difference between the measured value and the target weight. Across eight trials, an average error of 0.5% was recorded, with a weighing accuracy of 99.5%. The results of medium-speed rice weighing can be seen in Table 3.

Tabel 3. Medium speed testing

| Target weight | Weight at HMI (gram) | Error (%) | Information |
|---------------|----------------------|-----------|-------------|
| 50            | 50                   | 0         | Equal       |
| 100           | 100                  | 0         | Equal       |
| 150           | 150.7                | 0.47      | Heavier     |
| 200           | 200.1                | 0.05      | Heavier     |
| 250           | 251                  | 0.40      | Heavier     |
| 300           | 301.6                | 0.53      | Heavier     |
| 350           | 351.6                | 0.46      | Heavier     |
| 400           | 399.5                | 0.13      | lighter     |

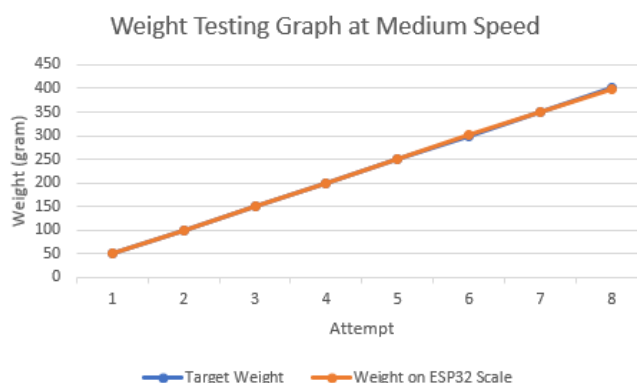


Figure 10. Weight Testing Graph at Medium Speed

Table 3 and the graph in Figure 10 present the rice granule weighing data at medium speed. The results show little difference between the measured value and the target weight. Across eight trials, the average error was recorded at 0.255%, with a weighing accuracy of 99.745%. The results of the high-speed rice granule weighing experiment can be seen in Table 4.

Tabel 4. High speed testing

| Target weight | Weight at HMI (gram) | Error (%) | Information |
|---------------|----------------------|-----------|-------------|
| 50            | 50.6                 | 1.20      | Heavier     |
| 100           | 100.5                | 0.50      | Heavier     |
| 150           | 150.1                | 0.07      | Heavier     |
| 200           | 201.8                | 0.90      | Heavier     |
| 250           | 250.1                | 0.04      | Heavier     |
| 300           | 300.8                | 0.27      | Heavier     |
| 350           | 350.8                | 0.23      | Heavier     |
| 400           | 400.2                | 0.5       | Heavier     |

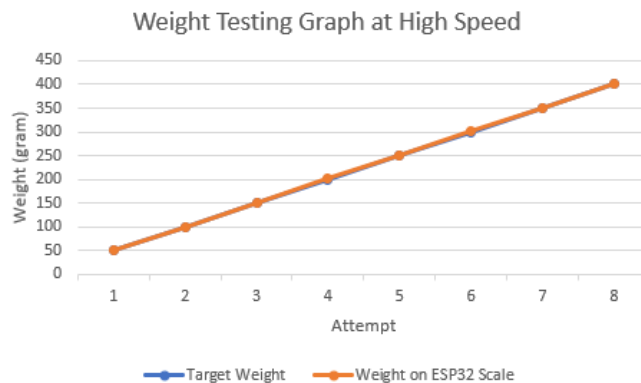


Figure 11. Weight Testing Graph at High Speed

Table 4 and the graph in Figure 11 present the rice grain weighing data in high-speed mode. The results show a discrepancy between the measured values and the target weight. Across eight trials, the average error was recorded at 0.464%, with a weighing accuracy of 99.536%.

#### 4. CONCLUSION

The Microcontroller-based automatic granule weighing system integrated with a Human Machine Interface (HMI) has demonstrated reliable and accurate performance across various speed modes. Testing was conducted using rice granules as the material, with three speed settings—low, medium, and high—and eight weight variations. The system achieved an average error of 0.5% at low speed, 0.255% at medium speed, and 0.464% at high speed. Overall, the total average error across all modes was 0.406%, with a combined accuracy of 99.594%. The medium speed produced the most optimal results, showing the highest accuracy and lowest deviation from the target weights. These results confirm that the system is capable of consistent and precise weighing performance, even under varying speed conditions. The load cell sensor, combined with the weight amplifier, effectively converted load into high-resolution digital data, which was processed and displayed in real time by the microcontroller via the HMI screen.

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