AN-NAJAH NATIONAL UNIVERSITY

Computer Engineering Department

Hardware Graduation Project

Innovative Packaging Machine

Students

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Under the supervision of

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Disclaimer

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Abstract

Packaging and weighing processes are essential in the food industry, especially for products such as nuts that require accurate portioning and secure sealing.

This project presents the design and implementation of an Automatic Nuts Filling and Sealing Machine aimed at providing a low-cost, compact, and semi-automated solution suitable for small-scale production. The system integrates mechanical components for vibration-based feeding, electronic weighing using a load cell and HX711 module, and a sealing mechanism adapted from a manual heat-sealing machine.

The machine operates by dispensing nuts from a hopper using a vibration motor, measuring the weight in real time, and stopping the flow once the desired weight is reached. The measured quantity is then released into a pre-positioned plastic bag, which is sealed using a controlled heat-sealing bar.

An Arduino microcontroller serves as the central control unit, coordinating sensor readings, motor activation, and timing logic.

The developed prototype demonstrates acceptable accuracy, reliability, and ease of operation. Although constrained by manual bag placement and limited production speed, the system successfully validates the feasibility of low-cost automation for nut packaging. Future improvements may include fully automated bag feeding, enhanced sealing control, and industrial-grade mechanical components.

1 Introduction

Automation in food packaging has become increasingly important due to the need for efficiency, consistency, and cost reduction. Small businesses and local producers often rely on manual or semi-manual methods for weighing and packaging nuts, which can lead to inconsistencies in weight, reduced productivity, and increased labor costs.

This project focuses on developing a compact and affordable automatic nuts filling and sealing machine that addresses these challenges.

The proposed system combines simple mechanical mechanisms with embedded electronics to automate the core steps of nut packaging: dispensing, weighing, and sealing.

By using commonly available components such as Arduino, load cells, and vibration motors, the project emphasizes practicality and ease of replication. The main objective is to design a functional prototype that can be further expanded into a fully automated industrial system.

Organization of the Report: This report is organized as follows. Chapter 2 discusses the constraints encountered during the project and the relevant coursework that supported its development. Chapter 3 explains the system methodology, including design overview, control logic, and hardware integration. Chapter 4 presents the results and discusses system performance. Chapter 5 concludes the report and suggests future improvements. Chapter 6 lists the references used in this project.

2 Constraints and Earlier course work

2.1 Constraints

Several constraints influenced the design and implementation of this project:

- Budget limitations restricted the use of industrial-grade components, leading to the selection of low-cost motors and sensors.
- Mechanical precision was limited due to the use of basic fabrication tools.
- Manual placement of bags was required, reducing the level of automation.
- Vibration-based feeding introduced minor fluctuations in weight accuracy.
- Safety considerations limited the heating power of the sealing unit..

2.2 Early Courses

While we benefited from a wide range of courses throughout our academic journey, certain ones proved particularly impactful in the successful development of our image-processing controlled robot. These courses provided the necessary balance between theoretical knowledge and practical application, enabling us to design a system that integrates computer vision, wireless communication, and robotic control in a functional and efficient manner.

Our introduction to microcontrollers and automation began with the **PIC Lab**, where we gained hands-on experience working with the Arduino Uno and developed a strong understanding of sensor-based logic and hardware-software integration. This foundation was later expanded through the **Microcontrollers and Microcontrollers Lab** courses, where we learned to implement more complex systems involving multiple peripherals and communication modules. These skills were directly applied in our project, as the Arduino Mega served as the central controller for both the robotic car and its mounted arm.

The **Wireless Communication course** introduced us to essential concepts of data transmission and connectivity, which became crucial for establishing the link between the robot and external devices.

On the other hand, the **Digital 3 course** focused on developing our ability to interpret datasheets, calculate current and voltage requirements, and design circuits that meet system specifications. These skills proved invaluable when working with the Arduino Mega and its peripherals, ensuring reliable power distribution and proper interfacing between the robotic platform, its arm, and the HC-05 Bluetooth module.

Our ability to manage the system's power requirements and ensure stable hardware performance was strongly supported by the **Electronic Circuits course**, which enhanced our understanding of circuit design and electrical behavior. Similarly, the **CPU Lab** equipped us with practical skills such as soldering, wiring, and debugging—capabilities that were invaluable during the assembly and troubleshooting phases of the robotic platform.

Finally, the **Technology Project Management course** contributed to the business-oriented side of the project. It guided us in conducting feasibility studies, managing costs, and planning the overall system workflow—ensuring that our work extended beyond a purely technical prototype into a structured, project-managed product.

3 Methodology

3.1 Standards and Specifications

The system operates using low-voltage DC standards (5V and 12V) to ensure safety and compatibility with common electronic components.

Serial communication protocols are used between the Arduino and peripheral modules. The heat-sealing mechanism follows standard thermal sealing principles used in commercial plastic packaging.

3.2 Design Overview

The system consists of four main subsystems:

1. Feeding System: A hopper with a vibration motor to control nut flow.
2. Weighing System: A load cell connected to an HX711 amplifier for accurate weight measurement.
3. Control System: An Arduino microcontroller to process sensor data and control actuators.
4. Sealing System: A heat-sealing bar adapted from a manual sealing machine for bag closure.

3.3 Control and Automation

The Arduino continuously reads weight data from the HX711 module.
When the measured weight reaches the predefined target, the vibration motor is stopped.
A mechanical gate then releases the nuts into the bag.

The user manually positions the bag, and the sealing mechanism is activated for a fixed duration to seal the bag.

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3.6 Programming and Circuit Integration

• The Arduino was programmed using the Arduino IDE. The HX711 library was used for load cell calibration and weight measurement. Transistors and relays were used to safely control high-current devices such as the vibration motor and heating element. Proper grounding and power isolation were implemented to ensure stable operation.

3.7 Safety Measures

• Electrical insulation was applied to all exposed connections.

• Heat-resistant materials were used around the sealing bar.

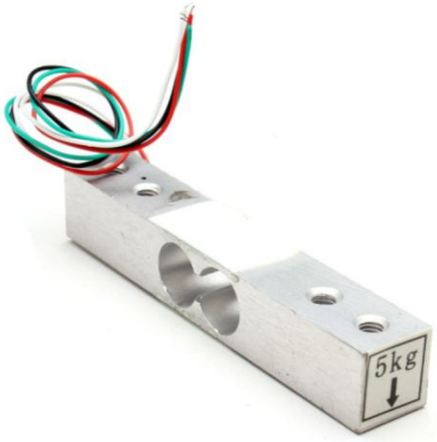
• Current-limiting components were used to protect the Arduino.

3.8 Component List and Description

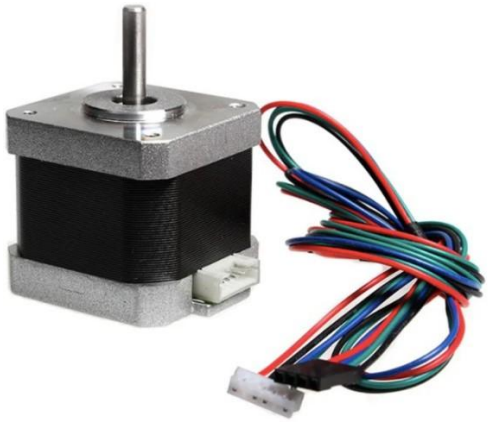
The system is built using the following key hardware components:

- **Arduino mega:**

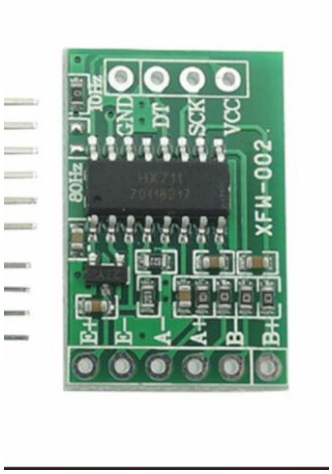
- Load Cell (5kg)**:**



- **NEMA 17:**



- HX711 Load Cell Amplifier**:**

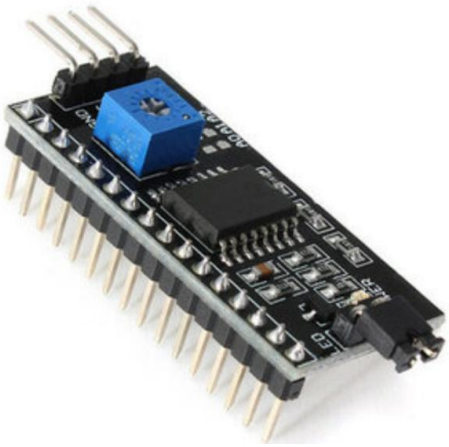


- Vibration Motor**:**

- **Sealing Wire**
  - **:**

- **MG 996R:**

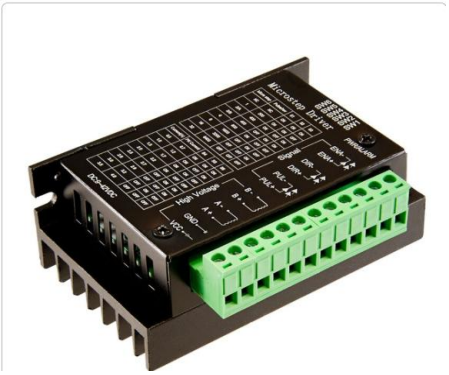
- **I2C:**



- **AC 110V-220V To DC 5V 5A 25W Power Supply:**

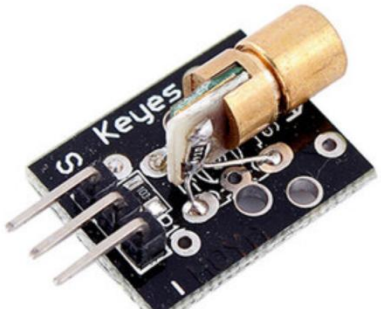
- **ESP32:**

- **TB6600 4A 9-42V MicroStep Stepper Motor Driver (Metal Case):**



- **LCD:**

- **KY-008 5V Transmitter Laser Module:**



4 System Architecture and Block Diagram Description

The overall system architecture of the Automatic Nuts Filling and Sealing Machine follows a modular design approach. Each subsystem operates independently while being coordinated by the central control unit (Arduino Uno). This modularity simplifies debugging, maintenance, and future expansion.

The system begins with the feeding unit, where nuts are stored in a hopper. A vibration motor mounted at the base of the hopper regulates the flow of nuts toward the weighing container. The weighing subsystem measures the mass of the nuts using a load cell connected to an HX711 amplifier, which converts the analog signal into a digital form readable by the Arduino.

Once the desired weight is reached, the control unit disables the vibration motor and activates the mechanical gate to release the nuts into the bag. Finally, the sealing subsystem is triggered to close the bag opening using a heat-sealing bar.

5 Hardware Design Details

5.1 Arduino Uno

The Arduino Uno serves as the main controller of the system. It reads sensor data, executes control logic, and drives actuators. The choice of Arduino Uno was based on its simplicity, availability, and sufficient I/O pins for the project requirements.

5.2 Load Cell and HX711 Module

The load cell is a strain gauge-based sensor that converts applied force into an electrical signal. Due to the very small output voltage of the load cell, the HX711 amplifier is used to amplify and digitize the signal. Calibration is performed using known weights to ensure accurate measurements.

5.3 Vibration Motor

A 12V vibration motor is used to control the flow rate of nuts. The motor is driven through a transistor-based switching circuit to protect the Arduino from high current draw. By controlling the motor’s on/off timing, the system can fine-tune the amount of nuts dispensed.

5.4 Sealing Mechanism

The sealing mechanism is adapted from a manual heat-sealing machine. It consists of a heated upper jaw and a fixed lower jaw. When activated, the upper jaw presses against the bag opening, melting the plastic layers together to form a strong seal.

5.5 Power Supply

The system uses a combination of 5V and 12V DC power supplies. The Arduino and sensors operate at 5V, while the vibration motor and sealing unit use 12V. Proper voltage regulation and grounding are implemented to ensure stable operation.

6 Software Design and Flowchart Description

The software is written in C++ using the Arduino IDE. The program structure consists of initialization, continuous sensor reading, decision-making, and actuator control.

At startup, the system initializes the HX711 module and performs tare calibration. During operation, the Arduino continuously reads the weight value. If the measured weight is below the target value, the vibration motor remains active. Once the target weight is reached, the motor is stopped and the gate mechanism is triggered.

After dispensing, the system waits for the user to place the bag correctly before activating the sealing process. Timing delays are used to ensure consistent sealing quality.

7 Testing and Validation

Several tests were conducted to validate the system performance. Weight accuracy was tested using standard calibration weights. The vibration feeding mechanism was evaluated for consistency and flow control. The sealing quality was tested using different sealing times and temperatures.

The results showed that the system achieved acceptable accuracy for small-scale packaging, with minor variations due to nut size and vibration behavior. The sealing mechanism produced strong and reliable seals when operated within the recommended temperature range.

8 Cost Analysis

The project was designed with cost efficiency in mind. Most components were selected based on availability and low price. The estimated total cost of the prototype is significantly lower than commercial packaging machines, making it suitable for small businesses and educational purposes.

9 Risk Analysis and Limitations

Potential risks include overheating of the sealing unit, mechanical wear of moving parts, and electrical noise affecting sensor readings. These risks were mitigated through proper insulation, heat-resistant materials, and software filtering.

Despite its success, the system has limitations such as semi-manual operation, limited speed, and dependence on operator accuracy when placing bags.

10 Ethical, Environmental, and Safety Considerations

The system was designed to minimize waste by ensuring accurate portioning. Electrical safety was prioritized by using low-voltage components and proper insulation. The project complies with basic ethical standards by promoting efficient resource usage and safe operation.

11 Project Management and Timeline

The project was completed over several phases including requirement analysis, hardware assembly, software development, testing, and documentation. Effective time management and incremental testing contributed to successful project completion.

12 Conclusions and Recommendation

12.1 Conclusions

This project successfully delivered a working prototype of an automatic nuts filling and sealing machine.

The system met its main objectives and demonstrated reliable performance under test conditions.

12.2 Recommendations

- Improve mechanical precision of the gate mechanism
- Add temperature control for the sealing bar
- Integrate a display for user interaction.

12.3 Future Work

- Fully automated bag feeding system
- Higher-capacity industrial motors
- Improved enclosure and safety design

13 Final Summary

This report presented the design and implementation of an Automatic Nuts Filling and Sealing Machine as a computer engineering hardware project. The system successfully integrates mechanical, electrical, and software components to achieve semi-automated packaging. The project demonstrates practical application of embedded systems knowledge and provides a strong foundation for future industrial development.

14 References

[1] Arduino Uno Datasheet – https://docs.arduino.cc

[2] HX711 Load Cell Amplifier Datasheet

[3] Food Packaging Heat Sealing Principles