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AUTOMATED DEVICE FOR MONITORING AND SHAKING BLOOD BAGS

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Abstract:

This project presents the design and implementation of an automated Shaking and Weight Device of the Blood Bag to enhance the accuracy and efficiency of blood collection processes in medical settings. Traditional manual methods for blood bag handling often introduce risks such as inconsistent agitation, imprecise volume measurement, and human error, which compromise blood product quality. The proposed system integrates a load cell with an HX711 amplifier for real time weight monitoring and a Tower Pro MG996R servo motor for gentle, periodic agitation to ensure thorough anticoagulant mixing. An Arduino UNO microcontroller coordinates these subsystems, while a 16×2 LCD and buzzer provide real-time feedback and alerts. Testing demonstrated the device's capability to standardize blood collection, reduce clotting risks, and improve transfusion safety. The project Demonstrates the potential of cost- effective automation in healthcare, offering a scalable solution for clinical environments.

Keywords: Blood Collection Device, Automated Agitation, Arduino-based System

1. Introduction

1.1 Background of Blood Bag Handling

Blood bag management is a vital part of medical facilities, particularly in blood donation centers and hospitals, The process involves the collection, storage, and handling of blood bags to ensure the safety and effectiveness of blood products for patients, Proper management is essential to maintain the integrity of blood components, such as red blood cells, plasma, and platelets, each of which has specific preservation requirements [1].

Previously, blood bag handling processes often relied on manual methods, which introduced challenges such as human error, inconsistent agitation, and imprecise volume monitoring. This may compromise blood quality, leading to potential risks like clotting, contamination, or inadequate preservation [2].

For instance, inaccurate volume measurements may affect transfusion outcomes [3]. One of the essential steps in this process is the uniform mixing of blood with anticoagulants during collection, as well as the accurate measurement of the collected blood volume. This is where the shaking and weight device for blood bags plays a pivotal role. The shaking mechanism in the device ensures that anticoagulants are thoroughly mixed with the blood, preventing clot formation and preserving the viability of blood components [4].

1.2 Previous Studies

In this section, previous studies dealing with blood bag handling systems are reviewed. The literature highlights research focused on developing automated mechanisms for blood bag agitation and volume estimation.

Emphasis is placed on ensuring proper mixing of blood with anticoagulants and achieving accurate weight-based volume measurements. These studies illustrate the advantages of replacing manual methods with automated systems to reduce human error and improve transfusion safety. This paper presents the design of a shaking machine for shaking the blood bag and volume estimation without sensor. The amount of blood in the bag is related to load torque on the DC motor. The volume of the blood bag increases in blood donation process until the desired volume, which the current increases too. The current and load torque can be used to estimate volume of the blood bag and blood flow rate at the same time via the principles of closed-loop speed control system, observer and adaptive compensator.

The blood and anticoagulant should be mixed gently and periodically (at least every 60 seconds) during collection. Mixing should be achieved by manual inversion of the blood pack, or automatically by placing the blood pack on a mechanical agitator or by using a rocking device. The volume of blood withdrawn must be controlled to protect the donor from excessive loss of blood and to maintain the correct proportion of anticoagulant to blood. The most efficient way of measuring the blood volume in plastic bags is by weight. The mean weight of 1 mL of blood is 1.06 g, and therefore, for example, a unit containing 470 mL of blood should weigh 470 × 1.06 g plus the weight of the pack(s) and the anticoagulant. [3]

1.3 Aims of the Project

The aim of this project is

1. To measure the blood bag weight in real time using a load cell and provide continuous data to the system.
2. To ensure proper mixing of collected blood with anticoagulant by applying a consistent shaking motion.
3. To automate the process of blood collection monitoring, reducing the need for constant manual supervision.
4. To alert medical staff when the target blood volume is reached through visual and/or audio indicators.
5. To display key information such as current weight and system status using an LCD screen.
6. To use affordable, open-source components (e.g., Arduino, HX711) to keep the device cost-effective and easily replicable.

1.4 Project Outline

The Project is organized as follows:

- In chapter one, an introduction to the subjects of the thesis, previous studies, and the objective to

the thesis are given.

- In chapter two, a description Blood collection process and the requirements for preservation are considered.
- In chapter three, a design of shaking and weight and of the blood bag device are given.
- In chapter four, the results and discussions of the device are given.
- In chapter five, conclusions and suggestions for future work are summarized.

2. Theoretical Background

2.1 Blood Donation Process

Blood donation is a vital process that requires careful monitoring and management to ensure donor safety and blood product integrity [5].

Blood consists of several cellular elements, red blood cells, white blood cells, platelets, and plasma, each component serves a different function and requires specific handling considerations during collection and storage. The donation workflow begins with donor screening, where individuals get evaluated based on age (typically 18-65 years), weight (minimum 45-50 kg depending on collection volume), vital signs, and medical history, this screening ensures donor safety and blood product quality [6].

When approved, the collection process starts with venipuncture, allowing blood to flow through sterile tubing into collection bags containing anticoagulants. The standard collection volume ranges from 350-450 ml based on donor weight, which lasts 8-12 minutes [7].

During collection, several critical parameters need precise control, The blood to-anticoagulant ratio(Rb/a)must be maintained at approximately 7:1to prevent clotting while avoiding excessive dilution, This requires continuous blood volume monitoring, which is accurately determined by weight measurement (1 ml of blood weighs approximately 1.06 g). Simultaneously, the blood bag requires gentle but consistent agitation at least every 60 seconds to ensure proper mixing with an anticoagulant. Inadequate mixing results in micro clots and reduced product quality, while excessive agitation can cause hemolysis and cellular damage [8].

A manual approach to blood bag handling presents significant limitations; the process is labor-intensive, requiring dedicated personnel to maintain continuous monitoring and agitation. This creates consistency challenges, additionally; staff availability often limits collection capacity, particularly in mobile donation settings. These limitations highlight the need for automated solutions that can standardize the blood bag handling process [9].

Post-collection, blood may be processed into components (red cells, plasma, and platelets), each requiring specific handling and storage conditions.

The shelf life of these products varies based on the anticoagulant used CPDA-1 preserves whole blood for 35 days, while SAGM extends viability to 42 days; Platelets maintain viability for only 5 days, while fresh frozen plasma can be stored for up to one year [10].

Table 1. Comparison of storage conditions for different blood components.

WHOLE BLOOD	RED CELLS	RED CELLS - FROZEN STATE
• Acid Citrate Dextrose (ACD) • Citrate phosphate Dextrose solution (CPD) • Citrate phosphate dextrose adenine. (CPDA-1) • Heparin • EDTA (Ethylene diamine tetra acetic acid)	• CPD - SAG (Saline, adenine, glucose) • CPD - SAGM (Saline, adenine, glucose, mannitol) • CPD - ADSOL (Adenine, saline, glucose, mannitol)	• High glycerol solution • Low glycerol solution

This variance in storage requirements further emphasizes the importance of precise handling during the initial collection phase to ensure maximum product quality and longevity.

An automated blood bag handling system capable of precise weight measurement and standardized agitation would address current limitations while enhancing efficiency and product quality. Such a system would reduce the work for healthcare staff while ensuring constant monitoring of critical collection parameters, ultimately improving the safety and efficacy of blood transfusion products.

2.2 Blood Bag Technology

Blood bag technology has undergone significant transformation since its invention in the 1950s, when it replaced glass bottles as the primary blood storage container [11].

The earliest blood bags were simple single-unit containers made of polyvinyl chloride (PVC). These initial designs made advancements in blood storage, offering advantages such as reduced breaking risk, lighter weight, and improved storage efficiency compared to glass containers. The blood bags progressed from these single-unit designs to the multi-bag systems available today. Modern blood collection systems typically feature a primary collection bag connected to several satellite bags through tubing, allowing for component separation without breaking the sterile environment [12].

This advancement has been crucial in maximizing the utility of each donation by enabling the separation of whole blood into its components (red blood cells, plasma, and platelets), each one requires distinct storage requirements and therapeutic applications. Innovation in blood bag design has been driven by the need to enhance blood preservation, extend storage duration, and improve safety.

Significant milestones include the introduction of anticoagulant solutions directly integrated into collection bags, the development of leukocyte reduction filters (LRFs), and the incorporation of sampling pouches for testing without compromising the primary collection. Current blood bags are mainly manufactured from medical-grade PVC with DEHP, which provides flexibility and durability while maintaining compatibility with blood components. Blood and its components have stringent storage requirements that directly impact their viability and therapeutic efficacy:

- Whole blood and red blood cell concentrates must be refrigerated at 2 6°C with carefully controlled temperature variations, typically allowing storage for 35-42 days depending on the preservative solution [14].
- Platelets require storage at 20-24°C with continuous gentle agitation to prevent aggregation, limiting their shelf life to 5-7 days [15].

- Fresh frozen plasma must be frozen within 8 hours of collection and maintained at -18°C or below, extending its viability to 1 year [16].
- Cryoprecipitate, Once thawed must be used within 6 hours if stored at room temperature or within 24 hours if refrigerated [17].

Table 2. Blood component storage requirements.

Component	Temperature range	Shelf Life	Storage Unit
Whole Blood	1-6C	21 or 35 Days	Refrigerator
Red Blood Cells	1-6C	42 Days	Refrigerator
Cryo/Pooled Cryo	-18C or Colder	1 Year	Freezer
Plasma	-18C or Colder	1 Year	Freezer
Platelets	20-24C	5 Days	Incubator/Agitator or Monitored Room

These storage requirements present significant logistical challenges for blood banks and hospitals. Limitations include:

- The relatively short shelf life of platelets necessitates frequent replenishment.
- The need for specialized equipment to maintain precise temperature control.
- Challenges in transporting blood products while maintaining appropriate conditions.

Proper handling of blood bags is critical throughout the collection, processing, transportation, and administration phases. Key considerations include:

- Physical Handling: Blood bags must be handled gently to prevent damage to the container integrity and to minimize mechanical stress on blood cells. Rough handling can lead to hemolysis, platelet activation, or micro clot formation [18].
- Temperature control: Strict temperature control during transportation and storage is essential, requiring precise cooling systems and temperature monitoring devices. Temperature changes can accelerate biochemical deterioration and compromise component quality [19].
- Agitation Requirements: Platelets require continuous gentle agitation to prevent aggregation, while whole blood during collection needs intermittent mixing with anticoagulant. The intensity and frequency of agitation must be carefully controlled to prevent damage to cellular components [20].
- Protection from Light: Certain blood components, particularly platelets, are susceptible to damage from prolonged exposure to light, necessitating protective coverings or specially designed storage containers [21].
- Position and Orientation: Blood bags should be stored in specific orientations to optimize gas exchange and prevent pressure damage to components. For instance, platelet bags are typically stored horizontally to maximize the surface area for gas exchange [22].

2.3 Importance of Precise Measurement and Agitation

The integrity and therapeutic efficacy of blood products depend significantly on two critical parameters during the collection process, precise volume measurement and consistent agitation. These parameters serve as fundamental quality control mechanisms that directly influence the viability and functionality of collected blood components. According to standards established by the American Association of Blood Banks (AABB) and the World Health Organization (WHO), blood collection units must maintain specific blood-to- anticoagulant ratios, typically 450 mL ± 10% of blood to 63 mL of anticoagulant solution. This narrow tolerance range necessitates highly accurate measurement systems capable of measuring volume with precision better than ±5 mL.

Research indicates that even minor deviations from the target volume can disrupt the blood-to-anticoagulant balance, increasing the risk of clotting or excessive dilution, which may compromise blood quality and affect transfusion safety. Inaccurate volume measurement during blood collection creates cascading effects that jeopardize both product quality and donor safety. When blood volume exceeds the intended amount, insufficient anticoagulation can occur, leading to micro clot formation within the collection bag. This reduces component yield and introduces the potential for clotted material to cause adverse transfusion reactions. Conversely, under-collection results in excessive anticoagulation, which may lead to citrate toxicity in recipients, presenting symptoms such as hypocalcemia, paresthesia, and, in severe cases, cardiac arrhythmias.

Thus, precise volume measurement is essential not only for maintaining the integrity of blood products but also for ensuring the safety of donors and recipients. Continuous agitation during blood collection serves multiple crucial functions that directly affect product quality. Its primary role is to ensure thorough mixing of blood with anticoagulant preservative solutions.

WHO guidelines mandate that blood be gently mixed with anticoagulant at least every 60 seconds during collection to prevent clot formation since anticoagulant is pre-placed in the bag, inadequate mixing as blood enters can lead to stratification, increasing clotting risks. Manual inversion of the blood pack, while effective, is subject to inconsistency due to human variability, whereas mechanical agitators offer more uniform mixing, reducing the likelihood of inadequate anticoagulation. However, the mechanical forces applied during agitation must be carefully calibrated; Excessive agitation (characterized by high frequency or amplitude) can induce mechanical stress on cellular components, potentially causing premature hemolysis. Safe operation of mechanical agitators requires maintaining agitation within a frequency and amplitude range that ensures thorough mixing without damaging blood cells.

Precise measurement and controlled agitation are not merely technical preferences but essential quality control mechanisms that influence clinical outcomes, operational efficiency, and regulatory compliance. These factors underscore the need for automated systems that deliver consistent, accurate performance across these critical parameters. By integrating precise volume monitoring and standardized agitation, automated blood bag handling devices can overcome the limitations of manual methods, ensuring reliability and consistency in blood collection processes.

3. System Design and System Model

3.1 System Overview

The system architecture consists of three main functional modules working in harmony: the weight measurement subsystem, the shaking mechanism subsystem, and the control and display interface. these modules are managed by a central microcontroller that coordinates their operation and provides user interaction capabilities. the weight measurement subsystem utilizes a precision load cell connected to an amplifier circuit to continuously monitor the blood bag's weight during collection, This data is processed in real time by the microcontroller to calculate the volume of collected blood based on the established conversion factor of 1.06 g/mL.

The shaking mechanism subsystem uses a servomotor controlled by timed intervals to provide gentle but consistent agitation of the blood bag at programmable intervals. This ensures thorough mixing of blood with anticoagulant solutions while preventing cellular damage that could result from excessive mechanical stress. The control and display interface provides real-time feedback to operators through an LCD screen and programmable alarms that activate when predetermined weight thresholds are reached.

The system is designed to meet the following key functional requirements:

- Precise Weight Measurement: Capable of measuring blood bag weight with accuracy.
- Consistent Agitation: Provides uniform, gentle shaking at programmable intervals with adjustable intensity settings.

- Real-time Monitoring: Continuously displays current blood volume.
- Automated Alerts: Generates audible and visual alerts when target volumes are approached (typically 450mL ±10%) and when critical thresholds are exceeded.
- User Customization: Allows operators to customize operational parameters such as target volume, agitation frequency, and alarm thresholds.
- Cost-effective: utilizing open-source microcontroller technology and readily available components, the system is affordable while achieving professional- grade performance.

3.2 System Overview

In this project, we design a shaking and weight measurement system for blood bags using the following components:

- Arduino UNO R3
- HX711 load cell amplifier and load cell
- Tower Pro MG996R servo motor
- LCD display (16×2)
- Connection wires

1) Arduino UNO

Arduino UNO R3 is a microcontroller board based on the ATmega328P microcontroller, It features 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, USB connection, power jack, ICSP header, and a reset button.

The Arduino UNO R3 serves as the brain of our system, processing weight measurements from the load cell and controlling the servomotor for the shaking mechanism. Its reliable performance and extensive library support make it ideal for this medical application.

Table 3. Comparison of different microcontrollers.

Comparison Points	Arduino UNO R3 (Selected)	Arduino Nano	Raspberry Pi Pico	ESP32
Processing Power	16 MHz (ATmega328P)	16 MHz (ATmega328P)	133 MHz (Dual-core RP2040)	240 MHz (Dual-core Tensilica LX6)
I/O Pins	14 digital, 6 analog	22 digital, 8 Analog	26 digital, 3 analog	34 digital, 18 analog
Power Supply	5V (regulated via USB/DC jack)	5V (USB)	3.3V (requires level-shifting)	3.3V (requires level-shifting)
Ease of Use	Extensive libraries, beginner-friendly	Compact size, breadboard-Friendly	Complex setup for 3.3V sensors	Advanced IDE/config needed
Scalability & Medical Fit	Modular design enables easy integration of medical-grade components; stable 5V operation ensures sensor accuracy and	Compact size limits expandabilit; fragile for medical environments despite space efficiency.	Processing power unnecessary for simple automation; 3.3V logic complicates sensor	Wireless features add unneeded complexity; better for IoT than precision medical

	safety in clinical settings.	compatibilit.	application.

Figure 1. Arduino UNO R3 microcontroller.

2) HX711 Load Cell Amplifier and Load Cell

The HX711 is a precision 24-bit analog-to-digital converter (ADC) specifically designed for weigh scales and industrial control applications requiring high precision. It interfaces with the load cell to accurately measure the weight of the blood bag. The load cell is a transducer that converts force (weight) into an electrical signal through the deformation of strain gauges mounted in a Wheatstone bridge configuration. The HX711 module provides:

- Two selectable differential input channels
- On-chip power supply regulator
- Programmable gain amplifier with selectable gain of 32, 64, and 128
- Low noise operation with high resolution up to 24 bits

Table 4. Comparison of different weight sensors.

Comparison Points	Load Cell (Selected)	Piezoelectric Sensor (Rejected)	Capacitive Sensor (Rejected)
Static Accuracy	±0.1% error (ideal for precise blood volume measurement).	Poor accuracy (drifts under static loads).	±0.5% error (noise-prone in humid environments).
Integration Complexity	Plug-and-play with HX711 (no external circuitry).	Requires charge amplifiers and shielding.	Needs advanced signal conditioning (filters, calibration).
Cost	Cost-effective for batch production.	Overpriced for static weighing.	Priced between Piezoelectric sensor and load cell (Calibration adds hidden costs).
Clinical Reliability	Stable performance over time; minimal maintenance.	Temperature-sensitive; frequent recalibration needed.	Dust/humidity interference reduces lifespan.

When a blood bag is placed on the load cell, the weight causes a deformation that changes the resistance in the strain gauges. This change is detected and amplified by the HX711, which converts the analog signal to digital data that the Arduino can process.

Figure 2. HX711 load cell amplifier and load cell.

3) Tower Pro MG996R Servo Motor

The Tower Pro MG996R is a high-torque metal gear servo motor capable of providing precise angular control for the blood bag shaking mechanism. Its specifications include:

- Operating voltage: 4.8-7.2V
- Stall torque: 9.4 kg-cm (at 4.8V) to 11 kg-cm (at 6V)
- Operating speed: 0.17 sec/60° (4.8V) to 0.14 sec/60° (6V)

The MG996R servo's high torque capability ensures reliable operation even with heavier blood bags, while its precise positional control allows for consistent shaking patterns. The servo motor is programmed to generate oscillating movements that ensure proper mixing of blood with anticoagulant solutions.

Table 5. Comparison of different shaking components.

Category	Tower Pro MG996R (Servo)	DC Motor	Linear Actuator
Precision & Control	Offers good closed-loop control via PWM.	Has low inherent precision in open-loop setups.	Provides high precision in linear motion thanks to integrated position feedback
Cost	Moderately priced.	Generally inexpensive at the base level.	Typically higher in cost.
Control Complexity	Very user-friendly with readily available libraries for PWM control	Simple if used for basic applications.	Offers simplified control for linear motion.
Speed Control	The PWM control allows for fast response and adjustable speed.	Speed is adjustable through PWM, but maintaining a constant speed requires extra feedback control, increasing the system complexity.	Typically offers preset or adjustable speeds optimized for linear applications.
System	Easily integrated with standard	Requires added sensors and conversion hardware to achieve the	As a dedicated linear solution, it integrates directly

Integration	servo controllers.	required precision, which can complicate integration and increase long-term maintenance.	with the device's linear motion needs.

Figure 3. Tower Pro MG996R Servomotor.

4) LCD Display (16×2)

The 16×2 LCD display provides a user interface for the system, displaying essential information such as:

- Current weight of the blood bag
- System status and alerts

This LCD features 16 columns and 2 rows of character display. It connects to the Arduino using the I2C interface protocol, requiring only two data pins (SDA and SCL) plus power and ground. The I2C adapter module mounted on the back of the LCD reduces the number of connections needed, simplifying the wiring and improving reliability. The display uses the LiquidCrystal_I2C library for programming, which provides functions for text positioning, display clearing, and custom character creation. This allows for clear communication of system status to the operator during the blood collection process.

Figure 4. 16×2 LCD display with I²C adapter.

5) Buzzer

The buzzer is a vital component in our blood bag shaking and weighing system, providing audible alerts to notify operators of important events during the blood collection process, ensuring that operators can monitor the process without constant visual attention.

Figure 5. Buzzer.

Technical Specifications:

- Type: Piezoelectric active buzzer
- Operating voltage: 3.3-5V DC
- Sound level: ~85dB at 10cm
- Current consumption: <25mA at 5V

Since the buzzer draws minimal current, it can be driven directly from an Arduino digital pin without requiring additional components or amplification. The buzzer can be programmed to produce different tones and patterns for various alerts.

6) Enclosure

For the purpose of this experiment a simple housing and silicon glue was used to keep the components safe, in one piece, and to ease the transport of the device.

3.3 Testing Methodology

The blood bag weighing and shaking device was evaluated under controlled conditions to simulate the clinical environment closely. The primary objective of the testing process was to ensure that each subsystem could reliably perform its intended function while the device operated as an integrated whole. To assess the accuracy of weight measurement, the load cell, paired with the HX711 amplifier, was calibrated using a series of standardized weights. In this phase, known weights were applied incrementally to the sensor, and the corresponding digital readings were recorded.

These results were then compared to theoretical expectations based on the conversion factor of 1.06 g/mL. Different blood bag volumes, representing the range of volumes typically seen during blood collection, were used to ensure the consistency of the measurements.

The calibration process confirmed that the sensor readings closely matched the applied loads. The shaking mechanism was evaluated by setting the servo motor at predetermined intervals that mimic the real-world need for periodic agitation of the blood bag. Observations were focused on ensuring that the mechanical movement enabled effective mixing of the anticoagulant with the collected blood, without inflicting excessive stress on the sample. Through careful observation and adjustments to the servo's operating parameters, it was confirmed that the agitation provided was gentle and consistent.

Furthermore, the performance of the user interface comprising a 16×2 LCD and an auditory buzzer was examined. During the tests, the display consistently provided clear, real-time feedback regarding the current weight and system status. The buzzer was activated at designated threshold levels to alert operators when the blood bag approached its target volume. Ultimately, the testing methodology validated that the integrated system was effective in achieving accurate weight measurement, maintaining appropriate agitation, and providing clear, real-time feedback all of which are critical for safe and efficient blood bag handling in medical environments.

3.4 Component Wiring

The system's components were interconnected as follows to ensure seamless operation:

3.4.1 HX711 & Load Cell Wiring

- HX711 VCC: Connected to Arduino 5V.
- HX711 GND: Connected to Arduino GND.
- HX711 DT (Data): Connected to Arduino Digital Pin 3.
- HX711 SCK (Clock): Connected to Arduino Digital Pin 4.

3.4.2 LCD (16×2) with I²C Adapter Wiring

- LCD VCC: Arduino 5V.
- LCD GND: Arduino GND.
- LCD SDA: Arduino Analog Pin A4 (I²C data line).
- LCD SCL: Arduino Analog Pin A5 (I²C clock line).

3.4.3 Tower Pro MG996R Servo Motor Wiring

- Servo Signal (Control): Arduino PWM Digital Pin 9.
- Servo V+ (Power): Arduino 5V.
- Servo GND: Arduino GND.

3.4.4 Buzzer Wiring

- Buzzer (+): Arduino Digital Pin 8.
- Buzzer (–): Arduino GND.

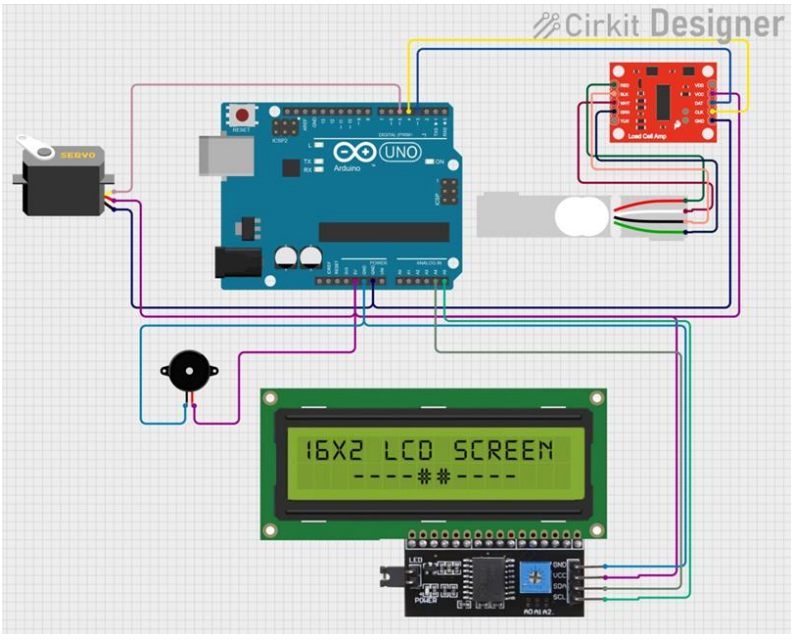

Figure 6. Wiring diagram for component connections.

4. Results and Discussion

4.1 Results

The device demonstrated the following outcomes during testing:

- Weight Measurement: Achieved ±10 mL accuracy in volume measurement, validating the 1.06 g/mL blood density conversion factor.

- Agitation Efficiency: The servomotor maintained consistent shaking intervals (every 60 seconds) with adjustable amplitude, ensuring thorough anticoagulant mixing.
- User Interface Reliability: The LCD displayed real-time weight data, while the buzzer triggered alerts at 90% and 100% of the target volume (450 mL).

Furthermore, the performance of the user interface comprising a 16×2 LCD and an auditory buzzer was examined.

4.2 Discussion

The results confirm that the device meets the project's objectives:

- Accurate Weighing: The load cell and HX711 combination proved reliable for real-time weight monitoring, addressing the limitations of manual methods.
- Effective Agitation: The servomotor has controlled shaking ensured proper anticoagulant mixing, reducing the risk of clotting.
- User-Friendly Interface: The LCD and buzzer provided intuitive feedback, enhancing operational efficiency.

Challenges encountered included minor calibration drifts in the load cell due to the enclosure not properly installed, however this was not true before installing it. Overall, the device offers a practical solution for improving blood bag handling in medical settings.

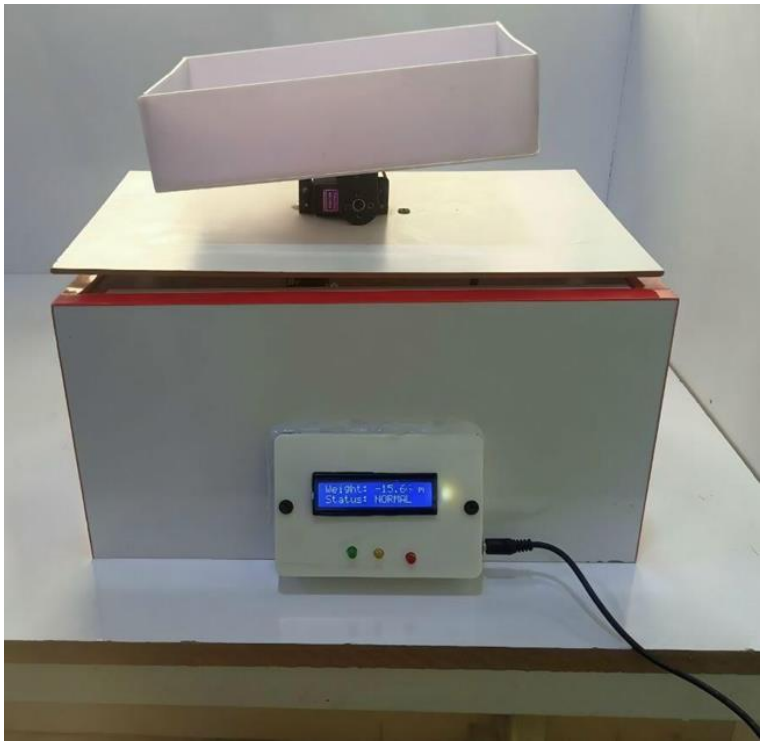

Figure 7. Image of Shaking and Weight Device of the Blood Bag

5. Conclusions and Future Work

5.1 Conclusion

The project successfully developed a functional prototype addressing key challenges in blood bag handling:

- Clinical Relevance: An automated solution ensures compliance with WHO and AABB standards

for blood-to-anticoagulant ratios, directly enhancing transfusion safety.

- Process Standardization: Automated agitation replaces inconsistent manual mixing, reducing risks of clotting and hemolysis.
- Scalability: The use of modular components (Arduino, HX711) allows for cost-effective adaptation to larger-scale medical environments.

By integrating these features, the device bridges the gap between manual practices and automated healthcare solutions, demonstrating viability for real- world implementation.

5.2 Future Work

To further enhance the device's functionality and adaptability, the following improvements are proposed:

- Wireless Integration: Incorporate Wi-Fi module for remote monitoring and data logging, enabling real-time updates to centralized systems.
- Enhanced Durability: Use medical-grade materials for the enclosure and shaking platform to ensure sterility and long-term reliability in clinical environments.
- Advanced Calibration Algorithms: Implement machine-learning techniques to automate calibration and compensate for environmental factors.
- Multi-Bag Compatibility: Design a scalable system capable of handling multiple blood bags simultaneously, improving efficiency in high-volume donation centers.
- Battery Backup: Integrate a rechargeable power source to maintain functionality during power outages, critical for mobile blood donation units. These advancements would expand the device's utility, aligning it with evolving healthcare standards and ensuring broader adoption in diverse medical settings.
- Enhanced User Interface and Customization: Upgrade the current 16×2 LCD interface to a graphical touchscreen with multi-language support. A customizable interface would allow operators to tailor device parameters— such as agitation profiles, alert thresholds, and operational modes—to fit clinical needs.

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