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Original Article

Smart Digital Pill Counter for Pharmaceutical Application

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Abstract *- This paper is focused on creating a counting machine utilizing digital tablet technology and microcontroller hardware. Manual pill counting processes in the pharmaceutical and healthcare industry have always been a manual and labor-intensive process. This project is intended to address the challenges of a fully automated pill counting machine using microcontroller-based technology to improve the speed of work and accurate pill counting. The presented system is designed to improve performance in tablet counting and counting tasks through error reduction by a human user. The device uses an IR sensor in conjunction with a stepper motor system to ensure the user can sense with substantial accuracy and encourage proper flow of tablets, independent of size, as well as prevent expensive rework problems. Additionally, it guarantees the productivity level of quality control expected in the pharmacy industry by verifying compliance with regulations. Whether a user is in a boutique pharmacy store or a major manufacturing environment, the users of the digital tablet counter will appreciate the ease of use, multi-functional capability, and low-cost features. It minimizes human resource dependency, accelerates the counting process, and enhances the overall efficiency of operation. Its state-of-the-art, user-friendly feature has less maintenance, enabling it to function in almost all circumstances. This innovation opens opportunities for further innovations, for example, the use of IoT systems for permanent monitoring and programmed audit in stock management. That is, the electronic counter provides a new way of counting tablets in the pharmaceutical industry, improving patient safety, regulatory compliance, and overall efficiency.*

Keywords *- Arduino Uno, IR sensor, OLED display, Pharmaceutical automation, Stepper motor.*

1. Introduction

Over the years, the development of modern digital tablet counting machines has been impacted by various innovations and new advancements. This paper presents the most relevant approaches in innovations and contemporary technologies, as well as the difficulties encountered by modern designs. In pharmaceuticals, one of the most critical processes to ensure is the accurate and timely counting of tablets during packaging, dispensing, and quality control processes [1]. Some small operations still use manual methods, but they are fraught with difficulties such as human error, time inefficiency, and inconsistencies in pill counting. Counting pharmaceutical tablets is crucial for keeping track of patient dosages, ensuring patient safety, and managing pharmaceutical stock. In the past, counting tablets using trays and spatulas was time-consuming and resulted in human error. This was more the case in retail pharmacies or hospitals, where the volume of tablets was much greater. This manual counting was inefficient, time-consuming, and resulted in inconsistencies in the dispensed dosage and medications, thus compromising patient care. To address these hurdles, researchers and industry have investigated automated and semi-automated systems for tablet counting. Earlier systems, such as photoelectric-based systems, offered speed but were inflexible. Subsequent innovations utilized microcontrollers, solenoid-based counting mechanisms, and image-processing techniques, which were far more accurate than photoelectric counting and offered a wider range of flexibility. However, both systems have inherent limits: most of the previous automated counting systems are either too expensive for small pharmacies, the devices themselves can be very large and bulky to operate, and, perhaps most challenging, many of the existing automated systems are incapable of accurately dispensing tablets as a function of shape and size variations in the tablets. This situation indicates there is a research gap in the field; while there are industrial-scale automated counters, there is still a dearth of affordable, compact, and user-friendly tablet counting systems that would be appropriate for so-called small to medium scale pharmacies and clinical situations This can be tackled by designing a semi-automated device with minimal cost, high accuracy, easy handling of different interchangeable units, and a simple user interface. The challenge lies in finding a “happy medium” between expensive industrial counter machines and the worker-intensive, error-prone manual methods. The intention of this work is to develop a reliable, pharmaceutical tablet counter that can achieve the added objectives of cost, worker effort, and dispensing efficiency. The digital electronic tablet counter resolves all the mentioned issues with an automated system that boosts precision, dependability, and efficiency in the pill counting procedure.

With respect to strategic importance, this machine is used in pharmaceutical packaging plants and any other location that requires the manipulation of high volumes of pills with great precision, in addition to pharmacies and stock control systems. It is furthermore utilized in the production of other medicine preparations like tablets and capsules. The construction of the digital tablet counter rests on a circular disk, which serves the function of the main storage for the pills. Unlike other systems caricaturing every slot on the discs as a place where a particle is captured, this system employs a disk. This system contains a disk that can capture and hold a set of (usually about ≈50 to 60) pills and move with them during any given rotation. After a user-defined counting period, the user can specify the number of pills, which, through the keypad, enables the dust cleaning process to commence.

The system uses a stepper motor to control the rotation of the disk so that pills are continuously supplied towards the pill separator. This separator is important for controlling the flow of pills that are fed into the counting mechanism, as only one pill can pass through at the same time. The pill separator is adjustable manually with respect to the size of the pills, thus making it easier to work with various kinds of tablets and different sizes. A counting process is facilitated by an Infrared (IR) sensor, located further to the side of the pill separator. The sensor counts the pill as the pill comes out of the separator and as the pill moves through the separator.

The sensor is located outside the circumference of the disk, which permits the counting of the pill while it is in movement from the disk to the pill-collecting box [10]. The sensor function is activated by the pill and disabled by the pill-collecting box. The pill counter sensor’s remarkable accuracy makes it useful for finely determining the number of pills in each batch for packaging and for other activities that require careful counting. The counted number is final and is visible on the OLED screen. The operator is able to see the counting progress in real time. In addition to this, there is a fully automated system that counts and signals with a buzzer once the preset limit is reached. The counted pills are funneled through a guiding channel that efficiently deposits them into a storage container that is designed for proper storage after counting, thereby maintaining order. This design differs from most other systems by relying on a single IR sensor system in place of multiple sensor systems, providing a highly accurate, cost-efficient, and reliable system.

Aimed at the pharmaceutical tablet segment, the digital counters developed for tablets automate and streamline operations within the industry. Unlike manual methods, this machine enables ease in performing tasks due to its high precision and efficiency. Its innovation features a circular disk, sensor, adjustable pill separator, and an easy-to-use interface that accommodates various pill sizes. Due to the previously mentioned characteristics, the machine serves as a valuable asset to ensure compliance with dose control and optimize productivity in clinical settings.

1.1. Early Manual Counting Methods

Before the advent of automated solutions, pharmaceutical counting was predominantly a manual task that required workers to count pills. They used simple machines such as abacuses or hand-held counters. These methods were slow, required a lot of work, and were error-prone, especially with large numbers of tablets. Manual counters faced frequent inaccuracies due to tiredness, changing levels of attention, and the counting limits of people. Countless counters also faced problems meeting tight pharmaceutical standards that needed to be followed under manual counting, especially during high-volume mass production [3].

1.2. Semi-Automated Counting Systems

The need to count tablets less manually prompted the onset of semi-automated tablet counters. The first inventions were mechanical in nature, in which motion was given to pills and fed into counting slots or notches that would separate the counting element from the pill. Some of these systems used rotating slabs with fixed cavities that restricted the number of pills passing. Despite their success with maintaining speed and accuracy while counting pills, such machines continued to suffer from mechanical wear, a need for constant recalibration, and difficulties with different pill sizes and shapes. In 1965, a patent was issued for a mechanical tablet counter that employed a rotating disk with cavities to separate pills. Each cavity contained one tablet, and as the disk spun, the tablets would drop through a counting gate. Although this method was quicker than manually counting pills, it was restricted by the need for pills to be uniform in size and shape, and required regular upkeep to guarantee accurate operation.

1.3. Infrared Counting Technologies

The next major advancement was the creation of systems that employ optical and Infrared (IR) sensors. These systems use infrared beams to identify pills remotely. The counting circuit triggers when a pill interrupts a light beam, generating a pulse that increases the total by one. In these more flexible and dependable systems, the automated counting of pills of various sizes and shapes is done much faster and incorporated. In the 1990s, Cremer and Multilane started manufacturing sophisticated counting machines that incorporated high-speed optical sensors working in conjunction with conveyor belts or rotating plates. These advanced devices counted pills at an unprecedented rate of hundreds per minute, meeting the pharmaceutical industry's need for mass production. However, all of these systems struggled with speed issues because their dust problems would accumulate on the sensors, resulting in inaccurate counts necessitating regular cleaning [9]. Some of these issues were tackled by infrared sensor technology, and further miniaturization allowed them to fit into portable devices.

Infrared sensor technology addressed some of these difficulties. Infrared sensors, being less prone to dust interference, offered more dependable performance [10]. In 2002, a patent was granted for a tablet counter that utilized infrared sensors and a vibrating plate to guarantee that pills were fed individually into the counting sensor. This advancement represented a significant step forward in terms of precision and speed, as it enabled more reliable counting of irregularly shaped tablets.

1.4. Existing Challenges and Limitations

Problems with current systems continue to persist, despite advancements in counting technology. Adding more sensors to machines increases their cost, making them uneconomical for small to medium-sized enterprises. Additionally, a sizable proportion of these systems is designed to handle only one specific pill shape or size, which means their flexibility is extremely limited because they must be modified or changed in some way to accommodate other pills. Regarding tablets that are dusty or coated with powder, when optical or infrared sensors are used, these systems are highly problematic because they require regular cleaning and maintenance [14]. The most common cleaning method is to use a soft cloth or brush to remove any dust or debris from the surface of the tablet. Achieving the ideal balance between speed and precision poses a brand-new problem. While high-speed systems can handle thousands of pills per minute, ensuring accuracy at such speeds requires highly precise sensors and mechanical components, which greatly increases the cost and complexity of the machine. A variety of operational settings, including lighting, dust, and humidity, as well as environmental factors, have the potential to impact sensor-based systems, resulting in inconsistent outcomes during operations [14].

Recent advancements in affordable, single-sensor systems - Advances have recently been made with less expensive single-sensor systems. As a result of innovation, these new machines are affordable as they work with a single sensor, unlike multi-sensor systems, which are expensive and not efficient for small to medium-scale operations. Most of these devices use a single infrared sensor and place it strategically along skill sets, such as rotating disks. The elegant nature of this model costs little to maintain and calibrate while still providing a high degree of precision in output.

Examples of such systems are digital counters, which operate on the principles of optics and sensors, and counting tablets. Figure 1 shows that the input component is on the left-hand side and the output component on the right-hand side, and these are connected to the Arduino board. A single infrared sensor and a manual pill separator, which controls the throughput of the pills while ensuring accurate counting. One outstanding feature of the pill separator is that only one pill at a time can reach the sensor, and hence, accurate counting is achievable without the need for many sensors.

Also, the use of a circular disk as the main container for the pills allows for a wider range of accommodating pills of different shapes and sizes without too many mechanical alterations. The machine is specifically designed to be affordable and suitable for smaller-scale pharmaceutical packaging operations, pharmacies, and inventory management.

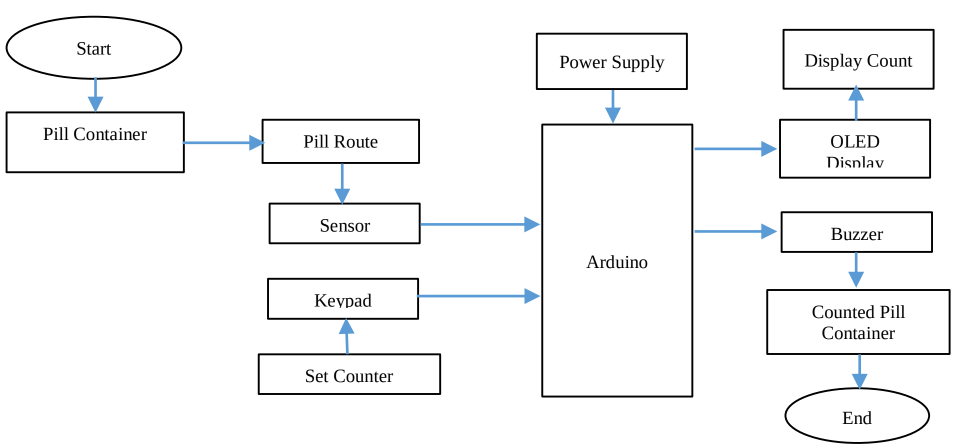

Fig. 1 Block diagram implementation

1.5. Comparison with Existing Research

Table 1. Comparison with existing research

S.No	Name	Key Points	Hardware	Features	Author(s)	Journal	Comparison with this Research
1	Microcontroller-Based Retail Pharmaceutical Tablets Counting Device	Portable, low-cost, highly accurate, handles pill sizes from 8mm to 18mm	PIC16F877A microcontroller, photoresistor, vibrating DC motor, keypad	Portable, user-friendly, counts up to 999 tablets, and has a visual output	Amy Chang, Soon Chin Fhong	The 5th Student Conference on Research and Development, 2007	The device is also portable, but the project uses a circular disk for more reliable counting and a custom pill separator
2	Pharmacy Automation-Pill Counting Design	Manual counting is inefficient; automated counting improves accuracy and reduces labor. Two counting mechanisms	ATmega32 microcontroller, stepper motor, solenoid valve, optical sensor, LCD	Two pill-counting mechanisms, real-time display, and automation reduce human error.	Omer Mohamed Adam Adlan, Abdelrasoul Jabar Alzubaidi	IJERA – Int. Journal of Engineering Research and Applications, March 2015	The system also has automation, but the project uses a stepper motor for rotation and more modular controls for counting and inventory.
3	Tablet Counting Machine Based on Image Processing	Image-based counting, RGB to grayscale conversion, noise filtering	Webcam, Dell Optiplex computer, USB interface	Low-cost, portable, no need for mechanical modifications, high accuracy	Chanchai Phromlikhit, Fusak Cheevasuvit	12th Biomedical Engineering International Conference, 2012	The project uses a mechanical disk and stepper motor, while the other system uses a webcam for image processing, which provides more flexibility with different tablet shapes but depends on lighting conditions.
4	ELECTRONIC TABLET AND CAPSULE COUNTER	Uses the photoelectric principle, counts 1,200 to 1,500 tablets per minute, variable speed motor	Mechanical feeder, photoelectric sensors, electronic counter	High-speed counting, simple interface, adjustable speed	NT Company	American Journal of Hospital Pharmacy, Vol. 16, May 1959	The project is more flexible and cost-effective, using a microcontroller and simpler components, while the Triumph system uses mechanical-electronic parts for speed but lacks modern programmability

1.6. Research Gap between this Research Work and Existing Methods

Table 2. Research gap between this research work and existing methods

Aspect	Existing Methods	Research Gap	This Research Contribution
Cost and Accessibility	Chang et al. (2007), Adlan & Alzubaidi (2015): High-cost systems with complex hardware.	High-cost, complex systems limit adoption in small-scale pharmacies and research labs.	Low-Cost Design: Utilizes easily accessible mechanical and electronic components like stepper motors, IR sensors, and membrane keypads, making it affordable for small-scale environments.
Adaptability to Various Tablet Shapes and Sizes	Phromlikhit et al. (2012): Image processing-based system adapts to different tablet shapes.	Dependence on image quality, lighting, and overlapping tablets causes errors, limiting performance.	High Adaptability: The pill separator mechanism ensures high accuracy, overcoming image processing limitations such as lighting and overlapping pills.
Flexibility in Operation	Adlan & Alzubaidi (2015): Dual solenoid valve system for precision and bulk dispensing.	Struggles with smooth operation when switching between batch dispensing and real-time inventory counting.	Seamless Operation: Easy transition between batch dispensing and real-time counting for inventory management using a simple toggle mechanism, improving flexibility.
Precision and Reliability	Triumph Model (1959): Mechanical-electronic	Lacks modern programmability and	High Precision: Combines mechanical reliability with stepper motor control for

	hybrid, fast and accurate in high-throughput environments.	flexibility, unsuitable for data-driven pharmacy operations.	precise and accurate counting, providing a scalable and adaptable solution suitable for modern workflows.
Modern Data Integration	Triumph Model (1959): No digital interfaces or integration with modern systems.	Cannot integrate with modern pharmacy data systems, limiting its applicability in data-driven workflows.	Modern Integration: Designed for easy scalability and integration into current pharmacy workflows, facilitating inventory management and data-driven operations.

2. Execution Flowchart

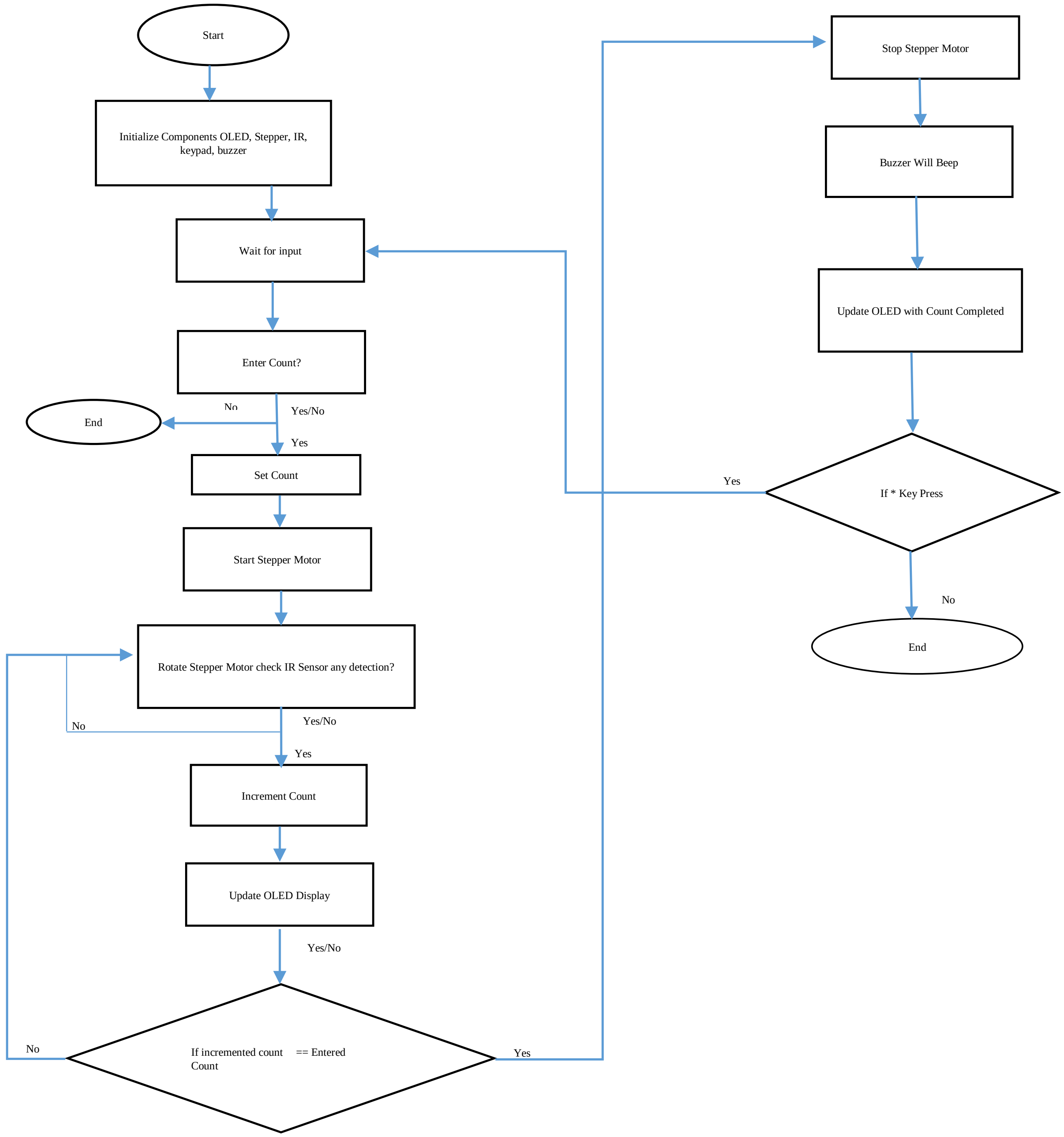

Fig. 2 Flow chart

3. Circuit Diagram

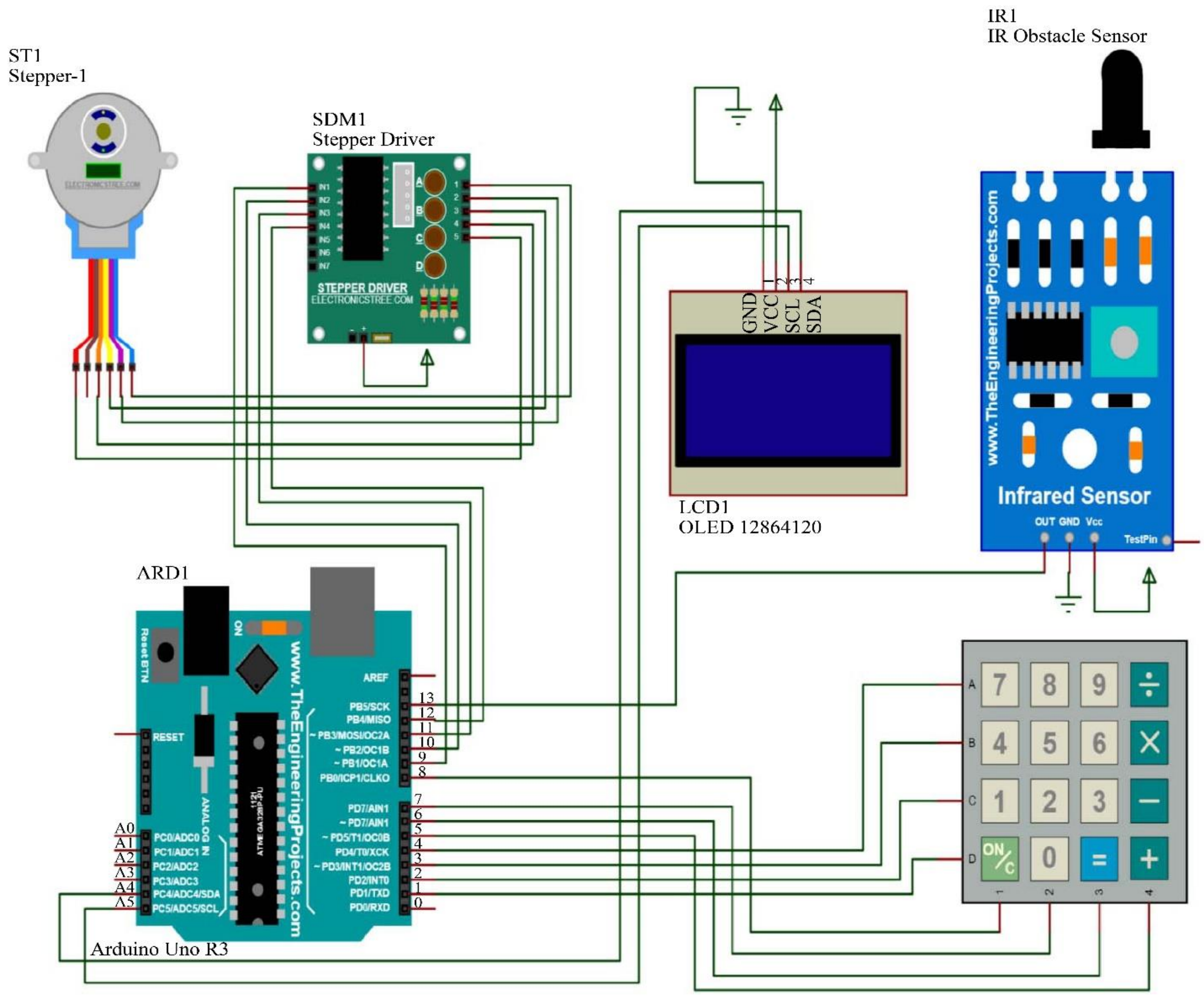

Fig. 3 Circuit diagram

4. Design Implementation

To resolve the problem of manual and traditional methods of tablet counting, we propose an automated digital pharmaceutical tablet counter that balances efficiency, precision, and versatility. The system's design incorporates Infrared (IR) sensors to ensure proper detection and counting of tablets, which perform consistently with differing tablet sizes and shapes. The system's microcontroller functions as the CPU of the device by analyzing sensor data for counting and overseeing operations of stepper motor control that necessitate the maintenance of a steady and uniform flow of tablets. It is the stepper motor that guarantees positioning accuracy as well as the elimination of the inconsistencies arising from the vibratory or rotary mechanisms used by most conventional machines. The intuitive design features an OLED display that shows feedback, including the number of tablets counted and the system status, while the keypad touchscreen allows users to set a desired value. Adjustable pill separators enable the counter to handle different tablet sizes seamlessly without costly recalibration. This solution is based on an automated digital pharmaceutical tablet counter to replace the traditional counting methods, which are prone to human errors, take too long, and rely on expensive equipment. Budget-limited pharmacies and laboratories will appreciate the system as an economical and dependable solution up to the task. Infrared sensors (IR sensors) are used to scan and count, and the system works for any shape or size tablet in the count. The document refers to the use of configurable computers and states that each controller would analyse sensor inputs and direct a stepper motor for the uninterrupted flow of the tablets. The system's interface is designed to be as user-friendly as possible. Users can set target counts, which are tracked on an OLED screen. The solution is simple to use and cost-effective. The system is designed to be a smart solution that enhances productivity and flexibility, while minimizing counting discrepancies in pharmacies and small-scale enterprises.

5. Methodology

5.1. Problem Identification and Requirement Analysis

This tablet-counting equipment is designed to enhance the inefficiencies, inaccuracies, and limitations associated with old-style methods for counting tablets. A counting tablet must be highly precise, allow for varying screen sizes, be relatively inexpensive, be easy to use, be relatively low maintenance, and be versatile in its use. The primary focus is on small to medium-sized businesses, such as pharmacies, hospitals, and research laboratories.

5.2. Hardware Implementation

The IR sensor detects tablets moving through the counting channel. A microcontroller serves as the processing unit that manages data from sensors, controls motors, and processes user inputs. The stepper motor guarantees accurate rotation of the tablets on the disk for a steady flow. The Keypad Interface enables users to set the desired tablet count. The OLED display shows the tablet count and other system parameters. Power Supply is that the system works. The rotating disk organizes the tablets in a streamlined system. The Adjustable Pill Separator is calibrated to various tablet sizes. The Collection box, as in Figures 4 and 5 below, is used to collect the counted tablets.

Fig. 4 Hardware implementation

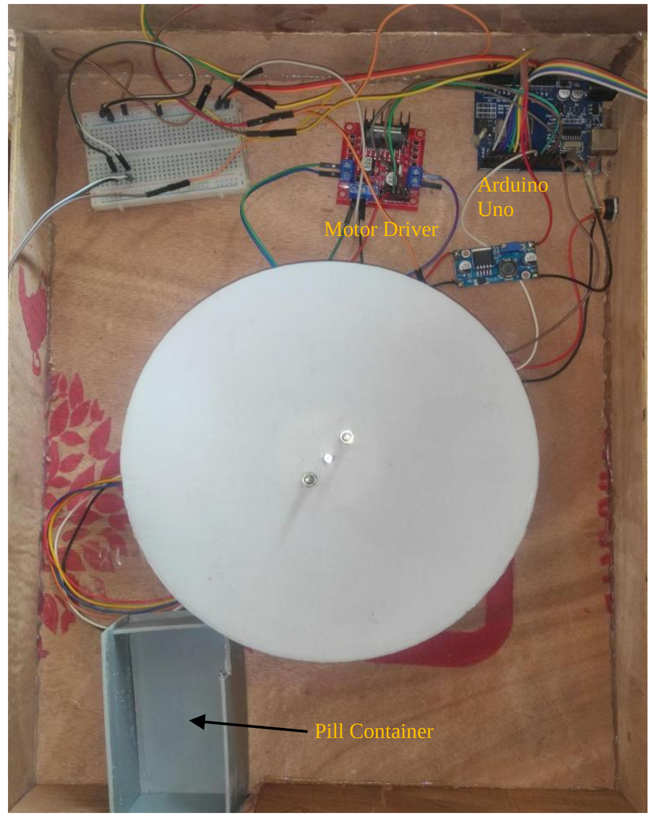

Fig. 5 Internal structure

5.3. IR Sensor Integration and Calibration

Positioned strategically to detect tablets falling through the counting channel, the sensor has been set to identify single tablets to the exclusion of double counting and missing detection. Reliability is ensured by testing the sensor's sensitivity to light and other environmental factors. The sensor is set to identify single tablets to the exclusion of double-counting and missing detection. Reliability is ensured by testing the sensor's sensitivity to light and other environmental factors.

5.4. Microcontroller Integration for Components

The construction of software for a digital pharmaceutical tablet counter entails integrating advanced hardware counting mechanisms and microcontroller programming logic in such a way that guarantees accurate counting of tablets. The first stage involves setting up the microcontroller to receive data from the sensor (infrared sensor) capable of detecting individual tablets. The data is processed within the microcontroller to ensure real-time counting accuracy of the tablets.

At the same time, feedback from the sensor permits control of the stepper motor, which drives the flow of tablets, ensuring proper and controlled movement of tablets within the system. When the count is complete, the microcontroller checks the value held in the counter against the integer value set by the user using the keypad. All processed data and auxiliary data, such as integer value, target integer value, monitored system alerts, and the status of system alerts, are easily interfaced with the OLED display. Other functionalities in the program are the alarm, referred to as the buzzer, and the stopping of a stepper motor when the target is set or when it detects a no-data signal from the IR sensors. With the level of implementation done in the above, convenience, precision, complete automation, and simplicity are achieved beyond any manual or traditional method.

5.5. Integration of User Interface

Digital pharmaceutical counters and devices that utilize advanced hardware counting systems require sophisticated counting approaches, algorithmically programmed to microcontrollers. The first stage involves configuring infrared sensors to detect distinct tablets, allowing microcontrollers to receive this data. On count completion, the microcontroller compares the number counter against the user-defined integer set through a keypad. All computed and auxiliary information, such as integer number value, the target set integer number value, and statuses of monitored system alerts, is displayed on an OLED for easier interfacing. Other programmed functionalities include using the alarm, also known as a buzzer, or stopping the stepper motor upon reaching the defined target or detecting a no-data signal from the IR sensor. With this level of implementation, convenience, precision, automation, and simplicity are achieved, far beyond what can be accomplished via manual or traditional methods.

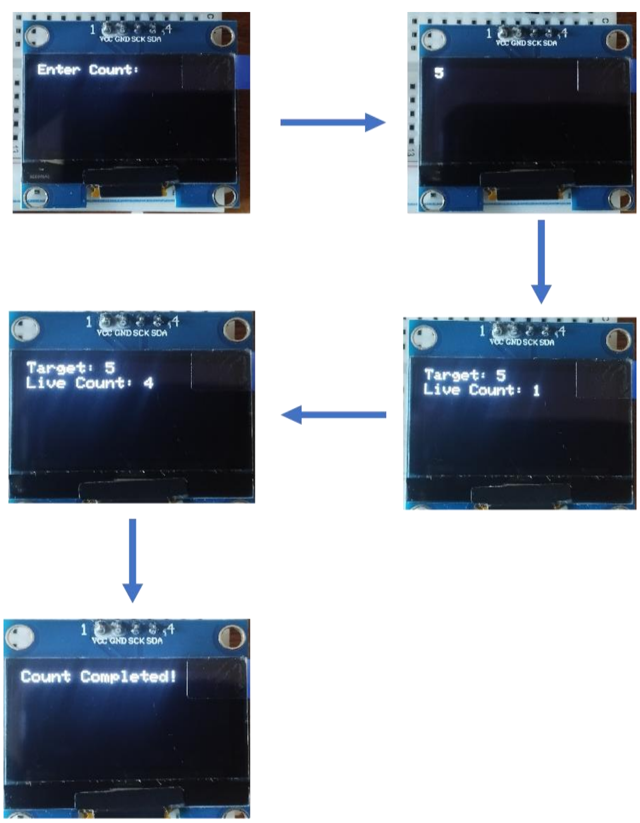

Fig. 6 Display status

5.6. Step of Operations

- Prepare Tablets -To prepare tablets, place them in the designated input tray, making sure they are free from any dirt or moisture.
- Set Quantity - Input the desired number of tablets on the digital display
- Start Counting - Press '#' to begin counting. The device uses sensors to count the presence of a count and increment the count
- Monitor Display - Check the display for the live count as shown in Figure 6.
- Automatic Dispensing - The device halts its operation when the predetermined count is achieved, releasing tablets into a tray or container.
- Repeat - refill tablets as needed, and repeat the process.

6. Result

The development of a digital tablet counter for pharmacies solves all the manual and automatic issues involved with the counting of tablets. This device incorporates an IR sensor for immediate recognition of tablets, a microcontroller for exact governance, and a stepper motor for smooth transport of the tablets, making it modular. While maintaining accuracy, reliability, and versatility, the system can optimize for many different sizes of tablets. The tablet movement is to be monitored and aids in enhancing system interaction by incorporating a keypad along with an OLED screen, which diminishes the application barrier for small-scale pharmaceuticals and retail pharmacies. Concerning the project objectives, it has been successful in completely automating the counting of tablets and associated operator tasks and has greatly reduced operator-related errors while boosting productivity. The alarm system adds greater trust by giving timely alerts about breakdowns or low stock quantities. Compared to other systems, this one is far better in terms of initial investment, power usage, and servicing. This makes the solution ideal for smaller operations because it is less complex, requires reduced funds, and easier servicing is needed.

7. Conclusion

The digitized tablet counter for pharmacies is one more technological advancement towards precision and safety in healthcare and pharmacy practices. This device helps resolve one of the challenges in health care systems, which revolves around the appropriate counting of tablets and dosages. Counting tablets more aids in the safety of patients and boosts the trust in health systems and practitioners by reducing the manually counted errors. Moreover, this device also proves compliance with all the necessary guidelines regarding the enforcement laws about the production and distribution of drugs. In every field, and particularly in the field of healthcare, where one has to ensure the quality of work done, the precision of the work done at every stage is vital, including the tablet counts. Therefore, the ability to perform accurate counts using the logical automated systems relieves a lot of stress from the pharmaceutical companies. Optimizing time-consuming tasks is now made possible with the digital tablet counter.

In the pharmaceutical and healthcare sectors, counters pose a considerable human interface problem. Flexibility to address the issue of counting tablets accurately and effectively is provided by the digital pharmacy tablet counter. Older methodologies pose threats with discrepancies, inaccuracies, ineffectiveness, and bottlenecks - all of which can compromise a patient's safety. To decrease manual work, our system incorporates a counting sensor and a stepper motor, which improves precision alongside smoother tablet control to reduce manual interventions. No costly modifications are required. Small pharmacies and large-scale operations that provide tablets of differing dimensions can benefit. Compliance with town and country planning laws is now easily attained. Improved productivity and flexibility of device features are drawn from the industry-standard regulatory criteria. Quality is preserved and productivity is enhanced.

Furthermore, the automation and control features that this device offers fulfill the requirements of precision and efficiency automation in the industry, and the very few changes in operation and upkeep that this device needs are so easy that they increase the value of the device. On this basis, the device is surrounded, which enables it to be competitive and requires very low maintenance, unmatched in the industry. This range also includes, in primary positions, single standing pharmacies, and in the centre, local and regional pharmacists, and in the back, industrial manufacturing units, thus confirming the multi-directional integration in every workflow. The use of these industrial gadgets has a direct impact on minimising the complexities faced by the pharmacies and the health sectors by using automation techniques. This impact is in the form of boosting the amount of automation in the thinner productivity and compliance within the health and pharmaceutical sectors. Accepting this change on the rise will give birth to a change in the prevention of health all across the country. This is the next advancement in the reorganization and use of microcomputer-based systems of the counter. The design is modular so that integration with advanced systems, such as IOT for remote monitoring and inventory control, is possible at the advanced levels of the counter. The devices bring a positive change by boosting the efficiency and the safety in the operation procedures of the healthcare sector.

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