

Design And Development of A Water Filling System Using An Arduino Mega 2560 Based on Flowmeter Sensor

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Abstract— The utilisation of automation technology is undergoing rapid proliferation in the industrial sector, including in the bottled drinking water industry. The objective of this study is to design and implement an automation system for filling bottled drinking water with a range of 30–330 millilitres using an Arduino Mega 2560 as the controller. The system has been designed to optimise the use of the YF-S201 pulse-based flowmeter sensor as a setpoint. The setpoint is determined by calibrating the pulse value obtained based on the time delay in filling volumes in multiples of 30 at values ranging from 30 to 330 millilitres. The accuracy value for volumes of 30 and 60 millilitres was found to be 99.3%, while volumes of 60–330 millilitres demonstrated an accuracy level of >99.6%. Subsequently, the system was integrated with a conveyor and E18-D80NK proximity sensor to detect bottles during the filling process, and a counter to enumerate the bottles post-water filling. The process was initiated upon the pressing of the interface button and the subsequent detection of the bottle by the proximity sensor. Thereafter, the system activated the filling pump until the pulse attained the setpoint. The status of the operating system was displayed on the LCD and could be controlled via push buttons. Preliminary testing indicated that the system demonstrated a capacity for precise bottle filling, with an error margin of less than 1%. This finding suggests that the system exhibits a low level of inaccuracy and responsiveness.

Index Terms— Automatic filling system; Arduino Mega 2560; YF-S201 sensor; Proximity sensor; Conveyor.

I. INTRODUCTION

Technological advancements have precipitated a marked improvement in the bottled water industry, particularly with regard to the automation of water filling. The implementation of an automatic water filling system has been demonstrated to enhance production efficiency, reduce labour requirements and minimise human error. It is evident that small industries and home industries frequently utilise conventional methods that are less efficient. A prime example of this

is AMDK filling. The rise in the number of small industries in the AMDK sector is proportional to the rise in the AMDK population. Consequently, many industries require a filling system that is both affordable and accurate, and which is also simple to implement in small and medium-sized industries [1].

The advent of automated mechanical systems for the purpose of filling bottles with liquid (liquid filling) represents a significant outcome of technological advancements within the industrial sector. The system has been designed to engender efficiency, which is expected to have a positive impact, especially on industries that produce liquid products. However, bottle-filling systems in small or home-based industries, such as those producing water, syrup, sauce, milk, and honey, are still inefficient because they generally still use manual methods [2].

It has been determined that the human body is composed of approximately 75% water, and that no individual can survive for a period exceeding four to five days without the consumption of this vital fluid [3]. AMDK is a fundamental component in the contemporary era, demonstrating persistent market expansion. As demonstrated by data provided by the Indonesian Bottled Water Association (ASPADIN), there is an evident increase in the consumption of AMDK, with a growth rate of 8–10% on an annual basis. This necessitates an efficient production system, particularly during the filling stage. It is imperative that such high demand is balanced with an efficient production system, particularly during the filling stage, which is a bottleneck in many small industries. Manual systems, which are still widely utilised, are not only slow but also prone to quality variations due to human error. [4].

The utilisation of time delay as a reference in extant research demonstrates that the system's accuracy remains relatively high at 6%. It is evident that, in light of the observed discrepancy, the present study undertook sensor calibration with the objective of implementing a setpoint that utilised pulses in the filling

process. The research design involved the creation of a 330-ml mineral water bottle filling system, utilising the Arduino Mega 2560 as the central control unit. The system incorporates YF-S201 water flow sensors, proximity sensors, and DC gearbox motors to ensure volume and time efficiency [5].

Another automated system was developed using a Twido Programmable Logic Controller (PLC) from Schneider Electric [6]. The system was designed to automatically fill and seal bottles, and uses infrared sensors to detect the presence of bottles on the filling line. The process of filling is facilitated by a direct current (DC) motor, while the movement of the bottles is achieved through the utilisation of a conveyor motor [16] [17]. Subsequent to the completion of the filling process, the bottle caps are automatically affixed by means of a solenoid. As demonstrated by the test results, the system has been shown to be capable of filling 250-ml bottles in approximately 14 seconds while maintaining stability. As demonstrated in previous research, there has been an emergence of low-cost automatic filling equipment intended for utilisation by Micro, Small and Medium-sized Enterprises (MSMEs). The system has been demonstrated to have the capacity to fill 500-ml bottles of Aloe Vera syrup by means of a time-step method [7].

In this research, a switching mode power supply (SMPS) was utilised to provide voltage to the system. In an SMPS, the AC input is subjected to direct rectification, after which it is filtered to yield the desired DC voltage. The DC voltage produced is then switched on and off at a high frequency by an electronic switching circuit, thereby generating AC current. In the event of effective isolation of the high-frequency transformer, the transformer's output will be electrically isolated by relay [8].

The present study proposes a design for an automatic filling system for bottles that utilises an Arduino Mega 2560 [9] [10] [11]. The system incorporates a YF-S201 water flow sensor to ensure volume precision and an IR proximity sensor to detect the position of the bottle [12] [13]. The selection of the Arduino Mega 2560 was made on the basis of an assessment of its superior input/output capacity and enhanced computational capabilities in comparison with the earlier model, the Arduino Uno. LCDs are utilised extensively due to their multifaceted functionality and straightforward programming. In order to establish a connection between an LCD and a microcontroller, it is necessary to connect the LCD's PORT to the microcontroller's corresponding PORT. It is imperative to acknowledge that this specific port on the microcontroller is exclusively dedicated to LCD functions. It is not possible to utilise this port for other functions, such as I/O functions [15].

II. METHODS

The primary instruments utilised in this research comprise a YF-S201 sensor for pulse input, an Arduino Mega 2560 as the primary controller, infrared proximity detection for bottle recognition, and a direct current (DC) water pump as the actuator. The data processing procedure entails the collection of water measurements ranging from 30 to 330 millilitres, which displayed on a 16x2 Liquid Crystal Display (LCD). The testing procedure is initiated by actuating the system by pressing the designated start or reset button, displayed the number of bottles and the volume LCD. The data processing was conducted through the collection of water volume measurements (ml) ranging from 30 ml to 330 ml.

Upon actuation of the start button, the system will display a start message on the LCD and activate the blue indicator light, indicating that the system is in a steady state and make the conveyor transport the bottle to the filling point. When the proximity detect the bottle, the conveyor will automatically halt and initiate the water pump. The volume of water flowing then displayed on the LCD using a predetermined calibration factor (pulse/mL). Upon attaining the designated setpoint, the water pump will cease operation, and the system will initiate the conveyor process for the subsequent bottle. The system will continue to run until the user initiates a cessation of this process by pressing the designated stop button. Upon actuation of the stop button, the system will initiate a sequence of events that will result in the deactivation of the system.

A. System Design

To facilitate understanding of how this automatic bottle filling machine works, please refer to the flowchart provided. The design process and water filling system at AMDK are explained in flowchart figure 1.

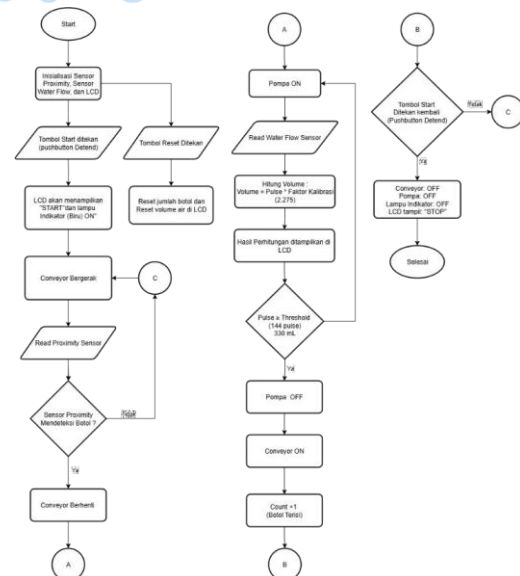


Fig. 1. System Flowchart

As illustrated in Figure 1, the process commences with the activation of the system via the designated start push button. In its initial state, the Arduino will initialise the components that are utilised. Upon completion of the system's readiness, the user is permitted to initiate the process by pressing the designated start button. Alternatively, the reset button can be utilised to restore the number of bottles and the water volume displayed on the liquid crystal display (LCD) to their default settings. Upon actuation of the start button, the LCD will display the start status and the blue indicator light will be activated. Subsequently, the conveyor belt will be programmed to transport the bottle to the proximity sensor.

B. Hardware Design

A block diagram was represented a visual view to elucidate concepts. The purpose of this diagram is to facilitate comprehension of the relationship between inputs and outputs in a system.

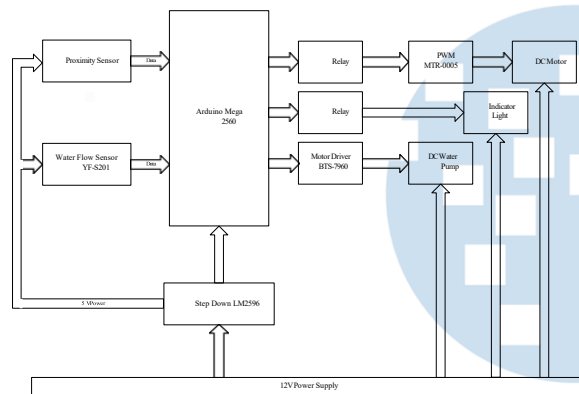


Fig. 2. Hardware Block Diagram

As illustrated in Figure 2, the components of the Arduino Mega 2560-based automatic bottle filling system function collectively within an open-loop system. The proximity sensor fulfils the function of initially detecting the bottle's presence on the conveyor, thus activating the water pump to initiate the filling process from the tank into the bottle. The filling volume is regulated by the YF-S201 water flow sensor based on the calculation of water flow pulses. The Arduino Mega 2560 processed the data from the proximity and water flow sensors and transmitting control signals to relays to activate actuator (conveyor). The primary function of the water pump is to facilitate the transportation of water from the storage tank to the bottles. The step-down module, on the other hand, plays a crucial role in ensuring that the voltage supplied to the system components meets the requisite specifications. In this open-loop system, the process as a whole is dependent on pre-set programming logic, with no provision for a feedback mechanism to dynamically adjust filling based on actual conditions. The proximity sensor is the initial trigger for the process, while the water flow sensor is used to estimate the volume of liquid being added, based on pulse calculations.

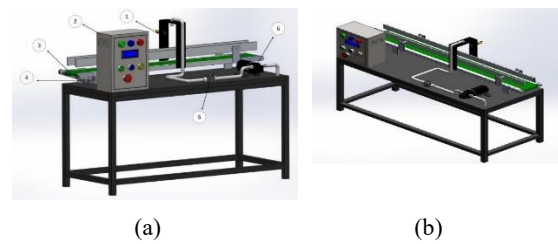


Fig. 3. 3D concept image (a) front view, (b) top view

As demonstrated in Figures 3(a) and (b), the system comprises a control box panel that incorporates electrical components. Within the mechanical system under consideration, the movement of the tool to the filling position is facilitated by a conveyor driven by a 12 V DC motor. The speed of the conveyor can be adjusted using the MTR-0005 driver.

The power system utilises a 12-volt power supply as its primary energy source, with an LM2596 step-down module incorporated to facilitate the distribution of power to the sensor, Arduino, and associated electronic components. The user interface employed is a 16x2 LCD integrated with a push button and indicator light.

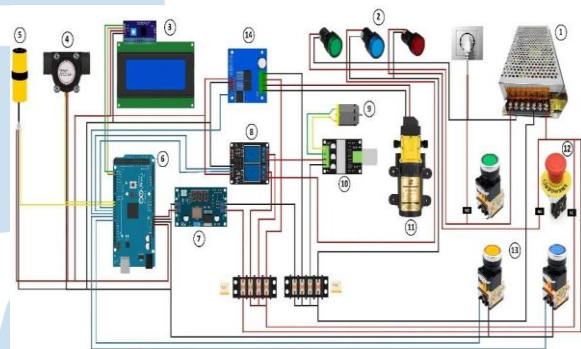


Fig. 4. Hardware Circuit Schematic

Figure 4 presents the electrical circuit of the system. The initiation of the filling process is facilitated by a proximity sensor connected to pin 3 of the Arduino digital board, which detects the presence of a bottle and subsequently activates the DC pump, that connect to BTS7960 driver on pin 6 of the Arduino. The volume of water is measured using a YF-S201 sensor on digital pin 2. The start push button is integrated with an MTR-0005 driver based on the PWM output from digital pin 5. There are three indicator lights are connected via a relay that is controlled by the Arduino digital pin. Furthermore, the availability of facilities on pins, such as I2C communication, PWM pins, and non-PWM digital pins, is taken into consideration. The circuit has been designed as an open-loop system that relies on initial sensor calibration.

C. Open Loop System Design

The system diagram for this device utilises an open-loop approach, incorporating an Arduino Mega 2560, a conveyor belt, an infrared proximity sensor, a DC pump, and a YF-S201 water flow sensor.

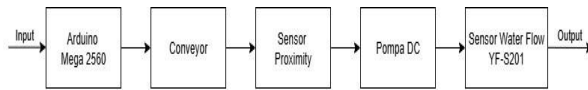


Fig. 5. Open Loop System Diagram

As demonstrated in Figure 5, the system diagram was an open-loop approach to regulate the filling process. In this system, the proximity sensor functions as the initial trigger for the process, detecting the presence of the bottle at the filling position. The water flow sensor is used to calculate the volume based on number of water pulses reading.

D. Experimental Calibration Setup

The experimental setup was designed to evaluate the performance and calibration characteristics of the flowmeter sensor. This procedure includes key components such as: pulse generation in the YF-S201 flowmeter sensor based on the volume measured from the discharge, average pulse data collection, error measurement, and determination of the calibration factor (mL/pulse).

1) Principles of measurement

The measurements are derived from the hall effect sensor mechanism. The measured volume value is derived by multiplying the discharge by the elapsed time.

$$Q = V \cdot t \quad \dots(2.1)$$

Where Q = Debit (mL/s)

V = Volume (mL)

T = time (s)

The value of V is proportional to N.
 $V \propto N$

Therefore, the linear equation can be written as

$$V = K \cdot N \quad \dots(2.2)$$

Where K is the calibration factor (mL/pulse) and N is the number of pulses counted (pulse)

2) Calibration procedure

Calibration was performed by calculating the measured pulse value for each volume to obtain the relationship between volume and pulse. Subsequently, the mean value of the test results was calculated on five occasions. The K value was then obtained using the following equation (2.2) : The following alterations were made:

$$K = \frac{\sum_i^N V_i}{\sum_i^N N_i} \quad \dots(2.3)$$

$$K_{avg} = \frac{V}{N} \quad \dots (2.4)$$

3) Error Analysis

Error testing was conducted using standard error and standard deviation measurements with the equation:

$$\%Error = \frac{(V_{reference} - V_{measured})}{V_{reference}} \times 100\% \dots (2.5)$$

For standar deviation measurement

$$SD = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2} \quad (2.6)$$

For 5 measurements the standard deviation is given by:

$$SD = \sqrt{\frac{1}{4}((x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + (x_3 - \bar{x})^2 + (x_4 - \bar{x})^2 + (x_5 - \bar{x})^2)}$$

where:

s = sample standard deviation

n= number of observations

x_i = individual measurement

\bar{x} = sample mean

III. RESULTS AND DISCUSSION

A series of tests and analyses were conducted to ensure that each component functioned in accordance with the specified specifications. The objective of this test was to evaluate the overall performance of the device and to ascertain the pulse value that was utilised as the setpoint in the water filling process.

A. Measurement and Testing

The device was subjected to a rigorous testing process, encompassing the evaluation of the performance of each electronic component employed. This included the power supply, the E18-D80NK proximity sensor, the keypad, and the DC motor.

1) Power Supply Testing

The power supply sensor was tested by comparing the output and input voltage readings between the power supply specifications and the multimeter. The testing procedure was repeated on three occasions.

TABLE I. POWER SUPPLY TESTING

Test	Input Voltage (VAC)	Output Voltage (VDC)	V Specification (VDC)
1.	225	12	12
2.	225	12	12
3.	225	12	12

As shown in Table 1, the experimental findings indicate that the power supply has the capacity to deliver a consistent voltage of 12 V DC. Voltage does not fluctuate to a significant degree that could be concluded that this power supply is suitable for supporting the entire system.

2) Proximity Sensor E18-D80NK Testing

The E18-D80NK proximity sensor is utilised for the purpose of detecting the presence of bottles at the filling position. Testing was conducted by moving an object closer to and further away from the sensor at distances ranging from 3 cm to 7 cm. The sensor produces a logic

signal of LOW when an object is detected and HIGH when no object is present. The most accurate and stable detection was observed to occur at a proximity of approximately 5 centimetres as shown on Table 2.

TABLE II. PROXIMITY SENSOR E18-D80NK TESTING

Test	Distance (cm)	Proximity indicator	Conditions
1.	3	On	Object Detected
2.	4	On	Object Detected
3.	5	On	Object Detected
4.	6	On	Object Detected
5.	7	Off	No Object

3) DC Motor Testing

A series of experiments was conducted with the objective of ascertaining the optimal operating voltage capable of producing stable motor performance for conveyor. The testing process entailed an evaluation of the sensor's impact on the final position accuracy of the bottle with various voltage input.

TABLE III. TESTING OF CONVEYOR WITH 12V INPUT VOLTAGE

Input Voltage (V)	Proximity Object Detection	Nozzle Position
12	ON	Incorrect
12	ON	Incorrect
12	ON	Incorrect
12	ON	Incorrect
12	ON	Incorrect

Tests are conducted to ascertain the optimal working voltage capable of engendering stable motor performance. These tests also include an evaluation of the sensors and their effect on the accuracy of the final position of the bottles under various input voltage variations.

TABLE IV. TESTING OF CONVEYOR WITH 8V INPUT VOLTAGE

Input Voltage (V)	Proximity Object Detection	Nozzle Position
8	ON	Correct
8	ON	Correct
8	ON	Correct
8	ON	Correct
8	ON	Correct

The test was conducted on five occasions to ensure that the conveyor functioned at the correct speed. This was necessary to ensure that when the proximity sensor detected a bottle, the water would be filled correctly into the bottle. The significance of this test lies in its

role in minimising errors that could potentially result in production losses during the filling process.

TABLE V. TESTING OF CONVEYOR WITH 12V INPUT VOLTAGE

Input Voltage (V)	Proximity Object Detection	Nozzle Position
12	ON	Incorrect
12	ON	Incorrect
12	ON	Correct
12	ON	Incorrect
12	ON	Correct

As demonstrated in the Table 3, Table 4 and Table 5, the motor was tested with a voltage supply ranging from 6 volts to 12 volts. Test results demonstrate that the motor is capable of propelling the conveyor at a voltage of 6 volts; however, the movement of the bottles is characterized by an absence of smoothness and an inherent instability. It has been demonstrated that the system functions most stably at a voltage of 8 volts, at which point the bottles are able to move smoothly and stop precisely at the expected filling position. It has been demonstrated that the application of a voltage in excess of 12 volts has the effect of accelerating the conveyor. This has been demonstrated to impede the process of bottle control, resulting in inaccurate bottle positioning during filling. This has been identified as a factor that is liable to compromise the accuracy of the filling process. Consequently, the operating voltage selected for the system implementation is 8 volts because the motor is able to consistently move the bottles to the filling position.

B. Testing of the water filling system and equipment

The objective of the system testing process, which involved the utilization of the waterflow sensor YF-S201, was to validate the accuracy of volume measurement at various set point volumes. The experiment was conducted by comparing the volume of water measured by the system with the actual volume and subsequently calculating the percentage error. The range of volumes that were examined was from 30 mL to 330 mL

1) Calibration Testing

During the calibration test of the YF-S201 water flow sensor, each measurement point was repeated five times for each specified set point delay. Each repetition was carried out using the same procedure. From the five repetitions, the system recorded the number of pulses read and the volume of water successfully discharged. Subsequently, the mean and standard deviation of the measured volume were calculated in order to ascertain the stability of the measurement results.

Furthermore, the mean pulse from each delay set point is employed as the setpoint pulse value, thereby

representing a specific target volume. Consequently, the target volume is assigned the most suitable setpoint pulse value, calculated based on the mean outcomes of five replicates. Moreover, the comparison between the target volume and the average measured volume is employed to calculate the error and accuracy percentages. This enables the determination of the level of system precision for each volume variation.

TABLE VI. DELAY SETPOINT MEASUREMENT

Setpoint (s)	Volume (ml)	St dev	Error (%)	Accuracy (%)
0.41	30.20	0.20	0.67	99.33
0.85	59.60	0.24	0.67	99.33
1.30	90.20	0.20	0.22	99.78
1.75	120.40	0.24	0.33	99.67
2.19	149.80	0.20	0.13	99.87
2.62	180.40	0.40	0.22	99.78
3.07	209.80	0.20	0.10	99.90
3.53	240.40	0.24	0.17	99.83
4.00	270.40	0.24	0.15	99.85
4.25	298.80	0.73	0.40	99.60
4.80	329.40	0.40	0.18	99.82

2) Testing Using Pulse Setpoint

After conducting volume testing and obtaining the pulse setpoint, each setpoint was tested to measure its accuracy. The test was conducted five times to detect valid accuracy. At the pulse calibration setpoint, the pulse value was rounded because the system uses integer values to provide pulse input to the flowmeter. The rounded values are as follows: 30 mL = 11 pulses, 60 mL = 24 pulses, 90 mL = 38 pulses, 120 mL = 52 pulses, 150 mL = 66 pulses, 180 mL = 79 pulses, 210 mL = 93 pulses, 240 mL = 108 pulses, 270 mL = 121 pulses, 300 mL = 130 pulses, and 330 mL = 144 pulses. The test values are shown in Table 7.

TABLE VII. MEASUREMENT USING PULSE SETPOINT

Setpoint (Pulse)	Volume (ml)	Volume Measurement (ml)	Stdev	ERROR	Accuracy
11	30	30.40	0.55	1.33%	98.67%
24	60	59.40	0.55	1.00%	99.00%
38	90	89.40	0.55	0.67%	99.33%
52	120	119.40	0.89	0.50%	99.50%
66	150	150.00	1.41	0.00%	100.00%
79	180	178.80	1.30	0.67%	99.33%
93	210	210.80	2.17	0.38%	99.62%
108	240	238.40	2.07	0.67%	99.33%
121	270	269.60	1.14	0.15%	99.85%
130	300	298.80	2.59	0.40%	99.60%
144	330	329.40	0.89	0.18%	99.82%

Following the testing of the pulse set point, a range of values was obtained for each filling volume. The accuracy of the results obtained was generally less than 1%. The lowest values of accuracy were observed at volumes of 30 and 60 mL. This is due to the YF-S201 flowmeter sensor exhibiting superior measurement accuracy when the pulse rate exceeds 35 beats per minute. When a volume of 330 millilitres of water was added, an accuracy value of 99.82% was obtained, indicating that the set point of 144 has a satisfactory level of accuracy. This value is significant given that, in the context of the overall system testing, bottles with a capacity of 330 millilitres were utilised.

3) System Validation

After conducting the pulse test, a comprehensive system test was carried out using 330 mL AMDK bottles. The 330 mL volume was chosen for the system test because the majority of AMDK bottles have a volume of 330 mL. In addition, the 330 mL bottle design has an ideal height, making it easier to control on the conveyor. As demonstrated in Table 6, the system functions at an optimal level, exhibiting a minimal error margin of 0.18%, as indicated by the accuracy of 99.82% recorded in Table 7. Furthermore, the information displayed on the user interface is found to be comprehensive.

TABLE VIII. OVERALL SYSTEM TESTING

No	Condition	Sensor Input	System Action (Actuator)	Stop/Move Criteria	Output/Indicator
1	System turned on (standby)	—	Conveyor OFF/ON according to initial mode, pump OFF	Waiting for START button / auto mode to activate	LCD: "STOP/READY", standby indicator light
2	START button pressed / auto mode active	—	Conveyor ON to bring the bottle to the filling position	Bottle reaches proximity sensor area	LCD: "START", process indicator active
3	Bottle enters detection area	Proximity detect bottle	Conveyor OFF (stops precisely at the nozzle), pump still OFF	Bottle is in filling position (stable)	LCD: status "ready"
4	Filling process begins	Flow sensor starts counting pulses	Pump ON, conveyor OFF	Pulse begins to increase toward setpoint	LCD displays running volume
5	Filling in progress	Pulse continues measured	Pump ON	If pulse \geq setpoint	LCD display volume approaching the target
6	Setpoint reached	Flowmeter reached setpoint	Pump OFF	After the pump stops	LCD: "filling done"
7	Bottle removed from filling station	Proximity sensor starts "not detected"	Conveyor ON	Bottle move exits proximity area	Bottle counter increases, LCD updates bottle count
8	Cycle repeats	Proximity detects the next bottle	Return to step 3	STOP button pressed / system stopped	System returns to standby

In comparison with previous research, the present system focuses on low-cost implementation and calibrated pulse-based volume control. The comparison is summarised in Table 9.

TABLE IX. TESTING OF CONVEYOR WITH 12V INPUT VOLTAGE

Previous research	Comparison and contribution of this study
Microcontroller-based automatic water filling [5]	Previous work showed that microcontroller filling can be implemented, but the present work adds calibrated YF-S201 pulse setpoints for 30-330 mL volume control.
PLC-based automatic filling and capping [6]	PLC implementation provides stable industrial operation, while this study offers a lower-cost Arduino Mega 2560 alternative with conveyor, proximity detection, pump control, LCD interface, and bottle counting.
Low-budget Aloe Vera syrup filling [7]	The previous system used a time-step method for filling, while this research uses pulse counting from the flowmeter to reduce dependence on pump running time only.
IoT drinking-water usage monitoring [14]	The cited IoT system focuses on monitoring water usage in dispensers. In contrast, this study controls the filling process and evaluates volume accuracy directly.
This research	The system achieved 98.67%-100.00% accuracy for 30-330 mL, with 99.82% accuracy at the 330 mL AMDK target volume and the highest accuracy of 100.00% at 150 mL.

IV. CONCLUSION

A series of tests were conducted on a volume range of 30 mL to 330 mL in order to ascertain the functionality of the water filling system that uses the YF-S201 water flow sensor. The conclusion of these tests is that the system operates correctly and with sufficient accuracy. The consistent volume and pulse measurement results indicate the stability of the sensor and the effectiveness of the system. The calibration factor calculated for each volume also tends to be stable, with an average value of 2.352 mL/pulse. It has been demonstrated that the system is capable of measuring and distributing water volume with adequate precision within the range of 30-330 mL. In tests involving larger volumes (210–330 mL), the system demonstrated stability with a low error rate. The mean error was 0.38% at a volume of 210 mL, and 0.15% at a volume of 270 mL. For the commonly used AMDK volumes of 240 and 330 mL, the errors were found to be 0.67% and 0.184%, respectively. The system has been demonstrated to demonstrate capacity for filling a range of volumes, with a minimum of 30 mL and a maximum of 330 mL. This capacity has been determined through the conduction of a series of tests.

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