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Revolutionizing IV Infusions: Empowering Care with the DripControl+ App for Real-Time Monitoring and Precision Management

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ABSTRACT The demand for an effective and precise monitoring and control system for intravenous infusion therapy has increased due to concerns regarding medication errors and inefficiencies associated with current manual monitoring methods employed by nurses, particularly when caring for multiple patients across different rooms. This research aims to enhance intravenous infusion therapy by developing a real-time monitoring and control system. The system utilizes IoT technology and advanced sensors, including the load cell sensor for infusion volume detection, the FC-33 optocoupler sensor for precise infusion drop monitoring, and also a servo motor as an actuator to bend the infusion hose. Integrated with the NodeMCU ESP32 microcontroller, the system empowers healthcare professionals with the user-friendly DripControl+ app to remotely monitor and cont rol the infusion process. The results indicate a seamless collaboration among the system components. The FC-33 Optocoupler sensor exhibits an outstanding accuracy rate of 99.39%. The load cell sensor achieves an impressive 99.61% accuracy. The servo motor precisely follows predetermined positions. These outcomes effectively highlight the system's ability to accurately control the infusion drip rate with exceptional precision. The FC-33 optocoupler sensor and servo motor play crucial roles in achieving this accuracy. With an impressive average accuracy of 97.99%, the system has proven to be highly efficient. However, it should be noted that sudden changes in infusion speed could impact the accuracy of the readings. The future research could focus on refining the system's ability to respond to abrupt changes in infusion speed through advanced algorithms, such as machine learning.

INDEX TERMS DripControl+ app, intravenous infusion, real-time drip control, remote monitoring

I. INTRODUCTION

Intravenous therapy is a medical treatment to deliver liquid substances, such as blood, fluids, or medications, directly through the patient's vein, ensures a constant and controlled rate of delivery over a specified duration. It is the most efficient means of rapidly distributing fluids and drugs throughout the body. Intravenous infusion therapy is administered to patients who require medication rapidly— or steady but continuously. [1]

Intravenous infusions are usually administered through a needle (cannula) into a vein located in the upper arm such as the basilic vein —the cannula acts as a carrier for continuous delivery of fluids infusion. The intravenous infusion locations depend on the patient's medical condition and the type of infusion being administered. Generally, hospitalized patients will receive intravenous infusion therapy in order to fix electrolyte imbalances in the patient's body or to administer the medication directly into the bloodstream when the patient is unable to take the medication orally. [2], [3]

A standard Intravenous infusion set comprises a bag holding a solution, a drip chamber to allow estimation of the fluid administration rate, the roller clamp to regulating the flow of infusion liquid, and a cannula. The flow rate should be routinely evaluated. Drops per minute (DPM) is a crucial metric utilized to determine the infusion flow rate during intravenous therapy. When infusing intravenous fluids through a gravitational flow pathway, the rate of flow is precisely determined by the drops infusion per minute. The infusion flow rate considers the entire volume of the liquid being infused, the total duration of the infusion in hours, and the drop factor of the administering set. The drop factor indicates quantity of drops needed for compose 1 ml of infusion, and it greatly affects the calculation of drops per minute. For instance, a macro drip set with larger drops may have a drop factor of 20 drops/ml, whereas a micro drip set with smaller drops may have a drop factor of 60 drops/ml. Adult patients usually uses macro drip, while for pediatric patients uses micro drip. [4]–[6]

During the process of intravenous infusion therapy, there is a possibility of medication errors that necessitate continuous monitoring of the administration of intravenous infusion therapy. Medication errors that might occur such as the patient inadvertently pressing the infusion hose, the infusion hose getting bent, excessive hand movements by the patient, and the infusion fluid running out unnoticed —either by patients or nurses. The void of infusion fluid can lead the blood from the veins entering the infusion tube or air bubbles from the infusion bag entering the veins, resulting in a condition known as embolism [7]–[9].

Nurses currently carry out manual patient infusion monitoring by individually assessing the condition of each patient's infusion throughout a 24-hour period. However, hospitals frequently encounter a difficulty in managing the disparity between the patients and the available nursing staff. For instance, a nurse may be responsible for overseeing five patients spread across different rooms, which poses difficulties for nurses and renders the manual monitoring of patient infusions less efficient, particularly considering the additional responsibilities nurses have. As Nkurunziza *et al.* stated on their paper titled *Factors contributing to medication administration errors and barriers to self-reporting among nurses: a review of literature* that medication errors is a global challenge and 18.7%-56% of hospitalized patients face medication administration errors, and can be prevented by avoiding heavy workload employees [10], and a case reported in the Korean Journal of Anesthesiology recounted a situation where a patient receiving intravenous medication suffered a life-threatening overdose due to a misinterpretation of infusion rates. This unfortunate incident highlights the potential catastrophic consequences of relying solely on manual monitoring methods [11]. Recognizing this pressing need, it becomes essential to upgrade the technology used for monitoring and controlling infusion fluids. [12]–[14]

There have been so many innovations in infusion monitoring and control, Taufik *et al.* made an infusion volume monitoring tool with a load cell sensor, NodeMCU as a microcontroller, Thingspeak Web as an connection to User [15]. The result is the device made an error of 0.25 grams, whereas it should have been 0 grams. Similar research by Putung *et al.* developed an infusion monitoring device that incorporates a load cell sensor and an infrared proximity sensor, utilizing Arduino Nano as the microcontroller. The data are conveniently displayed on both the LCD and a smartphone through the Blynk app [16]. And other various kinds of research, by modifying the sensors or developing features from existing [7], [8], [10], [15]–[21], [22]–[31].

This innovative device incorporates a load cell sensor for detecting infusion volume and FC-33 optocoupler sensors for accurate infusion drop detection, this combination addresses multiple aspects of the infusion process, including both volume control and drip rate accuracy, this research aims to achieve minimal to negligible errors, ensuring more reliable medication delivery. The incorporation of an ESP32 microcontroller and the DripControl+ app represents a leap towards real-time monitoring and control. While previous research displayed data on LCDs and smartphones through apps like Blynk, this research leverages IoT technology to provide instantaneous updates and control over the infusion process, enhancing patient safety and healthcare provider convenience.

Enter Internet of Things (IoT)-based technology and sensors, poised to transform the landscape of medication infusion monitoring. By seamlessly connecting medical devices and systems through a network, IoT enables real-time data monitoring. Sensors embedded in infusion pumps, fluid lines, and patient monitoring equipment can continuously monitor parameters such as infusion rate and medication volume all in real-time. The benefits of this approach the shortcomings of manual monitoring, significantly reducing the risk of human errors and variations. The urgency and significance of addressing medication errors and inefficiencies in manual infusion monitoring methods cannot be overstated. The proposed IoT-based technology and sensor-driven approach holds immense promise in mitigating these challenges, offering a path towards safer, more efficient, and more cost-effective patient care.

II. MATERIALS AND METHOD

A. WORKING PRINCIPLE OF THE SYSTEM

Providing a clear and easy-to-understand visual representation of complex processes of the systems, a flowchart user is created. Making it easier for individuals to grasp the overall flow and structure. The user flowchart, displayed in FIGURE 1, provides an overview of the entire process.

Through the intuitive DripControl+ app, the user can seamlessly set the desired infusion rate, choosing between two options: 60 drops per minute or 20 drops per minute. The ESP32 microcontroller then takes charge, processing data from the database and facilitating smooth communication with both the optocoupler sensor and the MG90 servo motor. Once the desired drip rate is determined, the MG90 servo motor springs into action, deftly adjusting the infusion hose to regulate the flow in perfect synchronization with the user's chosen settings. The ingenious functionality of the MG90 servo motor enables it to bend the infusion hose as needed, ensuring that the flow of the infusion fluid precisely matches the desired drip rate with remarkable accuracy.

An essential safety feature of this monitoring system comes into play when the infusion fluid volume falls below 20% of the required amount. In such a scenario, the database promptly sends an alert to the DripControl+ app, promptly notifying nurses of the critical situation. This immediate notification empowers medical staff to take swift action and make necessary adjustments to safeguard the patient's well-being. The outputs and vital information are thoughtfully displayed on both the LCD screen and the DripControl+ app, facilitating continuous and comprehensive monitoring of the infusion process. The dual display allows healthcare professionals to stay informed and in control at all times.

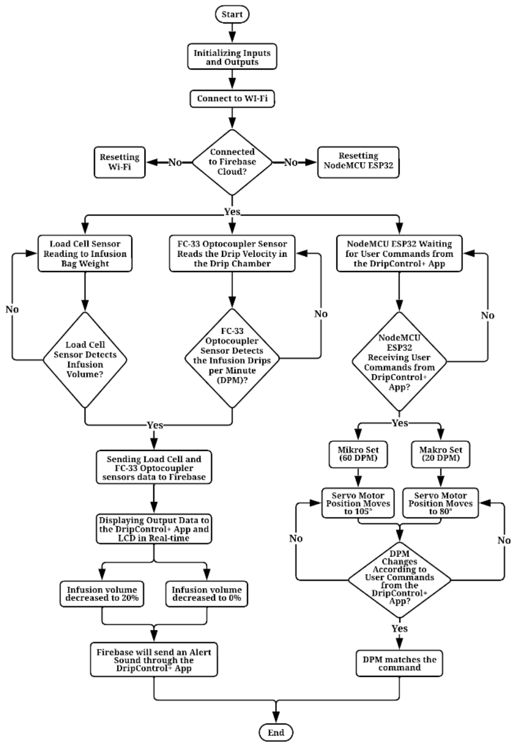

FIGURE 1. **Flowchart user**

A circuit block diagram consists of interconnected blocks that represent the functions of each component in the circuit. Block diagram comprising three main components: input, processing, and output. FIGURE 2 provides detailed explanations regarding the workflow.

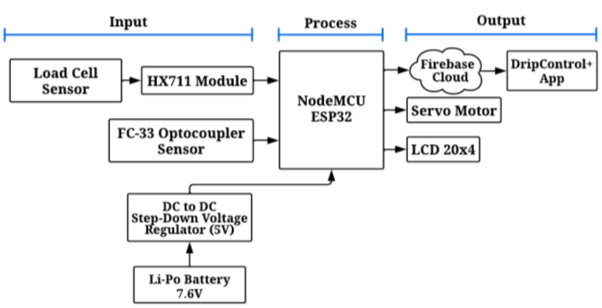

FIGURE 2. **Circuit Block Diagram**

Input of the system comprises:

1. LOAD CELL SENSOR

The load cell sensor is utilized to measure the weight of the administered infusion and determine the fluid volume in the infusion as a percentage. Subsequently, it provides input to the NodeMCU ESP32. A known weight was applied to the load cell to establish a linear relationship between sensor output and weight. Calibration coefficients were calculated and programmed into the microcontroller to convert sensor readings to accurate weight measurements. The accuracy of the load cell sensor was assessed by calculating the percentage error between the measured volume and the expected volume.

2. HX711 MODULE

The HX711 module amplifies the output signal from the load cell sensor, which is only about 2mV, enabling it to be read by the NodeMCU ESP32. It is also converts analog data into digital data, allowing the changes in resistance from the load cell sensor to be readable.

3. FC-33 OPTOCOUPLER SENSOR

FC-33 Optocoupler sensor is utilized to detect and compute the count of infusion drops per minute, additionally be utilized as an input for the NodeMCU ESP32. The optocoupler sensor was placed near the drip chamber of the infusion setup. The microcontroller was programmed to count the number of drops detected within a fixed time period. The accuracy of the optocoupler sensor was evaluated by comparing the detected drop count to the expected drop rate over a specific time period. The infusion setup was run for a fixed time duration. The optocoupler sensor's drop count was compared to the expected drop rate.

4. DC STEP-DOWN VOLTAGE REGULATOR

This regulator is used to take in the higher and fluctuating battery voltage from the primary power source, like a Li-Po battery, and convert it into a lower and constant voltage, typically around 5V.

5. LI-PO BATTERY

Li-Po battery is used to provide the electrical energy needed to run each component in the circuit. In the processing section, the NodeMCU ESP32 carries out the following tasks:

a. It receives input from the load cell and FC-33 Optocoupler sensors.
b. It detects notable changes or significant fluctuations the flow rate infusion drops and transmits the data to Firebase.
c. It exhibits the measurement outcomes on the LCD screen.
d. It processes data from the database, enabling seamless communication from DripControl+ app and MG90 servo motor.

The output, which are the results of processing section, comprises:

1. FIREBASE CLOUD

The Firebase Cloud is used as an intermediary or backend component that establishes communication and interaction between the DripControl+ app and the Firebase platform. It acts as a bridge, facilitating data exchange and handling various operations, such as processing user requests, fetching or updating data from the database, and executing specific functionalities required by the app.

2. DRIPCONTROL+ APP

The DripControl+ app is used as the system's software, enabling remote monitoring of the infusion's status. Additionally, it is seamlessly integrated with the hardware to allow medical personnel to control the infusion drip speed as required.

3. SERVO MOTOR

Servo Motor is used as an actuator to control the drips per minute of the infusion fluid by clamping the infusion hose. The servo motor's range of motion and angular control were calibrated to accurately reflect changes in infusion flow rates. The servo motor was integrated into the system, connected to the infusion flow control mechanism. The system was programmed to adjust the servo motor's position to change the infusion rate. Infusion rate adjustments were made through the DripControl+ app.

4. LCD 20×4

LCD is used to displays real-time infusion conditions such as Drips per Minute, and Infusion Volume Percentage on a 20×4 display that users can directly see on the device.

B. HARDWARE DESIGN MODEL

In hardware design model, there are two types of process carried out, namely mechanical design and electrical design. Mechanical design process involves designing the mechanical framework of the system with precise dimensions that match the components used, ensuring it functions properly and operates smoothly without any disruptions to the system's performance. Whereas the electrical design process is essential to identify the components, sensors, and other electronic materials used in a real-time infusion monitoring system. It also serves to understand the wiring that connects the components during the installation process. The system's mechanical design is depicted in FIGURE 3.

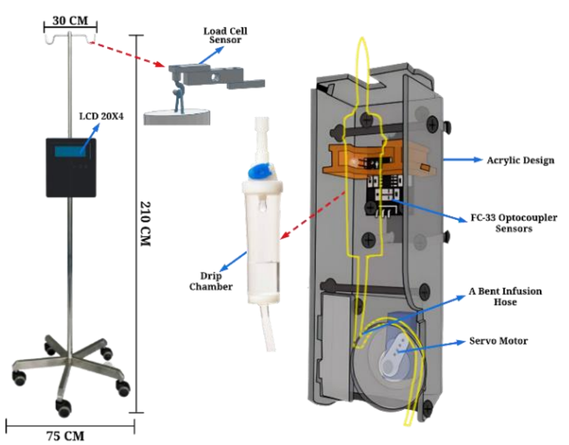

FIGURE 3. **Mechanical design of the system**

The infusion pole has been modified by adding a component box and an LCD display in the middle section of the pole Additionally, the infusion hook has been altered by integrating a load cell sensor. To control the infusion drip rate per minute, a special frame is constructed using acrylic. The frame has dimensions of 4 x 3.5 x 12.5 cm (Length x Width x Height). Inside the acrylic frame, there are several components, such as the FC-33 optocoupler sensor and a holder for supporting the drip chamber. At the bottom of the frame, a servo motor MG90 is installed to clamp the infusion hose.

The infusion control system comprises several essential electrical components, which are the NodeMCU ESP32 microcontroller, HX711 load cell sensor module, FC-33 optocoupler sensor, LCD 20x4 display, and MG90 servo motor. The system's electrical design can be observed in FIGURE 4.

The load cell and FC-33 optocoupler act as inputs to the NodeMCU ESP32 microcontroller, and they are connected to digital pins on the NodeMCU ESP32. The NodeMCU ESP32 processes the input data from the sensors and controls the Servo Motor accordingly while displaying relevant information on the LCD.

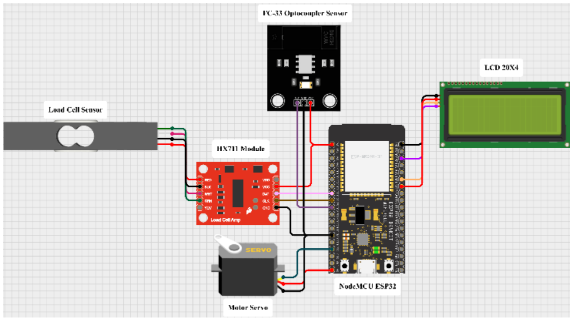

FIGURE 4. **Electrical Design of The System**

First, connect all VCC and GND terminals of each component to the power source. Then, connect the load cell sensor to the HX711 module. The connections between the load cell sensor and HX711 module are as follows: the red wire of the load cell sensor is connected to the E+ pin on the HX711, the black wire of the load cell sensor is connected to the E- pin on the HX711. The white wire of the load cell sensor is connected to the A- pin on the HX711, and the green wire of the load cell sensor is connected to the A+ pin on the HX711. Next, connect the SCK and DT pins on the HX711 module to pins D25 and D33 on the NodeMCU ESP32. Then, the OUT pin of the FC-33 optocoupler sensor is connected to pin D26 on the NodeMCU ESP32. The SIGNAL pin of the servo motor is connected to pin D35 on the NodeMCU ESP32. Finally, the SDA and SCL pins of the I2C 20x4 LCD are connected to the SDA and SCL pins on the NodeMCU ESP32.

C. SOFTWARE DESIGN MODEL

The DripControl+ application is designed and developed using the Kotlin programming language and the Android Studio platform. Firebase is used as the data storage to manage and store information from the application, such as user data, infusion history, and other settings. Meanwhile, the Arduino IDE is utilized to program and control the hardware system, including sensors, servo motors, and other components connected to the NodeMCU ESP32 microcontroller. The integration between the Android application using Kotlin and the Arduino hardware allows the DripControl+ app to provide accurate and real-time control over the infusion monitoring and control process for patients. The interface of the DripControl+ app is shown in FIGURE 5.

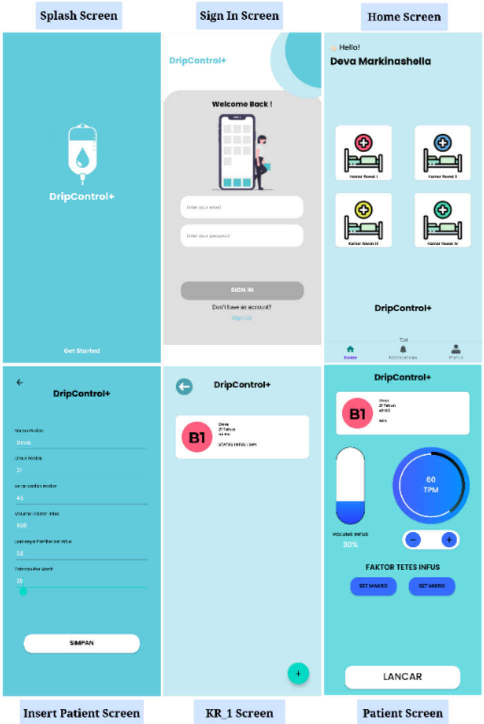

FIGURE 5. Software Design

D. TESTING DESIGN INSTRUMENT

Testing design instruments involve using various methods and tools to evaluate the performance and reliability of a system. In this case, tests will be conducted to check the accuracy of the FC-33 optocoupler sensor, load cell sensor, and motor servo.

III. RESULTS

A. FC-33 OPTOCOUPLER SENSOR MEASUREMENT

The FC-33 optocoupler's measurement occurs at pin D26 of the NodeMCU ESP32. This measurement is taken when the optocoupler detects the presence and absence of drops as shown in FIGURE 6. The V_{OUT} measurement results as illustrated in TABLE 1. The measurements taken on pin D26 of the NodeMCU ESP32 indicate a voltage of 0.34 VDC when a droplet is detected, and a voltage of 4.50 VDC when there is no droplet detected.

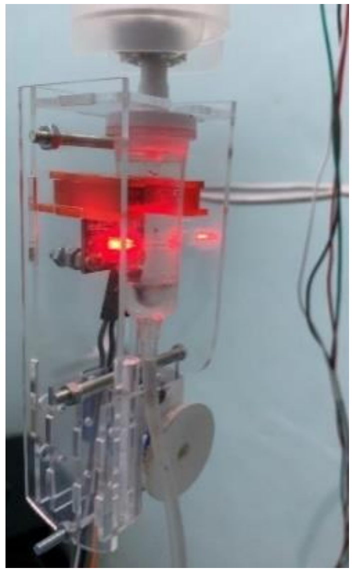

FIGURE 6. Infusion Drops Measurement

TABLE 1
Measurement Result of the FC-33 Optocoupler Sensor

V_{IN}	State	V_{OUT}
5 V_{DC}	There is droplet	0.34 V_{DC}
5 V_{DC}	No droplet	4.50 V_{DC}

Subsequently, a thorough examination is conducted to precisely determine the flow rate infusion liquid drops per minute. This involves comparing the readings obtained from the sensor in Arduino IDE software with actual reading using a stopwatch to ensure precise and accurate outcomes, as illustrated in TABLE 2.

TABLE 2
FC-33 Optocoupler Sensor Accuracy Testing

Drops per Minute Reading		Difference	Accuracy (%)
FC-33 Optocoupler Sensor	Actual		
10.4	10	0.4	96.15
15.1	15	0.1	99.33
20	20	0	100
25.2	25	0.2	99.20
30	30	0	100
35.2	35	0.2	99.43
40	40	0	100
45	45	0	100
50.1	50	0.1	99.80
60	60	0	100
Average Accuracy			**99.39**

The measurement results revealed slight discrepancies between the measured outcomes from the sensor reading and the actual reading, with an average percentage accuracy achieved is 99.39%. This level of accuracy unequivocally confirms the excellent performance of the FC-33 optocoupler sensor, demonstrating that it is functioning exceptionally well.

B. LOAD CELL CIRCUIT MEASUREMENT

The measurement procedure involves comparing the weight readings obtained from the load cell sensor with those from a digital scale as shown in FIGURE 7. To accomplish this, the infusion bag is weighed along with the acrylic and components. Subsequently, the sensor readings are converted into percentage values by subtracting the combined weight of the infusion bag, acrylic, and components from the weight of the infusion bag alone. The detailed results of these measurements are meticulously presented in TABLE 3.

FIGURE 7. Digital Scale Measurement

TABLE 3
Measurement Result of the Load Cell Sensor

Weight Reading (gram)		Infusion Volume (%)	Difference (gram)	Accuracy (%)
Digital Scale	Load Cell Sensor			
656	658	100	2	99.69
606	608	90	2	99.67
556	555	80	1	99.82
506	505	70	1	99.80
456	455	60	1	99.78
406	405	50	1	99.75
356	355	40	1	99.71
306	305	30	1	99.67
256	255	20	1	99.60
206	205	10	1	99.51
156	158	0	2	98.73
Average Accuracy				99.61

The measurement results revealed small differences between the load cell sensor reading and the digital scale reading, with an impressive average accuracy of 99.61%. This confirms that the load cell sensor is working exceptionally well.

C. SERVO MOTOR CIRCUIT MEASUREMENT

The aim of this measurement is to evaluate the servo motor's performance in maintaining a specific angle (set point) under different conditions. The measurement is done by measuring the voltage difference specified degree positions on the servo motor. In the first condition, the servo motor is set to a position of 80 degrees, representing to an infusion flow rate of 20 drops per minute. In the second condition, the servo motor is set to a position of 105 degrees, representing to an infusion flow rate of 60 drops per minute. A few attempts are performed to ensure precise and consistent data collection. The measurement findings are showcased in TABLE 4.

TABLE 4
Measurement Result of the Servo Motor

Number of Attempts	V_{IN} (V_{DC})	V_{OUT} (V_{DC})	
		80°	105°
1	5	0.34	0.41
2	5	0.32	0.42
3	5	0.34	0.42
4	5	0.32	0.41
5	5	0.33	0.40
6	5	0.31	0.41
7	5	0.33	0.40

Based on the measurement results, when the servo motor is set to 80 degrees, the voltage changes between 0.32 to 0.34 V_{DC}. When it's set to 105 degrees, the voltage changes between 0.40 to 0.42 V_{DC}. Since these voltage differences are within the allowed tolerance range of ±0.02 V_{DC} [34], it shows that the servo motor performs well in accurately following the set positions.

D. MEASUREMENT OF CONTROL INFUSION FLOW RATE

This measurement integrates components that includes an optocoupler sensor, servo motor, and the DripControl+ app to control the infusion fluid flow rate. The optocoupler sensor provide real-time feedback to the DripControl+ app, then the app sending instructions to the servo motor, and ensuring the desired flow rate is maintained efficiently. This measurement also compares the sensor reading with actual readings, as shown in TABLE 5.

TABLE 5
Measurement Result of Control Infusion Flow Rate

No.	Target from DripControl+ App (Drops per Minute)	Drops per Minute		Servo Motor Degrees	Accuracy (%)
		System	Actual		
1	20	20	20	80°	100
2	20	21	20	80°	95.24
3	20	20	20	80°	100
4	20	19	18	80°	94.73
5	20	20	19	80°	95
6	60	60	59	105°	98.33
7	60	60	61	105°	98.36
8	60	60	60	105°	100
9	60	60	59	105°	98.33
10	60	60	60	105°	100
Average Accuracy					97.99

The measurement showed a slight difference between the system readings and the actual values. However, the servo motor performed well in accurately following the set positions. With an average accuracy of 97.99%, the system demonstrated good performance.

IV. DISCUSSION

A. ANALYSIS OF THE FC-33 OPTOCOUPLER SENSOR ACCURACY TESTING

The graph in FIGURE 8 serves a visual representation of FC-33 optocoupler sensor accuracy testing.

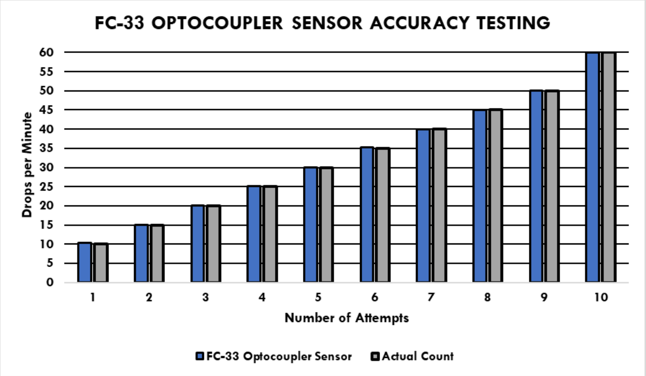

FIGURE 8. Graph of the FC-33 Optocoupler Sensor Accuracy Testing

The FC-33 Optocoupler sensor's measurements show that it produces a voltage of 0.34 V_{DC} when a droplet is detected and a voltage of 4.50 V_{DC} when no droplet is detected. This indicates that the sensor uses an active low signal, meaning it gives a low signal (0.34 V_{DC}) to indicate its active state when a droplet is present, whereas during its steady state, or when there is no droplet detected, it consistently gives a high voltage signal of 4.50 V_{DC}.

The information provided in TABLE 2 and FIGURE 8 reinforces the high accuracy and precision of the FC-33 Optocoupler sensor's measurements. The reported accuracy of 99.39% indicates that the sensor's readings are extremely close to the actual values, with only minor discrepancies ranging from 0.1 to 0.4 drops per minute. The graph in FIGURE 8 serves as a visual comparison between the sensor's measured outcomes and the actual readings, and it demonstrates that the differences between them are indeed very small.

The exceptional sensitivity and precision of the FC-33 Optocoupler sensor enable it to accurately detect and measure even the tiniest variations in the presence of dripping liquid, a task that may be challenging for human observation. The high accuracy rate achieved by the FC-33 optocoupler sensor in detecting drop rates can be attributed to its ability to precisely count the drops as they pass through the sensor's detection zone. This accuracy is critical in intravenous administrations, where even slight deviations in drop rates can lead to medication underdosing or overdosing. In clinical settings, accurate drop rate detection helps maintain the prescribed infusion rate, ensuring patients receive the intended medication dosage, which is especially crucial in critical care scenarios.

B. ANALYSIS OF THE ACCURACY LOAD CELL SENSOR MEASUREMENT RESULT

The graph shown in FIGURE 9 visually shows the comparison between the load cell sensor's measured outcomes and the measurements obtained from a digital scale.

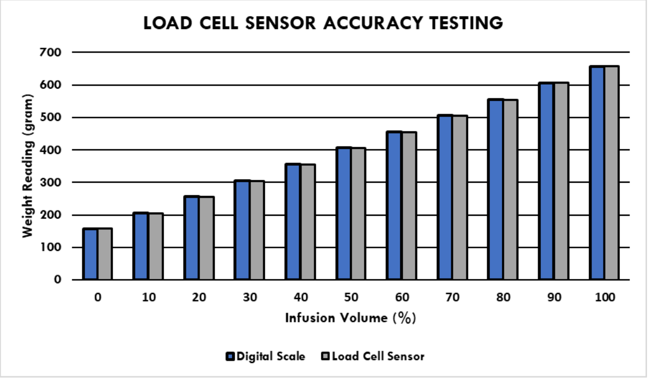

FIGURE 9. Graph of the Load Cell Sensor Accuracy Testing

The data presented in TABLE 3 and FIGURE 9 highlights the impressive accuracy of the load cell sensor's measurements. With a reported accuracy of 99.61%, the sensor's readings are remarkably close to the actual values, showing only minor discrepancies of 1 to 2 grams. The exceptional accuracy of the load cell sensor in monitoring infusion volume is rooted in its calibration process and linear relationship between weight and sensor output. This accuracy directly translates to precise monitoring of the administered fluid volume. In clinical contexts, accurate infusion volume monitoring is pivotal for preventing dosage errors, ensuring patients receive the correct amount of medication, and preventing adverse events caused by over- or under-infusion.

To address any potential inaccuracies for such small weights, proper calibration, environmental control, and careful handling of the load cell are crucial. Calibration ensures that the sensor's output is adjusted to match the actual weight values accurately. Environmental control helps mitigate the impact of temperature, humidity, and other external factors that might affect the sensor's performance. Additionally, proper handling and installation of the load cell play a vital role in obtaining accurate measurements consistently.

C. ANALYSIS OF THE SERVO MOTOR MEASUREMENT RESULT

Based on the data in TABLE 4, after 8 attempts at both 80 degrees and 105 degrees, the servo motor's output voltage shows remarkable stability with minimal variation, despite the 25 degrees difference in set positions. The changes in output voltage are consistently small, reflecting the servo motor's consistent performance. This component can be utilized to adjust infusion rates on the fly, responding to changes in patient conditions or prescribed dosages, thereby increasing the adaptability of the system.

D. ANALYSIS OF CONTROL INFUSION FLOW RATE MEASUREMENT RESULT

The graph shown in FIGURE 10 is a graphical representation of a comparison between three variables: input from the DripControl+ app, the system reading, and the actual reading of the infusion drops per minute. These results are essential in evaluating the performance and reliability of infusion systems, especially when the input is given by the user through

DripControl+ app. The proposed system significantly reduces the risk of human errors inherent in manual monitoring. It offers real-time, automated data collection, preventing oversight and enabling healthcare providers to focus on critical tasks.

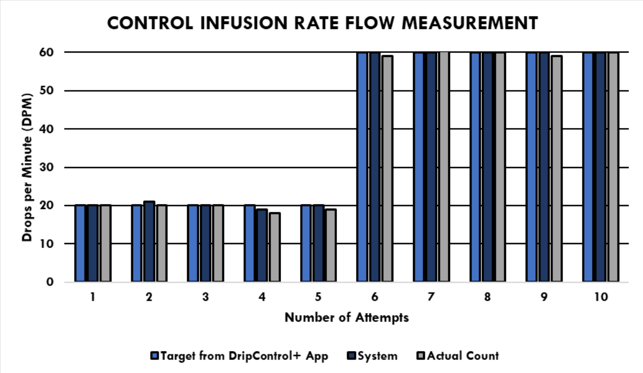

FIGURE 10. Graph of the Control Infusion Flow Rate Measurement Result

The data from TABLE 5 and FIGURE 10 shows that the overall system is impressively accurate, with a reported accuracy of 97.99%. The FC-33 Optocoupler sensor is essential for this accuracy as it measures the infusion speed and provides drop rate readings. It uses a sampling method, observing three drops of fluid to calculate the speed in drops per minute.

Another important factor contributing to the accuracy is the servo motor. It plays a huge role by accurately following the set positions, even after 10 attempts. By effectively controlling the flow of fluid, the servo motor ensures the desired infusion rate is attained and maintained, thus further enhancing the accuracy of drop rate readings. Additionally, the load cell sensor accurately measures the weight of the fluid, providing precise information about the infusion volume, which adds another level of accuracy to the overall system. The system's integration of adaptive algorithms or predictive mechanisms enhances its resilience against abrupt speed changes. This innovative feature distinguishes it from many other automated systems that may not possess such adaptive capabilities. The sudden changes in infusion speed can affect the accuracy of the speed readings on the device. These changes can be caused by various factors, such as air bubbles, clogs, pressure fluctuations, system malfunctions, or human error.

V. CONCLUSION

The advancement of a remote monitoring and control device for infusion flow rate, utilizing the DripControl+ app, represents innovative progress. The system integrates essential components, such as the load cell sensor, FC-33 optocoupler sensor, NodeMCU ESP32, and servo motor, effectively. The control infusion flow rate achieving an impressive 97.99% accuracy in drop rate readings. The seamless integration of the DripControl+ app enhances user convenience, while the precise servo motor control ensures consistent and accurate infusion rates. This advancement marks a significant step forward in improving medical infusion procedures and patient care. The future research could focus on refining the system's ability to respond to abrupt changes in infusion speed through advanced algorithms, such as machine learning. Additionally, exploring integration with electronic health records could enhance data synchronization and inform clinical decision-making, and the functionality of the DripControl+ application could be expanded to integrate data from other medical devices such as heart monitors, blood pressure monitors, and oxygen saturation levels.

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