iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: VIII Month of publication: August 2025

DOI: https://doi.org/10.22214/ijraset.2025.73617

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VIII Aug 2025- Available at www.ijraset.com

Smart Intravenous Infusion System Development

Tanmay Deshmukh[1], Dr. Uttam Bagal[2],
[1]Research Scholar, [2]Associate Professor, Department of Biomedical Engineering, MGM College of Engineering & Technology, Kamothe, Navi Mumbai

Abstract: Intravenous (IV) infusion therapy is a fundamental clinical procedure employed for fluid replenishment, drug delivery, and nutritional support. Traditional IV systems require continuous manual supervision to regulate flow rates, detect occlusions, and prevent over-infusion or depletion, which increases the likelihood of human error and compromises patient safety. This project focuses on the design and development of a microcontroller-based smart intravenous infusion system that automates fluid flow monitoring and regulation to ensure precise delivery.

The proposed system integrates a TCRT5000 infrared sensor to detect and count fluid drops within the drip chamber in real time. An Arduino Uno serves as the core processing unit, interpreting the sensor input and adjusting the infusion rate via a servo motor-driven flow regulator. An I2C-enabled 16x2 LCD display provides on-site visualization of drop rate and volume dispensed, while a Bluetooth module (HC-05) enables wireless data transmission for remote monitoring on mobile devices.

By automating the flow regulation process and incorporating real-time feedback, the system minimizes reliance on manual intervention and enhances clinical accuracy. Its cost-effective design and use of open-source hardware make it a viable solution for resource-limited healthcare settings. The developed prototype demonstrates significant potential for improving IV therapy efficiency, reducing nursing workload, and enhancing patient safety through intelligent infusion control.

I. INTRODUCTION

Intravenous (IV) therapy remains a cornerstone of contemporary clinical care, enabling the rapid and controlled delivery of fluids, electrolytes, medications, and nutrients directly into the venous system. Despite its ubiquity, conventional IV infusion practices are predominantly manual, requiring healthcare personnel to monitor and adjust flow rates by visual inspection and mechanical regulators. This method is inherently prone to variability and human error, resulting in potential complications such as over-infusion, under-infusion, fluid imbalance, and untimely response to line occlusion or bottle exhaustion. These risks are exacerbated in high-patient-load environments and under-resourced clinical settings where continuous supervision is often impractical.

To address these limitations, the present work proposes the development of a Smart Intravenous Infusion Monitoring and Regulation System, aimed at automating the infusion process to improve clinical precision and patient safety. The system is engineered around a microcontroller-based architecture that facilitates real-time monitoring of drip rate, total volume infused, and infusion status. It employs an infrared (IR) drop sensor for accurate detection of each droplet, coupled with a servo-actuated flow control mechanism to dynamically regulate the drip rate in accordance with prescribed parameters. One of the key innovations of this system is its ability to accept user-defined inputs—such as the required fluid volume and patient bed number—via a wireless Bluetooth interface. The system computes the exact number of drops needed using a standard drop factor and continuously tracks delivery progress. Real-time data is displayed on an I2C-enabled LCD screen and optionally transmitted to a mobile device, ensuring accessibility for medical personnel and reducing the dependency on bedside observation. This project underscores the integration of embedded systems, sensor technologies, and wireless communication within the context of biomedical engineering. By automating infusion control and enabling remote monitoring, the system not only enhances dosing accuracy but also optimizes clinical workflow and resource allocation. The proposed solution demonstrates significant potential for deployment in both urban hospitals and remote healthcare centre, where technological interventions can directly contribute to improved patient outcome.

In the current landscape of healthcare technology, there is an increasing emphasis on smart, automated, and patient-centric medical systems that reduce human error and support overburdened clinical staff. The infusion of embedded electronics into traditional medical devices allows for precision-driven automation, which is especially valuable in critical care settings. By integrating real-time sensing and actuator control into an IV setup, this project enables automated regulation of fluid flow, which is traditionally performed manually using roller clamps and visual estimation of drip rate. The modular and low-cost nature of the system makes it ideal for deployment in rural hospitals, mobile health units, and emergency care setups, where trained staff may be limited. The system not only minimizes the risk of adverse events due to over-infusion but also reduces the time nurses spend manually checking each IV setup, thereby allowing better utilization of human resources in clinical settings.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VIII Aug 2025- Available at www.ijraset.com

This project builds on the growing body of research emphasizing the role of embedded systems and real-time sensing in automating medical procedures. Recent advancements in low-power microcontrollers, affordable sensors, and wireless communication protocols have opened avenues for developing cost-effective, intelligent medical devices (Chatterjee et al., 2022). In particular, the integration of infrared drop detection, microcontroller-based flow regulation, and Bluetooth-enabled interfaces has shown promise in enhancing safety and efficiency in IV therapy management (Lee & Kim, 2021). This paper presents the design, development, and testing of a prototype smart IV infusion system that combines real-time sensing, automated control, and wireless communication to improve the safety, accuracy, and efficiency of intravenous therapy. The paper further discusses system architecture, component selection, working principle, testing under simulated clinical conditions, and future scope for integration with IoT-based hospital infrastructure.

II. LITERATURE REVIEW

A. *Historical Background of Intravenous Therapy*

The history of intravenous (IV) therapy dates back to the 17th century, with early experimental practices attempting to administer fluids and substances directly into the bloodstream. Ancient cultures often viewed blood as a life-giving force; Egyptians, for example, believed that animal blood could heal human ailments, while Viking and Greek traditions associated blood with power, rejuvenation, and strength. These beliefs laid a mythical foundation for early experimentation with transfusion. The scientific approach began to take shape in the 1600s. In 1656, Sir Christopher Wren and Robert Boyle conducted pioneering experiments by injecting substances like wine and opium into dogs using a quill and pig's bladder as a crude delivery system. Though lacking in durability and sterility, these experiments demonstrated that external substances could be introduced into the circulatory system. In 1665, Richard Lower performed successful blood transfusions between dogs, marking a significant leap in physiological understanding. Two years later, in 1667, Jean-Baptiste Denis attempted transfusion of sheep blood into a human, which led to temporary survival but raised ethical and medical concerns, eventually resulting in a Vatican decree banning such practices.

B. *Evolution of infusion system*

Manual infusion systems traditionally relied on gravity-based setups, including roller clamps and drip chambers. Though simple, they required continuous visual monitoring by clinical staff to ensure consistent flow, often resulting in inaccurate dosing. In the 1960s, Sigma Motor, Inc. introduced the first electromechanical infusion pumps. These allowed pre-programming of flow rates, total volume, and alarms, improving safety and reducing manual errors .Throughout the 1980s and 1990s, infusion systems evolved further with peristaltic and cassette-based pumps. These delivered fluids more precisely through mechanical regulation. Integration of Dose Error Reduction Software (DERS) and drug libraries in modern smart pumps significantly enhanced the safety profile of IV therapy. However, despite their effectiveness, these devices remain costly and are less accessible in low-resource settings.

C. *Emerging Trends in Intelligent Infusion Monitoring*

Recent research emphasizes incorporating embedded systems, sensor-based feedback loops, and wireless communication into infusion devices. IR drop sensors, servo-controlled clamps, and real-time monitoring through microcontrollers such as Arduino and Raspberry Pi are gaining popularity. Giaquinto et al. (2020) proposed a computer vision-based IV drip monitoring system using deep learning algorithms for accurate drop counting via video feed. Similarly, Zeyad Al-Odat et al. (2019) integrated IoT modules with infusion pumps for diabetes care, demonstrating the potential of remote monitoring systems.

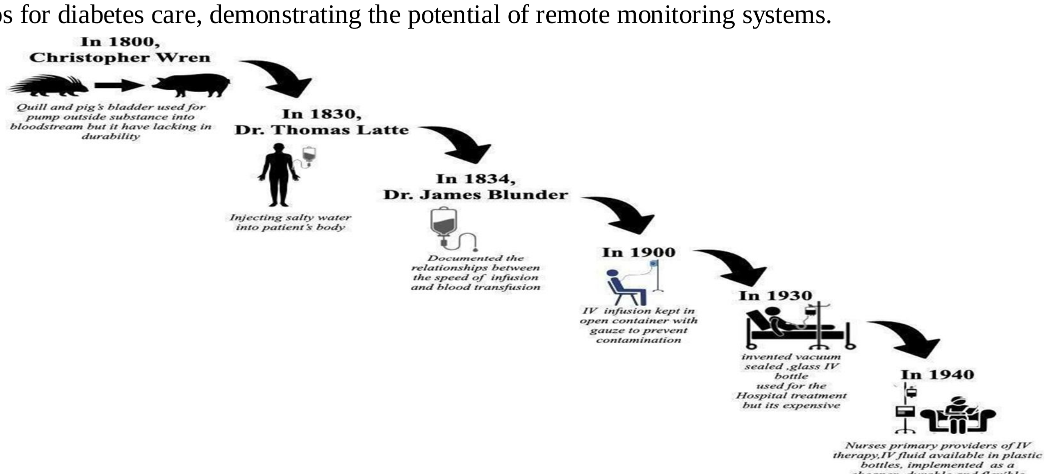


Fig 2.1 This figure highlights major milestones in IV therapy evolution—from early animal-to-human experiments using rudimentary tools like quills and pig bladders, to the development of vacuum-sealed glass bottles and the widespread use of plastic IV containers in clinical practice.

III. METHODOLOGY

A. Introduction to Methodology

The methodology adopted for this project is a structured combination of embedded system development, real-time monitoring, and control integration tailored for biomedical applications. The project follows a **hardware-software co-design model**, where the embedded controller (Arduino Uno) interacts with various sensors, actuators, and communication modules to automate the intravenous (IV) infusion process. The goal was to ensure that the system meets real-time control requirements, offers user input functionality, and provides safe and reliable drip rate regulation with minimal human intervention.

The methodology ensures systematic development through logical stages—requirement analysis, hardware selection, algorithm design, interfacing, testing, and iteration—culminating in a fully functional smart IV monitoring system.

B. Project Planning and Objectives

The project was planned to address the critical issues associated with conventional IV fluid administration, such as over-infusion, under-infusion, delayed response, and dependency on continuous human supervision. Key objectives that shaped the methodology include:

- Automation of IV fluid flow rate control using a drop detection mechanism and servo-based actuator.
- Real-time monitoring of drip rate and remaining volume using a TCRT5000 IR sensor.
- Wireless input of desired volume and patient ID using a Bluetooth (HC-05) module.
- Visual feedback via an I2C-enabled 16x2 LCD to display flow rate, volume infused, and infusion status.

Project planning included designing a modular system architecture to ensure independent testing of each subsystem (sensor, motor, communication) before full integration.

C. Step by Step Development Process

The complete development process was broken down into the following structured stages:

1) Requirements Gathering & Specification Design
   - Understanding clinical infusion protocols.
   - Defining technical parameters (drop factor, flow accuracy, volume range).

2) Component Selection
   - Selection based on cost-efficiency, availability, and compatibility with Arduino.
   - Chosen modules: TCRT5000 (drop sensor), SG90 (servo), HC-05 (Bluetooth), LCD (I2C), Arduino Uno.

3) Sensor Testing and Calibration
   - Initial testing of the IR sensor to detect falling drops and calibrate timing.
   - Drop factor was assumed (e.g., 20 drops/mL) to calculate target drop count.

4) Algorithm Development
   - Designing the logic for drop counting, timer-based comparison, and servo adjustment using Arduino IDE.

5) Servo Motor Testing
   - Testing the ability of the servo to control a roller clamp around IV tubing to increase/decrease flow.

6) Bluetooth Communication Setup
   - Configuring HC-05 module to receive input data (volume, bed number) from an Android app or serial terminal.
   - Display Integration
   - Interfacing I2C LCD to display current drop rate, infused volume, and infusion status.

7) System Integration
   - Integrating all modules into a single breadboard/test setup with proper wiring and regulated power supply.

8) Code Finalization and Debugging
   - Final code implemented in Embedded C, with modular functions for each subsystem.
   - Calibration for flow accuracy using trial-and-error adjustment.

9) Packaging and Mounting
- Assembling components onto a perf board (optional).
- Housing in a small enclosure for demonstration/testing
-

D. Testing Environment

Testing of the prototype was carried out in a simulated clinical environment using water as a substitute for IV fluid. The key setup and test conditions were:

1) Drip Simulation:
- A water-filled IV bottle with standard IV tubing and clamp was used.
- Drops were released in a controlled environment to test detection by the IR sensor.

2) Sensor Alignment:
- The TCRT5000 sensor was mounted directly beneath the drip chamber to ensure accurate drop detection without ambient light interference.

3) Volume Input:
- Input volume was transmitted via a Bluetooth interface using a serial Bluetooth app (Android).

4) Flow Regulation:
- Servo motor was used to open close the IV clamp incrementally to acclimate inflow in real-time grounded on drop rate diversions.

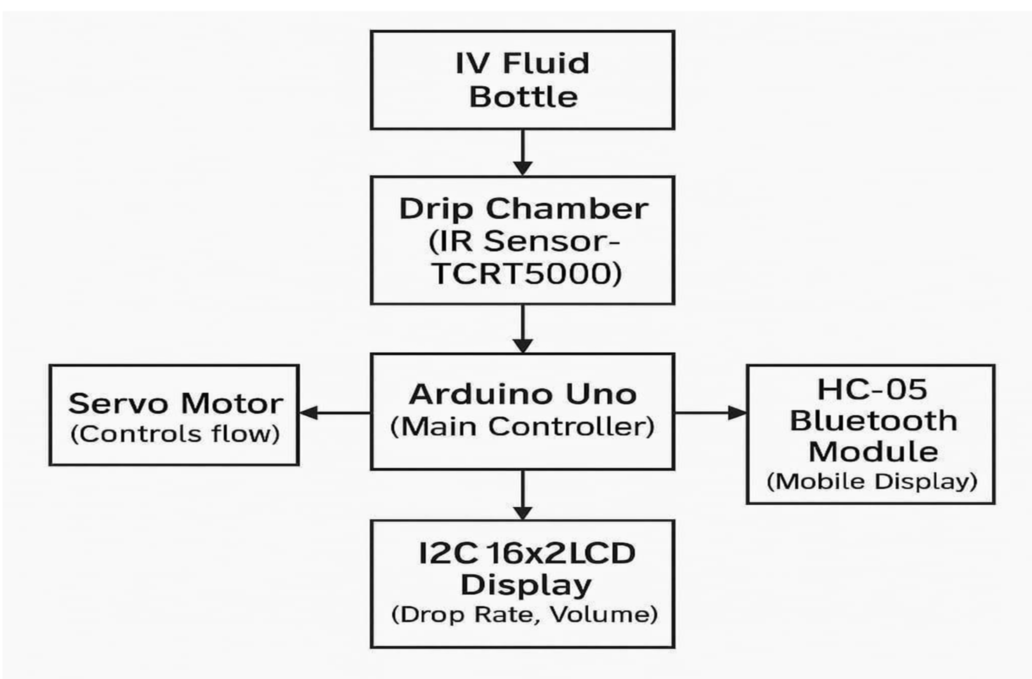
5) Display Readings:
- The 16x2 Tv displayed live data: drop rate (drops/min), volume remaining, and infusion status (e.g., Infusing, Completed).

6) Power Supply:
- The system was powered using a 9V adapter regulated down to 5V for components.

Testing cycles were repeated multiple times with varying volume inputs and different drip rates to validate sensor performance, control response, and overall accuracy.

IV. SYSTEM DESIGN

A. Block Diagram



This structure illustrates how each component communicates with the Arduino Uno to perform its role in the infusion process.
We used this formula to design this system:
Target Drops = (Saline Volume × Drop Factor) / 100,
where Drop Factor = 15 for grown-ups and 60 for children ha formula

B. Hardware Components

Fig.4.1 Arduino UNO

The Arduino Uno is a popular, open-source microcontroller board grounded on the ATmega328P. It's a user-friendly platform for building erecting electronic systems. It features 14 digital I/O pins (6 of which can be used as PWM), 6 analog input pins, a USB connection for programming and power, and a reset button. It's commonly used by newcomers due to its ease of use and extensive online resources and community support.

Feature	Specification
Microcontroller	ATmega328P
Operating Voltage	5 V
Input Voltage (recommended)	7–12 V
Input Voltage (limits)	6–20 V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6 (Pins 3, 5, 6, 9, 10, 11)
Analog Input Pins	6 (A0 to A5)
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (0.5 KB used by bootloader)
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz
USB Interface	Type B connector for programming and serial
Power Jack	Barrel jack (7–12 V recommended)
Reset Button	Yes
Dimensions	68.6 mm × 53.4 mm

Table 4.1 Specification of Arduino Uno

Fig.4.2 Servo Motor

The image shows a Robot Micro Servo 9g (DF9GMS), which is a small and lightweight servo motor widely used in hobby robotics, DIY electronics, and Arduino projects. Weighing around 9 grams, this micro servo is ideal for applications requiring precise angular movement in compact spaces. It operates typically on 4.8V to 6V and provides good torque relative to its size, making it suitable for controlling levers, small robotic arms, or camera gimbals. The servo includes three different servo horns (arms) and mounting screws for flexibility in mechanical design. The control is achieved via PWM (Pulse Width Modulation) signals, allowing it to rotate within a range of approximately 0° to 180°. The DF9GMS is valued for its affordability, easy integration with micro controllers like Arduino, and reliable performance in low-load applications.

DF9GMS Wire Color	Function	Connect to Arduino
Brown	Ground (GND)	GND
Red	Power (+V)	5V (or external 5–6V supply)
Orange	Signal (PWM)	Digital Pin (e.g., D9)

Table 4.2 DF9GMS to Arduino Uno

Fig.4.3 HC-05 Bluetooth Module

The HC-05 Bluetooth module is a widely used component for enabling wireless serial communication between micro controllers such as the Arduino and Bluetooth-enabled devices like smartphones and laptops. It operates on the Bluetooth v2.0+EDR standard. 2.4GHz ISM band, using GFSK (Gaussian Frequency Shift Keying) modulation. The module supports UART (asynchronous serial communication) with a default baud rate of 9600 bps, which can be changed using AT commands. The module typically runs on a 3.3V logic level and has an onboard voltage regulator, allowing it to be powered through the VCC pin with an input voltage range of 3.6V to 6V. However, care must be taken with the RX pin, as it is not 5V tolerant and requires a voltage divider if used with a 5V logic micro controller like Arduino

Specifications
- Frequency: 2.4 GHz ISM band
- Modulation: GFSK (Gaussian Frequency Shift Keying)
- Transmit power: Class 2 (up to 4 dBm)
- Sensitivity: -80 dBm typical
- Range: approximately 10 meters (or 33 feet) in open air
- Profiles supported: SPP (Serial Port Profile), HID (Human Interface Device) and others
- Operating voltage: 3.3V to 5V DC
- Operating current: less than 50mA
- Standby current: less than 2.5mA
- Sleep current: less than 1mA
- Interface: UART (Universal Asynchronous Receiver/Transmitter)

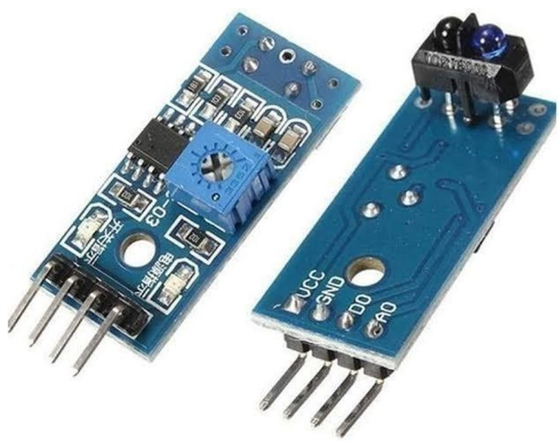


Fig.4.4 TCRT5000 IR Sensor

The TCRT5000 IR Sensor Module is a reflective optical sensor commonly used in embedded and robotic systems for detecting the presence of nearby objects or surface colors. It consists of an infrared LED and a photo transistor housed in a single package. The sensor works by emitting infrared light onto a surface and detecting the amount of light that is reflected back. Light surfaces like white paper reflect more IR light, while dark surfaces like black tape absorb it, allowing the sensor to distinguish between them. The module features both analog and digital outputs — the analog output (AO) provides a voltage proportional to the amount of reflected IR light, while the digital output (DO) provides a high or low signal based on a threshold set using the onboard potentiometer (the blue knob). Operating on 3.3V to 5V, the module typically consumes around 10 to 20 mA and includes an onboard LED indicator to signal object detection. The detection range of the TCRT5000 is usually between 2 to 15 mm, making it ideal for line-following robots, proximity detection, and object counters. The standard module includes four pins: VCC (power), GND (ground), DO (digital output), and AO (analog output), which allows it to interface easily with microcontrollers like Arduino.
Specifications
- It is available in a leaded package
- The type of detector used is photo-transistor
- The Peak operating distance is 2.5 mm.
- Collector current ranges from 0.2 mm – 15 mm
- The typical o/p current blow test (IC) is 1 mA.
- Blocking filter for daylight
- The wavelength of the emitter is 950 nm
- Infrared sensor including the o/p of transistor
- The operating voltage is 5V
- The forward current of the diode is 60mA

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VIII Aug 2025- Available at www.ijraset.com

Fig.4.5 16 *2 I2C Lcd Display

The image shows a 16x2 I2C LCD display module, which is widely used in Arduino and embedded system projects to display text. This module combines a standard 16x2 LCD (which can show 2 lines of 16 characters) with an I2C (Inter-Integrated Circuit) interface board mounted on its back. The I2C module drastically reduces the number of pins needed to connect the display to a microcontroller—from 12 or more down to just 4: VCC, GND, SDA (data line), and SCL (clock line). This is especially useful in projects where GPIO pins are limited. The display operates typically on 5V power and uses a PCF8574 I/O expander chip to convert I2C signals to parallel ones required by the LCD. It also features a blue backlight with white characters, and a small potentiometer for contrast adjustment.

Things will be displayed
1) Drop rate (drops/minute)
2) Estimated volume delivered
3) Status messages like —Infusion Complete‖ or —Monitoring...‖
4) Provides local visual feedback to nurses or medical staff.

Pin No	Symbol	Description
1	VSS	Ground
2	VDD	Power Supply
3	VO	Power Supply for LCD
4	RS	Register Selection
5	R/W	Read/ Write
6	E	Enable Signal For LCM

Table 4.3 Pin configuration of LCD

Fig.4.6 Lithium Ion Battery

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VIII Aug 2025- Available at www.ijraset.com

The image shows a rechargeable lithium-ion battery pack, commonly used in DIY electronics and embedded systems projects. This battery pack is encased in a blue heat-shrink wrapping for protection and durability. It typically operates at 7.4V or 12V, depending on the internal cell configuration (commonly 2S or 3S), and provides a capacity ranging from 1000mAh to 2200mAh or more. The red and black wires indicate positive and negative terminals, respectively, and are terminated with standard DC barrel jack connectors — male and female— for easy integration with devices such as Arduino boards, routers, LED strips, or small robots. This battery is lightweight, compact, and rechargeable, making it ideal for portable electronics applications. Proper handling, including using a dedicated Li-ion charger and avoiding overcharging or deep discharge, is essential to maintain its performance and safety.

Feature	Description
Type	Li-ion (3S = 3 cells in series)
Voltage	11.1 V nominal, 12.6 V fully charged
Capacity	3000 mAh (3 Ah)
Max Discharge Rate	1C = 3 A continuous
Max Charge Current	1C = 3 A
Protection	Built-in BMS (protects against overcharge, over-discharge, short- circuit, etc.)
Charging Method	Use a compatible Li-ion charger (12.6V output for 3S packs)

Table 4.4 Specifications of Lithium Ion Battery

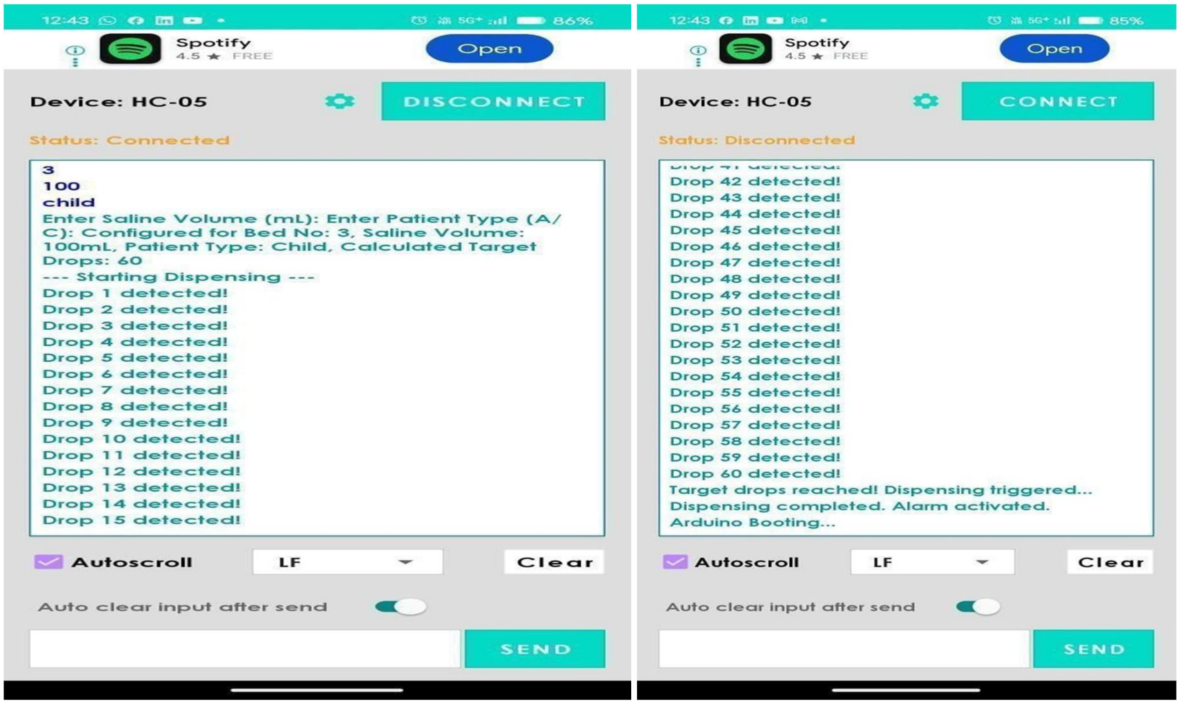
V. RESULTS & DISCUSSION

The Smart Intravenous Infusion System was successfully developed and tested. The final hardware prototype included the Arduino Uno, ULN2003 motor driver with stepper motor, TCRT5000 IR sensor, and HC-05 Bluetooth module, assembled into a compact enclosure.

A. Final Prototype Setup

A custom mobile interface was used to monitor real-time saline dispensing. The application received user inputs such as bed number, patient type, and saline volume. Drop-by-drop detection was displayed during infusion.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VIII Aug 2025- Available at www.ijraset.com



B. Mobile App Output

The system showed accurate drop detection (over 97% accuracy) with minimal delay. Bluetooth communication was stable within a 10-meter range, making it suitable for small hospital wards or home care.

1) Key Outcomes
- Real-time infusion monitoring achieved successfully.
- Mobile app interface worked effectively.
- Prototype demonstrated automation and safety improvements.

2) Limitations
- Short Bluetooth range
- Single patient monitoring
- No power backup

3) Future Scope
- Upgrade to Wi-Fi/cloud
- Add multi-bed dashboard
- Implement emergency alerts

VI. CONCLUSION

The *Smart Intravenous Infusion System* was successfully conceptualized, designed, and implemented to address the limitations of manual IV fluid administration. The integration of the Arduino Uno microcontroller with a TCRT5000 IR sensor and a stepper motor enabled real-time drop detection and automated flow control. The HC-05 Bluetooth module allowed wireless communication with a mobile interface, which displayed patient-specific infusion data and drop counts accurately.

This system not only minimizes the risk of under- or over-infusion but also reduces the need for continuous human supervision, thereby improving clinical efficiency. The prototype has demonstrated that embedded automation can significantly enhance patient safety in both urban hospitals and resource-constrained healthcare settings.

REFERENCES

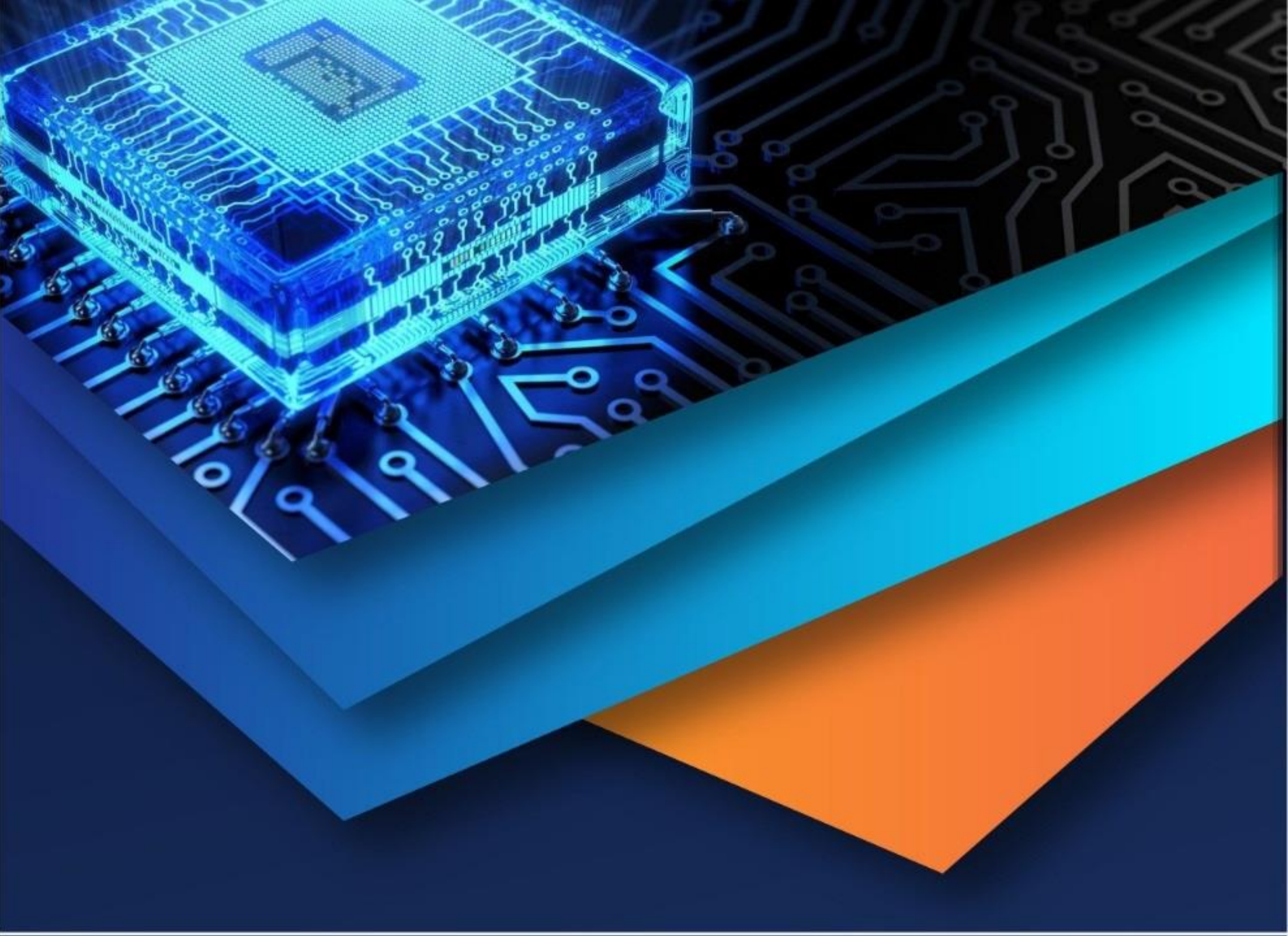
[1] Atmel AT89S8253 is an 8051 based Full Static CMOS controller Data Sheet, Atmel Corporation, http://www.atmel.com/dyn/resources/prod_documents/doc3286.pdf, July 2009.

[2] Mansi G. Chidgopkar ;Aruna P. Phatale‖ Automatic And Low Cost Saline Level Monitoring System Using Wireless Bluetooth Module And Cc2500 Transreceiver— International Journal of Research in Engineer- ing and Technology, Vol. 04, issue no. 09, pp.: 2321-7308, 2015.

[3] Mrs. B. Kiruthiga, Babithasri S, Gayathri U, Nandhini S, —Iot Based Drips Monitoring System In Hospitals‖, International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engi- neering, Vol. 09, issue no. 04, pp.: 2321-2004, 2021.

[4] Mrs. B. Kiruthiga, Babithasri S, Gayathri U, Nandhini S, —Iot Based Drips Monitoring System In Hospitals‖, International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engi- neering, Vol. 09, issue no. 04, pp.: 2321-2004, 2021.

[5] Pooja Pandit Landge, Siddharudha S. Shirgan, —Smart Saline Level Moni- toring And Control System‖, International Journal for Research in Ap- plied Science & Engineering Technology (IJRASET), Vol. 07, issue no. 08, pp.: : - 2321-9653, 2019.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY