

## MEASUREMENT OF INFUSION FLOW RATE USING A DROPLET SENSOR BASED ON ARDUINO UNO

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### ABSTRACT

**[Title: Measurement of Infusion Flow Rate Using A Droplet Sensor Uno Based On Droplet Sensor]** A research has been conducted to help the medical staff in the hospital. The purpose of this study is to calculate and regulate the infusion flow rate of the infusion into the patient's body. This research uses an experimental method. The liquid released from the infusion is converted into droplets, which are then detected by the LM393 optocoupler sensor, which consists of three sensors arranged around the detection area by emitting infrared light through a transmitter to detect the shadow of the droplet so that the signal is received by the receiver of the optocoupler sensor. Which is processed with the Arduino Uno microcontroller. The Arduino Uno provides the results received from the sensor and coded using the Arduino IDE software to be displayed on a 16x2-character Liquid Crystal Display (LCD). The sample used in this study was Sodium Chloride (NaCl). The calibration tools performed were droplet sensor test, servo motor test, and Real Time Clock (RTC) DS3231 module test. The results of the detection in the droplet sensor configuration showed a high degree of accuracy, with an error value of 2.414%. so that this research can be implemented in the detection and appropriate management of infusion flow rates. The current testing being carried out is still on a laboratory scale. However, in the future, this system can be developed to monitor infusions in real-time over a longer period of time and using more complex data processing functions.

Keywords: *Infusion; Optocoupler Sensor; Servo Motor; Flow Rate; RTC DS3231*

### INTRODUCTION

Intravenous infusions or drips are frequently used medical devices. Indiscriminate infusion can have a significant impact on patients according to medical circles. Therefore, infusion control must be performed directly by the nurse, which includes monitoring the rate of infusion and the condition of the remaining infusion in the patient (Sucipta et al., 2021). Infusion therapy involves injecting fluids directly into the patient's blood vessels using a needle or cannula and is used for various medical conditions such as direct therapy, treating dehydration, and maintaining electrolyte balance (Heriana, 2014).

Nearly 90% of hospitalized patients are treated with infusions (Chang & Peng, 2018). The use of infusions in hospitals is still done manually and there are often problems such as administering incorrect doses, poor drip calculations, and delays in changing bottles which can cause death by allowing excessive blood to enter the blood vessels. To overcome this problem, there is a need for a device that can centrally monitor the use of infusions in hospitals, making the nurse's job easier while maintaining personal safety (Blake, J. W. C., & Giuliano, K. K. 2020).

The use of automated infusions can be electronically controlled to provide the correct and measured dose. The drug flow rate can be regulated with a servo motor via a flow controller (Mohammed, Z. K. A., & Ahmed, E. S. A., 2017). However, electronically controlled motor drives can cause physiological effects at low flow rate settings, resulting in inappropriate flow rates (Rao, K. R., & Supriya, K. E., 2020).

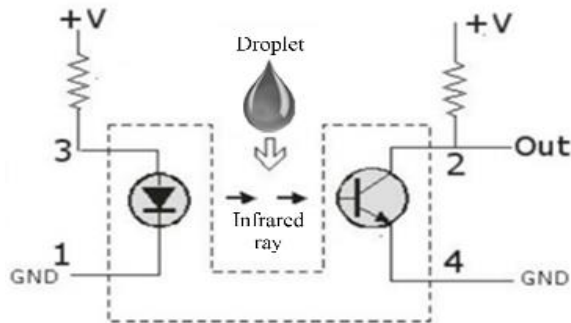
Various studies have been conducted using different detection systems such as gravity sensors (Chen *et al.*, 2015), TDR sensors (Cataldo *et al.*, 2012) and camera sensors (Maaß *et al.*, 2012). These studies achieve a high level of accuracy, but have shortcomings, such as the need for large dimensions and susceptibility to motion interference for gravity sensors, high power consumption when using TDR, and high cost when using camera detectors.

Other studies have also been conducted using learning-based computer vision (Giaquinto *et al.*, 2020), electrodes, and optical sensors (Safitri *et al.*, 2021). However, the data on infusion system parameters required for monitoring, controlling, or notifying the patient's caregivers has not yet been

made available by these investigations. (Syaifudin *et al.*, 2022).

To overcome this problem, a new simpler method of measuring infusion flow rate using an optocoupler sensor has been investigated. This system counts the number of infusion drops to obtain a drip flow rate that can be used for monitoring and control. Measure the number of drops of this infusion. This is done simply by counting pulses from the receiver, but with a high degree of accuracy. If this tool can be developed and sold commercially, it will certainly make the job of nurses much easier.

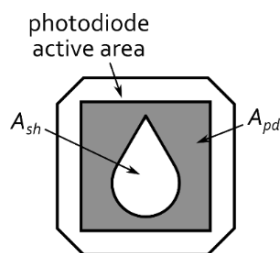
Droplet volume measurements are made by measuring the area of the drop shadow on the optocoupler receiver, as shown in Figure 1.



**Figure 1.** Optocoupler sensor circuit diagram (Source: <https://www.electroschematics.com/arduino-optical-position-rotary-encoder>)

The optocoupler sensor has 4 pins: pin 1 is the cathode, pin 2 is the collector, pin 3 is the anode, and pin 4 is the emitter. The resulting current is inversely proportional to the area of the image produced. The larger the image, the smaller the voltage signal peak produced because the area cut by the image is larger, and vice versa. Meanwhile, the fall time can be obtained from the time interval between the start time of the shadow closing the active area and the end time of the shadow leaving the active area.

Droplet volume measurements were made by measuring the drop shadow area on the photodiode detector as shown in Figure 2



**Figure 2.** Shadow projection on optocoupler

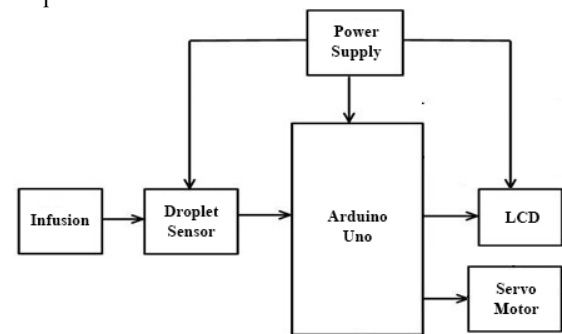
As seen in figure 2, where  $A_{pd}$  is the area of the photodiode,  $A_{sh}$  is the projection of the image

area on the photodiode, The peak of the voltage signal generated will be lower as the size of the shadow increases because the area blocked by the shadow is larger. And vice versa. The fall time, on the other hand, can be calculated by measuring the time it takes for the shadow to enter and leave the active area.

**METHOD**

Monitoring systems can be built around the measurement of droplets, including droplet velocity and droplet volume. Both flow rate and the type of fluid used in the infusion can be determined from these two parameters. By counting the number of droplets in a given period of time, this measurement can be easily calculated. Infrared barrier detectors can be used as digital sensors to count droplets. Only the number of occurrences in a given time period is taken into account, not the signal amplitude or pulse width. In contrast to velocity measurement, volume measurement can be realized by measuring the area of the droplet image on the photodiode. This type of area measurement uses an analog signal from the photodiode detector because there is a relationship between the area of the image and the analog signal. (Umar, L. *et al.*, 2022).

The method used in this research is an experimental method with the help of an Arduino Uno microcontroller and a droplet sensor, where the work steps from start to finish in this experiment follow systematically arranged work steps.



**Figure 3.** Block Diagram

In Figure 3, the input voltage of the power supply used is 220 volts direct current (DC). This tool uses three optocoupler sensors, the system will work when the infrared rays emitted by the transmitter are blocked by an object, which means the infrared rays cannot be detected by the receiver. The receiver sends a signal to the Arduino Uno microcontroller. The output is displayed on the 12x6 LCD in the form of the number of drops/minute. Then, the buzzer will sound when the IV fluid runs out. The servo motor is used as a

machine to drive the roller clamp set, which functions to regulate the amount of infusion fluid that comes out.

The photodiode detector should be wide enough to distinguish droplet size for different nozzle sizes and infusion solutions to measure the shadow area of droplets. This is challenging because few photodiodes have a large sensitive area. A large sensitive area photodiode can be made by building a photodiode array to deal with this situation. To add up the current generated by all the photodiodes, these photodiodes can be connected in parallel. (Umar, L. *et al.*, 2022).

This research began with the preparation and fabrication of a series of tools in the form of droplet sensors. This sensor is made using an optocoupler sensor. Programming is the next step, programming is done using Arduino IDE software. After programming is completed, the sensor is calibrated to test the accuracy of the sensor. Calibration is performed using sodium chloride (NaCl) liquid. Servo motor calibration must be performed to determine the accuracy of clamping the infusion tubing. Data collection cannot be performed until all calibrations have been performed. Data collection was performed by performing 5 experiments. Analysis of the droplets per minute data cannot be performed until the fluid has been tested to draw conclusions.

### Preparation and Production of Tool Sets

Inspection of equipment and materials is performed to ensure readiness and prevent damage. This prototype consists of a frame made of boxes. Inside the box are various components, including an optocoupler sensor and a holder for the infusion set support (drip chamber). At the bottom is a servo motor that is used to clamp the infusion tubing. The Arduino UNO is placed on the back of the box as the main controller. When the optocoupler sensor detects drops, the Arduino will provide information on the LCD display.

The Arduino UNO is the controller for all circuits that receive voltage. The sensor is activated when droplets pass between the transmitter and receiver. The use of a servo motor as a hose clamp when operating this tool is based on information obtained from the optocoupler sensor. The initial position of the servo motor is open to allow infusion flow. Next, the servo moves to increase the angle so that there is no infusion flow in the tubing. Next, the servo is controlled to increase or decrease the opening angle based on data received from the optocoupler sensor.

### Tool Calibration

The calibration process is performed using fluid variations based on the specific density and viscosity of the liquid. The calibration fluid used in this process is sodium chloride (NaCl). As reviewed by Reid Searl (2007), infusion flow can be calculated using the following equation (1):

$$DPM = \frac{\text{Volume (ml)}}{\text{Time (s)}} \quad (1)$$

DPM = Drops Per Minute

Test were performed five times for each fluid type to ensure the accuracy of the data generated. The collected data is the stored and processed using SigmaPlot software.

### Servo Motor Testing

Testing is performed by programming the servo for the number of infusion flow drops. Measurements were performed 5 times with a servo angle interval of 4° for each test to obtain the desired DPM.

### Droplet Calculation

Drip counting is performed using a stopwatch, where the period of each drip is manually calculated by varying the drip settings on the infusion tubing. The LCD screen display the calculation data as the effect of droplets passing through the gap between the transmitter and receiver on the optocoupler. In the case of droplet calculations, we need to find the percentage of error in the tool. The percentage of error can be determined using the equation (2):

$$\% \text{ error} = \left| \frac{\text{testing} - \text{stopwatch}}{\text{stopwatch}} \right| \times 100\% \quad (2)$$

### Data Analysis

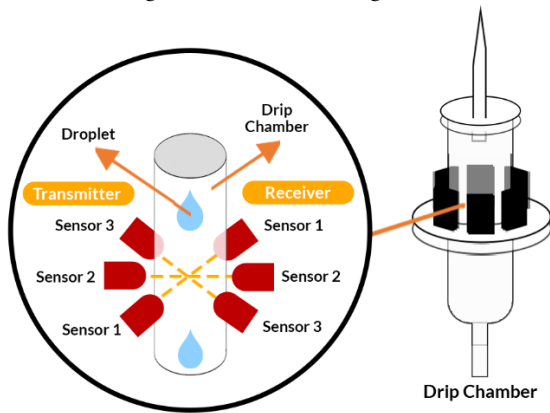
The experimental results are analyzed, and conclusions are drawn from each stage. At this stage, it is observed whether the sensor measurement range is accurate. From this analysis, the level of feasibility of the created droplet sensor design is determined and can be used as a reference for further research as well as to realization of instruments that can be used in health care facilities.

## RESULTS AND DISCUSSION

### Hardware Design

The hardware design will provide a value for the drip rate of the infusion fluid in DPM (Drops Per Minute) units. The design of the Arduino UNO based infusion flow rate control device consists of a framework using sturdy materials such as boxes,

bolts, and other supporting tools. The tool is equipped with an adapter as a power supply to make it easier for users. The physical form of the hardware design tool is shown in Figure 5.



**Figure 4.** Infusion flow rate control device

The physical form of the device in Figure 4 shows an Arduino as the data processing brain, an optocoupler sensor as the infusion drip speed detector, a DS3231 RTC module used as the real-time clock, a buzzer, and an LED as the device indicator. All components are connected to the Arduino UNO using jumper cables.

**Servo Motor Testing**

Servo angle measurements of the number of infusion flow droplets were performed 5 times with a servo angle interval of 4° for each test to obtain the desired drop per minute to draw conclusions. The results of the tests are shown as below.

**Table 1** Servo angle measurement

Test	Servo angle	Drop per Minutes
1	12°	20
2	16°	24
3	20°	28
4	24°	32
5	28°	36

Table 1 shows the relationship between the servo angle and the number of DPM. The drip rate increase by 1 drop per minute for each degree of servo motor movement. The larger the servo angle, the faster the number of drops per minute that occur in the infusion.

**Droplet Calculation**

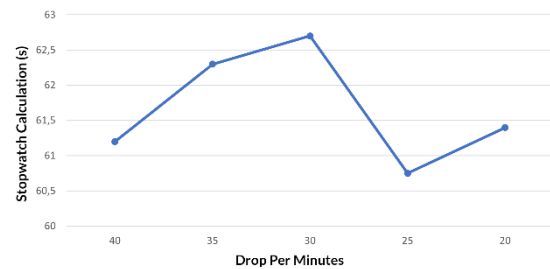
The test was performed by taking samples in the form of sodium chloride (NaCl). The sample was retested five times to ensure consistent and accurate data. The tool used for comparison is a stopwatch to calculate the period of each drop.

Equipment testing data and calibration of liquid droplet velocity measurements using a stopwatch comparison tool can be seen in Table 2:

**Table 2** Droplet sensor test results

Liquid Test	Servo Angle	DPM	Time	Error	
Sodium Chloride (NaCl) 0,9%	1	48°	40	61,2 s	1,96 %
	2	43°	35	62,3 s	3,69 %
	3	38°	30	62,7 s	2,91 %
	4	33°	25	60,7 s	1,23 %
	5	28°	20	61,4 s	2,28 %

The calibration results in Table 2 show the difference in time on the tool by programming and manually using a stopwatch as a comparison, so that the error percentage obtained in the sample is 2.414%, so from the whole experiment, the average accuracy level of the sensor is 97.586%.



**Figure 5.** Droplet sensor test results graph

The graph in Figure 5 shows the results of droplet sensor measurements on sodium chloride samples, comparing the number of drops per minute to stopwatch calculations. The graphs are created with the help of the sigmaplot application.

**CONCLUSIONS**

The system device consists of a servo motor, an RTC module, an Arduino Uno, and three optocoupler sensors arranged around the sensing area. The working mechanism of the device is that the fluid released from the infusion is converted into droplets, which are then detected by a sensor. The detection results are processed by a microprocessor and displayed on a 16x2 LCD screen. The number of droplets is measured by counting the number of droplet periods using a stopwatch. The detection results in the droplet sensor configuration show an average level of accuracy for the sensor of 97.586%. The droplet speed increases by one drop per minute for each degree of servomotor movement, using the arc as a comparison. So, the conclusion is that this tool can be of use because the measurements will be quite accurate.

Inseparable from the shortcomings in both the system design and the devices produced, the appearance of the tool needs to be improved to make it more attractive and increase its aesthetic appeal so that it can be widely commercialized.

#### ACKNOWLEDGEMENT

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