International Journal of Advanced Health Science and Technology
Multidisciplinary : Rapid Review : Open Access Journal e-ISSN:2808-6422; p-ISSN:2829-3037

RESEARCH ARTICLE OPEN ACCESS

Manuscript received May 18, 2022; revised August 20, 2022; accepted August 12, 2022; date of publication August 25, 2022
Digital Object Identifier (**DOI**): https://doi.org/10.35882/ijahst.v2i4.135

How to cite: Yudistira Marsya Puvindra, Arief Marwanto, Eka Nuryanto Budisusila, and Vugar Abdullayev, "Enhancement Drip Dose Infusion Accuracy Based on Optocoupler and Microcontroller Sensor", International Journal of Advanced Health Science and Technology, vol. 2, no. 4, pp. 267–273, Augustus. 2022.

Enhancement Drip Dose Infusion Accuracy Based on Optocoupler and Microcontroller Sensor

Yudistira Marsya Puvindra[1], Arief Marwanto[1], Eka Nuryanto Budisusila[1], and Vugar Abdullayev[2]
[1] Electrical Engineering Study Program, Universitas Islam Sultan Agung, Semarang, 50112, Indonesia
[2] Azerbaijan State Oil and Industry University, Azerbaijan

Corresponding author: Arief Marwanto (e-mail: arief@unissula.ac.id).

"This work was supported in part by Department of Electrical Engineering, Universitas Islam Sultan Agung, Semarang, Indonesia"

ABSTRACT Setting the speed of infusion drops in a manual manner is by adjusting the clamp on the infusion set, where the nurse must count the number of infusion drops in the chamber at the same time as looking at the time on the watch. This makes the setting is subjective and cannot be shown with numbers. In addition, nurses cannot monitor the infusion rate continuously. Therefore, it is necessary to enhancement the accuracy of giving infusion drops so that they can be objective and can be shown with numbers and monitor continuously. This enhancement in accuracy is done by making a instrument with an optocoupler to detect infusion drops. For processing uses an arduino microcontroller to be the speed and the volume of infusion and detects changes in the rate of infusion drops significantly. And for the display uses a OLED display and a buzzer as an indicator. The results of this instrument, it can be seen that the optocoupler can detect infusion drops in the infusion set properly. This good sensor reading has implications for accurate readings of the infusion drop rate and infusion drop volume. This enhancement in accuracy is not only for the macro drip (20 drops/cc) but also for the micro drip (60 drops/cc). The accuracy of volume readings ranges from 95-99% for the macro drip and 94.5-97% with the micro drip. And for speed accuracy ranges from 92.37-98.46%. Based from the results of this test, enhancement the accuracy of the infusion drip dose administration can be done by making a patient infusion drip dose calculator. This equipment uses an optocoupler sensor, arduino microcontroller, OLED display and buzzer. With the use of this instrument, nurses can be more accurate in regulating the rate of infusion drops given to patients and can monitor it continuously if there is a significant change in infusion rate.

INDEX TERMS Arduino, OLED, optocoupler, fluid therapy, infusion drops

I. INTRODUCTION

The organs in the human body are mostly made up of the water element. Lungs (90%), blood (82%), skin (80%), muscles (75%), brain (70%), and bones (20%). Thus, water plays an important role in human life to survive. In some cases, the composition of this fluid can change and harm the condition of the human body. Such as cases of bleeding, dehydration, diarrhea, burns, certain diseases, etc.[1]–[4]

To overcome these cases, a fluid therapy is needed. Fluid therapy itself has the meaning of an act of giving water and electrolytes with or without nutrients. This fluid therapy can use the gravity technique using an infusion set or using mechanical motor movements such as an infusion pump or syringe pump.

All of these fluid therapy techniques cannot be done carelessly. The reason is because there is a dose of liquid that has been prescribed by a doctor to achieve a patient's recovery. Excess or lack of fluid therapy that is given could affect the patient. Starting from the length of the healing process, the worsening of the patient's condition, swelling, shortness of breath and even death. [2], [5], [14], [6]–[13]

Drops per minute (dpm) is used to calculate flow rate of fluid therapy. Thera are two size of infusion set, macro drip and micro drip. Macro drip is use for adult patient, and micro drip for child patient. Macro and micro drip can be called drop factor. Drop factor is the number of drops required to have any volume of 1 ml. Macro drip which is 20 drops/cc and micro drip 60 drops/cc. [15]

The use of an infusion pump and a syringe pump can be said to be the most sophisticated at this time, because the speed of incoming fluid can be adjusted using these instruments. No wonder these instruments are often used for patients in the ICU, VIP or patients with special conditions that require an accurate dose of drug/fluid therapy to be given. As for the usual patient, a manual infusion set that utilizes the force of gravity is used. [16]–[22]

In contrast to infusion pumps and syringe pumps which the dose of fluid therapy is controlled by a motor and monitored by sensors and displays, for manual infusion, the dose setting is done manually. Which is subjective and cannot be shown the exact number. The nurse will adjust the number of drops that are regulated through the clamp on the infusion tube and observe the number of drops that come out of the infusion chamber. The number of drops is counted simultaneously by looking at the watch. So at the same time the nurse must pay attention the infusion chamber and the watch at the same time. This makes the infusion dose adjustment subjective and cannot be demonstrated in exact figures. Likewise with monitoring the speed, the nurse will regularly recalculate the rate of infusion drops manually and it is not possible to do continuous monitoring.. It is feared that the drip rate may change due to obstruction or other reasons.[4], [23]–[25]

There are so many innovations related to fluid therapy, KK Thariyan using 3 sensors but the accuracy level is unknown [23]. Hanna Firdaus, make a central infusion monitor system with volume and droplet detection parameters per minute using the TCRT- 5000 sensor with an error of 4% at a flow rate of 30 ml/s [2]. And many innovation about it, no exception telemonitoring and modified the sensors [3], [4], [7], [19], [23], [24], [26]–[32].

From these problems, it becomes very important to make a drip rate meter for the infusion dose, which can display the number of drops per minutes of the infusion that comes in accurately, and can provide a warning alarm when the drip rate changes drastically with a better approach using an infusion set. So that the setting of the infusion drop rate given by the nurse can be seen with a number that can be accounted for and has an objective value to support the suitability of the dose of infusion drops given to the patient so that the purpose of infusion is achieved maximally.

II. MATERIALS AND METHOD

The method used in the manufacture of an Arduino-based drip dose counter is by describing the device to be made, designing hardware model, system architecture model, designing software model, and designing testing instrument.

A. WORKING PRINCIPLE OF THE SYSTEM

In order to use this instrument, the user must place the main unit into the infusion pole, then place the sensor into the drip chamber to detect infusion drops. Set the desired infusion rate and select the infusion set to use 60 drops/ml or 20 drops/ml. Adjust the infusion rate using roller clamps and observe the screen for the drip rate. Drastic changes in infusion drops will make the sensor sound to inform the nurse to recheck the infusion.

Optocoupler sensor will read the infusion drops and receive it as sampling data to be converted into the infusion drop rate by the microcontroller and will be displayed on the screen. When the infusion drops change drastically, the microcontroller will activate the buzzer.

B. HARDWARE DESIGN MODEL

In designing this hardware model, it can be seen from the block diagram which consists of 3 parts, namely input, process and output. And the workflow and power flow will be explained in FIGURE 1.

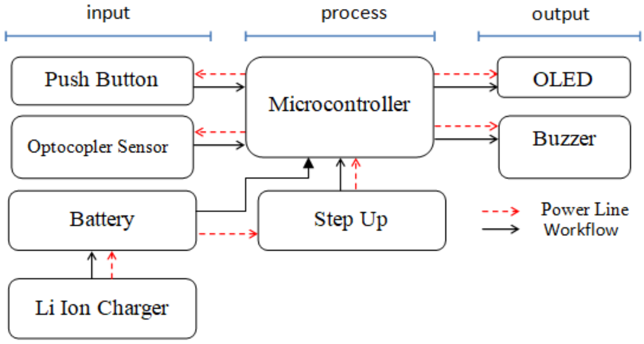

FIGURE 1. Model System Architecture

The input consists of:

1) PUSH BUTTON

This button is used to set the rate of drip infusion and also select the infusion set that is used, either 20 drops/cc or 60 drops/cc.

2) OPTOCOUPLER SENSOR

This sensor is expected to be able to calculate the number of infusion drops which will later be an input to the microcontroller.[33]

3) BATTERY

The battery here supplies voltage to the microcontroller after the voltage is increased by a step up. As well as informing the value of the battery voltage to the microcontroller.

While in the process section, there is microcontroller that functions as follows:

1) Receives input from the sensor
2) Receives input from the battery about the battery voltage condition
3) Counts the number of drops per unit of time (minutes)
4) Recognize a significant changes in the rate of infusion drops
5) Displays the measurement results to the LCD
6) Activates buzzer as a sign of infusion speed change significantly

In the output that receives input from the microcontroller, consists of:

1) OLED

OLED is used to display the rate of drip infusion and the number of drops that have been processed by the program in the microcontroller.

2) BUZZER

The buzzer serves as a marker when the infusion drips and the infusion rate changes significantly.

In addition to the input, process and output sections, there are supporting sections consisting of:

3) STEP UP MODULE

Step up module serves to increase the voltage from 3.7 Volt DC to 5 Volt DC to be used as input voltage from the microcontroller.

4) LI-ION CHARGE MODULE

The Li-Ion Charge module functions to charge the Li-Ion battery so that there is sufficient power for the instruments from the Li-Ion battery.

C. SOFTWARE DESIGN MODEL

Software system instrument is a program that is inserted into the microcontroller so that the microcontroller can work according to the purpose. In designing the software instrument, a flowchart of the program as a whole is made first, then the program code is made in C language using a special application to program Arduino.

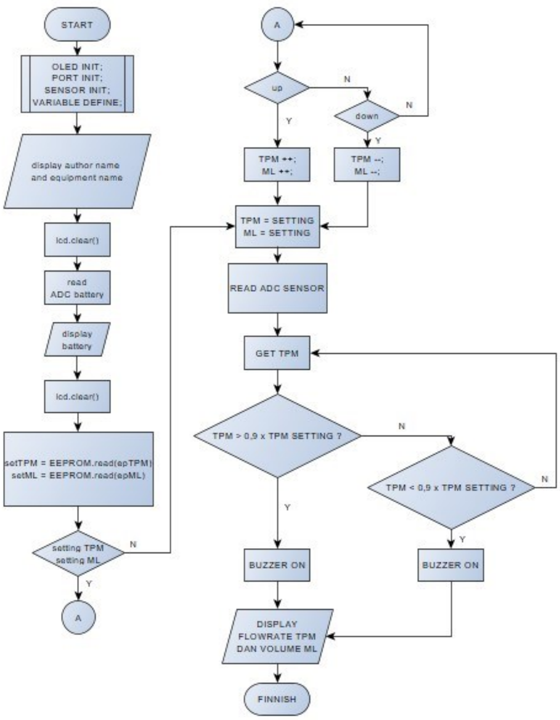

FIGURE 2. Flow Chart Instrument

The flowchart software can be seen in FIGURE 2. And from the flowchart, a program was made using the C language for Arduino. The program used to create Arduino programs is the Arduino Integrated Developer Program (Arduino IDE). The program is a program that can be downloaded for free from www.arduino.cc.

FIGURE 3. An Infusion with main unit and optocoupler sensor

Microcontroller, display OLED, push button and buzzer are in main unit. It is use 1 battery Li-Ion, step up module and Li-Ion charge circuit to support power of unit.

D. TESTING DESIGN INSTRUMENT

After the hardware and software parts are completed, then the next process is testing the instrument as a whole. Tests that will be carried out on the Infusion Dosage Calculator are testing the battery charge circuit, step up, optocoupler, buzzer and testing the function of the instrument (FIGURE 3).

III. RESULTS

A. LI-ION CHARGE CIRCUIT MEASUREMENT

Li-Ion charge circuit measurement is done in a condition of before charge and after charge. The test is carried out by comparing the results of battery voltage measurements with digital multimeter Zotek ZT-X with a voltage value as seen in the data sheet (TABLE 1).

TABLE 1
Measurement Results Of The Li-Ion Charge Circuit

Measurement Condition	Voltage Measurement	Data Sheet	Measurement Difference
Standby	4.093 Volt	4 Volt	0.093 Volt
Charge	4.236 Volt	4.2 Volt	0.036 Volt

In the stand-by condition, the Li-ion charge circuit measured a voltage of 4.093V with a reference value of 4 V. And in a charge condition the measured voltage was 4.236 Volt with a reference value of 4.2 V.

B. STEP UP CIRCUIT MEASUREMENT

Step Up circuit measurement was carried out at module voltage output step up and measurement of the variable resistor value and compared with the voltage value based on the calculation. In step up circuit measured 5.050 V and compared to the results of the calculation by taking into account the measured value of the R variable with a result of 4.98 V.

C. OPTOCOUPLER CIRCUIT MEASUREMENT

The measurement of the optocoupler is carried out at pin 2 microcontroller when the optocoupler detects droplets and does not detect droplets as shown in TABLE 2.

TABLE 2
Measurement Results of The Optocoupler

Condition	Pin2 Voltage
There is Liquid	0 Volt
No Liquid	4.31 Volt

Measurements on pin 2 of the microcontroller produce a voltage of 4.31 Volt when there is no liquid and 0 Volt when there is liquid.

D. BUZZER CIRCUIT MEASUREMENT

Buzzer circuit measurement done on pin 9 microcontroller when the buzzer sounds and when the buzzer off as shown in TABLE 3.

TABLE 3
The Results of The Measurement of The Buzzer Circuit

Condition	Pin 2 Voltage
Buzzer Sounds	5.04 Volt
Buzzer Off	0 Volt

Measurements on pin 9 of the microcontroller generated a voltage of 5.04 Volt when the buzzer sounded and 0 Volt when the buzzer was off.

E. MEASUREMENT OF INFUSION DOSAGE VOLUME WITH MEASURING CUP CALIBRATION

The measurement volume of the infusion dose was carried out using a measuring cup which was seen when the glass showed 1ml, 2ml, 3ml, 4ml, 5ml using a drip factor of 20 drops/ml and 60 drops/ml then compared with the readings of the instrument as shown in TABLE 4.

TABLE 4
Analysis Of The Measurement Volume Of The Infusion Dose Factor Of 20 drops/ml

Measuring Cup Reading Volume (ml)	Instrument Reading Volume (ml)	Difference (ml)	Acc.
1	1.05	0.05	95%
2	2.05	0.05	97.5%
3	3.05	0.05	98.34%
4	4.05	0.05	98.75%
5	5.05	0.05	99%

TABLE 4 shows the difference between the readings of the instrument and the measuring cup at 0.05 ml for each measured value. The accuracy of the instrument for speed readings ranges from 92.37-98.46%. This can be caused by the infusion speed that changes suddenly and affects the speed reading on the device, because it uses a sampling method of 3 drops of speed and is used as a reading of the speed of drops per minute of the instrument.

TABLE 5
Analysis of The Measurement Volume of The Drip Factor Infusion Dose of 60 drops/ml

Measuring Cup Reading Volume (ml)	Instrument Reading Volume (ml)	Difference (ml)	Accuracy
1	0.97	0.03	97%
2	1.89	0.11	94.5%
3	2.91	0.09	97%
4	3.86	0.14	96.5%
5	4.79	0.21	95.8%

In TABLE 5, it can be seen that the difference between the readings of the instrument and the measuring cup ranges from 0.03 – 0.21 ml. Furthermore, the percentage of accuracy ranges from 94.5 to 97%.

F. MEASUREMENT OF INFUSION DRIP SPEED

The measurement of the drip rate of the infusion is done by comparing the speed of the drip infusion that is read by the instrument on the diplay with the speed of manual calculation with a stopwatch for 60 seconds (TABLE 6).

TABLE 6
The Results of The Measurement Infusion Drip Speed

Testing	Flow Rate by instrument (dpm)	Flow Rate by stopwatch (dpm)	Difference (dpm)
I	16	17	1
II	24	26	2
III	36	38	2
IV	44	49	5
V	64	65	1

IV. DISCUSSION

A. ANALYSIS OF THE LI-ION CHARGE CIRCUIT TEST RESULTS

From the Li-Ion charge circuit results presented in TABLE 1, the results of the Li-Ion charge circuit measurement before charging using a multimeter are 4.093 V while the information according to the datasheet is 4 V. From the difference in values, the absolute error obtained is 0.093 V with the relative error of voltage measurement is:

$$Relative\ error = \left[\frac{0.093V}{4V}\right]x100\%$$

$$Relative\ error = 2.325\%$$

Meanwhile the results of measuring the voltage of the Li-Ion charge circuit when charging using a multimeter is 4.236 V while the information according to the datasheet is 4.2 V. From the difference in values, an absolute error of

0.036 V is obtained with a relative error of voltage measurement is:

$$Relative\ error = \left[\frac{0.036V}{4.2V}\right] x100\%$$
$$Relative\ error = 0.857\%$$

The difference value can be caused by the condition of the components in the circuit. But the relative error value is still quite low.

B. ANALYSIS OF THE STEP UP CIRCUIT TEST RESULTS

From the results of the measurement of the V_{out} voltage are 5.050 V, with a R1 value of 89.8 K Ohms and a total series R3 value of 12.3 K Ohms. So that the calculated V_{out} value is 4.98 V. From the difference in values, an absolute error of 0.07 V is obtained with the relative error of voltage measurement is:

$$Relative\ error = \left[\frac{0.07V}{4.98V}\right] x100\%$$
$$Relative\ error = 1.405\%$$

The difference value can be caused by the tolerance value of the resistor and the condition of the components in the circuit. But the relative error value is still quite low.

C. ANALYSIS OF THE OPTOCOUPLER CIRCUIT TEST RESULT

From the results of testing the optocoupler, the measurement of the incoming voltage to the microcontroller are 4.31 V to make it have the ability to detect the presence of dripping liquid. The voltage is enough to give a High or 1 on the microcontroller.

D. ANALYSIS OF THE BUZZER CIRCUIT TEST RESULTS

From the results of testing the buzzer circuit presented in TABLE 3 the results of the measurement of the incoming voltage to the buzzer are 5.04 V to activate the buzzer. The voltage is sufficient to activate the buzzer with a normal voltage required of 3-5 V.

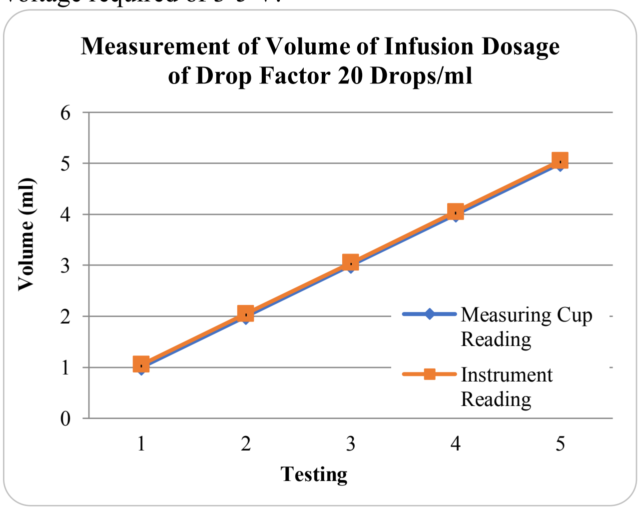

FIGURE 4. Graph of the Measurement of Volume of Infusion Dosage of Drop Factor 20 Drops/ml

E. ANALYSIS OF THE VOLUME INFUSION DOSAGE

The volume infusion dosage test results are carried out using 1 type of infusion set and using a 10 ml measuring cup which is placed at the end of the infusion outlet after the device is started to run.

In TABLE 4, it is known that the accuracy value of the instrument for volume reading with a drop factor of 20 is at a value of 95-99%. With a difference of 0.05 for each measurement. With the comparison of the graph in FIGURE 4. This could be due to an excess of 1 drop when the instrument has been pressed to start but the end of the infusion has not yet entered the measuring cup, or it is caused by an incorrect sensor reading.

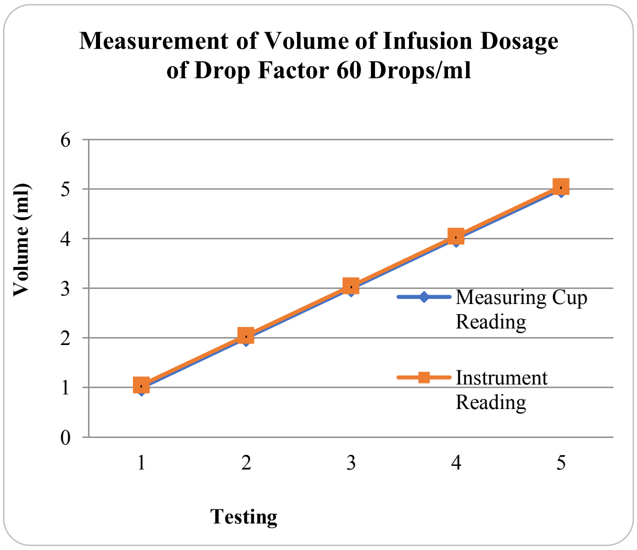

FIGURE 5. The Measurement of Volume of Infusion Dosage of Drops Factor of 60 Drops/ml

In TABLE 5, it is known that the accuracy value of the instrument for volume reading with a drop factor of 60 is at a value of 94.5-97%. And the comparison of the chart reading of the instrument with the measuring cup is shown in FIGURE 5. This could be because the drops in the infusion set chamber are not the same as the drops at the end of the infusion set tube. The drip at the end of the infusion set drips every 3 drops in the chamber. In addition, the volume of each 1 drop of infusion with a drop factor of 60 is 0.01666667 ml/drop while the value displayed on the device is only 2 digits behind the comma, thus allowing for discrepancies in readings that are not displayed.

F. ANALYSIS OF THE INFUSION DROP RATE TEST RESULTS

The results of the infusion drip rate test are compared with the method of counting the number of drops for 1 minute which becomes the real drip rate per minute (dpm) reading.

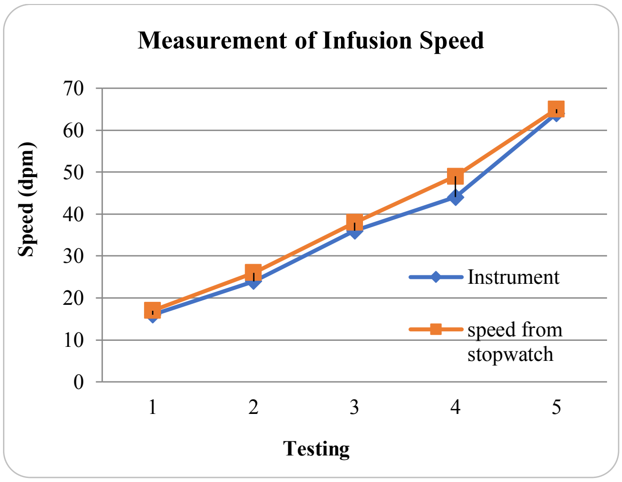

FIGURE 6. Measurement of Infusion Speed

In TABLE 6, it is known that the accuracy of the instrument for speed readings ranges from 92.37-98.46% and the comparison of the graph in FIGURE 6. This can be caused by the infusion speed that changes suddenly and affects the speed reading on the device, because it uses a sampling method of 3 drops of speed and is used as a reading of the speed of drops per minute of the instrument.

V. CONCLUSION

Increasing the accuracy of drip infusion doses can be done by making a patient infusion drip counter with an optocoupler sensor placed in the drip chamber infusion set which provides an input signal to the arduino microcontroller. With an accuracy of reading the volume infusion drops 95-99% with the macro drip and 94.5-97% with the micro drip. This accuracy can be improved if in the future a wider range of numbers is displayed. And the reading of the measurement of the volume of the infusion drops will be the same as the infusion output to the patient if the infusion set used is in accordance with the drop factor specifications listed on the infusion set packaging. Because the author had found several brands of infusion sets that did not match the drop factor specifications listed on the infusion set packaging. In addition, at the infusion set micro, the tip of the infusion drips every 3 drops in the drip chamber.

And the appearance of the number of infusion drops can be done by processing the optocoupler sensor readings on the Arduino microcontroller and displayed on the OLED display and turning on the buzzer when the speed reading changes drastically. With an accuracy of 92.37-98.46% speed reading. This accuracy is highly dependent on the position of the sensor in the chamber. And for certain brands of infusion sets, the chamber size can be larger or smaller. So it is necessary to design an optocoupler sensor with a design that can be placed well in all brands for the future.

REFERENCES

[1] A. P. Pudji, A. M. Maghfiroh, and N. Thongpance, “Design an Infusion Device Analyzer with Flow Rate Parameters using Photodiode Sensor,” *Indones. J. Electron. Electromed. Eng. Med. informatics*, vol. 3, no. 2, pp. 39–44, 2021, doi: 10.35882/ijeeemi.v3i2.1.

[2] H. Firdaus, B. G. Irianto, Sumber, and J. Lu, “Analysis of the Drop Sensors Accuracy in Central Peristaltic Infusion Monitoring Displayed on PC Based Wireless (TCRT5000 Drop Sensor),” *J. Electron. Electromed. Eng. Med. Informatics*, vol. 4, no. 1, pp. 42–49, 2022, doi: 10.35882/jeeemi.v4i1.5.

[3] N. Sholihah, A. Kholiq, and S. Sumber, “Monitoring Infusion Pump Via Wireless (Occlusion part),” *Indones. J. Electron. Electromed. Eng. Med. informatics*, vol. 2, no. 1, pp. 34–41, 2020, doi: 10.35882/ijeeemi.v2i1.7.

[4] D. D. Damayanti, H. G. Ariswati, I. D. G. Wisana, and H. Winarno, “Automatic Dehydration Level Detection Devices,” *Indones. J. Electron. Electromed. Eng. Med. informatics*, vol. 2, no. 2, pp. 87–94, 2020, doi: 10.35882/ijeeemi.v2i2.5.

[5] N. Jannah, S. Syaifudin, L. Soetjiatie, and M. Irfan Ali, “Simple and Low Cost Design of Infusion Device Analyzer Based on Arduino,” *Indones. J. Electron. Electromed. Eng. Med. informatics*, vol. 2, no. 2, pp. 80–86, 2020, doi: 10.35882/ijeeemi.v2i2.4.

[6] F. A. D. Saputra, B. Utomo, S. Sumber, and M. Shahriar Arefin, “Development of Measuring Device for Non-Invasive Blood Sugar Levels Using Photodiode Sensor,” *Indones. J. Electron. Electromed. Eng. Med. informatics*, vol. 2, no. 2, pp. 74–79, 2020, doi: 10.35882/ijeeemi.v2i2.3.

[7] M. Taylor and R. Jones, “Risk of Medication Errors With Infusion Pumps,” *Patient Saf.*, no. December, pp. 61–69, 2019, doi: 10.33940/biomed/2019.12.7.

[8] K. Wright, “Do calculation errors by nurses cause medication errors in clinical practice? A literature review,” *Nurse Educ. Today*, vol. 30, no. 1, pp. 85–97, 2010, doi: 10.1016/j.nedt.2009.06.009.

[9] J. I. Westbrook, M. I. Rob, A. Woods, and D. Parry, “Errors in the administration of intravenous medications in hospital and the role of correct procedures and nurse experience,” *BMJ Qual. Saf.*, vol. 20, no. 12, pp. 1027–1034, 2011, doi: 10.1136/bmjqs-2011-000089.

[10] N. R. Hardiker and S. Bakken, “Requirements of tools and techniques to support the entry of structured nursing data,” *Stud. Health Technol. Inform.*, vol. 107, no. June 2014, pp. 621–625, 2004, doi: 10.3233/978-1-60750-949-3-621.

[11] P. Y. Han, I. D. Coombes, and B. Green, “Factors predictive of intravenous fluid administration errors in Australian surgical care wards,” *Qual. Saf. Heal. Care*, vol. 14, no. 3, pp. 179–184, 2005, doi: 10.1136/qshc.2004.010728.

[12] D. H. Cousins, B. Sabatier, D. Begue, C. Schmitt, and T. Hoppe-Tichy, “Medication errors in intravenous drug preparation and administration: A multicentre audit in the UK, Germany and France,” *Qual. Saf. Heal. Care*, vol. 14, no. 3, pp. 190–195, 2005, doi: 10.1136/qshc.2003.006676.

[13] F. Report, “Critical Paths for Creating Data Platforms: Patient Safety: Intravenous Infusion Pump Devices,” p. 93, 2012.

[14] P. T. Lee, F. Thompson, and H. Thimbleby, “Analysis of infusion pump error logs and their significance for health care.,” *Br. J. Nurs.*, vol. 21, no. 8, pp. S12, S14, S16-20, Apr. 2012, doi: 10.12968/bjon.2012.21.Sup8.S12.

[15] U. of S. Australia, “Drops per minute (DPM) - Worksheet,” pp. 1–4.

[16] S. Syaifudin, M. Ridha Mak’ruf, S. Luthfiyah, and S. Sumber, “Design of Two Channel Infusion Pump Analyzer Using Photo Diode Detector,” *Indones. J. Electron. Electromed. Eng. Med. informatics*, vol. 3, no. 2, pp. 65–69, 2021, doi: 10.35882/ijeeemi.v3i2.5.

[17] C. B. Putra, H. G. Ariswati, S. Sumber, and M. Zahar, “Automatic Blood Collection and Mixer in a Blood Transfusion System Equipped with Barrier Indicators,” *Indones. J. Electron. Electromed. Eng. Med. informatics*, vol. 2, no. 2, pp. 60–67, 2020, doi: 10.35882/ijeeemi.v2i2.1.

[18] M. P. Assalim T P, D. Titisari, W. Caesarendra, and B. A. Prakoso, “Analysis of the Effect of Red LED and Infrared Flip Flop Frequency on SpO2 Measurement Accuracy,” *Indones. J. Electron. Electromed. Eng. Med. Informatics*, vol. 4, no. 2, pp. 62–67, 2022,

doi: 10.35882/ijeeemi.v4i2.3.

[19] A. G. Anjani *et al.*, "Application of IoT Using nodeMCU ESP8266 on the Syringe Pump Device to Increase Patient Safety," *Indones. J. Electron. Electromed. Eng. Med. Informatics*, vol. 4, no. 1, pp. 23–27, 2022, doi: 10.35882/ijeeemi.v4i1.4.

[20] K. K. Giuliano and C. Niemi, "The urgent need for innovation in I.V. Smart pumps," *Nurs. Manage.*, vol. 46, no. 3, pp. 17–19, 2015, doi: 10.1097/01.NUMA.0000461066.79777.06.

[21] M. Husch *et al.*, "Insights from the sharp end of intravenous medication errors: Implications for infusion pump technology," *Qual. Saf. Heal. Care*, vol. 14, no. 2, pp. 80–86, 2005, doi: 10.1136/qshc.2004.011957.

[22] E. T. Pierce, V. Kumar, H. Zheng, and R. A. Peterfreund, "Medication and volume delivery by gravity-driven micro-drip intravenous infusion: potential variations during 'wide-open' flow.," *Anesth. Analg.*, vol. 116, no. 3, pp. 614–618, Mar. 2013, doi: 10.1213/ANE.0b013e31827bc235.

[23] E. D. Kurniawan, A. Adam, M. I. Salik, and P. L. Gareso, "Programmable Syringe Pump for Selective Micro Droplet Deposition," *J. Elektron. dan Telekomun.*, vol. 19, no. 2, p. 75, 2019, doi: 10.14203/jet.v19.75-82.

[24] S. Zheng, Z. Li, and B. Li, "The design of liquid drip speed monitoring device system based on MCU," *AIP Conf. Proc.*, vol. 1864, no. August, 2017, doi: 10.1063/1.4992940.

[25] V. Wirtz, "9-Wirtz2003 (9)," 2003.

[26] L. F. Wakidi, K. Maulidya S. P, and M. Nosike, "Electronic Infusion Flow Regulator with Occlusion Detection," *J. Teknokes*, vol. 15, no. 1, pp. 14–20, 2022, doi: 10.35882/teknokes.v15i1.3.

[27] T. Mulyono and U. Faruq, "Desain Pompa Multi Syringe Untuk Analisa Sistem Alir D esign of Multi Syringe Pump for Flow System Analysis," vol. 14, no. 1, pp. 17–21, 2013.

[28] M. C. Layson, "Intravenous (IV) monitoring and refilling system," *Int. J. Eng. Adv. Technol.*, vol. 9, no. 1, pp. 3038–3043, 2019, doi: 10.35940/ijeat.A1613.109119.

[29] K. K. Thariyan, S. Verma, S. R. Taneja, R. C. Gupta, and S. S. Ahluwalia, "Design and development of a unique drop sensing unit for infusion pump," *J. Sci. Ind. Res. (India).*, vol. 61, no. 10, pp. 798–801, 2002.

[30] K. K. Giuliano, "IV Smart Pumps: The Impact of a Simplified User Interface on Clinical Use," *Biomed. Instrum. Technol.*, no. December, pp. 13–21, 2015, doi: 10.2345/0899-8205-49.s4.13.

[31] D. Qiliang, L. Jianhao, and T. Lianfang, "Simulation and Design of Intravenous Infusion Dripping Rate Detection based on Infrared Ray," *Proc. 3rd Int. Conf. Multimed. Technol.*, vol. 84, no. Iv, pp. 918–925, 2013, doi: 10.2991/icmt-13.2013.113.

[32] S. Hossain, S. Sharmin, T. Faruk, and M. K. Islam, "Low-Cost Digitization of Infusion Pump for Real-time Automated Flow Rate Monitoring and Warning," *ICIET 2019 - 2nd Int. Conf. Innov. Eng. Technol.*, pp. 23–24, 2019, doi: 10.1109/ICIET48527.2019.9290599.

[33] P. Saputra, Syamsuddin, and Hiden, "Indonesian Physical Review," *Indones. Phys. Rev.*, vol. 4, no. 1, pp. 43–50, 2021.