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Accuracy of Infrared Photodiode Sensors at The Flowrate Measurement in Infusion Device Analyzer with 2 Channel TFT Display

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ABSTRACT Infusion is a medical procedure involving the delivery of fluids, medications, nutrients, or other substances into a patient's circulatory system through intravenous flow. In its implementation, commonly used infusion tools are infusion pumps and syringe pumps, as these devices assist in accurately and precisely controlling the flow rate. However, with continuous usage, there is a potential for inaccuracies in measuring the flow rate of fluids from these devices. Therefore, periodic calibration is necessary. According to Regulation No. 54 of 2015 from the Ministry of Health, calibration of medical devices, including infusion devices, must be conducted at least once a year to ensure their ongoing accuracy. The purpose of this research is to design an Infusion Device Analyzer (IDA) with a flow rate parameter. The contribution of this research is that the tool can accurately calculate the correct value of the flow rate that comes out of the infusion pump and syringe pump. One of the innovations resulting from this study is the Infusion Device Analyzer, equipped with a 7-inch TFT LCD screen that displays graphical parameters of the flow rate. This is achieved through the use of Infrared Photodiode sensors, which measure the rate of fluid flow. The performance graph displayed on the TFT LCD can visualize the stability of fluid flow when using various types of devices like syringe pumps and infusion pumps. The results of this research show a range of error values in the performance of various brands of infusion devices. When using the Terumo Syringe Pump, there is an error value of 0.86% (100 mL/h) for Channel 1 and 0.69% (100 mL/h) for Channel 2. For the B-Braun Syringe Pump, the error value is 1.30% (100 mL/h) for Channel 1 and 0.85% (10 mL/h) for Channel 2. For the Terumo Infusion Pump, the error value is 0.46% (50 mL/h) for Channel 1 and 0.82% (10 mL/h) for Channel 2. Finally, for the B-Braun Infusion Pump, the error value is 0.90% (10 mL/h) for Channel 1 and 1.70% (50 mL/h) for Channel 2. The development of technology like the Infusion Device Analyzer (IDA) holds the potential to enhance accuracy and ease in measuring the performance of infusion devices. With graphical displays and real-time accessible data, medical professionals can more effectively monitor fluid flow in patients. Additionally, IDA's ability to transmit data via Bluetooth to other devices like PCs and Delphi programs facilitates further analysis and monitoring. In conclusion, infusion is an important medical procedure that utilizes infusion tools such as infusion pumps and syringe pumps to administer fluids and other substances into the patient's body. Periodic calibration is crucial to ensure the accuracy of infusion device performance. Innovations like the Infusion Device Analyzer have the potential to enhance monitoring and accuracy in measuring fluid flow in patients, thereby improving the quality of medical care. The results obtained from this study can be implemented for the calibration of the infusion pump and the syringe pump so that it can be determined whether the device is suitable or not.

INDEX TERMS Infrared Photodiode Sensor, Calibration, Real Time, Flow Rate.

I. Introduction

Delivering medications and fluids intravenously is a common practice in modern medical procedures. Administering medications or fluids directly into a patient's blood circulation results in a predictable and immediate absorption of the drug or fluid administered, this may play a vital role in the treatment of certain acute conditions which require immediate action by drugs or fluids.[1] One of the healthcare service provided in hospitals is intravenous therapy, known as an infusion. Infusion is a very important and basic treatment.[2] Infusion is performed for patients who urgently need medication or require a continuous and slow administration of fluids due to dehydration. [3] Infusion is a chemical liquid infused through the bloodstream via the intravenous route over a certain period.[4] One of the infusion devices used is the infusion pump and syringe pump. The infusion pump is one of the developments of medical devices that automatically enter intravenous fluids into the patient's body. [5] An infusion pump is used to deliver medications and nutrients to the patient. They might

include insulin, blood plasma,chemotherapy drugs and other hormones.[6] The most important element in the infusion pump is a system for controlling the droplet speed of intravenous fluids using an electronically controlled pumping mechanical system. [7] A syringe infusion is a medical apparatus used for the delivery of nourishment and drugs in a precised and controlled amount intravenously. [8]
These devices are important for accurately control of the flow tests, and in some instances volume, occlusion pressure tests and air in the line as well.[9] 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. [10] However, these medical device can sometime have inaccurate measurements. In some hospitals, the infusion is still done manually, where medical personnel observe the liquid droplets directly and then control the rate using a mechanical resistor (clamp). This method is certainly far from accurate. An infusion pump is a medical aid that functions to control and ensure the correct dose of infusion fluid given to patients treated. [11] Using an infusion pump or syringe pump for a long time will affect the precision and accuracy of the tool, which can result in compression due to the presence of air bubbles, causing disruption to the flow rate setting.[12] Failure to calibrate the infusion pump and syringe pump may result in the patient receiving the incorrect dose. Errors associated with the administration of medications through intravenous infusion pumps to critically ill patients can result in adverse drug events.[13] According to Regulation No. 54 of 2015 of the Ministry of Health, calibration is the process of determining the accuracy of a measuring instrumen by comparison with an established standard.[14] And although during manufacturing process, various international and national regulations such as IEC 60601-Medical electrical equipment: General requirements for basic safety and essential performance of medical devices.[15] This procedure ensures traceability of the measurements, being needed to calibrate the IDA using appropriate methods.[16] Healthcare devices, including infusion pumps and syringe pumps, must be calibrated at least once a year as continued use may degrade their accuracy. Calibration of these devices can be performed using an infusion device analyzer (IDA), flow measurement and occlusion. [17]

In a study by Thongpance and Pititeeraphab, the acceptable standard error for pump flow rate and volume, based on ECRI guidelines (2001), is ≤ 5% for critically ill patients and ≤ ± 10% for general patients. The study used a load cell sensor to measure volume and average flow rate in real-time with a 16x2 LCD character display. [18] in 2020 the study of Comparison of Flowrate and Occlusion in a Vertical Infusion Pump and Horizontal Infusion Pump presented Infusion pump droplets can be controlled and monitored using infrared sensors.[19] A study by Syaifuddin et all used an STM32 microcontroller with photodiode and infrared sensor installed in the chamber to read flow rate.[20] The device integrates a 16x2 character LCD display. Another study conducted in 2021 by Andjar Pudji, Anita Miftahul Maghfiroh, and Nuntachai Thongpance used a sensor coupled to a photodiode to detect infusion droplets.[21] The signal was amplified using a UA741 comparator and a NE555 monostable circuit. Flow rate and residual volume readings were generated by an Arduino Nano, and the measurement results are displayed in realtime on the TFT display with the ability to save data to an SD card. [22] the study by Farisadina Tyagita designed an instrument analyzer. Infusion use an infrared photodiode sensor to display graphical time representation of actual flow parameters over time and numerical average on a PC via Microsoft Excel. However, this study did not use TFT screens. In the most recent study by Anisa Rahma Astuti in 2022, the study used the developd process and congestion sensor with real time graphical display on 2 channel TFT LCD.[23] This make it easy for user to analyze rate stability in an infusion set used with an infusion pump or syringe pump in real time.

Based on the above identified problems and within the specified limits, the researchers have previously equipped devices for real-time flow rate graphs correction and flow data storage. The use of graphs is important to demonstrate that the syringe settings and IDA readings are within tolerance. The Chart serve as a monitoring tool based on data activity. Therefore, their use was necessary in this study to observe a constant flow rate and the time taken to reach the specified setting.

The accuracy of the device can be determined by the module of the sensor used, the location of the sensor, and the device's detection settings. therefore, the author intends to develop a device called the ACCURACY OF INFRARED PHOTODIODE SENSOR ON FLOWRATE MEASUREMENT IN INFUSION DEVICE ANALYZER 2-CHANNEL TFT DISPLAY. This module utilizes an Arduino Mega as its controller and integrates a 7-inch TFT LCD screen to efficiently display measurement results in both numerical and graphical formats. Furthermore, the module has the capability to perform data acquisition up to six times for each configuration. Moreover, the specially designed Arduino program provides the capability to transmit data to the Delphi program, serving the purpose of visualizing and analyzing data. This collected data can also be adequately stored in the Microsoft Excel format. And The research findings indicate that the module performs well, as it accurately measures and compares flow rates using various brands of syringe pumps and infusion pumps, as well as different infusion sets and syringes. The smallest error was observed in the module using the Terumo Syringe Pump at a setting of 10 ml/h in Channel 2, with an error value of 0.12%. On the other hand the highest error was observed in the module using the B-Braun

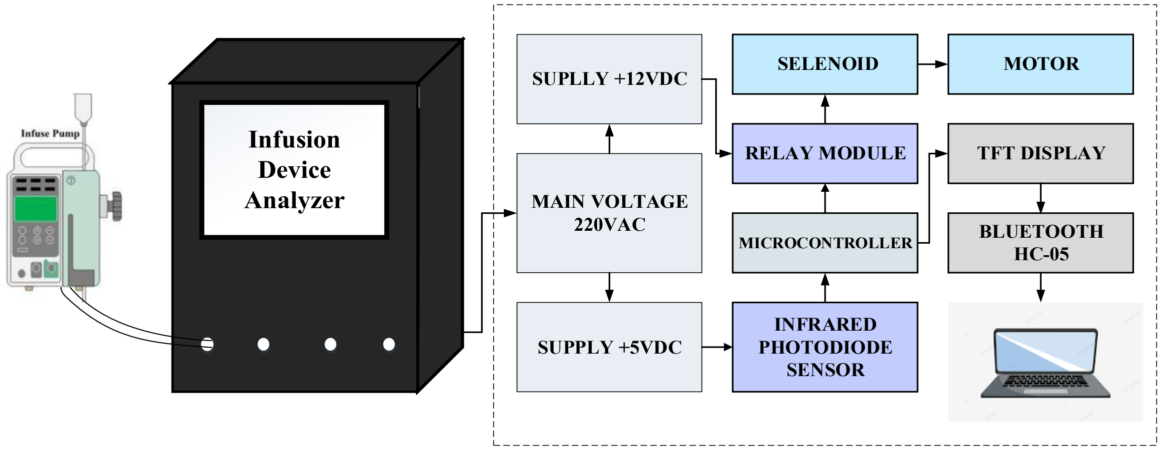


Figure 1. Block diagram of the infusion device analyzer module. The output of the infrared photodiode sensor serves as a reference input that calculates the number of drops that have been set through the program by the microcontroller.

Infusion Pump at a setting of 50 ml/h in Channel 2, with an error value of 1.70%. These findings highlight the impact of factors such as sensor placement, presence of bubbles in the tubing, and device positioning on the accuracy of the measurements. The results obtained from this study can be implemented for the calibration of the infusion pump and the syringe pump so that it can be determined whether the device is suitable or not.

II. Materials and Methods

A. Experimental Setup

This study collected data six times at setting of 10mL/H, 50mL/H, and 10mL/H using both the Syringe Pump and Infusion Pump, with Infusion set is connected to a longer tube that in turn connects to the pump. [24] Comparing the reading betweeen from the module and the IDA.

1) Materials And Tool

This research used an Infra-red sensors and photodiodes are used to detect intravenous droplets of fluid, which are then used to calculate fluids' volume.[25] with the arduino mega as the microcontroller and Bluetooth HC-05 as the data senders.

2) Experiment

In this study, after the Design was completed, it was tested using an infusion pump and syringe pumpas the media. It was compared with the standar IDA device. The results from the design were displayed throught a TFT display, and the data were sent to a PC via Bluetooth with stroge in Microsoft Excel for each Measurement.

B. The Diagram Block

In FIGURE 1 show the diagram of the system. The system starts working when the power button is activated, the power supply circuit an the entire circuit receive PLN voltage. Then, the infusion pump or syringe pump is set to a flowrate of 10mL/H, 50mL/H, and 100mL/H. and the start button is pressed. The fluid from infusion pump and syringe pump will flow throught the tubing connected to the IDA. There are flowrate parameters for the both Channel 1 and Chanel 2. The fluid exiting the infusion pump or syringe pump will flow toward the device and be detected by the infrared photodiode sensor on Channel 1 and channel 2 in the form of droplets. The output from the infrared photodiode sensor will be used as input reference by arduino, which calculates the number of droplets set through the program. The arduino will be programmed to calculate the accuracy and duration of the set droplet count to determine the flowrate value. The output from the microcontroller includes an LCD TFT and Bluetooth, which will be connected a laptop to manage the data. The LCD TFT display shows the flow rate and real-time flowrate graph along with the measurement time counter. The results from the flow rate graph display will be transmitted via Bluetooth HC-05 to a PC for data transfer tp Excel, allowing the plotting of the flowrate values over time to visualize the flow speed conditions. Additionally, numerical data from the result will also be displayed to facilitate data retrieval.

C. The Flowchart

In FIGURE 2 show the flowchat of the system. In Figure 2, before turning on the device, prepare the infusion pump or syringe pump and set the desired flow rate. When the device is turned on, the LCD TFT will initialize. The flow rate parameter is selected by choosing from the flow rate or occlusion settings. Simultaneously with the selection of the flow rate parameter, the inlet solenoid valve opens, and the solenoid valve connected to the pressure sensor automatically closes. Then, water flows from the infusion tubing to the drip chamber, where an infrared photodiode sensor detects the fluid. The sensor reads when there is flowing water and processes it through the microcontroller on the Arduino. The flow rate reading will repeat if no droplet detection is made by the photodiode and infrared sensor. Droplets are counted after being detected by the photodiode and infrared sensor. When the counted droplets match the set quantity, the time between each droplet is measured. This time is then converted into hours and divided by 20. The number 20 represents the drip chamber specification, where 1 mL equals 20 droplets. Therefore, the result, originally in droplets per hour, is converted to mL per hour. After processing, the flow rate value for each droplet is displayed as a number and a flow rate graph with a time counter on the LCD TFT display. When the stop button is pressed, the sensor stops working, and the drain solenoid opens, allowing water to flow to the outlet for disposal. The results are sent via Bluetooth HC-05 to a PC using Excel for further analysis.

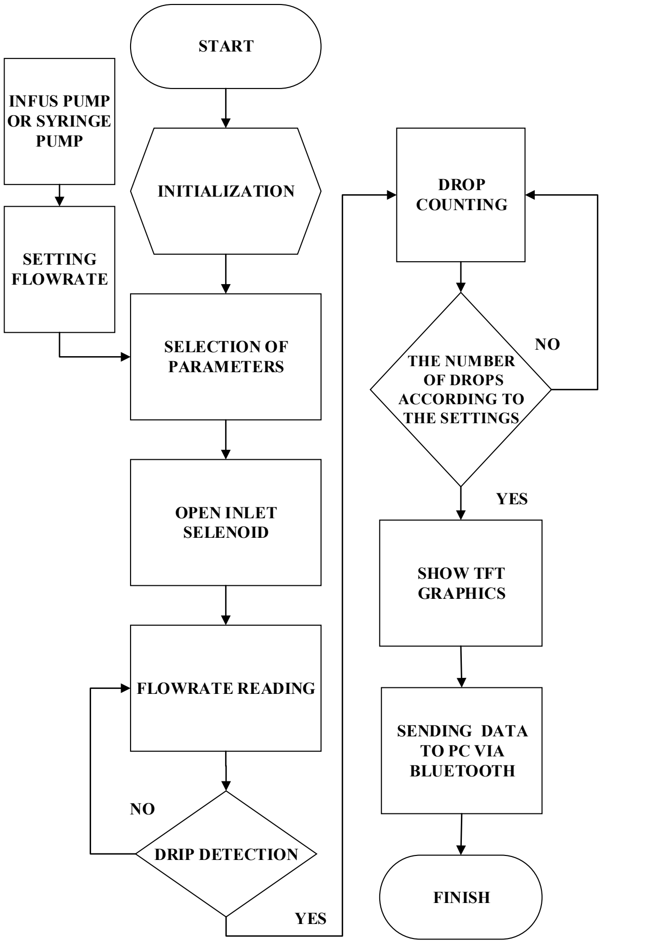


Figure 2. The flowchart, the drop count reading is processed by the microcontroller, which is then displayed on the TFT display and saved to Microsoft Excel, sent via Bluetooth HC-05

D. System Circuit

In FIGURE 3, two power supplies are used: +12V is used for operating the relay, and +5V is used for operating the sensor and Nextion TFT LCD. This module utilizes 6 solenoid valves, where each channel has 3 solenoids used to control the flow in the module. Among them, 3 solenoids are the drain solenoid, occlusion solenoid, and flow rate solenoid. The solenoid in Channel 1 is connected to the solenoid in Channel 2. These solenoids are controlled by the relay module to drive the solenoid valves connected to the Arduino's analog pins A8, A9, A10, and A11. A8 is used to control the occlusion solenoid, A9 is used to control the flow rate solenoid, A10 is used to control the drain solenoid, and A11 is used to activate the motor. The HC-05 module is connected to pins 10 and 11 as RX and TX, respectively, and it is used for transmitting data via Bluetooth.

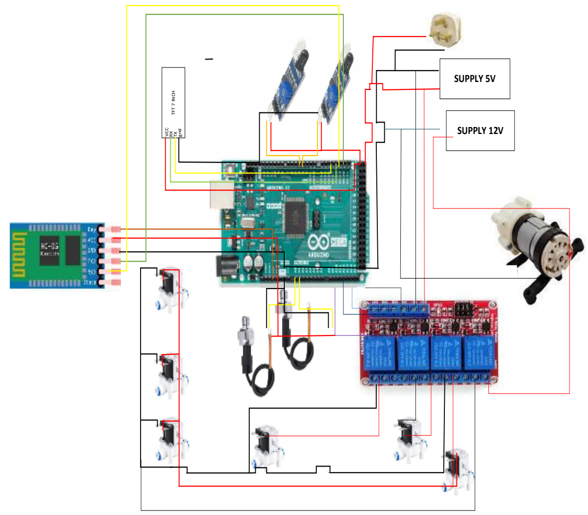


Figure 3. Photodiode infrared sensor modul system

D. Data Analysis

Data acquisition is carried out 6 times according to ECRI. The average is the value or result obtained by dividing the sum of the collected or measured data by the number of data points or measurements. The formula for calculating the average is in Eq. (1):

$$X = (\sum xi) / n \quad (1)$$

where X the average, ∑xi is the sum of the data values, and n is the number of data points (1, 2, 3, ..., n). Standard deviation is a value that indicates the level or degree of variation in a group of data or the standard measure of deviation from the mean. The formula for standard deviation (SD) is in Eq. (2):

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(Xi-\bar{X})^2}{(n-1)}} \quad (2)$$

where SD is the standard deviation, x ̅is the desired value, and n is the number of data points. Uncertainty is the result of calculations due to the smallest scale value, calibration errors, changes in measurement parameter values, and environmental factors that may affect measurements, making it difficult to obtain the true value. The formula for uncertainty is in Eq. (3) :

$$UA = \frac{SD}{\sqrt{n}} \quad (3)$$

U is the result of multiplying the Type A standard uncertainty by the coverage factor. The value of the coverage factor is 2, the formula for U is in Eq. (4):

$$U = UA \times 2 \quad (4)$$

Error is the difference between the average value of the desired quantity and the measured value. The formula for error is in Eq. (5) :

$$Error = Xn - X \quad (5)$$

Error is the percentage difference between the deviation (Error) and the desired value. The formula for percentage error is in Eq. (6):

$$Error = \frac{(Xn-X)}{Xn}\ x\ 100\% \quad (6)$$

The formula for Relative Error is in Eq. (7): =

$$r = \frac{True\ Error}{True\ Value}\ x\ 100\ \% \quad (7)$$

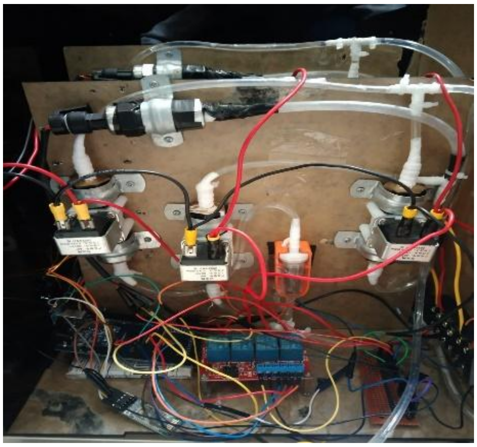


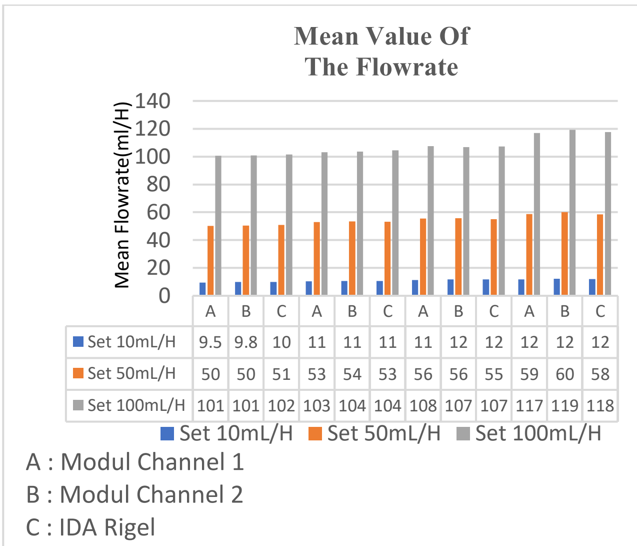
Figure 4. **The part of the Design module in infusion device analyzer**

III. Result

In FIGURE 4 The Infusion Device Analyzer module was tested using Terumo syringe pump, B-Braun syringe pump, Terumo infusion pump, and B-Braun infusion pump. Various brands of infusion sets and syringes were used in the testing. The research results indicate that the infusion device analyzer module performed well and was able to display numerical values and graphs on a 7-inch TFT LCD screen. The drip sensor in the module was able to accurately read the flow rate of both the syringe pump and infusion pump, and it could compare the measurement results with the standard Infusion Device Analyzer.

The Infusion Device Analyzer (IDA) module is equipped with Bluetooth transmission, allowing the generated data to be viewed not only through the 7-inch TFT LCD but also through Delphi via Bluetooth transmission. The data is automatically saved in Microsoft Excel every 0.9 seconds. The following are the flow rate measurement results for Syringe pump and Infusion pump.

In FIGURE 5 represents the plotted results from the standard infusion device analyzer and the module. The Excel graph shows the measurement result of the modul channel 1, channel 2 and standart device analyzer with setting 10mL/H, 50mLH, dan 100mL/H. Measurement of the module with the terumo syringe pump at a setting of 10ml/h obtained an average value of channel 1 of 9.5ml/h, an average value of Channel 2 of 9.83ml/h, and an average value of rigel of 9.95ml/h h. In the 50ml/h setting, the average value for channel 1 was 50.17ml/h, the average value for channel 2 was 50.33ml/h, and the average value for rigel was 50.8ml/h. In the 100ml/h setting, the average value for channel 1 was 100.7ml/h, the average value for channel 2 was 100.8ml/h, and the average value for rigel was 101.5ml/h. Measurement of the module with a B-Braun syringe pump at a setting of 10 ml/h obtained an average value of channel 1 of 10.5 ml/h, an average value of Channel 2 of 10.67 ml/h, and an average value on rigel of 10. 58ml/h. In the 50ml/h setting, the average value for channel 1 was 53ml/h, the average value for channel 2 was 53.5ml/h, and the average value for rigel was 53.12ml/h. In the 100ml/h setting, the average value for channel 1 was 103.2ml/h, the average value for channel 2 was 103.7ml/h, and the average value for rigel was 104.5ml/h. Measurement of the module with the terumo infusion pump at 10ml/h setting obtained an average channel 1 value of 11.33ml/h, an average channel 2 value of 11.83ml/h, and an average value on rigel of 11.75ml/h h. In the 50ml/h setting, the average value for channel 1 was 55.5ml/h, the average value for channel 2 was 55.67ml/h, and the average value for rigel was 55.04ml/h. In the 100ml/h setting, the average value for channel 1 was 107.5ml/h, the average value for channel 2 was 106.8ml/h, and the average value for rigel was 107.4ml/h. Module measurements with b-braun infusion pumps at a setting of 10 ml/h obtained an average value of channel 1 of 11.83 ml/h, an average value of Channel 2 of 12.33 ml/h, and an average value on rigel of 11, 92ml/h. At the 50ml/h setting, the average value of channel 1 was 58.67ml/h, the average value of Channel 2 was 60.16ml/h, and the average value on rigel was 58.46ml/h. At the 100ml/h setting, the average channel 1 value was 117ml/h, the average channel 2 value was 119.3ml/h, and the average value on rigel was 117.7ml/h.



	A	B	C	A	B	C	A	B	C	A	B	C
Set 10mL/H	9.5	9.8	10	11	11	11	11	12	12	12	12	12
Set 50mL/H	50	50	51	53	54	53	56	56	55	59	60	58
Set 100mL/H	101	101	102	103	104	104	108	107	107	117	119	118

Figure 5. **Diagram of Mean Value Flowrate Measurement Results for Modul and IDA RIGEL**

In FIGURE 6 above is the percentage error value in the Rigel IDA module and comparator using the terumo syringe pump, b-braun syringe pump, terumo infusion pump, and b-braun infusion pump which are set at 10ml/h, 50ml/h, and 100m/h . Module measurement with a terumo syringe pump setting of 10ml/h obtained a channel 1 error value of 0.45% and a Channel 2 error value of 0.12%. At the 50ml/h setting, the channel 1 error value is 0.63% and the Channel 2 error value is 0.47%. At the 100ml/h setting, the channel 1 error value is 0.86% and the Channel 2 error value is 0.69%.

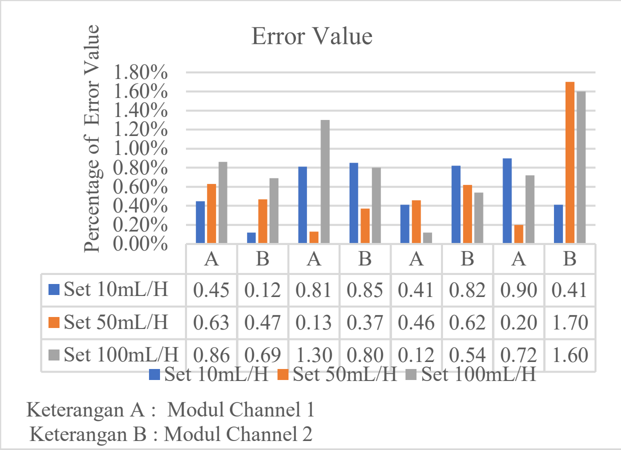


Figure 6. Diagram of Percentage Error Value Module Channel 1 and Channel 2

Module measurement with a b-braun syringe pump at a setting of 10ml/h obtained a channel 1 error value of 0.81% and a Channel 2 error value of 0.85%. At the 50ml/h setting, the channel 1 error value is 0.13% and the Channel 2 error value is 0.37%. At the 100ml/h setting, the channel 1 error value is 1.3% and the Channel 2 error value is 0.8%.

Module measurements with an infusion pump terumo setting of 10ml/h obtained a channel 1 error value of 0.41% and a Channel 2 error value of 0.82%. At the 50ml/h setting, the channel 1 error value is 0.46% and the Channel 2 error value is 0.62%. At the 100ml/h setting, the channel 1 error value is 0.12% and the Channel 2 error value is 0.54%.

Module measurements with a b-braun infusion pump setting of 10ml/h obtained a channel 1 error value of 0.9% and a Channel 2 error value of 0.4%. At the 50ml/h setting, the channel 1 error value is 0.2% and the Channel 2 error value is 1.7%. At the 100ml/h setting, the channel 1 error value is 0.72% and the Channel 2 error value is 1.6%

TABLE 1.
Measurement Results of Syringe Pump Terumo

Setting Flowrate Loss		Mean Of Rigel	Mean Of Modul	SD	Error%	Data
10ml/h	CH1	9,95ml/h	9,5ml/h	0,547	0,45%	±0.0%
	CH2		9,83ml/h	0,408	0,12%	±0.0%
50ml/h	CH1	50,80ml/h	50,17ml/h	0,752	0,63%	±0.0%
	CH2		50,33ml/h	0,516	0,47%	±0.0%
100ml/h	CH1	101,53ml/h	100,67ml/h	0,516	0,86%	±0.0%
	CH2		100,83ml/h	0,408	0,69%	±0.0%

In TABLE 1 above represents the flow rate measurement results of the Terumo Syringe Pump. In the measurement conducted using the Rigel IDA as the reference, with a setting of 10 ml/h, the average value obtained was 9.95 ml/h. Meanwhile, when the measurement was performed using the module, the average value for Channel 1 was 9.5 ml/h, which served as the data storage, was also 9.5 ml/h, with a standard deviation (SD) of 0.547, %Error of 0.45%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 9.83 ml/h, with an SD of 0.408, %Error of 0.12%, and data loss of 0.0%.

In the measurement with a setting of 50 ml/h, the average value obtained from the Rigel IDA was 50.805 ml/h. Meanwhile, when the measurement was conducted using the module, the average value for Channel 1 was 50.17 ml/h, with an SD of 0.752, %Error of 0.63%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 50.33 ml/h, with an SD of 0.516, %Error of 0.47%, and data loss of 0.0%.

In the measurement with a setting of 100 ml/h, the average value obtained from the Rigel IDA was 101.532 ml/h. Meanwhile, for Channel 1, the average value was 100.67 ml/h, with an SD of 0.516, %Error of 0.86%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 100.83 ml/h, with an SD of 0.408, %Error of 0.69%, and data loss of 0.0%.

TABLE 2.
Measurement Results of Syringe Pump B-Braun

Setting Flowrate Loss		Mean Of Rigel	Mean Of Modul	SD	Error%	Data
10ml/h	CH1	10,58 ml/h	10,5ml/h	0,547	0,81%	±0.0%
	CH2		10,67ml/h	0,942	0,85%	±0.0%
50ml/h	CH1	53,13 ml/h	53ml/h	0,894	0,13%	±0.0%
	CH2		53,5ml/h	0,591	0,37%	±0.0%
100ml/h	CH1	104 ml/h	103,17ml/h	0,983	1,3%	±0.0%
	CH2		103ml/h	1,032	0,80%	±0.0%

In TABLE 2 above represents the flow rate measurement results of the B-Braun Syringe Pump. In the measurement conducted using the Rigel IDA as the reference, with a setting of 10 ml/h, the average value obtained was 10,58 ml/h. Meanwhile, when the measurement was performed using the module, the average value for Channel 1 was 10.5 ml/h, with a standard deviation (SD) of 0.547, %Error of 0.81%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 10,67ml/h, with an SD of 0.516, %Error of 0.85%, and data loss of 0.0%.

In the measurement with a setting of 50 ml/h, the average value obtained from the Rigel IDA was 53,128 ml/h. Meanwhile, when the measurement was conducted using the module, the average value for Channel 1 was 53 ml/h, with a standard deviation (SD) of 0.894, %Error of 0.13%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 53,5 ml/h, with a standard deviation (SD) of 0.019, %Error of 0.37%, and data loss of 0.0%.

In the measurement with a setting of 100 ml/h, the average value obtained from the Rigel IDA was 104 ml/h. Meanwhile, for Channel 1, the average value was 103,17 ml/h, with a standard deviation (SD) of 0.983, %Error of 1.30%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 103 ml/h, with an SD of 1,0328, %Error of 0.80%, and data loss of 0.0%.

TABLE 3.
Measurement Results of Infusion Pump Terumo

Setting Flowrate Loss Data		Mean Of Rigel	Mean Of Modul	SD	Error%
10ml/h	CH1	11,75 ml/h	11,3ml/h ±0.0%	0,516	0,41%
	CH2		11,8ml/h ±0.0%	0,408	0,82%
50ml/h	CH1	55,04 ml/h	55,5ml/h ±0.0%	0,551	0,46%
	CH2		55,7ml/h ±0.0%	0,516	0,62%
100ml/h	CH1	107,4 ml/h	107,5ml/h ±0.0%	0,547	0,12%
	CH2		106,8ml/h ±0.0%	0,752	0,54%

In TABLE 3 above represents the flow rate measurement results of the Terumo Infus Pump. In the measurement conducted using the Rigel IDA as the reference, with a setting of 10 ml/h, the average value obtained was 11,75 ml/h. Meanwhile, when the measurement was performed using the module, the average value for Channel 1 was 11,3 ml/h, was also 11,3 ml/h, with a standard deviation (SD) of 0.516, %Error of 0.41%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 11,8ml/h, with an SD of 0.408, %Error of 0.82%, and data loss of 0.0%.

In the measurement with a setting of 50 ml/h, the average value obtained from the Rigel IDA was 55,04 ml/h. Meanwhile, when the measurement was conducted using the module, the average value for Channel 1 was 55,5 ml/h, with an SD of 0.551, %Error of 0.46%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 55,67 ml/h, with an SD of 0.516, %Error of 0.62%, and data loss of 0.0%.

In the measurement with a setting of 100 ml/h, the average value obtained from the Rigel IDA was 107,38 ml/h. Meanwhile, for Channel 1, the average value was 107,5 ml/h, with an SD of 0.547, %Error of 0.12%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 106,83 ml/h, with an SD of 0,752, %Error of 0,54%, and data loss of 0.0%.

TABLE 4.
Measurement Results of Infusion Pump B-Braun

Setting Flowrate Loss Data		Mean Of Rigel	Mean Of Modul	SD	Error%
10ml/h	CH1	11,92 ml/h	11,83ml/h ±0.0%	0,752	0,9%
	CH2		12,33ml/h ±0.0%	0,816	0,4%
50ml/h	CH1	58,46 ml/h	58,67ml/h ±0.0%	1,032	0,2%
	CH2		58,46ml/h ±0.0%	0,752	1,7%
100ml/h	CH1	117,7 ml/h	115,5ml/h ±0.0%	1,225	0,72%
	CH2		119,3ml/h ±0.0%	0,516	1,6%

In TABLE 4 above represents the flow rate measurement results of the Terumo Infus Pump. In the measurement conducted using the Rigel IDA as the reference, with a setting of 10 ml/h, the average value obtained was 11,92 ml/h. Meanwhile, when the measurement was performed using the module, the average value for Channel 1 was 11,83 ml/h, with a standard deviation (SD) of 0.752, %Error of 0.90%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 12,33ml/h, with an SD of 0.816, %Error of 0.41%, and data loss of 0.0%.

In the measurement with a setting of 50 ml/h, the average value obtained from the Rigel IDA was 58,46 ml/h. Meanwhile, when the measurement was conducted using the module, the average value for Channel 1 was 58, 67 ml/h, with an SD of 1,032, %Error of 0.20%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 58,46 ml/h, with an SD of 0.752, %Error of 1.70%, and data loss of 0.0%.

In the measurement with a setting of 100 ml/h, the average value obtained from the Rigel IDA was 117,7 ml/h. Meanwhile, for Channel 1, the average value was 111,5 ml/h, with an SD of 1,225, %Error of 0.72%, and data loss of 0.0%. For Channel 2, the measurement yielded an average value of 119,3 ml/h, with an SD of 0,516, %Error of 1.60%, and data loss of 0.0%.

IV. Discussion

The Infusion Device Analyzer module developed in this research successfully serves as a comprehensive system for analyzing infusion devices. It utilizes an Arduino Mega as the main controller and incorporates a 7-inch TFT LCD screen for displaying measurement results in both numerical and graphical formats. The module allows for data acquisition to be performed six times for each setting, providing sufficient data for analysis.One key achievement of this research is the successful implementation of the Arduino program, which enables the transmission of data to a Delphi program for visualization and further analysis. This integration allows for a more comprehensive examination of the data and facilitates comparisons with standard Infusion Device Analyzers. The research findings show that the module works well in terms of measuring and comparing in a study by Andjar Pudji, Anita Miftahul Maghfiroh and Nuntachai Thongpance, the contribution of this research is that the tool can calculate the correct value of the flow rate that comes out of the infusion pump and syringe pump. The water released by the infusion pump or syringe pump will be converted into droplets which are then detected by the sensor. This tool uses an infrared sensor and a photodiode. The results obtained by the sensor will come by Arduino nano and code it to the 16x2 Character Liquid Crystal Display (LCD) and can be stored on an SD Card so that it can be analyzed further. The results show that the average error of the syringe pump performance read by the module is 0.87. [21] When Comparing the result of the study conducted by Syaifudin about the uses a flow rate formula that is applied to the water level system to obtain 3 calibration results. Infrared photodiode sensor will detect the presence of water flowing in the chamber from an infusion or syringe pump. Then the sensor output will be processed by STM32 and 3 calibration results will be displayed on the 20x4 LCD. This tool has an average error value on channel 1 of 3.50% and on channel 2 of 3.39%.[20]

When comparing the flow rates measurement with the highest error value of 1.70%. compared to previous research conducted by Anisa Rahma Astuti the study used the developd process and congestion sensor with real time graphical display on 2 channel TFT LCD. with the highest error value of % Error 7.32%.[23] The error values obtained indicate the deviation between the measurement module and the measurement reference obtained from Rigel IDA. It is worth noting that certain factors can affect the error values obtained during measurements. These factors include the placement of the sensor on the infusion set, the presence of bubbles in the tubing, and the position of the device itself. Therefore, it is important to consider these factors carefully when taking measurements and interpreting the resultsThe limitations of the device should also be acknowledged. The time required for drop detection is relatively long due to the characteristics of the tubing used and the possibility of leaks in the tubing connections and solenoid valves. These limitations can affect the overall efficiency and accuracy of the module.

The creation of research on the infusion device analyzer holds significant benefits in the medical field. This device enables healthcare professionals to monitor and analyze the performance of infusion devices more accurately. With this research in place, errors in drug dosages due to the inaccuracy of the infusion device can be minimized, thus enhancing patient safety. Additionally, this research can also assist in identifying potential damage to infusion devices, allowing for maintenance or replacement actions to be taken before more serious issues arise. Consequently, the development of the infusion device analyzer not only improves efficiency in treatment but also contributes to an overall enhancement of medical care quality.

V. Conclusion

The purpose of this research is to make a tool capable of enabling the Infusion Device Analyzer module to function effectively as a comprehensive control system designed for the analysis of infusion devices. This module utilizes an Arduino Mega as its controller and integrates a 7-inch TFT LCD screen to efficiently display measurement results in both numerical and graphical formats. Furthermore, the module has the capability to perform data acquisition up to six times for each configuration. Moreover, the specially designed Arduino program provides the capability to transmit data to the Delphi program, serving the purpose of visualizing and analyzing data. This collected data can also be adequately stored in the Microsoft Excel format.

The research findings indicate that the module performs well, as it accurately measures and compares flow rates using various brands of syringe pumps and infusion pumps, as well as different infusion sets and syringes. The smallest error was observed in the module using the Terumo Syringe Pump at a setting of 10 ml/h in Channel 2, with an error value of 0.12%. On the other hand, the highest error was observed in the module using the B-Braun Infusion Pump at a setting of 50 ml/h in Channel 2, with an error value of 1.70%. These findings highlight the impact of factors such as sensor placement, presence of bubbles in the tubing, and device positioning on the accuracy of the measurements.

To further enhance the research, several suggestions are proposed. These include using a fixed drip sensor for more accurate readings, incorporating a fan or blower to minimize heat generated by the solenoids, developing a program to display multiple settings simultaneously when using both channels, and expanding the number of channels to facilitate simultaneous calibration testing of more than two devices. Overall, the Infusion Device Analyzer module demonstrates promising functionality and accuracy, but further improvements and refinements can be made to enhance its performance in future research and applications.requests are needed to using other types of thermocouple sensors and other thermocouple amplifier Standards, to be more accurate in temperature readings. Using a Standard with similar sensors, and also making tools portable to make it easier to use.

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