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Syringe Pump Equipped with Nearly Empty and Occlusion Based sensors Microcontroller ATmega 2560

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Abstract

Syringe pump is tool functional medical for do injection fluid drug in a way continuously with objective therapeutic nor diagnostic. Use of installed syringe pump in a way sustainable can cause happen occlusion causes fluid incoming medication to in body No flow in a way constant and formed pressure great on syringe and flow liquid that if left will happen swelling. On tools This uses the FSR402 sensor as detector occlusion. Apart from that, the A4988 driver is also used as stepper motor controller whose speed can customized in accordance with specified settings. Arrangement done on the Nextion TFT LCD which is this TFT can Also used as a display tool. This tool aim For help enter dose drug in a way slowly in accordance with specified speed with exists detector occlusion as detector If exists blockage. This tool use 20 ml and 50 ml syringes which is the target volume can customized start from 0 – 50 ml with flow rate 5 – 50 ml/hour with addition multiples of 5. Testing done with IDA 4 Plus tool with results that is; the average error value for 20ml syringe was 0.2% with the largest error occurs at a Flowrate of 10 ml/hour, namely 0.5% and the smallest error occurs at a volume of 50 ml/hour, namely 0.1%. And to 50ml syringe, the average error value is 0.13% with the largest error occurs at a flowrate of 20 ml/hour, namely 0.2% and the smallest error occurs at a volume of 10 ml/hour, namely 0.07%. Occlusion sensor testing required For change the occlusion sensor is 10 Psi.

Keywords

Syringe pump, occlusion , *microcontroller* , *Arduino mega2560*

Specification table

Hardware name	<i>Syring Pump Equipped with Nearly Empty and Occlusion Based sensors Microcontroller ATmega 2560 (Occlusion)</i>
Subject area	• <i>System Electronics and Microcontrollers</i> • <i>Therapeutic</i>
Hardware type	• Measuring physical properties and sensors in the laboratory • Field measurements and sensors • Electrical engineering and computer science • Mechanical engineering and materials science • <i>Mechatronics engineering</i>
Closest commercial analogue	<i>Device hard This provide control equipped syringe with occlusion sensor</i>
Open source license	https://creativecommons.org/licenses/by-sa/4.0/
Hardware costs	71.91 US\$
Source file repository	DOI 10.17605/OSF.IO/4R65D
OSHWA certification UID	-

1. Device hard in context

Equipment health is one of the influencing factors role important in organize service health in society [1]. Giving drug risky tall need tool infusion with speed control infusion that has accuracy tall For prevent the danger life patient to risk tall [2]. This is practical can achieved through use tool health system called a syringe pump [3]. According to search library, thought Rangga halim et al do study with title "Design build a syringe pump using a stepper motor based Arduino". Research conducted by them designed using a stepper motor with stem thread as mover its linear. The stepper motor will rotate produce linear movement prosperous and able controlled the speed as well as own high resolution [1]. According to search literature, Lely erica daughter do study with title "syringe pump with nearly empty indicator based on microcontroller atmega 328" research conducted they aim For designing syringe pump equipped with almost blank based on atmega328 which can used as 3 minute reminder before fluid run out of hose No Keep going continuously attached to the body patient when fluid has finished [4]. According to literature study, Fivit Marwita et al do study with title "Design get up tool syringe pump based 8535 microcontroller" research conducted by them designed use Atmega 8535 as center controls and indicators If fluid Already finished and as reminder use the buzzer, and research the has works with Good in a way which whole own level 96.21% accuracy as well percentage error amounted to 3.79% [5]. Based on description on clear stated that's it use this syringe pump tool required For make something tool with title "Syringe pump equipped with Nearly empty and occlusion based microcontroller atmega 2560 (Nearly empty)". Which one tool This equipped with a buzzer alarm as identify If fluid from syringe approach finished and will be sounds.

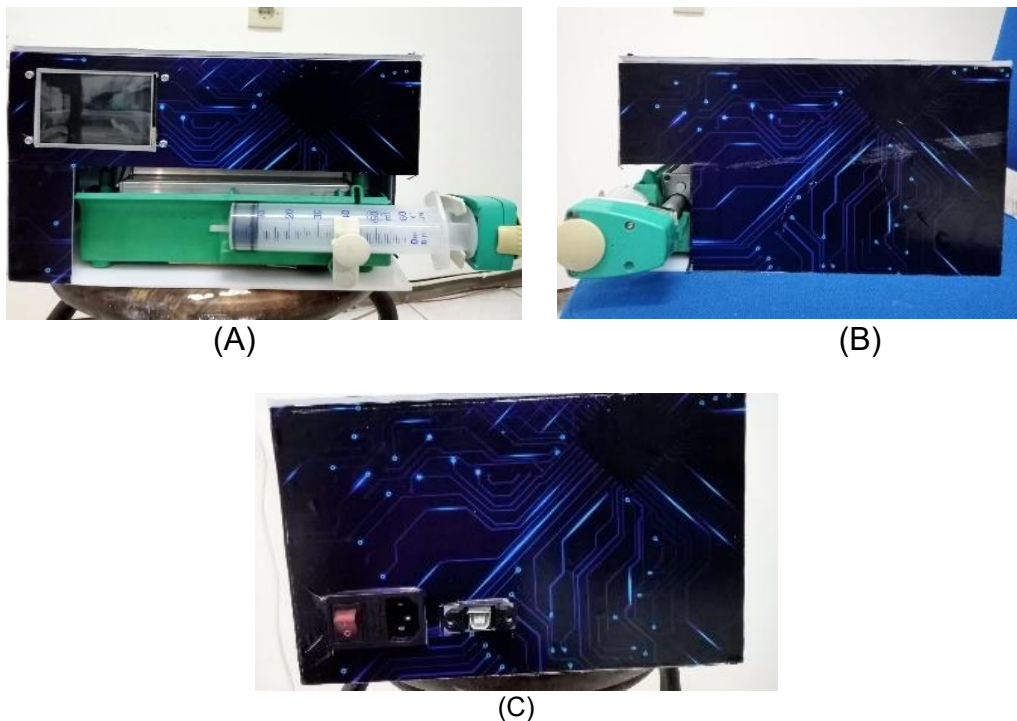


Fig. 1 (A) Looks Front (B) View side (C) View Behind

Based on description on clear stated that's it use this syringe pump tool required For make something tool with title "Syringe pump equipped with Nearly empty and occlusion based microcontroller atmega 2560 (Occlusion)". Wich one tool This equipped with a buzzer alarm as identify If happen blockage in the regulated hose For pressure 10 Psi. In **Fig. 1** there are Nextion used as settings and also display. On tools This use potentio slider for detect syringe. Plungers [6] For push syringe [7]. movement syringe regulated by the stepper motor [8] which the stepper motor will Work in accordance order from the A488 motor driver [9]. Main control of the tool This is microcontroller ATmega 2560 [8]. Occlusion sensor using FSR402 [10] as a pressure sensor will detect If pressure excessive when the plunger goes and will activates the buzzer [4].

2. Hardware description

Syringe pump is used as tool injection Keep going continuously in period time certain [11] [12]. In injection must there is occlusion monitoring [13] For see is happen blockage [14] on the process. So we use the FSR 402 sensor [15] as detector occlusion located on the plunger at the back syringe [16]. The plunger is driven by this stepper motor will Keep going move

until detector occlusion detect exists blockage [17][18]. Can seen in **Fig. 2** syringe block, Nextion for settings and displays, microcontrollers, stepper motors, motor drivers and buzzers.

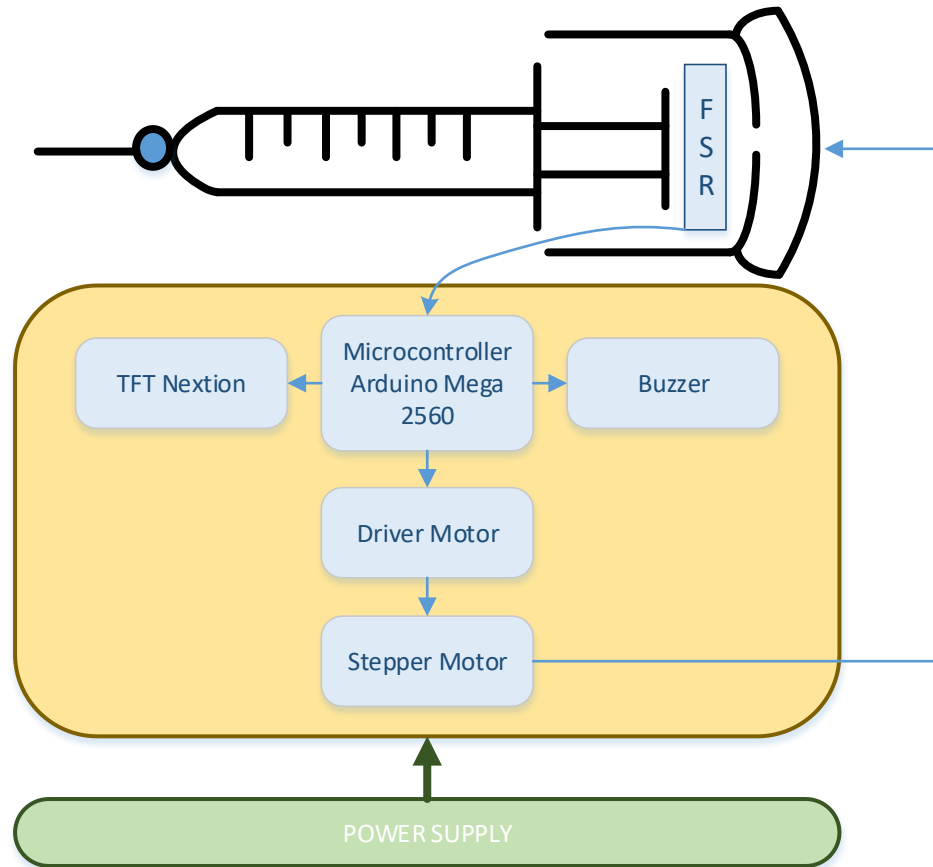
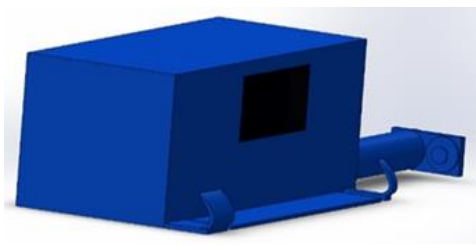


Fig. 2 . Block diagram of the syringe pump model

In the block diagram as in **Figure 2**, before start it syringe pump circuit, user need enter syringe as needed. Then potentiometer will detect size syringe. Then, it is necessary to arrange *flowrate* and also the volume used. Then if already in accordance, so press knob *start*. When *starting* Already pressed then the injection process started. During the injection process started, stepper motor works in accordance with the motorbike driver ordered regulated by a microcontroller. The stepper motor moves syringe. Movement syringe will be monitored with an occlusion detector and also a *nearly empty detector*. Where if happen occlusion then the pressure sensor will detect exists pressure overload and *buzzer* on and the motor will stop. If No happen occlusion so injection will keep going until regarding detection limits *nearly empty* and *buzzer* will sound.

2.1. Syringe Pump hardware

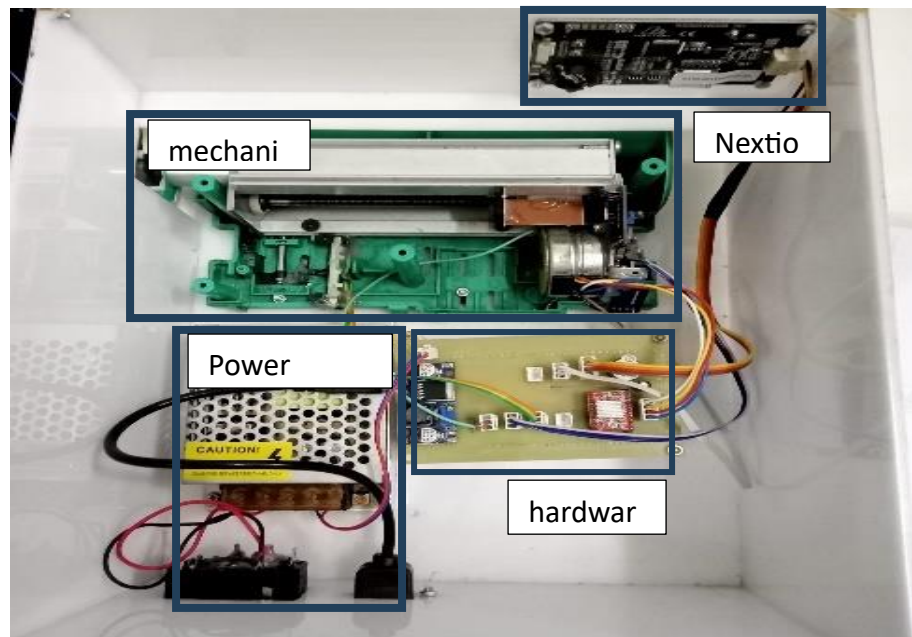
The syringe pump is equipped with nearly empty and also the occlusion that we use syringe pump frame from House where is the pain. We need for hardware, the nearly empty detector uses an infrared sensor, which is the sensor will detect happen liquid in the syringe will run out and run out and if happen so will sound on the buzzer, detector where occlusion occurs using the FSR sensor. If happen something obstruction in the hose fluid syringe so will be detected with these sensors and will sound on the buzzer. The syringe pump can detect the syringe that we use, ie 20 ml syringe or 50 ml syringe using sensor potentiometer slider and use display ie nextion which is where nextion for setting the flowrate, timer and volume on the syringe pump, **Figure a**. source power to the syringe pump use supply Power direct from PLN 220 Volt and also use ON/OFF button used for turning it off and on the syringe pump **Figure b**



(a) Front View



(b) Rear View

Fig. 3 . Syringe Pump Design**Fig. 4.** Final Result of Syringe Pump

2.2. Hardware Circuits

The microcontroller that we use in this syringe pump is Arduino atmega 2560. So arduino mega 2560 [19] Alone has many input/output pins and the largest memory capacity between version Arduino other [20] . Apart from the hardware is open source, the software used for coding it is also open source , namely Arduino IDE [3] . Therefore That this arduino IDE can be used For program microcontroller [21] others who don't produced like NodeMCU , WemosD1 and others [22] .

Table 1

Summary Arduino ATmega2560 specifications

Goods	Specification
Board Size	101.52 x 53.3 mm
Connectors	USB-B
SRAM	8 kB
Operational Voltage	5V
Input Voltage	7-12V
Digital I/O pins	54 (With 15 PWM outputs)
Analog Pins	16
DC current/ I/O pin	20Ma
Flash Memory	256 KB
EEPROM	4KB
Clock Speed	16 MHz
LEDs	13
Interfaces	UART, 12C, SPI

The main sensor used in study This are infrared photodiode and FSR sensors as well as component supporter other such as A4988 motor driver, potentiometer, stepper motor, buzzer and also Arduino Mega 2560 as microcontroller in research This. On tools this is our tool This started from the FSR 402 sensor reading mark pressure on the syringe form ADC value. Which later working For detector when happen occlusion . FSR 402 has 2 working pins as ground & data which is connected to leg A0 and the other pin works for VCC. On planning tool this is also available component potentiometer slide that works For detect size syringe used . Potentiometer has 3 legs that each function as VCC, GND, and connected with Arduino Uno on pin A2. On tools this also uses step down module used For lower voltage as an Arduino supply . The stepdown module has 4 pin with the – and + power supply outputs, the OUT- and OUT+ pins are connected with GND and VIN on Arduino. Furthermore For control on the tool This controlled full on the Nextion LCD, except the power button. Nextion LCD foot pin consists of 4 pins , namely VCC, TX, RX and GND pins.

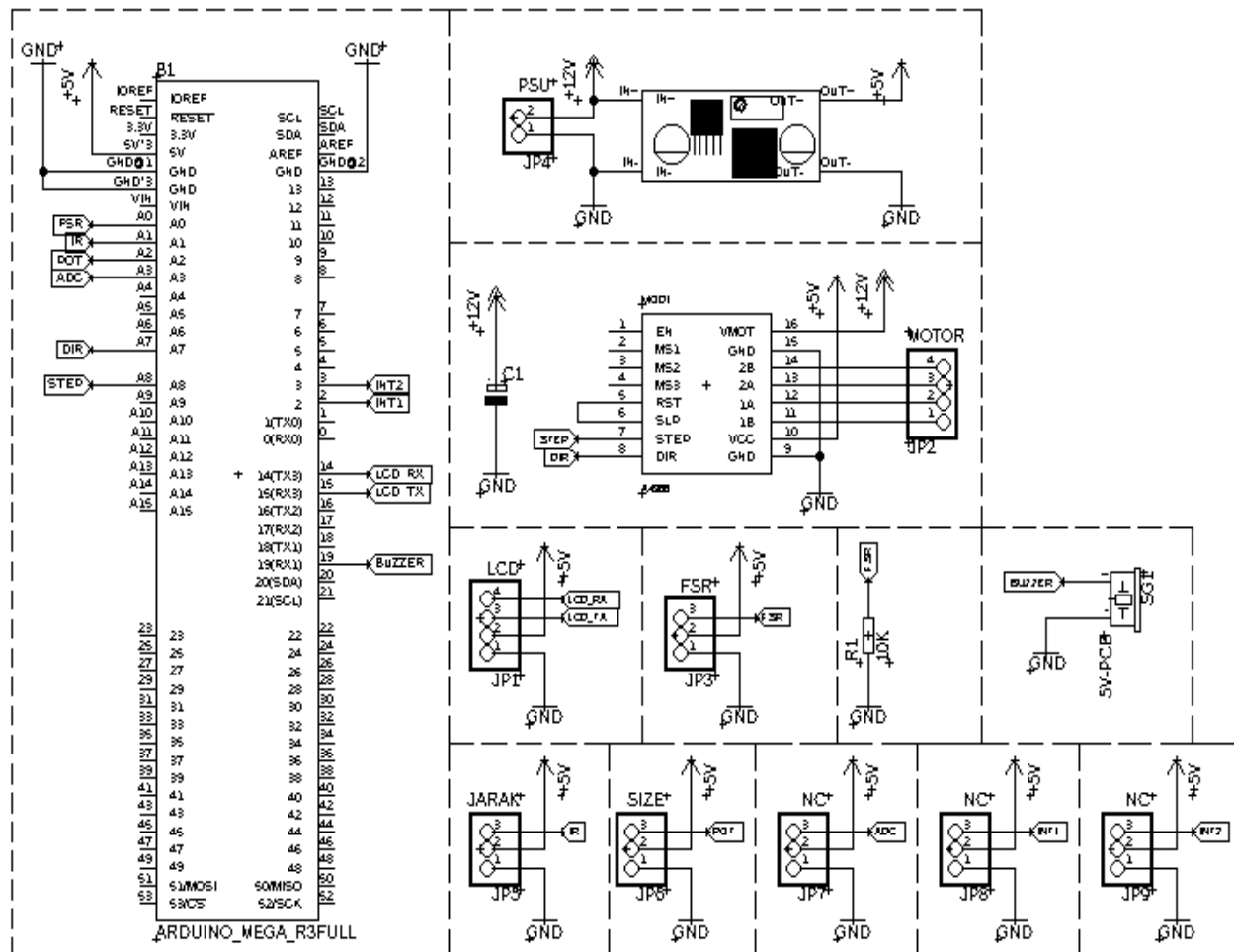


Fig. 5. Circuit device hard main

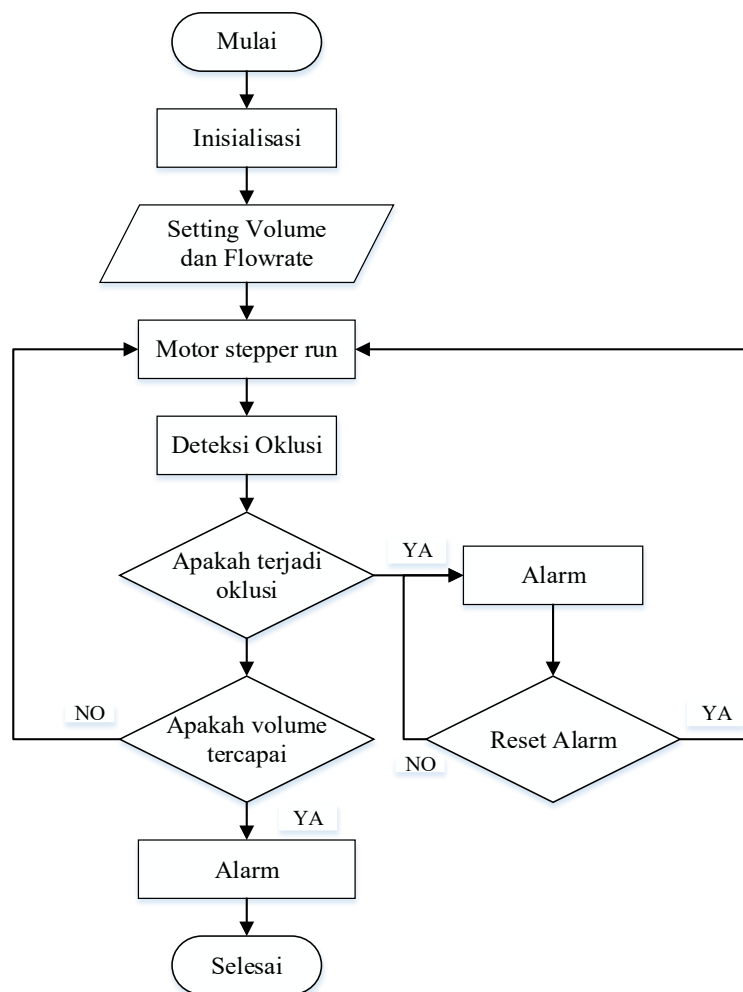


Fig. 7 Flowchart syringe pump

2.3. Syringe pump firmware

Program above is A system control Arduino -based that utilizes various sensors and devices For organize and monitor an involved process motor settings , volume measurements , as well as alarm control . In section first , some imported libraries , such as TimerOne For arrangement time and multitasking, as well EEPROMex For data storage permanent . Next , the various pins on the Arduino are defined with using #define, including pins for opto sensors (RPM), FSR (Force Sensitive Resistor) sensors, IR (Infrared) distance sensors, potentiometers (POT), as well as pins for motor and buzzer control . A number of constants and settings mark logic is also defined , such as ON and OFF for logic high and low , as well as BOUNCE for pause knob . There are also several EEPROM registers defined For keep mark arrangement specific to location different memory .

This program also has a number of page defined view with different values , are used For show various statuses and settings on the connected LCD display . Various arrangement important others are also initialized , incl offset setting , ADC value for various type syringe , as well as alarm settings for condition certain like occlusion and emptiness syringe . Motor speed and quantity Sample data is also set For ensure smoothness operation and accurate data retrieval .

Global variables used in this program defined For keep various possible value accessible to all function in the program, like time (hours, minutes , seconds), ADC value of various sensors, types syringe used , as well speed Genre . System status like is the motorbike medium? running (start), the presence of alarms from sensors (ir_alert , fsr_alert), and conditions others are also saved in global variables .

In the setup function , that is executed very when the Arduino is powered on , serial communication with the PC and LCD begins , and TimerOne initialized For set the time interval . Fashion pins for various pins are also organized , and pages initial on the LCD is reset to page title . Setting data be read from EEPROM to ensure arrangement No is lost moment the device is restarted. The beep function is called For give sign that system has been restarted with emit as many beeps as possible three times.

Loop function , which is executed repeatedly throughout device lit , covers various task like reading input from LCD, reading data from sensors, and converting motor speed of time . If the motor is in condition running (start), volume data is read and displayed on the LCD every time second . If the timer reaches 0, the motor will stops and the alarm is finished will activated . If not in start condition , the display on the LCD will updated every 500 ms in accordance with medium page active . Function updateBlinking called For arrange alarm flashing , and PC debug used For send status data to PC for debugging purposes . Other functions are not shown here , like inputLCD , readSensor , convertSpeed , readCondition , motorRunning , and lcdCommand , will handle various aspect operational other in system this is like reading input from LCD, processing sensor data, conversion motor speed , condition reading , motor operation , and shipping order to the LCD. as shown in Figure 8 .

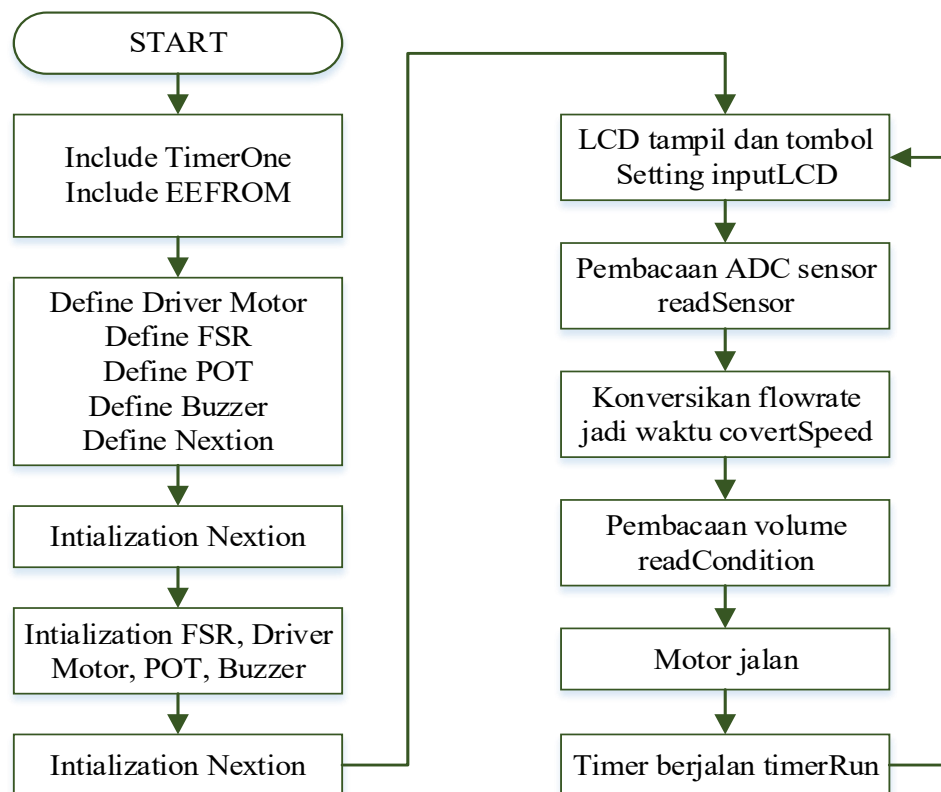


Fig. 8 Syringe pump firmware flowchart

2.4. Occlusion Sensor

Occlusion sensor on syringe pump [23][24] own very important benefits in guard safety patients and efficiency operational [25] [26] . With detect blockage Genre fluid medical in a way early , this sensor prevent enhancement possible pressure fatal , avoid damage to vessels blood [27] [28] or network patient . Additionally , an occlusion sensor ensure dose fluid medical treatment provided still accurate and consistent , reducing risk dose excessive or not enough [29] . This is also possible intervention quickly by the staff medical moment occlusion detected , so reduces tool downtime and ensures maintenance No disturbed [30] . With automatic monitoring carried out by sensors, staff medical can more focused [31] on the task others , improve efficiency operational in a way whole . On the other hand , the occlusion sensor help identify problem technical on the syringe pump or track Genre fluid , prevent damage tools that can happen consequence pressure excessive [32] . In terms of comfort and security patient , this sensor reduce pain [33] [8] and discomfort caused by occlusion , as well reduce stress on staff medical . Additionally , with obey regulations health requirements exists detection occlusion , syringe pump with this sensor can fulfil standard necessary and helpful health in documentation as well as tracking quality care and maintenance equipment medical . By overall , the occlusion sensor on the syringe pump is vital components that ensure safety [4] , effectiveness , and efficiency in giving fluid medical [27] . Use of the FSR402 sensor on the syringe pump for detection Very effective occlusion because of this sensor give fast response to change pressure . With arrangement mark appropriate threshold , system can detect occlusion with accurate and delivering warning to user For take action corrective . Good implementation from this sensor in code and circuit electronics are very important For ensure safety and reliability syringe pump system.

2.5. Cost

It's expensive price product commercial syringe pump available on the market (>2000 USD) and the rehabilitation process becomes long and expensive constraint in carry out used For giving drug in a way intravenous with precision high , which is very important For drugs such as insulin, agents chemotherapy, and anesthesia especially for people who have middle to lower income (Figure 9). But this design has cheap cost which is 74.91 US\$ for One product syringe pump. Besides that design This is open source so other researchers can develop it with other features and improvements.



Fig. 9 . Syringe Pump s700 TERUMO

2.6. Summary

Syringe pump can used For giving drug in a way intravenous with precision high , which is very important For drugs such as insulin, agents chemotherapy , and anesthesia . The contributions of this research are explained as follows:

- (a) Hardware design This uses the FSR402 sensor as an occlusion sensor For detect exists blockage Opada hose .
- (b) Device hard This use potentio slider as detector size syringe in a way automatic in accordance with the syringe inserted .
- (c) Device use ATmega2560 microcontroller so making tool This eat Lots place.

3. Design file summary

3.1. Design file

In section This explained regarding the resulting design files , both hardware designs (schematics and boards circuit print (PCB)) or program listing for operation syringe pump, like seen in Table 3.

Table 3

Summary of syringe pump

Design file name	File type	Open source license	Location of the file
Syringe pump layout.bd	layout, eagle file	CC BY-SA 4.0	DOI 10.17605/OSF.IO/4R65D
Syringe pump.sch	skematik eagle file	CC BY-SA 4.0	DOI 10.17605/OSF.IO/4R65D
Syringe pump.Ino	Arduino IDE	CC BY-SA 4.0	DOI 10.17605/OSF.IO/4R65D
Box syringe pump.cdr	Design COREL	CC BY-SA 4.0	DOI 10.17605/OSF.IO/4R65D
Nextion syringe.HMI	Nextion Editor	CC BY-SA 4.0	DOI 10.17605/OSF.IO/4R65D

3.2. Schematics and Boards

Hand pump syringe designed using the Eagle application program (6.3.0, free version for Windows, CadSoft Computer GmbH, Germany. In the series there is ATmega2560 microcontroller , motor driver, buzzer and also leading pins nextion , occlusion sensor and also sensor for size syringe . and also the pin to the stepper motor.

3.3. Arduino IDE

Arduino IDE (Integrated Development Environment) is device software used For writing , editing , compiling , and uploading code to board Arduino development . this IDEA designed For makes it easier programming microcontrollers on Arduino boards and devices simila. (Version 1.8.4, visit website: [URL](#).)

4. Summary of bill of materials

Table 4

Syringe pump materials list

Pointer	Component	Amount	Cost per unit (USD)	Total cost (USD)	Source of materials	Type of material
Occlusion sensor	FSR402	1	8.50	8.50	https://www.aliexpress.us/item/2251832606658857.html	Plastic , Metal , and semi-conductor
Detector size syringe	Slide potentiometer	1	11.50	11.50	https://www.aliexpress.us/item/3256806808317996.html	Metal
Board	ATmega2560	1	31.36	31.36	https://www.aliexpress.us/item/2255800034804448.html	Semi-conductor
Buzzers	Active Buzzer Magnetic 5V	1	0.09	0.09	https://www.aliexpress.us/item/3256806439909386.html	Plastic
Motorbike drivers	A4988	1	0.99	0.99	https://www.aliexpress.us/item/3256806907784724.html	Plastics , metals and semi-conductors
Stepper motors	micro precision 36 stepper motor	1	2.47	2.47	https://www.aliexpress.us/item/3256806861491663.html	Metal
Displays	Nextion NX3224K028	1	21.80	21.80	https://www.aliexpress.us/item/2251832706212776.html	Plastics , metals and semi-conductors

5. Building instructions

5.1. Printing Design

The syringe pump box is designed with Corel which one is Corel Alone is device soft design graphic vector developed by Corel Corporation. This is one device the most famous and numerous software used in the world for make picture vectors , illustrations , and layouts page . In this design there is hole For putting nextion , plunger, syringe , power button and also USB. Design in **Figure 10** Then printed use material acrylic white with 5mm thickness . so that expected strong For supports the hardware system of the syringe pump.

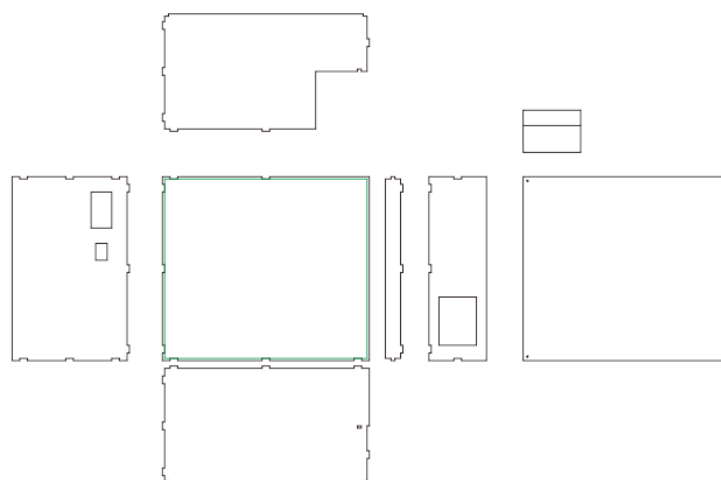


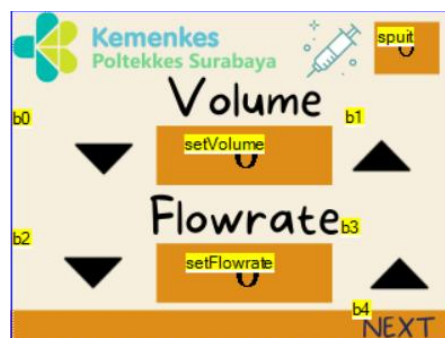
Fig. 10 . Syringe Pump Box Design

5.2. Nextion Design

Nextion is brand smart display device (smart display) developed by the ITEAD Studio company . Device This designed For provide solution screen easy touch used and integrated with various project electronics, esp in context development IoT (Internet of Things) prototypes and applications. In terms of This nextion used as input settings for the required flowrate, volume or timer. After that, nextion is also used as a monitor display of the fluid coming out and the remaining time until fluid expired. In **Figure (A)** is a title page there is the name of the author and also the title of the tool. then in **Figure (B)** there are volume and flowrate settings that need to be entered, there is also the size of the syringe which can be immediately read if there is a syringe. For **Figure (C)** is the time setting which can be filled automatically or can be set manually as well as the start button which is used to start the motorbike. Then in **Figure (D)** is the monitor screen where there is a target volume, volume coming out and also the time remaining until the liquid runs out. as for the alert that will be reads “OKLUSI” if happen blockage and “NEARLY” if fluid almost exhausted and “EMPTY” if fluid finished.



(A)



(B)

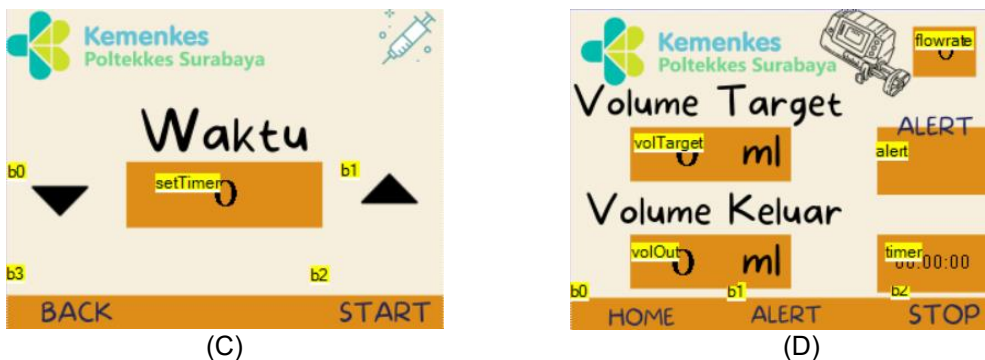


Figure 11 (A) Title display on Nextion , (B) Volume and flowrate setting display (C) Time setting display (D) Monitor display.

6. Instructions operation

Syringe pump is device medical use For arrange Genre fluid to in or go out from body patient in a way precise and controlled. Operation started with prepare a filled syringe drug or solution to be infused. Next, the syringe loaded to in pump with insert the plunger into in mechanism mover . User Then arrange rate desired infusion using the control panel on the syringe pump, OK via keypad or screen touch depending on the model. After arrangement finished. the pump will start move the plunger sequentially automatic with speed that has been determined For arrange Genre incoming fluid to in body patient through connected hose with a syringe. Supervision Keep going continuously required For ensure infusion taking place with Correct in accordance with recipe medical and for anticipate possibility change or necessary distractions adjustment or action emergency .

7. Validation and characterization

Based on results compared flowrate measurements with IDA 4 Plus you get data like above is done 5x , an average error of 0.2% is obtained with the largest error occurs at a Flowrate of 10 ml/hour , namely 0.5% and the smallest error occurs at a volume of 50 ml/hour , namely 0.1%. the result can be see in **Table 7**.

Table 7

The results of the data are compared with commercial syringe pump

Fake (ml/hour)	Spuit 50ml/hour	
	Module Flowrate (ml/hour)	Setting Comparison (ml/hour)
10	10.19	10.25
20	20.82	20.62
30	30.2	29.34
40	40.12	39.35
50	49.35	50.69

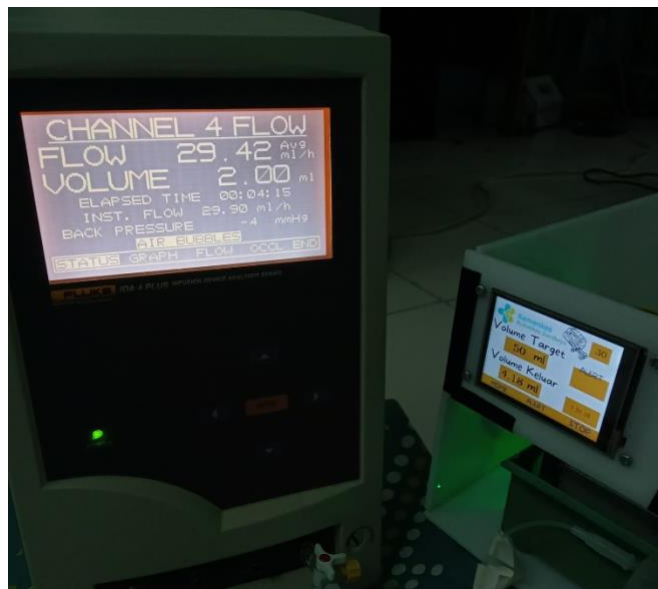


Figure 13 . Flowrate measurement using IDA4 PLUS

The syringe pump calibration process using IDA 4 Plus is shown very satisfying results in determine accuracy Genre fluid . Compared to with a commercial syringe pump , though No identical in a way overall , the tests carried out disclose that difference the result almost No significant . Second this type of syringe pump capable give arrangement approaching flow desired value with high accuracy , meet standard clinical For precision infusion . With so , though There is variation in technology and design between the IDA 4 Plus and a commercial syringe pump others , both give almost performance equivalent in matter accuracy and reliability in arrangement Genre fluid medical . Then calculated using standard deviation (StDv) as shown in Eq. (1).

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

where yi indicates the predicted value, xi indicates the actual value, and N is the measurement data. The measurement results are the average StDv value of the flowrate is 0.4 ml/jhour (**Table 8**).

Table 8. Measurement results standard deviation (StDv) value for syringe pump using flowrate 10, 20, 30, 40, and 50 ml/hour

Flowrate (ml/hour)	StDv (ml/hour)
10	0.4
20	0.3
30	0.5
40	0.3
50	0.2

8. Conclusion

This study serve development Syringe Pump device is equipped with nearly empty and occlusion based Microcontroller Atmega 2560. Design This need cheap cost which is 71.91 US\$ for one product Syringe pump. RMSE mean and deviation the standard being measured based on sarong hands and frame outside hand is 0.4 ml/hour. On research Next, researchers can replace the Arduino mega with a mini so No eat Lots place and make a small box .

Statement ethics

Writer confirm that informed consent was obtained from subject. This research has passed the ethical test conducted by the Committee Ethics Poltekkes Health Research Ministry of Health Surabaya, Indonesia, No. EA /1245/KEPK-Poltekkes_Sby /V/2022

Statement writer credit

Endang Dian Setioningsih : Conceptualization , Methodology , and Software. **Sumber** : Data collection and measurement. **Wanda Salwa Salsa Bila** : Design and Validation Syringe pump, Mechanical Design.

Saying Thank You

Funding: This work was supported by the Health Polytechnic of the Ministry of Health Surabaya, Indonesia [HK.01.02/2/1155/ 2022].

Declaration of interests

The authors declare that there is no conflict of interest.

Reference :

- [1] FR Halim, Suwandi, and A. Suhendi, "Design and Build a Syringe Pump using an Arduino-Based Stepper Motor," *e-Proceeding Eng.* , vol. 3, no. 2, pp. 2078–2085, 2016.
- [2] NF Hikmah, I. Sapuan, and Triwiyanto, "Design of a Syringe Pump Based on an ATmega 8535 Microcontroller Equipped with an Occlusion Detector," *J. Phys. Appl.* , vol. 1, no. 3, pp. 74–91, 2013.
- [3] I. Saidi, L. El, A. Ounip, and M. Benrejeb, "Design of an Electrical Syringe Pump Using a Linear Tubular Step Actuator," *Int. J. Sci. Tech. Auto. Control Comput. Eng. IJ-STA* , vol. 4, no. 2, pp. 1388–1401, 2010.
- [4] LE Putri, Muhammad Ridha Mak'ruf, and Abd. Kholiq, "Syringe Pump With Nearly Empty Based Microcontroller Atmega328," *J. Electron. Electromed. Eng. Med. Informatics* , vol. 1, no. 2, pp. 25–30, 2019, doi: 10.35882/jeemi.v1i2.5.
- [5] F. Marwita and BY Wibisono, "Design of a Syringe Pump Device Based on the Atmega 8535 Microcontroller," *Sinusoida* , no. 2, 2022, [Online]. Available: <https://ejournal.istn.ac.id/index.php/sinusoida/article/view/1463%0Ahttps://ejournal.istn.ac.id/index.php/sinusoida/article/download/1463/964>
- [6] NL Velikanov, VA Naumov, and SI Koryagin, "Characteristics of Plunger Pumps," *Russ. Eng. Res.* , vol. 38, no. 6, pp. 428–430, 2018, doi: 10.3103/S1068798X18060175.
- [7] MDPRD Rumbara, Sahid, H. Siswanto, "Jounal Homepage: MAKING OF INJECTION PUMP EQUIPMENT BASED ON AUTOMATION IN MAKING OF INJECTION PUMP BASED ON AUTOMATION IN," *J. Met. Indonesia* , vol. 41, no. 1, pp. 26–31, 2019.
- [8] I. Virgala, M. Kelemen, A. Gmitterko, and T. Lipták, "Control of Stepper Motor by Microcontroller," *J. Autom. Control* , vol. 3, no. 3, pp. 131–134, 2015, doi: 10.12691/automation-3-3-19.
- [9] LF 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.
- [10] AM Arrieta, "EVALUATING AND MODELING FORCE SENSING RESISTORS FOR LOW FORCE APPLICATIONS," *event asme org.* , vol. 3703, no. 2000, pp. 1–11, 2017.
- [11] H. Coskun, O. Gul, O. Ferhanoglu, and YD Gokdel, "Design and implementation of a low-cost high-performance

- syringe pump system," 2017 21st Natl. Biomed. Eng. Meet. BIYOMUT 2017, 2018, doi: 10.1109/BIYOMUT.2017.8478979.
- [12] E. Batista, N. Almeida, E. Filipe, and A. Costa, "Calibration and use of syringe pumps," vol. 02007, p. 02007, 2013, doi: 10.1051/metrology/201302007.
- [13] T. Mulyono and U. Faruq, "Multi Syringe Pump Design for Flow System Analysis Design of Multi Syringe Pump for Flow System Analysis," *BASIC SCIENCE*, vol. 14, no. 1, pp. 17–21, 2013.
- [14] ED Kurniawan, A. Adam, MI Salik, and PL Gareso, "Programmable Syringe Pump for Selective Micro Droplet Deposition," *J. Elektron. and Telekomun.*, vol. 19, no. 2, p. 75, 2019, doi: 10.14203/jet.v19.75-82.
- [15] A. Farina *et al.*, "User preference for a portable syringe pump for iloprost infusion," *Patient Relat. Outcome Meas.*, vol. 6, no. May, p. 139, 2015, doi: 10.2147/prom.s81473.
- [16] Y. Hiung *et al.*, "Customizing a high flow rate syringe pump for injection of fluid into a microfluidic device based on polyimide film," *ARPJ J. Eng. Appl. Sci.*, vol. 11, no. January, pp. 3849–3855, 2016.
- [17] RN Ikhsani, DJDH Santjojo, and SP Sakti, "Design of low noise micro liter syringe pump for quartz crystal microbalance sensor," *Int. Conf. Electr. Eng. Comput. Sci. Informatics*, vol. 2, pp. 598–602, 2018, doi: 10.1109/EECSI.2018.8752626.
- [18] S. Rajasekwaran, S. V Aishwarya, S. Gowthami, R. Suguna, V. Vasunthera, and S. Sathes, "IoT Based Low Cost Syringe Pump for Telemedicine and Health Care," *Int. Res. J. Mod. Eng. Technol. Sci.*, vol. 04, no. 06, pp. 2582–5208, 2022, [Online]. Available: www.irjmets.com
- [19] AG Anjani *et al.*, "Application of IoT Using nodeMCU ESP8266 on the Syringe Pump Device to Increase Patient Safety," *Indonesia. J Electron. Electromed. Eng. Med. Informatics*, vol. 4, no. 1, pp. 23–27, 2022, doi: 10.35882/ijeemi.v4i1.4.
- [20] WA Salah, BA Zneid, A. Abu_al_aish, and M. Nofal, "Development of Smart and Portable Controllable Syringe Pump System for Medical Applications," *J. Eng. Technol. Sci.*, vol. 55, no. 3, pp. 300–312, 2023, doi: 10.5614/j.eng.technol.sci.2023.55.3.7.
- [21] R. Ramadhani and Syaifudin, "Pressure Sensor Accuracy Analysis on 2 Channel Occlusion Infusion Device Analyzer Parameters," *Pros. Semin. Nas. Health. Surabaya Health Polytechnic*, pp. 1–5, 2020.
- [22] TZ Siregar, S. Harahap, KN Lumbantobing, and RC Nainggolan, "Analysis of the motor rotation detection circuit on the Merkterumo Type Te-331 syringe pump," *J. Darma Agung*, vol. 28, no. 3, pp. 561–566, 2020.
- [23] HAS wen zeng, Ian Jacobi, "Characterization of syringe-pump-driven induced pressure fluctuations in elastic microchannels," *R. Soc. Chem.*, vol. 3, pp. 1–6, 2014, doi: 10.1039/b000000x.
- [24] HCS Zida Li, Sze Yi Mak, Alban Saurent, "Syringe-pump-induced fluctuation in all-aqueous microfluidic system implications for flow rate accuracy," *R. Soc. Chem.*, vol. 3, pp. 1–6, 2010, doi: 10.1039/b000000x.
- [25] F. Suyatno, L. Yuniarsari, and B. Syawaludin, "Engineering a Microcontroller-Based X-Ray Diagnostic Aircraft Prototype," *Prima*, vol. 6, p. 39, 2009.
- [26] T. Zuchri Siregar *et al.*, "ANALYSIS OF MOTOR ROTATION DETECTION CIRCUITS ON THE MERKTERUMO TYPE TE-331 SYRINGE PUMP EQUIPMENT by," *Darma Agung* vol. 28, no. 3, pp. 561–566, 2020.
- [27] Y. Zhou *et al.*, "Standing air bubble-based micro-hydraulic capacitors for flow stabilization in syringe pump-driven systems," *Micromachines*, vol. 11, no. 4, p. 11, 2020, doi: 10.3390/M11040396.
- [28] MA Khan, S. Tehami, and O. Mazhar, "Designing of microcontroller based Syringe Pump with variable and low delivery rates for the administration of small volumes," 2015 IEEE 21st Int. Symp. Dec. Technol. Electron. Packag. SIITME 2015, pp. 135–138, 2015, doi: 10.1109/SIITME.2015.7342311.
- [29] B. Mallick and C. Mohanta, "Development of a Syringe Infusion Pump," *J. Control Syst. its Recent Dev.*, vol. 6, no. 3, pp. 19–32, 2023, [Online]. Available: <https://doi.org/10.5281/zenodo.10401078>
- [30] MR Islam, R. Zahid Rusho, and SM Rabiul Islam, "Design and implementation of low cost smart syringe pump for telemedicine and healthcare," 1st Int. Conf. Robot. Electr. Signal Process. Tech. ICREST 2019, pp. 440–444, 2019, doi: 10.1109/ICREST.2019.8644373.
- [31] H. Igarashi, Y. Obata, Y. Nakajima, T. Katoh, K. Morita, and S. Sato, "Syringe pump displacement alters line internal

pressure and flow," *Can. J. Anesth.* , vol. 52, no. 7, pp. 685–691, 2005, doi: 10.1007/BF03016554.

- [32] A. Supriyanto, R. Anggriani, SW Suciya, A. Surtono, Junaidi, and S. Hadi, "A Control System on the Syringe Pump Based on Arduino for Electrospinning Application," *J. Phys. Sci.* , vol. 32, no. 1, pp. 1–12, 2021, doi: 10.21315/JPS2021.32.1.1.
- [33] M. Bawafie, M. Harip, C. Zawiyah, C. Hasan, and MA Nordin, "A Review of Internet of Things (Iot) For the Design of Smart Syringe Pump in Biomedical Application," *Sci. J. Innov. Soc. Sci. Res.* , vol. 2, no. 1, pp. 1–12, 2022.