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Design of Intravenous Fluid Infusion Device

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Abstract: A syringe pump project entails the design or assembly of a device specifically engineered for the accurate administration of liquids, frequently utilized in both medical and research environments. Essential components generally consist of a syringe, a motor, a control interface, and a power supply. This device enables precise control over dosage and timing, thereby enhancing the delivery of medications and the execution of biological experiments with exceptional accuracy. Opportunities for enhancement may include the development of user-friendly interfaces, remote control functionalities, and integration with advanced technologies such as artificial intelligence or machine learning. Although there are some limitations, including noise production and challenges in returning to the zero-point, syringe pumps continue to be indispensable instruments for fulfilling their intended purposes in healthcare and scientific inquiry.

Keywords: Design of Intravenous Fluid Infusion Device. Syringe pump. Precision drug delivery. Arduino-based infusion system.

1. Introduction:

Injection pumps in both scientific and practical applications focus on the creation and design of devices that precisely and effectively administer medications to patients, particularly within the healthcare sector. The graduation project centered on an injection pump involves the development of a mechanical or electronic apparatus that delivers medications at predetermined rates and accurate volumes through continuous subcutaneous or intravenous methods. The process of developing an injection pump encompasses various technical and design considerations, including the establishment of accuracy and speed in medication delivery, the assurance of patient safety, and the minimization of dosage errors. Furthermore, it entails research and development related to the materials utilized, control systems, and programming essential for the efficient operation of the device. This graduation project presents students with the opportunity to apply their knowledge of engineering and medical principles in a hands-on project, enhancing their skills in design, innovation, and collaboration. Moreover, this initiative can play a significant role in improving patient care and advancing medical technology to address the increasing demands of healthcare.

2. Literature Review

In modern literature, attention is directed towards the creation of an Internet of Things (IoT) enabled injection pump device utilizing Arduino. This ambitious initiative merges automation with internet connectivity technologies. The objective of this project is to offer a streamlined and intelligent method for administering injections and monitoring them remotely, thereby simplifying the process for healthcare professionals to accurately and effectively oversee and modify medication dosages. This technological advancement presents novel opportunities to enhance healthcare delivery and improve communication between medical practitioners and patients.

2.1 A Control System on the Syringe Pump Based on Arduino for Electrospinning Application

In this study, a control system utilizing a syringe pump has been developed to regulate the volume and flow rate of liquids or solutions. The syringe pump is constructed by modulating the speed and pulse width of stepper motors, which are governed by an Arduino Uno microcontroller board. The components employed include a stepper motor serving as the syringe driver, the Arduino Uno functioning as the controller, a four-digit seven-segment display, and a keypad matrix for input. The operation of the syringe pump involves driving the injection mechanism at a speed calibrated to the desired flow rate. The flow rate and volume are controlled by adjusting the delay time of the stepper motor through the PWM pins of the Arduino Uno. The syringe pump has been found to operate effectively within a flow rate range of 0.10 to 12.00 ml h–1. This system has potential applications in medical environments for managing the volume and flow rate of drug solutions, as well as in the production of nanofibers via the electrospinning technique.

2.2 Advanced Control System For Syringe & Infusion Pump Using Iot

The controlled and accurate delivery of fluids is a fundamental requirement in various fluid flow applications, including microfluidics, Micro Electro Mechanical Systems (MEMS), micro-machining, and medicinal biological systems. Typically, such fluid deliveries are facilitated by syringe pumps, which utilize syringes operated by electric motors. In this study, a syringe pump is managed using a Raspberry Pi, a System on a Chip (SoC) that offers greater user-friendliness compared to traditional microcontroller systems. The Raspberry Pi operates on a Linux platform, allowing for straightforward coding and control through the Python programming language. The syringe pump is driven by a stepper motor, which features 200 steps per revolution, enabling a more precise flow rate than other electrical actuators. This stepper motor is connected to a Dual H-Bridge L293D motor driver, which is powered via the GPIO (General Purpose Input/Output) pins, an essential component of the Raspberry Pi. A lead screw mechanism is employed in this setup to convert the rotary motion of the motor into the linear motion of the syringe. The lead screw's pitch length is minimal and adjustable, resulting in a highly accurate fluid flow rate, which is determined through experimental measurement.

2.3 Syringe Pump Created Using 3D Printing Technology and Arduino Platform

A syringe pump designed for analytical laboratory applications has been created as an open-source project. The majority of its components are fabricated using a 3D printer, while other essential parts, such as the lead screw, guide rods, stepper motor, bearings, and electronic components, are sourced from specialized retailers. The control interface utilizes an Arduino UNO, enabling device interaction, adjustments to settings, and selection of operating modes through an LCD Keypad Shield, eliminating the need for a computer connection. The microcontroller's software is developed using the Arduino IDE. The assembly process for the syringe pump takes several hours and requires minimal soldering. A versatile clamp accommodates syringes with diameters ranging from 6 to 25 mm. This syringe pump is capable of both infusing liquids and refilling empty syringes. For assessing its analytical performance, a 10mL glass syringe (Kloehn) was employed, dispensing volumes of 1 mL and 5 mL. The systematic error recorded was below 0.1%, while the random error was less than 3 μL.

3. Problem Statements

1. Technical compatibility: You may encounter difficulty in compatibility of the devices used with each other, which requires advanced engineering and programming skills to overcome these challenges.

2. Security and Privacy: Data security and privacy must be guaranteed while connected to the Internet and interacting with medical devices, and this requires the application of strong security measures and adherence to relevant health legislation.
3. Reliability: It must be ensured that the device operates reliably and without any malfunction or malfunction, especially when used in a biomedical environment.
4. Legal Compliance: You may face challenges regarding project compatibility with local and international medical legislation and regulations, which requires a good understanding of relevant laws and regulations.
5. Implementation cost: Developing and implementing a pump pump project may be expensive, especially with the need for advanced technologies and high-quality medical devices.
6. Collaboration and communication: You may need to cooperate with multidisciplinary teams such as doctors, engineers, and programmers to ensure the success of the project and achieve its goals effectively.

4. Objectives

The injection pump utilizes Bluetooth technology to facilitate convenient remote control and monitoring. Users can access an application on their smartphones to modify and oversee the pump's functions, enabling them to efficiently manage both the volume of fluid injected and the timing of the injections.

5. Electronic Circuit Components:

1. Arduino Nano
2. Stepper motor
3. DRV8825 Driver for stepper motor
4. HC-05 Bluetooth

5.1 Arduino nano

The Arduino Nano is a compact, open-source electronic development board that utilizes an 8-bit AVR microcontroller. There are two versions of this board: one is equipped with the ATmega328p microcontroller, while the other features the ATmega168.

Although the Arduino Nano can execute functions comparable to other boards on the market, its smaller dimensions make it particularly suitable for projects that require limited memory and fewer GPIO pins. The board is designed with a USB interface, utilizing a mini USB port, in contrast to most Arduino boards that typically employ a standard USB port. Notably, this model does not include a DC power jack, meaning it cannot be powered by an external power supply. Additionally, the device is compatible with breadboards, allowing for the creation of a variety of electronic projects.

The flash memory serves to store programs, with the ATmega168 offering 16KB of flash memory (of which 2KB is allocated for the bootloader) and the ATmega328 providing 32KB. In terms of EEPROM, the ATmega168 has 512 bytes, while the ATmega328 has 1KB. The SRAM capacities are 1KB for the ATmega168 and 2KB for the ATmega328. Overall, the Nano board is quite similar to the UNO board, with the primary distinction being its smaller size and the absence of a DC power jack.

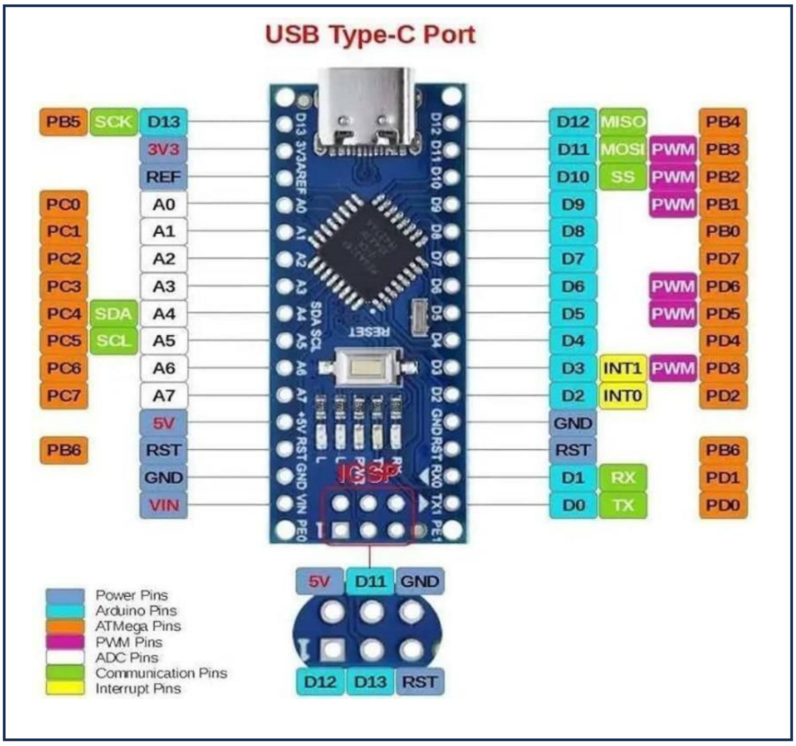

Figure (1) Arduino nano

5.2. Stepper motors

Stepper motors are distinguished by their ability to move in discrete steps, with the shaft rotating a specific angle for each electrical pulse received by one of the motor's coils. Unlike servo motors, stepper motors operate without a feedback mechanism, which contributes to their simplicity and lower cost. The angle of rotation for the shaft is determined by the internal design of the motor, typically ranging from 0.90% to 90%. Consequently, stepper motors are employed in applications that necessitate precise movements, such as 3D printers, plotters, hard drives, laser drives, scanners, CNC machines, and robotics.

A stepper motor comprises two primary components: the rotor and the stator. The rotor is a permanent magnet, while the stator consists of multiple coils that function as electromagnets when an electric current flows through them. These electromagnets create a magnetic field that influences the rotor when energized. The rotor is activated sequentially by each coil that receives an electric current.

The supply voltage for the motor can vary significantly based on its type, typically falling within the range of 3 to 10 volts. Additionally, the current drawn by the motor generally fluctuates according to the resistance of the motor windings.

The advantages of the stepper motor can be summarized as follows:

- The stepper motor provides accurate positioning, with a good stepper motor being accurate to 3-5% This error is not cumulative from one step to the next.
- The stepper motor is inexpensive and easy to use.
- The stepper motor has a very long service life.
- The stepper motor maintains its position when no electric pulses are applied.
- The stepper motor does not get damaged by overloading, it just stops working.
- Stepper motors have high torque at low speeds.

Disadvantages:

- Resonance vibration occurs if not properly controlled.
- Low torque at high speeds.
- It is difficult to operate at high speeds.
- Low Efficiency It consumes more power than it delivers, so it tends to work with. The presence of heat.

Figure (2) Stepper motors

5.3 drv8825 driver

It is an electronic chip (IC) specially designed to control bipolar stepper motors. Also known as stepper motor driver or micro stepping driver.

In this study, a control system for electronic circuits was developed to manage stepper motors. The system comprises a stepper motor driver integrated circuit (IC) and a microcontroller. The driver IC facilitates the implementation of the control mechanisms, while the Microcontroller Unit (MCU) generates the square wave required as input for the motor driver. Various control modes were explored, including full-stepping, half-stepping, and micro-stepping. Several practical motor movements commonly utilized in various applications were tested. Observations were conducted regarding the motor's speed at different input waveform frequencies, the sound produced by the stepper motor across a range of micro-stepping levels, and the acceleration profile. Notable findings indicated that utilizing higher micro-stepping levels results in smoother motor movements. Additionally, it was discovered that incorporating an acceleration profile within the microcontroller program allows for achieving speeds significantly exceeding the rated start-on speed of the stepper motor.

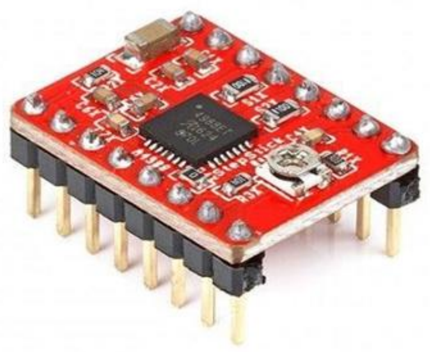

Figure (3) drv8825 driver

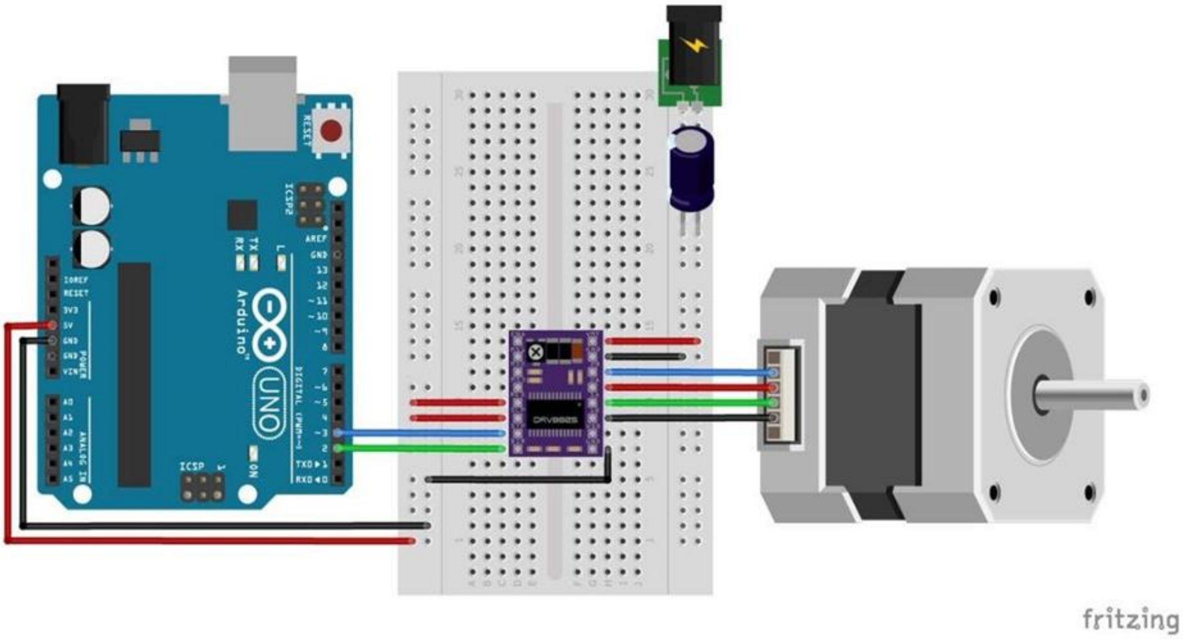

Figure (4) Connecting the motor using the drive

5.4 HC-05 Bluetooth Module

HC-05 is a Bluetooth module which is designed for wireless communication. This module can be used in a master or slave configuration.

Figure (5) Hc-05 Bluetooth

Bluetooth communication between Devices

E.g. Send data from Smartphone terminal to HC-05 Bluetooth module and see this data on PC serial terminal and vice versa.

To communicate smartphone with HC-05 Bluetooth module, smartphone requires

Bluetooth terminal application for transmitting and receiving data. You can find Bluetooth terminal applications for android and windows in respective app. store.

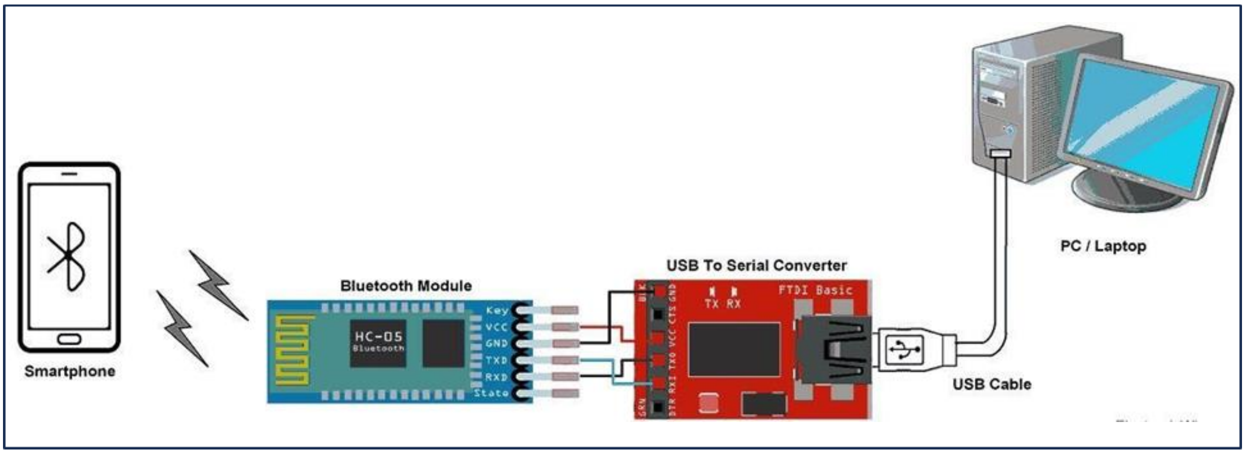

Figure (6) Connecting Bluetooth with the mobile phone

To facilitate communication between a smartphone and the HC-05 Bluetooth module, it is necessary to connect the HC-05 module to a PC using a serial to USB converter. Prior to initiating communication between the two Bluetooth devices, the HC-05 module must first be paired with the smartphone.

To pair the HC-05 with the smartphone, begin by searching for new Bluetooth devices on your phone. You should locate a device named "HC-05." Select the option to connect or pair with this device; the default PIN for the HC-05 is either 1234 or 0000. Once the two Bluetooth devices are paired, launch terminal software on the PC (such as Teraterm or Realterm) and choose the port corresponding to the USB to serial module connection. Additionally, set the baud rate to the default of 9600 bps.

On the smartphone, open the Bluetooth terminal application and connect to the paired HC-05 device. Communication is straightforward; simply type in the Bluetooth terminal application on the smartphone. The characters will be transmitted wirelessly to the HC-05 module, which will then relay them serially to the PC, where they will be displayed in the terminal. Similarly, data can be sent from the PC to the smartphone.

5.5 limit switch

The device referred to as the end-of-stroke switch serves the purpose of halting or altering the direction of a motor's movement upon contact with the product. Internally, it features two terminals: one is normally open (NO) while the other is normally closed (NC).

Figure (7) limit switch

Design and Implementation:

After we get to know all the hardware components, we connect all the components together as shown in the figure below, and as the code in the attachment will show.:

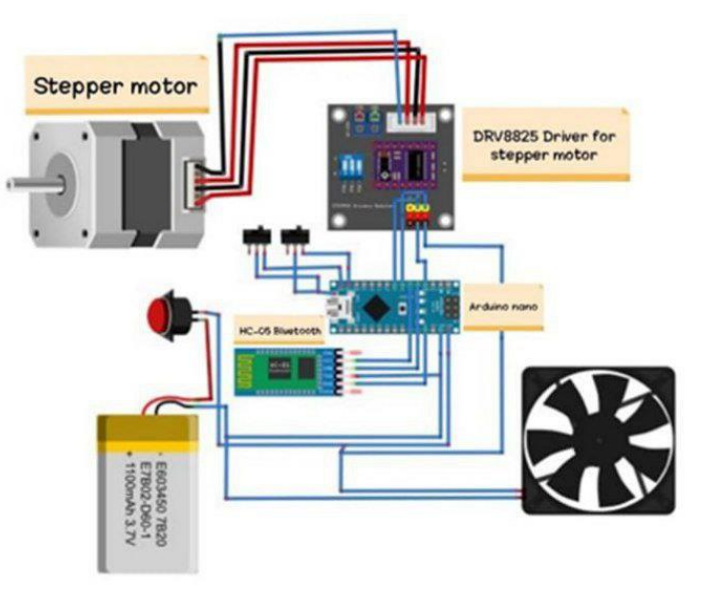

Figure (8) Final blinding

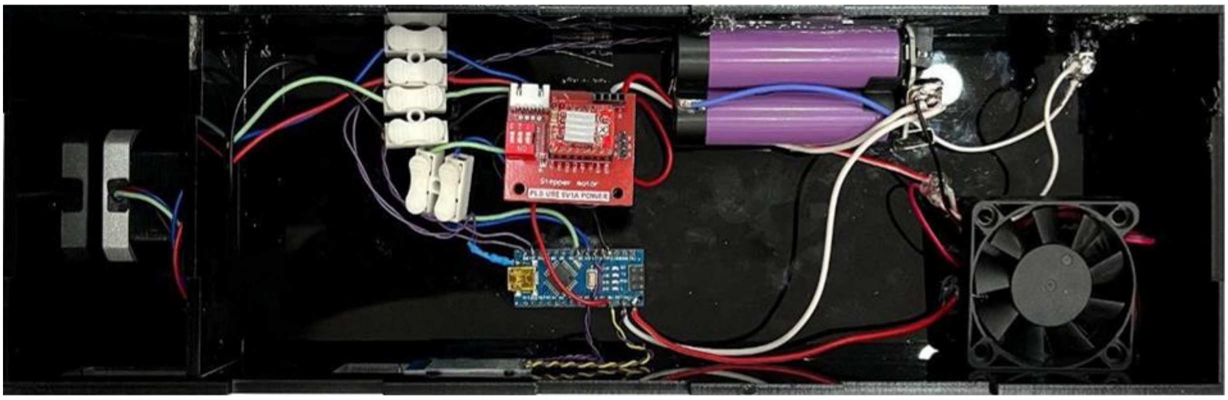

Figure (9) Device base

A control interface was developed utilizing the RemoteXY application to manage an Arduino board through the HC-05 Bluetooth module. This software interface features two text fields: the first allows users to enter the desired injection volume, which can range from 10 ml to 50 ml, while the second field is designated for indicating the injection duration, either in minutes or as required.

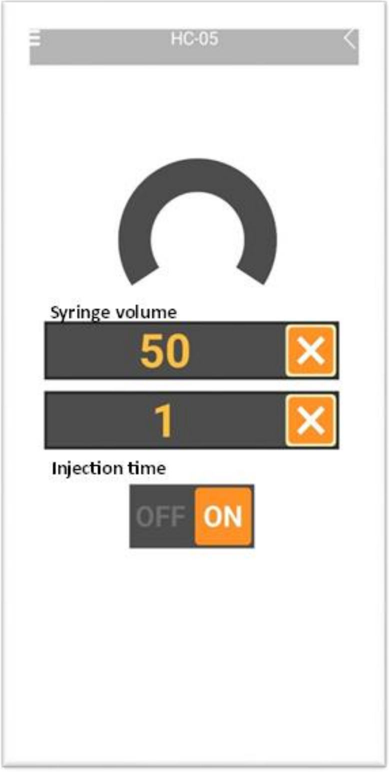

Figure (10) the program

6. Results and Discussion

6.1 Results

This apparatus functions as a control system designed to ensure exceptional precision in liquid injections, applicable for both administering medications in exact dosages and performing biological experiments. Users can conveniently set the injection volume and duration via a specialized control interface, enabling straightforward input of their desired parameters. The execution of the process is carried out with remarkable accuracy in accordance with the provided data, rendering it highly beneficial for both medical and research applications. However, certain limitations may arise, including elevated noise levels and challenges in easily resetting the injection to the zero point. Despite these issues, the device's effectiveness in fulfilling its intended purposes remains significant.

6.2 Discussion

The use of a syringe pump is of significant importance in the field of medicine and scientific research for several reasons:

1. Injection Precision: The syringe pump enables high precision in both the volume and timing of injections, making it ideal for delivering medications in precise doses or for conducting experiments requiring extreme accuracy.
2. Automated Control: The device allows for automated control of injection processes, reducing human error and ensuring consistent and repeatable operations.
3. Time and Effort Savings: Utilizing a syringe pump helps save time and effort as it can be programmed to execute operations automatically without the need for continuous manual intervention.
4. Versatile Applications: The syringe pump can be used in a variety of medical and research applications, including drug delivery, intravenous nutrition, and conducting biological experiments.

5. Cost-Effectiveness: Compared to traditional control systems, a syringe pump can be a cost-effective alternative, especially when utilizing open-source production technologies like Arduino.

In summary, the syringe pump is a vital tool that contributes to improving precision and efficiency in drug delivery and conducting biological experiments, making it indispensable in the fields of medicine and scientific research.

7. Conclusion:

From the investigation into the implementation of the syringe pump, several conclusions can be drawn in this thesis; the most important results can be summarized as follows:

1. It provides accurate doses of medical drugs such as anesthetics, dyes, etc.
2. It has the ability to work continuously for long periods to administer medications to patients as determined by the treating physician.
3. It reduces the margin of error in the dosage given to the patient.
4. It reduces patient discomfort from needle punctures.
5. It operates independently of the physician's work.

8. Future Developments:

Several advancements can be expected for the syringe pump device in the future, including:

1. Enhanced Precision: Improving injection and control techniques to achieve greater accuracy in volume and timing.
2. User Interface Enhancements: Improving control interfaces to simplify usage and make them more efficient.
3. Remote Control: Adding options for remote control through wireless communication technologies to increase flexibility and convenience.
4. Integration of Technologies: Developing integration between syringe pump devices and other technologies such as artificial intelligence and machine learning to enhance performance and efficiency.
5. Increased Compatibility: Improving the ability of syringe pump devices to be compatible with a wider range of tools and other medical equipment.
6. Design Improvements: Developing designs to make devices more durable and easier to maintain and operate.
7. 7.Energy Efficiency: Improving energy consumption to reduce costs and environmental impact.

These are some potential ideas for future developments of the syringe pump device, which would enhance its performance and expand its applications in the fields of medicine and scientific research.

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