Design and Implementation of Microcontroller Based Portable Drug Delivery System

Mohammed Sabah Jarjees*

Received on: 5/5/2011
Accepted on: 8/9/2011

Abstract

Portable drug delivery system or portable syringe pump system is a small infusion pump used to gradually deliver drugs, at low doses and at a constant or controllable rate of drug to a patient who needs to take a drug dose regularly in specific periods all the day.

The aim of this research is to design and perform a prototype of a portable drug delivery system controlled by micro controller. The micro controller will control the dose of liquid or medication which will be given to the patient and the time of repetition of the dose. The dose rate will be adjusted by controlling the operation of stepper motor which will drive the syringe pump through fine mechanism set.

Keywords: Drug delivery system, Microcontroller, Stepper motor.

الخلاصة

جهاز الحاقن الالي المحمول او ما يسمى بالمضخة الدواء هو عبارة عن جهاز حقن صغير يستخدم لحقن الدواء بصورة تدريجية منتظمة للمريض الذي يحتاج الدواء بصورة دورية وبكميات ثابتة لمدة اربع وعشرون ساعة.الهدف من البحث هو تصميم وتنفيذ منظومة حقن الية باعتماد تقنية المسيطر الدقيق, الذي يقوم بالسيطرة على جرعة السائل المحقون (الدواء) الذي يعطى الى المريض بشكل متكرر وباوقات ثابتة. نسبة الجرع يسيطر عليها من خلال عمل المحرك الخطوي الذي يسوق مضخة الحاقن خلال مجموعة ميكانيكة.

1. Introduction

The drug delivery system or syringe pump in general is a small infusion pump used to gradually administer small amounts of fluid (with or without medication) to a patient. [1]

The syringe pump will deliver specific amount of medication dose gradually to the patient in regular periods of time. The design had been achieved by using microcontroller that drives a stepper motor in specified period of time proportional to the dose Rate required to be injected by syringe pump system.

The most popular use of syringe drivers is in palliative care to continuously administer drugs such as analgesics (painkillers), and in delivering of the insulin solution to patient who seafaring from the Diabetes disease, to deliver the desferrioxamine solution to patient having Thalasemia disease, antiemetic (medication to suppress nausea and vomiting), hormones, or other medicines, such as opiates .

*Technical College of Mosul, Foundation of Technical /Baghdad

https://doi.org/10.30684/ etj.29.12.16
University of Technology-Iraq, Baghdad, Iraq/2412-0758

2. Review:

There are many types of the drug delivery system as the following:

2.1 Continuous infusion usually consists of small pulses of infusion, usually between 500 nano-liters and 10000 micro liters [2].

2.2 Intermittent infusion has a "high" infusion rate, alternating with a low programmable infusion rate to keep the cannula open.

2.3 Patient-controlled is infusion on-demand, usually with a preprogrammed ceiling to avoid intoxication.

2.4 Total parenteral nutrition usually requires an infusion curve similar to normal meal times [3].

2.5 Some pumps offer modes in which the amounts can be scaled or controlled based on the time of day.

2.6 The fixed drug delivery system which includes large volume pump (peristaltic pump): scan pump nutrient solutions large enough to feed a patient. Large-volume pumps usually use some form of peristaltic pump [4].

2.7 Portable drug delivery system which includes Small volume pumps (syringe pump) infuses hormones, such as insulin, or other medicines, such as opiates.

3. Materials And Methods:

The portable drug delivery pump is designed so that the device will deliver pre adjusted dose (1ml, 2ml, 3ml, 4ml or 5ml) in repetition sequence every selected period of time (T) from 1hour to 24 hours. On this base, the device mainly consists of:

3.1 Microcontroller (AT89C51)[5]:

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pin out. The on-chip flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer.

By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications. This chip provides the following standard features: 4 Kbytes of Flash, 128 bytes of RAM, 32 I/O lines, two 16-bit timer/counters, and five vector two-level interrupt architecture, a full duplex serial port, on chip oscillator and clock circuitry.

The microcontroller will be programmed to control the operation of the delivery system. After selecting a suitable dose and period, the microcontroller will give signals that drive the stepper motor and consequently driving the syringe pump to deliver the required dose at the end of each assigned time cycle.

3.2 Stepper motor [6] :

The Stepper Motor Controller is a complete solution for intelligent motion control. Stepper motors are used when precise control of movement is needed. With each movement of the motor, the drive shaft steps a precise amount of distance .The degrees per pulse is set in the motor's manufacturing and is provided in the characteristic sheets for that motor.

Almost any two phase (sometimes called four phase) uni-polar stepper motor with a voltage rating of from 9 to 24 volts and a current rating of 900 milliamps or less may be used. A uni-polar motor has two center tapped windings with six leads and has its voltage and either its current or resistance marked on the nameplate. Another motor characteristic is its stepping angle which is also marked on the nameplate. An angle of 1.8 degrees or less is preferred because each step is smaller but 7.5 degrees or even more can be used. Although many surplus motors come without a wiring diagram, you can easily find the correct connections with an ohmmeter. Fig (1) is a diagram of a typical stepper motor coils connection. The winding resistance will be a few hundred ohms or less. To find the center tap first measure between any two leads. If you measure open circuits try again until you get a reading and then record its value. Number these leads 1 and 2. Connect the meter to lead 1 and a lead other than 2 until you get another reading and then number it 3. If this value is the same as the 1-2 value then lead number increases more voltage drops across the motor and less across the resistor to maintain a more constant torque. A constant current driver circuit would do the same thing.

3.3 Stepper motor drive [7]

There are many circuit driver techniques that could be used to drive the stepper motor. One of these methods is driving the stepper motor by using four power transistors that energize the four coils of the stepper motor in organized sequence depending on the stepper motor itself and the program of the microcontroller. Fig (2) shows the typical connection of transistor type stepper motor driver circuit which consist of:

a) Four power transistors (NPN type BDX)
b) Four resistances 1KΩ
c) Four diodes (1N4002 Silicon Diode)

Another type of stepper motor circuit driver as shown in Fig (3) is using Darlington array IC (ULN2003) which is high voltage; this circuit used in proposed device, high current Darlington arrays each containing seven open collectors' Darlington pairs with common emitters. Each channel rated at 500 mA and can withstand peak currents of 600 mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout.

This circuit driver is efficient, compact, simple, and cheap give high power. For this reason it had been chosen as the driver of the stepper motor in our design.

3.4 Syringe pump mechanism

The syringe pump driving mechanism consists mainly of the following parts:

3.4.1 Set of gears which will give the required moment that will rotate the driving shaft.

3.4.2 Driving shaft which will move the syringe rod fixture.

3.4.3 Syringe fixture: The syringe fixture consists of three parts, the first part is the movable fixture which is used to fix and move the moving rod of the syringe pump. The other two parts are the stationary parts which are used to fix the syringe pump body.

3.5 Detailed description: The operation of the portable drug delivery system pump is controlled by the microcontroller by using a suitable program as shown in Fig.(4) The device that had been designed and performed is portable and its supplied by 18V dc voltage using 2×9V batteries.

After switch on and resetting the device, time and dose can be set using push buttons to increase or decrease the required value which will be displayed by three digit 7-segment displays. The first digit displays the dose (1, 2, 3, 4 & 5ml) while the other two digit display the time of repetition (1 to 24 hours). Two modes of operation had been programmed; the 1st mode is the test mode while the 2nd mode is the actual operation mode. In the test mode each hour will represent one minute to make experiments and tests easy and simple.

When pressing the start push button, the microcontroller will start counting the assigned time and will supply a proper sequence of signals that will energize the coils of the stepper motor and consequently moving it at the end of each adjusted period in specified increment such that each 1ml dose last 25 seconds as a final result. The dose delivery will be repeated in sequence.

Depending on the time and dose values, when the drug in the syringe end and the syringe become almost empty the stepper motor will stop automatically by closing a limit switch connected directly to the interrupt pin of the microcontroller.

The proposed device used to inject the drug to the patient with Thalasemia disease by the following rate

1. Injection time 1 to 24 hours step on hour.
2. Injection volume 1 to 5 ml step 1 ml.

The numbers of steps in stepper motor control the speed of it and when keep this speed constant can be calibrated time require for injection 1ml of drug (1 ml in 25 second).

$$d = V \times t \qquad \text{……… 1}$$

Where:
d: distance (horizontal movement)
V: velocity (speed of motor)
t: time (injection time)

Therefore by using this low can be achieved these specifications. The algorithm of the microcontroller program can be shown in Fig. (5).

4 Results:

The main result of our project was designing a portable drug delivery system as shown in Fig (6) using a microcontroller which drives a stepper motor and consequently drives the syringe pump system to deliver a specified medication dose at the end of the specified time in repetition cycle.

The general specifications of our device are:

1. Microcontroller based Portable drug delivery system
2. Syringe size: 5ml
3. Two modes of operation (Test mode and normal operation mode).
4. Delivery time cycle In operation mode 1 to 24 hours.
5. Injection rate: 25s / 1ml
6. Audible alarm
7. Power supply: 18V DC (2×9V batteries).

5 Conclusions And Future Work

The following conclusions obtained when compare the proposed drug delivery system with portable infusion pump type Micrel as shown in Fig (7) which is used in Ibn-Alather hospital in Mosul:

The idea of designing and performing portable drug delivery device is achieved. The features of the device that is performed are:

1. Efficient and practical.

2. Easy to use by nurse and physician.
3. Easy to fix the syringe.
4. Quick and easy way in selection of Time period and dose rate.
5. Low power consumption.
6. Light weight.
7. Work very smoothly specially in injection process.
8. Audible alarm when syringe is almost empty.

6 References:

[1] N. A. Kshirsagar, "*DRUG DELIVERY SYSTEMS*", Department of Clinical Pharmacology, Indian Journal of Pharmacology, 2000.

[2] Didier Maillefer, Stephan Gamper, " *HIGH-PERFORMANCE SILICON MICROPUMP FOR DISPOSABLE DRUG DELIVERY SYSTEMS*", Institute of Microsystems, IEEE, 2001.

[3] S. Gopalakrishnan, A. Chenthilnathan, "*FLOATING DRUG DELIVERY SYSTEMS*", Journal of Pharmaceutical Science and Technology Vol. 3, India, 2011.

[4] P. K. GAUR, S. MISHRA, "*TRANSDERMAL DRUG DELIVERY SYSTEM*", Asian Journal of Pharmaceutical and Clinical Research, Volume 2,2009.

[5] ATMEL, AT89C51, *8-bit Microcontroller with 4K Bytes Flash*

[6] *Stepper Motor Basics, Industrial Circuits Application Note.*

[7] *Thomas L. Hopkins, "STEPPER MOTOR DRIVER CONSIDERATIONS COMMON PROBLEMS & SOLUTIONS",* Application Note. 2003.

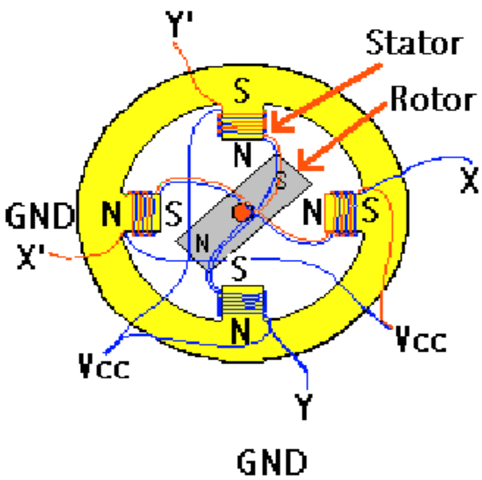


Figure (1): diagram of a stepper motor coils connection.

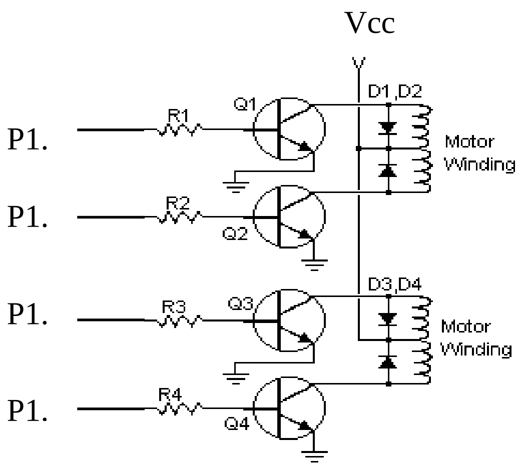
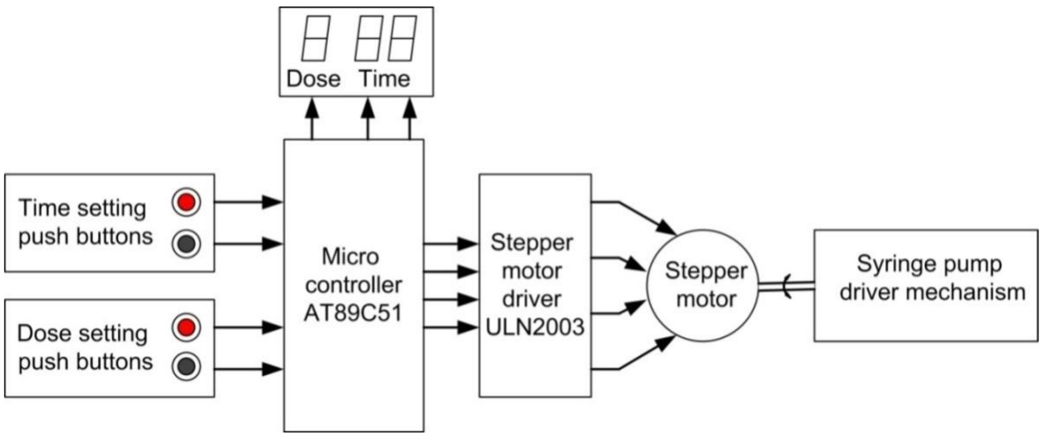
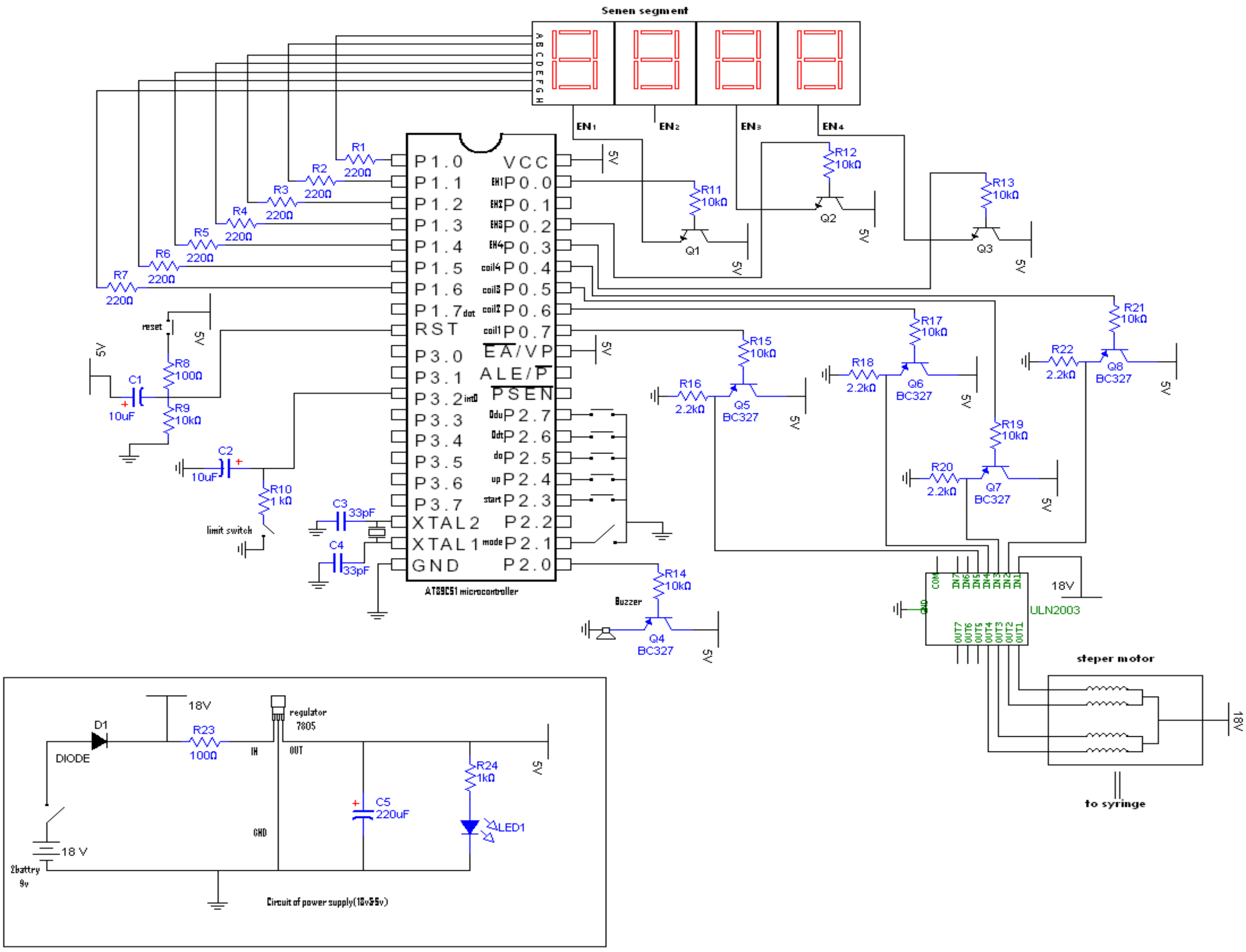


Figure (2) typical connection of transistor type stepper motor driver circuit



Figure(3) : The block diagram and connection of (ULN2003) as stepper motor driver of Drug Delivery System.



Figure(4): The circuit diagram of portable drug delivery system pump.

P0: Speed of Stepper motor (Constant Speed)
$P0=FF_{16}$ Stepper motor stop.
P1: Number of ml injection
P2: Time of Repetition (from 1 to 24 hours)

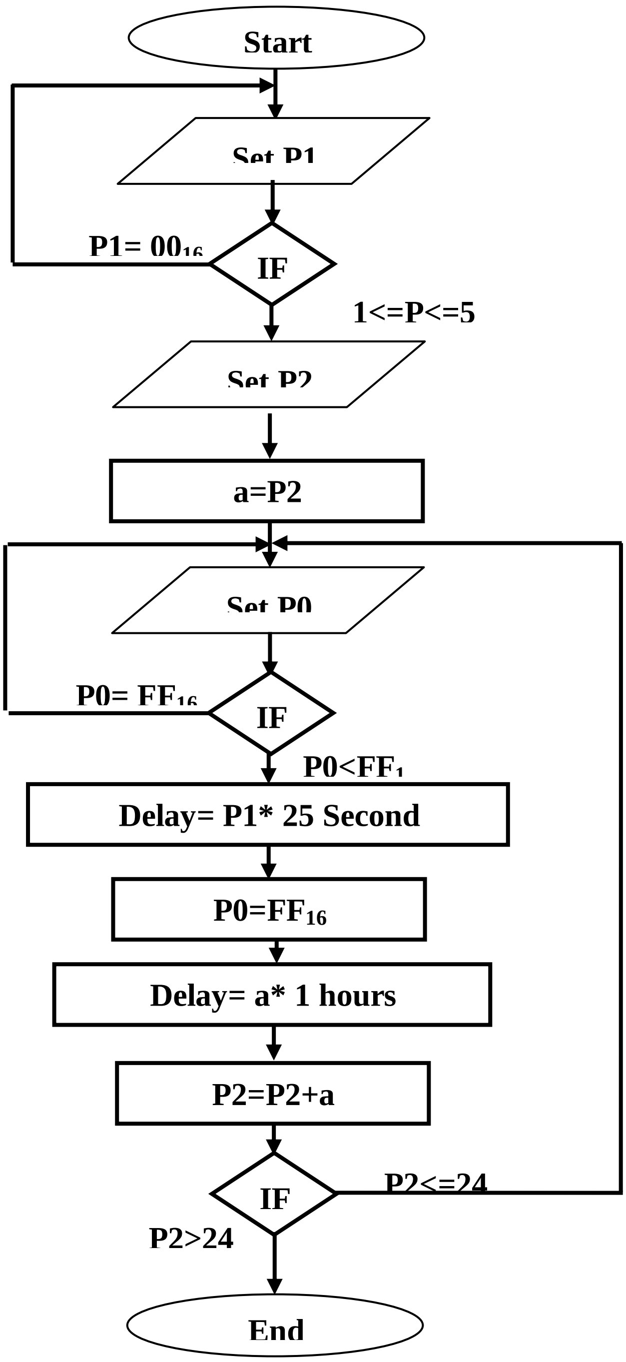


Figure (5) Microcontroller program algorithm

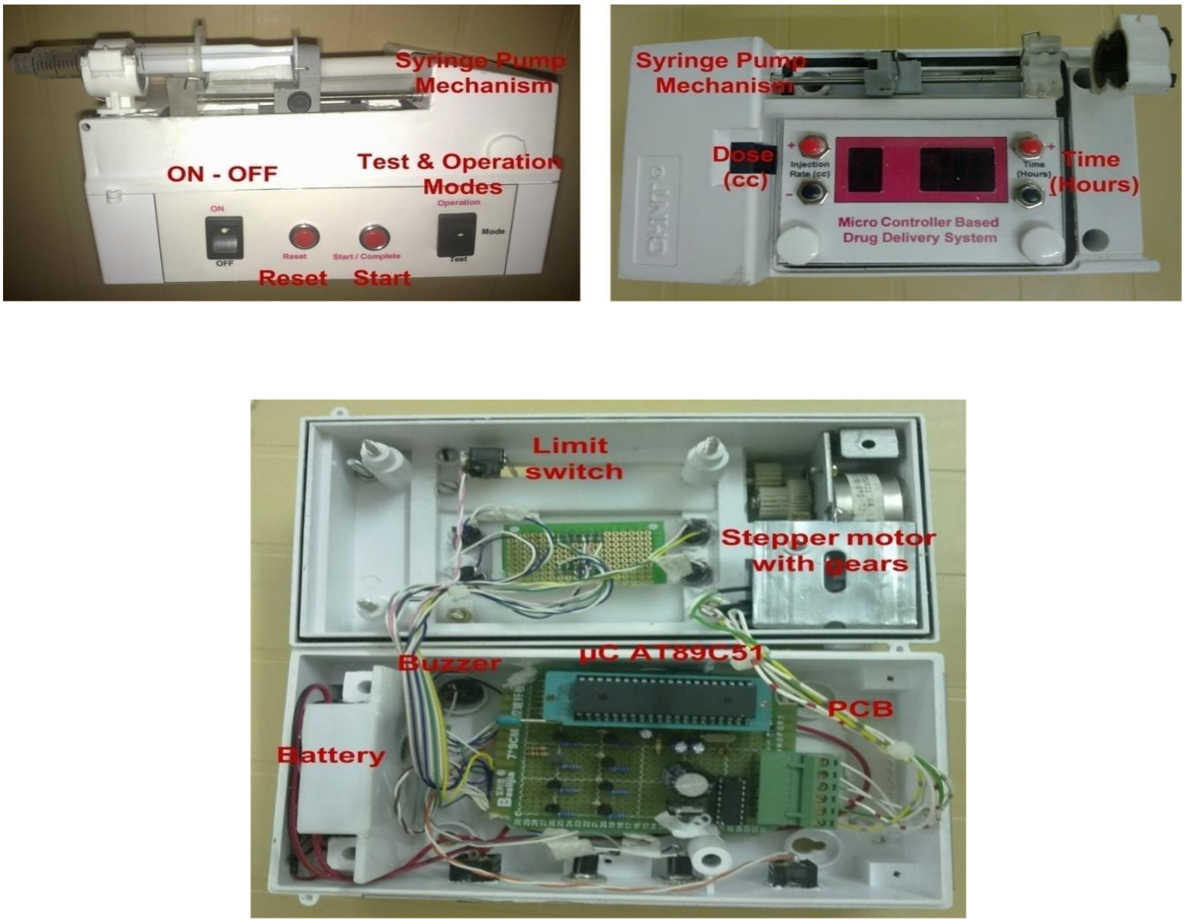


Figure (6): Internal and External Shape of Drug Delivery System

Figure (7): Micrel infusion pump