Abstract - In every aspect of life automation is required to reduce the work. So we have designed Automatic flow control system for Insulin Infusion Process. This system will overcome the current drawbacks of insulin flow control pump used for injection of insulin into the body of diabetes patients. Infusion pumps can administer fluids in ways that would be impractically expensive or unreliable if performed manually by nursing staff. For example, it can inject as little as 0.1 mL per hour injections (too small to inject), injections every hour, injections with repeated doses requested by the patient, up to maximum number per hour (e.g. in diabetes patients), or fluids whose volumes vary by the time of day. The MFC system is having unit to measure the patient’s blood glucose level and accordingly automatically adjusts the flow of insulin through the pump. This system can also be used for precise flow control of biomedical fluids as well as medicines. The MFC eliminates the need for continuous monitoring of diabetes patients in ICU to take care of their lab method sugar measurement after an hour and then adjusting the Insulin pump speed in the presence of doctors. So in absence of responsible doctor the MFC can take care of all the necessary things with reduced man power. The proposed system has blood glucose measuring unit through which the nurse or doctor can measure patient’s blood glucose level in time and accurately there after the insulin flow into the body of patient is adjusted or set. The Insulin pump flow can be set automatically on the amount of sugar or manually by the nurse or doctor as according to the need. The Proposed system is having three IPs running at a time and also having PC interface through which the total control and setting can be made.

Key Words: MFC, IPs , PC , BGM.

I. INTRODUCTION

Today, diabetes has become the fourth killer after the cardiovascular disease, cerebrovascular disease and cancers in recent years. According to the health association of China: In the next ten years, the incidence of diabetes will increase rapidly, probably up to 14%[2]. Doctor prescribe medicines or other treatments to reduce chance of developing eye disease, kidney disease, and other conditions that are common in people with diabetes. These conditions are called complications of diabetes. Diabetes can also damage blood vessels. Small sores or breaks in the skin may become deeper skin sores (ulcers). The infected limb may need to be amputated if these skin ulcers do not heal. The most effective treatment method for the diabetics is long-term insulin injecting. At present, the common insulin injector includes the disposable syringe and the mechanical pen-like injector, such as Novolin-Pen and Ergo-Pen. The former is very cheap, but not accurate. The injector pen should be adjusted by turning the thread scales on its tail before each injection which converts to an amount of insulin dosage. Once a slip occurs, it will do harm to the patients[2]. In view of the shortcomings existing in the current products mentioned above, a novel design of automatic insulin injection process using microcontroller is put forward. It can realize the accurate setting, storage and display for the insulin dosage, and drive a miniature stepper motor to push the insulin into the patient’s body automatically and accurately, which is very convenient for the
diabetics to manipulate and ensures a best therapy effect as well. Also this syringe can infuses fluids, medication or nutrients into a patient's circulatory system. The project syringe can administer fluids in ways that would be impractically expensive or unreliable and not possible manually for any person to provide such small insulin doses continuously for many hours as well. For example, they can administer as little as 0.1 mL per hour injection and such doses in continuous manner for every hour. Also Injections with repeated boluses requested by the patient, up to maximum number per hour e.g. in analgesia patient, and fluids whose volumes vary in the time of day. So MFC system is the need for today's biomedical fields where there is a demand of precision, accurate and controlled fluid infusion for many hours is required. As the inventions in biomedical field increasing continuously MFC system is such a system which fulfills all the aspects of the Insulin infusion Process Because the system provides quite high but controlled pressures for the flow, Provides a closed loop operation by measuring the patient blood glucose level, Provides Central control on the flow control operation for at least three patients

II. SYSTEM DESCRIPTION

The Microcontroller based flow control for Insulin Infusion Process consists of main four sections as shown in Fig. 01.

I. Glucose measuring Unit.
 II. Controlling Unit.
 III. Three Patient Controlled Units.
 IV. PC Interface Unit.

Controlling unit consists of controller, keypad, PC interface and LCD. Three units each consists of stepper motor, mechanical activator, insulin tube or syringe. The glucose measuring system consists of glucometer sensor followed by data processing parts, keypad and LCD. On three controlled units or receiving units there are three patient bodies connected to respective IPs & the total insulin injection process will going to be carried out at the same time from single controlling unit. Insulin injection process is having selectable rate insulin tube or syringe for the delivery of insulin or other similar medication, including selection of the interval between motor-driven syringe advance and including control of the plunger displacement for delivery of an insulin bolus of predetermined size. Process is having slow-rate, highly accurate dispensing which can be used to inject small amounts of medication at a relatively constant rate for days at time.
Circuit of the IP system is mainly made up of the driver unit for the stepper motor, and alarm circuit. The MCU is the core of the whole system to set injection dose, store and dynamically display. When patients with diabetes are injected, the controller will send pulses with certain frequency to the stepper driver unit.

The stepper driver module provides enough current to drive the miniature stepper motor, which propels the actuator to push the piston inside the liquid container and finish the injection with a preset dose and also doses goes on adjusted according to the feedback of blood glucose level of the particular patient.

The human-computer interaction module is consisted of key and stroke segment LCD parts with additional feature of direct PC interface also, provides total system control from single computer, which is used to complete such interactive operations as dose set in automatic & manual mode settings. In case of power failure Control unit can be driven through battery supply and system operation is carried using keypad & LCD. Through PC control the system is best to use which is having three different windows for the three controlling units. In PC control mode first the mode is selected i.e. Auto or Manual for each patient or controlling unit then the amount of patient sugar is measured using BGM unit. The measured sugar appears on the respective patient window and the IPs speed adjusted according to the mode selected.

III. HARDWARE ORIENTATION

1. Power supply:
   - In the circuit using IC 7805,IC7812, we can get +5V AND +12V DC supply.
   - In the circuit, +5V DC supply is required for:
     ➢ AVR ATMEGA16
LCD Display
- And +12V DC supply is required for:
- DRV 8825.
- Stepper motors.

A. The controller
This kind of MCU is ATmega32 - featuring, High-performance, Low-power AVR with 8-Bit RISC architecture and rich peripheral resources and so on. RTC module provides an exact real-time clock for the system. Some dual I/O functions, such as supporting stroke segment LCD driver, comparing capture model, PWM wave output (CCP), supporting BSL mode of download, are utilized in the application. Controller takes the data from BGM unit process the data display the amount of sugar on LCD or PC and accordingly takes the decision of Insulin flow adjustment. The role of controller is to do multiple tasks such as sort the sugar value measured according to the patient and adjust or set the speed of respective IP only without disturbing the other patients IP.

B. The driver unit for the stepper motor.
The motor unit is the most important part of the system. Taking size and power into consideration, we choose DRV 8825 as the motor driver which is micro-stepping driver and designed for low voltage portable applications. The chip has micro, full and half-stepping capability. Three driver units along with three mechanical assemblies take care of the accurate Insulin flow adjustment. To reduce the flow rate to required range proper gearing mechanism is used along with DRV 8825 micro-stepping feature. The working of DRV is controlled by the controller by software as well as by hardware means.

C. Human-Computer Interaction unit
Human-Computer Interaction unit is composed of two parts: the stroke segment LCD screen, the membrane switches and computer with controller interface. The LCD along with keypad is used in case of actual monitoring person or nurse presence or any power failure case where we are not able to use the PC interface. Through keypad the mode is selected like automatic injection or manual injection of insulin. Measured sugar is displayed on the LCD and accordingly speed of IPs are set. Also it is having the feature to stop the IPs & reverse movement of the pumps. When it is time for the patient to inject, only needs to press the Injection button. With the of second part having direct PC interface, there are three different controlling windows for the three patients. First select the mode of operation of IPs, then it automatically takes the sugar data via serial port as the blood sugar is measured through BGM unit and accordingly adjusts the three IPs with respect to respective blood glucose amount of each patient. As the injection process going on any time we take the amount of blood glucose level which will be displayed on the PC screen and therewith doses goes on adjusted automatically. It is having feature to measure the blood glucose and adjust the IPs speed in run time. Also having feature to control & monitor indivisual patient. In run time any patients IP can be stopped or moved back without disturbing the other patients status.

D. Blood Glucose Measuring Unit
This unit was facilitated with glucometer sensor, keypad, controller, LCD display. Blood of the respective three patients is taken after some intervals on the completion of insulin doses and the glucose level was check in this unit which is then fed to control unit to take the corresponding decisions of insulin doses. The measured blood sugar is displayed on the LCD or on the PC GUI according to the selected mode. Same BGM unit is used for the three patients but at a time only single patients sugar is measured and not simultaneously.
IV. TESTING AND SIMULATION RESULTS

Part 1: Blood Glucose Measuring Unit

Diabetes Mellitus is a disease with high blood sugar (glucose) levels which results from defects in insulin secretion. The blood sugar concentration or blood glucose level is the amount of glucose (sugar) present in the blood of a human or animal. The glucose sensor is electrochemical strip which is having glucose oxidase enzymes. Our existing glucometer employs glucose dehydrogenase to generate electrons on a strip covered with blood, and the change in voltage across the strip is measured over time to determine glucose concentration. This method is called Amperometric Method of blood glucose measurement. Resistance across the strip drops over time due to the chemical reaction on the strip and the increase in the product of the enzyme-catalyzed reaction. Measurement of the corresponding voltage drop is correlated with known blood glucose concentrations to determine the patient’s blood glucose concentration. This is direct and in-time method to take the sugar measurements.

A biosensor makes use of biological material for its sensing function. There are three main parts of a biosensor: (i) biological detection elements, which recognize the substance of interest, (ii) a transducer, which converts the bio-recognition event into a measurable signal and (iii) a signal processing system, which converts the signal into a workable form.

The enzyme on the strip acts as a bio-recognition element, which recognizes glucose molecules. These enzyme molecules are located on an electrode surface, which acts as a transducer. glucose molecules are recognized by the enzyme and acts as a catalyst to produce gluconic acid and hydrogen peroxide from glucose and oxygen from the air. The electrode recognizes the number of electron transfer due to hydrogen peroxide/oxygen coupling. The electrons flow is depends to number of glucose molecules present in blood. The glucose sensor is an electrochemical diagnostic strip which uses glucose oxidase enzymes in conjunction with three electrically conductive electrodes. The glucometer strip is having three electrodes namely working electrode, reference electrode and counter electrode. When blood is placed onto the test strip, it reacts with a enzyme due to that amount of glucose in the blood turns either into gluconic acid or gluconolactone, depending on the type of reagent used on the strip.

![Fig 02:-Glucometer Strip](image)

**Chemical reaction at reaction zone**

GOD

Glucose +O2 + H2O $\rightarrow$ Gluconic acid + H2O2

H2O2 $\rightarrow$ O2+2H+ + 2e-
The signals from glucose sensor which is change in current are passed to signal condition unit. This output of the Biosensor collected at working electrode is connected to amplifier LM358. The glucometer requires 220 millivolts maintained across the two electrodes using LM358 Op-Amp. One of the electrodes is a reference electrode and the other is the working electrode. The reference electrode is connected to electrical ground (common), and the working electrode is maintained at 220 mV. When a blood sample is placed on the test strip, the resistance of the strip immediately drops, causing current flow proportional to amount of blood molecules. The average current produced by the glucose test strip is 20μA. The output of LM 358 is given to the filter circuit. The current is converted to voltage through a current-to-voltage converter made with the help of LF356 which also acts as Low Pass Butterworth filter. A current to-voltage converter is simply an op amp with a feedback resistor. The output voltage from LF356 is in the rage of 1-10 mv. Both LM358 & LF356 required external bias voltage of range 2-3 volts.

This output is actual voltage signal corresponding to the amount blood glucose. In the fig 03 if strip with blood sample is placed at con3 location initially the output voltage of LF356 increases rapidly for 1-2 sec time period proportional to blood glucose amount and then settle to a stable value after 2 seconds. This analog voltage is connected to ADC pin of ATmega32. We taken average of all voltage values at the output in the controller and then calculated the mean value after 2 seconds to measure the actual blood glucose of the patient.

The Blood glucose level is measured in the molar concentration i.e in mmol/L (millimoles per litre). In some countries the mass concentration is measured in mg/dL (milligrams per deciliter). As the molecular weight of glucose (C₆H₁₂O₆) is 180, the difference between the two units is 18 factor, so that 1 mmol/L of glucose is equivalent to 18 mg/dL. Concentrations below 3.9 mM (70 mg/dL) or above than 10 mM (180 mg/dL) are considered to be hypoglycemic or hyperglycemic, respectively. Using these concentrations, as specified in the lab protocol, allows for analysis of the full range of biologically relevant concentrations.
So the final correct value of glucose is now displayed on the LCD or PC with correct unit.

![Blood glucose amount displayed](image)

**Fig 05:** Blood glucose amount displayed

## Part 2: Central Control Unit with keypad & LCD

In the central control unit via keypad and LCD depending on measured glucose concentration IPs speed is adjusted.

Single BGM unit is used for three patients so first and main function of the ATmega32 is to sort the measured blood glucose value according to the patient. User has the flexibility to use either hardware or PC software mode to use the total MFC system. As firstly the system started all the IPs are off, to start any pump first we select the auto or manual mode via keypad & LCD, then select the particular patient i.e its IP. Now first measure the blood glucose of the patient through BGM unit with a single switch and sort the value according to the patient under observation. Depending on amount of glucose adjust the speed manually in manual mode of operation and in automatic mode the control unit itself sets the speed of IPs on the basis of previously loaded data of blood glucose speed chart. For the automatic mode this blood glucose speed chart is set in software itself according to the demand of doctors. This chart gives information about for what amount of sugar value what will be the required speed of IPs. So on the amount of sugar value ATmega32 automatically go on adjusting the speed of IPs in automatic mode of operation. The Particular IP is started with the frequency pulses from the ATmega32 to the DRV 8825, which then provides 4 output pulses to the stepper motor to rotate it. The controller is having hardware toggle mode on compare match, this feature of ATmega32 is used to drive three DRV8825 at the same time without interrupt or interference with each other. The minimum speed of any IP is 0.1ml/hr and maximum is 10ml/hr.

In ICUs for the diabetes patients the speed of IP is adjusted with respect to amount of sugar i.e if the blood sugar concentration is large then high speed is set on IP to inject or infuse more amount of insulin into the body of patient. Likewise the programming is done for the full user interface with the system. For the low speed of IPs controller generates low frequency square wave signal to respective DRV 8825 and for high speed of IP the controller will generate high frequency square wave. Also the controller does the role of direction controlling of the stepper motors to run in forward(clockwise) or backward(anticlockwise), stop the motors or to move back the motors to their initial positions.

To interface three IPs to ATmega32 three Driver ICs DRV8825 are used. 2 Pins of controller controls a single IP so total of 6 pins of controller controls all the three IPs full operation. 3 pins of ATmega32 are used to set the direction of three IPs i.e forward or reverse, and 3 pins to run the IPs with proper frequency or speed with the use of DRV8825.
The aim of this work was to demonstrate a total system for Controlled Insulin Infusion Process with closed loop configuration. In ICU there is detailed and clear observation on patients condition is required. As the case with diabetes patients in ICU Our MFC system provides all the necessary things with reduced manpower with less doctor interaction .Initially the doctor takes care of all the things about patient condition and speed adjustment according to the modes and later he will reliable on his staff for the total observation of patients. The BGM unit with its flexibility to use for any patients with total system interface gives intime and correct value of blood sugar. On the account of BGM unit sugar value directly feed to the system so the record keeping becomes easy and suitable. The designed Microcontroller based flow control system for Insulin Infusion process provides close loop system with automatic speed adjustment of Insulin Pumps without stopping or interrupting them. Also through PC interface the total system becomes more easy to use. In designed system it provides control for Three ICU patients which can also be increased so a single staff can take care of all the patients from a single control unit from a single PC. As all the necessary units for the Insulin Infusion process comes under a single system through this project it becomes more cost effective and more economical as well. In present MFC system out-off four units two are successfully simulated. Hence this system proves to be very advantageous as well as efficient, the one which might become the bench mark in the history of automation.

REFERENCES


BIOGRAPHIES

Shashank Surywanshi born in Kolhapur district in India, on 7th October 1986. He has obtained her B.E degree in Electronics Engg from Shivaji University, Kolhapur, Maharashtra, India in 2010. Presently, he is a P.G student of Electronics in Shivaji University, Kolhapur, Maharashtra, India. His area of interest includes Basic electronics PCB designing and Embedded Systems.