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Microcontroller Based Insulin Infusion pump for Diabetes

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ABSTRACT

Continuous glucose monitoring system intended to drive a pump that will administer insulin for the purpose of combating diabetes. The system begins with a microcontroller unit having an analog voltage input that is derived from a calibrated linearity curve relative to that of glucose concentration, the microcontroller algorithm processes the data and determines whether an output of insulin or glucagon is needed. The output of the microcontroller unit is a time variable pulse which is dependent on the glucose concentration reading. The proteus software test for the microcontroller unit indicates that the algorithm can be used to properly read glucose concentrations and provide an output accordingly. However, there are delays within the microcontroller which affect the response of the output. For the full custom IC design of the drug driver circuit, it is observed that the parasitic capacitances and resistances affect the propagation delay and power dissipation of the circuit but can still be used in a drug driver system.

Keywords: driver, linearity curve, glucose concentration, insulin, propagation delay.

1. INTRODUCTION

Many researchers have attempted to find methods for diagnosing and treating diabetes disease. One of the approaches is to design an automated closed-loop insulin delivery system. A fully automated closed-loop insulin delivery system (also known as an artificial pancreas) could potentially be the ultimate answer for blood glucose (BG) control in diabetic patients. This system can mimic the activity of a normal pancreas and is capable of maintaining physiological BG levels for insulin dependent diabetic patients.

Such an artificial pancreas system can theoretically produce tight glucose control without finger-stick BG measurements, subcutaneous insulin injections, or hypo-glycemic/hyperglycaemic events, thereby, dramatically improves the quality of life for an insulin-dependent diabetic patient. The artificial pancreas is a system of integrated devices containing only synthetic materials, which substitutes for a pancreas by sensing plasma glucose concentration, calculating the amount of insulin needed, and then delivering the correct amount of insulin. Typically, such a device is comprised of a glucose monitoring sensor, an insulin pump, and a control algorithm to regulate the pump to deliver no insulin in order to maintain normal glycemia in presence of sensor measurements.

Loop control a feedback is taken from the body by placing the sensor which senses the glucose level in body. The output of the sensor is given to the controller and based on the error the controller pumps the required amount of insulin to the body. The controller is main part in the loop control, so, for designing the control algorithm we first develop the model of the glucose insulin kinetics of the normal person and then simulate them. The simulation results are stored in the lookup table and based on that the insulin pump the insulin to the body. The data acquisition and control is easier in proteus, hence the glucose insulin system is simulated in proteus.

Diabetes, a complication caused by high blood sugar concentration in the body, is a common disease with which a person has abnormally high concentrations of glucose because the pancreas cannot produce enough insulin. The right concentration of glucose needed in the body and the right amount of insulin will be considered to compensate the lack and excess amount of glucose concentration. Recent studies developed a closed-loop implantable biomedical system for maintaining the level of blood glucose which is close to the function of a normal pancreas

A glucose sensor was used as the source of data measured based on a glucose concentration calibration curve. A drug driver circuit was designed to control the insulin delivery of the system [2]. Also, actual design of insulin delivery system prototype has been made with the use of continuous glucose monitoring system (CGMS) [1]. A research was also made regarding the development of algorithms to prevent blood sugar level abnormalities on the basis of ahead-of-time prediction of glucose concentration by using CGMS data and suitable timeseries models [4].

Also, an "Insulcagon" prototype that uses a glucose sensor interfaced to a microcontroller which activates either insulin or a glucagon pump depending on the situation had been previously made [12]. However, existing studies and research can be improved and developed through further investigation of glucagon, a hormone secreted by the pancreas that raises blood glucose levels, the opposite of insulin. The pancreas releases glucagon when blood glucose levels fall too low. To develop an alternative drug driver system for a continuous glucose monitoring system suitable for implantation, specific objectives must be met, such as: (1) to implement full custom integrated circuit (IC) design of a drug driver circuit. (2) Proper algorithm of a microcontroller unit will be programmed.

Furthermore, (3) actual hardware will be used to test the microcontroller algorithm to simulate an ideal insulin pump to automatically regulate glucose levels in the blood identical to the function of a pancreas. This study can provide an artificial implantable pancreas for ideal prevention and treatment for diabetes. Also, the number of medical complications and medical costs involving blood glucose levels can be greatly reduced. This study focuses only on the design of the drug driver circuit and its interface with the microcontroller unit; it does not include the details about the glucose sensing device or the read-out circuit.

II. LITERATURE REVIEW

Diabetes is colleague along different abnormalities in insulin metabolism. The sugar, starch and other food component are transformed in to energy along insulin. Scientists are developing external insulin which is fed in a certain rate according to maintain the carbohydrate levels of 60-120 mg/dl. The diabetes is classified as Type-1 and Type-2. In case of Type-1 the controlling of insulin is exact difficult. For these patients regulation of blood carbohydrate concentration is maintained by releasing the external insulin along insulin infusion instrument.

The insulin pump is an electro medical instrument which delivers insulin over narrow and flexible plastic tube that ends along a needle inserted just under the skin near the abdomen. The pump releases doses of insulin at meals and during the several periods of the day based on the values of carbohydrate sensors. Carbohydrate concentration may change dynamically depending on the physical activities of the human. So, the insulin requirement may vary. In 1961, the first diabetic model developed by Bolie which consisted differential equation each for carbohydrate and insulin.

A similar model was developed by Ackerman et al. for carbohydrate insulin dynamics. The interaction effects of carbohydrate and insulin were obtained from the first two models. But these models failed the accountancy of distribution of insulin and carbohydrate over out the body. The minimal model developed by Bergman et al. (1981) had 3-compartments as lumped representation of human body.

This model lacked the dynamics of carbohydrate transport and distribution in tissues and effects of glucagon, which raises the blood carbohydrate concentration. Cobelli et al. in 1982 utilised 5- compartment models for carbohydrate, insulin and glucagon effects each lumped into its own whole body blood pool. This also included the use of threshold functions for saturation. Comparison of the peripheral versus portal route for insulin administration in closed loop carbohydrate control was done by Cobelli and Ruggeri (1983).But they were unable to describe the carbohydrate distribution in the body.

Lehmann and Deutsch in 1992 developed a nonlinear model which included a carbohydrate sub-model was a single compartment extra cellular pool and a 2-compartment model of insulin representing plasma and active concentrations. This was tual absorption kinetics of carbohydrate by the blood stream. Puckett in 1992 developed a modeling study of diabetes mellitus in which a two blood pool system representing insulin and carbohydrate concentrations which were directly affected by metabolic flux terms and exogenous signals.

Along the help of Light foot in 1995, Puckett also demonstrated inter and intra patient variability and steady state behaviour using his models [8]. Sorensen treated carbohydrate and insulin separately along coupling over metabolic effects utilizing threshold functions. A whole body lumped representation was also included to complete the carbohydrate-insulin system along counter regulation. A small inclusion into this model was made by Sorenson to include meal disturbances and parameters for uncertainty analysis.

III. PROPOSED DESIGN

The effects of glucose and insulin regulation are observed by developing a mathematical model for the pancreatic function. One of the main functions of pancreas is to regulate the concentration of glucose in the blood by releasing an enzyme, called insulin. We developed a steady state model for glucose to obtain the equilibrium concentrations. The total volume of blood and interstitial fluids is considered as single large compartment. The complete inflow of the compartment must be balanced by the total outflow. Glucose enters into body through absorption from gastrointestinal tract or through production in liver. The parameter for input flow rate is Q. The blood Glucose is utilized in three ways.

In protues we use simulation loop to use the threshold operator and integrator block which are present in control design and simulation tool kit. In the front panel of protues we represent the food intake and glucose concentration and insulin concentration graphs where as in the back panel. We implement the modelling equations obtained for a normal,type-1 and type-2 diabetic persons.

A. METHODOLOGY

The main objective of this study is to design the drug driver system for controlling an in system is composed of a full custom design circuit, and a microcontroller unit that core of the system that will be program algorithms. Furthermore, actual hardware with the microcontroller algorithm to simulate pump to automatically regulate glucose identical to the function of a pancreas. Designing driver system for controlling using a full custom design circuit. Actual hardware microcontroller Algorithm pump to regulate glucose identical for functioning pancreas. microcontroller based pump is designed and implemented to infuse either insulin or glucagon..

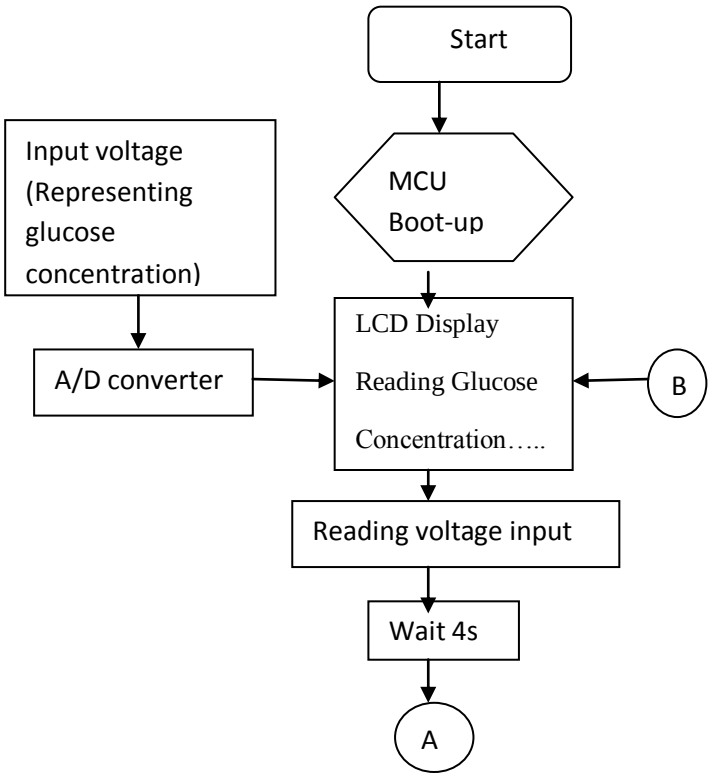
B. Circuit Operation and Discussion

Ideally, the circuit is intended to drive an ionic polymer metal composite (IPMC) behavior under an applied voltage. IPMC' voltages range from 1V to 4V. The drug driver inputs one of which is inverted with inputs fb and f have voltage values of 2 corresponds to outputs A and B respectively

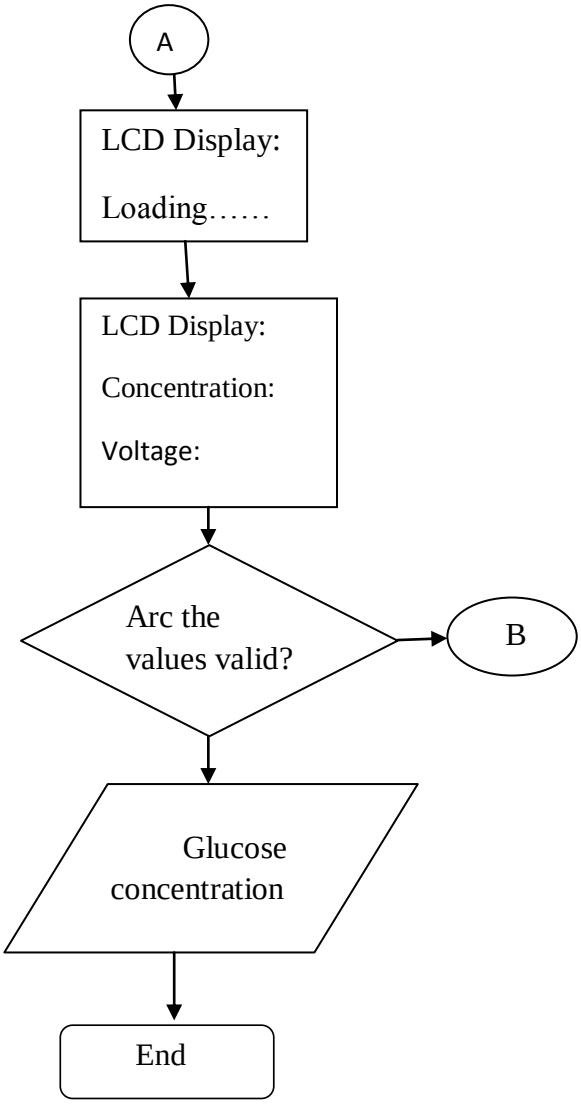
the voltage values of 1.5V and 0. An output IPMC due to the actuators limitations with h to water electrolysis.

IV. Microcontroller Algorithm

The microcontroller algorithm used is a two-point calibration which is based on the linearity curve of a glucose sensor strip



Algorithm Flowchart



Microcontroller Algorithm Flowchart

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V. Microcontroller Circuit

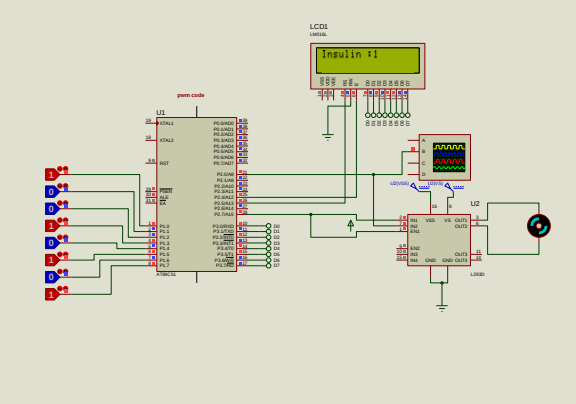
Atmel AT89C51 Algorithm allows a insulin pump for controlling glucagon.ADC converter based linearity curve technology is used to process the input voltage. This technology environment and management controller used in this system programming for existing algorithm

Atmel is supported with C compilers programming language to be researchers are more familiar. this system was programmed compiler software to have close to a human pancreas. Driver that can be used to drive depending on a given glucose of the microcontroller the glucose concentration, the glucose sensor strip. The microcontroller waits for a certain time, represented by the wait time of four seconds, to acquire a glucose concentration reading.

This waiting time compensates the time of the insulin or glucagon to take effect. After acquiring a glucose concentration, this data is loaded to the main process of the program. Also, this data is used to provide other information to be displayed on the liquid crystal display (LCD) like “Concentration” and “Voltage”. Validation of data information is also considered for instances when values are out of the acceptable ranges. Whenever the value is invalid, the microcontroller would not provide any output and repeat the process of monitoring and acquiring data. When a valid value is acquired, the process would proceed and make use of the valid data in providing the proper output response.

A. Testing of Microcontroller Circuit

In this study, actual pumps for the insulin and glucagon are not considered. Thus, an assumption is made about the parameters of the pump which are considered during the programming of the microcontroller algorithm. Considering that the pump operates as a DC voltage device with a constant flow rate during the time that the pump is on. Given these parameters, the pumps can be represented with LEDs: monitoring the time that the LEDs are on and relating it to the assumed flow rate of the pump, and drug sensitivity of the patient, the amount of the administered drug can be determined. Simulation was done with the aid of Isis Proteus 7 to project the response of the microcontroller. The schematic diagram of the microcontroller circuit simulated in Isis Proteus 7. Also, the actual prototype was implemented to test and verify the response of the microcontroller with an embedded program.



VI. RESULTS AND DISCUSSION

At normal operating conditions, the supply voltage is 2.5V at 37 degrees Celsius, being the normal human body temperature. There are differences in the propagation delay of the circuit but are justified because of the amount of parasitic produced in the layout. Despite of the computed percentage differences, they can still be neglected when used as a drug driver circuit for a pump since the unit of delays are in nanoseconds and will not produce excessive amounts of the drug. It was also observed that the power dissipation of the circuit increased in the post layout simulation, this is due to the parasitic capacitances and resistances that are produced in the layout.

VII. CONCLUSIONS

A full custom IC design is practical to use for a drug driver circuit due to the miniaturization of the devices used which is needed for the circuit to be viable for implantation. It is seen that the effects of the parasitic capacitances and resistances have not impaired the function of the circuit and is still operational as a drug driver. The variation in voltage and temperature that affects the propagation delay of the circuit has no considerable trend. Also, the power dissipation of the circuit is directly proportional to the increase in supply voltage and inversely proportional to the temperature change.

The actual hardware test shows that the microcontroller interprets the input analog voltage correctly in accordance with the linearity curve of glucose level to voltage and produces the proper output for a hyperglycaemic, hypoglycaemic or normal glucose level reading. However, a problem arises regarding the "on" time of the output of LEDs, it does not correspond to the simulated time output.

This could be due to the internal delays and slow response of the microcontroller circuit that is seen all throughout the hardware including the LCD display. A microcontroller unit can be programmed with a proper algorithm with the aid of simulation tools and code compilers. It can be programmed to output a desired signal based on proper analog input with the use of the glucose blood level linearity curve. Through simulation, the algorithm can be verified to work properly with accordance to the desired response that will drive a drug driver circuit accordingly.

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