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Design of Smart Phone Monitoring System of Insulin Pump

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Abstract

Insulin pump is an important electronic device that provides automatic insulin delivery. It has assisted many diabetics around the world to be able to live an orderly life by regulating blood sugar levels. There are many problems that occur due to high glucose levels such as foot problems and eyes problems. This paper presents the design of insulin pump using GSM wireless technology to monitor the pump operation. This paper aims to provide continuous monitoring of glucose concentration by establishing a direct connectivity between patients and their physicians or even their relatives using a wireless monitoring system. The system has a simple structure that generally consists of a drive circuit, motor and controller device. The proposed design delivers a predefined dose of insulin automatically. The system is simulated and verified in different operation cases such as the normal conditions when the pump functioning properly, where the glucose concentration is always within the allowable level and also tested when an error occurs in the pump, where the glucose concentration becomes more or less than the normal level. All results reported in this paper and all monitors transmitted GSM messages are accurate. The results revealed that the design of the insulin pump and the wireless monitoring system worked properly and had good performance.

I. INTRODUCTION

Developing insulin pumps is an attractive research field due to the high demand for such technology to replace the traditional methods. The first prototype of insulin pump was demonstrated in 1963 by Dr Arnold Kadish. Then a few years later, Dean Kamen introduced the first invented infusion insulin pump [1]. Diabetes is a lifelong disease that is classified as a dangerous disease if it is not properly controlled will cause harm in the society [2]. There are two types of diabetes; the first type required insulin therapy to allow the body cells to acquire the glucose from the blood for use as energy. Other types can be controlled by following a specific diet and exercise system [3]. Both types are observed in all age stages [4]. The normal glucose concentrations are within a range of 70–120 mg/dl before meals and less than 180 mg/dl after meals [5]. This paper introduces a wireless insulin pump monitoring system by sending a GSM alert message if the pump failure is occurrs. The failure is noticed when the concentration of glucose in the blood is at an abnormal level. The rest of the paper includes summary of the related works, types of insulin pumps, method and the results obtained.

II. SURVEY OF RELATED WORKS

Designing insulin pump has attracted the interest of many scientific researchers around the world due it is an essential device for a large number of patients in all over the world. The significant of this paper is in applying wireless monitoring for the pump operation and in its structure by using Arduino while most of the published papers are based on microcontroller devices and ignore monitoring issues. Smita[6] presented an embedded system of insulin pump based on ATmega16 and stepper motor, the paper concludes that the system has high accuracy. In Soudabeh T et al [7] a simulation of controller for glucose concentration in the blood is presented, the method used fuzzy logic theory, the paper conclude that it works successfully with less effort and provides good performance in the disturbance of meal eating.in Zameera et al [8] a design of insulin pump is shown which used to deliver small insulin value in predefined time. This design based on microcontroller and used servo motor to control an insulin syringe via a screw, the conclusion of the paper explains that it works accurately. Ahmed [9] in his master thesis used Fuzzy and Genetic Algorithms controller to control the injection pump, conclude that it has good response of blood regulation.

III. CLASSIFICATION OF INSULIN PUMPS

The structure of insulin pump can be classified in respect to the operation mechanism to two categories:

- The first type as shown in Figure.1 is not required sensor, the injection of insulin is controlled by regular time intervals depending on the planed program of the time eating of the patient

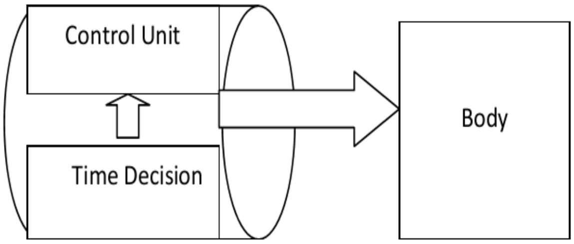

Figure.1: Insulin pump

- The structure of the second type as shown in Figure.2 the injection of insulin is dependent on the ratio of glucose concentration in the blood measured by the sensor.

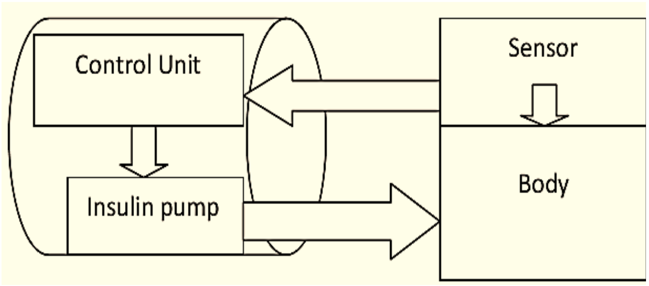

Figure.2: Sensor Insulin Pump

However both categories have challenges in providing efficient operations such as measurement accurancy and uncertainty factors influecing the glucose concentrations such as stress and meals [10]. Also as shown in Fig.1 and Fig.2 the major structures of insulin pump can be classified as open loop controller and closed loop controller respectively.

IV. METHODOLOGY

The design in this paper is divided into two parts; insulin pump whose task is to receive sensor signals and provide the required insulin dose, the second part is monitoring of insulin pump and alarm sent by internal circuit using smartphone technology and light alarm. The implanted internal circuit, as shown in the Figure.3, consists of an Arduino port whose task is to drive and control the stepper motor of the pump used The control unit receives the data from the external sensor through the receiving circuit and analyzes this data the make decision according to it, the correct work of the insulin pump is very necessary to give the patient semi-normal life, where the processor is driving a stepping motor by Darlington circuit to ensure it is function well without overloading the processor overworked, the control unit also responsible to monitor the insulin tank in the pump and send an alarm when it was less than the required level.

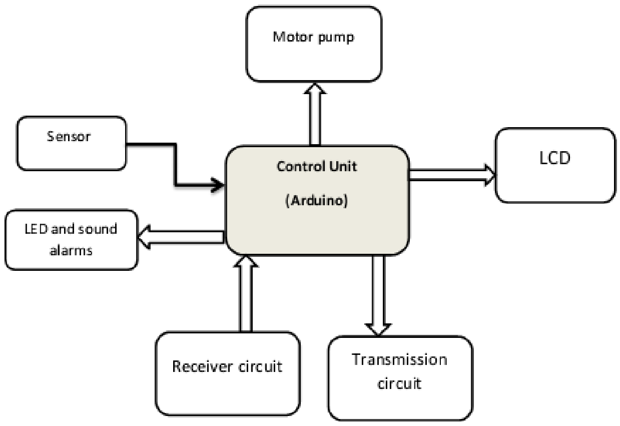

Figure.3: Block diagram

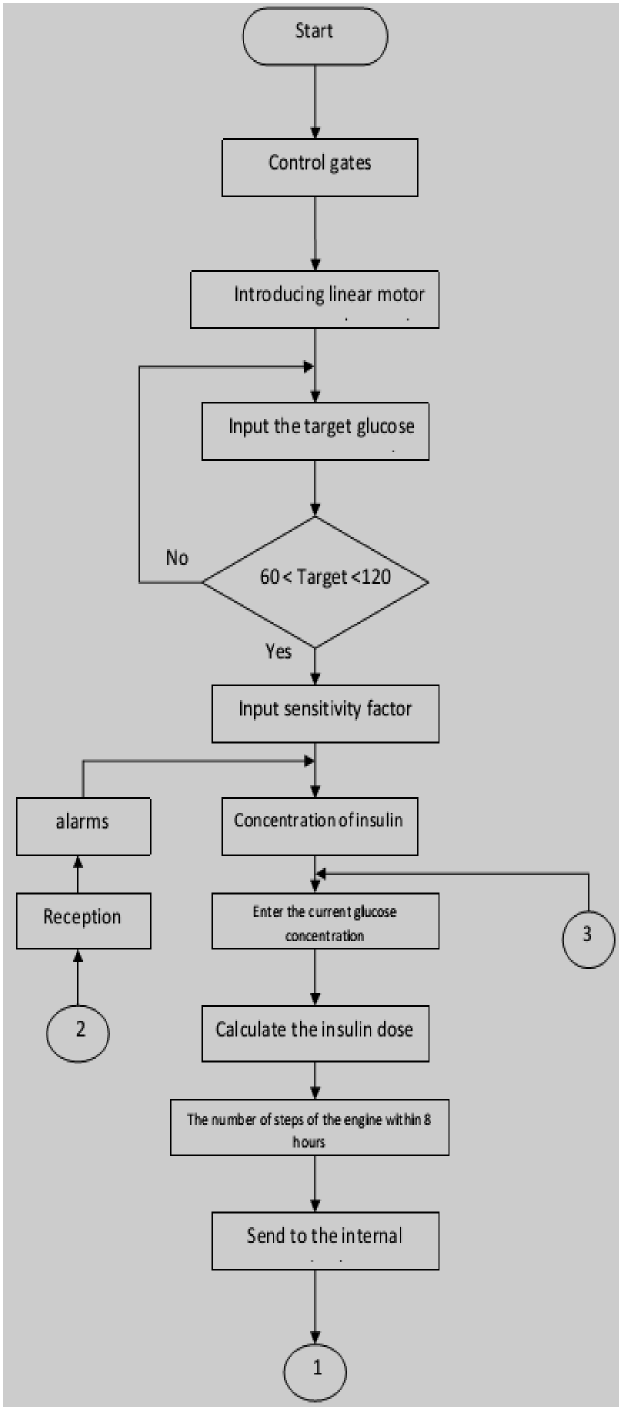

Figure.4: Algorithm

The LCD unit that used in this design is 2x16. The display unit offers a simple method of identifying the operation of the control unit. Figure 4 and Figure 5 show the operating algorithm of monitoring and controlling the insulin pump. The device reads the blood glucose values during fixed time intervals (we chose 8 hours), and then compare this value with a standard blood sugar value determined by the doctor and entered at the first operation of the pump, after that the insulin dose required to be given to the patient during this period is determined based on the difference between the two values, and from that the number of pulses or steps that the linear motor must perform is calculated and these data are transmitted wirelessly to the implanted internal circuit which drives the motor that in turn drives the approved pump.

Three LEDs were used to indicate the status of the pump and works as alarm unit.

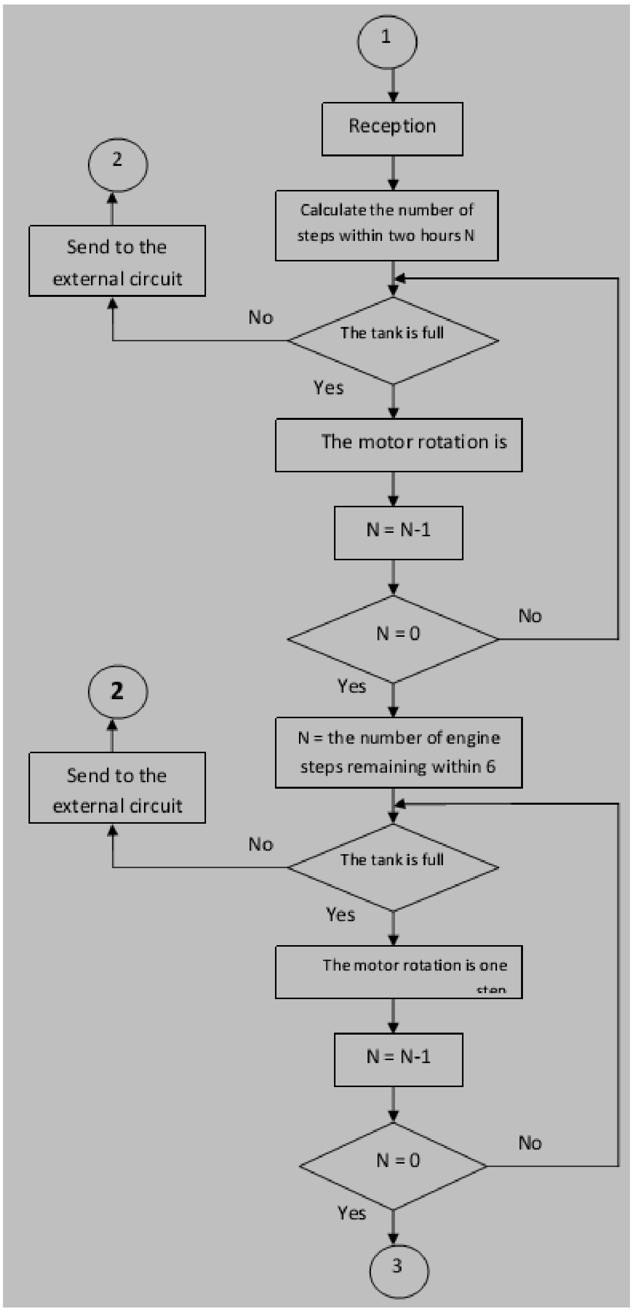

Figure.5: Algorithm of the Controlling the step Motor

The daily dose is given as shown in Table. I. This operation is performed according to the insulin sensitivity factor which defines the amount of blood sugar grams that effected by the unit of insulin.

Table. I:
Insulin dose

Insulin Sensitivity Factor (ISF)	The daily dose
75	20
60	25
50	30
43	35
38	40
30	50
25	60
20	75
15	100

The actuator part is connected to Arduino via drive circuit as shown in Figure.6 which consists of Darlington transistors with common emitters and inductive diodes for reverse loads, this drive circuit is important because maximum output of the Arduino gates is 5 Volt while the current consumption of the actuator is very high.

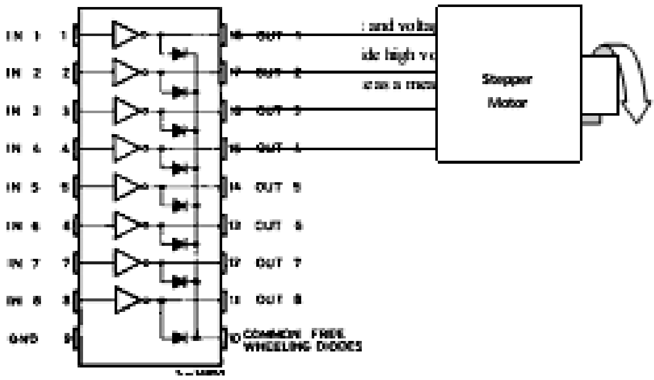

Figure.6: Motor Circuit

The current calculated from the simple relationship of ohm law

$$I = V / R \quad (1)$$

Where:
V: is the voltage
R: Coil resistors

V. RESULTS AND DISCUSSIONS

The main function of the insulin pump is to deliver the dose safely and in the correct time depending on the reading of the sugar level in the blood, this operation function is performed using software. This design was tested using electronic workbench software. The first operation of simulation is initiating the GSM transmitter and receiver as shown in Figure.7.

The insulin pump must function normally to ensure the blood sugar level normal at all times, any errors that occur in the operation of the insulin pump are very dangerous to the patient life. Therefore the monitoring system is necessary to alarm the patient if any error happened. The simulation assumed three cases of errors and the results examined alarm message of the monitoring system of the insulin pump in the following cases:

- Normal operation
- Hypoglycemia
- Hyperglycemia

- Insulin is finish

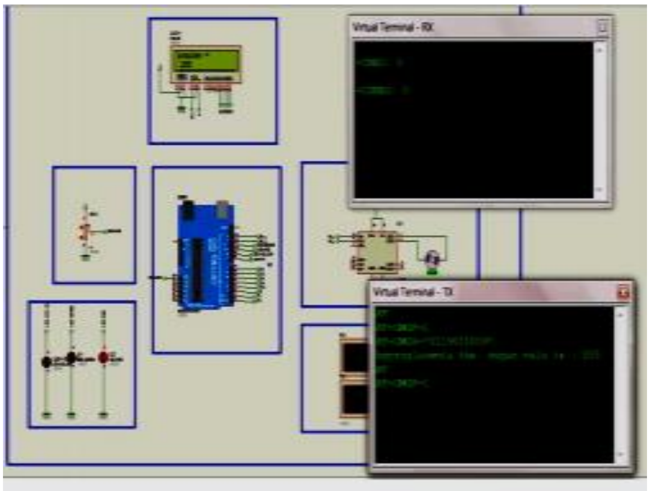

Figure.7: Step One

A. The normal operation

This operation case is shown in Figure.8. When the insulin level in the patient's blood is within normal levels (89 mg/dl), no message will be sent and the green LED is turned on. Also the LCD displays the measured insulin level where in this experiment case was 89 mg/dl.

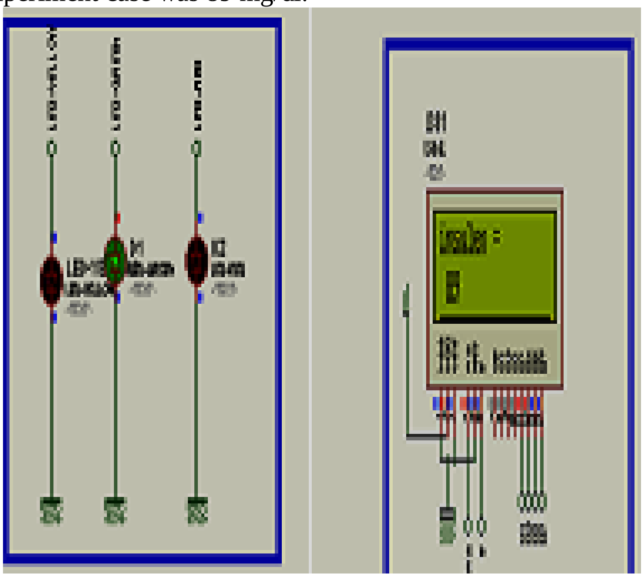

Figure.8: Normal Case

B. Case two; hypoglycemia

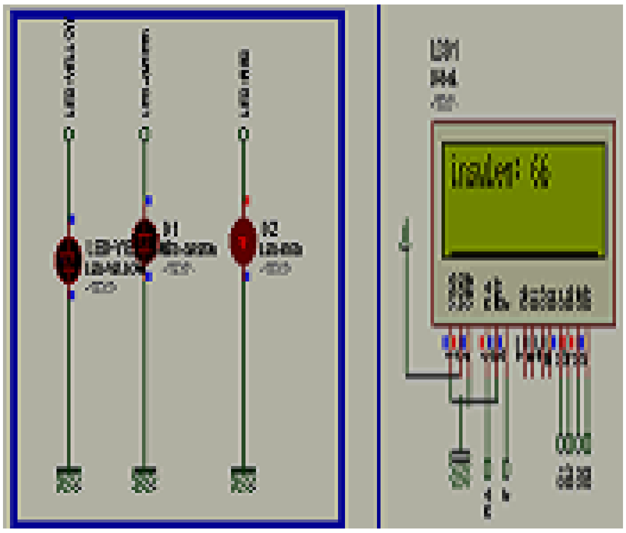

Figure.9: Case two

This operation case is shown in Figure.9. When the level of insulin in the patient's blood was within the levels (66 mg/dl), message will be sent and a red LED is turned on. Figure.10. shows the SMS message which was sent to the physician, demonstrating that there is hypoglycemia case, as showed in the measured value of insulin.

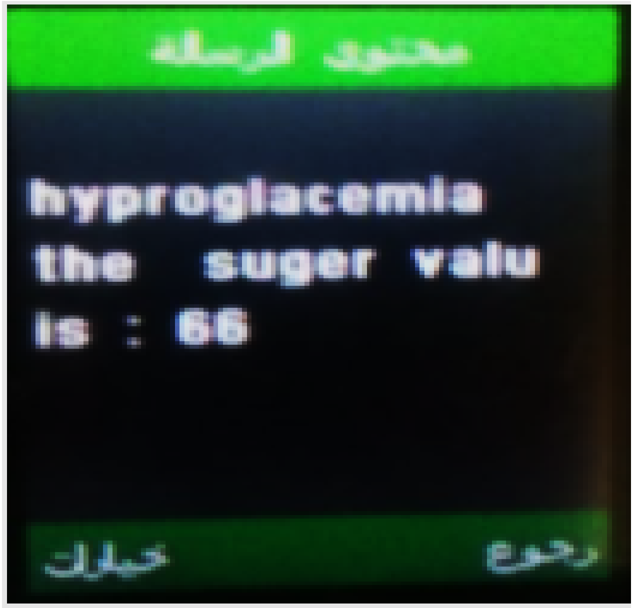

Figure.10: SMS of case two

C. Case three: hyperglycemia

This operation case is shown in Figure .11. When the level of insulin in the patient's blood was within the levels (255 mg/dl), there is message will be sent and a red LED is turned on. Figure.12. shows the SMS message which was sent to the physician, this message illustrates that there is hyperglycemia case, proved by the measured value of insulin.

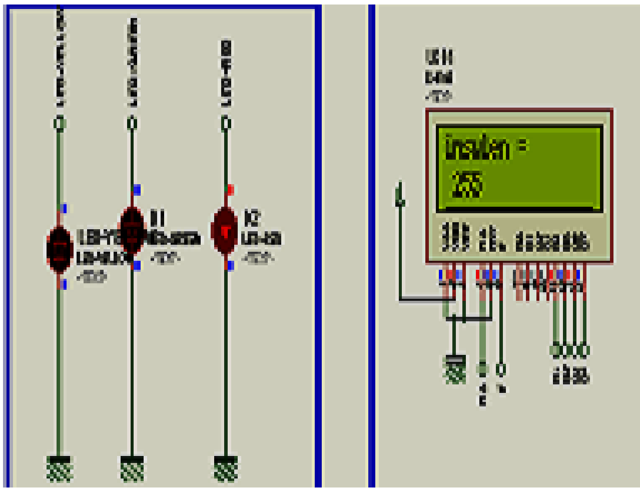

Figure.11: Case Three

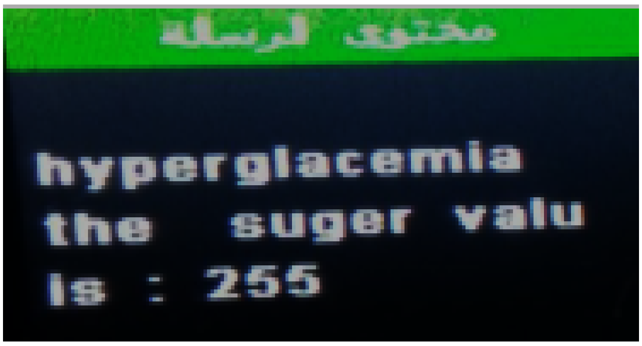

Figure.12: SMS of case three

D. Case four: Empty pump

This operation case is shown in Figure.13.When the level of insulin in the pump is less than (225 mg/d a yellow LED is turn on. `This step is required for alarming the patient to re-fill the tank.

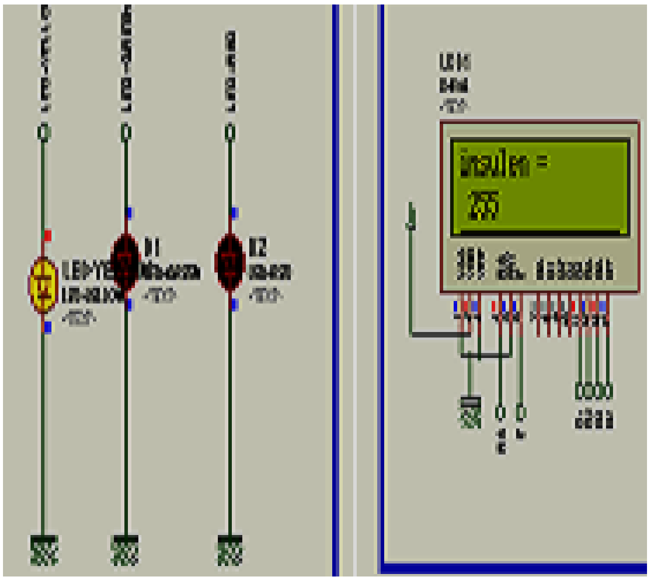

Figure.13: Case Four

VI. CONCLUSION

In this paper an advance design to monitor insulin pump has been developed using GSM technology and Bluetooth technology. The paper contains an advance design of the insulin pump. The significance of this paper is that it can enable patient monitoring using smart phone technology. The simulation results showed three operation cases of insulin pump; normal case, hypoglycemia and hyperglycemia. The overall results have managed to provide accurate results proving that the system is effective in assisting patients and physicians. The results are displayed in GSM message and also demonstrated in LCD. Flashing LED_s are used to indicate to each operation case.

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REFERENCES

[1] Insulin pump history *Accessed on [JAN -2020]* https://www.diabetes.co.uk/insulin/Insulin-pumps.html.

[2] Kaveh P, Shtessel YB. Blood glucose regulation via double loop higher order sliding mode control and multiple sampling rates. Modern Sliding Mode Control Theory. Berlin, Heidelberg: Springer; 2008. p. 427-45.

[3] Diabetes overview *Accessed on [JAN -2020]* https://www.diabetes.org/diabetes.

[4] Medical guidance for diabetes model and practices: Consultant in Endocrinology, Pune & Type I patient model.

[5] Leahy JL, Clark NG, Cefalu WT. Medical Management of Diabetes Mellitus. New York: M. Dekker; 2000.

[6] Smita D(2011) ," Design and development of insulin delivery system prototype" https://www.researchgate.net/publication/261048886

[7] Soudabeh T.D, Maryam Z, Marzieh K," Regulation of Blood Glucose Concentration in Type 1 Diabetics Using Single Order Sliding Mode Control Combined with Fuzzy On-line Tunable Gain, a Simulation Study", Journal of Medical Signals & Sensors,Vol(05),Issue(03),pp:131-140, (2015).

[8] Zameera T, Kalpana V, Channappa B," Designing Of Insulin Pump",International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE), ISSN: 0976-1353 Volume 23 Issue 6, (2016).

[9] Ahmed S,2017"Design Fuzzy Control System for Blood Glucose Level for Type-I Diabetes Mellitus Patients Using GA", thesis submitted to for Master of Science in Electrical Engineering, The Islamic University–Gaza(2017).

[10] Abu-Rmileh A, Garcia-Gabin W. Wiener sliding-mode control for artificial pancreas: A new nonlinear approach to glucose regulation. Compute Methods Programs Biomed 2012;107:327.