Design and Development of Portable Insulin Syringe Based on MSP430 MCU.

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Abstract— ***This Paper gives details of the design of an ultra-low power portable insulin syringe system based on advanced microcontroller MSP430 which is capable of calculating and delivering insulin depending on sugar level. The motivation behind the project was the need for a small, portable and ultra-low power insulin delivery system that is built from commercially available electronic components, to help the research of diabetes patient caring. There are many advantages of portable insulin pumps for diabetes patients, but most of them were designed as wearable devices which must be wearing continuously. These were either never commercialised or are far too complicated to be used in academic researches. The design considers practical constraints as a portable device in a multitude of environments, aiming to satisfy developers', researchers', and users' needs for reliability, power efficiency, ease-of-use, and a functional development environment. The paper starts with the specifications that point out the most important respects of the hardware and software design. It gives advantage of the capabilities of the ultra-low power chip architecture along with idea of how the whole system performs in the real environment.***

Keywords— ***Insulin Injection, 32-bit Microcontroller, Low power consumption, DC motor.***

I. INTRODUCTION

Diabetes is defined as a disorder of metabolism, which is the way that human body utilizes digested food for growth and energy. For glucose to transport into cells, the right amount of insulin, which is a hormone produced by the pancreas, has to be present[1]. If the delivered insulin is less than is required or no insulin is produced at all, glucose will accumulate in the blood and overflow into the urine. As a result, the human body loses its main fuel source, in addition to which the excess blood glucose is toxic to several organ tissues. This concentration of insufficient or no insulin is known as diabetes. In normal individuals the pancreas provides the correct amount of insulin (virtually) in all normal situations *[4]*

Diabetes related complications such as nerve damage, brain damage, vision loss etc. are a worldwide epidemic with high medical, economic and social costs. Tight control of blood glucose levels with diabetic patients reduces the mortality to 50%*[2].*

Insulin pump is a wearable small cell phone like device which contains mechanism to deliver a small quantity of insulin regularly and very precisely.

The manual method to insulin delivery for diabetes mellitus require significant efforts from clinical stand point and not guarantee of an optimal performance because for elder patient there may be chance of misunderstanding of the dose marking on the insulin injection. So the dose may be taken by patient either less or extra as compared to required dose of insulin to get glucose level at normal level. If the extra or less dose is taken by the patient it can be harmful to the body of that patient.

II. SYSTEM BLOCK DIAGRAM

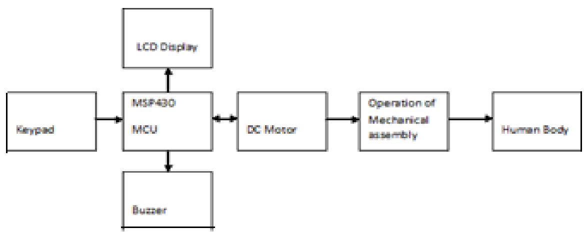

Figure 1: Block Diagram of System

Insulin syringe is mainly made up of the power module, the MCU MSP430, the driver unit for the dc motor, human-computer interaction, and alarm circuit .The syringe is proposed to be designed to drive a DC motor to complete each insulin injection with an exact preset dosage for diabetic patients. The MCU is the core of the whole system to set injection dose, store and dynamically display. When patients with diabetes are inject, the controller will send pulses with certain frequency to the DC driver unit. The DC driver module provides enough current to drive the miniature motor, which propels the actuator to push the piston inside the liquid container and finish the injection with a preset dose.

III. SOFTWARE MODULE

Due to the wide range of hardware platforms available, special attention will be given to Code Composer Embedded Workbench IDE if we use MSP430. The basic functions and step-by-step project development will be given for each tool. Topics covered will be the structure and management (source files, compiling, assembling and linking operations) of projects developed in both C (mainly) and/or Assembly language.*[4]*

Code Composer Studio

The CCS Embedded Workbench™ (EWB) is an Integrated Development Environment (IDE) that allows developing and managing projects for embedded applications. It is available for several microprocessors and 8-bit, 16-bit and 32-bit microcontroller. Among these is the MSP430 Microcontroller Family.*[5]*

Features of CCS:-

The tools included in the CCS EWB for the MSP430 are:

C/C++ Compiler;
Assembler;
XLINK Linker;
XAR Library Builder and the XLIB Librarian;
Editor;
Project manager;
Command line build utility;
C-SPY™ debugger.

Integrating these tools together in a unique workspace development environment facilitates efficient programming, providing a reduced development time.

IV. HARDWARE MODULE

Development Board:-

There are many development boards such as MSP430G4618,MSP430F5xxx and MSP430G2xxx among those MSP430G2XXX board is chosen because it gives us smooth operation of system. The MSP-EXP430G2 low-cost experimenter board called LaunchPad is a complete development solution for the MSP430G2xx Value Line series. The integrated USB-based emulator offers all the hardware and software necessary to develop applications for all MSP430G2xx series devices. The LaunchPad has an integrated DIP target socket that supports up to 20 pins. It also offers an on-board flash emulation tool allowing direct interface to a PC for easy programming, debugging, and evaluation.

The MSP-EXP430G2 is use with Code Composer Studio™ (CCS) IDE to write, download, and debug applications.

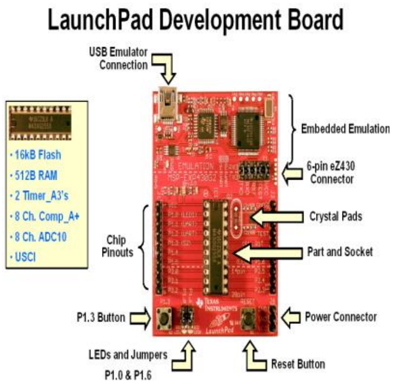

Figure 2: MSP430GEXP launchpad

DC motor:-

DC (Direct Current) Motors are two wire (power & ground), continuous rotation motors. When you supply power, a DC motor will start spinning until that power is removed. Because of the simple winding and control system, the main applications of these motors are the motion controls.*[7]*

Motor Driver Circuit:-

Driver circuit is required because when we interface motor with microcontroller then required current for motor can't be supply by controller hence to supply operating current for motor we require driver unit between microcontroller and motor.

H-Bridges:-

These four switches (or transistors) are arranged in a shape that resembles an 'H' and thus called an H-Bridge. Each side of the motor has two transistors, one is responsible for pushing that side HIGH the other for pulling it LOW. When one side is pulled HIGH and the other LOW the motor will spin in one direction. When this is reversed (the first side LOW and the latter HIGH) it will spin the opposite way.*[6].*

Table 1 : H-Bridge Operation

S1	S2	S3	S4	Result
1	0	0	1	Motor rotates in one direction.
0	1	1	0	Motor rotates in opposite direction.
0	0	0	0	Motor free runs.
0	1	0	1	Motor Brakes.
1	0	1	0	Motor Brakes.

V. MECHANICAL ASSEMBLY,OPERATION AND DESIGN STEPS

Mechanical assembly is constructed along with DC motor fitted to assembly and injection is connected in between motor and shaft. We use two handheld screws for handling assembly easily during insertion.Shaft is connected with long screw for injection.

Insulin injection is chosen of special purpose for insulin delievery which have printed scale on it.Two pin connector are connected to connect at output of motor driver i.e. for 12 V supply to motor driver circuit.

.

Figure 3: Mechanical Assembly

The proposed work can be described step by step as follows.

Step 1: Choosing MSP430

Microcontroller MSP430G2553

The MSP430 family of ultra-low-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency.

Features:

- Low Supply-Voltage Range: 1.8 V to 3.6 V
- Ultra-Low Power Consumption
  - Active Mode: 230 µA at 1 MHz, 2.2 V
  - Standby Mode: 0.5 µA
  - Off Mode (RAM Retention): 0.1 µA
- Five Power-Saving Modes
- Ultra-Fast Wake-Up From Standby Mode in Less Than 1 µs
- 16-Bit RISC Architecture, 62.5-ns Instruction Cycle Time
- On-Chip Comparator for Analog Signal Compare Function or Slope Analog-to-Digital (A/D) Conversion
- 10-Bit 200-ksps Analog-to-Digital (A/D) Converter with Internal Reference, Sample-and-Hold, and Auto scan.
- Serial Onboard Programming, No External Programming Voltage Needed.
- On-Chip Emulation Logic with Spy-Bi-Wire Interface.

Step2: Software design and Implementation of code for interfacing motor with MSP430.

Once the system is started it will initialize LCD and display on LCD as "SET HOME POSITION." Here position of piston can be set with the help of increment or decrement button i.e. by rotating motor in clockwise or anticlockwise. Then system will wait for pressing Enter button. After pressing Enter button it will display string "ENTER TO LOAD" Then by Pressing Enter button it will ask for glucose level. After that glucose level can select with the help of increment or decrement button. After Enter it will motor starts rotating and it will deliever predefined insulin calculated by MSP430.If Available insulin is "0" then start system from initial step else it will ask for new glucose level.

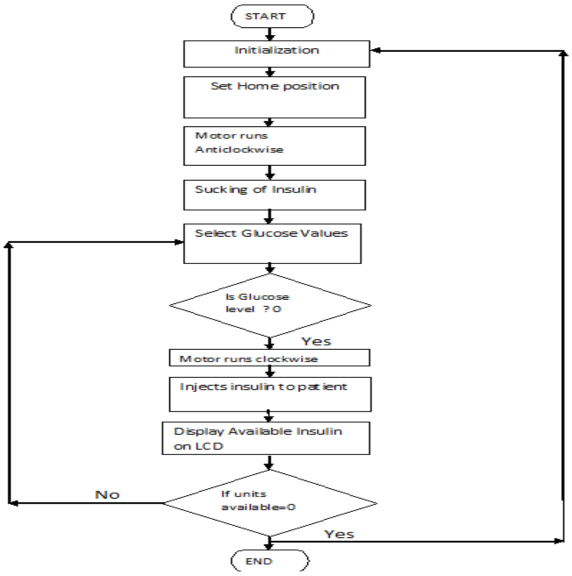

Figure 4: Flow Chart of System

Step3: Choosing the suitable motor driver unit.

L293D is a bipolar motor driver IC. This is a high voltage, high current pushpull four channel driver compatible to TTL logic levels and drive inductive loads. It has 600 mA output current capability per channel and internal clamp diodes.

The L293D is designed to provide bidirectional drive currents of upto 1 A at voltages from 4.5 V to 36 V. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V.

Features:

- Wide Supply-Voltage Range: 4.5 V to 36 V
- Separate Input-Logic Supply
- Internal ESD Protection
- Thermal Shutdown
- High-Noise-Immunity Inputs
- Output Current 1 A Per Channel(600 mA for L293D)[8]

As discussed in H-Bridge operation H bridge IC LM293D is chosen which is motor driver IC to drive DC motor. It has important features such as Which sources 20 mA. Also it takes 12 V power supply from power supply unit.

Three pins of LM293D are connected to development board i.e. to MSP430 microcontroller. These 3 pins can be used for creating logic.

These 3 pins are connected to MSP430 are Port pins P2.0, P2.1 and P2.2

P2.0 is for logic 1 or logic 0
P2.1 is for logic 1 or logic 0
P2.2 is for logic 0

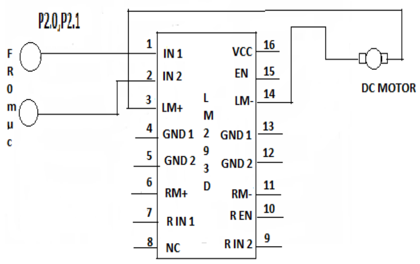

Figure 5: Motor driver connections

Truth table for this logic can be shown as follows

Table 2: Truth table for logic of motor

P2.0	P2.1	Motor action
0	0	Stop
0	1	Forward
1	0	Reverse
1	1	NA

Step 4: Choosing a suitable power module.

The basic step in the designing of any system is to design the power supply required for that system. The steps involved in the designing of the power supply are as follows,

1) Determine the total current that the system sinks from the supply.

2) Determine the voltage rating required for the different components. 230 V A.C transformer Centre tap transformer which have 12 V A.C. output which is given to rectifier circuit which gives DC voltage 5V and 12 V for system including board,motor driver circuit.

Step 5: Inputs to MSP430

It is important to initialize the system i.e. to give inputs to MSP430 this task can be accomplished with the help of Push buttons and these are input to MSP430 board. They are connected to port 2.3, 2.4, 2.5, 2.6 of microcontroller.

Step 6: Developing Human computer interaction

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

Step 7: Implementing Alarming unit.

It is important to give indication to patient such as whether injection is completed or not when execute system for insulin delievery thus termination of insulin delievery we can use different indicating components such as LED,Buzzer. When LED is chosen it can be visible but for elder patient it is inconvenience to see LED each time when terminate operation. So Buzzer is selected for indication which can also gives feedback detection. We use audible buzzer for indication of completion of insulin dose.

VI. RESULTS AND CONCLUSIONS

LCD Displays

When system is executed the flow of working of Portable Insulin Syringe is presented as below

Welcome Screen

Ready to suck insulin

Motor rotation

Availability of insulin

Recent glucose levels

New glucose levels

Motor rotation

Termination of dose

Figure 6: Flow chart of Execution

In this way overall working of system is described to achieve satisfactory infusion rate of insulin. To achieve this the following lookuptable which is universally accepted[9] is used. In this table required insulin dose is in the terms of small units for lower glucose level. But for simplicity the values of insulin dose in the range of 5 units are taken so that the movement of motor as well displacement of piston of insulin injection can be seen. This is shown by using printed scale on the reservoir of injection. These observation is summarized as follows.

Table 3: Result table

Glucose level	Required Insulin dose in units	Actual Insulin delievered in units
0-50	5	4.9
51-100	5	5.0
101-150	5	5.0
151-200	10	10
201-250	15	14.9
251-300	20	19.9
301-350	25	24.9
>350	30	30.1

VII. CONCLUSION

In this paper system is successfully implemented which is an affordable and effective solution for diabetes management. The product was able to deliver a precise quantity of insulin at proper intervals against simulated human body pressure.

The design of a basic microcontroller-based syringe has been presented. The design gives a basic "working" framework for the construction of a open-loop insulin delivery apparatus, allowing aspects of the apparatus to be tailored according to research needs (including the open-loop control algorithm). It provides a ready reference to other researchers in the construction of a open-loop insulin delivery system.

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