Design and Development of Portable Insulin Syringe using Low Power Embedded Systems.

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Abstract—This paper introduces the use of low power embedded system with the help of very efficient microcontroller. These applications are very useful in portable biomedical instruments such as Therapeutic Instruments e.g. Automated External Defibrillator (AED), Insulin delivery systems. as well as diagnostic instruments e.g. Thermometer, Blood Glucose Meter (BGM), Cholesterol meters, Thermometer, Electrocardiogram (ECG), Heart rate monitor, Pulsoximeter. Paper describes the various insulin delivery schemes. Later part is comparison of present microcontrollers which gives the idea of low power consumption. Then it describes the manufacturing of mechanical assembly for proposed application. After describing these applications it gives the idea about use of MSP430 in portable insulin syringe to deliver predefined dosage of insulin with the help of stepper motor.

Key words: Insulin Injection, MSP 430 Microcontroller, Low power consumption, Stepper motor

I. INTRODUCTION

Until recently, the embedded market has been primarily the domain of 8-bit microcontrollers. While embedded applications existed for 32-bit processors, they were limited to a few high-performance areas. The level of processing required for many embedded applications is increasing dramatically due to the convergence of communication and consumer applications and the delivery of higher levels of content, including video and high-end audio. This is driving the wider usage of 32-bit processors in system-on-chip (SoC) applications. With processor-enhanced FPGAs, an industry-standard architecture offers significant benefits over appropriectary architecture. Industry-standard processors have the several advantages:

• A broad selection of development tools

• A significant volume of available program code

• A large following of design engineers who have knowledge and experience using them

These benefits enable users to get their designs developed faster and to market sooner while reducing risk, and as a result, offer customers a better solution and increased value.

Diabetes mellitus is a chronic metabolic disorder and it is characterized by the disability of the body to maintain the blood glucose levels into physiological ranges. When a patient's blood sugar goes too high, insulin is given to the patient to bring his/her blood sugar back to a normal level. To prevent a patient's blood sugar from going too low, the patient is given a hormone called glucagon which raises the patient's blood sugar[2]. It is an autoimmune disease in which the beta- cells of the pancreas are destroyed, resulting in the absence of insulin secretion. 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%[3].

While other groups have described methods for automatically delivering insulin and glucagon, many of these systems still require human interaction to enter the venous blood sugar levels into the control system. We propose a new system that is used to automatically control blood sugar in people with diabetes through the fully automated measurement of blood glucose levels and the delivery of insulin and glucagon via the subcutaneous route.

Also the miniature syringe has been known as an important biomedical device because it has many potential applications in different areas of medicine and biology. Due to its small size, micro needles can reduce both puncture pain and tissue damage in a patient. By mechanically piercing the skin barrier, the miniature syringe can allow varying drug delivery with time for different therapeutics such as the continuous delivery of insulin to a diabetic patient [8].

II. COMPARATIVE STUDY OF ARM & MSP 430 MICROCONTROLLERS

Features	**MSP430**	**ARM**
Architecture	Von Neumann	Harward
ALU	RISC	RISC
Operating Voltage	1.8 to 3.6 V	2 to 3.6 V
No. of Pins	14	48,33
Packages	SMD	LQFP or HVQFN
I/o Pins	10	
Clock	On chip 16 MHz	1 MHz to 25 MHz.
No. of Instructions	27	Thumb instructions
MIPS	16 MIPS	Leader
Buses	16 bit Address and 16 bit Data bus	16 bit Address and 8 Data bus
On chip Debugging	Present	Selectable
Power saving modes	5	3
On Chip Memory	116KBFlash& 8KBytesRAM	32 KB Flash and 8KB SRAM
Hardware Interrupts	P1,P2 have interrupt capability	4 external interrupts.
Registers	16	16
On-chipTimer	One 16 bit Timer/Counter	04Timer/Counter
Watchdog timer	Present	Present
On-chipADC,DA	One16 bit Sigma to Delta	One 10 bit ADC

C	ADC with temperature sensor,DAC	support.s
Serial communication support	SPI&I2C, IrDA,USART	Two USsART UART or USB

Table 1: Comparison of microcontrollers

III. PROPOSED BLOCK DIAGRAM

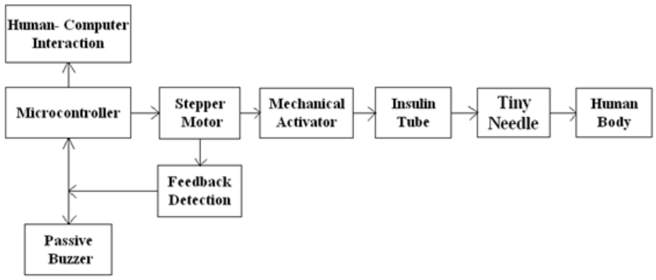

Figure 1: Block Diagram of Proposed System

The syringe is proposed to be designed to drive a stepper 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 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. The human-computer interaction module is consisted of key and stroke

As shown in above fig. following units are design.

1) Power module:

In terms of discharging current and volume, one battery with a rated voltage of 3.6 V is chose as the supply source for the whole system. By using low dropout linear voltage regulator, the output voltage is regulated at 3V.

2) The controller:

The MSP430 single-chip microprocessor is use as the controller for the whole system. This kind of MCU is 16-Bit RISC architecture, featuring ultra-low power consumption, low supply-voltage range, and rich peripheral resources and so on.

3) Stepper motor:

The motor unit is the most important part of the system. Taking size and power into consideration, We chose the motor driver which is a dual full-bridge motor driver and designed for low voltage portable applications.

4) Mechanical activator:

It is require to push insulin from insulin tube forward.

5) Insuline Tube:

It consists of insuline which is to be injected into an human body.

6) Tiny needle:

The insuline passes through this needle into veins of human body.

7) Passive buzzer:

The buzzer is use which can change its tone and volume by adjusting the duty ratio of the PWM wave.

8) Human-Computer Interaction unit:

Human-Computer Interaction unit is composed of two parts: the stroke segment LCD screen and the membrane switches. The stroke segment LCD has the advantages of low cost and a clear displaying content over its dot-array counterpart, thus it is very suitable for the elder patients to read.

IV. SOFTWARE MODULE

Software development tools:-

Due to the wide range of hardware platforms available, special attention will be given to Code Composer Essentials and IAR Embedded Workbench IDE. 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.[15]

IAR Embedded Workbench IDE:-

The IAR 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.[15]

IAR EWB main features:-

The tools included in the IAR 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.

V. HARDWARE MODULE

Stepper motor:-

Steppers are special motors that do not have any commutator to reverse flow of the windings current. Stepper motors are the best alternatives for applications that high accuracy motions are required such as CNC, printers and so on. Because of the simple winding and control system, the main applications of these motors are the motion controls.[10]

Why to use Stepper motor ?

Positioning systems have traditionally been implemented using DC motors, AC servo motors, Synchronous motors, Stepper motors, etc. DC motors are relatively easy to control. However it has disadvantages in using such motors for positioning systems like overheating of the armature windings. Also the torque to inertia is relatively low. For the above reasons positioning systems are now being implemented using stepper motors. Usually stepper motors were designed to provide precise positioning control within an integer number of steps. They have stable open loop operation to any step position and consequently no feedback is needed to control them.

Stepper motor driver unit:-

Stepper motor driver circuit is divided into two main parts: Signalling and switching. Signalling part is for generating the consequent and regular pulses (patterns) for motor driver. The switching part turns the control switches on and off according to the generated patterns. A four-phase stepper motor driver has two main parts as follows: control signal sequencer and motor driver as shown in fig 2 .[10]

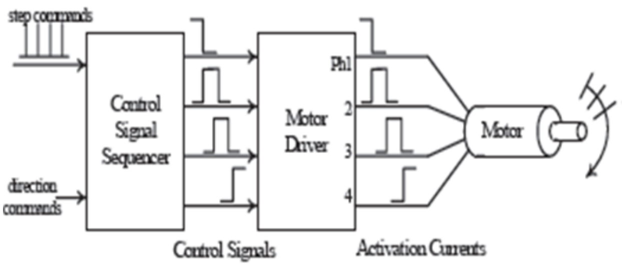

Figure 2: Motor Driver Unit

VI. MECHANICAL ASSEMBLY, OPERATION & DSIGN STEPS

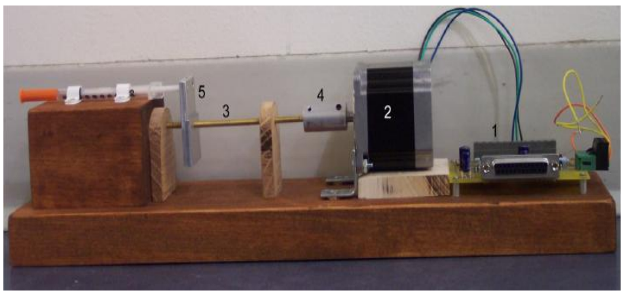

Figure 3. Mechanical Assembly

Taking the normal procedures to sterilize a syringe, a user will insert the syringe into our device. The syringe will be held in place with collapsible brackets (Figures 4 & 5, shown in red); the plunger of the syringe will fit into a bracket. The user will then use the numeric keypad to type in the dosage, then press "Enter" when complete. An auditory cue and a digital display (top of Figure 4) will instruct the user to insert the needle into a bottle of insulin. Having done

so, the user will press a Fill button located on the right side of the device (not shown in Figures 4 & 5) where a user's thumb will typically be located. This button will cause the motor to run and the bracket to pull on the plunger, therefore drawing fluid into the chamber of the syringe. The digital display will notify the user when the process is complete. An auditory cue and the display will then instruct the user to insert the needle into the body. Having done so, the user will press

the Inject button located adjacent to the Fill button. This button will cause the motor to run in the opposite direction as before, therefore pushing on the plunger and expelling the fluid. Again, the user will be notified when the process is complete with an auditory cue.

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

Step1: Software design and Implementation of code for interfacing stepper motor with MSP430.

Step2: Choosing the suitable motor 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.

Step3: Choosing a suitable power module.

In terms of discharging current and volume, one battery with a rated voltage of 3.6 V is chosen as the supply source for the whole system.

Step4: Implementing Alarming unit.

In order to explicitly remind patients of the termination of each injection, a passive buzzer module is used to signal an alarming sound after the end of each injection.

Step5: Developing Human computer interaction

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