Microstepping and High-Performance Control of Stepper Motors for Liquid Handling Robot in Biomedical Analyzers

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***Abstract*— Fundamental, applied and practical problems of optimal energy conversion and precision motion control of electromechanical systems are of a great importance. The solution of the aforementioned problems allows one to maximize the efficiency, minimize losses. And it can deploy in advanced motion platforms in aerospace, automotive, biomedical instruments, electronics, energy, manufacturing, power, robotics and other applications .This project aims to create a liquid handling robot for various biomedical instruments, like protein analyzer, blood analyzer. This project includes the controlling of a stepper motor using Trinamic Motion Control (TMC). This is the most advanced stepper motor driver and which can control a number of motors at a time. It drivers two-phase stepper motors offer an industry-leading feature set, including high-resolution microstepping, sensorless mechanical load measurement, load-adaptive power optimization, and low-resonance chopper operation. Standard SPI interface used to communication between PSoC and TMC. The stepper motor is used to do a number of functions of liquid handling robot, like mixing of reagents while testing, pippeting of reagents and blood, and it is also used to move robotic arms to take injection etc. Two sensors photo_logic slotted optical switch and capsensor used to detect different positions motor. controller used is PSoC 3 which provides both Verilog and C programming. So the project includes the comparison between the two languages. The advantage of using verilog is to reduce the time and storage consumption, accurate movement, according to the accuracy of movement of stepper motor gives the better results in analyzers.**

***Index Terms*— Microstepping, TMC, Capsensor, Liquid handling Robot, Homepositioning Sensor**

I. INTRODUCTION

Traditionally positioning systems have been implemented using motors like AC servo motors, Synchronous motors, DC motors, Stepper motors, etc. DC motors are relatively easy to control. However overheating of the armature windings makes disadvantages in using such motors for positioning systems . Also the torque to inertia is relatively low. For those reasons stepper motors are used to implement positioning systems. 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. Trinamic motion control used to control stepper motors because they provide high precision, reliability, efficiency and microstepping up to 256 microsteps. Controller used is PSoC ,which allows both Verilog and C programming. Verilog offers more precise and accurate control of stepper motor than C [1]. Here stepper motor controls different automated liquid handling robots for an automated analyzer. An automated analyzer is a medical laboratory instrument designed to measure different chemicals and other characteristics in a number of biological samples quickly, with minimal human assistance. These measured properties of blood and other fluids may be useful in the diagnosis of disease. And tasks of automated robots including conveyor belts, robotic arms, and automated pipetting stations.

There are mainly two types of automated analyzers are discussed here Centrifugal Analyzer, Discrete auto analyzers. In Centrifugal Analyzer Samples and reagents are added in a specially designed centrifugal type cuvet that has three main compartments. The cuvet placed on rotor. And it spun at high speed (4000 rpm) and then sudden stop results Mixing of sample and reagent. After mixing in cuvet, the rotor is spun at 1000 rpm. Discrete Analyzer employs a robust robotic sampling arm working in conjunction with a stepper motor-driven syringe. The functions done using syringe are aspiration, dispension and mixing of accurate and precise quantities of sample and reagent. Mixing and other function are take place in a miniaturized test tubes, called reaction wells.

II. PROPOSED SYSTEM

The overall architecture and data flow of the proposed scheme is illustrated in Figure 1.This project includes the working of automated liquid handling robot by controlling of a stepper motor using Trinamic Motion Control(TMC). Which is the most advanced stepper motor driver. Stepper motors have proven well suited for managing precise movement Of robotic arms, as well as the even more demanding precision and accurate working required for liquid aspiration and dispensing through the pipette syringe pump.

TMC can provide many advantages than any other motor driver in the market like a flexible ramp generator for automatic target positioning, it ensures absolutely noiseless operation combined with maximum efficiency and best motor torque,microstepping up to256 microsteps . TMC includes two modes, first mode controls the motor using step and direction Interface and next one is SPI Interface. SPI interface used to parameterize the driver for the application. which include microstepping, current control, power consumption ,energy consumption, stall detection. table 1 shows the parameters

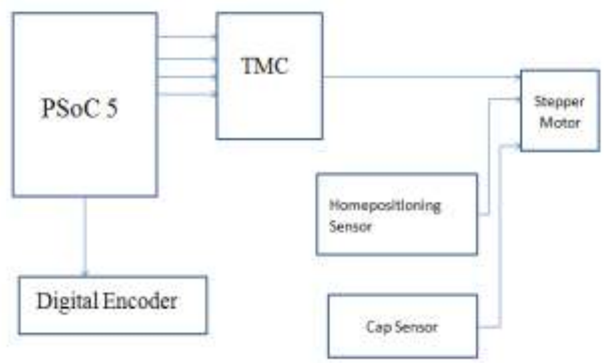

Fig. 1.Block diagram

Tab. 1.TMC Parameters

Register/ Bit	DRVCTRL (*SDOFF*=1)	DRVCTRL (*SDOFF*=0)	CHOPCONF	SMARTEN	SGCSCONF	DRVCONF
19	0	0	1	1	1	1
18	0	0	0	0	1	1
17	PHA	-	0	1	0	1
16	CA7	-	TBL1	0	SFILT	TST
15	CA6	-	TBL0	SEIMIN	-	SLPH1
14	CA5	-	CHM	SEDN1	SGT6	SLPH0
13	CA4	-	RNDTF	SEDN0	SGT5	SLPL1
12	CA3	-	HDEC1	-	SGT4	SLPL0
11	CA2	-	HDEC0	SEMAX3	SGT3	-
10	CA1	-	HEND3	SEMAX2	SGT2	DISS2G
9	CA0	INTPOL	HEND2	SEMAX1	SGT1	TS2G1
8	PHB	DEDGE	HEND1	SEMAX0	SGT0	TS2G0
7	CB7	-	HEND0	-	-	*SDOFF*
6	CB6	-	HSTRT2	SEUP1	-	VSENSE
5	CB5	-	HSTRT1	SEUP0	-	*RDSEL1*
4	CB4	-	HSTRT0	-	CS4	*RDSEL0*
3	CB3	MRES3	TOFF3	SEMIN3	CS3	-
2	CB2	MRES2	TOFF2	SEMIN2	CS2	-
1	CB1	MRES1	TOFF1	SEMIN1	CS1	-
0	CB0	MRES0	TOFF0	SEMIN0	CS0	-

In most of the automation of chemical or biochemical laboratories a liquid handling robot is used. This robot that dispenses a selected quantity of reagent, samples or other liquid to a designated container. The simplest version simply dispenses an allotted volume of liquid from a motorized pipette or syringe. task of automated robots including conveyor belts, robotic arms, and automated pipetting stations. conveyor belts can be used within the laboratory as aids for transporting laboratory specimens from one clinical laboratory workstation to another. Although conveyor-belt technology has been applied very successfully in industry and provides alternative to mobile robot specimen transportation, it is not able to cope with the large variety of specimen containers (ranging from micro specimen containers to large urine-collection containers) found in the clinical laboratory. Thus, for effective use of conveyor belts, specimens must be repackaged into containers that will fit on the conveyor belt. line.Fig 3 and 4 shows the robotic arm with conveyor belt and automated pippeting system.

Fig. 2.Robotic Arm with Conveyor belt

Fig. 3. Automated pipetting

B. Position Detection Sensors

Two sensors homepositioning sensor(photo logic slotted optical switch) and capacitive sensor(cap sensor) used to detect the different position of motor movement.

A capacitor is formed when 2 parallel conductive plates are brought near each other and a charge is placed on one of the plates. A current flows through the gap between the two plates. The amount of current that flows across the gap is determined by the voltage, the area of the plates, the material that separates the plates and the distance between the plates. Capacitive sensor (Cap sensor) Fig.4 used for detecting and measuring something conductive or something has a dielectric value different from air. Cap sensor works on basis of capacitive coupling. In an automated analyzer a needle with cap sensor used to detect the position of liquid in a test tube or in a cuvet. when it touches the liquid it changes its dielectric value, and from which we can detect the position of needle.after that needle moves very careful(small number of steps) steps for mixing the reagent.

Building Homepositioning sensor from a standard housing with a 0.125 (3.18mm) wide slot and the user can specify output logic state. Homepositioning sensor Fig.5 senses the home while the stepper motor is running, ie the supply power to the mirocontroller can be cut off anytime meaning that without warning, the stepper motor will be left hanging when the power is cut off, When the microcontroller is powered on again, the stepper motor need to return to the home position because the home position is the reference point. Since the motor can be started at any given position when the motor get powered, the HOME sensor could be found to be at either state. Hence, initially, the state is to be considered unknown. The typical homing implementation calls for a transition from high to low or a transition from low to high as chosen by the application. In order to easily capture the chosen transition, the HOME sensor was given to a GPIO pin with a Pin On Change Interrupt. Since the pin can be configured to raise the ISR flag either with a rising or a falling edge, we can capture on either edge.

Fig. 4. Capacitive Sensor

Fig. 5. Homepositioning Sensor

C. Encoder

An encoder is used for speed and/or position control.It is an electromechanical device. i.e, encoders turn mechanical motion into an electrical signal that is used by the control system to monitor specific parameters of the application and make adjustments if necessary to maintain the machine operating as desired. The parameters speed, distance, RPM, position among others monitored are determined by the type of application. Applications that utilize encoders or other sensors to control specific parameters are often referred to as closed-loop feedback or closed-loop control systems.

Fig. 6. Encoder

III. AUTOMATED ANALYSERS

Automated analyzers used in a diagnostic laboratory. Automation increase the number of tests performed by one individual in a given time period (short turnaround time).speeds up the result. Human factor is decreased during the mechanical and repetitive part of an assay as labor is an expensive commodity in Medical laboratories. To minimize the variation in results from one individual to another (for accuracy, coefficient of variation is reduced hence the reproducibility increases). The quality of patients test results is monitored continuously for improvement of testing process. Automation reduces the potential errors of manual analyses such as volumetric pipetting steps, calculation of results, and transcription of results .The microstepping drive designed in this paper was used in the biochemistry analytic instrument, solved oscillation and improved the response of step motor effectively.

A. Centrifugal Analyzer

In this type of analyzer samples and reagents are added in a specially designed centrifugal type cuvet. It contain three main compartments. Sample is added from the sample cup by auto-sampler into the sample compartment of the centrifugal cuvet. The reagent probe into the reagent compartment of the centrifugal cuvet adds Reagent. Both sample and reagents are allowed to equilibrate to the reaction temperature. Mixing of sample and reagent occurs when the rotor holding the cuvet is spun at high speed (4000 rpm) and then sudden stop. The spinning causes the sample to be added to the reagent while the sudden stop causes turbulence and results the mixing of sample and reagent. After mixing, the rotor is spun at 1000 rpm. The reaction mixture is pushed horizontally to the bottom of the cuvet.

B. Discrete auto analyzers

Discrete Analyzer employs a robust robotic sampling arm working in conjunction with a stepper motor-driven syringe. The syringe is used for aspirating, dispensing and mixing accurate and precise quantities of sample and reagent into miniaturized test tubes, called reaction wells. Discrete analyzers have the capability to run multiple tests one sample at a time or multiple samples one test at a time. They are the most versatile analyzers. Discrete analysis is a separation of each sample and accompanying reagents in a separate container. Each sample is treated differently according to the tests requested and programmed by the operator. These instruments are dependent on electronic control. Auto sampler aspirates sample from the sample cup and placed it in the reaction cuvet. Samples are programmed or adjusted to reach a prescribed depth in those cups to maximize use of available sample. Mixing of sample and reagents can be done using different methods such as spinning of the cuvet at high speed followed by sudden stop, Introducing the reagent into the cuvet by jet action, Introducing air bubbles into the cuvet.

IV. SOFTWARE REQUIREMENTS

PSoC Creator helps to configure and program analog- and digital-peripheral functionality by using a Cypress PSoC device. Using PSoC Creator, can select and place Components, write C and/or Assembly source, and debug and program the project/part. This dynamic hardware-software combination allows you to test the project in a hardware environment while viewing and debugging device activity in a software environment When it using with associated hardware.

PSoC controller allows C programming and Verilog programming. Verilog HDL has parallel and sequential execution where C only handles sequential instructions. In PSoC digital subsystem support Verilog and analog subsystem support C program. Using the digital programmable system makes application specific combinations of both standard and advanced digital peripherals and custom logic functions of the digital subsystem. These peripherals and logic are then interconnected to each other. Any pin on the device, providing a high level of design flexibility and IP security. Features like capabilities and architecture of the digital programmable system are mentioned and there is no need to interact directly with hardware and register level the programmable digital system at the. PSoC Creator includes features like high level schematic capture graphical interface to automatically place and route resources similar to PLDs. The analog programmable system provides application specific combinations of both standard and advanced analog signal processing blocks. These blocks are then interconnected to each other and as in the digital subsystem it also provide any pin on the device, with a high level of design flexibility and IP security. The features of the analog subsystem are mentioned here to provide an overview of capabilities and architecture.

V. CONCLUSION

This paper presents Microstepping drive for stepper motor is a well-known technique to improve precision stepper motor performance. In addition, micro stepping techniques are used to achieve high resolution electronically and to suppress mechanical resonance. Here the stepper motor is used to do a number of functions like mixing of reagents while testing, pippeting of reagents and blood, and it is also used to move robotic arms to take injection etc for automated liquid handling robot. PSoC controller is used in this module.which supports Both C and Verilog programming. verilog gives advantages over C because of their parallel execution property. It uses two sensors As the requirement of analyzers. They are homepositioning sensor(photo logic slotted optical switch) and capacitive sensor(capsensor).both are used to detect the position of motor and speed is detected using encoder. encoder provides more accurate position detection while using Verilog.

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