RTOS-BASED MULTI-AXIS SYNCHRONIZATION AND MULTI-AXIS CONTROL SYSTEM FOR INDUSTRY APPLICATIONS

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Abstract :
This article presents the current results obtained through projects and experimental work using 5-axis high-speed machining with high-end precision systems to improve working efficiency. In many machine control and automation, there are two or more axes of motion which must be coordinated. The term "Multi-Axis Synchronization" refers to the motion which requires coordination, and the techniques used to achieve control of the motion. The development of innovative products, and their realization through advanced manufacturing methods and process combinations, is a key issue in international competitiveness. In the field of embedded systems, with new rapid technologies, represented today mainly go through various complex precise designs. In these conditions, products are usually highly sophisticated in their design and working, to fulfill the high demands of their intended use. These demands regarding safety, quality, time, accuracy and weight reduction - as well as the new technology ideas - constrain the increase in efficiency of conventional production technologies. With today's increasing automation and machine sophistication, the control applications have become more demanding, and the control techniques have improved. Synchronized multi-axis movement using stepper motor without any collision can solve using RTOS by replacing with general purpose embedded OS. Development and applications of the control system based on the real-time operating system (RTOS) which constructs an open architecture control system with real-time performance, flexibility and low cost. In this paper, the RTOS-based control system is considered from RTOS evaluation, system-level design, to experiments and applications.

IndexTerms **- Machine Control and Automation, Multi-Axis Synchronization, RTOS, Embedded OS.**

I. INTRODUCTION

When two or more axes of motion are involved on a single machine, that machine is employing multi-axis motion. In our machines consist of 5 numbers of axial movements. Every axes used for different operations as listed below. Axis-1 is for cartridge movement. Axis-2 is for Aspiration probe movement. Axis-3 is for mixer movement. Axis-4 is for wash station movement. Axis-5 is for syringe pump operation. Axis of motion refers to one degree of freedom, or forward and backward motion along one direction. It is a linear motion, and may take the form of a conveyer belt, a rotary coupler, or many other types. The axes may be working independently, or moving together. The need for multi-axis synchronization arises whenever the axes must move together, and the relationship between their respective motions is important. Herewe consider two axes, the X direction and the Y direction. Each may move independently of each other, but if a two dimensional figure is to be drawn accurately, their motion must be coordinated. By Synchronization of two or more axes requires a definite relationship between one axis and the others. Individual axes were driven from this source with stroke and rail. The stroke determine the speed relationship, and the drive trains deliver the motion to the appropriate place. Such an approach works well if the desired gear ratio is constant and the drive train is short and direct. More complex arrangements require more costly mechanics, and the problems of backlash and mechanical wear become more pronounced. The working of the machine mainly depends on the combined movement of all the rails. This machine is created as medical device for protein analysis. Medical device should be more precise and accurate compare to conventional industrial machine. In these machine synchronization requires more than the coordination of starting and stopping. The position and velocity relationship between the axes will often be important to the proper operation of the machine. If there are interlocking moving parts on a machine, position coordination during motion may be required to avoid collision. If multiple axes control the orientation of a moving part, the position and velocity synchronization of the axes will determine how accurately the part is oriented as it moves. In some cases, a certain velocity or position achieved on one axis will be the signal to start motion on another axis. In such cases, the accuracy of the eventual position relationship of the axes will depend on how accurately the position of first axis is monitored by the second. In medical device resultant or outcome should be more important. So the result that obtained from the machine highly depends on the mix method, washing, axis's position, running time, volume consumption, etc. if one of this failed then the test result will be failed, it may lead to catastrophic. Using general purpose OS these test execution processes are done as pipelining like one after another. So that can't do any task like mixing, positioning and washing same time, or volume aspiration and positioning, etc. if we implement these, all tasks

sequentially that, may require more time to complete. This time-consuming process cannot produce the proper result because it is a time-dependent calculation and also needs to implement priority based execution during runtime. Certain execution is waiting for a response from another process. Sequential execution in general purpose OS can't implement this kind of process .so that need to find out a way to overcome this problem.

II. STEPPER MOTION CONTROL SYSTEMS

The availability of motion control has brought solutions to the problems inherent with the mechanical approach to synchronization. To understand how these solutions are achieved, it is helpful to review basic motion control systems. One axis of motion control consists of the motor, the motor drive, and the controller. The controller drive the motion directly by using RTOS program. These tasks running by the controller to generate continuously updated position (motion profiles) to the drive. The motor drive controls the current to the motor which will result in the commanded position. In a multi-axis system, one controller can control several motor and drive combinations. In stepper drive systems, the driver chip receives position commands in the form of low voltage pulses (steps), and adjusts the phase of the current in two sets of motor coils to align the motor shaft. Each new step received corresponds to an additional increment of rotation on the shaft. Current is maintained in the motor coils, even when the motor shaft is in the correct position. Common step motor resolutions range from 200 steps per revolution (full stepping) to 3200 steps per revolution (micro-stepping).

III. ELECTROMECHANICAL SYNCHRONIZATION

Stepper motor directly coupled with mechanical rail, and solve many problems. Individual axes are driven from individual motors. The speed and position relationship between axes is controlled with the microcontroller, and this may be infinitely and continuously adjusted. Motors deliver the motion directly to the appropriate place, eliminating the need for drive trains. The problems of backlash and mechanical wear are gone, resulting in precise, repeatable control and reduced maintenance. Complex position relationships between axes may be programmed and stored in the controller.

Controllers can also accept electronic inputs from sensors. RTOS controlled machine features give much greater design flexibility and run-time decision-making power to a machine than could be achieved with multi-axial movement components. Programmable acceleration and deceleration allow very smooth and controlled starts and stops to individual axes of motion. The smoothness reduces machine wear and makes a machine run more quietly. The control gives better precision in the axis synchronization, which results in better quality in overall machine function. The increased control also allows higher speed moves on the individual axes.

IV. REAL-TIME CONTROL SYSTEM CONCEPT

Normal microcontroller works on general purpose OS working with single super-loop design. All the execution isn't simultaneously. Multi-axis movement conventional embedded system is not efficient. This normally embedded OS work with sequential execution. So simultaneous movement of all required axis at the same time can't be possible or it very difficult to implement with normal general purpose OS. Normally this movement is done by one after another by sequential movement. So it isn't time critical and not a multipurpose. Synchronized multi-axis movement using stepper motor without any collision can solve using RTOS by replacing with general purpose embedded OS.A RTOS is the operating system guaranteeing a certain capability within specified time constraint. Faster processors and better compilers allowed for raising the level of abstraction in order to improve development productivity and quality. The use of real-time operating systems (RTOS) represents the third generation of embedded software development. RTOS introduce a new abstraction level that enables more complex applications, but not without complications. These operating systems are often very small and so are suitable for use in microcontrollers (MCUs). The main job of an RTOS is to provide multithreading, thereby allowing for separation of software functionality into multiple parallel programs, which are known as tasks. An RTOS creates the illusion of parallel execution by rapidly switching the executing task. Unlike general-purpose operating systems, an RTOS gives the developer full control over the multithreading and therefore enables the deterministic real-time behaviour. By using an RTOS, delegate the execution control to a highly optimized RTOS kernel that has been thoroughly tested and proven in use. Although using an RTOS implies a minor processing overhead, the RTOS-based design is often more efficient than a traditional super-loop design. This is because RTOS tasks can wait for activation events without wasting processor time, and response times can be faster because of shorter ISRs (interrupt service routines.) and pre-emptive scheduling. Moreover, today's MCUs often feature fast 32-bit cores with substantial amounts of Flash and RAM memory.

By use RTOS in this multi-axial movement. All the axis movement can be controlled by the individual task. All the movement can be monitor and that will not affect another axis movement at the same time. All the task are parallel processed, so we can't say that it is time-consuming. Or that will not wait for completion of other rail movements. During the time of task processing, every thread is check and monitor the position of all other rail position. If any misleading is can take place that will acknowledged into that thread for particular rail axis.

FreeRTOS kernel is a market leading real time operating system (or RTOS), and the de-facto standard solution for microcontrollers and small microprocessors. With millions of deployments in all market sectors, blue chip companies trust FreeRTOS because it is professionally developed, strictly quality controlled, robust, supported, free to products without a requirement to expose proprietary source code, and its IP is carefully managed.

- Provides a single and independent solution for many different architectures and development tools.
- It is known to be reliable. Confidence is assured by the activities undertaken by the Safe RTOS sister project.
- It is feature rich and still undergoing continuous active development.
- Has a minimal ROM, RAM and processing overhead. Typically an RTOS kernel binary image will be in the region of 6K to 12K bytes.
- It is very simple - the core of the RTOS kernel is contained in only 3 C files. The majority of the many files included in the .zip file download relate only to the numerous demonstration applications.
- It is truly free for use in commercial applications (see license conditions for details).
- Have commercial licensing, professional support and porting services available in the form of OPENRTOS from our partner WITTENSTEIN high integrity systems.
- Has a migration path to Safe RTOS, which includes certifications for the medical, automotive and industrial sectors.
- Is well established with a large and ever growing user base.
- Contains a pre-configured example for each port. No need to figure out how to setup a project - just download and compile.
- Has an excellent, monitored, and active free support forum.
- Has the assurance that commercial support is available should it be required.
- Provides ample documentation.
- Is very scalable, simple and easy to use.
- FreeRTOS offers a smaller and easier real time processing alternative for applications where eCOS, embedded Linux (or Real Time Linux) and even uCLinux won't fit, are not appropriate, or are not available.

V. IMPLEMENTATION

The axis is designed by the stepper motor with screw slider and axis rail. The angular movement of the stepper motor converted into linear movement using this arrangement. In the multi-axis design is done by the arrangement of two or more axis that specified above. The starting position of every axis can be represented as home. Photo sensor is used to implement this home arrangement. The step counter is started in this home position. So we can say that the step count is equal to zero. While the axis is linearly moved as we give rotation to the stepper motor. The distance moved by rail is directly proportional to step count. Every axes movement must be in synchronized otherwise that may collide with neighbour rail. This all rail movement can be controlled by any microcontroller.

By proper operation of this rail, the movement is dependent on the home sensor position and number of step rotated by the stepper motor Normal microcontroller works on general purpose OS working with single super-loop design. All the execution isn't simultaneously. The working is mentioned in flow diagram. In the stage of sample and reagent aspiration total of 3 rails are simultaneously run. This time all the state and speed of motor must be monitored. In the second stage wash process 4 axis is moved simultaneously .During this time 2 of the axis are moved across. This is because the relative positions are updated and checked for further processing. And any possibilities of collision can be avoided by accurate motion control. During the time of mixing process 4 axis are moved at same time .In this process more accuracy is important .If any slight difference in position or alignment may lead to collision. In Reagent 2 aspiration same processor are repeated in reagent and sample aspiration. Mixing process consists of all the rail must be go back to its home and the relative position are updated and monitored.

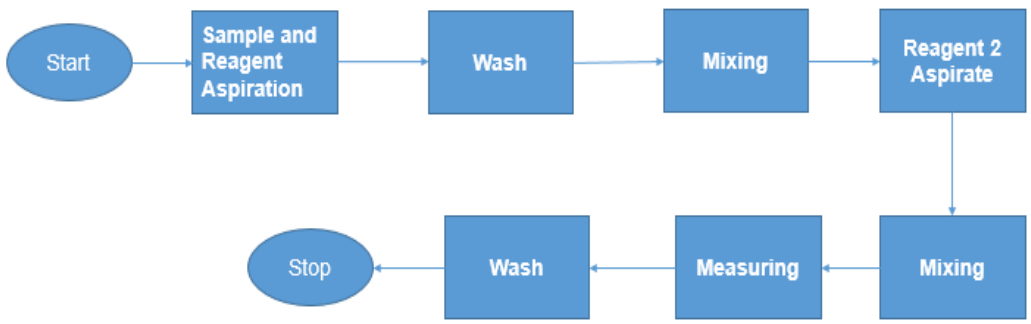

Fig.1 Block Diagram of Implemented Design

VI. SUMMARY

Axis control sections with drivers are controlled by the MCU. The MCU inputs are steps and positional feedback. Those signals are processed by the FreeRTOS. The PWM generates the required signals for the stepper driver chip. This project develops application in real time motion control systems using FreeRTOS. FreeRTOS is performing its own task scheduling and also deal with real-time multi-tasks problems, which is essential for more and more complicated high performance machine automation. Real-time Operating System is widely used in motion control systems and achieve time synchronization with high accuracy. However, the synchronization only involves data traffic between the different tasks. Some experiments and analyses on RTOS have been done to support the reasonableness and feasibility of the study work. Motion coordination is required in many processes, and can take many forms. The accuracy of motion synchronization in a machine directly affects the quality of the products made by that machine. In the past, the speed and accuracy of synchronization has been limited by the use of mechanical components. The development of real time motion control, however, has made great improvements in multi-axis synchronization possible. The flexibility of motion control has significant economic benefits as well, because it allows easy to add new axis in to machine. RTOS-based control system is almost the whole software architecture without DSPs. Such a control system not only has the real-time function but also opens ground level stepper motor control. The multi axial movement control system has the high accuracy positioning precision with different acceleration. Existing normal OS do not include synchronization of motion control. The synchronization scheme proposed in this projects enables synchronization all the way from the network master right down to the motor terminals. Because of much improved synchronization, the proposed scheme offers significant improvement in control performance. The proposed scheme also offers seamless synchronization across multiple axes. Axes can easily be added and the synchronization tailored to the individual motor controller. In future multiple axes may follow a single master, or multiple masters and control programs may be used simultaneously.

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