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Design and Implementation of Motor Driver Based on 32Bit Arm Cortex Processor

Engineering

KEYWORDS : Arm processer, Full or Half stepping, Speed control, Stepper motor, STM32F407.

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ABSTRACT

In motion control system, stepper motors are widely used in robotics and numerical machine tools, where the high-precision is required. In this paper the design and implementation of motor drive with Hybrid Stepper Motor (HSM). Based on STM32F407 32-bit arm processor, Impalement PI control to achieving desired speed in shortest possible time and improve position accuracy. Half stepping and full stepping technique is use to adjust the current in each winding of the stepper motor. This paper describes the running of the motor at different speed and achieves speed by maintaining pulse frequency. This experiment shows that the system for controlling stepper motor is high precise, stable and reliable.

INTRODUCTION

Stepper motor are used in positioning applications due to their durability, high efficiency.[1] Reluctance motors have attracted much attention over the past few years due to their simplicity of construction and low cost. Compared to dc motors, variable reluctance (VR) motors have advantages such as no mechanical brushes and no permanent magnets either on the rotor or on the stator. However, the drawbacks are complex drive electronics and nonlinear torque-current characteristics. These problems are being addressed in recent advances in power electronics and control [2]. Hybrid steeper motor is preferred because of small step angle. Its applications include position control of solar array antenna and robotics, etc. The stepping rate normally follows the excitation rate. However, due to the mechanical constructions, resonance and instability are noted at certain speeds. The behavior of the machine varies with loading condition and needs to be address. The possibility of simple excitation schemes like full and half-stepping modes that can be generated with simple digital devices is another major attraction for use of stepper motors. High frequency operation can achieved easily with these excitation schemes [1]. The mode of operations limited with medium frequency range that depends on the required precision of position and speed of the motor. Prediction of the speed resonance occur which is determined by rotor inertia and stiffness [1]. Resonance of motor identified with two-way mechanical or electrical parameters. Mechanical parameters consider the rotor position, speed, torque and vibration. Electrical parameters include the phase current and back Electromotive Force (emf).

Full step and half step consist pulse train of 50%duty cycle and 37.5%duty cycle respectively. In full stepping, the motor basic steps (1.8 degree) are not divided but in half step into two small step and with the PI controller algorithm we can drive motor. For better performance we use microstepping drive. Many microcontrollers are available to control a stepper motor, such as, AT89C51, 80C196MC and PIC microcontrollers. However, depending on the complexity of the control algorithm (i.e., microstepper and current limiting), it can be advantageous to choose a microcontroller with selected peripherals that will take care of most of the stepper motors overhead [3]. The arm cortex processor provides a high performance, low-cost platform that meets the system requirements of minimal memory implementation, reduced pin count, and low power consumption, while delivering outstanding computational performance and exceptional system response to interrupts. The STM32F407 arm controller is targeted for industrial and embedded applications, including remote monitoring, test and measurement equipment, network appliances and switches, factory automation, HVAC and building control, gaming equipment, motion control, medical and instrumentation [4]. The STM32F407 controller contains 17 timers in which two 32-bit advance timer it can have PWM generation mode and input capture and output compare for motion application. In the proposed work, motor speed controls are generated with STM32F407 arm processor.[4]

Section 2, report the brief over view of full stepping and half stepping driver and PI-controller. Section 3 describe control scheme of HSM. Section 4 Hardware design and finally, section 5 concludes the paper.

STEPPER DRIVER WITH PI CONTROLLER

- **Over view of Driver of motor**

Full stepping and half stepping are a stepper motor technology that controls the current in the motor winding, where the number of steps can be increased by manipulating the current that the controller sends to the motor during each step and the resonance problem can be reduced using driver for step rate. Full step and half step mode, which consists pulse train of different duty cycle are used to drive the hybrid stepper motor. To control speed and position of motor using PI algorithm maintain the frequency and time duration of the pulse train are generated using STM32F407 to enable the drivers. In this scheme, pulses applied to two-phase bipolar stepper motor windings. By varying the value of Kp and Ki we can able to vary duty cycle in percentage. The pulse width of generated PWM pulses is the output of PI controller. Four PWM signals generated with samples as follows predefine signals are inverted and through driver given to H-bridge, pulse train and inverted pulse train are given to one arm of the motor and to other arm pulse train with 50% delay and its inverted pulse train are given.

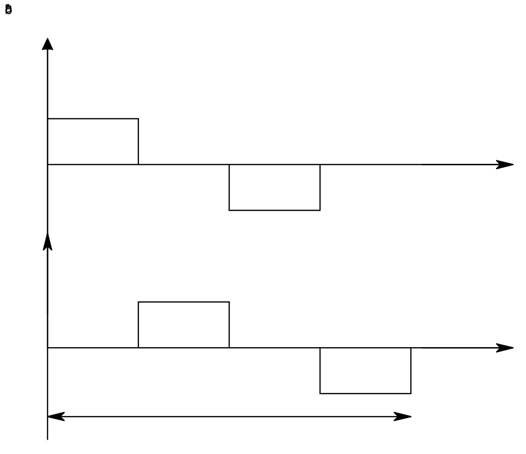

Figure 1(a) Full step sequence of current in motor

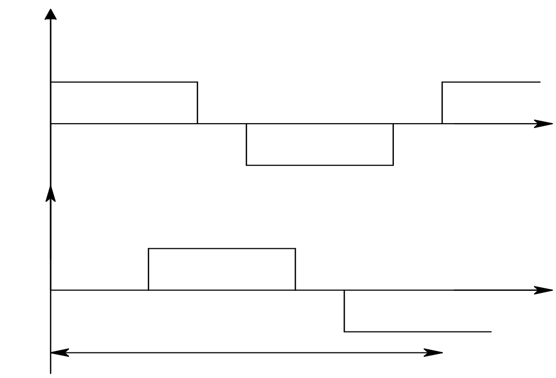

Figure 1(b) Half step sequence of current in motor

Figure 1(a) shows the wave drive current waveforms. Full step two phase on have excitation shown in Fig.2b which shows that at a time two phase on and current passing through both the winding. Half step excitation mode involves alternating single and dual phase operation and provides twice the resolution than full step mode, which increased smoothness at low speed. Voltage of driver was depends on torque requirement for desire speed and figure 2 shows the PWM signal for enabling motor to rotate.

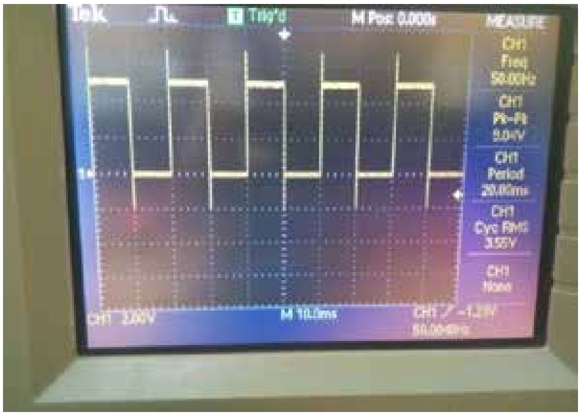

Figure 2 PWM pulse train for driver

CONTROL SCHEME OF HSM

- **Block Diagram of Control Scheme**

In this work, the current control in motor winding by PI controller. A PI controller is used to adjust the duty cycle of the switching pulses. The input of the PI controller is the speed error between the referent speed and feedback speed, and the output is the duty cycle of the switching pulses. Implement PI controller, with STM32F407 microcontroller and design algorithm in to it and generate PWM signal for the motor, the relation between the duty cycle and speed is generated in code. It is used due to simplest design, fast dynamic response and insensitive to motor parameters. Block diagram of controlling stepper motor is shown in fig.3. Speed of motor is sense by encoder and it provides actual speed of motor that signal compare with reference speed which is given as a set point with manual operation. According to error microcontroller generate PWM signal for reducing error. Driver gives the input to motor.

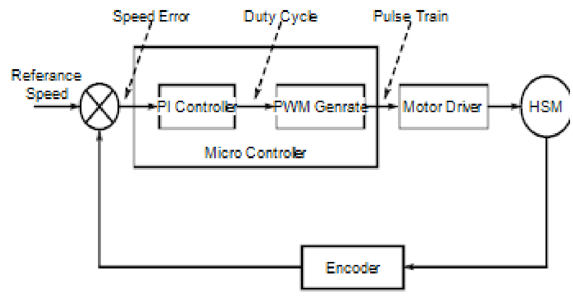

Fig.3 Speed control with encoder feedback

- **H-bridge circuit for current controlling**

The H-bridge circuit (Fig. 4) contains 4 switching device (MOSFETs) for each phase of the motor. With this H-bridge circuit, the currents flow through the phases of the motor. According to error switching is done in MOSFET. Source voltage applied to the motor driver is 12v DC. In this prospered work L6203 multi watt IC use as driver. For two different phase, two IC use to drive current in two different phase. When s1 and s4 is on same time s2 and s3 are off. By controlling the switching generate proper pattern for the switching of the phase.

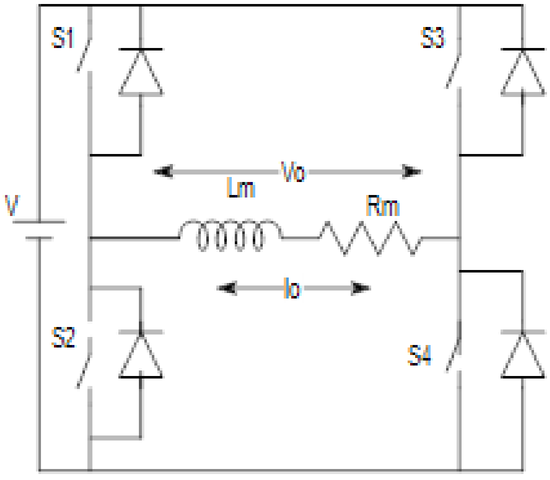

Figure 4 H-bridge driver for motor

Figure 5 Experimental set up

- **Speed and position control logic**

Here, Stepper motor is controlled by PI controller with updating pulse frequency. Motor can drive with a fixed angle in control the amount of angular displacement by controlling the number of pulses, actual position of motor sensed by encoder. Encoder gives the output of actual position of motor and with PI controller we can able to update number of pulses. Number of rotations is proportional to the number of pulses and speed is proportional to the pulse frequency. In the proposed control scheme, four switches, three for speed control and one for direction control are used, which are read by the microcontroller. For speed control, one switch is use for enter the required speed, second is to set entered speed as a set point, third is give command for running of motor. Microcontroller interface encoder as a feedback element controller read encoder continually and compare set speed with actual speed and PI controller decide to update pulse frequency for removing generated error. If error is zero then no need to update pulse frequency but when error occur controller need to take controlling action and update the frequency of pulse.

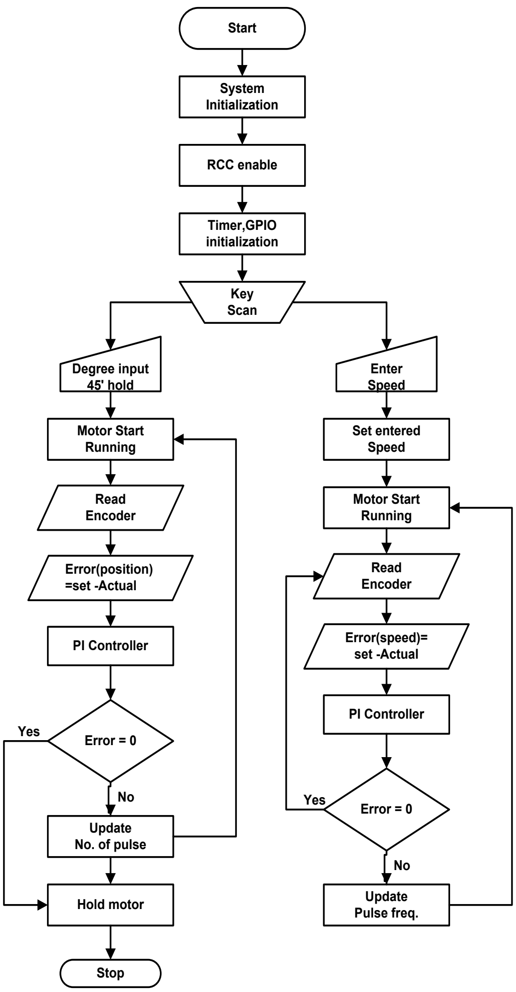

Figure 6. Main program flow chart of implementation scheme

For position control, one switch is use to enter required holding position of the motor after settling the value motor start to rotate. If the motor cannot reach at specific position encoder give feedback to the motor and generate error for controller and it takes action until motor reach at specific position.

Number of pulses for one rotation = Basic steps per rotation / sample increment x 360

CONCLUSION

In this paper, half stepping and full stepping technique, which consists discrete pulses used to drive the stepper motor. The stepper driver based on STM32F407 is suitable for small and medium stepper motors as it can achieve high resolution. Motor can controls specific number of rotations in required direction and speed are achieved by varying the number of pulses and pulse frequency which can control by PI controller. In this experiment shows smooth running, high precision, rapid response and stability of the system. For improving the performance go for the higher controlling technique.

APPENDIX

- **Parameter of Hybrid Stepper Motor[5]**

TABLE 1
PARAMETER OF MOTOR

Motor Parameters	Value
Winding Inductance	3.6 mH
Winding Resistance	1.13 Ω
Step Angle	1.8°
Maximum Detent torque	0.68 kg.cm
Holding Torque	18.9 kg.cm
Total Friction	0.003 kg.m/s
Total Inertia	480g.cm^2
Phase Current	2.8 A
Rated voltage	3.2 V

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