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Driver for 5-phase stepper motor pentagon connection with dedicated ICs

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Abstract

Stepper motors are very well suited for positioning applications since they can achieve very good positional accuracy without complicated feedback loops associated with servo systems. In this paper, an intelligent five-phase stepper motor driver of business card size proposed. Constant current chopping technique was applied for the purposes of high torque, high velocity and high efficiency. The driver was designed to drive a middle-sized hybrid stepper motor with wire current rating from 0.7 to 1.4A. An up-to-dated translator of five-phase stepping motor was used to drive the gates of N- channel MOSFET (Low side N-channel MOSFET Array) and level shift for NPN Darlington transistor (High side PNP Darlington transistor). The resolution in full/half mode is 0.72/0.36 degrees/step. Moreover, an automatic power down circuit was used to limit the power consuming as the motor stops. Additionally, a self-testing program embedded in an 80C31-CPU (PCL838) can self-test whether the driver is normal or not. This embedded program including linear acceleration and deceleration routines also can serve as a positioning controller. The dimension of this driver is approximate 90x70x40 millimeters, which is smaller than a business card. Experimental results demonstrate that the responses of the driver can reach 60 kilo pulses per second.

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Keywords: hybrid pentagon connection stepper motor; N-channel MOSFET Array; Darlington NPN transistor Array; sequencer; half/full control; PWM chopper.

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1. Introduction

Stepper motors are used to obtain the motion profiles in the field of Robotics and Automation Engineering. Stepper motors are preferred in applications where high precision controls in position and velocity, is important such as in aerospace, printers, scanners, copiers, faxes, optical and magnetic disk devices, medical equipment, X-Y plotters, CNC machines, semiconductor fabrication equipment, agricultural automation applications, textile equipment's and precision telescope positioning systems [3, 4]. Moreover reliability, lack of contact, aging, mechanical ruggedness and availability of torque at zero speed are the attractive features of Stepper Motors. Among the various types of stepping motors, the hybrid stepping motor has a permanent magnet rotor and a toothed magnetic structure on both the stator and rotor, so that a permanent-magnet torque as well as reluctance torque can be generated [1]. Two – phase stepper motors are commonly used, but five-phase stepper motors have the superior characteristics of resolution, vibration and performance compared with two phase's motors. When both stepping motors are operated in half step mode, two phase motor provides a resolution of 400 steps per revolution while a five phase motor has a resolution of 1000 steps. This resolution is 2.5 times higher when compared with two phase stepper motor. The applications where high precision, low vibration and low noise is required, five-phase hybrid stepper motor can be employed compared to two-phase hybrid stepper motor. Five-phase stepper motors are superior in dynamic performance [2]. A high precise position control using five-phase hybrid stepper motor is achieved in open loop control achieves. The higher the number of phases, smaller will be positioning deviations. Micro stepping is a technology that achieves low resonance, low noise operation, at extremely low speeds by controlling the flow of electric current fed to the motor coil and thereby dividing the motor's basic step angle into smaller steps. Pulse Width Modulation (PWM) technique is usually used to excite the driver to operate the motors. This paper proposes a compact five-phase pentagon stepper motor half/full driver for positioning or speed control applications.

2. Structure of five – phase stepping motor

The five-phase hybrid stepper motor is developed with high resolution with no low speed resonance problems. The five-phase stepper can also be classified under permanent magnet hybrid stepper motor. The stator windings are energized in the proper sequencer to produce a rotating magnetic field which turns the rotor. The significant advantage of the five-phase stepper motor is its excellent torque retention capability at high operating speed [13, 14]. The motor used for implementation is a five-phase hybrid stepper motor and it is shown in Fig. 1. The figures above show two cross-sections of a 5-phase hybrid stepping motor. Hybrid stepping motors are composed primarily of two parts, the stator and the rotor. The rotor in turn is comprised of three components: rotor 1, rotor 2 and the permanent magnet. The rotors are magnetized in the axial direction, with rotor 1 polarized north and the rotor 2 polarized south. The stator contains 10 magnet poles with small teeth, each of which is wrapped in wire to form a coil. The coil is connected to the facing magnet pole and is wound so it becomes magnetized to the small pole when current is run through it. (Running a current through a given coil magnetizes the facing poles to the same magnetism, either North Pole or South Pole.). The two facing poles form a single phase. Since there are five phases, A trough E, the motor is called a 5- phase stepping motor. There are 50 teeth on the outside of the rotor, with the teeth of rotor 1 and rotor 2 mechanically offset from each other by half a tooth pitch.

Fig. 2 helps to describe the relationship on the positions of the stator and rotor teeth when magnetized. When phase A is excited, its poles are polarized south. This attracts the teeth of rotor cup 1, which are polarized north, while repelling the teeth of rotor cup 2, which are polarized south. Therefore, the forces on the entire unit in equilibrium hold the rotor stationary. At this time, the teeth of the phase B poles, which are not excited, are misaligned with the south-polarized teeth of rotor 2 so that they are offset at 0.72° [5, 6].

When excitation switches from phase A to B shown in Fig. 2, the phase B poles are polarized north, attracting the south polarity of rotor 2 and repelling the north polarity of rotor cup 1. In other words, when excitation switches from phase A to B, the rotor rotates by 0.72°. As excitation shifts from phase A to phases B, C, D and E, then back around to phase A, the stepping motor rotates precisely in 0.72° steps. To rotate in reverse, the excitation sequence is reversed as phase A, E, D, C, B, then back to phase A. High resolution of 0.72° is inherent in the mechanical offset between the stator and rotor, accounting for the achievement of precise positioning without the use of an encoder or other sensors [18, 19].

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