Design of Stepper Motor Controller

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***Abstract*—Stepper motor is also called stepping motor or step motor. The name stepper is used because this motor rotates through fixed angular step in response to each input current pulse received by the controller. They can be controlled directly by computers, microprocessors & programmable controllers. Stepping motor may be compared with a synchronous motor as far as operation is concerned: a rotating field here generated by the control electronics, pulls a magnetic rotor along. Stepping motors are subdivided according to the manner in which rotating field is generated, that is with unipolar or bipolar stator windings. Unipolar and bipolar stepping motor can be operated Single Step Mode & Continuous Mode. The signal produced by the logic sequencer are so weak that they are unable to energies the motor windings, So power drivers raise the power level sufficiently to energies the motor windings. It is used in computer peripheral controller. Stepping motor can create an interface between that brain & mobile reality.**

***Index Terms*— Stepper Motor, Power Driver, Logic Sequencer**

I. INTRODUCTION

Stepper motor is also called stepping motor or step motor. The name stepper is used because this motor rotates through fixed angular step in response to each input current pulse received by the controller. The growing popularity of stepping motor is only due to falling prices another factor must be that they logically fit into digital thinking. So they can be controlled directly by computers, microprocessors & programmable controllers. Many computer peripherals such as disk drives, printer & plotters or computer controlled equipment like XY table & root limbs, make use of stepping motor. In computer CPU have a brain but not the (whole) body. Now with the aid of stepping motor they can create an interface between that brain & mobile reality.

Stepping motors are electromechanical converters. This type of motor response in well defined way to certain digital signals fed to their control electronics. Stepping motor may therefore be used as an open system (without feedback) for control purposes. This obviates problems often encountered in feedback system such as instability and overshoot. Stepping motor may therefore replaced conventional DC Servo system with feedback.

II. OPERATION

Stepping motor may be compared with a synchronous motor as far as operation is concerned: a rotating field here generated by the control electronics, pulls a magnetic rotor along. Stepping motors are subdivided according to the manner in which rotating field is generated, that is with unipolar or bipolar stator windings and the material from which the rotor has been constructed permanent magnetic material or soft iron.

Step Angle

The angle through which the motor shaft rotates for each command pulse is called the Step angle.

$\phi = 360^0$/ (Number of stator phase * Number of rotor teeth)

Smaller the Step angle, grater the number of step per revolution and higher the resolution or accuracy of positioning obtained. The angle can be as small as 0.72^0 or as large as 90^0 but the most common step angle 1.8^0, 2.5^0, 7.5^0, 15^0.

Stepping Motor Modes

Unipolar and bipolar stepping motor can be operated in following modes.

(1) Single Step Mode
- Whole Step
- Semi Step

(2) Continuous Mode
- Whole Step
    - Forward
    - Reverse
- Semi Step
    - Forward
    - Reverse

A bipolar stepping motor with a permanent magnetic rotor shown in figure A. At the onset, both windings carry current the stator is magnetized correspondingly and the rotor has oriented itself accordingly. If the polarity of current in A is reverse the field shifts 90^0 anticlockwise and pulls the rotor along. The sequence of activation for complete revolution is AB-A'B-A'B'-AB' that is for steps 90^0 each.

So digital sequences are applied to power driver in binary values 10011001, 01101001, 01100110, 10010110. These digital sequences in hexadecimal format shown in table V and VII. It is also possible before reversing polarity in phase, to switch off the current to that winding. The sequence then becomes: AB-B-A'B-A'-A'B'-B'-AB'-A-AB. In these semi step operation the steps are smaller but movement is less regular and on average, smaller because during the half the time only one half of the number phases is being used. Here in table VI and VIII represents the equivalent hexadecimal values they are 99, 09, 69, 60, 66, 06, 96, 90.

Unipolar stepping motors look the same as bipolar ones, but they are wound differently. Each phase now consists of a winding with a center tap or two separate windings, so that the magnetic field can be inverted without necessity of changing the direction of the current. A unipolar stepping motor with a permanent magnetic rotor is shown in figure B. At the onset, both winding carry a current the stator is magnetized correspondingly, and the rotor has oriented itself accordingly. If the polarity of the current in A is reversed the field shifts 90^0 anticlockwise and pulls the rotor along. The sequence of activation for a complete revolution is AB-A'B-A'B'-AB'-AB that is four steps 900 each. So digital sequences are applied to power driver in binary values 1010,0110,0101,1001. These digital sequences in hexadecimal format in shown in table I & III. It is also possible before reversing the polarity in a phase, to switch off the current to that winding. The sequence then becomes: AB-B-A'B-A'-A'B'-B'-AB'-A-AB. In this semi step operation the steps are smaller but the moment is less regular and on average, smaller because during half the time only one half of the number phases is being used. Here in tables II & IV represents the equivalent hexadecimal values they are 0A, 02, 06, 04, 05, 01, 09, and 08.

If unipolar windings are to be housed in the same space as one bipolar windings, it is evident that either fewer turns per winding, or thinner wire must be used. In either case, the result is fewer ampere turns and consequently a weaker magnetic field. A unipolar stepping motor therefore has a smaller moment than a bipolar one of the same dimensions. The maximum stepping rate is limited because the permanent magnet rotor causes an inductive voltage in the stator. Motors with relatively high rotating speeds, therefore often use soft iron rotors that have fewer poles than the stator, which is always unipolar4.

As shown in figure C stepping motor controller consists of logic sequencer, power driver .Logic sequencer provides digital sequences to power driver .Power driver increase the power level of the digital data and energies the windings of stepper motor. Microprocessor or logic sequencer can generate logic sequences.

A logic sequencer has EPROM (2732), 555 timer, counter (7493) and NAND gates. Digital sequences in table I & VIII are stored in EPROM using microprocessor .555 timers provides CLK signal to the counter. Counter's four output lines are connected to A0 to A4 address lines of EPROM. Four switches are connected to A4 to A7.So desire mode can be selected by switches S1 to S4.Each mode has 16 locations in EPROM; corresponding digital sequences are stored in it. To automatically reset the counter, there is 00H stored at the end of each table. Counter will automatically reset using NAND gates when all bits are zero so stepper motor can be run in selected mode until we change the switch position. Varying the CLK frequency can control speed of motor. It provides range from 1 to 100Hz4.

Power Drivers

The signal produced by the logic sequencer are so weak that they are unable to energies the motor windings, So power drivers raise the power level sufficiently to energies the motor windings. Power drivers are made of power transistor or thyristors, depending on the required power level. A possible circuit for unipolar power driver is given in fig B. It requires one darling tone transistor per winding. Bipolar motor need to be controlled to be via a bridge,i.e. four transistors per winding as shown in fig A. It is possible to use only two transistors per winding, but a symmetrical power supply is then required. In stepper motor, due to finite winding inductance, phase current cannot be switched off instantaneously. If the base drive of the switching transistor were suddenly removed a large inductance voltage would appear between transistor collector and emitter, causing permanent damage to the drive circuit. These possibilities are avoided by providing an alternative current path known as the freewheeling circuit for the phase current. When the switching transistor is turned off the phase current .When the switching transistor is turned off the phase current continue to flow through path provided by the freewheeling diode and freewheeling resistance5.

Applications

Stepper motor uses for operation control in computer peripherals, textile industry, It includes commercial, military and medical application where this motor performs such functions as mixing, cutting, sterling, metering, blending and purging. They also take part in in the manufacturing of packed food stuffs, commercial end products and even the production of science fiction movies3.

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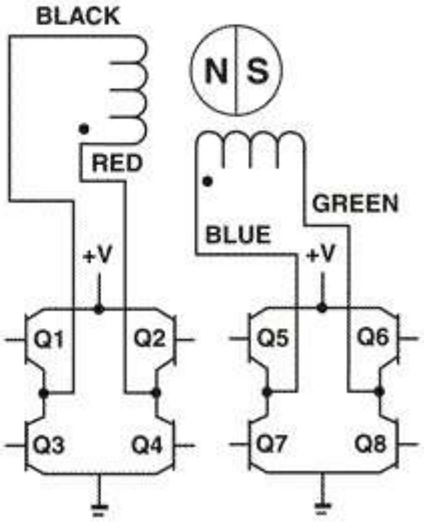
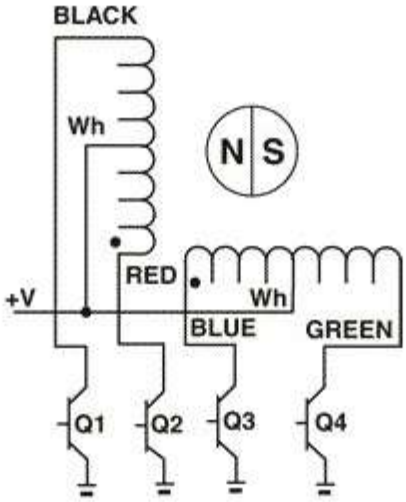
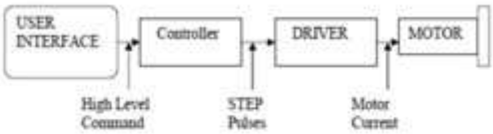
Figures





Bipolar Stepper Driver (Figure A) **Unipolar Stepper Driver (Figure B)**



Block Diagram of Stepper Motor Controller (Figure C)

Tables

Table I Whole Step (Unipolar)

1	2	3	4	HEX
1	0	0	1	09
1	0	1	0	0A

Table II Semi Step (Unipolar)

1	2	3	4	HEX
1	0	0	1	09
1	0	0	0	08

Table III Continue (Unipolar)

1	2	3	4	HEX
1	0	1	0	0A
0	1	1	0	06
0	1	0	1	05
1	0	0	1	09

Table V Whole step (Bipolar)

1	2	3	4	5	6	7	8	HEX
1	0	0	1	1	0	0	1	99
0	1	1	0	1	0	0	1	69

Table VI Semi Step (Bipolar)

1	2	3	4	5	6	7	8	HEX
1	0	0	1	0	1	1	0	96
0	0	0	0	0	1	1	01	06

Table VII Continue (Bipolar)

1	2	3	4	5	6	7	8	HEX
1	0	0	1	1	0	0	1	99
0	1	1	0	1	0	0	1	69
0	1	1	0	0	1	1	0	66
1	0	0	1	0	1	1	0	96

Table VIII Semi Continue (Bipolar)

1	2	3	4	5	6	7	8	HEX
1	0	0	1	1	0	0	1	99
0	0	0	0	1	0	0	1	09
0	1	1	0	1	0	0	1	69
0	1	1	0	0	0	0	0	60
0	1	1	0	0	1	1	0	66
0	0	0	0	0	1	1	0	06
1	0	0	1	0	1	1	0	96
1	0	0	1	0	0	0	0	90

Table IX Mode Select

A0	Counter
A1	Counter
A2	Counter
A3	Counter
A4	Forward(0) / Reverse(1)
A5	Step(0) / Continue(1)
A6	Whole(0)/Step(1)
A7	Bipolar(0) / Unipolar (1)

III. ACKNOWLEDGMENT

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