

Speed Control Methods for Stepper Motors

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Application Note

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Executive Summary

Stepper motors take in electrical signals and output mechanical movement. Their high accuracy and low cost make them popular in applications ranging from printers to cameras. Current in the stator coil creates magnetic fields that move a rotor. As the current into the stator is modified the rotor spins at different speeds. There are three main methods to accomplish this feat: series resistance, gearboxes and voltage regulation. The series resistance method incorporates a resistor in series with the motor. Different values of resistance will change the current through the circuit, thereby altering the motor speed.

A second method of speed control comes through mechanical gears. A gearbox utilizes gear ratios to step down and up rotational speed and torque. A set of known equations can allow a designer to select gears with a certain number of teeth to achieve the proper speed. A third method for stepper motor speed control is voltage regulation. By utilizing an LM555 timer, the current supplied will become a square wave. The “high” time of the signal will be when the rotor rotates.

These three methods allow for the speed to be controlled in any number of applications. Their ease of construction allows for quick speed control solutions. In cases with more complex needs, one single solution may not be enough. The three solutions presented may be integrated together as needed.

Key Terms: Stator, Rotor, Potentiometer, Pinion, Gearboxes

1. Introduction to Stepper Motors

Stepper motors are brushless, synchronous electromechanical devices that translate electrical pulses into mechanical movement (Stepper Motor Basics). A stator and rotor utilize magnetic fields to rotate. As seen from Figure 1 below, the stator has current-carrying coils.

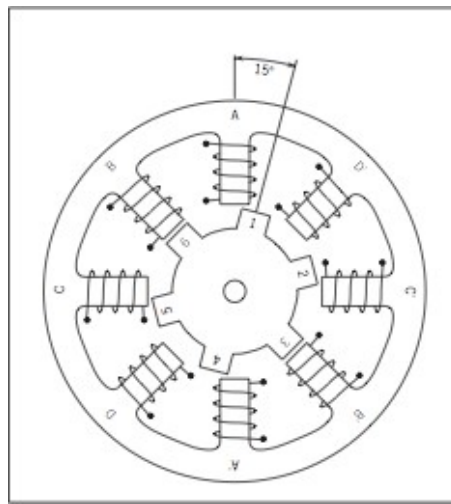


Figure I: Stator and Rotor Picture

A single coil carries current at one time, causing the magnetic rotor to align itself with the generated magnetic field. Each coil is turned on and off in response to the pulse supplied to stepper motor. The pulse frequency determines the speed of rotor rotation. The number of teeth determines the angle of rotation. As the number of teeth increases, so does the rotor accuracy. This design results in an open loop system, so a complicated feedback loop is unnecessary (Stepper Motors). This fact combined with their relatively low cost and small size make stepper motors an ideal solution in applications with velocity, displacement or directional concerns. Real-world applications include printers, CD-

ROM's and the zoom feature on cameras.

2. Application Note Objective

The speed of the rotors rotation in a stepper motor may be controlled in a variety of ways.

Three such possibilities are through a series resistance, gearbox and voltage regulation.

Each type has advantages over each other, and a methods implementation depends on the motor application and functionality.

3. Speed Control Methods

3.1 Series Resistance

Stepper motors operate based on input. As seen in Figure II below, speed and current are directly proportional to each other.

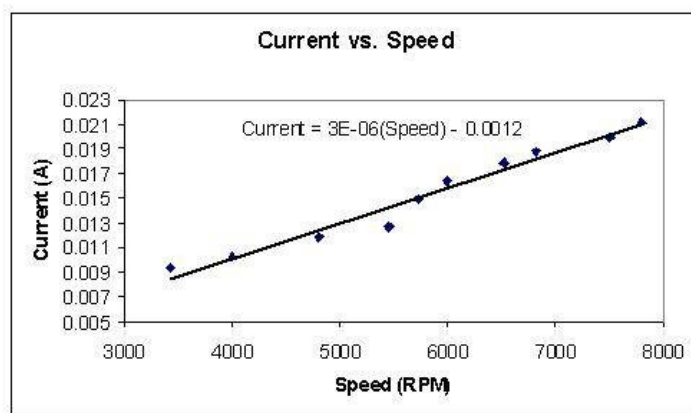


Figure II: Sample Current vs Speed Plot

By placing a resistor in series with the motor as in Figure III, the supplied current limited.

$V=I \cdot R$ explains this outcome.

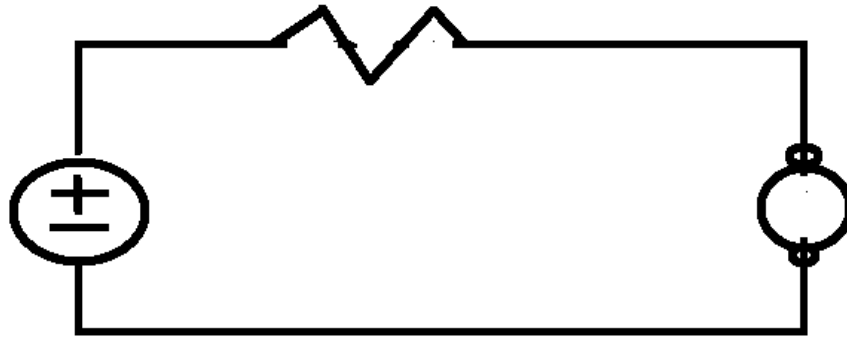


Figure III: Series Resistance Layout

Potentiometers allow for the most flexibility in this setup. In cases where the load will require different torques, the demanded current varies thus the resistance must be flexible.

Because stepper motors vary a great deal in capabilities, a single circuit will not suffice. For the purposes of this paper, a general case is considered. Considerations for this method include the range of current. The resistor or potentiometer must be able to limit the current. Often times the current levels are larger than most normal components are meant to handle. The selected part must have high current tolerances as a result.

3.2 Gearboxes

Mechanical gears provide another solution for speed regulation. This method requires a stepper motor to connect through an intermediate gearbox. The properties of gear ratios allow for this method. $Gear\ Ratio = Output\ gear\ \#\ teeth / Input\ gear\ \#\ teeth$. The output speed is given by the equation $Output\ Speed = (Input\ Speed) / (Gear\ Ratio)$. It is

important to understand gear ratios because it affects torque, as well. *Motor Torque x gear ratio = torque at the wheel* (Boston Gear Catalog). The chart below provides simple examples.

A = Input Gear Number of Teeth						
B = Output Gear Number of Teeth						
GR = Gear Ratio						
C = Input Gear Speed						
D = Output Gear Speed						
E = Input Gear Torque						
F = Output Gear Torque						
A	B	GR	C (RPM)	D (RPM)	E (Nm)	F (Nm)
5	4	0.8	1	1.25	1	0.8
4	5	1.3	1	0.8	1	1.25
5	5	1	1	1	1	1

Figure IV: Gear Ratio Example

The chart may be summarized by saying if a smaller gear is driving a larger one, the larger gear will output more torque but move slower. In the alternative case, a larger gear driving a smaller one will result in a faster spinning, but less torque output.

3.3 Voltage Regulation

The final method for stepper motor speed control is through voltage regulation. Many chips exist to achieve this, but the one discussed is the LM 555 Timer. The layout for Astable Operation may be seen below:

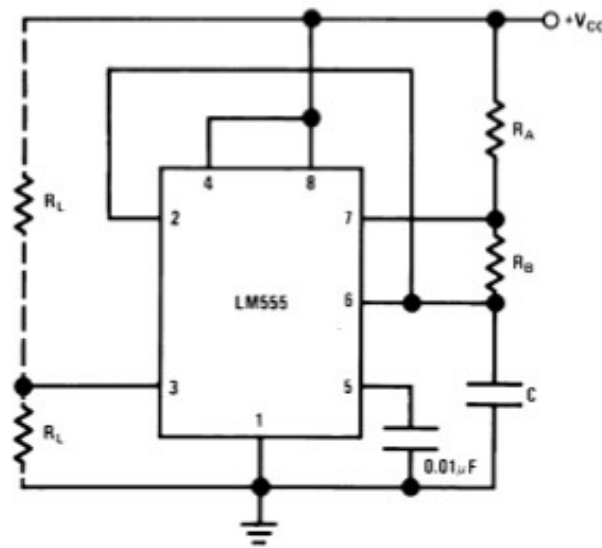


Figure V: LM555 Astable Layout

By selecting the proper values for R_A , R_B and C , the output can be manipulated into a square wave. The “high” time is given through the equation $T_{\text{high}} = 0.693(R_A + R_B)C$ and “low” time is given by $T_{\text{low}} = 0.693(R_B)C$. The Duty Cycle is thus given through the equation $D = (R_A + R_B) / (R_A + 2R_B)$. Another important piece of information is the frequency. It is given by $1 / (T_{\text{high}} + T_{\text{low}})$ or $1.44 / ((R_A + R_B)C)$. With this information, the speed can be regulated as needed (DC Speed Control).

4. Conclusion

The simple construction of stepper motors makes them ideal for applications where precise movement is required. They are easily integrable into systems and made to meet specifications. The methods of series resistance, gearboxes and voltage regulation are generic. They may be broken down into electrical and mechanical categories, which provide the advantage of two methods toward a solution. They may also be mixed and varied. For instance, the resistors utilized in the LM555 timer could be potentiometers to allow for a wide range of speeds.

References

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