PERFORMANCE OF A STEPPER MOTOR AS A SERVO AND DRIVE ACTUATOR

OBJECTIVE

To examine the performance of a 1.8° stepper motor for servo and drive actuator. It is important to note that an actuator is said to be employed as a servo and a drive actuator if the control output is in the form of rotary position and rotary speed respectively.

DESIGN AND FUNCTIONING OF THE STEPPER MOTOR

Our investigation of performance is based on a permanent magnet DC stepper motor with two phase bifilar wound stator with a Step angle of 1.8° ± 5% non-cumulative.

Although the type of the stepper motor can be divided into two fundamental designs, their working is the same. The rotor poles which is closest to the excited stator pole tries to align with it. With sequential excitation of the stator, each rotor pole at some position can be aligned with each stator pole resulting in Ns x Nr steps over 360°.

The two fundamental designs are Variable Reluctance structure and permanent magnet structures where rotor poles are salient poles and permanent magnet poles respectively.

ANALYSIS OF SERVO OPERATION

We begin from the reference point and move to successive angle graduations using finite number of pulses, assuming that each step should produce a change of 1.8°. But one of the most important things is that the errors produced are not cumulative. If they would have been cumulative, then over a period of time the error would become so large that its purpose would be rendered useless.

To measure the same, we moved the rotor through a range of different steps while recording their errors accordingly. For small step movements, we triggered them multiple times to get their cumulative error (in an attempt to mitigate low precision) and comparing them with the associated angle to verify that the error indeed is non-cumulative.

One important thing to note is that most of the errors still turned out to be zero because of measurement errors.

The errors are tabulated below, where Pulse Count denotes the number of steps and expected trigger count denotes the total number of times the motor was pulsed to find out the total error. Example: a motor being excited twice with a set of 20 pulses would result in expected trigger count to be 40.

Initial Angle	Final Angle	Pulse Count	Expected Trigger Count	Clockwise		Anticlockwise	
				Observed Trigger Count	Error	Observed Trigger Count	Error
0°	18°	1	10	10	0%	11	10%
18°	36°	1	10	10	0%	10	0%
36°	54°	1	10	10	0%	10	0%

Pulse Count = 1

0°	36°	4	20	20	0%	20	0%
36°	72°	4	20	20	0%	20	0%
72°	108°	4	20	20	0%	20	0%

Pulse Count = 4

0°	18°	10	10	11	10%	11	10%
18°	36°	10	10	10	0%	10	0%
36°	54°	10	10	10	0%	10	0%

Pulse Count = 10

0°	72°	40	40	40	0%	41	2.5%
72°	144°	40	40	40	0%	39	-2.5%
144°	216°	40	40	41	0%	40	0%

Pulse Count = 40

0°	180°	100	100	101	1%	100	0%

Pulse Count = 100

As could be seen that for higher angle graduations, the pulse errors don't add up. And as for the very low inconsistency in the observed and expected angle of travel, it can be concluded that stepper motor works very accurately as servo actuator.

One of the major reasons of error in low steps is due to the backlash the stepper faces as soon as it is turned on. That proves to significantly affect the position of it for lower steps but for higher steps its almost nullified.

ANALYSIS OF DRIVE OPERATION

For the drive operation analysis, we run the motor freely to find out if the accuracy of stepper motor for position is retained at higher speed as well as looking at the maximum speed the stepper motor can provide for free run.

Time taken	Expected number of Steps	Observed Steps	Expected ω (°/sec)	Observed ω (°/sec)	Error
11.10	200	197	32.43	31.94	-1.51%
12.06	200	203	29.85	30.29	1.474%
11.45	200	200	31.44	31.44	0%

Expected Steps = 200

Time taken	Expected number of Steps	Observed Steps	Expected ω (°/sec)	Observed ω (°/sec)	Error
5.17	100	94	34.81	32.72	-6%
5.4	100	100	33.33	33.33	0%
5.64	100	99	31.91	31.59	-1%

Expected Steps = 100

As it is observed that at for higher number of steps the precision of speed is higher and lower steps results in more inaccurate position when achieved through running freely.

And for measuring the maximum speed, the data is as tabulated below:

Time taken	Number of Steps	Observed ω (steps/sec)
3.86	600	155.44
6.377	1000	156.80
9.60	1500	156.25

Maximum ω (steps/sec)

Maximum speed as delivered by the stepper motor as a drive actuator is far less than the rate specified i.e. 10000Hz. This clearly brings out the drawback of stepper motor as a drive actuator.

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