

Hybrid Stepper Motor

Stepper motors, highly precise, digitally controlled motors, which are able to provide reliable operation without using detectors to sense or indicate position. The operation of the motor is controlled through electrical pulses. The direction of current flowing through the windings of the motor is switched with each pulse. The electrical pulse is converted into shaft rotation in steps of a fixed angle. Together with the driver, it constitutes an open loop controlling system, which is of low cost and simple to construct.



Characteristics

Precise Position Control

The specified number of pulses determines the output degree(s) generated.

Linear Speed Selection

The running speed is linearly variable and determined by the frequency of the pulses.

Forward & Reverse, Pause and Holding Function

The forward & reverse rotation is controlled by the polarity. There is still holding torque even while the motor rotor is being locked. There is still current flowing through the motor winding, but no pulse signal creating rotation from the outside controller.

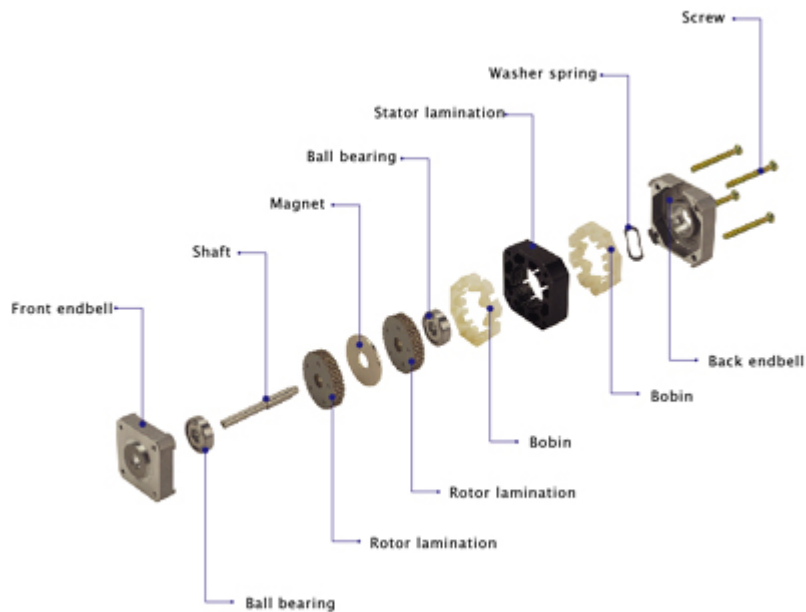
Low Speed Feature

Low frequency pulses being input, a stepper motor can operate at very low rotating speeds. This can be done without a speed reduction gearbox and thereby save power and maintain precision.

Long Life

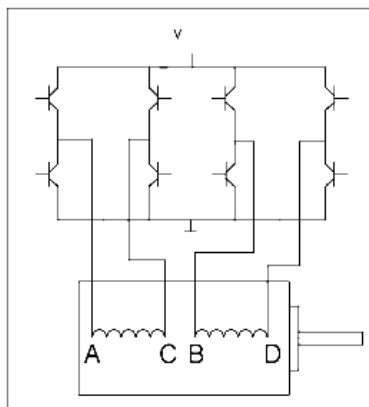
The brushless design provides stepper motors with a very long life. In fact, the stepper motor life is determined by the life of the bearings. Stepper motors are widely being used in many types of digitally controlled motion control applications, such as printers, intelligent (performance) stage lighting, office, bank and industrial equipment, medical, packaging, textile, aerospace, robotics and automotive

Basic Structure

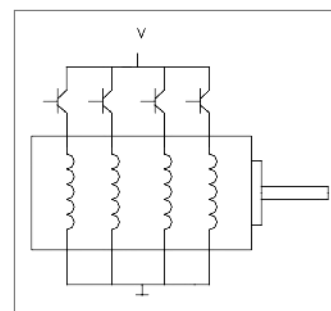


Operating Principles

The driver's internal logic circuit generates a series of pulses in a specified order that drive the stepper motor windings, causing the rotor to rotate forward, reverse, or lock in position. For example: a 2 phase 1.8 degree stepper motor normally is designed with two types of windings, i.e. 4-wire (bipolar) or 6-wire (unipolar).



4-wire Stepper Motor with Bipolar Driver



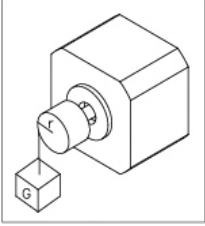
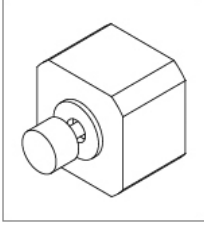
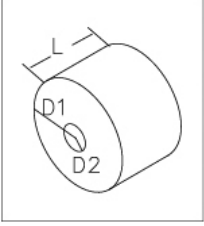
6-wire Stepper Motor with Unipolar Driver

When energizing its coils by special sequence (see item 3 in page 9) , this motor will rotate 1.8 degree per step. On average, a 4-wire stepper motor provides, 40% more holding torque than a 6-wire stepper motor, because 100% of the winding is used in a bipolar drive.

This is brief introduction to stepper motor operating principles. Various conditions and applications may need customized designs which we can provide.

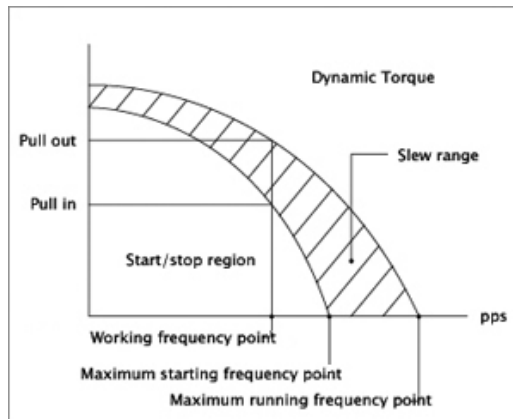
Type of Load

Generally speaking, motor load consists of torque and inertia load

<p>A. Torque load (Tf)</p> $Tf = G \cdot r$ <p>G: weight r: radius</p> 	<p>B. Inertia load (TJ)</p> $TJ = J \cdot \frac{dw}{dt}$ $J = M \cdot \frac{(D1^2 + D2^2)}{8} \text{ (Kg} \cdot \text{cm)}$ <p>M: mass D1: outside radius D2: inside radius $\frac{dw}{dt}$: angle acceleration</p>  
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Explanation of the Dynamic Torque Curve

The dynamic torque curve is an important aspect of stepper motor's output performance. The followings are some keyword explanations.



Keyword Explanation

- Working Frequency Point:** express the stepper motor's rotational speed value at this point.

Units: Hz
 $n = 0 \cdot \text{Hz} / (360 \cdot D)$
 n: rev/sec

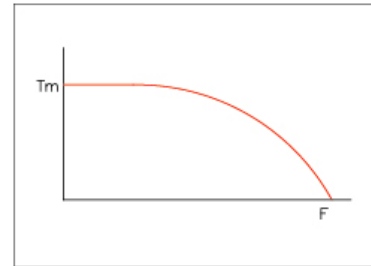
Units: Hz
 $n = 0 \cdot \text{Hz} / (360 \cdot D)$
 n: rev/sec

E.g.: 1.8° stepper motor, in the condition of 1/2 subdividing (each step 0.9°) runs at 500Hz, its speed is 1.25r/s.
- Start/Stop Region:** the region in which a stepper motor can be directly started or stopped.
- Slew Range:** the motor cannot be started directly in this area. It must be started in the start/stop region first, and then accelerated to this area. In this area, the motor cannot be directly stopped, either. Otherwise this will lead to losing-step. The motor must be decelerated back to the start/stop region before it can be stopped.
- Maximum starting frequency point:** at this point, the stepper motor can reach its maximum starting speed under unloaded condition.
- Maximum running frequency point:** at this point, the stepper motor can reach its maximum running speed under an unloaded condition.
- Pull-in Torque:** the maximum dynamic torque value that a stepper motor can load directly at the particular operating frequency point.
- Pull-out Torque:** the maximum dynamic torque value that a stepper motor can load at the particular operating frequency point when the motor has been started. Because of the inertia of rotation, the Pull-Out Torque is always larger than the Pull-In Torque.

Control of Acceleration and Deceleration

How to accelerate or decelerate in the shortest time is most important when the system's operating frequency point is in the slew range of the dynamic torque curve graph.

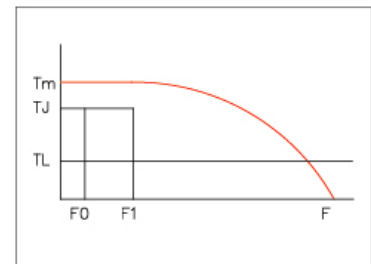
It is shown by the following graph: the dynamic torque's performance of stepper motor will always keep a horizontal straight line in low speed. But in high speed, the curve will slope down quickly influenced by the inductance.



(1) Accelerated Motion of Straight Line

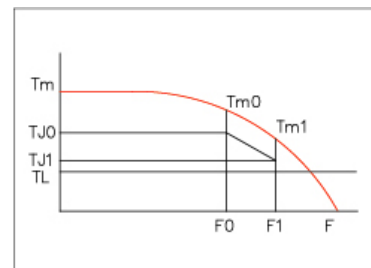
Motor's load value is known as TL, it has to be accelerated from F0 to F1 in the shortest time (tr), what is the value of tr? What is the value of pulse frequency of the acceleration F(t)?

- A. Generally $T_J = 70\% T_m$
- B. $tr = 1.8 \times 10^{-5} J \cdot 0 \cdot (F_1 - F_0) / (T_J - T_L)$
- C. $F(t) = (F_1 - F_0) \cdot t / tr + F_0, 0 < t < tr$



(2) Exponential Acceleration:

- A. Generally $T_{J0} = 10\% T_{m0}$,
 $T_{J1} = 70\% T_{m1}$,
 $T_L = 60\% T_{m1}$
- B. $tr = F_4 \cdot \ln[(T_{J0} - T_L) / (T_{J1} - T_L)]$
- C. $F(t) = F_2 \cdot [1 - e^{-(t/F_4)}] + F_0, 0 < t < tr$
 $F_2 = (T_L - T_{J0}) \cdot F_1 - F_0 / (F_{J1} - T_{J0})$
 $F_4 = 1.8 \times 10^5 \cdot J \cdot 0 \cdot F_2 / (T_{J0} - T_L)$



Note: J is the torque inertia of motor rotor plus its load.

0 is the angle of each step, it equals to the step angle of stepper motor when motor runs in full step. As for the control of deceleration, it can be realized by turning the accelerate pulse frequency above-mentioned.

Reduction of Vibration and Noise

In a non-loading condition, stepper motors may appear to have vibration or even lose steps when the motor is running at or close to resonant frequency.

Solutions for These Conditions

- A. Having the motor operate outside of this range.
- B. By adopting the micro-step driving method, you can divide one step into multiple steps thereby reducing the vibration. Micro-step is used for increasing a motor's step resolution. This is accomplished by controlling the motor's phase current ratio. Micro-step does not increase step accuracy. However, it will allow a motor to run more smoothly and with less noise. When the motor runs in half step mode, the motor torque will be 15% less than running in full step mode. If the motor is controlled by sine wave current, the motor torque will be reduced by 30%.