Introduction of Stepping Motors

Applications

MOONS' stepping motors are widely used to create the motion needed in many types of equipment. Examples include:

- office automation: printers, scanners, copy machines
- stage lighting: pointing, focus, color changes, spot size, special effects
- banking: check processing, credit card manufacturing, money scanners & counters
- medical: body scanning, blood analyzers, chemical analysis
- industrial: textile, packaging, robotics, conveyers, assembly, labeling
- telecommunication: phase shift, Tuning, mobile antenna positioning
- security: camera movement
- automotive: fuel metering, steering control

What is Stepping Motor

Stepping Motors provide precise position and speed control, without the need for feedback devices to sense position. The operation of step motors is controlled through electrical pulses that the drive converts to current flowing through the windings of the motor. As the current is switched the motor rotates in precise steps of a fixed angle. The motor and drive constitutes a low cost control system that is precise and simple to construct.

Performance Features of MOONS' Stepping Motors

- **Accurate Position Control**
  The number of control pulses defines the motor shaft position. Position error is very small (less than 1/10th of a degree), and non cumulative.

- **Precise Motor Speed**
  Step motor running speed, is exactly determined by the frequency of the control pulses. Because the speed is very precise and easy to control, step motors are often used where coordinated motion control is needed.

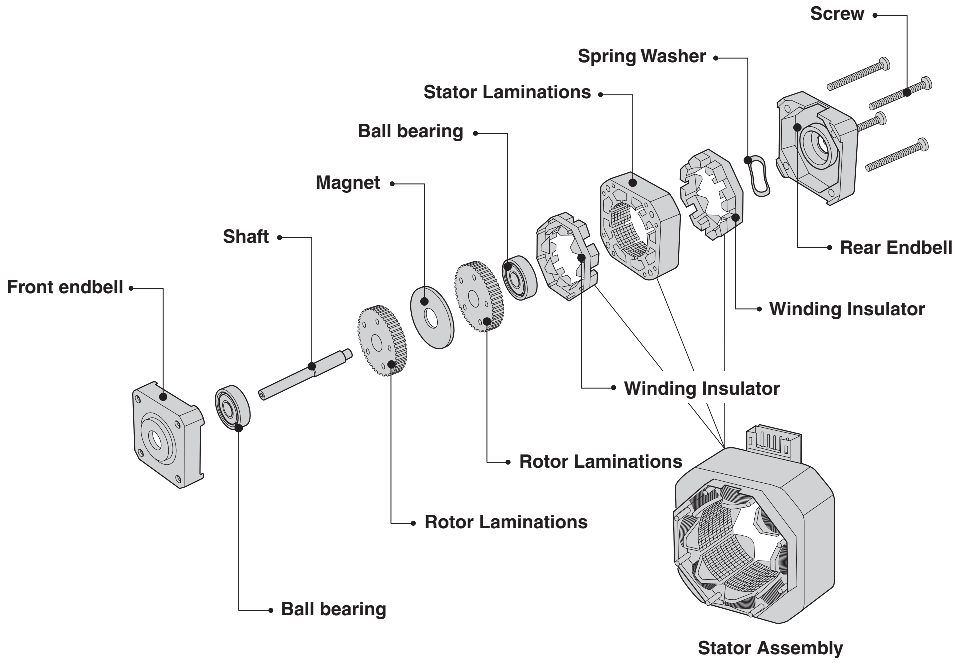
- **Forward & Reverse, Pause and Holding Function**
  Motor torque and position control is effective throughout the entire speed range, including zero speed holding torque. The zero speed holding torque locks the shaft at the desired position to hold the load in place.

- **Low Speed Operation**
  Step motors produce a large amount of torque, and are easy to control, at low speeds. This often eliminates the need for speed reduction gearboxes, reduces costs and saves space.

- **Long Life**
  The brushless design of step motors leads to motors with a very long life. Step motor life is usually determined by the life of the bearings.

Basic Structure and Motor Operation

- **Basic Structure**

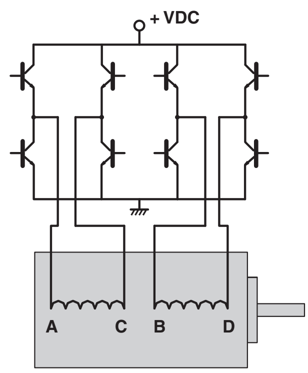


- **Operating Principles**

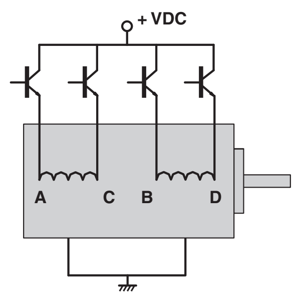
In response to each individual control pulse and direction signal, the drive applies power to the motor windings to cause the rotor to take a step forward, a step in reverse, or lock in position.

For example, in a 1.8 degree two phase step motor: When both phases are energized with DC current, the motor will stop rotating and hold in position. The maximum torque the motor can hold in place with rated DC current, is the rated holding torque. If the current in one phase is reversed, the motor will move 1 step (1.8 degrees) in a known direction. If the current in the other phase had been reversed, the motor would move 1 step (1.8 degrees) in the other direction. As current is reversed in each phase in sequence, the motor continues to step in the desired direction. These steps are very accurate. For a 1.8 degree step motor, there are exactly 200 steps in one revolution.

Two phase stepping motors are furnished with two types of windings: bipolar or unipolar. In a bipolar motor there is one winding on each phase. The motor moves in steps as the current in each winding is reversed. This requires a drive with eight electronic switches. In a unipolar motor there are two windings on each phase. The two windings on each phase are connected in opposite directions. Phase current is reversed by turning on alternate windings on the same phase. This requires a drive with only four electronic switches. Bipolar operation typically provides 40% more holding torque than unipolar, because 100% of the winding is energized in the bipolar arrangement.



2 phase step motor with bipolar driver



2 phase step motor with unipolar driver

Why Stepping Motor
encapsulated 2 phase NEMA 14
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2 phase NEMA 10 25.0 mm (1.00 inch)
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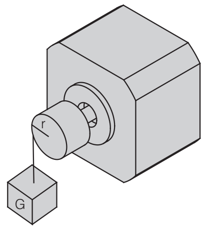
how to select

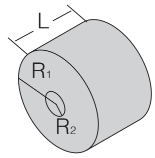
Technical Data and Terminology

- **Load Calculations**

A. Torque load (Tf)
Tf = G * r
G: weight
r: radius

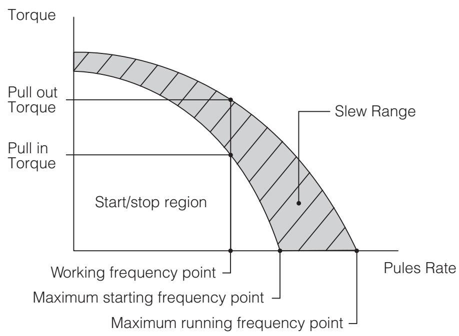


B. Inertia load (TJ)
TJ = J * dw/dt
$J = M * (R_1^2+R_2^2) / 2$ (Kg * cm)
M: mass
R1: outside radius
R2: inside radius
dw/dt: angle acceleration



- **Speed-Torque Characteristics**

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



A. Working frequency point express the stepping motors rotational speed value at this point
n = q * Hz / (360 * D)
n: rev/sec
Hz: the frequency value at this point
D: the subdividing value of motor driver
q: the step angle of stepping motor

E.g.: 1.8° stepping motor, in the condition of I/2 subdividing (each step 0.9°) runs at 500Hz its speed is 1.25r/s.

B. Start/Stop region: the region in which a stepping motor can be directly started or stopped.

C. 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 can not 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.

D. Maximum starting frequency point at this point, the stepping motor can reach its maximum starting speed under unloaded condition.

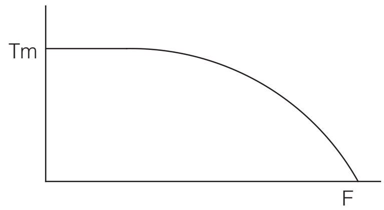
E. Maximum running frequency point at this point the stepping motor can reach its maximum running speed under an unloaded condition.

F. Pull-in Torque: the maximum dynamic torque value that a stepping motor can load directly at the particular operating frequency point.

G. Pull-out Torque: the maximum dynamic torque value that a stepping 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.

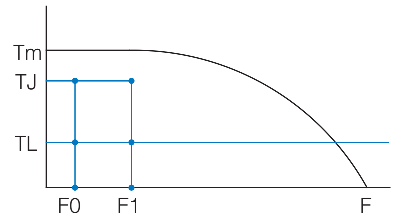
- **Calculate the Acceleration Torque**

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

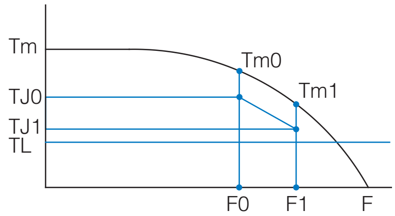


It is shown by the following graph: the dynamic torque's performance of stepping motor will always keep a horizontal straight line in low speed. But in high speed, the curve will slope down quickly influenced by the inductance.

A. 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?
   (1). Generally TJ = 70%Tm
   (2). $tr = 1.8 * 10^{-5} * J * q * (F1-F0)/(TJ-TL)$
   (3). $F(t) = (F1-F0) * t/tr + F0, \quad 0<t<tr$



B. Exponential Acceleration
   (1). Generally
      TJ0 = 70%Tm0,
      TJ1 = 70%Tm1,
      TL = 60%Tm1
   (2). $tr = F4 * \ln[(TJ0-TL)/(TJ1-TL)]$
   (3). $F(t) = F2 * [1 - e^{(-t/F4)}] + F0, \quad 0<t<tr$
      $F2 = (TL-TJ0) * (F1-F0)/(FJ1-TJ0)$
      $F4 = 1.8 * 10^{-5} * J * q * F2/(TJ0-TL)$



Note:
J is the torque inertia of motor rotor plus its load, q is the angle of each step, it equals to the step angle of stepping 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, stepping motors may appear to have vibration or even lose steps when the motor is running at or close to resonant frequency.

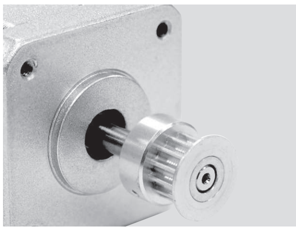
Solutions for these conditions

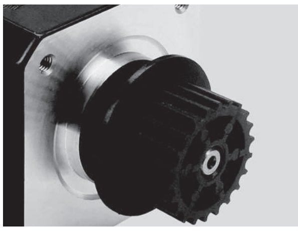
A. Have the motor operate outside of this speed range.

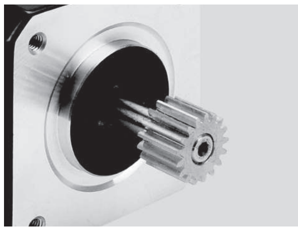
B. By adopting the micro-step driving method, you can divide one step into multiple steps thereby reducing the vibration, Micro-step is used for increasing a motor's step resolution. This is accomplished by controlling the motor's phase current ratio. Micro-step does not increase step accuracy. However 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%.

Shaft Options

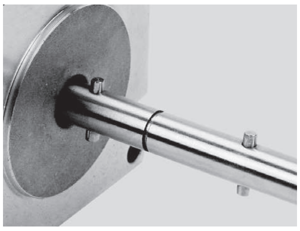
- **Press Fit Pulley & Gear**

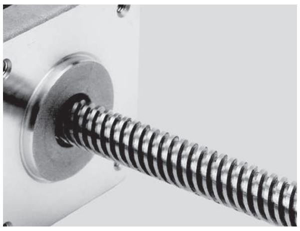

Metal Pulley

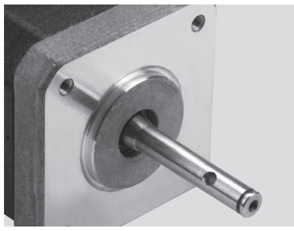

Plastic Pulley

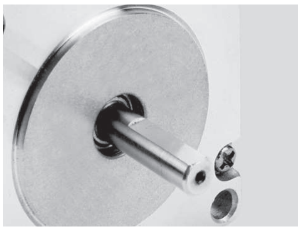

Gear

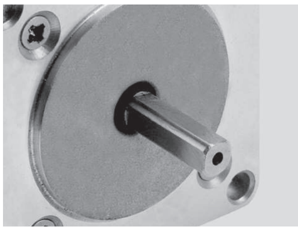
- **Shaft Options**

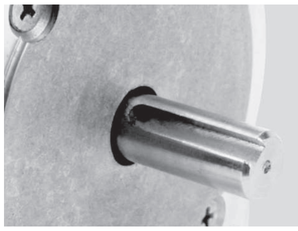

Dowel

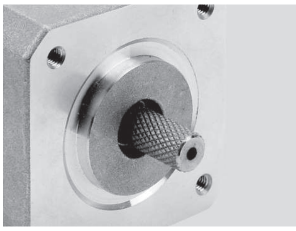

Worm Shaft


Cross Drilled Shaft


Single Flat


Double Flat


Key Way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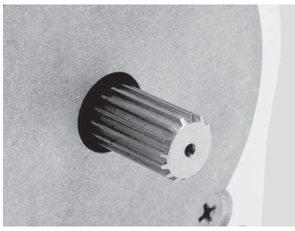
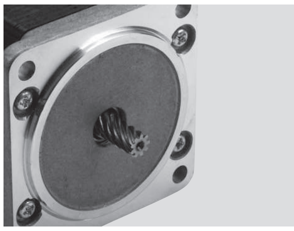
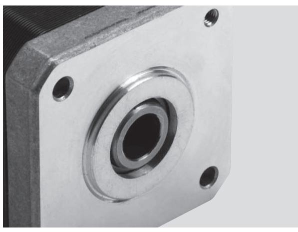

Hobbed Gear


Helical Cut


Hollow Shaft

- Many other special shafts are available.

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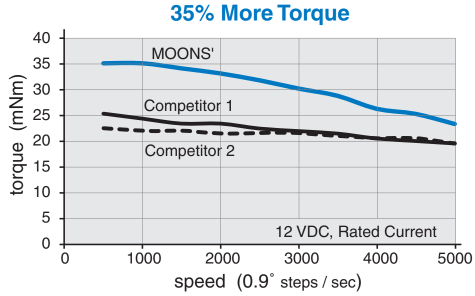
Encapsulated Stepping Motors

New Encapsulation Technology From MOONS' Offers Many Advantages

- **Ideal for Security Cameras**
  In addition to all the advantages of normal step motors, these new encapsulated motors can help achieve a breakthrough in miniaturization of security cameras. Small step motors are a core component in security camera systems. With MOONS' encapsulation technology, the 36mm diameter motor is now available with a thickness as little as 12.8mm.

- **Low Temperature Rise**
  The winding resistance of these new motors is nearly 30% lower than other motors with the same thickness and output-torque. In addition, the new encapsulation technology increases the heat-conducting property of these motors. The lower winding resistance and improved thermal conductivity combine to drastically lower the temperature of these motors to less than 80% of standard motors.

35% More Torque

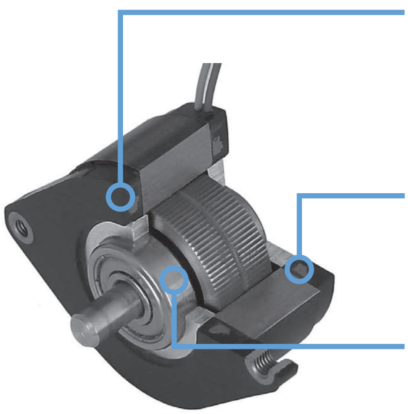


- **35% More Torque**
  Lower resistance coils allows these encapsulated motors to handle more power. With the same temperature rise the new motors can produce 35% more torque while dissipating the same amount of heat.

- **Quieter & Smoother**
  New materials and improved manufacturing processes, means these motors have a higher precision, more stable design. This controls vibration and reduces noise. It also makes the motor run smoothly.

- **More Load & Longer Life**
  MOONS' encapsulated stepping motors use large bearings that can handle large axial and radial loads, and ensure long life.

- **RoHS**
  Encapsulated stepping motors are RoHS compliant.



- **Molded Construction**
  Encapsulated winding.........Runs cooler – Longer life
  Better sealing.......................Longer life
  Reduced vibration..............Smoother moves - Quieter

- **High Winding Fill**
  Larger wire size..................More torque
  Uses less energy................Longer battery life

- **Large Ball Bearings**
  Large shaft loads................Fewer design restrictions
  Long Life.............................27 times with same load