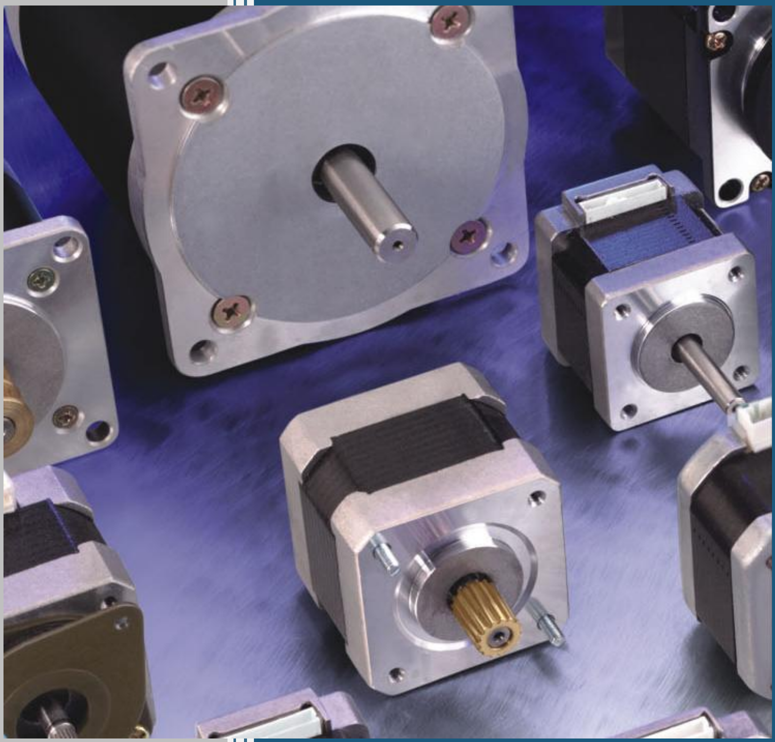
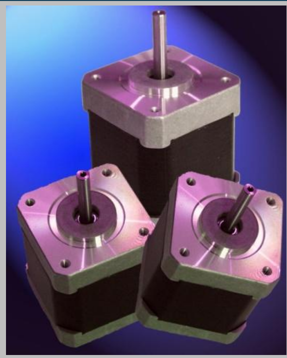
Astrosyn

Guide to Stepper Motor Selection



Astrosyn International Technology Ltd,
The Old Courthouse, New Rd Ave,
Chatham, Kent, ME4 6BE, England
Tel +44 (0) 1634 815175
Fax +44(0) 1634 826552
www.astrosyn.com

Introduction



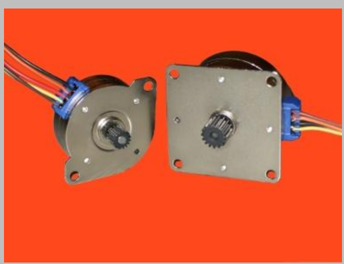
Choosing the right stepper motor for a particular application can be confusing for anyone without significant experience in the field. Simon Hunt of Astrosyn International Technology outlines some stepper motor fundamentals and offers advice on their selection for industrial applications.

Stepper motors have a number of features that make them the motor of choice for a wide range of applications, particularly in measurement and control. They are low cost, highly reliable, produce high torque at low speeds and benefit from a simple, rugged construction.

They also have the advantage of operating in open loop mode. As long as the motor runs within its specified torque, the position of the shaft is known at all times without the need for a feedback loop.

Stepper motors are available in three main types:

Permanent magnet motors.
These are widely used in non-industrial applications, such as computer peripherals, and are low-cost, low-torque and low-speed devices. Their design means that their step angles are relatively large, but their simplicity lends itself to high-volume production at low cost.



Variable reluctance motors.
These do not contain permanent magnets, giving them a good torque to inertia ratio. They are frequently used in small sizes for applications such as micro-positioning tables. However, they require a different driving arrangement from the other two types and are seldom used in industrial applications.

Hybrid motors. As their name suggests, these combine the operating principles of the previous two types, which enables them to provide higher torques. Experience at Astrosyn and elsewhere shows that these are by far the most widely used stepper motors in industrial applications and for that reason we will consider only this type here.

Making the right choice
Several factors affect the choice of stepper motors for particular applications, such as the type of motor, the torque requirement of the system, complexity of the controller, and the physical characteristics of the motor.

Choosing the right stepper motor depends upon the application. The motor's specification will include the following parameters:-

- the number of full steps per revolution
- whether to operate in full step, half step or microstep mode
- the rotational inertia of the rotor and shaft
- holding torque - the maximum restoring torque developed by the rotor when one or more phases of the motor are energised
- detent torque – the torque required to rotate the motor's shaft when the windings are not energised
- pull-out torque – the maximum torque that can be applied to a stepper motor

running at constant speed without causing a loss of synchronism
- expected ambient temperature range

A standard 1.8° stepper motor has 200 steps per revolution.

Full-step mode in single phase is when the motor is operated with only one phase energised at a time. This requires the least power from the driver power supply, and can be used where the motor is operated at a fixed speed. Dual phase provides increased torque, but uses more power.
Half-step operation involves alternating single and dual phase operation and provides twice the resolution, which results in increased smoothness at low speeds.
Microstep operation divides each full step into much smaller angles by using sine and cosine functions to drive the windings. Astrosyn supplies motors with resolutions of up to 12 800 microsteps per revolution, and this mode is used when smoother motion or increased resolution is required.

To design stepper motors with higher torque output, manufacturers need to increase the strength of both the permanent magnet in the rotor and the field produced by the stator. Rare earth magnets offer increased magnetic field strength, and further torque increases can be achieved through mechanical changes.

A stronger rotor magnet can be obtained by increasing its diameter, producing a larger cross-sectional area, but this decreases the acceleration of the motor because the torque-to-inertia ratio becomes worse.
However, torque output can be increased without degrading acceleration by adding further magnet sections or "stacks" to the same shaft. A second stack will enable twice the torque to be produced with double the inertia, so the torque-to-inertia ratio remains the same. Hence stepper motors are often available in single, double and three stack versions in each frame size.

Practical tips
As a rule of thumb, the torque-to-inertia ratio reduces by a factor of two with each increase in frame size. An unloaded 34-size motor can accelerate twice as fast as a 42-size motor, regardless of the number of stacks.

In the manufacture of stepper motors, the rotor is magnetised after assembly to produce the highest possible flux density. This means that stepper motors should not be dismantled, since this flux will be largely destroyed if the rotor is removed. Unlike with DC servo motors, it is not generally possible to demagnetise stepper motors by applying excess current.

However, too high a current can damage the motor in other ways: excess heating may melt the insulation or the winding transformers, and may soften the bonding material holding the rotor laminations. If the laminations are displaced, the effects can be the same as if the rotor was demagnetised.

Note that continuous operation at high speeds can lead to overheating of the rotor, but high speeds can be used successfully for positioning applications.

Because the shaft of a hybrid stepper motor passes through the centre of the permanent magnet, it must be made of non magnetic material to avoid a magnetic short circuit. Stepper motor shafts are therefore made of stainless steel, and this should be borne in mind when handling the motor.

Small diameter motors are particularly vulnerable if they are dropped on their shaft end, as this is likely to bend the shaft.