An Introduction to Stepping Motors

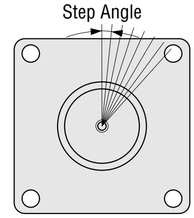
■ INTRODUCTION

Stepping motors are digitally controlled motors used for precise positioning. They enable simple, accurate control of rotation angle and rotation speed, so they are suitable for wide variety of applications. Oriental Motor has brought hybrid stepping motors into its product line to provide better levels of precision and performance when compared to other stepping motors. These motors have been used in many applications ranging from industrial equipment to office automation.
Oriental Motor also provides a complete product line with every type of product, as well as optional equipment that a stepping motor might need, from dedicated drivers, to controllers, precision gears and more.

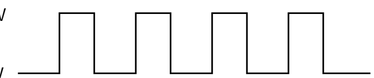
■ FEATURES

1. Easy Angle and Speed Control

Stepping motors move by rotating in steps of predetermined degrees called step angles. The degrees rotated and the speed of rotation are easily controlled using electrical signals called pulses.



Pulses
A pulse is an electrical signal that repeats ON and OFF voltages as shown in the illustration below. Each cycle of ON and OFF (1 cycle) is called a "pulse." Normally, 5 volts is used. ON is high and OFF is low.



2. High Torque/Good Response

Stepping motors are compact, but produce high torque.
This provides excellent acceleration and fast movement.

3. High Resolution/High Positioning Precision

There are two types of stepping motors: the 5-phase stepping motor, which rotates 0.72˚ for each pulse, and the 2-phase stepping motor, which rotates 1.8˚ for each pulse. The angular distance moved corresponds to the number of pulses input, with a stopping accuracy of ±3 arc minutes (0.05˚ with no load). [±5 arc minutes for the **PMU** and **PMC** series (0.08˚ with no load).]

4. Holding Torque

Stepping motors produce high holding torque even while stopped. The stop position can be held without relying on a mechanical brake.

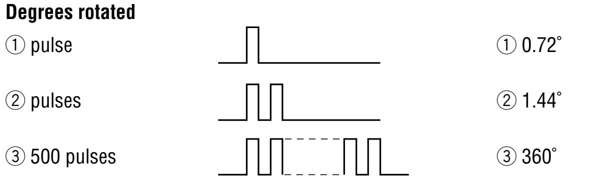
■ Applications

Factory Automation:
X-Y plotters, laser processors, electric discharge processors, CNC machines, sewing machines, etc.
Semiconductor fabrication equipment:
Wafer processing devices, wafer conveyors, IC bonders, dicing machines, IC inspection devices, etc.
Automation and labor-saving devices:
ATMs, ticket machines, postal sorters, laboratory systems, bill counters, vending machines, etc.
Medical equipment:
Analytical instruments, blood pumps, centrifuges, spectrographs, etc.
Office automation:
Copiers, faxes, word processors, printers, optical and magnetic disk devices, etc.

USING STEPPING MOTORS

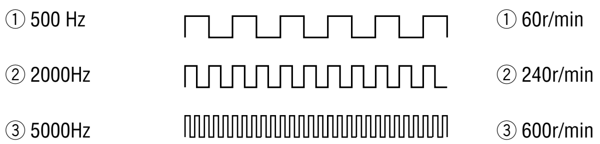
Stepping motors rotate according to the number of pulse signals, so speed of rotation can be controlled by the speed (frequency) of the pulse signal.

Degrees rotated



5-Phase Stepping Motor

Speed of rotation



5-Phase Stepping Motor

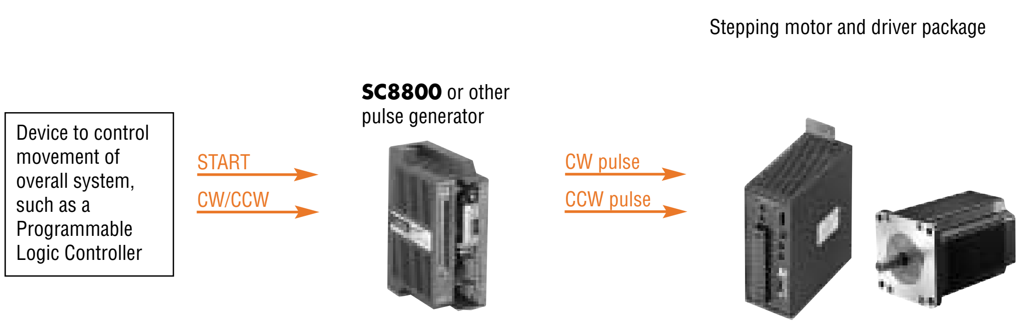
A specialized driver circuit is needed to run the stepping motor. Oriental Motor's drivers are designed for easy connection.

1. *Drivers*

Drivers are circuits that drive the stepping motor. They supply the optimum current for the number of motor phases.

2. *Controller (Oscillators)*

Controllers are circuits that control the stepping motor's angular distance of rotation and rotation speed. They create pulse signals according to settings.



STEPPING MOTOR AND DRIVER PACKAGES

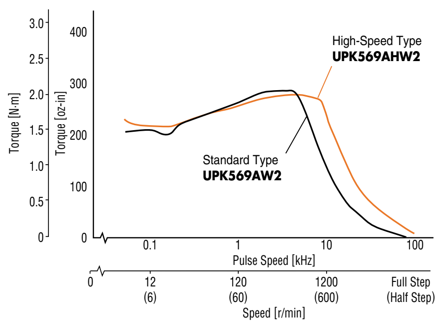
To get the most performance out of stepping motors, the best combination of motor and driver are joined in a package. They eliminate cumbersome initialization chores like adjusting the motor's operating current.

Types of Stepping Motor and Driver Packages

These stepping motor and driver packages deliver optimally matched motors and drivers together to fully realize the performance potential of the stepping motor. These packages can be divided into three types, five-phase stepping motors, two-phase stepping motors, and the newly-developed αSTEP motors, which do not lose synchronization. Oriental Motor provides a full product line, including the **TH** geared types, **PN** geared types, and other high-precision, high-strength geared types, high-resolution types, and the **NanoStep**, which uses microstep technology.

● Standard types and high-speed types

For some motor and driver packages, there are high-speed types available that emphasize the motor's high-speed responsiveness.
These high-speed types are useful when motor installation space is limited and torque is required at high-speed.



Be aware that the power supply capacity required for high-speed types is greater than for standard types.

● Standard types and high-resolution types

The product line of stepping motor and driver packages includes high-resolution types for which the two-phase stepping motor basic step angle of 1.8˚/step is cut in half to 0.9˚/step (for full step operation). These high-resolution types are useful when stopping precision and high-precision positioning are required.

● Full product line of geared types

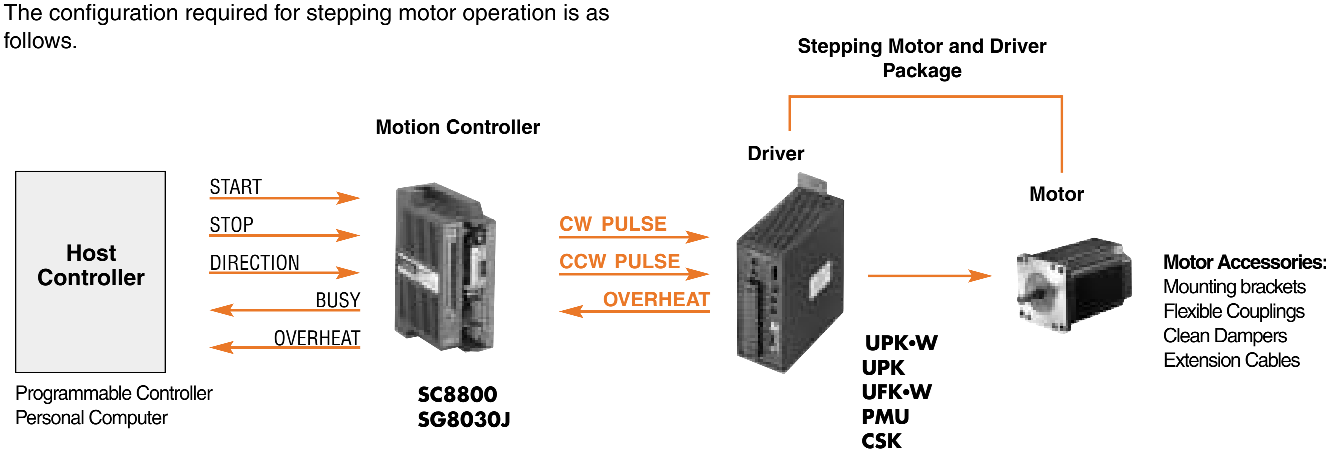
Sometimes in low-speed stepping motor operation, the distinctive intermittent step-like rotation is an issue. For these applications, consider geared types. The gears not only reduce speed and increase torque, but they also reduce the inertia of the load by the square of the gear ratio, so they improve starting and stopping responsiveness.

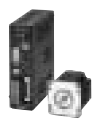
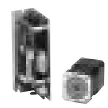
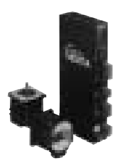
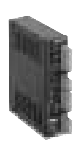
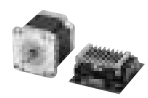
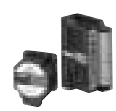
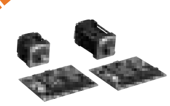
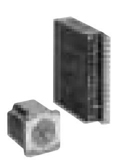
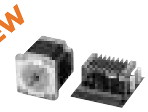
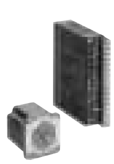
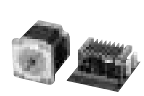
● NanoStep for low-vibration and low-noise operation

Generally, the motor step angle is 0.72˚ for full-step operation, but the **NanoStep** can further partition this electrically to resolutions as fine as 125,000 steps per revolution. This provides quiet, smooth rotation, even for low-speed operation.

■ Example of system configuration

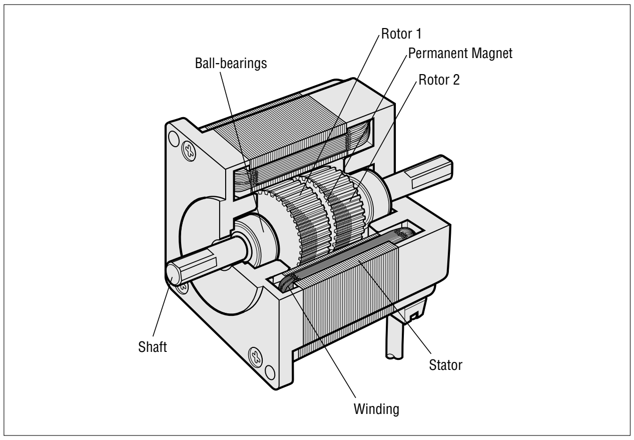
The configuration required for stepping motor operation is as follows.



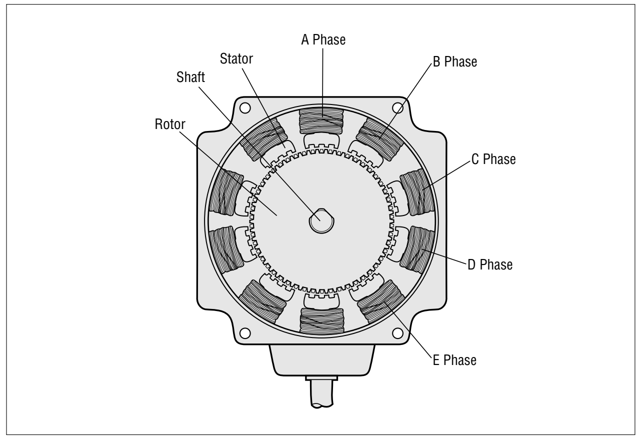
	BOX Type Driver (Single-Phase 100-115 VAC Input)	Circuit Board Driver (24 VDC Input)
αSTEP **No Missed Step** **High Response**	NEW  **AS Series** **●Round Shaft Type** Page B-43	NEW  **ASC Series** **●Round Shaft Type** Page B-43
5-Phase **Step Angle: 0.72˚** **High Torque**	NEW  **UPK•W Series** **●Standard Type** **●High-Speed Type** **●TH Geared Type** **●PN Geared Type** Page B-61  **UPK Series** **●Standard Type** **●High-Speed Type** Page B-107 NEW  **NanoStep UFK•W** Maximum 125,000 steps/rev. Low vibration, low noise **●Standard Type** **●TH Geared Type** **●PN Geared Type** Page B-121 NEW  **PMU Series** Motor Frame Size 1.1 in. (28mm) sq. Compact and lightweight motor **●High-Speed Type** **●Geared Type** Page B-151	 **CSK Series** **●Standard Type** **●TH Geared Type** Page B-175  **NanoStep RFK** Maximum 125,000 steps/rev. Low vibration, low noise **●Standard Type** Page B-163 NEW  **PMC Series** Motor Frame Size 1.1 in. (28mm) sq. Compact and light- weight motor **●Standard Type** **●Geared Type** Page B-195
2-Phase **Step Angle: 0.9** **High Torque**	NEW  **UMK Series** **●High-Resolution Type** Page B-209	NEW  **CSK Series** **●High-Resolution Type** Page B-233
2-Phase **Step Angle: 1.8˚** **High Torque**	 **UMK Series** **●Standard Type** Page B-209	 **CSK Series** **●Standard Type** **●SH Geared Type** Page B-233

The Basics of Stepping Motors

■ STRUCTURE



Motor Structure Diagram 1: Cross-Section Parallel to Shaft (5-Phase Stepping Motor)



Motor Structure Diagram 2: Cross-Section Perpendicular to Shaft (5-Phase Stepping Motor)

The figures above show two cross-sections of a 5-phase hybrid stepping motor. Hybrid Stepping motors are composed primarily of two parts, the stator and the rotor. The rotor in turn is comprised of three components: rotor 1, rotor 2 and the permanent magnet. The rotors are magnetized in the axial direction, with rotor 1 polarized north and rotor 2 polarized south.

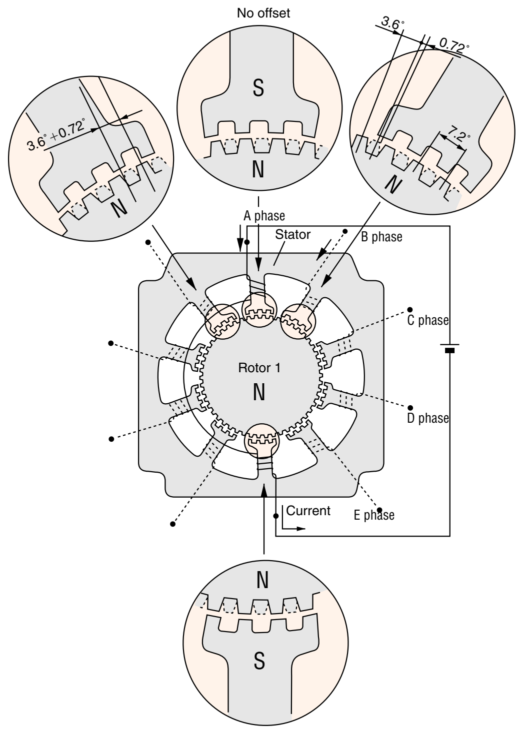
The stator contains 10 magnet poles with small teeth, each of which is wrapped in wire to form a coil. The coil is connected to the facing magnet pole and is wound so it becomes magnetized to the same pole when current is run through it. (Running a current through a given coil magnetizes the facing poles to the same magnetism, either north pole or south pole.) The two facing poles form a single phase. Since there are five phases, A through E, the motor is called a 5-phase stepping motor. There are 50 teeth on the outside of the rotor, with the teeth of rotor 1 and rotor 2 mechanically offset from each other by half a tooth pitch.

Excite: Send current through the motor coil.
Magnet pole: The projections of the stator, magnetized by excitation.
Teeth: The teeth of the rotor and stator.

PRINCIPLES OF OPERATION

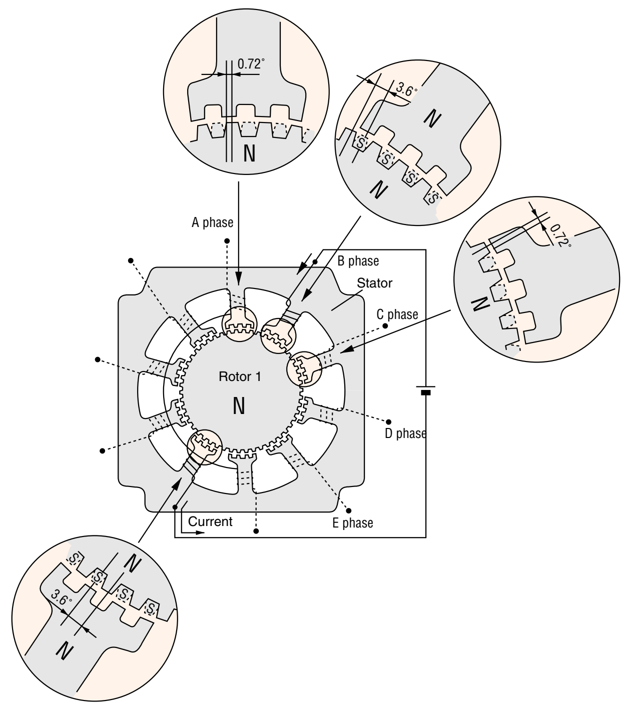
The following figure helps describe the relationship of the positions of the stator and rotor teeth when magnetized. A 5-phase stepping motor is used in the example.

1. When Phase A Is Excited



When phase A is excited, its poles are magnetized south and attract the teeth of rotor 1, which are magnetized north, while repelling the teeth of rotor 2, which are magnetized south, which balances it to a stop. The teeth of the phase B poles, which are not excited, are misaligned with the south-polarized teeth of rotor 2 so they are offset by 0.72˚.

2. When Phase B Is Excited



When the excitation switches from phase A to phase B, the phase B poles are magnetized north, attracting the south polarity of rotor 2 and repelling the north polarity of rotor 1. In other words, when excitation switches from phase A to phase B, the rotor rotates 0.72˚. As excitation shifts from phase A, to phase B, to phase C, to phase D, to E, to phase A, the stepping motor rotates in precise 0.72˚ steps. To rotate it in reverse, reverse the excitation order to phase A, phase E, phase D, phase C, phase B, phase A.

The high (0.72˚) resolution is created by the mechanical offset of the stator and rotor structures, which is why positioning can be performed accurately without the use of an encoder or other sensor. Since the only factors that might decrease stopping precision are variations in the processing precision, assembly precision, and DC resistance of the coil, a high stopping precision of ±3 arc minutes (with no load) is achievable. The driver performs the role of switching the phases, and its timing is supplied by the pulse signal input to the driver.
In the example above, excitation proceeds one phase at a time, but for the most effective use of the coils, four or five phases should be excited simultaneously.

■ CHARACTERISTICS

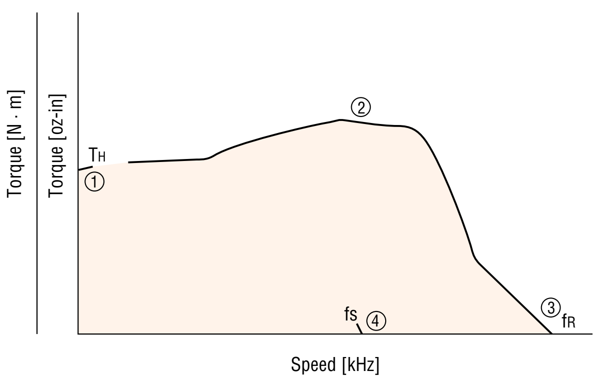
When using a stepping motor it must be determined that the motor characteristics are suited to the required load. The two main characteristics of stepping motor performance are:

- Dynamic Characteristics:
  Relating to speed and torque when the stepping motor starts or is rotating.
- Static Characteristics:
  Relating to the changes in angle that take place when the stepping motor is stopped or during motor standstill.

1. Dynamic Characteristics

(1) Speed vs. Torque Characteristics

This is the most common characteristic for expressing stepping motor performance. On the graph of this characteristic, the horizontal axis expresses pulse speed while the vertical axis expresses torque.
Pulse speed equals the pulse rate, which is the number of pulses per second. In stepping motors, the number of revolutions per minute is proportional to pulse speed.



Speed vs. Torque Characteristics

The speed vs. torque characteristics are determined by the motor and driver, so they vary greatly based upon the type of driver used.

① Holding Torque

The holding torque is the maximum holding power (torque) the stepping motor has when power is being supplied but the motor is not rotating (rated current).

② Pullout Torque

Pullout torque is the maximum torque that can be output at a given speed. When selecting a motor, be sure the required torque falls within this curve.

③ Maximum Response Frequency (f_R)

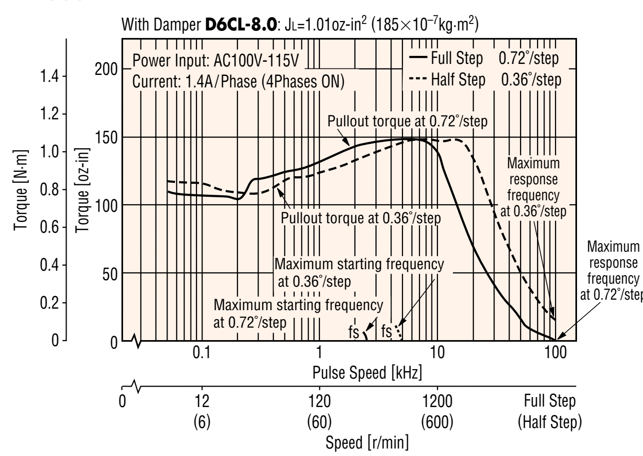
This is the maximum pulse speed that the motor can be operated at when gradually increasing or decreasing the speed, when the frictional load and inertial load of the stepping motor are 0.

④ Maximum Starting Frequency (f_S)

This is the maximum pulse speed at which the motor can start or stop instantly (without an acceleration or deceleration period) when the frictional load and inertial load of the stepping motor are 0. Driving the motor at greater than this pulse speed requires gradual acceleration or deceleration. This frequency drops when there is an inertial load on the motor. (See the description of inertial loads and starting frequency on the next page.)

The following figure shows the speed torque characteristics of the 5-phase stepping motor and driver **UPK566BW2**.

UPK566BW2



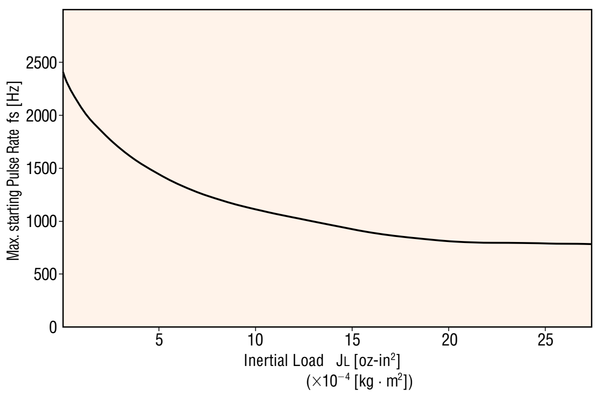
About the Logarithmic Scale:

Since the pulse speed range of the stepping motor extends from 10 Hz to 100 kHz, it becomes difficult to read the changes in torque below the commonly used figure for actual speed of 20 kHz if an ordinary scale is used. For that reason, a logarithmic scale is used to make the changes near 1 kHz and 10 kHz easier to read.

(2) Inertial Load vs. Starting Frequency Characteristics

The figure below illustrates the changes in starting frequency caused by inertial load. Since the stepping motor rotor and the equipment have their own inertia, lags and advances occur on the motor axis during instantaneous starts and stops. These values change with the pulse speed, but the motor cannot keep up with pulse speeds beyond a certain point and missteps result. The pulse speed just before a misstep occurs is called the maximum starting frequency.

UPK566BW2



Load Inertia vs. Starting Pulse Rate Characteristics

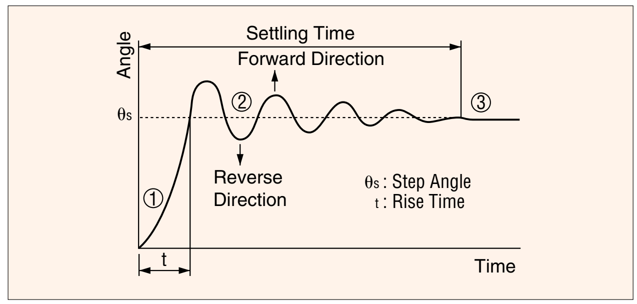
Changes in maximum starting pulse rate with load inertia may be approximated by the following formula.

$$f = \frac{f_S}{\sqrt{1 + \frac{J_L}{J_0}}} \text{ [Hz]}$$

f_S: Maximum starting pulse rate (Hz) of the motor
f: Maximum starting pulse rate (Hz) when applying load inertia
J_O: Rotor inertia (oz-in^2) [kg·m^2]
J_L: Load inertia (oz-in^2) [kg·m^2]
($J = GD^2/4$)

(3) Vibration Characteristics

When no pulse signal is input to driver, the stepping motor stops with a holding brake force equivalent to the maximum value of holding torque. As pulses are input, the motor operates in a repeating stepwise manner as shown below.

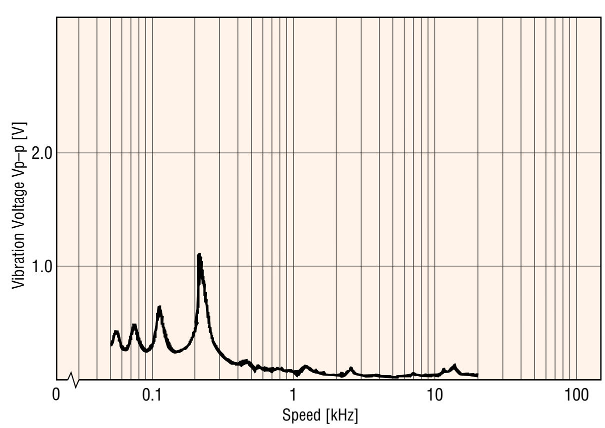


Single step response

① When a pulse signal is input, the motor accelerates towards the next step angle
② Due to the influence of the rotor inertia and the load inertia, the motor overshoots a certain angle, returns in the opposite direction, and then repeats this action.
③ After the motor has repeated sufficient damping oscillations, it stops at the set position.

A step-like movement that produces this kind of damped vibration is the cause of vibration at low speeds. The graph of vibration characteristics below shows the characteristics indicating the extent of vibration while the stepping motor is running.

UPK566BW2



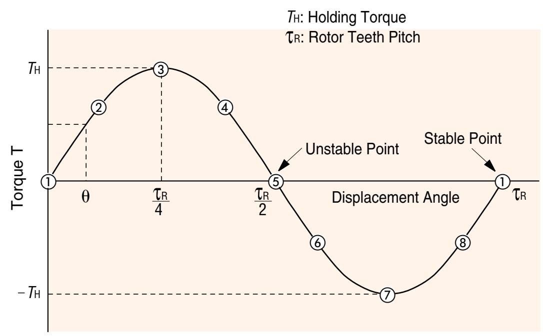
Vibration Characteristics

Rotation becomes smoother as the vibration level decreases. There is an area around 200 Hz where vibration is most pronounced, and should be avoided.

2. Static Characteristics

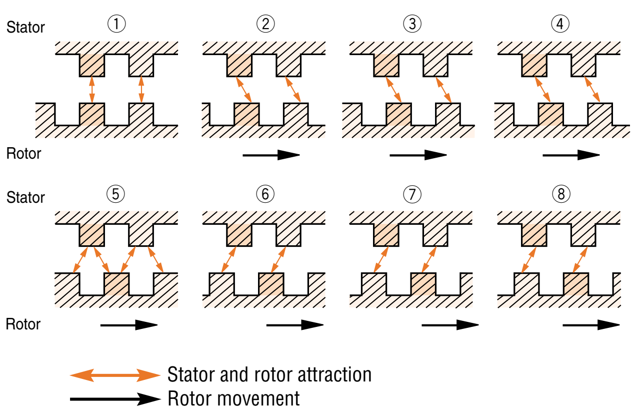
(1) Torque vs. Angle Characteristics

Torque-angle characteristics are the relationship between the angular displacement of the rotor and the torque which is applied to the shaft when energizing the motor with rated voltage. The curve for this characteristic is shown below.



Torque vs. Angle Characteristics

The illustrations below show the relationship of the positions of rotor and stator teeth at the numbered points in the diagram above.



When held stable at point ①, external application of a force to the motor shaft will produce a torque T (+) to the left, trying to return the shaft to stable point ① and the shaft will stop when the external force equals this torque. ② If additional external force is applied, there is an angle at which the torque produced will hit a maximum. This torque is the holding torque T_H. ③ When that external force is exceeded, the rotor moves to an unstable point ⑤ and beyond, producing a torque in the same direction as the external force T (−), so it moves to the next stable point ① and stops.

Stable points:

Locations where the rotor stops, with stator and rotor teeth exactly aligned. These points are extremely stable and the rotor will always stop there if no external force is applied.

Unstable points:

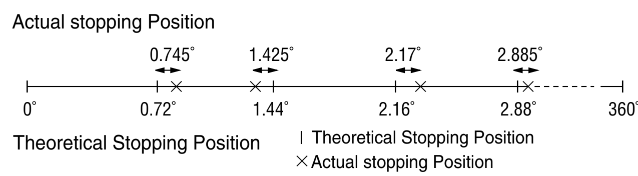
Locations where the stator and rotor teeth are half a pitch out of alignment. They are extremely unstable. A rotor at these locations will move to the next stable point to the left or right if even the slightest external force is applied.

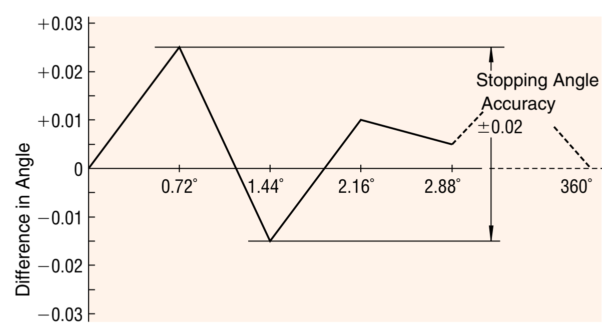
(2) Step Angle Accuracy

Under no-load conditions the stepping motor can maintain a step angle accuracy within ±3 arc minutes (0.05˚) [For **PMU** and **PMC** series, ±5 minutes (0.08˚)]. This slight error arises from difference in the mechanical precision of the stator and rotor teeth and variations in the electrical precision of the DC re sistance of the stator coil.

●Stopping Accuracy

This refers to the difference between the rotor's theoretical stopping position and its actual stopping position. A given rotor stopping point is taken as the starting point, then the stopping angle error is the difference between the maximum (+) value and the minimum (−) value when measuring each step of a full rotation.





The step angle error is ±3 arc minutes (0.05˚) [For **PMU** and **PMC** series, ±5 minutes (0.08˚)], but only under no load. In actual applications, there is always frictional load. The angle precision in such cases is produced by the angular displacement caused by angle-torque characteristics based upon the frictional load. If frictional load is constant, the angle of displacement is constant for rotation in one direction. When operating from both forward and reverse, however, double the displacement angle is produced by the round trip.
When stopping precision is required, always position from one direction only.

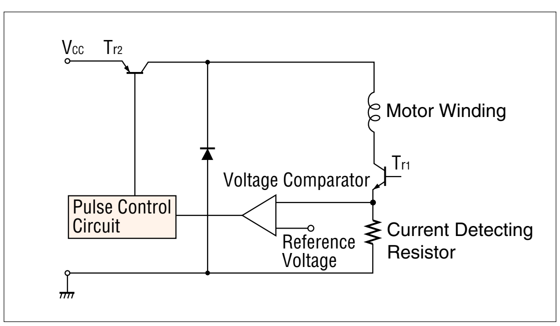
■ AC Input Drivers and DC Input Drivers

There are two ways of driving stepping motors: constant-current drive and constant-voltage drive. The circuitry of constant-voltage drive is simpler, but it is harder to achieve torque at high speeds. For that reason, constant-voltage drives are used less often as equipment speeds have increased.
Constant-current drive is currently the most commonly used drive method, since it provides excellent torque at high speeds. All Oriental Motor stepping motor and driver packages use constant-current drivers.

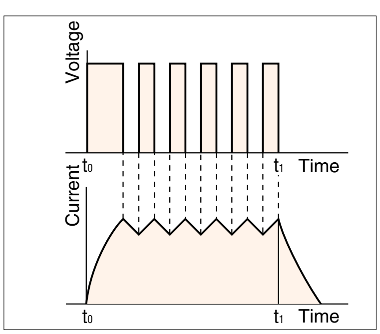
1. *An introduction to constant-current drivers*

Stepping motors rotate by the switching of current flowing through several coils. When the speed increases, the switching also becomes faster and the current rise cannot keep up, so torque drops. By chopping a DC voltage that is far higher than the motor's rated voltage, a constant current can be kept flowing to the motor, even at high speeds.

The current flowing to the motor coil is compared to the reference voltage. When the detection resistor the voltage is lower than the reference voltage (when it hasn't reached the rated current), the switching transistor (Tr_2) stays on. When it is higher than the reference voltage (when it exceeds the rated current), Tr_2 goes off, the current is controlled so that the rated current is always flowing.



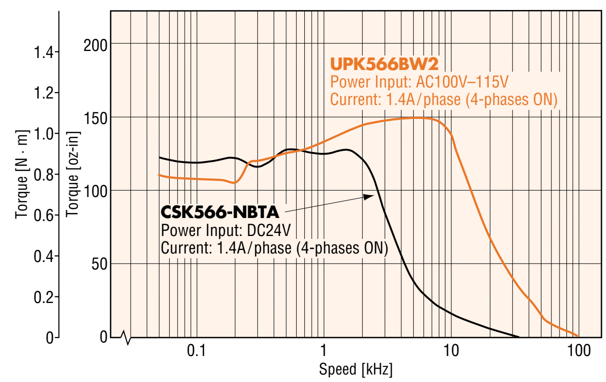
Basic circuit for constant current chopper driver



Relationship between voltage drive and constant current drive

2. *The difference between AC input and DC input characteristics*

A stepping motor is driven by a DC voltage applied through a driver. In the case of Oriental Motor's 24 VDC input drivers, 24 VDC is applied to the motor; in the case of 115 VAC and 230 VAC input, the input is rectified to DC and then approximately 140 VDC is applied to the motor (there are some products which are exceptions to this).
This difference in the voltages applied to the motors appears as a difference in the torque characteristics in the high speed region. This is because the higher the applied voltage, the faster the rise of current flowing through the motor coil, so that a fixed current can flow even in the high speed region. Thus, the AC input unit has superior torque characteristics throughout, from the low speed region to the high speed region, and a large speed ratio can be obtained.
It is recommended that this motor be used together with an AC input unit that can respond to a variety of conditions.



Comparison of characteristics of AC input unit and DC input unit

Advantages of High-Resolution

2-PHASE, HIGH-RESOLUTION STEPPING MOTORS

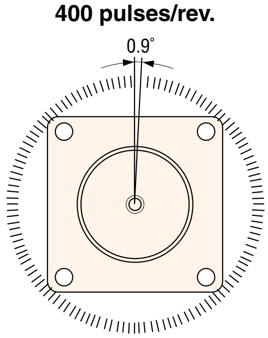
The 2-phase, high-resolution (0.9° per step) stepping motor has half the step angle of the standard (1.8° per step) stepping motor. The high-resolution type increases motor resolution from 200 pulses (360° /1.8°) to 400 pulses (360° /0.9°). If an even smaller step-angle is needed, half-step driving and micro-step driving are other options. Such options, however, do not improve accuracy. The excitation coil of the 2-phase, high-resolution stepping motor is located in exactly the same position, the number of rotor teeth is twice as many as standard stepping motors. Other structures are exactly the same as the standard motors.

FEATURES

1. High Resolution

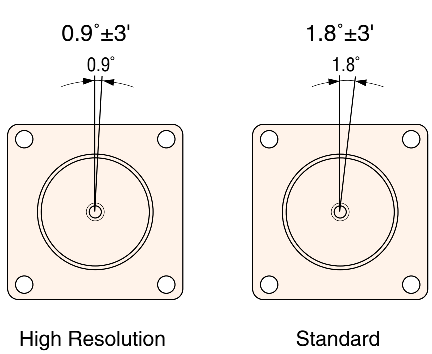
Even with the same fundamental structure as the standard stepping motor, doubling the number of rotor teeth (100 rotor teeth) produces high-resolution with 0.9° per step (400 pulses per revolution).

400 pulses/rev.



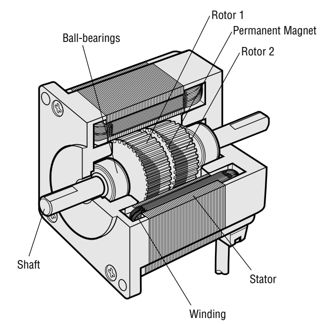
2. Improved Positional Accuracy

Positioning accuracy is important, especially in bi-directional positioning. The high-resolution motor (0.9° per step) has higher positioning accuracy than the standard stepping motor (1.8° per step).

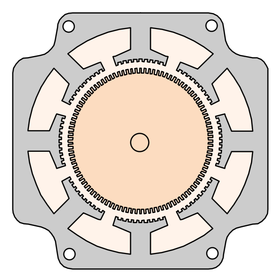


STRUCTURE

The magnet coil is set in exactly the same position as in the 2-phase 1.8° stepping motor. But the number of teeth is doubled to 100. See the following figures for structural details and the cross-sectional structure of the 2-phase 0.9° stepping motor.



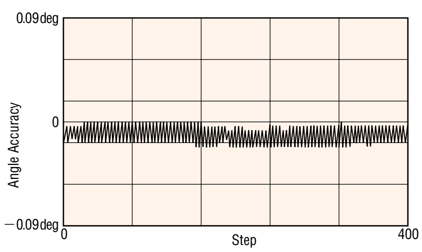
Structure of the 2-Phase High-Resolution Stepping Motor (0.9° per step)



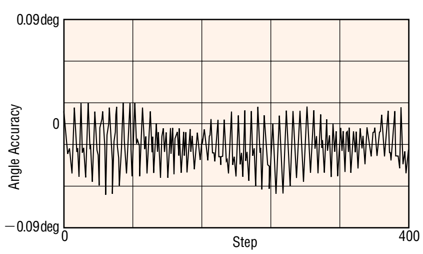
Cross-Section Perpendicular to Shaft

■ STEP ANGLE ACCURACY

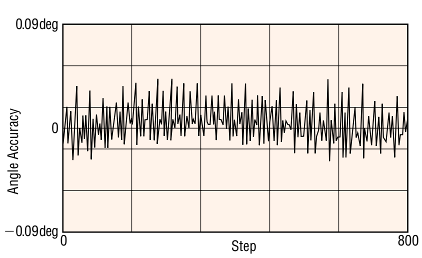
There are a variety of reasons why step angle errors can occur. In most cases, angle differentials occur in conjunction with the total accuracy of the machinery. Each part of the motor is manufactured with high accuracy. However, when they are assembled, composite errors usually occur. Static angle differential is less than ±3° (0.05°), under no-load condition. The angle discrepancy is closely related to the number of teeth. About 0.5-1 % of the pitch angle of the teeth causes such errors.
The following figures show the static angle discrepancy for each (1) full-step 2-phase high-resolution stepping motor, (2) full-step 2-phase standard stepping motor, (3) half-step 2-phase standard stepping motor.
Even though (1) and (3) rotate with the same 0.9°, (1) shows smaller errors. Comparing (2) and (3) indicates that the half-step driving of the standard stepping motor does not improve accuracy.
In short, although it is possible to make each step-angle smaller by the driver, it does not contribute to increasing accuracy. Rather, angle discrepancy per step increases. The 2-phase standard stepping motor (1.8° per step) can use half step driving to achieve 0.9° per step. However, this does not produce the same accuracy as the 2-phase high-resolution stepping motor (0.9° per step) run at full step. Half-step driving is not for improving accuracy, but for solving other problems like vibration and irregular rotation.



(1) 2-Phase 0.9˚ Stepping Motor (Full Step)



(2) 2-Phase 1.8˚ Stepping Motor (Full Step)

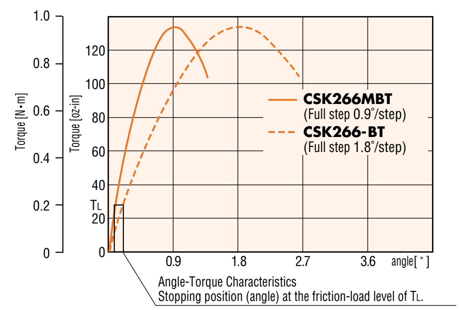


(3) 2-Phase 1.8˚ Stepping Motor (Half Step)

Figure 3 Angle Accuracy

■ FRICTIONAL LOAD DELIVERS POSITIONAL ERRORS

The positional errors of machinery do not depend solely on the angle accuracy of the motor. Different load levels for each step naturally contribute to positional inaccuracy. Even under stable loading, it creates positional inaccuracy when used in bi-directional positioning. In such cases, the magnitude of the positional accuracy is several times worse than the angle inaccuracy of the motor itself.
The following figure shows one of the fundamental characteristics of two stepping motors. Those curves compare the 2-phase standard stepping motor and the 2-phase high-resolution stepping motor, by showing their angle-torque characteristics. The peak of each curve illustrates its holding torque (maximum static torque at excitation).



Angle-Torque Characteristics

These curves display the angle discrepancy between ideal and actual positions, against loading under static excitation status. The 2-phase high-resolution stepping motor reaches its peak at half angle, comparing to the 2-phase standard motor. The slope of the high-resolution motor's load-torque characteristic curve is steeper than the one for the standard motor's. The former yields half the discrepancy of the latter, even under the same load. Since the slope of the curve varies, based on the number of teeth and torque. The positional accuracy of the high-resolution motor under actual load is quite higher. When a stepping motor is used in practice for the purposes mentioned above, sufficiently large torque is normally selected, in the attempt to minimize the positional discrepancy on loading. The 2-phase high-resolution stepping motor is the most suitable.

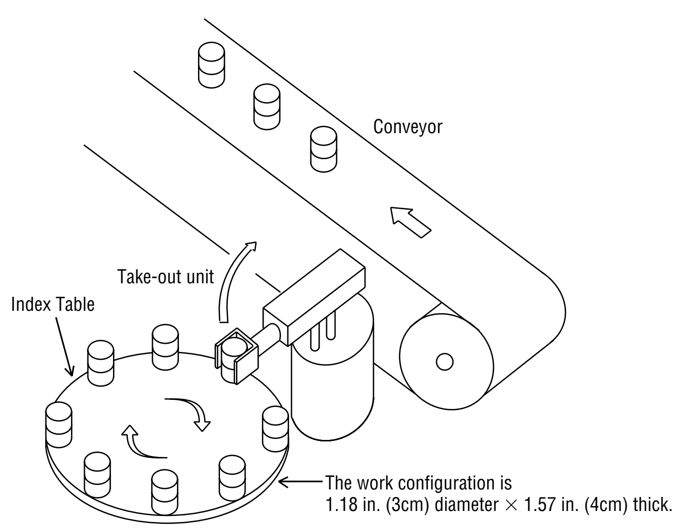
Advantages of Geared Stepping Motors

Speed reduction gearheads have come into wide use with the general objectives of increasing torque and reducing speed. However, they are also used in combination with stepping motors requiring high positioning precision in order to achieve higher resolution, lower vibration, high inertia drive and downsizing.
Here we will explain the advantages of geared stepping motors comparing the case for selecting the motor alone and the case for selecting a geared type.

■ SELECTION CONDITIONS

In the following example, a geared motor will be selected for an index table application with the following conditions:

Index table diameter	7.87 inches (20 cm)
Index table thickness	0.31 inch (0.8 cm)
Index table material	Aluminum
Work diameter	1.18 inch (3 cm)
Work thickness	1.57 inch (4 cm)
Work material	Steel
Work count	8
Total moment of inertia	203 oz-in^2 (37.1 kgcm^2)
Resolution	0.4˚ max.
Positioning time	0.2 second max.
Positioning angle	45˚



■ SELECTION EXAMPLE

This selection procedure calculates the minimum positioning time and calculates various parameters for two different conditions: when the motor alone is selected for the motion of the index table in the figure on the left, and when a geared motor is selected.

1. Inertia

The ratio of the moment of inertia of the load converted for the motor output shaft, and the rotor inertia is called the inertia ratio and is expressed with the following equation.

$$\text{Inertia ratio} = \frac{\text{total inertia}}{\text{rotor inertid} \times \text{gear ratio}^2}$$

If the inertia ratio is too large, this may affect the startup and settling times due to overshoot and undershoot during starting and stopping. For the **UPK•W** series, a maximum inertia ratio of 10 is a good guideline.
Therefore, you could select a motor alone for this device that would give you an inertia ratio under 10. For example, the **UPK5913AW2** would be appropriate, as it has an inertia ratio of 9.3, as calculated below:

$$\text{Inertia ratio} = \frac{203\ (\text{oz-in}^2)}{21.9\ (\text{oz-in}^2) \times 1} = 9.3$$

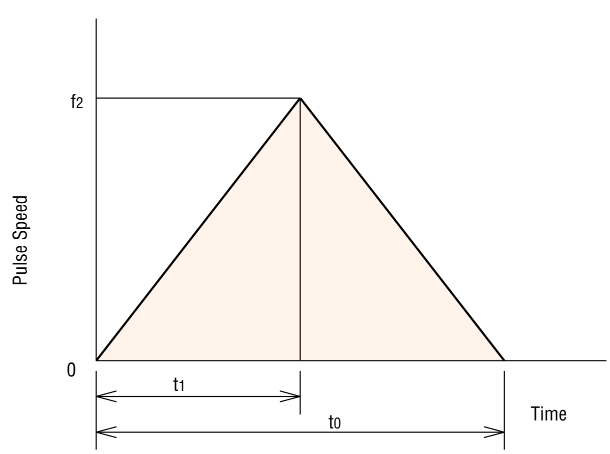
However, you could also select a smaller motor with a gearhead attached, which would also give you an inertia ratio under 10. For example, the **UPK564AW-T7.2** would be appropriate, as it has an inertia ratio of 4.1, as calculated below:

$$\text{Inertia ratio} = \frac{203\ (\text{oz-in}^2)}{21.9\ (\text{oz-in}^2) \times 7.22} = 4.1$$

Below, we calculate various parameters for both types.

2. Positioning time

We will compare the minimum positioning time using a motor alone and using a geared type. The drive pattern is a triangularwave drive, like that shown in the figure, and the acceleration/deceleration rate is 20 ms/kHz.



If the pulse velocity is f2, the positioning time t1, the operation pulse count A, and the acceleration rate Tr, then the following equation holds.

$$Tr = \frac{T_1\ (ms)}{f_2\ (kHz)} = 20\ (ms/kHz) \qquad (1)$$

$$A = t_1 \times f_2\ (pulses) \qquad (2)$$

$$t_0 = 2 \times t_1\ (ms) \qquad (3)$$

From Equations (1) and (2),

$$t_1 = \sqrt{20 \times A}\ (ms) \qquad (4)$$

●For motor alone:

Half step of 0.36˚/step and operation pulse count A = 45/0.36 = 125.
From Equation (4), t_1 = 50 milliseconds. Therefore, the positioning time t_0 = 100 ms.

●For geared motor:

Half step of 0.1˚/step and operation pulse count A = 45/0.1 = 450. Therefore, the positioning time t_0 = 190 ms.

■ SELECTION RESULTS

The table below summarizes the results of these calculations.

●Comparison of operation conditions

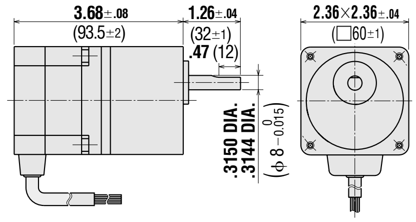
Product	**UPK5913AW2** (half step)	**UPK564AW-T7.2** (full step)
Total moment of inertia	203 oz-in² (37.1 kgcm²)	
Operation pulse count	125 pulses	450 pulses
Operation pulse speed	2500 Hz	4700 Hz
Acceleration/deceleration time	50 msec	95 msec
Positioning time	100 ms	190 ms
Required torque	369 oz-in (2.6 N·m)	1140 oz-in (8.1 N·m)
Inertia ratio	9.3	4.1
Acceleration/deceleration rate	20 ms/kHz	20 ms/kHz

■ ADVANTAGES OF GEARED TYPES

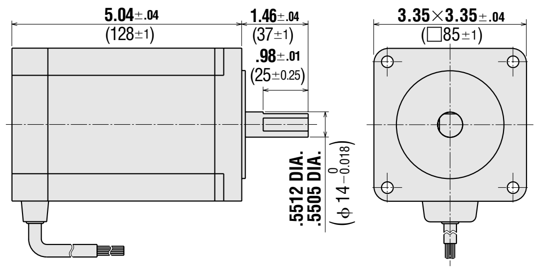
Using geared motors provides the following advantages.

●Downsizing

This does not mean just increasing the torque by using a geared type motor. Rather, whereas the inertia that the motor itself can drive is 10 times the rotor inertia, the geared type can drive this inertia multiplied by the square of the gear ratio. Therefore, for driving an inertial body such as in this case, selecting a geared type makes it possible to reduce the installation dimension from 3.35 inch (85 mm) to 2.36 inch (60mm) square and the total length from 5.04 inch (128 mm) to 3.68 inch (93.5 mm).



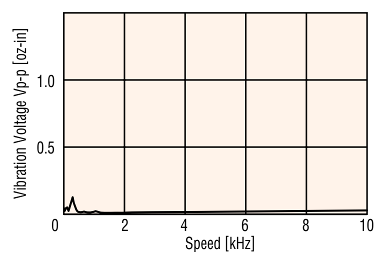
UPK564AW-T7.2 Dimensions



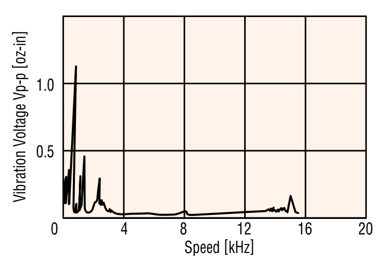
UPK5913AW2 Dimensions

●Reduced Vibration

Vibration can be reduced for the following reasons:
① The vibration characteristic itself is reduced.
② Through speed reduction, the low-speed region at which the motor vibrates can be avoided.
③ Because the motor is smaller, its own vibration is reduced.



UPK564AW-T7.2 Vibration data



UPK5913AW2 Vibration data

●Positioning time

Because this comparison uses an inertia structure that can be driven by the motor itself, the advantages of geared motors for acceleration were not obvious. However, the larger the inertia body, the more the geared motor reduces the acceleration time.

●Positioning angle

For a five-phase stepping motor alone, since the basic step angle is 0.72°, 30° and 60° positioning was not possible. However, since 7.2 : 1, 36 : 1, and other gear ratios are available for geared motors, 30° and 60° positioning is possible. This time, to compare a motor alone and a geared motor under the same conditions, 45° positioning was used because it can be used by both types of motors.

Selecting a Stepping Motor

This section describes certain items that must be calculated to find the optimum stepping motor for a particular application. This section shows the selection procedure and gives examples.

SELECTION PROCEDURE

1. Determining the drive mechanism component
Determine the mechanism and required specifications. First, determine certain features of the design, such as mechanism, rough dimensions, distances moved, and positioning period.

↓

2. Calculate the required resolution
Find the resolution the motor requires. From the required resolution, determine whether a motor only or a geared motor is to be used.

↓

3. Determine the operating pattern
Determine the operating pattern that fulfills the required specifications. Find the acceleration (deceleration) period and operating pulse speed in order to calculate the acceleration torque.

↓

4. Calculate the required torque
Calculate load torque. Calculate acceleration torque. Calculate required torque. Calculate the load torque and acceleration torque and find the required torque demanded by the motor.

↓

5. Select the motor
Make a provisional selection of a motor based on required torque. Determine the motor to be used from the speed-torque characteristics. Select a motor whose speed-torque characteristics satisfy the requirement.

↓

6. Check the selected motor
Confirm the acceleration/deceleration rate and inertia ratio. Check the acceleration/deceleration rate and inertia ratio in order to determine the suitability of the selection.

↓

Selection complete

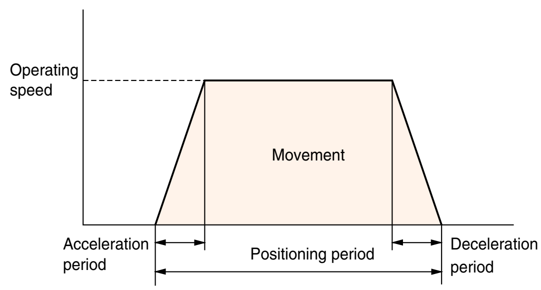
Oriental Motor also provides selection services and will run calculations to check a selection. Use the Selection Request Form at the end of the catalog.
For technical questions about selection calculations, contact your nearest Oriental Motor office. Engineers are available to answer your questions.

■ APPROACHES TO SELECTION CALCULATIONS

This section describes in detail the key concerns in the selection procedure: the determination of the operating pattern, the calculation of the required torque and the confirmation of the selected motor.

1. *Determining the Operating Pattern*

The required changes in the movement of the drive mechanism are translated into motor movement, creating an operating pattern as shown in the figure below. Motor selection is based on the operating pattern.



Operating Pattern

(1) Finding the number of operating pulses A [pulses]

The number of operating pulses is expressed as the number of pulse signals that adds up to the angle that the motor must move to get the work from point A to point B.

$$\text{Operating pulses A [Pulses]} = \frac{\text{(Distance per movement)}}{\text{(Distance per motor rotation)}} \times \text{(No. of pulses required for 1 motor rotation)}$$

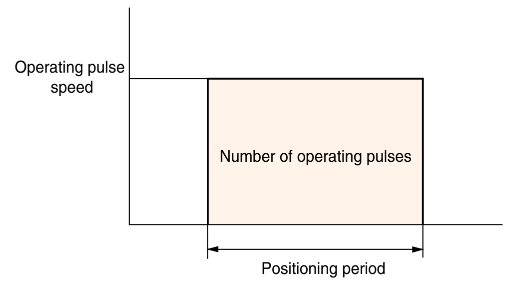
$$= \frac{l}{l\text{rev}} \times \frac{360°}{\theta s} \qquad \theta s : \text{Step angle}$$

(2) Determining the operating pulse speed f_2 [Hz]

The operating pulse speed is the pulse speed required to rotate the motor the required number of operating pulses during the positioning period. The operating pulse speed can be found from the number of operating pulses, the positioning period and the acceleration (deceleration) period.

To move objects in a short period of time, a fast motor rotation speed (pulse speed) is required. To accelerate up to that speed in a short period of time requires a large force. That force is the acceleration torque, which is described later.
The reason that a high horsepower sports car can accelerate quickly is that it produces a large acceleration torque. Conversely, if the acceleration period is long, a car can be powered with lower horsepower. In other words, the length of time for accelerating a given object with a motor (instead of the car's horsepower) is related to the size of the acceleration torque.

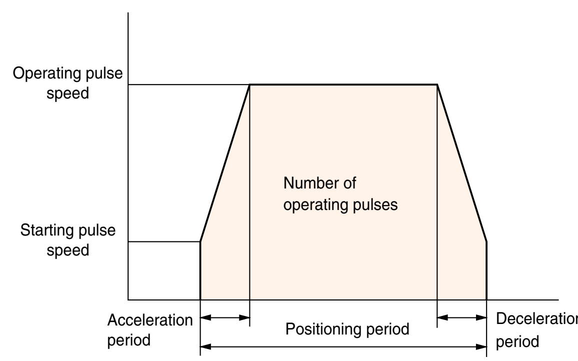
①For start-stop operation
Start-stop is a method of operation in which the operating pulse speed of a motor being used in a low-speed region is suddenly increased without an acceleration period. It is found by the following equation. Since rapid changes in speed are required, the acceleration torque is very large.



$$\text{Operating pulse speed } f_2 \text{ [Hz]} = \frac{\text{Number of operating pulses [pulses]}}{\text{Positioning period [sec]}}$$

$$= \frac{A}{t_0}$$

② For acceleration/deceleration operation
Acceleration/deceleration is a method of operation in which the operating pulses of a motor being used in a medium- or high-speed region are gradually changed. It is found by the equation below. Usually, the acceleration (deceleration) period (t_1) is set as a proportion of acceleration torque at roughly 25% of the respective positioning periods. For gentle speed changes, the acceleration torque can be kept lower than in start-stop operations.



$$\text{Operating pulse speed } f_2 = \frac{\text{Number of operating pulses [pulses]} - \text{Starting pulse speed [Hz]} \times \text{Acceleration (deceleration) period [sec]}}{\text{Positioning period [sec]} - \text{Acceleration (deceleration) period [sec]}}$$

$$= \frac{A - f_1 \cdot t_1}{t_0 - t_1}$$

2. Calculating the Required Torque T_M [oz-in]

Calculate the required torque from the operating pattern by the following procedure.

(1) Calculate the load torque T_L [oz-in]

Load torque is the frictional resistance produced by the parts of the drive mechanism that come into contact with each other. It is the torque constantly required when the motor is operating. Load torque varies greatly with the type of drive mechanism and the mass of the work. See page B-28 for methods of finding the load torque for different drive mechanisms.

(2) Calculate the acceleration torque Ta [oz-in]

Acceleration torque is the torque only required in acceleration and deceleration operation of the motor. Find the acceleration torque using the equations below depending on what slope is used for acceleration (deceleration) of the drive mechanism's total inertia.
See page B-29 for formulas that can be used to calculate the total inertia of the drive mechanism section.

For start-stop operation

$$\text{Acceleration torque } T_a\ [\text{oz-in}] = \frac{\text{Inertia of rotor } [\text{oz-in}^2] + \text{Total inertia } [\text{oz-in}^2]}{\text{Weight acceleration } [\text{in./sec}^2]} \times \frac{\pi \times \text{Step angle } [°] \times (\text{Operating pulse speed})^2\ [\text{Hz}]}{180° \times \text{coefficient}}$$

$$= \frac{J_0 + J_L}{g} \times \frac{\pi \cdot \theta s \cdot f_2^2}{180 \cdot \mathbf{n}}$$

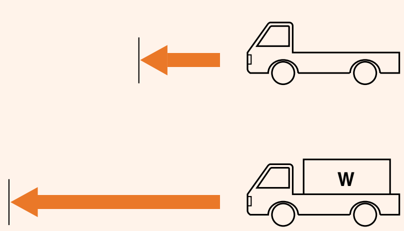
For acceleration/deceleration operation

$$\text{Acceleration torque } T_a\ [\text{oz-in}] = \frac{\text{Inertia of rotor } [\text{oz-in}^2] + \text{Total inertia } [\text{oz-in}^2]}{\text{Gravitational acceleration } [\text{in./sec}^2]} \times \frac{\pi \times \text{Step angle } [°]}{180°} \times \frac{(\text{Operating pulse speed})\ [\text{Hz}] - (\text{Starting pulse speed})\ [\text{Hz}]}{\text{Acceleration (deceleration) period [sec]}}$$

$$= \frac{J_0 + J_L}{g} \times \frac{\pi \cdot \theta s}{180} \times \frac{f_2 - f_1}{t_1}$$

Inertia

Inertia is the size of the force requied to keep a moving object in steady motion. Objects always have inertia.



When a truck running at a given speed is suddenly stopped, a truck that is carrying a load will take longer to stop than an unloaded truck (assuming the same braking force) because the loaded truck has greater inertia that tends to keep it in motion. To change the operating status of an object with a large inertia (starts, stops, acceleration, deceleration), a large external force is needed. This external force is called the acceleration torque. The size of the acceleration torque required to move an object is related to the size of the inertia and the size of the acceleration found from the operating speed and acceleration period.

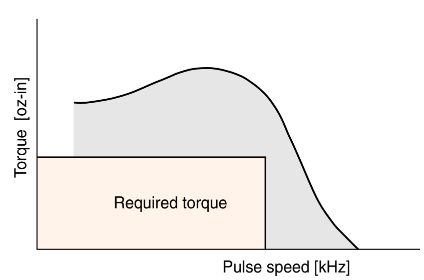
(3) Calculate the required torque T_M [kgcm]

The required torque is the sum of the load torque required by the stepping motor and the acceleration torque.
The motor requires the most torque during the acceleration portion of the operating pattern. During acceleration, load torque from the frictional resistance and acceleration torque from the inertia are both required. To avoid problems when incorporating a stepping motor into a device, an additional safety factor needs to be estimated. The required torque can be found from the following equation.

$$\text{Required torque } T_M\ [\text{oz-in}] = \left(\text{Load torque [oz-in]} + \text{Acceleration torque [oz-in]}\right) \times \text{Safety factor}$$

$$= (T_L + T_a) \times 2$$

Select a motor for which this required torque falls within the pull-out torque of the speed-torque characteristics.



3. Checking the Motor Selection

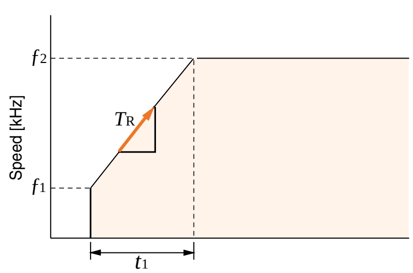
Check the following two items for the selected motor in order to ensure an optimal selection.

(1) Check the acceleration/deceleration rate

Most controllers, when set for acceleration or deceleration, adjust the pulse speed in steps. For that reason, operation may sometimes not be possible, even though it can be calculated. The table below shows reference data for a stepping motor combined with an Oriental Motor **SG** series controller. Calculate the acceleration/deceleration rate from the following equation and check that the value is at or above the acceleration/deceleration rate in the table.

$$\text{Acceleration/deceleration rate } T_R\,[\text{sec}\;\;/\text{kHz}] = \frac{\text{Acceleration (deceleration) period [sec]}}{\text{Operating pulse speed [kHz]} - \text{Starting pulse speed [kHz]}} = \frac{t_1}{f_2 - f_1}$$

* Calculate the pulse speed in full-step equivalents.



Acceleration Rate (Reference Values)

Motor Frame Size inch (mm)	Applicable Products	Acceleration/deceleration rate T_R [sec/kHz]
1.1 (28) 1.65 (42) 2.22 (56.4) 2.36 (60)	**UPK•W** Series **NanoStep**™ **UFK•W** **UPK** Series **PMU** Series **NanoStep**™ **RFK** **CSK** Series **PMC** Series **UMK** Series	20 minimum
3.35 (85) 3.54 (90)	**UPK•W** Series **NanoStep**™ **UFK•W** **UPK** Series **CSK** Series **UMK** Series	30 minimum

If below the minimum value, change the operating pattern's acceleration (deceleration) period.

(2) Check the inertia ratio

Large inertia ratios (inertial loads) cause large overshooting and undershooting during starts and stops, which can affect startup times and settling times. Depending on the conditions of usage, operation may be impossible. Calculate the inertia ratio with the following equation and check that the values found are at or below the inertia ratios shown in the table.

$$\text{Inertia ratio} = \frac{\text{Total inertia of the machine [oz-in}^2]}{\text{Inertia of the motor's rotor [oz-in}^2]} = \frac{J_L}{J_0}$$

Inertia Ratio (Reference values)

Applicable Products	Inertia ratio
UPK•W Series **NanoStep**™ **UFK•W** **UPK** Series **NanoStep**™ **RFK** **CSK** Series **UMK** Series	10 maximum
PMU Series **PMC** Series	5 maximum

When these values are exceeded, we recommend a geared motor. Using a geared motor can increase the drivable inertial load.

$$\text{Inertia ratio} = \frac{\text{Total inertia of the machine [oz-in}^2]}{\text{Inertia of the motor's rotor [oz-in}^2]} \times (\text{Gear ratio})^2 = \frac{J_L}{J_0 \cdot i^2}$$

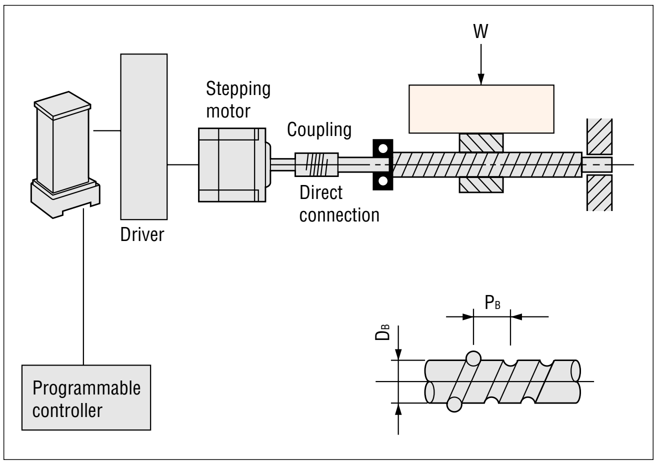
Note:
These values are estimates of common conditions.
Your application conditions may vary. If in doubt, contact your local Oriental Motor office for assistance.

■ SELECTION EXAMPLES

In these examples, 5-phase stepping motors and drivers in the **UPK•W** series are selected for a ball screw system, an index table system and a belt drive.

Example 1: Ball Screw

1. Determine the Drive Mechanism



Total mass of the table and work:	W = 90 lb (40 kg)
Frictional coefficient of sliding surfaces:	μ = 0.05
Ball screw efficiency:	η = 0.9
Internal frictional coefficient of pilot pressure nut:	μ_0 = 0.3
Ball screw shaft diameter:	D_B = 0.6 inch (1.5cm)
Total length of ball screw:	L_B = 23.6 inch (60cm)
Material of ball screw:	Iron [density ρ = 4.64 oz/in^3 (7.9×10^{-3} kg/cm^3)]
Pitch of ball screw:	P_B = 0.6 inch (1.5cm)
Resolution (feed per pulse):	Δl = 0.001 inch (0.03mm)./step
Feed:	l = 7.01 inch (180mm)
Positioning period:	t_0 = 0.8

2. Calculating the Required Resolution

(see basic equations on page B-26)

$$\text{Required resolution } \theta_s = \frac{360° \times \text{Demanded resolution } (\Delta l)}{\text{Ball screw pitch } (P_B)} = \frac{360 \times 0.03}{15} = 0.72°$$

A 5-phase stepping motor and driver in the **UPK•W** series can be connected directly to the application.

3. Determine the Operating Pulse

(see basic equations on pages B-17, 26 and 27)

(1) Finding the number of operating pulses (A) [pulses]

$$\text{Operating pulses (A)} = \frac{\text{Feed per unit } (l)}{\text{Ball screw pitch } (P_B)} \times \frac{360°}{\text{Step angle } (\theta_s)}$$

$$= \frac{180}{15} \times \frac{360}{0.72} = 6000 \text{ pulses}$$

(2) Determining the acceleration (deceleration) period t_1 [sec]

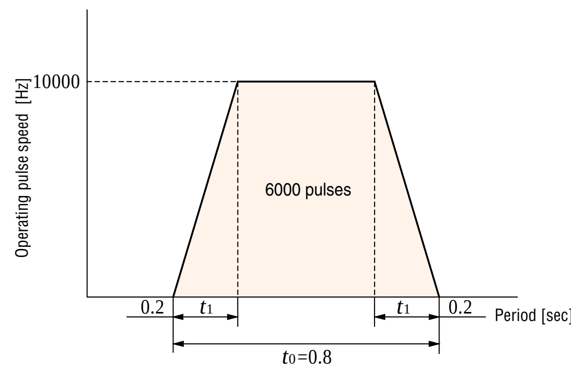
An acceleration (deceleration) period of 25% of the positioning period is appropriate.

$$\text{Acceleration (deceleration) period } (t_1) = 0.8 \times 0.25 = 0.2 \text{ sec}$$

(3) Determining the operating pulse speed f_2 [Hz]

$$\text{Operating pulse speed } f_2 = \frac{\text{Number of operating pulses [A]} - \text{Starting pulses speed } [f_1] \times \text{Acceleration (deceleration) period } [t_1]}{\text{Positioning period } [t_0] - \text{Acceleration (deceleration) period } [t_1]}$$

$$= \frac{6000 - 0}{0.8 - 0.2} = 10000 \text{ Hz}$$



4. Calculating the Required Torque T_M [oz-in] (See page B-18)

(1) Calculate the load torque T_L [oz-in]

(See page B-28 for basic equations)

$$\text{Load in shaft direction } F = F_A + W(\sin\alpha + \mu\cos\alpha)$$
$$= 0 + 90(\sin 0 + 0.05\cos 0)$$
$$= 4.5 \text{ lb.}$$

$$\text{Pilot pressure load } F_0 = \frac{F}{3} = \frac{4.5}{3} = 1.5 \text{ lb.}$$

$$\text{Load torque } T_L = \frac{F \cdot P_B}{2\pi\eta} + \frac{\mu_0 \cdot F_0 \cdot P_B}{2\pi}$$
$$= \frac{4.5 \times 0.6}{2\pi \times 0.9} + \frac{0.3 \times 1.5 \times 0.6}{2\pi}$$
$$= 0.52 \text{ lb.}$$

(2) Calculate the acceleration torque Ta [oz-in]

Calculate the total inertial moment J_L [oz-in^2]

(See page B-29 for basic equations)

$$\text{Inertia of ball screw } J_B = \frac{\pi}{32}\rho \cdot L_B \cdot D_B^4$$
$$= \frac{\pi}{32} \times 4.64 \times 23 \times 0.6^4$$
$$= 1.36 \text{ oz-in}^2$$

$$\text{Inertia of table and work } J_T = W\left(\frac{P_B}{2\pi}\right)^2$$
$$= 90 \times \left(\frac{0.6}{2\pi}\right)^2$$
$$= 0.83 \text{ lb-in}^2$$

$$\text{Total inertia } J_L = J_B + J_T$$
$$= 1.36 + 13.1 = 14.5 \text{ oz-in}^2$$

Calculate the acceleration torque T_a [oz-in]

$$\text{Acceleration torque } T_a = \frac{J_0 + J_L}{g} \times \frac{\pi \cdot \theta_s}{180^\circ} \times \frac{f_2 - f_1}{t_1}$$

$$= \frac{J_0 + 14.5}{386} \times \frac{\pi \times 0.72}{180} \times \frac{10000 - 0}{0.2}$$

$$\fallingdotseq 1.63 J_0 + 23.6 \text{ oz-in}$$

(3) Calculate the required Torque T_M [oz-in]

$$\text{Required torque } T_M \text{ [oz-in]} = (T_L + T_a) \times 2$$

$$= \{8.3 + (1.63 J_0 + 23.6)\} \times 2$$

$$= 3.26 J_0 + 63.8 \text{ oz-in}$$

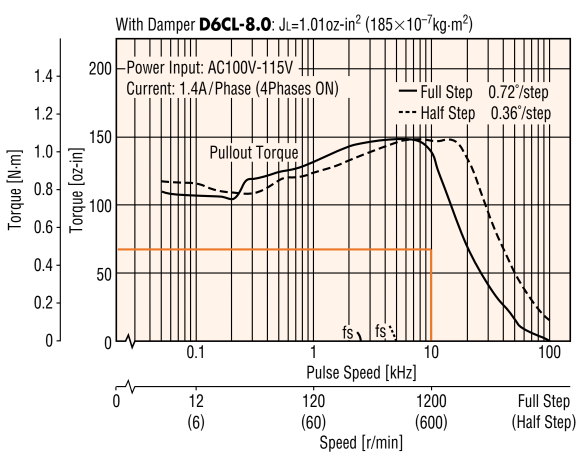
5. Selecting a Motor

(1) Provisional motor selection

Model	Rotor Inertia [oz-in^2]	Required torque [oz-in]	Required torque [N·m]
UPK566BW2	1.53	68.8	0.48
UPK569BW2	3.06	73.8	0.52

(2) Determine the motor from the speed-torque characteristics

UPK566BW2



Select a motor for which the required torque falls within the pull-out torque of the speed-torque characteristics.

6. Checking the Motor Selection (See Page B-19)

(1) Check the acceleration/deceleration rate

$$\text{Acceleration/deceleration rate } T_R = \frac{\text{Acceleration (deceleration) period}}{\text{Operating pulse speed } (f_2) - \text{Starting pulses speed } (f_1)}$$

$$= \frac{0.2 \text{ [sec]}}{10 \text{ [kHz]} - 0} = 0.79 \text{ in-sec/kHz}$$

T_R = 0.79 in-sec/kHz, so the motor can be used.

(2) Check the inertia ratio

$$\text{Inertia ratio} = \frac{\text{Total inertial } (J_L)}{\text{Inertial moment of the motor's rotor } (J_0)}$$

$$= \frac{14.5}{1.53}$$

$$= 9.5 \leqq 10$$

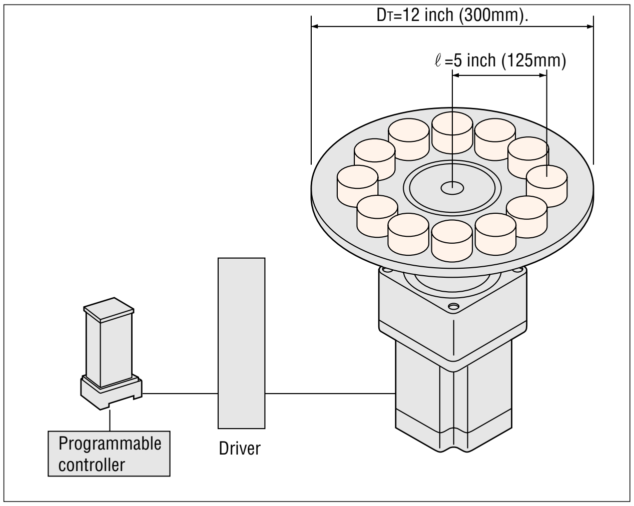
Therefore, the motor can be used

Based on the above, the selection for this application is the standard **UPK•W** series motor, **UPK566BW2**.

Example 2: Index Table

Geared stepping motors are suitable for systems with high inertia, such as index tables.

1. Determine the Drive Mechanism



Diameter of index table:	D_T =11.8 inch (300mm)
Index table thickness:	L_T =0.39 inch (10mm)
Diameter of load:	D_W =1.18 inch (30mm)
Thickness of load:	L_W =1.57 inch (40mm)
Material of table and load:	Iron [density ρ =4.64 oz/in^3 (7.9×10^{-3} kg /cm^3)]
Number of load:	12 (one every 30˚)
Distance from center of index table to center of load:	l =4.92 inch (125mm)
Positioning angle:	θ =30˚
Resolution:	$\Delta\theta$ =0.04˚
Positioning period:	t_0 =0.4

2. Calculating the Required Resolution

$$\text{Required resolution } \theta_s = 0.04^\circ$$
$$= 0.02 \times 2 \text{ Pulses}$$

The **PN** geared **UPK•W** Series (gear ratio 36:1) can be used.

3. Determine the Operating Pulse

(see basic equations on pages B-17, 26 and 27)

(1) Finding the number of operating pulses (A) [pulses]

$$\text{Operating pulses (A)} = \frac{\text{Angle rotated per movement } (\theta)}{\text{Gear output shaft step angle } (\theta_s)}$$
$$= \frac{30^\circ}{0.02^\circ} = 1500 \text{ Pulses}$$

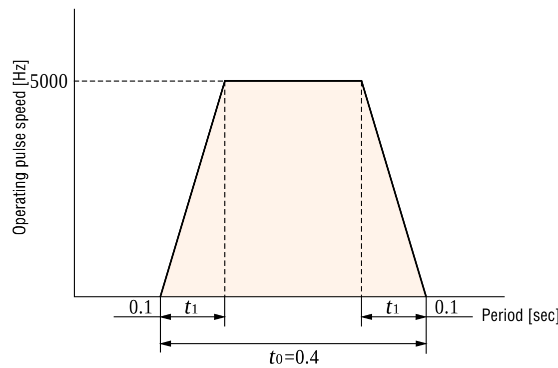
(2) Determining the acceleration (deceleration) period t_1 [sec]

An acceleration (deceleration) period of 25% of the positioning period is appropriate.

Acceleration (declaration) period (t_1) = 0.4 × 0.25 = 0.1 sec

(3) Determining the operating pulse speed f_2 [Hz]

$$\text{Operating pulse speed } f_2 = \frac{\text{Number of operating pulses [A]} - \text{Starting pulses speed } [f_1] \times \text{Acceleration (deceleration) period } [t_1]}{\text{Positioning period } [t_0] - \text{Acceleration (deceleration) period } [t_1]}$$
$$= \frac{1500 - 0}{0.4 - 0.1} = 5000 \text{ Hz}$$



4. Calculating the Required Torque T_M [oz-in] (See page B-18)

(1) Calculate the load torque T_L [oz-in]

(See page B-28 for basic equations)

Frictional load is omitted because it is negligible. Load torque is considered 0.

(2) Calculate the acceleration torque Ta [oz-in]

Calculate the total inertia J_L [oz-in^2]

(See page B-29 for basic equations)

$$\text{Inertia of table } J_T = \frac{\pi}{32} \cdot \rho \cdot L_T \cdot D_T^4$$
$$= \frac{\pi}{32} \times 4.64 \times 0.39 \times 11.8^4$$
$$= 3778 \text{ oz-in}^2$$

$$\text{Inertia of work } J_W = \frac{\pi}{32} \cdot \rho \cdot L_W \cdot D_W^4$$
$$= \frac{\pi}{32} \times 4.64 \times 1.57 \times 1.18^4$$
$$= 1.5 \text{ oz-in}^2$$

The center of the load is not on the center of rotation, so since there are 12 pieces of work:

$$J = J_0 + W \cdot l^2$$
$$= 1.5 + (\pi \times 0.6^2 \times 1.57 \times 4.64) \times 4.92^2$$
$$\fallingdotseq 211 \text{ oz-in}^2$$

Basic Equations

$$J_W = 211 \times 12$$
$$= 2532 \text{ oz-in}^2$$

$$\text{Total inertia } J_L = J_T + J_W$$
$$= 3778 + 2532$$
$$= 6310 \text{ oz-in}^2$$

Calculate the acceleration torque *Ta* [oz-in]

$$\text{Acceleration torque } T_a = \frac{J_0 \cdot i^2 + J_L}{g} \times \frac{\pi \cdot \theta_s}{180°} \times \frac{f_2 - f_1}{t_1}$$
$$= \frac{J_0 \times 36^2 + 6310}{386} \times \frac{\pi \times 0.02}{180°} \times \frac{5000 - 0}{0.1}$$
$$= 58.6 J_0 + 285 \text{ oz-in}^2$$

(3) Calculate the required Torque T_M [oz-in]

$$\text{Required torque } T_M \text{ [oz-in]} = (T_L + T_a) \times 2$$
$$= \{0 + (58.6 J_0 + 285)\} \times 2$$
$$= 117.2 J_0 + 570 \text{ [oz-in}^2\text{]}$$

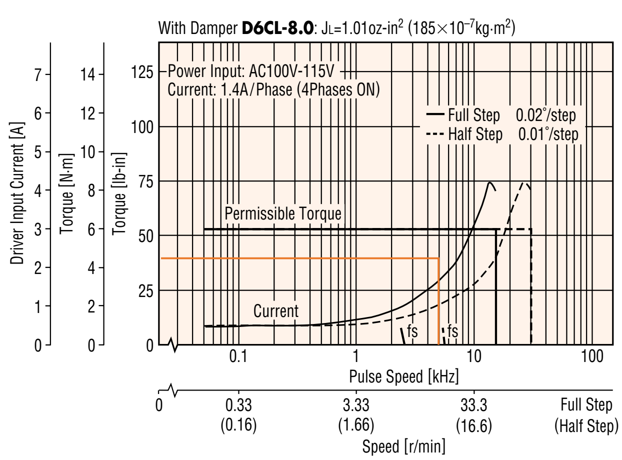
5. Selecting a Motor

(1) Provisional motor selection

Model	Rotor Inertia [oz-in^2]	Required torque	
		oz-in	[N·m]
UPK564BW-N36	0.96	682.5	4.82

(2) Determine the motor from the speed-torque characteristics

UPK564BW-N36



Select a motor for which the required torque falls within the pull-out torque of the speed-torque characteristics.

6. Checking the Motor Selection (See Page B-19)

(1) Check the acceleration/deceleration rate

$$\text{Acceleration/deceleration rate } T_R = \frac{\text{Acceleration (deceleration) period}}{\text{Operating pulse speed } (f_2) - \text{Starting pulses speed } (f_1)}$$
$$= \frac{0.1 \text{ [sec]}}{5 \text{ [kHz]} - 0}$$
$$= 20 \text{ msec/kH3}$$

T_R = 20 msec/kH3, so the motor can be used.

(2) Check the inertia ratio

$$\text{Inertia ratio} = \frac{\text{Total inertia } (J_L)}{\text{Inertia of the motor's rotor } (J_0) \times i^2}$$
$$= \frac{6308}{0.96 \times 36^2}$$
$$= 5.1 \leqq 10$$

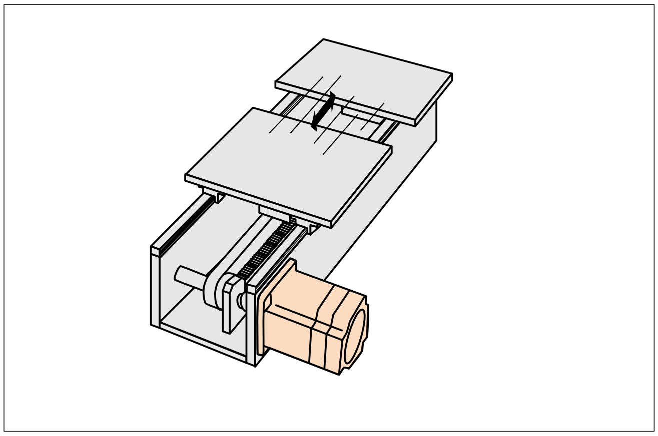
Therefore, the motor can be used

Based on the above, the selection for this application is the **PN** geared **UPK•W** series motor, **UPK564BW-N36**.

Example 3: Belt Drive

In this example, the αSTEP **AS** series is selected for a belt drive system.

1. Determine the Drive Mechanism



Total mass of the table and work:	W = 3 lb. (48 oz)
External force:	F_A = 0 lb.
Frictional coefficient of sliding surfaces:	μ = 0.05
Table tilt:	α = 0°
Belt and pulley efficiency:	η = 0.8
Pulley diameter:	D_P = 1.57 inch (40mm)
Length of pulley:	L_P = 0.78 inch (20mm)
Material of belt drive:	Aluminun [density ρ = 1.65 oz/in^3 28×10^{-3} kg/cm^3)]
Resolution (feed per pulse):	Δl = 0.005 inch (0.127mm)/step
Feed:	l = 50inch (1270mm)
Positioning period:	t_0 = 0.7 s
Acceleration and deceleration period:	t_0 = 0.2 s

2. Calculating the Required Resolution

(see basic equations on page B-26)

$$\text{Required resolution } \theta s = \frac{360° \times \text{Demanded resolution}(\Delta l)}{\text{Pulley diameter (DP)} \times \pi}$$

$$= \frac{360 \times 0.005}{1.6 \times \pi} = 0.36°$$

3. Determine the Operating Pulse

(see basic equations on pages B-17, 26 and 27)

(1) Finding the number of operating pulses (A) [pulses]

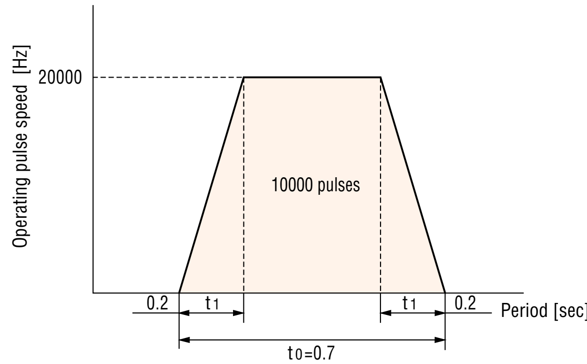
$$\text{Operating pulses (A)} = \frac{\text{Feed per unit } (l)}{\text{Pulley diameter (DP)} \times \pi} \times \frac{360°}{\text{Step angle}(\theta_s)}$$

$$= \frac{50}{1.6 \times \pi} \times \frac{360}{0.36} = 10000 \text{ pulses}$$

(2) Determining the operating pulse speed f_2 [Hz]

$$\text{Operating pulse speed } f_2 = \frac{\text{Number of operating pulses [A]} - \text{Starting pulses speed } [f_1] \times \text{Acceleration (deceleration) period } [t_1]}{\text{Positioning period } [t_0] - \text{Acceleration (deceleration) period } [t_1]}$$

$$= \frac{10000 - 0}{0.7 - 0.2} = 20000 \text{ Hz}$$



(3) Determining the operating speed N [r/min]

$$\text{Operating Speed} = f_2 \times \frac{\theta_s}{360} \times 60$$

$$2000 \times \frac{0.36}{360} \times 60 = 1200\text{r/min}$$

4. Calculating the Required Torque T_M

(See page B-18)

(1) Calculate the load torque T_L [oz-in]

(See page B-26 for basic equations)

$$\text{Load in shaft direction } F = F_A + W(\sin\alpha - \mu\cos\alpha)$$

$$= 0 + 3(\sin 0 - 0.05\cos 0)$$

$$= 0.15 \text{ lb. } (2.4 \text{ oz})$$

$$\text{Load torque } T_L = \frac{F \cdot D_P}{2\eta}$$

$$= \frac{2.4 \times 1.6}{2 \times 0.8}$$

$$= 2.4 \text{ oz-in}$$

(2) Calculate the acceleration torque T_a [oz-in]

Calculate the total inertial moment J_L [oz-in^2]

(See page B-29 for basic equations)

$$\text{Inertia of belt drive } J_P = \frac{\pi}{32} \cdot \rho \cdot L_P \cdot D_P^4$$

$$= \frac{\pi}{32} \times 1.65 \times 0.8 \times 1.6^4$$

$$= 0.85 \text{ oz-in}^2$$

Inertia of table and work $J_T = W\left(\frac{D_P}{2}\right)^2$

$= 48 \times \left(\frac{1.6}{2}\right)^2$

$= 30.72$ oz-in^2

Total inertia $J_L = J_P \times 2 + J_T$

$= 0.85 \times 2 + 30.72 = 32.42$ oz–in^2

Calculate the acceleration torque *Ta* [oz-in]

Acceleration torque $T_a = \frac{J_0 + J_L}{g} \times \frac{\pi \cdot \theta_s}{180°} \times \frac{f_2 - f_1}{t_1}$

$= \frac{J_0 + 32.42}{386} \times \frac{\pi \times 0.36}{180°} \times \frac{20000 - 0}{0.2}$

$= 1.63 J_0 + 52.8$ oz-in

(3) Calculate the required Torque T_M [oz-in]

Required torque T_M [oz-in] $= (T_L + T_a) \times 1.5$

$= \{2.4 + (1.63 J_0 + 52.8)\} \times 1.5$

$= 2.45 J_0 + 82.8$ oz-in^2

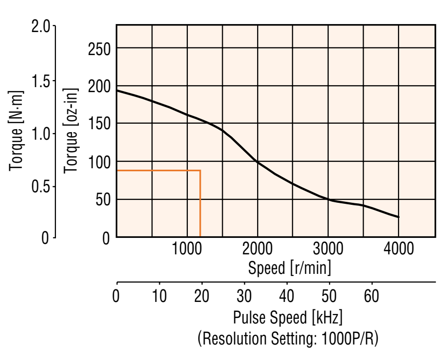
5. Selecting a Motor

(1) Provisional motor selection

Model	Rotor Inertia oz-in^2 (kgcm^2)	Required torque	
		oz-in	N·m
AS66AA	2.22 (0.405)	88.2	0.64

(2) Determine the motor from the speed-torque characteristics

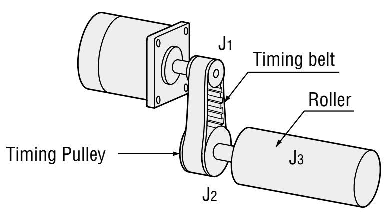
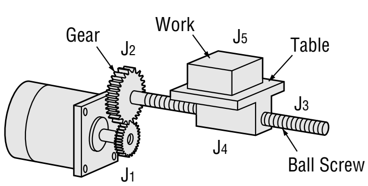
AS66AA



Select a motor for which the required torque falls within the pull-out torque of the speed-torque characteristics.

■ BASIC EQUATIONS

1. Basic calculation formulas

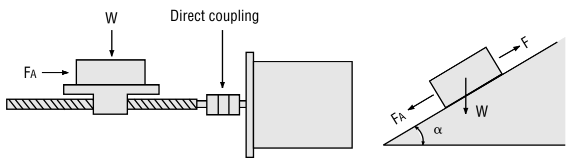
Drive mechanism	Resolution (minimum feed) step angle	Movement and number of pulses
Basic	$\Delta l = \Delta l_0 \dfrac{\theta s}{i}$ [inch/step] .... ①	$l = A \cdot \Delta l$ [inch] .... ⑥
Belt drive 	$\Delta l = \dfrac{\pi \cdot D}{360^\circ} \cdot \dfrac{\theta s}{i}$ [inch/step] .... ② $D = \dfrac{360^\circ \cdot \Delta l \cdot i}{\pi \ \theta s}$ [inch] .... ③	$l = v \cdot t$ [inch] .... ⑦ $N = \dfrac{l}{\Delta l}$ [pulse] .... ⑧
Ball screw 	$\Delta l = \dfrac{P_B}{360^\circ} \cdot \dfrac{\theta s}{i}$ [inch/step] .... ④ $P_B = \dfrac{360^\circ \cdot \Delta l \cdot i}{\theta s}$ [inch/rev] .... ⑤	$N = f \cdot t$ [pulse] .... ⑨

Δl = Resolution (minimum feed) [inch/step]
Δl_0 = Unit of movement at final step [inch/°]
θs = Step angle [°/step]
i = Gear ratio
P_B = Lead pitch [inch/rev]
v = Movement speed [inch/sec]
f = Pulse speed [Hz]
D = Final pulley diameter [inch]
N = Number of pulses [pulse]
l = Movement [inch]
t = Positioning period [sec]

Speed and pulse speed	Final rotation speed and pulse speed	Total inertia seen from the motor
$\nu = \Delta l \cdot f$ [inch/sec] ⑩ $f = \dfrac{\nu}{\Delta l}$ [Hz] ⑪	$N = \dfrac{\theta s \cdot f}{6 \cdot i}$ [r/min] ⑯ $f = \dfrac{6 \cdot i \cdot N}{\theta s}$ [Hz] ⑰	J_L : Total inertia in motor shaft equivalents J_n : Inertia of parts
$\nu = \dfrac{\pi D}{360^\circ} \cdot \dfrac{\theta s}{i} \cdot f$ [inch/sec] ⑫ $f = \dfrac{360^\circ \cdot i \cdot \nu}{\pi D \cdot \theta s}$ [Hz] ⑬		$J_L = J_1 + \dfrac{J_2 + J_3}{i^2}$ [oz-in²] ⑱
$\nu = \dfrac{P_B}{360^\circ} \cdot \dfrac{\theta s}{i} \cdot f$ [inch/sec] ⑭ $f = \dfrac{360^\circ \cdot i \cdot \nu}{P_B \cdot \theta s}$ [Hz] ⑮		$J_L = J_1 + \dfrac{J_2 + J_3 + J_4 + J_5}{i^2}$ [oz-in²] ⑲

2. Formulas for load torque

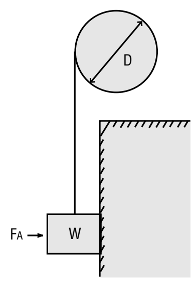
Ball screw



$$T_L = \left(\frac{FP_B}{2\pi\eta} + \frac{\mu_0 F_0 P_B}{2\pi}\right) \times \frac{1}{i} \text{ [oz-in]} \quad ⑳$$

$$F = F_A + W(\sin\alpha + \mu\cos\alpha) \text{ [lb.]} \quad ㉑$$

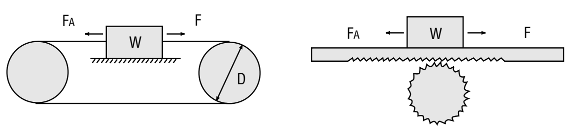
Pulley



$$T_L = \frac{\mu F_A + W}{2\pi} \cdot \frac{\pi D}{i}$$

$$= \frac{(\mu F_A + W)D}{2i} \text{ [oz-in]} \quad ㉒$$

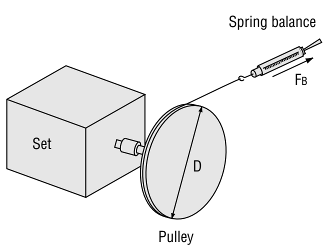
Wire belt drive, rack and pinion drive



$$T_L = \frac{F}{2\pi\eta}\,\frac{\pi D}{i} = \frac{FD}{2\eta i} \text{ [oz-in]} \quad ㉓$$

$$F = F_A + W(\sin\alpha + \mu\cos\alpha) \text{ [lb.]} \quad ㉔$$

By actual measurement

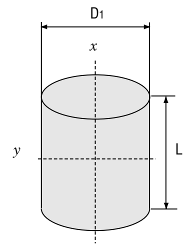


$$T_L = \frac{F_B D}{2} \text{ [oz-in]} \quad ㉕$$

F = Weight in shaft direction [lb.]
F_0 = Pilot pressure weight [lb.] (≒1/3 F)
μ_0 = Internal friction coefficient of pilot pressure nut (0.1 to 0.3)
η = Efficiency (0.85 to 0.95)
i = Gear ratio
P_B = Ball screw pitch [inch/rev]
F_A = External force [lb.]
F_B = Force when main shaft begins to rotate [lb.]
W = Total mass of work and table [lb.]
μ = Frictional coefficient of sliding surfaces (0.05)
α = Angle of inclination [˚]
D = Final pulley diameter [inch]

3. Formulas for calculating inertial moments

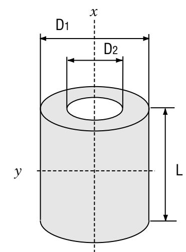
Inertia of a cylinder



$$J_x = \frac{1}{8} W D_1^2 = \frac{\pi}{32} \rho L D_1^4 \ \text{[oz-in}^2\text{]} \quad \text{㉖}$$

$$J_y = \frac{1}{4} W \left(\frac{D_1^2}{4} + \frac{L^2}{3} \right) \ \text{[oz-in}^2\text{]} \quad \text{㉗}$$

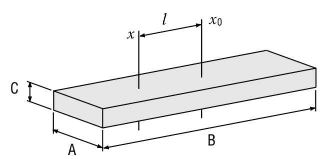
Inertia of a hollow cylinder



$$J_x = \frac{1}{8} W \left(D_1^2 + D_2^2 \right) = \frac{\pi}{32} \rho L \left(D_1^4 - D_2^4 \right) \ \text{[oz-in}^2\text{]} \quad \text{㉘}$$

$$J_y = \frac{1}{4} W \left(\frac{D_1^2 + D_2^2}{4} + \frac{L^2}{3} \right) \ \text{[oz-in}^2\text{]} \quad \text{㉙}$$

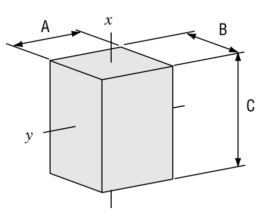
Inertia for offcentered axis of rotation



l = Distance between x and x_0 axes [in.]

$$J_x = J_{x0} + W l^2 = \frac{1}{12} W \left(A^2 + B^2 + 12 l^2 \right) \text{[oz-in}^2\text{]} \quad \text{㉚}$$

Inertia of a rectangular pillar



$$J_x = \frac{1}{12} W \left(A^2 + B^2 \right) = \frac{1}{12} \rho A B C \left(A^2 + B^2 \right) \text{[oz-in}^2\text{]} \quad \text{㉛}$$

$$J_y = \frac{1}{12} W \left(B^2 + C^2 \right) = \frac{1}{12} \rho A B C \left(B^2 + C^2 \right) \text{[oz-in}^2\text{]} \quad \text{㉜}$$

Inertia of an object in linear motion

$$J = W \left(\frac{\nu}{\omega} \right)^2 = W \left(\frac{A}{2\pi} \right)^2 \text{[oz-in}^2\text{]} \quad \text{㉝}$$

A = Unit of movement [inch/rev]

Density	
Iron	$\rho = 4.64$ [oz/in³]
Aluminum	$\rho = 1.65$ [oz/in³]
Bronze	$\rho = 5$ [oz/in³]
Nylon	$\rho = 0.65$ [oz/in³]

J_x = Inertia on x axis [oz-in²]
J_y = Inertia on y axis [oz-in²]
J_{x0} = Inertia on x_0 axis [oz-in²]
W = Weight [lb.]
D_1 = External diameter [inch]
D_2 = Internal diameter [inch]
ρ = Density [oz/in³]
L = Length [inch]

Q&A Stepping Motors

Q1. At how high a temperature can stepping motors be used ?

A1. The permissible temperature for the coils is 266˚F (130˚C), since the insulation of the motor is Class B. The motor can be used if the motor surface temperature is 212˚F (100˚C) or less. Try to use the motor at the lowest temperature possible and mount it to a metal plate that is a good heat conductor, since heat does affect the life of the motor's ball bearings. Type A insulation 221˚F (105˚C) is a UL/CSA certification condition.
When applying for UL/CSA certification as a set, use with a motor case surface temperature no higher than 167˚F (75˚C).

Q2. Are there ways to keep the motor temperature down?

A2. There are several ways:
① Adjust the operating current (a margin of torque must be present, since lowering the current decreases the torque). This suppresses heat generation during operation.
② Use the driver functions. The "All Windings Off" function and the "Automatic Current Cutback" function suppress heat generation when the motor is stopped.
③ Install the motor on a plate with good heat conductivity.
④ Install a fan to cool the motor.

Q3. Is there any way to suppress vibration during operation?

A3. There are several ways:
① Use a clean damper. Vibration is absorbed by internal inert bodies and silicon gel.
② Adjust the operating current. Vibration can be suppressed by decreasing the torque.
③ Use microstep drive. Use the **NanoStep** **UFK•W** or **RFK** 5-phase stepping motor and microstep driver to suppress vibration.
④ Use geared motors. Geared motors suppress of vibration.

Q4. Why does the motor move a little when the power is turned on?

A4. The rotor of the motor has 50 teeth and there are 50 locations where it can stop with stability. Depending on where the rotor has stopped before the power is turned on, it may move up to ±3.6˚.

Q5. Is it alright to machine the motor shaft?

A5. When the shaft is machined, some impact may be felt by the ball bearings within the motor. Therefore, machining is not recommended. On a similar note, do not disassemble the motor. (Disassembling the motor will not only dramatically lower performance, it can also cause it to cease functioning if foreign matter gets inside.)

Q6. How long can the motor's lead wires be extended?

A6. They can be extended to approximately 66 feet (20m) when a stepping motor is being used. Extending them further may lower the torque's high-speed characteristics. To extend the leads, use lead wire that has the cross-sectional area for the current values shown in the table below.

Rated Current of Motor	Lead Wire Cross-Section	AWG No.
1 A or less	3.1×10^{-4} inch^2 (0.2mm^2)	24
1 to 3 A or less	7.8×10^{-4} inch^2 (0.5mm^2)	20
3 to 5 A or less	19.4×10^{-4} inch^2 (1.25mm^2)	16

Q7. How far apart can the driver and controller (pulse generator) be?

A7. Oriental Motor drivers use photocouplers that are resistant to the effects of external noise, so they may be separated up to approximately 6.6 feet (2m). When wiring is involved, always use either twisted pair wire (0.008 inch^2 [0.2mm^2] or larger) or shielded wire for connections and keep it as far away as possible from noise sources.

Q8. What is AWG22 motor lead wire?

A8. AWG stands for "American Wiring Gage." The AWG standards stipulate the core construction and conductor cross-sectional area of lead wires as AWG numbers. The larger the AWG number, the smaller the cross-sectional area. The AWG number is shown on the motor's external appearance drawing.

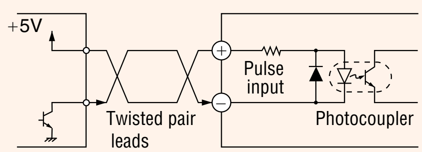
AWG No.	Conductor Cross-Section
26	1.6×10^{-4} inch^2 (0.1mm^2)
24	3.1×10^{-4} inch^2 (0.2mm^2)
22	4.7×10^{-4} inch^2 (0.3mm^2)
20	7.8×10^{-4} inch^2 (0.5mm^2)

Glossary

■ **Photocoupler**
Photocouplers are electronic components that relay electrical signals as light. They are electronically insulated on the input and output sides, so noise has little effect on them.

■ **Open Collector**
Open collectors are a type of signal circuit output. They can be connected even when the power supply voltage differs on the input and output sides.

■ **Twisted Pair Leads**
Twisted pair leads entwine two leads as shown in the figure below. They are used to reduce noise in signal wires. Because the leads face in opposite directions from each other and carry the same current, noise from the ambient surroundings is canceled out and noise effects reduced.



■ **Emitter Common**
This refers to a signal output in which the emitters of multiple open collector outputs are shared.

■ **Overhung Load (See page B-36)**
The load on the motor shaft in the vertical direction.

■ **Angle-Torque Characteristics (See page B-10)**

■ **Current Down**
This function automatically lowers the current supplied to the motor to a pre-set value after stopping. It serves to reduce the heat generated by the motor while stopped.

■ **Inertial Load**
This refers to the total inertia of the drive mechanism that works on the motor's output shaft.

■ **Inertial Load-Auto Starting Frequency Characteristics (See Page B-9)**

■ **Resonance**
This refers to the phenomenon in which vibration becomes larger at specific speeds. For 2-phase stepping motors, the area between 100-200 Hz is a resonance area; 5-phase stepping motors, have lower levels of resonance in their resonance area.

■ **Permissible Torque**
The permissible torque is the maximum torque that can be applied to the gear's output shaft.

■ **Controller**
The controller is a circuit that outputs pulse signals for controlling the motor.

■ **Maximum Permissible Speed**
This refers to the maximum speed (in r/min) of the gear output shaft.

■ **Maximum Response Frequency (See Page B-8)**

■ **Maximum Starting Frequency (See Page B-8)**

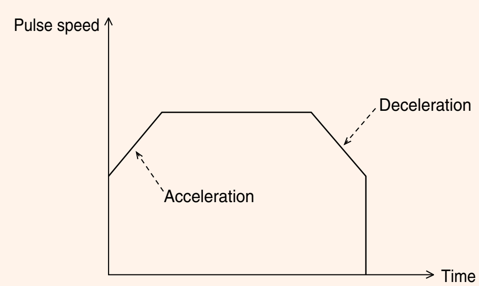
■ **CW, CCW**
The direction of motor rotation is expressed as CW (clockwise) or CCW (counterclockwise). These directions are as seen from the output shaft.

■ **Vibration Characteristics (See Page B-9)**

■ **Step Angle**
The step angle is the angular distance (in degrees) that the motor moves at the input of one pulse from the driver. It differs depending on the motor structure and excitation system.

■ **Thrust Load (See Page B-36)**
The thrust load is the load in the direction of the motor axis.

■ **Acceleration, Deceleration**
During motor startup and stopping, the pulse speed can be changed gradually.



■ **Stopping Accuracy (See Page B-10)**

■ **Insulation Class**
The insulation class is a UL grade that rates the heat resistance of the motor coils. Stepping motors use Grade B coils, so their permissible coil temperature is 266˚F (130˚C). The surface of the motor will be about 212˚F (100˚C) when this temperature is reached at the coils.
Type A insulation 221˚F (105˚C) is a UL/CSA certification condition.
When applying for UL/CSA certification as a set, use with a motor case surface temperature no higher than 167˚F (75˚C).

■ **Insulation Resistance**
A value reflecting the extent of the insulation properties.

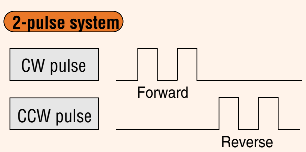
■ **Withstand Voltage**
The maximum voltage that the insulation can hold.

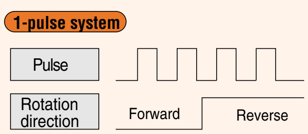
■ **Speed-Torque Characteristics (See Page B-8)**
This is a chart showing changes in torque caused by speed. It is needed when selecting a motor.

■ **Loss of Synchronism**
Stepping motors are synchronized by pulses. They can lose their synchronization when speed changes rapidly or an overload occurs. Loss of synchronism is the term for losing synchronization with the input pulse.

■ **2-Pulse Input**
This system uses two types of pulses, a CW pulse and a CCW pulse.

■ **1-Pulse Input**
This system uses a pulse signal and a rotational direction (CW/CCW) signal.





■ **Rated Current**
The rated current is determined by motor temperature rise. It is the current value that can flow to the motor coils continuously when stopped.

■ **Constant-Current Driver (See Page B-11)**
A control circuit that sends current to the motor at a constant current level.

■ **Driver**
A control circuit that sends current to the stepping motor coils.

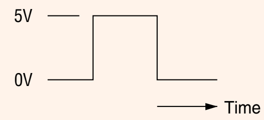
■ **Backlash**
This refers to the play in the gear output shaft when the motor shaft is fixed. It affects positioning precision when positioning occurs from both directions. The term originally referred to looseness between gear teeth.

■ **No Backlash**
The absolute absence of backlash.

■ **Low Backlash**
Backlash is minimized. This can be achieved using special mechanisms.

■ **Half Step**
Refers to half of the basic step. It is used to increase resolution and promote smoother motion.

■ **Pulse Signals**
Pulse signals are rectangular electric signals as shown below.



■ **Number of Pulses**
The number of pulse signals.

■ **Pulse Speed**
The number of pulses input in one second.

■ **Full Step**
The step angle determined by the motor structure. The basic step angle is 0.72˚ for a 5-phase stepping motor.

■ **Pullout Torque (See Page B-8)**

■ **Negative Logic Circuit**
An input circuit that engages when an L level voltage is applied.

■ **Frictional Load**
The total frictional torque of the drive mechanism that works on the motor output shaft.

■ **Excitation**
Refers to sending current to the motor coils.

■ **Maximum Holding Torque (See Page B-8)**
This refers to the holding power of the stepping motor at rest (when excited at rated current).

■ **Excitation Sequence**
The excitation sequence is the order in which current is sent to the motor coils. It varies with the type of motor and excitation system.

■ **Excitation Timing Output**
This is a signal that indicates that the excitation sequence is initialized; it is output every 7.2˚. For 5-phase stepping motors, it is output every 10 pulses (for full step) or 20 pulses (for half step).

■ **Inertia of Rotor**
The value that indicates the size of the inertia of the rotor itself.

■ **1-Step Response (See Page B-9)**

Before Using a Stepping Motor

■ PRECAUTIONS

1. Precautions for Installation

- Do not use in a place where there is flammable and/or corrosive gas.
- Products for use only in equipment of protection class I. (**UPK•W**, **UFK•W**)
- The motor and the driver must be properly grounded.
- When installing the motor into your equipment, ensure that the motor lead wires are fixed and do not move. In addition, do not apply any pressure to these lead wires.
- Installation must be performed by a qualified installer.
- Ensure the driver's terminal cover is attached before using.
- For the five-phase and two-phase 24 VDC stepping motor and driver package and stepping motors alone, use a DC power supply with reinforced insulation for the primary side. Otherwise, there is a danger of electrical shock.

2. Precautions for Operation

- Always turn off the power to the driver before conducting checks or performing work on the product.
- The surface temperature of motors and drivers can exceed 158˚F (70˚C) (depending on operation conditions). In case this product is accessible during operation, please attach the following warning label so that it is clearly visible.

Warning Label

- Do not touch these terminals while the power is ON. Contact could cause electric shock or fire.

3. Precautions for Troubleshooting

- Refer to the troubleshooting section of the operation manual if the motor or driver is not functioning properly. If the problem cannot be corrected, contact your nearest Oriental Motor office. Do not disassemble the motor or driver.
- The driver incorporates double-pole/neutral fusing for the power input. If the driver POWER LED is OFF, it is possible that only the neutral fuse is tripped. High voltage supplied on the hot side may cause electric shock. Turn the power OFF immediately and request service.

■ SELECTING A POWER SUPPLY TRANSFORMER

When using a stepping motor, the power supply will almost always be either single-phase 115 VAC or single-phase 220-240 VAC. When using a motor in single-phase 220-240 VAC, use a power supply transformer to bring the voltage down to single-phase 115 VAC. Transformer capacitance is given by the following equation.

Transformer Capacitance [VA] = Driver Power Voltage [V] × Driver Input Current [A]

The driver input current of the stepping motor can be found in the specifications or in the speed-torque characteristics.

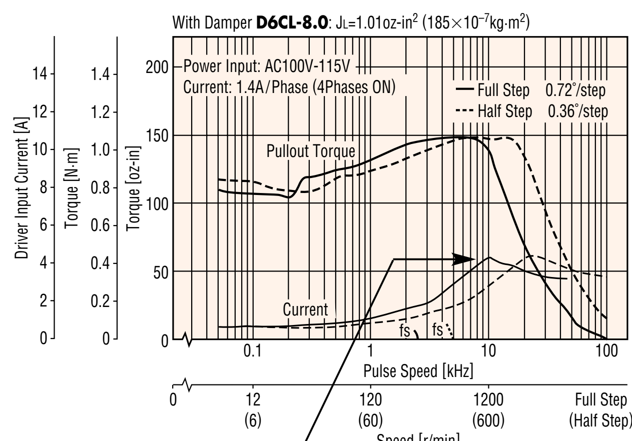
1. Specifications

Motor & Driver				
	Single shaft	**UPK564AW2**	**UPK566AW2**	**UPK569AW2**
	Double shaft	**UPK564BW2**	**UPK566BW2**	**UPK569BW2**
Holding torque	oz-in N·m	58.3 0.42	115 0.83	230 1.66
Rotor Inertia	oz-in² kg·m²	0.96 175×10⁻⁷	1.53 280×10⁻⁷	3.07 560×10⁻⁷
Rated current	A/phase	1.4		
Basic step angle		0.72˚		
Insulation class		Class B [266˚F (130˚C)]		
Power source		Single-phase 115 V ±15%, 60 Hz, 4.8 A		

Gives the maximum value for input current.

2. Speed vs. Torque Characteristics

UPK566BW2



Gives the changes in input current caused by speed

■ DETECTING THE HOME POSITION

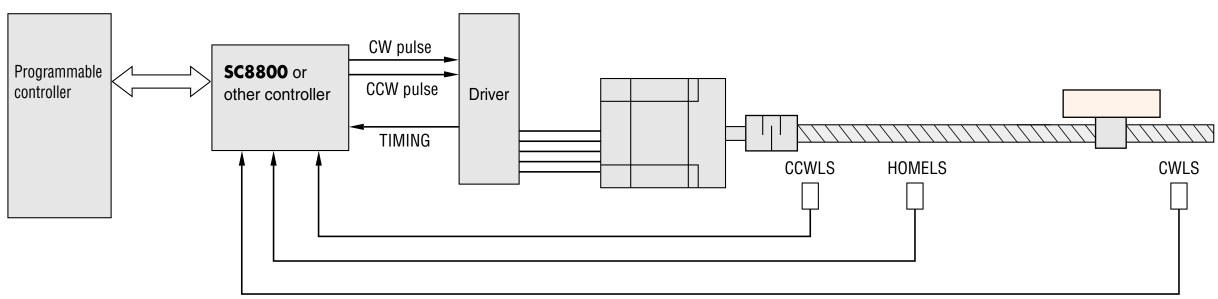
1. Home Position Detection

Stepping motor movements can be controlled accurately using pulses. During startup or power outages, however, the motor uses the position it was at when the power was turned on as its origin. When there is a discrepancy between the logical origin and the origin when the power is turned on, it is meaningless to have the motor accurately follow instructions. For this reason, it is imperative to have the motor return to the origin when the power is turned on. The mechanical origin in this case is called the "home," and finding it is called home detection (origin return).

Home detection requires the following three sensors, for which photo-microsensors are usually used.

1. HOMELS (home sensor)
2. CWLS (overrun prevention sensor)
3. CCWLS (overrun prevention sensor)

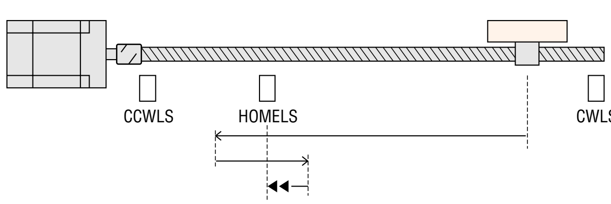
The figure below shows the handling of sensors and signals required to detect the home position with a single-axis ball screw.

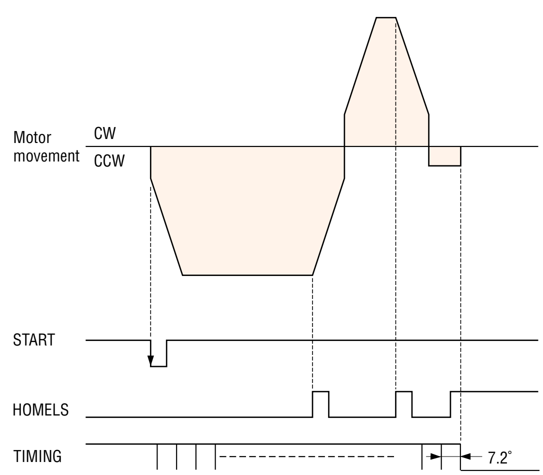


2. Home Detection Methods

The home is where the following two signals are simultaneously on.

1. HOMELS
2. TIMING (a signal output every time the motor rotates 7.2˚)





To prevent the effects of mechanical backlash, always search for the home position in one direction. The point where the TIMING signal is output while HOMELS is detected is where the motor stops.

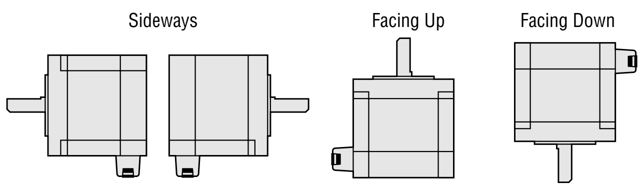
Oriental Motor's **SC** series of controllers for stepping motors contain built-in origin detection programs. Users can find the origin simply by inputting a start signal.

NOTES FOR USE

Installation of Stepping Motor

1. Direction of mounting

There are no restrictions on the direction of mounting, but motors are usually mounted sideways. They can also be mounted facing up or down.
Regardless of how the motor is mounted, take care not to apply an overhung load or thrust load on the shaft.

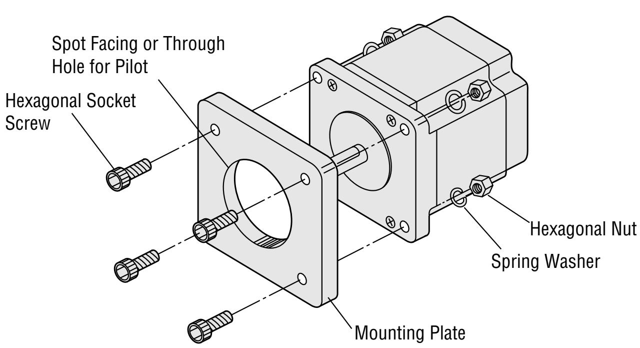


Note:
1. Do not disassemble the motors.
2. Do not apply any type of shock to the motor shaft.

2. Mounting

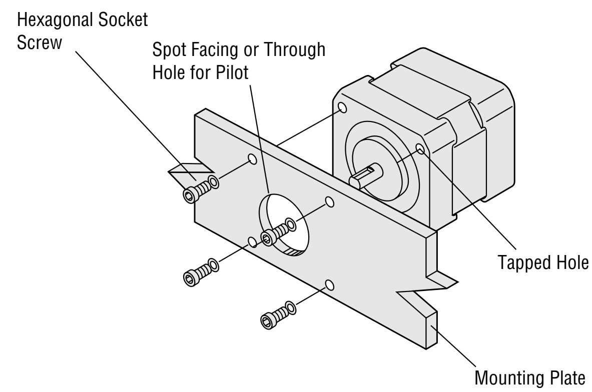
Mount the motor tightly against a metal surface with good thermal conductivity such as steel or aluminum.
Secure the motor firmly using a hexagonal socket screw, nut, etc.
Refer to the table below to determine the proper thickness of the mounting plate.

●Through Hole Type



Applicable Motor	Model	Minimum Thickness of the Mounting Plate
αSTEP	**AS66A□, ASC66AK**	0.2 inch (5mm)
	AS98A□	0.31 inch (8mm)
5 Phase	**UPK56□W2, UPK56□JW, UPK56□, UFK56□W, RFK56□, CSK56□**	0.2 inch (5mm)
	UPK59□W2, UPK59□JW, UPK59□, UFK59□W, CSK59□	0.31 inch (8mm)
2 Phase	**UMK26□, UMK26□M, CSK26□, CSK26□M, PK26□**	0.16 inch (4mm)
	UMK29□, PK29□	0.31 inch (8mm)
Low Speed Synchronous	**SMK237**	0.16 inch (4mm)
	SMK5100, SMK5160	0.31 inch (8mm)

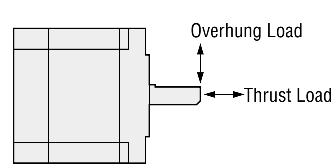
●Tapped Hole Type



Applicable Motor	Model	Minimum Thickness of the Mounting Plate
αSTEP	**ASC46AK**	0.16 inch (4mm)
5 Phase	**PMU3□, PMC3□**	0.08 inch (2mm)
	UPK54□W2, UPK54□JW, UPK54□, UFK54□W, RFK54□, CSK54□, PMU33MG, PMC33MG, CSK543TG	0.16 inch (4mm)
	UPK543W-T, UPK564W-T, UPK564JW-T, CSK564TG	0.2 inch (5mm)
	UPK56□W-N, UPK56□JW-N, UFK56□W-N	0.31 inch (8mm)
2 Phase	**UMK24□, UMK24□M, CSK24□, CSK24□M, PK24□, PK24□M**	0.12 inch (3mm)
	CSK243SG	0.16 inch (4mm)
	CSK264SG	0.2 inch (5mm)
Low Speed Synchronous	**SMK014**	0.2 inch (5mm)

3. Permissible Overhung Load and Permissible Thrust Load

Overhung loads and thrust loads that exceed the permitted values shorten bearing life and cause fatigue by repeated load on the output shaft. Keep overhung loads to within the values of the tables below. Keep thrust loads below the weight of the motor used. (For geared types, see the motor's specifications.)



Permissible Overhung Load

● αSTEP

[lb. (kg)]

Distance from shaft end inch (mm)	0	0.2 (5)	0.39 (10)	0.59 (15)	0.79 (20)
ASC46AK	4.4 (2)	5.51 (2.5)	7.49 (3.4)	11.4 (5.2)	—
AS66A□, ASC66AK	13.8 (6.3)	16.5 (7.5)	20.9 (9.5)	28.6 (13)	41.8 (19)
AS98A□	57.3 (26)	63.9 (29)	74.9 (34)	85.9 (39)	105 (48)

●5-Phase Stepping Motor

[lb. (kg)]

Distance from shaft end inch (mm)	0	0.2 (5)	0.39 (10)	0.59 (15)	0.79 (20)
PMU3□, PMC3□	5.51 (2.5)	7.49 (3.4)	11.4 (5.2)	—	—
UPK54□W, CSK54□	4.4 (2)	5.51 (2.5)	7.49 (3.4)	11.4 (5.2)	—
UPK56□W2, UPK56□JW, UFK56□W, CSK56□	13.8 (6.3)	16.5 (7.5)	20.9 (9.5)	28.6 (13)	41.8 (19)
UPK59□W2, UPK59□JW, UFK59□W, CSK59□	57.3 (26)	63.9 (29)	74.9 (34)	85.9 (39)	105 (48)
PMU33MG, PMC33MG	2.02 (0.92)	2.51 (1.14)	3.3 (1.5)	4.82 (2.19)	—
UPK543W-T, CSK543TG	2.2 (1)	3.08 (1.4)	4.4 (2)	6.61 (3)	—
UPK564W-T, UPK564JW-T, UFK564W-T, CSK564TG	15.4 (7)	17.6 (8)	22 (10)	26.4 (12)	33 (15)
UPK596W-T, UPK596JW-T, UFK596W-T	48.5 (22)	55.1 (25)	66.1 (30)	77.1 (35)	88.1 (40)
UPK566W-N5, UPK566JW-N5, UFK566W-N5	44 (20)	48.5 (22)	55.1 (25)	61.7 (28)	70.5 (32)
UPK566W-N7.2, UPK566JW-N7.2, UFK566W-N7.2, UPK566W-N10, UPK566JW-N10, UFK566W-N10	55.1 (25)	59.5 (27)	66.1 (30)	74.9 (34)	85.9 (39)
UPK566W-N25, UPK566JW-N25, UFK566W-N25, UPK566W-N36, UPK566JW-N36, UFK566W-N36, UPK566W-N50, UPK566JW-N50, UFK566W-N50	72.7 (33)	79.3 (36)	88.1 (40)	99.2 (45)	114 (52)

●2-Phase Stepping Motor

[lb. (kg)]

Distance from shaft end inch (mm)		0	0.2 (5)	0.39 (10)	0.59 (15)	0.79 (20)
UMK24□, UMK24□M, CSK24□, CSK24□M, PK24□, PK24□M		4.41 (2)	5.51 (2.5)	7.49 (3.4)	11.4 (5.2)	—
UMK26□, UMK26□M, CSK26□, CSK26□M, PK26□, PK26□M		11.9 (5.4)	14.7 (6.7)	19.6 (8.9)	28.6 (13)	—
UMK29□, PK29□		57.3 (26)	63.9 (29)	74.9 (34)	85.9 (39)	105 (48)
CSK243SG, PK243SG		2.2 (1)	3.3 (1.5)	4.4 (2)	6.61 (3)	—
CSK264SG PK264SG	**3.6 ~ 10**	6.61 (3)	8.81 (4)	11 (5)	13.2 (6)	15.4 (7)
	18, 36	17.6 (8)	22 (10)	26.4 (12)	30.8 (14)	35.2 (16)
PK296SG		48.5 (22)	55.1 (25)	66.1 (30)	77.1 (35)	88.1 (40)

●Low Speed Synchronous Motor

[lb. (kg)]

Distance from shaft end inch (mm)	0	0.2 (5)	0.39 (10)	0.59 (15)	0.79 (20)
SMK014	4.41 (2)	5.51 (2.5)	7.49 (3.4)	11.4 (5.2)	—
SMK237	11.9 (5.4)	14.7 (6.7)	19.6 (8.9)	28.6 (13)	—
SMK5100, SMK5160	57.3 (26)	63.9 (29)	74.9 (34)	85.9 (39)	105 (48)

4. Recommended Location for Motor Installation

Install motors in a location that meets the following conditions.

- Indoors
- Ambient temperature +14°F (−10°C) ~ +122°F (+50°C) (non-freezing)
- Ambient humidity less than 85% (non-condensing)
- No excessive vibration or shocks
- Free from water or oil (If water or oil is liable to come in contact with the motor, install a cover.)
- Free from corrosive gas or dust
- Good ventilation and radiation

●Motor Mounts (Optional)

Five varieties of stepping motor fixtures are available. See page B-296 for details.

■ DRIVER INSTALLATION: AC Input Types

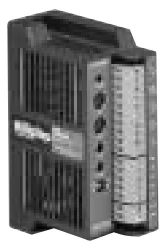
1. Installation Direction and Method

Drivers are designed to dissipate heat through natural convection (UDK5128NW2 has a built-in fan), so be sure to follow the instructions below when installing them. When installing the driver vertically in the device, use bracket A; when installing the driver parallel to the bottom, use bracket B.

(1) Models With Built-in Brackets

●Driver Model
UPK•W Series: UDK5107NW2, UDK5114NW2, UDK5128NW2
UDK5214NW
NanoStep UFK•W: DFU1514W
NanoStep RFK: DFR1507A, DFR1514A

UPK•W, UFK•W Driver



RFK Driver

(2) Installation Bracket Models

●Driver Model
αSTEP: ASD24A-A, ASD30A-A, ASD12A-C, ASD16A-C
(Only available bracket A)
UPK Series: UDK5107NA, UDK5114NA, UDK5128NA
UMK Series: UDK2109A, UDK2112A, UDK2120A
UMK2160A□
PMU Series: PMD07A

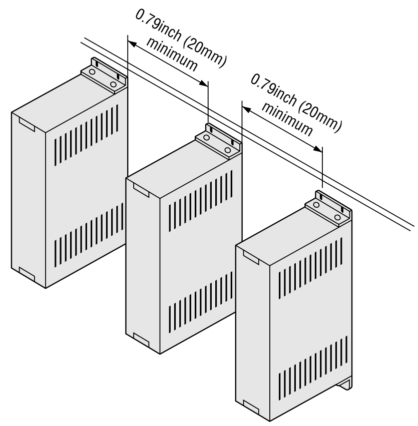
Using bracket A

Using bracket B

●Firmly install on a metal plate that has good heat conductance, such as an iron or aluminum 0.08in. (2mm) or more in thickness
●To directly install the driver itself without using the screws provided, pay particular attention to the length of the screws.

2. Using Multiple Axes

When using multiple stepping motor axes, internal temperature rises will make the drivers hotter than the ambient temperature. At least 0.8inch (20mm) must be allowed between driver units and at least 1inch (25mm) between drivers and other equipment or structures. Install a forced-air cooling fan if ambient temperatures exceed 122˚F (104˚F for some products).



3. Recommended Location for Driver Installation

Install drivers in a location that meets the following conditions.

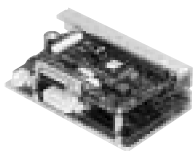
●Indoors
●Ambient temperature +32˚F (0˚C) ~ +122˚F (+50˚C) (non-freezing)
[+32˚F (0˚C) ~ +104˚F (+40˚C) for **UMK** series driver (UDK2109A, UDK2112A, UDK2120A)]
●Ambient humidity less than 85% (non-condensing)
●Free from corrosive gas or dust
●Free from water or oil
●When attaching the driver in a close space such as a control box, or somewhere close to a heat-radiating object, vent holes should be uses to prevent overheating of the drivers.
●When the driver is to be installed in a location where a source of vibration will cause the driver to vibrate as well, install a shock absorber.
●In situations where drivers are located close to a large noise source such as high frequency weldering machines or large electromagnetic switches, take steps to prevent noise interferance, eitherby inserting noise filters or connecting the driver to a separate circuit.
●Take care that pieces of conductive material (filings, pins, pieces of wireings, etc.) Do not enter the drivers.

■ DRIVER INSTALLTION: DC Input Types

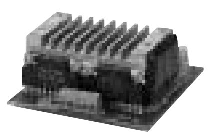
1. Mounting Direction

Install the driver in the following manner to control overheating, as much as possible.

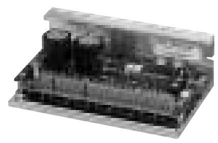
(1) Horizontal Installation



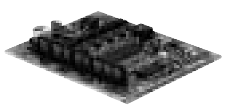
ASD18A-K
ASD36A-K



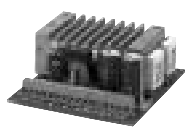
CSD5807N-T
CSD5814N-T



CSD5828N-T

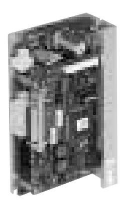


PMD03C

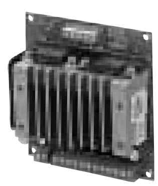


CSD2109N-T
CSD2112N-T
CSD2120N-T

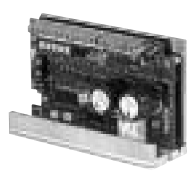
(2) Vertical Installation



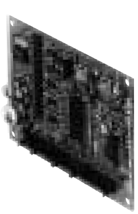
ASD18A-K
ASD36A-K



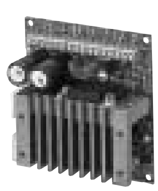
CSD5807N-T
CSD5814N-T



CSD5828N-T



PMD03C



CSD2109N-T
CSD2112N-T
CSD2120N-T

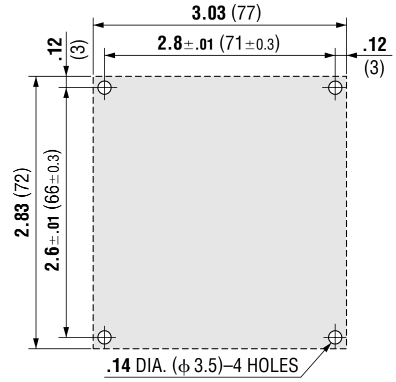
Caution:
The driver can generate a great deal of heat depending on the operating conditions. Make sure that the temperature of the heat sink does not exceed 176˚F (80˚C). [194˚F (90˚C) for CSD5808N-T]
When the temperature of the heat sink exceeds 176˚F (80˚C), forced cooling is required. Make sure that the temperature of the motor case does not exceed 212˚F (80˚C).

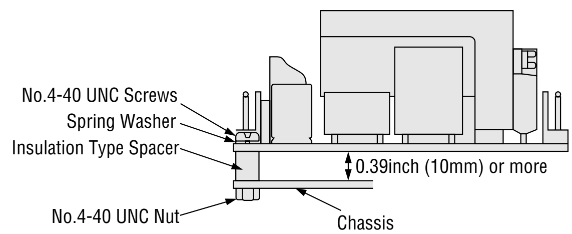
2. Securing the driver

(1) Mounting with the circuit board

●CSD5807N-T, CSD5814N-T, CSD2109N-T, CSD2112N-T, CSD2120N-T

Unit = inch (mm)

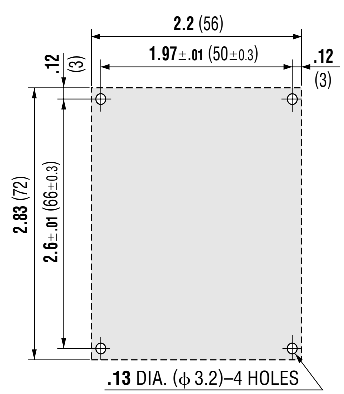


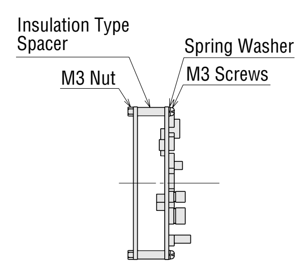


Note: Always use insulation type spacer when securing the driver to your equipment.

●PMD03C

Unit = inch (mm)



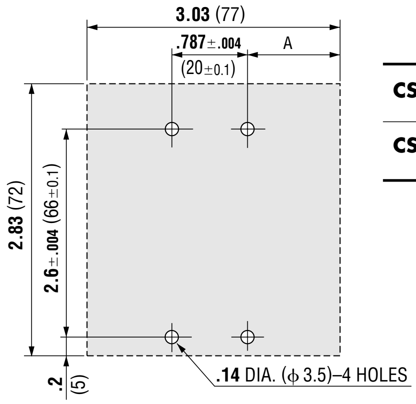


Note: Always use insulation type spacer when securing the driver to your equipment.

(2) Mounting with the heatsink

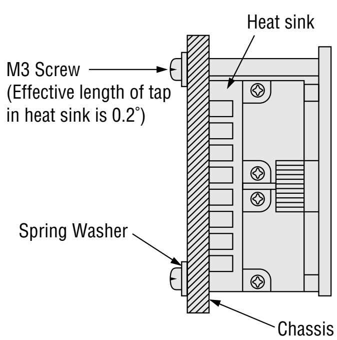
(The heat sink should always be installed to good heat conducting metal)

●CSD5807N-T, CSD5814N-T, CSD2109N-T, CSD2112N-T, CSD2120N-T



Unit = inch (mm)

	A
CSD58□□N-T	0.96 (24.4)
CSD21□□-T	1.71 (43.4)



Note : When using long screws, be sure they don't touch any components. The screw length should be less than the thickness of the chassis plus 0.2inch (5mm).

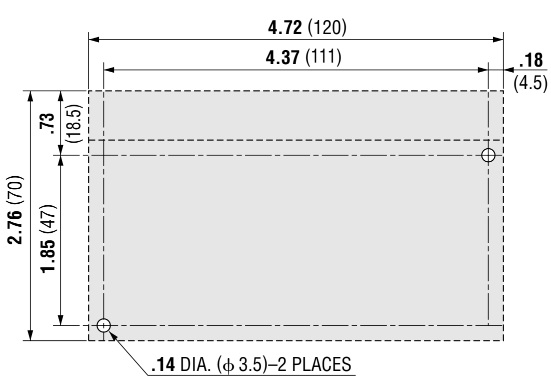
●ASD18A-K, ASD36A-K, CSD5828N-T

This driver is designed to be used screwed directly to the metal chassis (box-shaped object) in order to ensure heat radiation. Always install the driver bottom surface or side surface against the metal chassis.

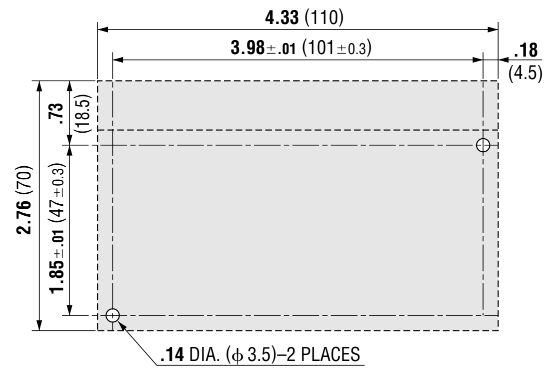
When installing at the bottom

Unit = inch (mm)

ASD18A-D, ASD36A-K



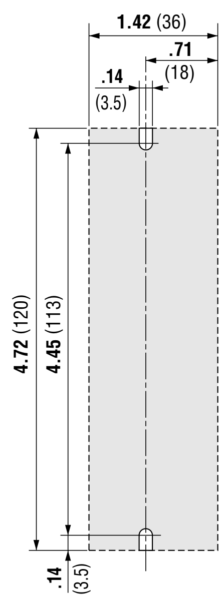
CSD5828N-T



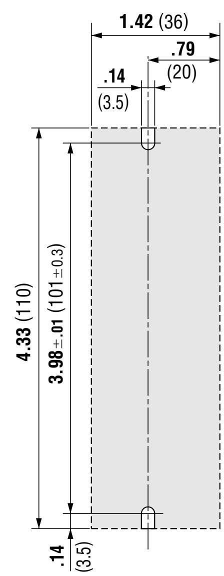
When installing at the side

Unit = inch (mm)

ASD18A-K, ASD36A-K



CSD5828N-T



Note : When using long screws, be sure they don't touch any components. The screw length should be less than the thickness of the chassis plus 0.2inch (5mm).

3. Recommended Location for Driver Installation

Install drivers in a location that meets the following conditions.

- ●Indoors
- ●Ambient temperature +32˚F (0˚C) ~ +104˚F (+40˚C) (non-freezing)
- ●Ambient humidity less than 85% (non-condensing)
- ●Free from corrosive gas or dust
- ●Free from water or oil
- ●When attaching the driver in a close space such as a control box, or somewhere close to a heat-radiating object, vent holes should be uses to prevent overheating of the drivers.
- ●In situations where drivers are located close to a large noise source such as high frequency weldering machines or large electromagnetic switches, take step to prevent noise interferance, eitherby inserting noise filters or connecting the driver to a separate circuit.

General Specifications

Item	5-phase stepping motor		2-phase stepping motor
	Package : **UPK•W**, **UPK**, **UFK•W**, **RFK**, **CSK**	Package : **PMU**, **PMC**	Package : **UMK**, **CSK** Motor : **PK**
Shaft Runout	0.002 inch (0.05mm) T.I.R at top of output shaft *1		
Perpendicularity	0.003 inch (0.075mm) T.I.R *1		
Concentrictly	0.003 inch (0.075mm) T.I.R *1		
Shaft Radial Play *2	0.001 inch (0.025mm) max. of 1.1 lb. (0.5kg)		
Shaft Axial Play *3	0.003 inch (0.075mm) max. of 2.2 lb. (1kg)		
Step Accuracy *4	±0.05 degrees	±0.08 degrees	±0.05 degrees
Insulation Resistance	100MΩ minimum under normal temeprature and humidity, when measured by a DC500V megger between the motor coils and the motor casing.		
Dielectric Strength *5	Sufficient to withstand 1.0kV, 60Hz applied between the motor coils and casing for one minute, under normal ambient temperature and humidity.		
Insulation Class	Class B [266˚F (130˚C)] *6		
Temperature Rise	144˚F (80˚C) or less as measured by the Resistance Change Method after the rated voltage is applied to the stepping motor at rest.		
Ambient Temperature Renge	+14˚F (−10˚C) ~+ 122˚F (+50˚C)		

*1 [T.I.R (Total Indicator Reading):It refers to the total dial gage reading when the measurement section is rotated 1 revolution centered on the reference axis center.
*2 [Radial Play:It refers to the displacement in shaft position in the radial direction when a 1.1lb. (0.5kg) load is applied in the radial direction to the motor shaft tip.
*3 [Axial Play:It refers to the displacement in shaft position in the axial direction when a 2.2lb. (1kg) load is applied to the motor shaft in the axial direction.
*4 [This value is for full step with no load. (The value changes with size of load.)
*5 [For motors with a motor size of 1.65inch (42mm)×1.65inch (42mm) or less, 60Hz, 0.5kV for 1minute.
*6 [UL and CSA standards recognized products are recognized as A category [221˚F (105C˚)].

Lead Wire Specifications

Type of Motor		Series	Package Model	Number of Lead Wires	Lead Wire Specifications	
					UL Style No. *1	AWG No.
5-Phase	AC Input Package	**UPK•W**	**UPK54□W, UPK543W-T**	5	–	26
			UPK56□W2, UPK56□JW, UPK59□W2, UPK59□JW, UPK564W-T, UPK564JW-T, UPK596W-T, UPK596JW-T, UPK56□W-N, UPK56□JW-N		–	22
		UPK	**UPK54□**		–	26
			UPK56□, UPK59□		–	22
		NanoStep UFK•W	**UFK56□W, UFK59□W, UFK564W-T, UFK596W-T, UFK56□W-N**		–	22
		PMU	**PMU3□H2, PMU33H-MG**		3265	26
	DC Input Package	**NanoStep RFK**	**RFK54□**		–	26
			RFK56□		–	22
		CSK	**CSK54□, CSK543TG**		3265	26
			CSK56□, CSK59□, CSK564TG		3266	22
		PMC	**PMC3□2**		3265	28
			PMC33H2, PMC33MG		3265	26
2-Phase	AC Input Package	**UMK**	**UMK24□, UMK24□M**	6	3265	24
			UMK26□, UMK26□M		3265	22
			UMK29□		3265	20
	DC Input Package	**CSK**	**CSK24□, CSK24□M, CSK243SG**		3265	24
			CSK26□, CSK26□M, CSK264SG		3265	22
	Motor	**PK**	**PK24□, PK24□M, PK243SG**		3265	24
			PK26□, PK26□M, PK264SG		3265	22
			PK29□, PK296SG		3265	20
			PK26□-E	8	3265	24
			PK29□-F		3265	22

*1 UL3265: Rated Voltage 150V
UL3266: Rated Voltage 300V