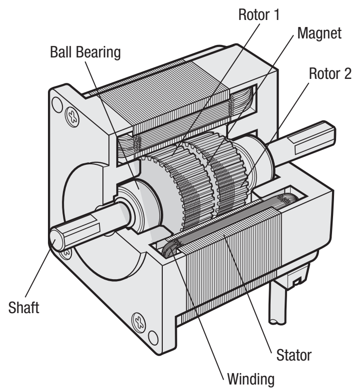
Stepping Motors

Structure of Stepping Motors

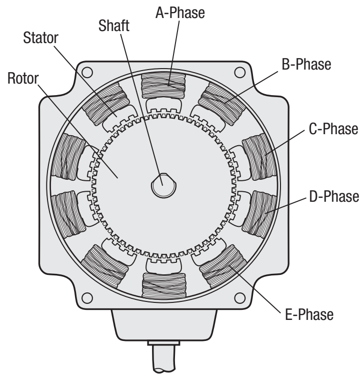
A cross section of Oriental Motor's 5-phase stepping motor is shown below.
A stepping motor mainly consists of two components, namely a stator and a rotor.
The rotor consists of rotor 1, rotor 2 and permanent magnets. The rotor is also magnetized in the axial direction. If rotor 1 is the N pole, for example, rotor 2 becomes the S pole.



Motor Structural Drawing: Cross Section Parallel with the Shaft

The stator has 10 magnetic poles with small teeth, each pole being provided with a winding.
These windings are connected by pairs of magnetic poles facing each other in such a way that when current is supplied, each pair of magnetic poles are magnetized to the same polarity. (This means that when current is supplied to a given winding, the pair of magnetic poles facing each other are magnetized to the same pole of N or S.)
Each opposing pair of magnetic poles constitutes one phase. Since there are five phases, from A to E, the motor is called a "5-phase stepping motor."
There are 50 small teeth on the outer perimeter of each rotor, with the small teeth of rotor 1 and rotor 2 being mechanically offset from each other by 1/2 of the tooth pitch.

Excitation: Condition where current is flowing through the motor windings
Magnetic Pole: Projected part of the stator that becomes electromagnet when excited
Small Teeth: Teeth on the rotor or stator



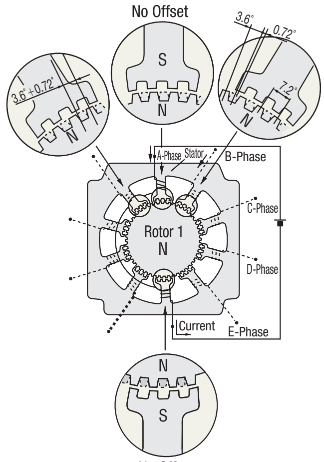
Motor Structural Drawing: Cross Section Vertical to the Shaft

Stepping Motor's Principle of Operation

The position relationship of small teeth on the stator and rotor under actual magnetization is explained.

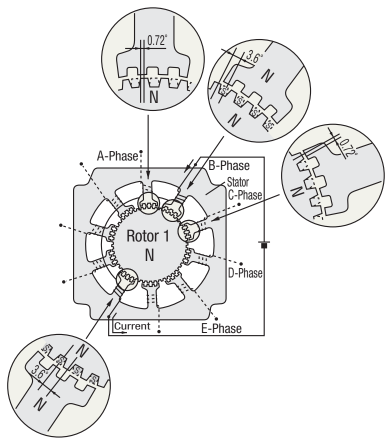
When Phase "A" is Excited

When phase A is excited, the magnetic poles of phase A are magnetized to the S pole and attract, and are attracted by, the small teeth on rotor 1 that has the N polarity, while repelling against the small teeth on rotor 2 that has the S polarity, and consequently the magnetic forces are balanced and the rotor remains stationary. Here, the small teeth on the magnetic poles of the unexcited phase B are offset by 0.72° with the small teeth on rotor 2 that has the S polarity. This is the position relationship of small teeth on the stator and rotor when phase A is excited.



When Phase "B" is Excited

Next, when switching from A-phase excitation to B-phase excitation, the B-phase magnetic pole is magnetized to the N pole and is attracted to rotor 2 which has S pole polarity, and repelled from rotor 1 which has N pole polarity.

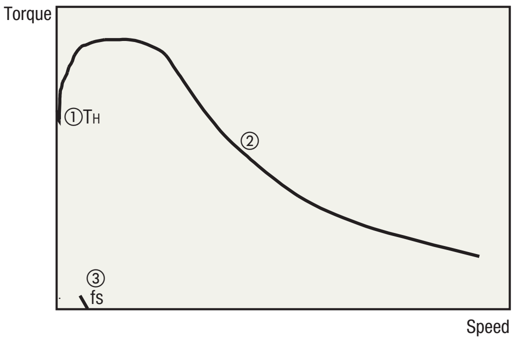


In other words, switching the excited phase from A to B causes the rotor to turn by 0.72°. As it is now clear, the stepping motor rotates precisely 0.72° each pulse every time the excited phase is switched in the sequence of phases A → B → C → D → E → A. To rotate the stepping motor in the opposite direction, simply reverse the excitation sequence to phases A → E → D → C → B → A.
A high resolution of 0.72° is attained from the mechanical offset produced by the stator and rotor structures. This is why stepping motors can acquire accurate positioning without using an encoder or other sensors. With stepping motors, the stopping accuracy is also high at ±3 arc minutes (no load), because the stator and rotor finishing accuracy and assembly precision as well as DC resistance of windings are the only factors of variation. When a stepping motor is actually used, a driver is used to switch the excited phase, while pulse signals input to the driver are used to control the switching timings. In this example, the phases are excited one at a time. In reality, 4 or 5 phases are excited simultaneously to effectively utilize the windings.

Basic Characteristics of Stepping Motors

When using a stepping motor, it is important that the characteristics of the motor match the operating conditions.
The following explains important characteristics to consider when using a stepping motor.
Stepping motor characteristics are largely classified into two categories.

- Dynamic Characteristics:
  These characteristics relate to starting or rotation of the stepping motor, and have to do with the operation and cycle time of the device.
- Static Characteristics:
  These characteristics relate to the angle change that occurs when the stepping motor is at standstill, and have to do with the accuracy of device.



Speed – Torque Characteristics

Dynamic Characteristics

◇Speed - Torque Characteristics

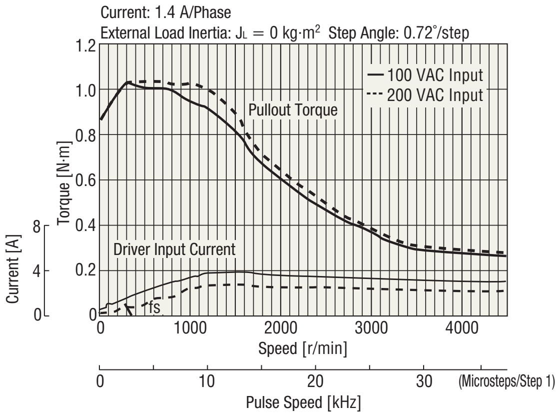
The characteristics diagram below is the characteristics that indicate the relationship between the speed and torque when a stepping motor is driven. These characteristics are always used when selecting a stepping motor. The horizontal axis represents the speed of the motor output shaft, while the vertical axis represents the torque.
The speed – torque characteristics are determined by the motor and driver, so they vary greatly based upon the type of the driver used.

① Maximum Holding Torque (T_H)
The maximum holding torque (holding force) the stepping motor has when power (rated current) is being supplied but the motor shaft is at standstill.

② Pullout Torque
The maximum torque that can be output at a given speed.
When selecting a motor, ensure that the required torque falls within this curve.

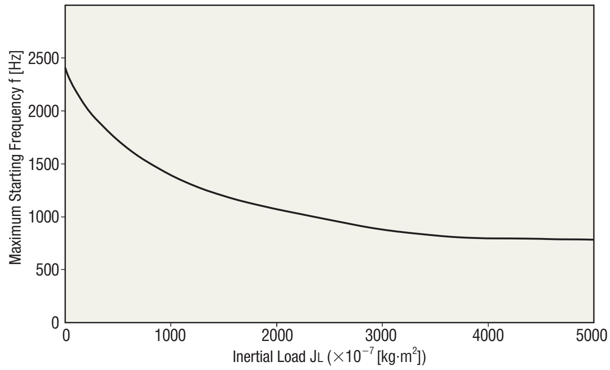
③ Maximum Starting Frequency (fs)
This is the maximum pulse speed at which the motor can start or stop instantaneously (without an acceleration or deceleration time) when the frictional load and inertial load of the stepping motor are 0.
You must gradually accelerate/decelerate the motor when running it at pulse speeds greater than this. This frequency drops when there is an inertial load on the motor. (Refer to "Inertial Load – Starting Frequency Characteristics.")

Maximum Response Frequency (f_r)
This is the maximum pulse speed at which the stepping motor can be operated via gradual acceleration/deceleration when the frictional load and inertial load of the stepping motor are 0.
The following figure shows the representative speed – torque characteristics of a 5-phase stepping motor and driver package.



◇Inertial Load – Starting Frequency Characteristics

These characteristics indicate how the starting frequency changes due to the inertial load.
The stepping motor rotor itself, and the load, are subject to the moment of inertia. Accordingly, motor shaft time lag or advancement occurs upon instantaneous start or stop. The value of this lag or advance varies according to the pulse speed, but once a certain level is exceeded, the motor can no longer follow-up the pulse speed and eventually missteps.
The pulse speed immediately before the occurrence of misstep is called the "starting frequency."



Inertial Load – Starting Frequency Characteristics

The maximum starting frequency at a given inertial load can be approximated by the formula below.

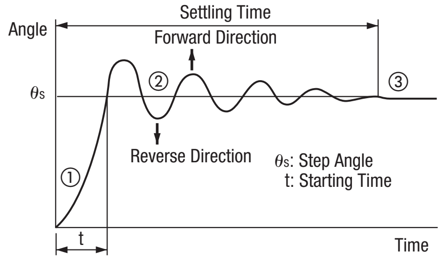
$$f = \frac{fs}{\sqrt{1+\frac{J_L}{J_O}}} \text{ [Hz]}$$

fs :Maximum starting frequency of motor [Hz]
f :Maximum starting frequency under inertial load [Hz]
J_O :Rotor Inertial Moment [kg·m²]
J_L :Load Inertia [kg·m²]

◇Vibration Characteristics

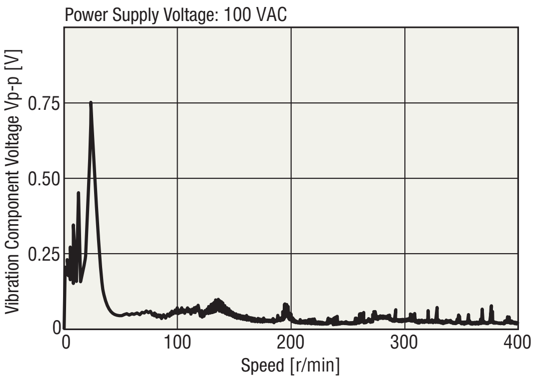
Stepping motors rotate in continuous steps. The single-step response explained below represents one of these step actions.

① When one pulse is input to the stepping motor at standstill, the stepping motor accelerates toward the next step angle.
② The accelerating motor passes the step angle and overshoots a certain angle, then the motor is pulled back in the opposite direction.
③ After undergoing damped oscillations, the stepping motor stops at the position corresponding to the specified step angle.



1-Step Response

Step action where the aforementioned damped oscillation occurs is the cause of vibration at low speeds.
Vibration characteristics indicate the magnitude of vibration that occurs while the stepping motor is rotating.
The smaller the vibration level, the smoother the motor rotation will be.

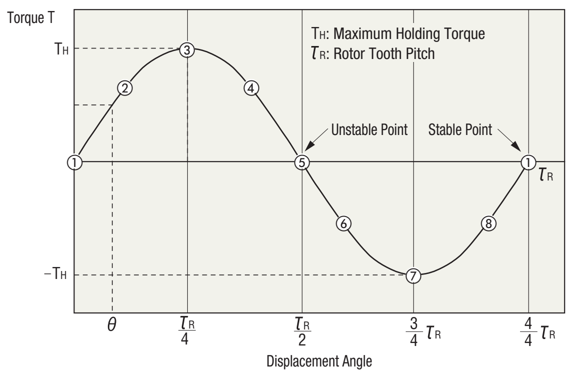


Vibration Characteristics

●Static Characteristics

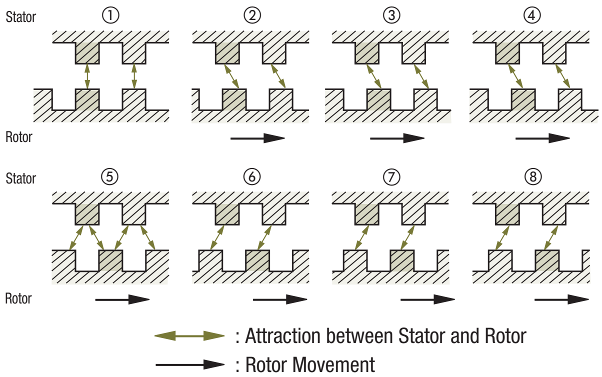
◇Angle – Torque Characteristics

When the motor is excited with the rated current and torque is applied externally to the motor shaft to change the rotor angle, the relationship of angle and torque in this condition is referred to as the "angle – torque characteristics." These characteristics are shown in the figure below.



Angle – Torque Characteristics

The figure below shows the position relationship of small teeth on the stator and rotor at each point in the above characteristics diagram.
When the magnetic forces are balanced at stable point ① and the motor is at standstill, applying an external force to the motor shaft causes a torque T (+) to generate in left direction that tries to pull back the motor to stable point ①, and the motor consequently stops at the angle where this torque balances out with the external force. ②
When the external force is gradually increased, the generated torque reaches the maximum level at a certain angle. The generated torque at this angle is the maximum holding torque T_H. ③
If the applied external force exceeds this torque, the motor passes the unstable point ⑤, after which a torque T (–) is generated in the same direction as the external force and the motor moves to the next stable point ① and stops there.



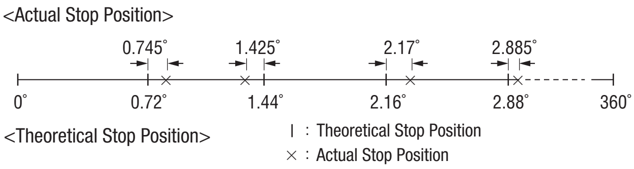
Stable Point:
This is where the small teeth on the stator and rotor are completely opposing each other and the motor is at standstill. The motor is very stable at this point and once the external force is removed, the motor always stops at this location.

Unstable Point:
This is where the small teeth on the stator and rotor are offset by a 1/2 pitch. The motor is very unstable at this point and if an external force is applied, no matter how small, the motor moves to the next stable point on the right or left.

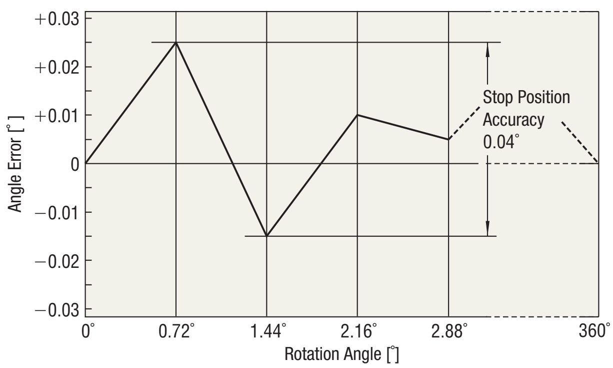
◇Angle Accuracy

Stepping motors have an angle accuracy of within ±3 arc minutes (0.05°) under no load condition. This slight error is caused by the mechanical precision of the stator and rotor as well as minor variation in the resistance of stator windings.
Stop position accuracy below is generally used to indicate the angle accuracy of stepping motors.

Stop Position Accuracy:
This is the actual offset between the theoretical stop position and actual stop position of the rotor. The stop position accuracy represents the band between the maximum value in the (+) direction and maximum value in the (–) direction when measurement is taken step by step over a 360° range starting from an arbitrary stop position of the rotor.



Although the specified stop position accuracy is within ±3 arc minutes, this is the value under no load. In actual applications, frictional load always exists. Accordingly, the angle accuracy no longer conforms to the angle – torque characteristics and angular displacement occurs according to the frictional load. If the frictional load is constant, the displacement angle is also constant for uni-directional operations. If an operation is performed from forward and reverse direction, however, the total displacement angle generated in each reciprocating cycle is doubled.
If a certain level of stopping accuracy is required, be sure to perform positioning from one direction.



Motors of Stepping Motor and Driver Packages

All 5-phase stepping motor and driver packages featured in this catalogue consist of a 5-lead motor that adopts the new pentagon wiring method and a driver equipped with a dedicated excitation sequence. This unique combination of motor and driver is a proprietary technology of Oriental Motor that achieves the following benefits:

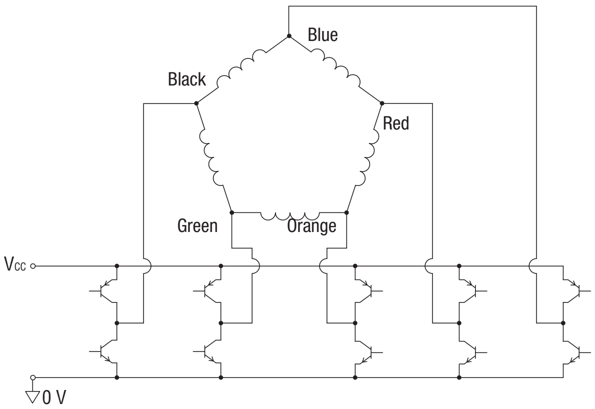
- Simple wiring for five leads
- Low vibration

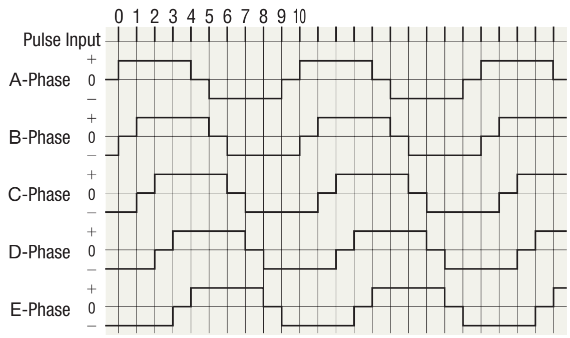
The following explains the aforementioned wiring method and excitation sequence:

New Pentagon Wiring, 4-Phase Excitation: Full Step System

0.72˚/step

This method, where 4 phases are always excited together based on a unit step of 0.72˚ (0.36˚), is unique to 5-phase stepping motors. This method provides a greater damping effect and ensures stable operation.



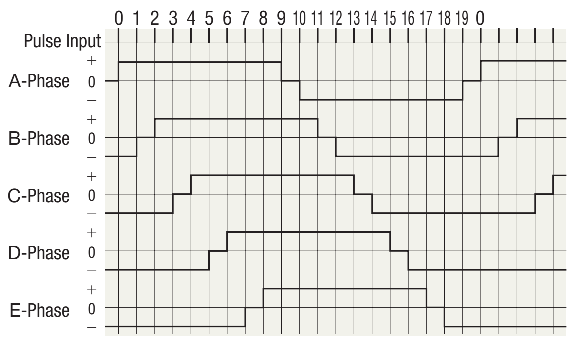


New Pentagon Wiring, 4-Phase Excitation Sequence

New Pentagon Wiring, 4-5-Phase Excitation: Half-Step System

0.36˚/step

Under this method, 4-phase excitation and 5-phase excitation are alternated based on a unit step of 0.36˚. 1000 steps per rotation can be achieved.



New Pentagon Wiring, 4-5-Phase Excitation Sequence

Stepping Motor Drivers

Stepping motors are driven by one of two methods, namely the constant-current drive method and constant-voltage drive method.

The constant-voltage drive method requires only a simple circuit configuration, but achieving the desired torque characteristics is difficult in the high-speed range.

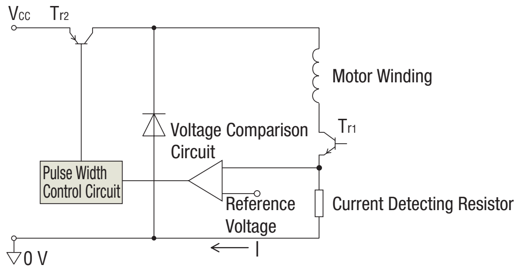
On the other hand, the constant-current drive method, which is widely used today, offers excellent torque characteristics in the high-speed range.

All stepping motor drivers by Oriental Motor adopt this drive method.

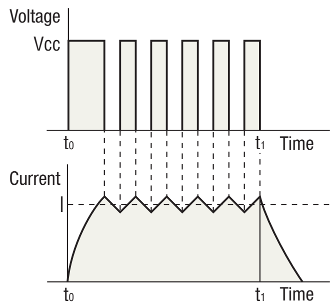
Overview of the Constant Current Drive System

Stepping motors are turned by sequentially switching the supplied current among the respective windings. As the motor speed increases, however, the speed of this switching also increases and the resulting delay in the rise of current leads to loss of torque.

Accordingly, DC voltages considerably higher than the rated voltage of the motor are chopped to make sure the rated current is supplied to the motor even at high speed.



To be specific, the current flowing through the motor windings is detected as a voltage using a current sensing resistor and the detected voltage is compared against the reference voltage. If the voltage detected by the sensing resistor is lower than the reference voltage (below the rated current), the switching transistor Tr2 is kept ON. If the detected voltage is higher than the reference voltage (exceeds the rated current), Tr2 is turned OFF. This current control makes sure the rated current is supplied at all times.



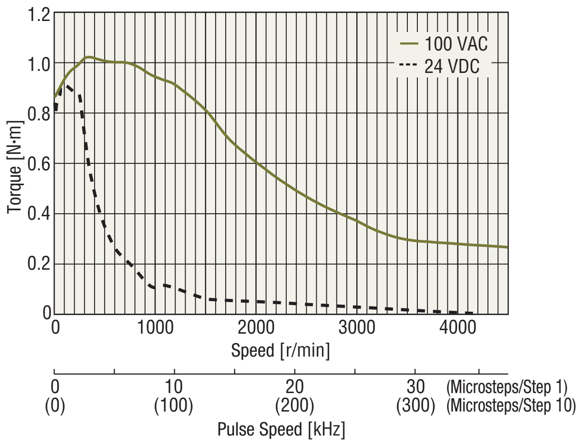
Constant Current Chopper Drive and its Relationship to Voltage and Current

Characteristics Differences between AC Input and DC Input

With stepping motors, the motor is driven by applying DC voltage via the driver. At Oriental Motor, 24 VDC is applied to the motor for 24 VDC input packages. With 100 VAC and 200 VAC input packages, the AC voltage is rectified to DC voltage and approximately 140 VDC is applied to the motor. (Some products are excluded.)

The difference in the applied voltage to the motor manifests as different torque characteristics in the high-speed range. This is because when current starts flowing to the motor windings, the speed is higher when the applied voltage is higher and the rated current can be supplied even in the high-speed range. In other words, AC input packages produce excellent torque characteristics and high speed ratios over the entire speed range from low to high.

If you are considering a stepping motor and driver package, we recommend that you choose an AC input package that supports the various operating conditions of your device.



Microstep Technology

With 5-phase stepping motors, the basic step angle 0.72˚ can be divided further (by up to 250) without using any mechanical speed reduction mechanism.

◇Features

Stepping motors run and stop at each step angle determined by the salient-pole structure of the rotor and stator, which allows for accurate and easy position control. The downside of these characteristics of rotating by each step angle is that the rotor speed changes. As a consequence, resonance or more vibration occurs at a given speed.

Microstep drive is a technology that divides the basic step angle of the motor by controlling the current flowing through the motor winding, thereby achieving low-noise operation and ultra-low speed.

- Since the basic step angle of the motor (0.72˚/full step) can be divided to levels between 1/1 to 1/250, smooth operation by fine angle feed becomes possible.
- Thanks to this technology that changes the motor drive current smoothly, we have achieved low-noise operation by suppressing motor vibration.

◇Up to 250 Microsteps

Microstep drivers let you set different step angles (out of 16 types, up to 250 microsteps) using two step angle setting switches and switch between the step angles set by the two switches by inputting a step angle switch signal externally.

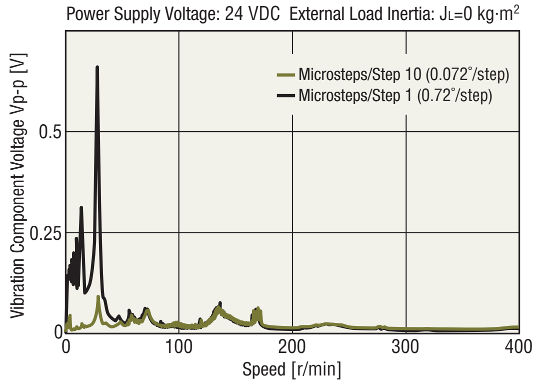
Characteristics

- Low Vibration

  Electrically dividing the step angle using the microstep technology. Stepped motion in the low-speed range has been made smoother, thereby dramatically reducing vibration.

  Normally a damper or other device is used to reduce vibration. With microstep technology, Oriental Motor products, which use low-vibration motors to begin with, achieve even less vibration.

  Because our products can dramatically simplify anti-vibration measures they are ideal for applications and equipment where vibration should be avoided.



Vibration Characteristics

- Noise Reduction

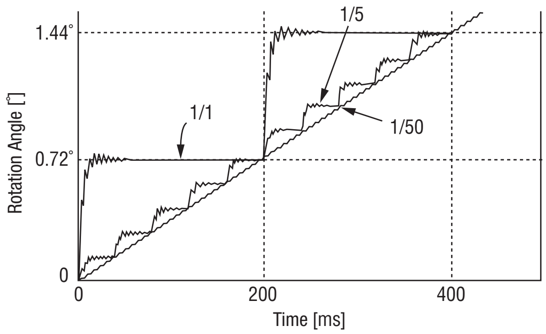
  Thanks to the microstep technology, vibration noises in the low-speed range have been reduced to achieve low-noise operation.

  Our products provide outstanding performance in environments where noise should be avoided.

- Improved Controllability

  A microstep drive that employs the new pentagon wiring method that is known for its excellent damping characteristics.

  As a result, there is less overshooting and undershooting in each step and compliance with the pulse pattern is also improved. (Linearity also improves.) Starting and stopping shocks are also mitigated.



Step-Response Variation

How to Select Power Transformer

When a stepping motor is used overseas, in many cases a single-phase 115 VAC or single-phase 220 to 240 VAC power supply is used. If a stepping motor is used in any such overseas region, use an appropriate power transformer according to the applicable power-supply input specification.

The transformer capacitance can be calculated as follows:

Transformer capacitance [VA] = Driver power supply voltage [V] × Driver input current [A]

The driver input current of a stepping motor can be determined from the specification list and speed – torque characteristics of the motor.

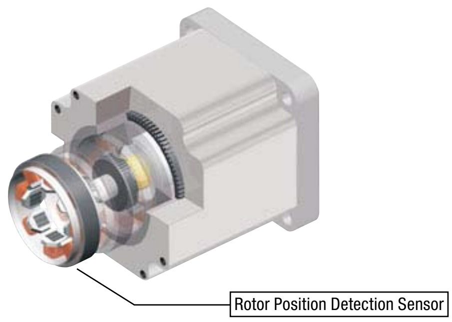
●Refer to page I-2, if you are using any certified Oriental Motor product overseas.

Closed Loop Stepping Motor and Driver Packages αSTEP

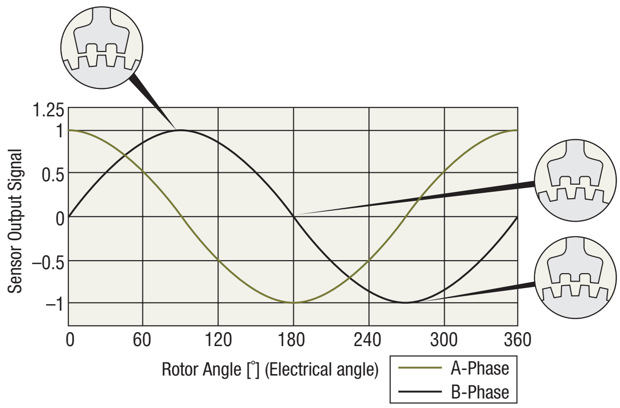
Overview of the Control Method

◇Built-In Rotor Position Detection Sensor

A built-in rotor position detection sensor is provided on the back shaft side of the motor.



The sensor windings detect the change in magnetic reluctance according to the rotor rotation position.

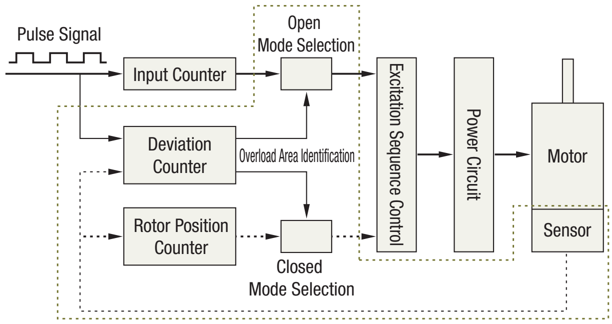


Output Signal of Rotor Position Detection Sensor

◇Incorporating Our Unique Closed Loop Control

A deviation counter is used to calculate the deviation (time lag/advance) of the actual rotor rotation position relative to the command position specified by the pulse signal.
An overload region is determined from the calculation result based on the deviation counter, and the operation control is switched between the open mode and closed mode accordingly.

- Normally, the motor is operated in the open mode.
- In an overload condition, the motor is operated in the closed mode.

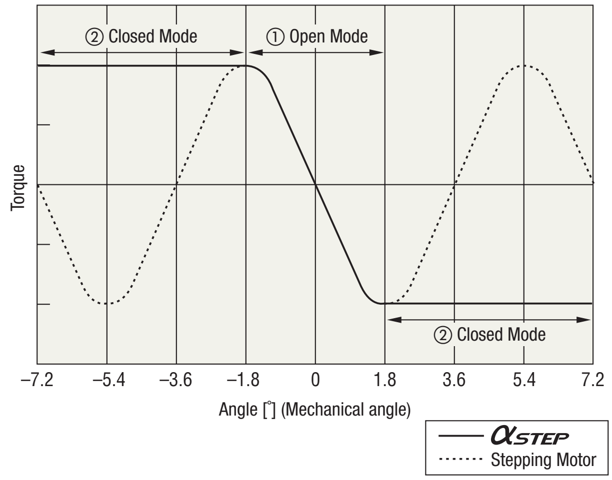


: Unique Control Section of αSTEP

Rotor Position Counter: Indicates the excitation sequence through which the maximum torque is generated at the rotor position.

αSTEP Control Diagram

In the closed loop mode, the excitation state of motor windings is controlled in such a way that the maximum torque generates at the rotor rotation position. This control method ensures that the angle – torque characteristics are free from any unstable point (overload region).



Angle - Torque Characteristics

Features of αSTEP

◇Greater Performance than Stepping Motors

- Easy-to-use torque characteristics in the high-speed range

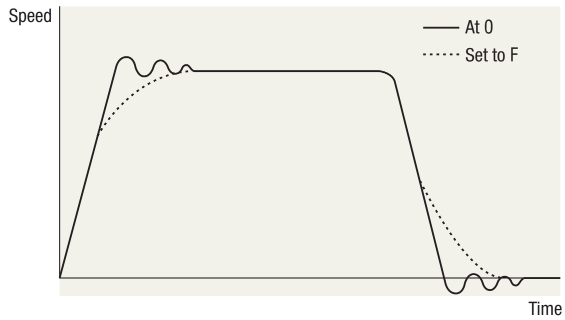
  αSTEP, as with the normal stepping motor, there is no need to consider the following points when operating.

  - Starting Pulse Speed Limit

    High-speed operation can be achieved with ease by utilizing the slew region.

- Adjustable responsiveness at start/stop using velocity filters

  Responsiveness at start/stop can be adjusted to one of 16 steps without changing the controller data (starting pulse speed, acceleration/deceleration rate).
  Use this function to reduce shocks applied to the load or reduce vibration during low-speed operation.



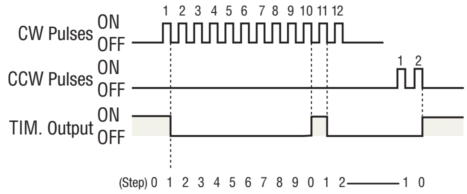
Effect of Velocity Filter

Selection Calculations
Motors
Motorized Actuators
Cooling Fans
Service Life
Standard AC Motors
Speed Control Motors
Stepping Motors
Servo Motors
Gearheads
Linear Heads
Motorized Actuators
Cooling Fans

Return-To-Mechanical Home Operation Using Excitation Timing Signal

Excitation Timing Signal

The excitation timing (TIM.) signal is output when the driver is initially exciting the stepping motor (step "0").
With Oriental Motor's 5-phase stepping motor and driver packages, initial excitation occurs at power on, after which the excitation sequence is advanced with each input of a pulse signal until the motor shaft rotates by 7.2˚ to complete one sequence.

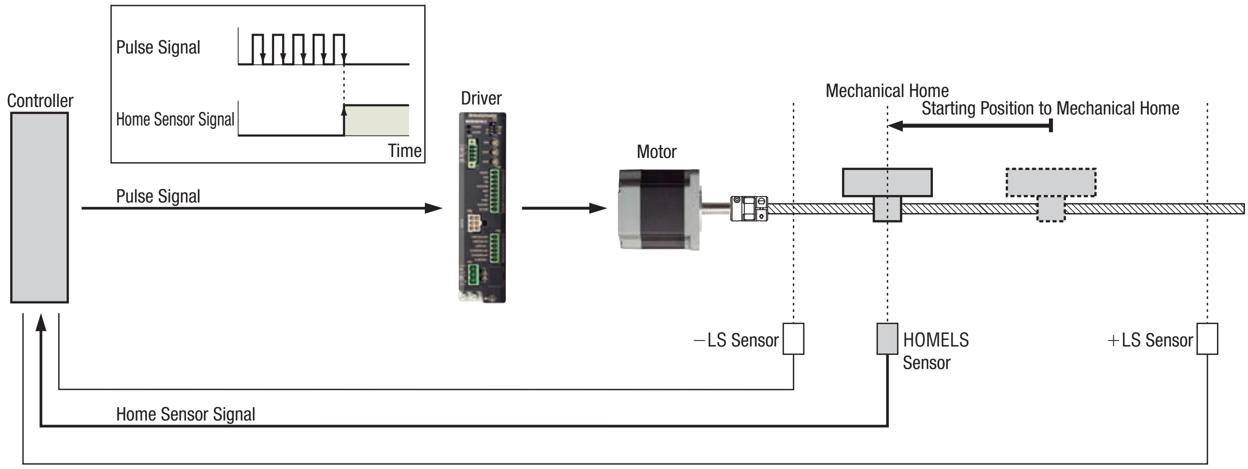


Relationship of Excitation Sequence and Excitation Timing Signal (5-phase stepping motor and driver packages)

Utilize this timing signal if you must achieve return-to-mechanical home operation with high repeatability.
The following explains the return-to-mechanical home operation of a stepping motor and how the timing signal can be utilized.

Return-To-Mechanical Home Operation for Stepping Motors

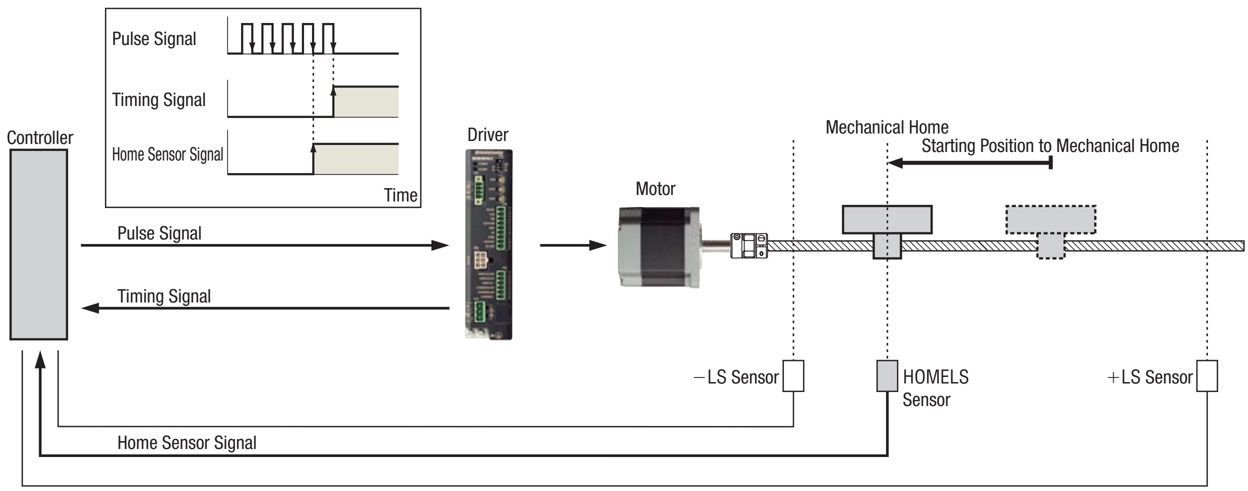
To turn on the power and start automatic equipment, or to restart such equipment following a power outage and subsequent recovery of power, the stepping motor must be returned to the mechanical reference position. This operation is called the return-to-mechanical home operation.
During the return-to-mechanical home operation of a stepping motor, the mechanism part to be positioned is detected with a home sensor and once the detection signal is confirmed, the controller stops the output pulse signal and stops the stepping motor.
Because of the mechanism of return-to-mechanical home operation, the detection performance of the home sensor determines the accuracy of the mechanical home position.
The detection performance of the home sensor changes according to the ambient temperature and approach speed of the mechanism detection part, which must be somehow reduced in applications where return-to-home operation with high repeatability is required.



Return-To-Mechanical Home Operation Using Sensors (3-Sensor Mode: HOME, CW LS and CCW LS)

Improved Repeatability Using Excitation Timing Signal

One way to prevent the mechanical home position from shifting even when the detection performance of the home sensor changes is to stop pulse signal output according to the AND gate with the timing signal. The timing signal is output in the state of initial excitation, so mechanical home operation can always be performed in the initial excitation state by stopping the pulse signal input when the timing signal is output.



Relationship of Cable Length and Transmission Frequency

The longer the pulse line, the lower the maximum transmission frequency becomes. This is because, the effects of the resistance component and stray capacitance, for example, in the cable cause a CR circuit to be formed to delay the rise and fall of pulses.
Cables generate stray capacitance between wires or between a wire and ground. Since the conditions vary depending on the cable type, wiring, route, etc., providing a specific value is difficult.

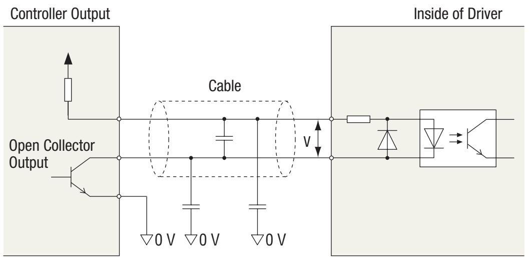


Image Diagram of Stray Capacitance in Cable

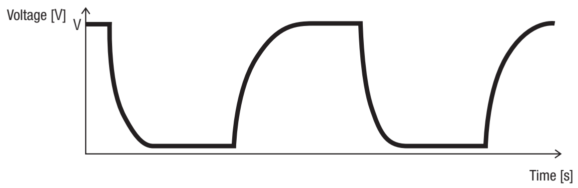


Image of Pulse Waveform

Transmission frequencies (measured values provided for reference) are shown below based on combined operation with Oriental Motor products.

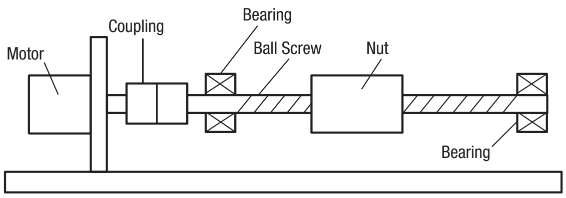
Maximum Transmission Frequency (Reference value)

Driver	Controller	Cable	Maximum Transmission Frequency
RK Series	**EMP400**	**CC01EMP5** (1 m)	170 KHz
		CC02EMP5 (2 m)	140 KHz

Effects of Coupling Rigidity on Equipment

Specifications that indicate coupling performance include permissible load, permissible speed, torsional spring constant, coupling backlash (play) or absence thereof, and permissible misalignment and so forth. In general, for equipment that require good positioning performance and low vibration. the primary condition in selecting a coupling is "high rigidity and no backlash" However, coupling rigidity may have only a small influence relative to the overall rigidity of the equipment.
Here, one example is given where the rigidity of the entire ball-screw drive system is compared between when the jaw coupling (**MCS** coupling, etc.) is used and when the bellows coupling associated with high rigidity is used. (The data is an excerpt from KTR's technical reference, so the coupling sizes are different from those of Oriental Motor products.)

Overview of Test Equipment



Equipment with Ball Screw Drive

Specifications of Parts

Torsional spring constant of jaw coupling
$C_j = 21000$ [N·m/rad]
Torsional spring constant of bellows coupling
$C_b = 116000$ [N·m/rad]
Servo motor rigidity
$C_m = 90000$ [N·m/rad]
Ball screw lead
$h = 10$ [mm]
Ball screw root diameter
$d = 28.5$ [mm]
Ball screw length
$L = 800$ [mm]
Bearing rigidity in axial direction
$R_{brg} = 750$ [N/μm]
Rigidity of ball screw nut in axial direction
$R_n = 1060$ [N/μm]
Elastic modulus of ball screw
$R_f = 165000$ [N/mm²]

① Obtain the torsional rigidity of the ball screw, bearing and nut.
The rigidity of ball screw in axial direction R_s is calculated as follows:

$$R_s = (R_f \cdot d^2)/L$$
$$= (165000 \times 28.5^2)/800$$
$$= 167526 \text{ [N/mm]}$$
$$= 167.5 \text{ [N/μm]}$$

Accordingly, the total axial direction rigidity R_t of the ball screw, bearing and nut is calculated as follows:

$$\frac{1}{R_t} = \frac{1}{2R_{brg}} + \frac{1}{R_s} + \frac{1}{R_n}$$
$$= \frac{1}{2 \times 750} + \frac{1}{167.5} + \frac{1}{1060}$$
$$= 0.00758$$
$$\therefore R_t = 131.9 \text{ [N/μm]}$$

This axial direction rigidity is converted to torsional rigidity C_t.

$$C_t = R_t\left(\frac{h}{2\pi}\right)^2$$
$$= 131.9 \times 10^6 \times \left(\frac{10 \times 10^{-3}}{2\pi}\right)^2$$
$$= 334.1 \text{ [N·m/rad]}$$

② Obtain the overall equipment rigidity C using jaw coupling.

$$\frac{1}{C} = \frac{1}{C_m} + \frac{1}{C_j} + \frac{1}{C_t}$$
$$= \frac{1}{90000} + \frac{1}{21000} + \frac{1}{334.1}$$
$$= 0.003052$$
$$\therefore C = 327.7 \text{ [N·m/rad]}$$

③ Obtain the overall equipment rigidity C using bellows coupling.

$$\frac{1}{C} = \frac{1}{C_m} + \frac{1}{C_b} + \frac{1}{C_t}$$
$$= \frac{1}{90000} + \frac{1}{116000} + \frac{1}{334.1}$$
$$= 0.0030128$$
$$\therefore C = 331.9 \text{ [N·m/rad]}$$

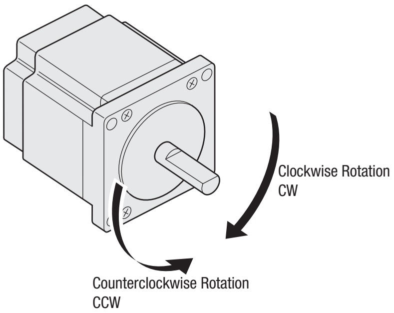
④ Calculation Results

	Coupling Rigidity [N·m/rad]	Overall Equipment Rigidity [N·m/rad]
When jaw coupling is used	21000	327.7
When bellows coupling is used	116000	331.9

The rigidity of the jaw coupling is 1/5 the rigidity of the bellows coupling, but the difference in overall equipment rigidity is 1.2%.

Glossary

CW, CCW
These symbols indicate the rotation directions of the motor. CW indicates the clockwise (forward) direction as viewed from the output shaft, while CCW indicates the counterclockwise (reverse) direction.



Overhung Load
Overhung load is the load applied vertically to the motor output shaft. A permissible value is determined for each product.

Angle Accuracy
In general, angle accuracy indicates the difference between the actual angle by which the motor has rotated and the theoretical angle. Although the angle accuracy is expressed in different ways depending on the reference used, stop position accuracy is a commonly used measure of angle accuracy for stepping motors.

Angular Transmission Accuracy
In general, when the speed reduction mechanism, etc. is installed, angular transmission error refers to the difference between the theoretical rotation angle and actual rotation angle of the output shaft as calculated from the input pulse count. It is used to indicate the accuracy of the speed reduction mechanism.

Inertial Load (Moment of load inertia)
The size of the force that tries to maintain the current state of motion of an object. An object always has an inertial load. If the inertial load is higher, a larger torque is required during acceleration/deceleration. The size of this torque is proportional to the size of the inertial load, and to the size of the acceleration determined by the operating speed and acceleration time.

Automatic Current Cutback Function
This function automatically reduces the motor current by approximately 50% when the pulse signal stops to suppress heat generation from the motor and driver. (The current is reduced by approximately 40% for the 2-Phase **CMK** Series.) Once pulse signal stops, the motor current automatically drops to the setting value of current at motor standstill within approximately 0.1 second.

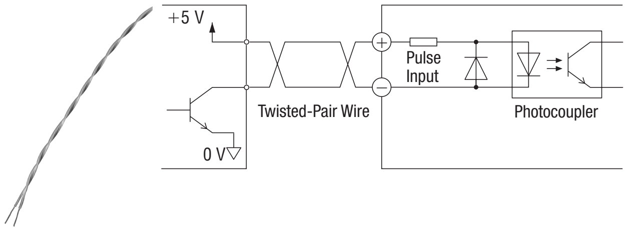
$$\text{Holding torque [N·m]} = \frac{\text{Maximum holding torque [N·m]} \times \text{Current at motor standstill [A]}}{\text{Motor rated current [A]}}$$

Resonance
This is a phenomenon where vibration increases in a specific speed range. It is caused by the natural frequencies of the motor and its mechanism and vibration during operation. With 2-phase stepping motors, there is a region of 100 to 200 Hz where particularly large resonance occurs. With 5-phase stepping motors, vibration is substantially lower compared to 2-phase stepping motors.

Thrust Load
Load applied to the motor output shaft in the axial direction. A permissible value is determined for each product.

Misstep
Stepping motors rotate in synchronization with pulse signals, but they lose synchronicity if the speed changes suddenly or an overload situation occurs. When the stepping motor is no longer synchronized with input pulses, the motor has "misstepped." As long as the motor has been selected correctly and is driven properly, it will not misstep suddenly. With servo motors, an overload alarm may have occurred.

Twisted-Pair Wire
This wire, made by twisting two wires as shown below, is used as a protection against the noise of signal lines. When a twisted pair wire is used, equal current flows from opposite directions to cancel out the effect of noise entering from the surroundings.



Backlash
Backlash is the play of a gear or coupling. Since the range of backlash angle cannot be controlled, the general rule is that the smaller the backlash, the easier it is to achieve high-accuracy positioning. Oriental Motor provides harmonic gears that have non-backlash, as well as **PS** gears and **TH** gears with reduced backlash (low backlash).

Pulse Input Mode
Mode of controlling the CW and CCW directions according to the pulse command. The 1-pulse (1P) input mode and 2-pulse (2P) input mode are available. In the 1-pulse input mode, the pulse signal and rotation direction signal are used. In the 2-pulse input mode, the CW pulse is input to switch to the CW direction, while the CCW pulse is input to switch to the CCW direction.

Photocoupler (ON, OFF)
Photocouplers transmit electric signals by converting them to light. Accordingly, the input side and output side are electrically insulated and therefore photocouplers are less affected by noise. At Oriental Motor, the state where the internal photocoupler (transistor) of the driver is carrying current is defined as "ON", and the state where the photocoupler is not carrying current is defined as "OFF".

Photocoupler State 

Gravitational Operation
Gravitational operation refers to a motion whereby a load that has been hoisted is lowered. Since the motor is turned by gravity, in a servo motor system the motor functions as a generator and may damage the driver. Accordingly, a regeneration circuit is required. With a stepping motor, speed control is possible even in gravitational operation because motor rotation is synchronized with pulses.

Step "0"
At this position, the excitation sequence is at the initial state. With 5-phase stepping motors, the excitation sequence returns to the initial state every 7.2˚.

Excitation Sequence
Stepping motors turn when current is supplied to the motor windings according to the determined combination and order. The excitation sequence refers to the order in which current is supplied to the motor windings.
The specific sequence varies depending on the motor structure and excitation mode.