MOTION GUIDE

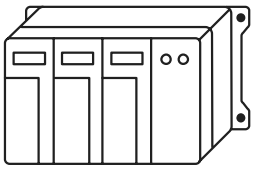
Thank you for purchasing Autonics product.

Before use, be sure to read the safety considerations and use them correctly.

Autonics

CONTENTS

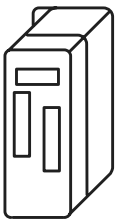
Stepper Motor System Configuration



PC/PLC

Start / Stop signal
Setting signal for rotating direction
PC dedicated software (atMotion)

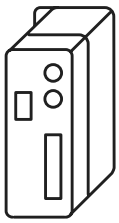
→



Motion controller

Controls rotation angle and speed

→



Motor driver

Provides power to the motor in the order of the motor phase

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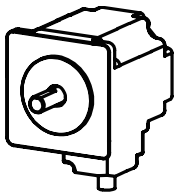
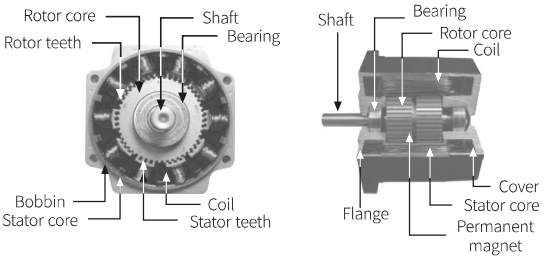


Stepper motor

What is a Stepper Motor?

Stepper motor is a high accuracy position control motor which digital control rotating by a set mechanical angle decided by input pulses is available. It is available to control a rotation angle and speed accurately and it has lots of proper applications to be used.

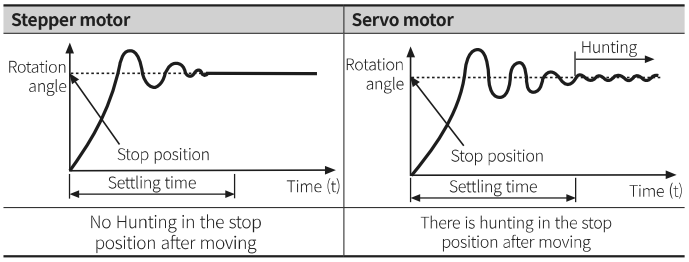


■ Features

It is available to control a rotation angle and speed easily.
5-phase stepper motor is available to control the rotation angle and speed easily by electrical pulse (digital) signal as it is the motor rotating by a set mechanical angle decided by input pulse (digital) signal.

It is available to control a position in a high resolution and accuracy.
The Autonics 5-phase hybrid stepper motor rotates by 0.72°/ pulse and it is a high-resolution motor, which is available to rotate by 0.00288°/pulse when using micro step driver with 250 division. And, it stops in a high accuracy of ±3min (0.05° at non-load) when driving by 0.72°/ pulse.

Settling time is short and there is no hunting status when stopped.
Settling time which motor axis is stopped after normal and reverse rotation by load inertia is short when motor is stopped at a stop position. There is no hunting which motor axis is stopped with delicate normal and reverse rotation when holding a stop position after settling time.

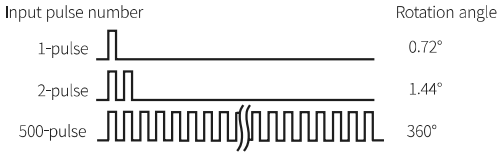


It is a high torque and response motor.
Stepper motor is small & light and can get a high torque. Also, rapid starting/ stopping and reversing are available due to rapid acceleration as it has a stopping and starting torque.

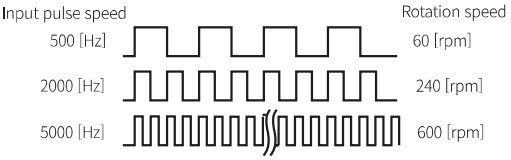
It has a self-holding torque.
The 5-phase stepper motor has a high holding torque when stopped in power on. Therefore, it is available to hold a stop position without mechanical break or control signal.

■ Full step operation of 5-phase stepper motor (0.72°)

• Rotation angle [°] = Step angle [°] × Pulse number



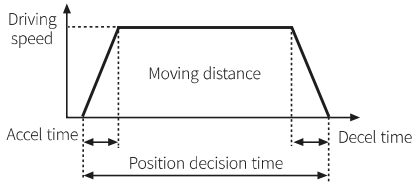
• Rotation speed [rpm] = $\frac{\text{Pulse speed [Hz]}}{\text{360° step angle [°]}} \times 60$ [sec]



■ Decision of driving pattern

It is shown as the drawing converting the operation of the driving equipment to the rotating operation of the motor in the equipment using stepper motor. The below chart by starting speed acceleration /deceleration time, driving speed and position decision time of motor. The stepper motor is selected based on driving pattern chart.

• Driving pattern



■ Calculation of the driving pulse speed

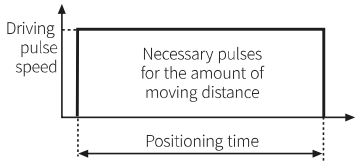
It is the necessary pulse speed in order to rotate as much as the necessary pulse number in the set position decision time.
The necessary pulse number, the position decision time and the acceleration/ deceleration time calculate the driving pulse speed.

• For start-stop driving

Start-stop driving is what the stepper motor stops after revolving as much as the necessary pulse number for the position decision time operating in the driving pulse speed without acceleration/ deceleration on the motor driving.
Start-stop driving is used when driving a motor in low speed. Also, it needs high acceleration/deceleration torque as it needs a rapid speed change. The driving pulse speed of start-stop driving is calculated as follows.

$$\text{Driving pulse speed [Hz]} = \frac{\text{Necessary pulses [pulse]}}{\text{Positioning time [sec]}}$$

• Driving pattern



■ Calculation of necessary pulses

It is the number of the pulse that should be input to stepper motor in order to transfer an object from starting position to target position by the carrying equipment. It is calculated as follows.

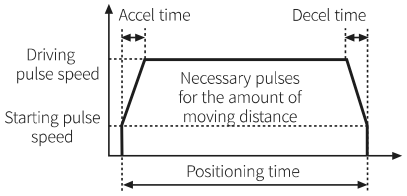
$$\text{Necessary pulses} = \frac{\text{Moving distance of object}}{\text{Moving distance for 1 revolution}} \times \frac{360^\circ}{\text{Step angle}}$$

• For acceleration/deceleration driving

Acceleration/deceleration driving is what stepper motor stops decelerating the speed into the starting region after driving at the pulse speed for certain time when driving in accelerating the rotation speed of the motor by changing slowly the driving pulse speed in the starting region for the positioning time. Acceleration/ deceleration time should be set properly depending on the carrying distance/speed and positioning time. In case of acceleration/deceleration driving it needs lower acceleration/deceleration torque than self-start driving as its speed changes gently. The driving pulse speed of acceleration/deceleration is calculated as below.

$$\text{Driving pulse speed [Hz]} = \frac{\text{Necessary pulses - Starting pulse speed [Hz]} \times \text{Accel·Decel time [sec]}}{\text{Positioning time [sec]} - \text{Accel·Decel time [sec]}}$$

• Driving pattern

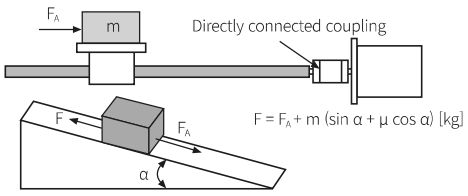


■ Calculation of load torque (T_L)

Load torque indicates the friction power of a contacting part of the carrying equipment and this torque is always needed when the motor is driving.
Load torque is changed by the kinds of carrying equipment and the weight of an object. The calculation of load torque according to the kinds of carrying equipment is as below. Simple calculations without considering the constant are shown as below because it is impossible to get mechanical constant in many cases. Load torque can be calculated referring to below figures and numerical formulas.

[Index]
F : Load of axis direction [kg]
F0: Pre-pressure load [kg] (≅ 1/3 F)
η: Efficiency ratio (0.85 to 0.95)
i: Deceleration rate
FA: External force [kg]
m: The total weight of work and table [kg]
μ: Friction coefficient
α: Slop angle [°]
μ0: Internal friction coefficient of pre-pressure NUT (0.1 to 0.3)
PB: Ball-screw pitch [cm/rev]
FB: The force when starting the revolution of main shaft [kg]
D: Outside diameter of pulley

• Ball-Screw driving



[Calculation of load torque]

$$T_L = \left(\frac{F \cdot P_B}{2\pi\eta} + \frac{\mu_0 F_0 P_B}{2\pi} \right) \times \frac{1}{i} \text{ [kgf·cm]}$$

[Simple calculation of load torque]

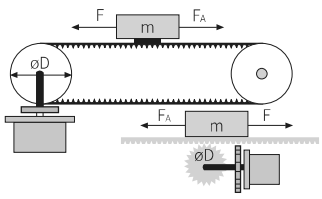
Horizontal load

$$T_L = \frac{m \cdot P_B}{2\pi\eta} \times \frac{1}{i} \text{ [kgf·cm]}$$

Vertical load

$$T_L = \frac{m \cdot P_B}{2\pi\eta} \times \frac{1}{i} \times 2 \text{ [kgf·cm]}$$

• Wire·Belt/Rack·Pinion driving



[Calculation of load torque]

$$T_L = \frac{F}{2\pi\eta} + \frac{\pi D}{i} = \frac{FD}{2\eta i} \text{ [kgf·cm]}$$

$$F = F_A + m (\sin\alpha + \mu\cos\alpha) \text{ [kg]}$$

[Simple calculation of load torque]

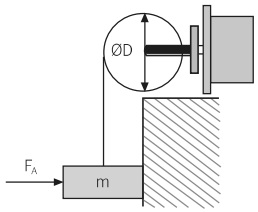
Horizontal load

$$T_L = \frac{D}{2} \times m \times \frac{1}{\eta} \times \frac{1}{i} \text{ [kgf·cm]}$$

Vertical load

$$T_L = \frac{D}{2} \times m \times \frac{1}{\eta} \times \frac{1}{i} \times 2 \text{ [kgf·cm]}$$

• **Pulley driving**



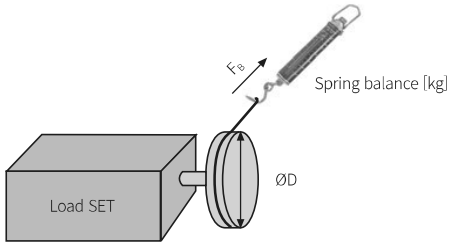
[Calculation of load torque]

$$T_L = \frac{\mu F_A + m}{2\pi} \times \frac{\pi D}{i} = \frac{(\mu F_A + m)\, D}{2i} \text{ [kgf·cm]}$$

[Simple calculation of load torque]

$$T_L = \frac{D}{2} \times m \times \frac{1}{i} \text{ [kgf·cm]}$$

• **By real measurement**



It is the calculation method by reading the scale mark of the spring balance at the time when the pulley is rotated when drawing the spring balance slowly. It is available to get more accuracy load torque than by the calculation.
It is available to calculate the load torque as follows with the value (FB) calculated by the spring balance.

$$T_L = \frac{F_B D}{2} \text{ [kgf·cm]}$$

■ Calculation of acceleration / deceleration torque (T_a)

Acceleration·Deceleration torque is for accelerating or decelerating the carrying equipment connected to the motor. It changes largely depending on the time of acceleration·deceleration and the value of load inertia moment of the carrying equipment. Therefore, the torque between self-start driving and acceleration·deceleration driving will show a big difference.

• For start-stop driving (high acceleration·deceleration torque is required)

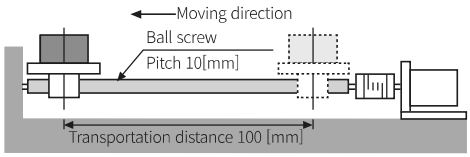
$$\text{Accel · Decel torque [kg·cm]} = \frac{\text{Rotator inertia moment [kgf·m}^2\text{]} + \text{Load inertia moment [kg·m}^2\text{]}}{\text{Gravitational acceleration [cm/sec}^2\text{]}} \times \frac{\pi \times \text{Step angle [°]} \times \text{Driving frequency}^2 \text{ [Hz]}}{180° \times 3.6 \,/\, \text{Step angle[°]}}$$

• Acceleration/Deceleration driving

$$\text{Accel · Decel torque [kg·cm]} = \frac{\text{Rotator inertia moment [kg·m}^2\text{]} + \text{Load inertia moment [kg·m}^2\text{]}}{\text{Gravitational acceleration [cm/sec}^2\text{]}} \times \frac{\pi \times \text{Step angle [°]}}{180°} \times \frac{\text{Driving frequency [Hz] - Starting frequency [Hz]}}{\text{Accel · Decel time [sec]}}$$

Selecting 5-phase Stepper Motors : Calculation of the Necessary Pulses and the Driving Pulse Speed

■ Driving ball-screw



When carrying an object as follow figure for 1 sec. by using 5-phase stepper motor (0.72°/step), the number of the necessary pulse and the speed of the driving pulse are calculated as follows.

$$\text{Necessary pulses} = \frac{\text{Desired transportation distance}}{\text{Transportation distance of 1 rotation}} \times \frac{\text{1 rotation (360°)}}{\text{Rotation angle per 1 pulse}}$$

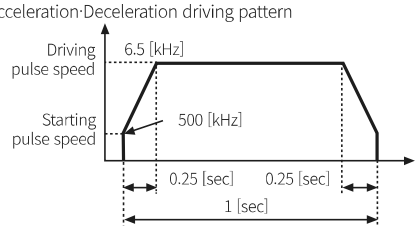
$$\frac{100}{10} \times \frac{360°}{0.72°} = 5{,}000 \text{ [Pulse]}$$

If it executes start-stop driving for a second the speed of the driving pulse is calculated as 5,000 [Pulse] / 1 [sec] = 5 [kHz] but, the start-stop driving is impossible at 5 [kHz].

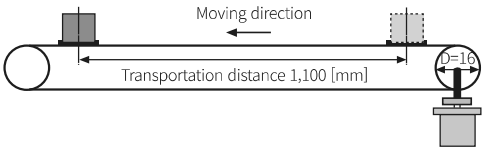
It should be driven with acceleration·deceleration driving. If calculating with setting the acceleration ·deceleration time as 25% of the position decision time and 500 [Hz] of the starting pulse speed, it will be calculated as follows.

$$\text{Driving pulse speed [Hz]} = \frac{\text{5000 [Pulse] - 500 [Hz]} \times \text{0.25 [sec]}}{\text{1 [sec] - 0.25 [sec]}} = 6.5 \text{ [kHz]}$$

• Acceleration·Deceleration driving pattern



■ Driving the timing belt



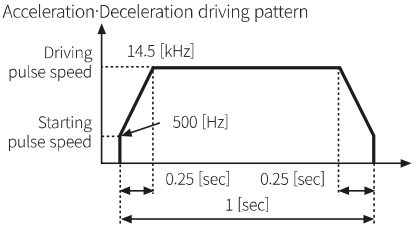
When carrying an object as following figure for 1 sec. by using 5-phase stepper motor (0.72°/step), the moving distance/revolution is approx. 50[mm] by 2πr as the circumference of the pulley. As the moving distance/revolution is 50[mm] the number of the necessary pulse is calculated as follows.

$$\text{Necessary pulses} = \frac{1{,}100}{50} \times \frac{360°}{0.72°} = 11{,}000 \text{ [Pulse]}$$

If driving with acceleration·deceleration like the example of a ball-screw the driving pulse speed is calculated as follows.

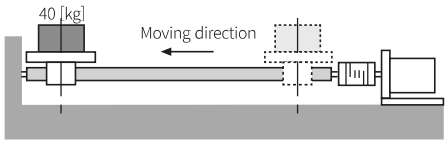
$$\text{Driving pulse speed [Hz]} = \frac{\text{11,000 [Pulse] - 500 [Hz]} \times \text{0.25 [sec]}}{\text{1 [sec] - 0.25 [sec]}} = 14.5 \text{ [kHz]}$$

• Acceleration·Deceleration driving pattern



Selecting 5-phase Stepper Motors : Calculation of Load Torque (T_L)

■ Driving ball-screw with horizontal load

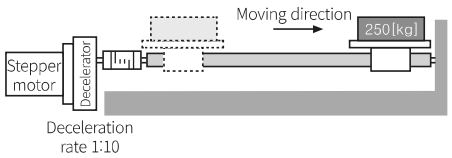


When carrying an object by using a ball-screw with 10 [mm] pitch, 90 [%] of efficiency, and 40 [kg] of the load weight, as following figure, the load torque is calculated as follows.

$$T_L = \frac{m \cdot P_B}{2\pi\eta} \times \frac{1}{i} \text{ [kgf·cm]}$$

$$T_L = \frac{40 \text{ [kg]} \times 1 \text{ [cm]}}{2\pi \times 0.9} \times \frac{1}{1} \fallingdotseq 7.07 \text{ [kgf·cm]}$$

■ Driving ball-screw and decelerator with horizontal load



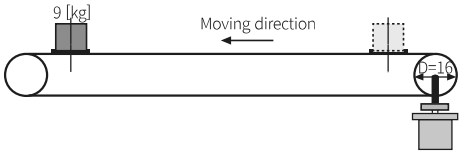
When carrying an object by using a ball screw with 5 [mm] pitch, 90 [%] of efficiency and 250 [kg] of the load weight as following figure, the load torque is calculated as follows.

$$T_L = \frac{m \cdot P_B}{2\pi\eta} \times \frac{1}{i} \text{ [kgf·cm]}$$

$$T_L = \frac{250 \text{ [kg]} \times 0.5 \text{ [cm]}}{2\pi \times 0.9} \times \frac{1}{10} = 2.21 \text{ [kgf·cm]}$$

The calculation result is for a horizontal load. Vertical load torque is 2 times of the horizontal load torque. Its result is only for load torque.
Acceleration·Deceleration torque should be added for real necessary torque of the motor. But, it is very difficult to get the moment of load inertia in the calculation.
In order to solve the difficulty it will be easy to calculate applying the start-stop driving or a large safety rate when acceleration·deceleration is rapid at the calculated load torque.

■ Driving timing belt with horizontal load



When carrying an object by using a timing belt with 90 [%] of efficiency, 16 [mm] diameter of pulley and 9 [kg] of the load weight as following figure, the load torque is calculated as follows.

$$T_L = \frac{D}{2} \times m \times \frac{1}{\eta} \times \frac{1}{i} \text{ [kgf·cm]}$$

$$T_L = \frac{1.6 \text{ [cm]}}{2} \times 9 \text{ [kg]} \times \frac{1}{0.9} \times \frac{1}{1} = 8 \text{ [kgf·cm]}$$

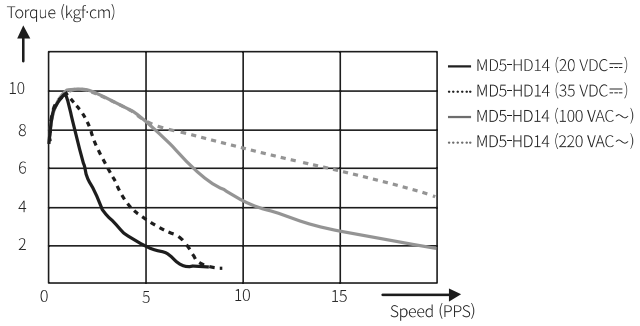
What is a Motor Driver?

It is an exclusive driving circuit to drive the stepper motor and provides power to the motor in the order of the motor phase. Under the same driver conditions, the higher the power supply, the better torque characteristics motors can have. Proper safety countermeasures must be ensured when supplying high power supply. It may cause high heat generation.

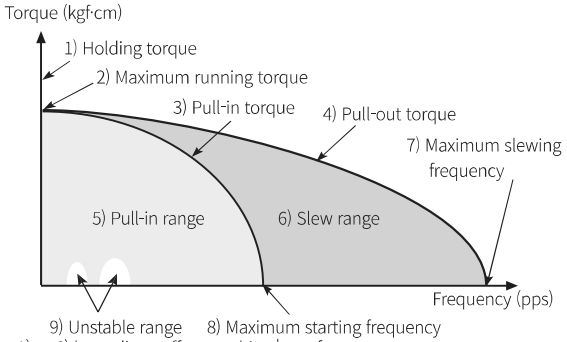
■ Power supply

AC power driver	DC power driver
• 100 - 220 VAC~	• 20 - 35 VDC⎓
• High torque characteristics	• Relatively low torque characteristics
• Relatively complex circuit structure due to AC to DC conversion circuit	• Simple circuit structure

• MD5 Series comparison



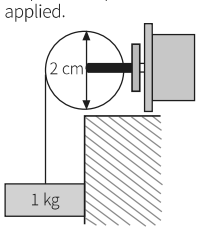
Glossary



• 1) to 6) have direct effect on driver's performance.

■ Torque

Torque, moment of force, is the tendency of a force to rotate an object.
Torque unit: N·m or kgf·cm (1 N·m = 10.1972 kgf·cm)
Required torque to rotate a rotator of which radius is 1cm in case of 1 kg weight is applied.



■ 1) Holding torque

The amount of torque the motors produce at standstill while rated current is applied to the motors. In general, it is referred to as stepper motor's driving capacity.

■ 2) Maximum running torque

Max. torque when running stepper motor with low speed (10 pps).

■ 3) Pull-in torque

Max. torque to drive a load within starting frequency range.

■ 4) Pull-out torque

Max. torque required for a stepper motor to drive without pull-out within maximum starting frequency.

■ 5) Pull-in range (maximum starting range)

Max. torque range that a stepper motor can drive a load with a certain frequency lower than max. starting frequency.

■ 6) Slew range (pull-out range)

Max. torque range required for a stepper motor to drive without pull-out within maximum starting frequency

■ 7) Maximum slewing frequency)

Max. frequency at which a stepper motor can rotate without fail to synchronize when driving a motor within max. starting frequency range in order to increase input frequency.

■ 8) Maximum starting frequency)

Maximum frequency is required for stepper motors to start & stop and forward & reverse rotation without de/acceleration in the state of no load. If it is required to drive a motor with higher frequency than max. starting frequency, drive a motor from max. starting frequency and do de/acceleration driving.

■ 9) Unstable range

Within low speed area, resonance may occur.
Drive the motor after taking the measurement for resonance area.

■ Resonance

The motor may cause resonance within the specific frequency area. Take the measurement before driving the motor.

- 5-phase stepper motor driver resonance area: Approx. 300 to 500 pps
- 2-phase stepper motor driver resonance area: Approx. 200 pps

[How to improve vibration characteristics]

- Adjusting RUN current
- Changing input pulse frequency
- Applying micro step function
  : dividing motor's basic step angle into 250 divisions (0.72° to 0.00288°) by controlling coil current
- Selecting geared type motors
- Using DAMPER
- Using anti-vibration rubber
- Using elastic couplings

■ Missing step

A phenomenon that a stepper motor is incapable of rotating as the frequency of input pulse.

Major Causes	Troubleshooting
Motor failure	Change a motor.
Rapid De/Acceleration of Motor	Reduce driving speed / Make motor's acceleration time longer.
Improper motor torque selecting for load	Change a motor having high torque. Select a geared type motor.
Wrong driving speed setting (lower than max. starting frequency)	Drive a motor within starting frequency band. (Refer to motor's characteristics.)
Low input current	Increase input current

■ Heat generation

Possible causes for heat generation include applying higher power supply, driving with higher RUN current than rated current and long time & continuous driving without stops.

[How to improve heat generation characteristics]

- Adjusting RUN current
- Adjusting RUN DUTY ratio
  : setting STOP time longer than RUN time.
- Mounting heat prevention panels
- Applying Auto current down, HOLD OFF functions
- Using a fan

APPENDIX

Safety Certification for Product and Component

- For detailed certification information, visit the website of each certification body.
- For the status of certification on our product, visit the Autonics website.

■ CE

- Country: European Union

CE marking is the conformity marking, meaning that it complies with all Directives of the Council of European Union regarding safety, health, environmental, and consumer protection standards.
If a product judged to be a risk to the consumer's health, safety, and environmental protection, is sold in the European market, the CE mark must be affixed. It is an essential certification for entry into the European market.

■ UL Listed

- Country: United States

UL listing is the American standard for safety. It is a non-mandatory standard, but most States mandate this standard. This certification is highly favored by consumers.
UL Listed Mark means the end product meets standards of safety.

■ UL Recognized

- Country: United States

UL listing is the American standard for safety. It is a non-mandatory standard, but most States mandate this standard. This certification is highly favored by consumers.
UL Recognized Mark means the components intended for use in a complete product or system meet standards of safety.

■ TR CU

- Country: Eurasian Economic Union

The EAC certification is accredited by five member countries of the Eurasian Economic Union (EAEU): Russia, Kazakhstan, Belarus, Armenia, and Kyrgyzstan.
Regulated products without the EAC mark are prohibited to access the markets of 5 members of EAEU.

- Type of certification
  : Certificate of Conformity (CoC),
  Declaration of Conformity (DoC)

■ KC

- Country: Republic of Korea

The KC certification mark must be affixed on an imported or domestically manufactured electrical product that is to be distributed or sold in Korea.
Type of certification: safety certification, EMC certification

- Safety certification: Korean Agency for Technology and Standards (KATS) affixes and manages the KC certification mark for electrical appliances, household goods, and children's products by dividing the steps into safety certification / safety confirmation / supplier's declaration of conformity (SODC) according to the different levels of potential danger.
- EMC certification: Manufacture, sale, or import for equipment that may cause harm to the radio environment and broadcasting communication network, or that may cause or receive significant electromagnetic interference, the KC certification mark is issued through electromagnetic compatibility (EMC) testing.

■ KCs

- Country: Republic of Korea

The Minister of Employment and Labor evaluates the safety of hazardous or dangerous machinery, equipment, facilities, protective devices, and protective equipment based on the 'safety certification standards.' Occupational Safety and Health Agency (Ulsan, in South Korea) certifies safety through comprehensive tests complying with the 'safety certification standards.'
Any person who intends to manufacture, import, or change major structural parts of products subject to safety certification, must obtain this certification.

■ S-Mark

- Country: Republic of Korea

The S-Mark is the optional certification system to prevent industrial accidents.
Korea Occupational Safety and Health Agency (KOSHA) conducts a comprehensive evaluation for the safety and reliability of product, and the capability of quality control in manufacturing.
Due to non-mandatory, there is no regulation or disadvantage on the uncertified product.

TUV NORD

• Country: Germany

TUV is a leading German private certification body that has been responsible for many testing and certification tasks related to safety in the industry for a long time.
It is intended to protect people and property from fire and other accidents. Currently, TUV is conducting tests and inspections on safety and quality in various industries such as machinery, electronics and electricity, automobiles, chemical facilities, nuclear power, and aircraft.
It is voluntary standards, and certification is issued complying with various EU Directives and German safety regulations.

Metrology Certification

• Country: Russia

Metrology Certification is a certificate for measuring and test equipment. Registration of measuring equipment is currently being revised and implemented following the Russian Federal Law, and is managed and supervised by the measurement authority, which is the subject of the certification.
Measurement authorities review and test measuring equipment to be used in the Russian Federation based on the State System of Measurement (SSM), issue certificates, and manage them in the government's online database for users and buyers to browse.

GOST

• Country: Russia

GOST is national technical standards set by the Euro Asian Council for Standardization, Metrology and Certification (EASC). The abbreviation GOST stands for GOsudarstvennyy STandart, which means State Union Standard in Russian.
The current GOST standard includes over 20,000 titles and is widely used in common in the Commonwealth of Independent States (CIS) (12 countries).
All countries of the CIS currently adopt and use the GOST standard, but the certificates issued by each country and the subject of the issuing certification body are different, so each country's GOST certificate can be regarded as a different certificate. The national standards of Russia are the GOST R, those of Kazakhstan are GOST K, etc.

CCC

• Country: China

The China Compulsory Certificate system (CCC) is a compulsory mark for products that met Chinese technical standards and are allowed to be imported by the Chinese government.
Foreign-imported industrial products are examined through CCC certification process whether they meet safety standards or not. The certified products are distributed and sold with the CCC mark or factory code according to the product.
CCC certification is administered by the China Quality Certification Center (CQC).

China RoHS

• Country: China

China RoHS is the Chinese government regulation to control and eliminate the environmental impact of toxic and hazardous substances and elements in electrical/electronic equipment.
China's Measures for the Administration of the Control of Pollution by Electronic Information Products like the EU RoHS Directive have been enacted, and regulate additional hazardous substances compare to EU RoHS. Marking a logo or label for marking information is mandatory.
In addition, there is a certification system before selling the product to ensure its conformity by conducting test analysis. Products to be exported to China will be screened prior to customs entry. Customs entry is only permitted for products that meet conformance standards.

PSE

• Country: Japan

PSE is a compulsory certification administered by the Ministry of Economy, Trade and Industry (METI) and governs by the Electrical Appliances Safety Law in Japan.
The purpose is to minimize the occurrence of harm and damage caused by electrical equipment by regulating the manufacture and sale of electrical appliances and bring an engagement of the private sector to ensure the safety of electrical appliances.
Manufacture, import, and sell electrical appliances in the Japanese market, the technical standards for those products must be satisfied and the PSE certification mark must be displayed.

Communication Standards

• For detailed information on communication, visit the related association's website.

■ EtherNet/IP

EtherNet/IP

EtherNet/IP is an industrial network protocol that conforms Common Industrial Protocol to standard Internet. It is one of the leading industrial protocols in the United States and is widely used in a variety of industries, including factories.
EtherNet/IP and CIP technologies are managed by ODVA, Ind., a global trade and standards development organization founded in 1995 with over 300 corporate members.
EtherNet/IP uses the most widely adopted Ethernet standards - Internet Protocol and IEEE 802.3 - to define functions for the transport, network, data link, and physical layer. CIP uses object-oriented design to provide EtherNet/IP with services and device profiles needed for real-time control and to promote consistent implementation of automation functions across a diverse ecosystem of products.

■ EtherCAT

EtherCAT

EtherCAT (Ethernet for Control Automation Technology) is an Ethernet-based fieldbus system developed by Beckhoff Automation. After releasing the technology from ETG (EtherCAT Technology Group) in 2003, it is standardized in IEC 61158 since 2007. It is a communication method that uses the frame according to IEEE 802.3 and physical layer and is an Ethernet protocol-based automation software that requires low jitter, short cycle time, and reduced hardware cost.
EtherCAT supports almost all topologies which have the advantage of flexibility and user-friendly. Due to the high-speed network, EtherCAT is suitable for applications requiring simultaneous operation.

■ DeviceNet

DeviceNet

DeviceNet is a digital multidrop network to interconnect industrial controllers and I/O devices. DeviceNet provides users a cost-effective network for distribution at no cost, deploys and manages simple devices across the architecture.
DeviceNet uses CAN (Controller Area Network), a network technology used in automobile vehicles, for its data link layer, and this network is used in almost all industries. DeviceNet is approved by CENELEC for its official standard and is also used as a global standard.

■ HART

HART
COMMUNICATION PROTOCOL

HART is the global standard for digital information communication via analog wires between smart devices and control or monitoring systems.
It is the duplex communication protocol and supports various analog I/O modules with HART connection. It sends and receives digital information through 4-20 mA current.
It provides a reliable and long-term solution for plant operators who seek the benefits of smart devices with digital communication while maintaining existing facilities for analog instrumentation and plant wiring. Many sites that have applied the HART protocol can access to many digital process, maintenance and diagnostic information.

■ ProfiNet

PROFI NET

PROFINET, designated and announced by PI (PROFIBUS & PROFINET), is the open standard for industrial Ethernet in automation technology. It provides solutions for process automation, factory automation and motion control. It enables the integration of existing fieldbus systems such as PROFIBUS, Interbus and DeviceNet into an open Ethernet-based network. PROFINET, the protocol for communication, configuration and diagnosis in the network, uses Ethernet standard as well as TCP, UDP, IP.
It achieves fast and safe data exchange, enabling the concepts of innovative machine and plant. Thanks to its flexibility and openness, PROFINET offers the users a freedom in building machine and plant architectures and significantly increases plant availability by optimal use of resources available to users.

■ ProfiBus

PROFI BUS®

ProfiBus is the open standard commonly used for process automation in the production site.
• Configuration
- Master: It determines data traffic, transmits messages, and performs as role of Active Station.
- Slave: It means I/O devvices, valves, motor drivers, transmitters, etc. Slave receives a message and transmits the message depending on the Master's request.

Up to 124 slaves and 3 masters can be connected to one communication line, and the communication method uses the half duplex method. Each device is connected to the bus in parallel and each device has its network address, so the installation location is irrelevant. Each device can be moved or removed during the communication.

■ CC-Link

CC-Link

CC-Link is the open field network and the global standard with SEMI certification.
As high-speed field network, CC-Link can process both control data and information data at the same time. With a high communication speed of 10 Mbps, it supports a transmission distance of 100 meters and connects to 64 stations.
It achieved high-speed response of up to 10 Mbps, guaranteeing punctuality. With CC-Link, complex production lines can be simplified and built at low cost. There are advantages of reducing the cost of wiring components, shortening the wiring construction period, and improving maintainability.
CLPA provides a memory map profile that allocates data for each product type. CC-Link compatiable products can be developed based on this profile, and users can use the same program for connection and control even if existing product is replaced to other vendors' one.

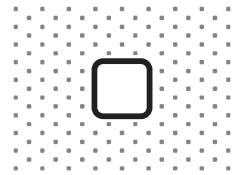
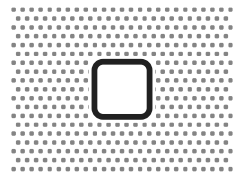
IP Code (protection against dust and water)

■ IEC (International Electro-technical Commission) Standard

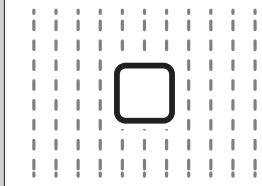
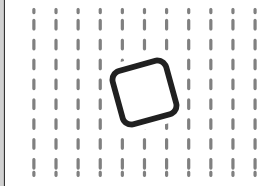
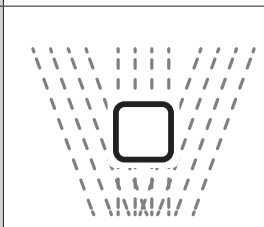
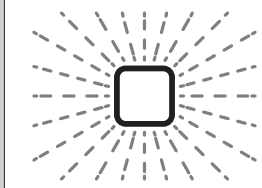
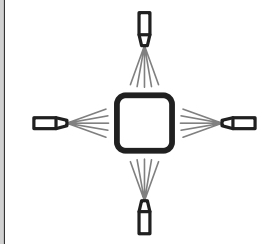
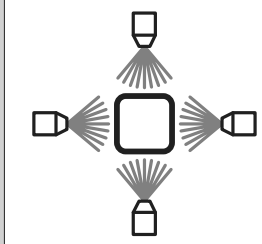
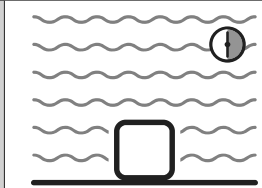
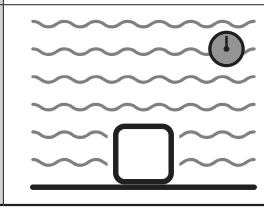
The IP Codes are defined in the IEC standard 60529.

IP ❶ ❷

❶ Degree of protection against dust (protected from solid foreign objects)

Numerals	Degree of protection	
0	Non-protected	
1		Protection against the objects with 50 mm diameter or more The object probe, sphere of 50 mm diameter, must not fully penetrate. - Test means : Rigid sphere without handle or guard. - Test force: 50 N ± 10%
2		Protection against the objects with 12.5 mm diameter or more. The object probe, sphere of 12.5 mm diameter, must not fully penetrate. - Test means : Rigid sphere without handle or guard. - Test force: 30 N ± 10%
3		Protection against the objects with 2.5 mm diameter or more. The object probe, sphere of 2.5 mm diameter, must not fully penetrate. - Test means : Rigid steel rod with edges free from burrs. - Test force: 3 N ± 10%
4		Protection against the objects with 1 mm diameter or more. The object probe, sphere of 1 mm diameter, must not fully penetrate. - Test means : Rigid steel rod with edges free from burrs. - Test force: 1 N ± 10%
5		Protection against the dust with or without pressure. - Dust-protected enclosures allow a limited quantity of dust to penetrate; complete protection against contact. Test duration: 8 hours Dust (the talcum powder) : It must be able to pass a square-meshed sieve that its nominal wire with 50 µm diameter; the nominal width of a gap between wires 75 µm. The amount of talcum powder: 2 kg/m³
6		Protection against the dust under pressure. - Dust-tight enclosures do not allow any dust to penetrate. Test duration : 2 hours (a volume of dust: 40 to 60 / hour) 8 hours (a volume of dust: less than 40 / hour Depression : Less than 2 kPa (20 mbar) on the manometer. Dust (the talcum powder) : It must be able to pass a square-meshed sieve that its nominal wire with 50 µm diameter; the nominal width of a gap between wires 75 µm. The amount of talcum powder: 2 kg/m³

❷ Degree of protection against ingress of water (protected from liquids)

Numerals	Degree of protection	
0	Non-protected	
1		Protection against vertically falling water drops. Water drops flow over the whole area of four sides on a fixed and tilting enclosure. - Test duration : 10 min (2.5 min in each of four sides)
2		Protection against vertically falling water drops when the enclosure tilted up to 15° from its normal position. Uniform flow of water drops over the whole area of the enclosure. - A rotation speed of turntable: 1r / min - Test duration: 10 min
3		Protection against spraying water at an angle up to 60° on either side of the vertical. The oscillating tube has spray holes over an arc of 60° either side of the center point. It sprinkles through an angle of 120° and 60° on either side of vertical. Then, the enclosure is turned through a horizontal angle of 90°, and continue the test for 5 min. - Test duration : 10 min (5 min in each of sides) - Mean flow rate per hole: 0.07 L/min
4		Protection against splashing water from any direction. - No harmful effects on the product. The oscillating semicircle tube with spray holes sprinkles through an angle of 360°. - Test duration: 10 min - Mean flow rate per hole: 0.07 L/min
5 [01]		Protection against projecting water in jets from any direction. - No harmful effects on the product. Spraying a stream of water from the test nozzle (internal diameter: Ø 6.3 mm) at all directions. - Test duration: 3 min - Distance from nozzle to enclosure surface : 2.5 to 3 m - Delivery rate: 12.5 L/min ± 5%
6 [01]		Protection against powerfully projecting water in jets from any direction. - The product is hermetically sealed. Spraying a stream of water from the test nozzle (internal diameter: Ø 12.5 mm) at all directions. - Test duration: 3 min - Distance from nozzle to enclosure surface : 2.5 to 3 m - Delivery rate: 100 L/min ± 5%
7 [02]		Protection against temporary immersion in water under defined conditions of pressure and time. - The product is hermetically sealed. Immersion in water under defined conditions - Test duration: 30 min - Water level: 1 m
8 [02]		Complete protection against continuous immersion in water. - The product is hermetically sealed. Immersion in water under defined conditions. - Test duration: more than 8 hours - Water level: 10 m

01) The degree of protection against spraying does not guarantee the effects of immersion.
02) The degree of protection against immersion does not guarantee the effects of spray.

■ DIN (Deutsche Industric Normen) Standard

The DIN standard is defined in the DIN 40050-9.

IP	❶	❷

❶ Degree of protection against dust (protected from solid foreign objects)

Same as IEC standard

❷ Degree of protection against ingress of water (under high temperature and high pressure)

Letters	Degree of protection	
9K	Water resistance under high temperature and high pressure	Protection against high-temperature vapor and high-pressure water at all directions. - No harmful effects on the product.

■ JEM (Japan Electrical Manufacturers' Association) Standard

The JEM standard is defined in the JEM 1030.

IP	❶	❷	❸

❶ Degree of protection against dust (protected from solid foreign objects)

Same as IEC standard

❷ Degree of protection against ingress of water (protected from liquids)

Same as IEC standard

❸ Degree of oil proof / oil resistance

Letters	Degree of protection	
F	Oil proof type	Protection against oil drop and oil powder in all directions - Even of oil penetrates in the product, it operates normally.
G	Oil resistant type	Protection against oil drop and oil powder in all directions - Special coating prevents penetration of oil into the product.

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