HIWIN®

Torque Motor

Installation Manual

www.hiwinmikro.tw

MW99UE01-2104

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0. Revision History

Revision History		
Version	Date	Revision Contents
M01UC01-1403	2014/03	First version
MR01UC01-1705	2017/05	1. Add motor sizing configurator 2. Add interface design contents 3. Add thermal protection device 4. Add technical terms
MR01UC01-1904	2019/04	1. Move safety instructions to the first chapter 2. Edit cooling contents 3. Edit motor interface design contents
MW99UE01-2104	2021/04	1. Add TM-2/IM-2 2. Add intended use 3. Add product code and logistics content 4. Edit axial force 5. Add power supply and controller sizing 6. Edit symbols 7. Add Tolerances and Hypotheses 8. Add technical terms 9. Add Maintenance and Troubleshooting form 10 Add Decommissioning and disposal

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1. Introduction

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HIWIN torque motor, with the constitution of a stator and a rotor, can be directly driven without decelerator. With servo drive control, excellent acceleration and good uniformity of movement can be easily achieved. Due to the hollow shaft design, cable systems or mechanical parts can easily feed through the motor.

1.1 General precautions

Before using the product, please carefully read through this manual. HIWIN MIKROSYSTEM(HIWIN) is not responsible for any damage, accident or injury caused by failure in following the installation instructions and operating instructions stated in this manual.

- Before installing or using the product, ensure there is no damage on its appearance. If any damage is found after inspection, please contact HIWIN or local distributors.
- Ensure the wiring is not damaged and can be normally connected.
- Do not disassemble or modify the product. The design of the product has been verified by structural calculation, computer simulation and actual testing. HIWIN is not responsible for any damage, accident or injury caused by disassembly or modification done by users.
- Keep children away from the product.
- People with psychosomatic illness or insufficient experience should not use the product alone. The supervision of managers or product docents is definitely needed.

If the login information does not match your order, please contact HIWIN or local distributors.

1.2 Warning notice system

Safety notices are always indicated using a signal word and sometimes also a symbol for the specific risk. Different safety alert symbols refer to different types of dangers. Please be aware of personal safety while handling the goods with warning labels on it.

⚠ DANGER!
Imminent danger!
Indicates that death or severe personal injury will result if proper precautions are not taken.

⚠ WARNING
Potentially dangerous situation!
Indicates that death or severe personal injury may result if proper precautions are not taken.

ATTENTION!
Potentially dangerous situation!
Indicates that property damage or environmental pollution can result if proper precautions are not taken.

Warning symbols

	No access for people with active implanted cardia devices.		Substance hazardous to the environment!
	Warning!		Warning of crushing of hands!
	Warning of electricity!		Warning of hot surface!
	Warning of magnetic field!		

Mandatory signs

	Wear head protection!		Refer to user manual!
	Wear protective gloves!		Disconnect before carrying out maintenance or repair.
	Wear safety footwear!		Lifting point

1.3 Basic safety notices

⚠ DANGER!

Danger from strong magnetic fields!

Strong magnetic fields around torque motor systems pose a health risk to persons with implants (e.g. cardiac pacemakers) that are affected by magnetic fields.

- Persons with implants that are affected by magnetic fields should maintain a safe distance of at least 300 mm from torque motor systems.

ATTENTION!

Risk of physical damage to watches and magnetic storage media.

Strong magnetic forces may destroy watches and magnetisable data storage media near to the torque motor system! 。

- Do not bring watches or magnetisable data storage media into the vicinity (<300 mm) of the torque motor systems!

- ◆ When taking or placing the product, do not just pull the cable and drag it.
- ◆ Do not subject the product to shock.
- ◆ Ensure the product is used with rated load.
- ◆ According to IEC 60034-5 standard, all HIWIN torque motors have the following class of protection: IP20 for the stator and IP00 for the rotor.
- ◆ HIWIN torque motors have a insulation class F (TM-2 / IM-2 series) and class B (TMRW series) according to IEC 60085 standard.
- ◆ HIWIN torque motor certification test meets the following standards.

CE	LVD Safety: 2014/35/EU reference standard	EN 60034-1:2010
	EMC (Including EMI+EMS): 2014/30/EU reference standard	EN 61000-6-4:2007+A1:2011
		EN 61000-6-2:2005
		EN 61000-4-2:2009
		EN 61000-4-3:2006
		EN 61000-4-3:2008
		EN 61000-4-3:2010
		EN 61000-4-8:2010
UL	Rotating Electrical Machines reference standard 1004-1	

1.3.1 Intended use

Torque motors are components of a rotary drive system for the precise positioning in terms of time and location of fixed mounted loads, e.g. system components, within an automated system. Torque motors are designed for installation and operation in any position. The loads being moved must be solidly mounted to the rotor.
Torque motor components must not be used outdoors or in potentially explosive atmospheres.
Torque motor components may only be used for the intended purpose as described.

- Torque motors must be operated within their specified performance limits.
- For the safe operation of torque motors, suitable safety precautions must be taken to protect the motor against overload.
- Proper use of the torque motors includes observing the assembly instructions and following the maintenance and repair specifications.
- Use of the torque motor components for any other purpose shall be considered improper use.
- Use only genuine spare parts from HIWIN.

1.3.2 Reasonably foreseeable misuse

Torque motors must not be operated:

- Outdoors
- In potentially explosive atmospheres.

1.3.3 Conversions and modifications

Conversions or modifications to the torque motors are not permitted.

1.3.4 Residual risks

During normal operation, there are no residual risks associated with the torque motor components. Warnings about risks that may arise during commissioning, maintenance and repair work are provided in the relevant sections.

1.3.5 Personnel requirements

Only authorized and competent persons may carry out work on the torque motor components. They must be familiar with the safety equipment and regulations before starting work (See Table 1.1)

Table 1.1 Personnel requirements

Activity	**Qualification**
Commissioning	Trained specialist personnel of the operator or manufacturer
Normal operation	Trained personnel
Cleaning	Trained personnel
Maintenance	Trained specialist personnel of the operator or manufacturer
Repairs	Trained specialist personnel of the operator or manufacturer

1.3.6 Protective equipment

Table 1.2 Personal protective equipment

<table>
<tr><th>Operating phase</th><th>Personal protective equipment</th></tr>
<tr><td>Commissioning</td><td>When in the vicinity of the torque motor components, the following personal protective equipment is required:
◆ Safety shoes</td></tr>
<tr><td>Normal operation</td><td>When in the vicinity of the torque motor components, the following personal protective equipment is required:
◆ Safety shoes</td></tr>
<tr><td>Cleaning</td><td>When cleaning the torque motor components, the following personal protective equipment is required:
◆ Safety shoes</td></tr>
<tr><td>Maintenance</td><td rowspan="2">When carrying out maintenance and repairs, the following personal protective equipment is required:
◆ Safety shoes</td></tr>
<tr><td>Repairs</td></tr>
</table>

1.3.7 The danger of strong magnetic fields

The permanent magnet in the torque motor rotor has a very strong magnetic field. When there is no input current, the strong magnetism of the motor comes from the permanent magnets on the rotor, and the magnetic field strength is inversely proportional to the distance (**Figure 1.1**); and additional electromagnetic fields are generated during motion.

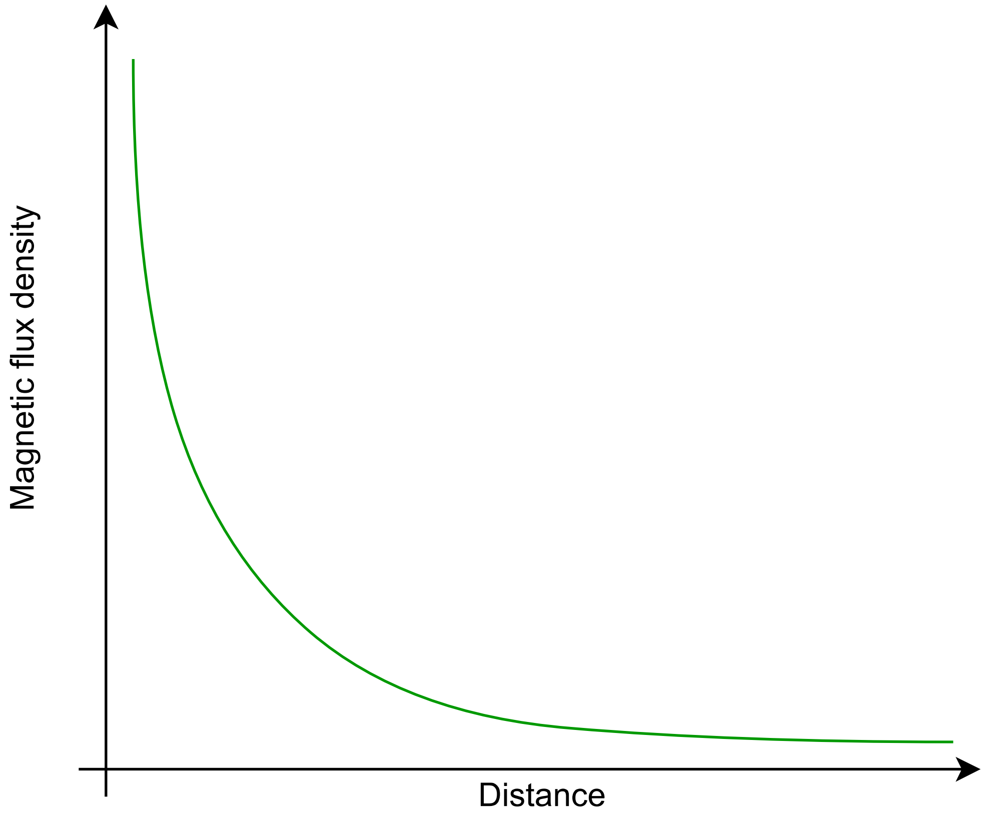

Figure 1.1 Schematic representation of the static magnetic field of a rotor

DANGER!

Electrical shock hazard!

When the rotor rotates inside the stator, an induced voltage is generated.

You may suffer from electrodes if you use a defective cable connector.

- Do not touch the cable connector.
- Connect the stator power cable or isolated the power cable correctly.

DANGER!

Risk of death as a result of strong magnetic fields!

Strong magnetic fields around torque motor systems represents a danger for people with active medical implants, who come close to the motors. This is also the case when the motor is switched off.

- If you are affected, stay a minimum distance of 300 mm from the permanent magnets

DANGER!

Risk of crushing from strong forces of attraction!

There is a risk of crushing from the strong forces of attraction emitted by the rotors and stators, as they are assembled with opposing polarity!

- Assemble the rotors and stators carefully!
- Do not place fingers or objects between the rotors and stators!
- The rotor and magnetizable objects may accidentally attract each other and collide!
- Two rotors may accidentally attract each other and collide!
- The magnetic force of the rotor acting on the object may be as high as several kN, which may cause a certain part of the body to be clamped.
- Do not underestimate the attraction force and operate carefully.
- Wear safety gloves when necessary.
- At least two people are required to cooperate during operation.
- If the assembly steps have not yet reached the installation of the rotor, please place the rotor in a safe and proper place first.
- Never take multiple rotors at once.
- Never place two rotors directly together without any protection.
- Do not bring any magnetizable materials close to the rotor! If the tool must be magnetized, please hold it firmly with both hands and slowly approach the rotor!
- It is recommended to install the rotor immediately after unpacking!
- When installing the stator and rotor, an installation auxiliary device is required to assemble the stator and rotor individually. Please follow the correct method.
- Keep the following tools at hand at any time to release body parts (hands, fingers, feet, etc.) clamped by magnetic force.
  - Hammer made of non-magnetized solid material (about 3Kg)
  - Two wedge blocks composed of non-magnetized materials (wedge-shaped sharp angle 10°~15°, minimum height 50mm).

1.3.8 Wiring precautions

1. Before using the product, carefully read through the specification noted on product label, and ensure the product is used with power supply specified in product requirement.
2. Check if the wiring is correct. Incorrect wiring may make the motor operate abnormally, or even cause permanent damage to the motor.
3. Select extension cord with isolation net. The isolation net must be grounded.
4. Do not connect power cable and temperature sensor cable to the same extension cord.
5. Power cable and temperature sensor cable contain isolation net. The isolation net must be grounded.

1.3.9 Operation precautions

1. Avoid excessive friction when the motor is running.
2. Ensure there is no object in the motion range of the system.
3. Before starting the motor, ensure the water cooling system works properly.
4. Before starting the motor, ensure the main switch is on.
5. Before transmitting electricity, ensure at least one ground wire is connected to all electrical products.
6. Do not directly touch motor parts after motor is assembled.
7. If the current exceeds the maximum specified current, magnetic components in the motor may be demagnetized. When it happens, please contact HIWIN or local distributors.
8. Do not operate the product in an environment that exceeds its rated load.
9. When the motor is running, its temperature must be within the specification.
10. If any abnormal odor, noise, smoke, temperature rise or vibration is detected, stop the motor and turn off the power immediately.
11. Fixed operation environment conditions must comply with EN 60721-3-3 (Please refer Table 1.3 on the next page)

Table 1.3 Operation environment conditions Class 3K3

Environmental parameter	Unit	Value
Air temperature	(℃)	+5~+40
Relative humidity	(%)	5~85
Absolute humidity	(g/m^3)	1~25
Rate of change of temperature 1)	$(℃/min)$	0.5
Air pressure 2)	(kPa)	78.4~106
Solar radiation	(w/m^2)	700
Movement of surrounding air 3)	(m/s)	1
Condensation	-	Not allowed
Formation of ice	-	Not allowed

1) Averaged over a period of time of 5 min.
2) Conditions in mines are not considered. Severity value is different from Class 3k3. (up to 78.4 kPa) (altitudes up to 2000 m).
3) Uncontrollable air flow may affect cooling systems based on natural convection.

Mechanically active substances	Class 3S1
Mechanical conditions	Class 3M3

1.3.10 Maintenance and storage precautions

1. Do not store the product in an inflammable environment or with chemical agents.
2. Store the product in a place without humidity, dust, harmful gases or liquids.
3. Install the product in location with less vibration.
4. The way to clean the product: wipe with alcohol (70%)
5. The way to discard the damaged product: recycle it according to local laws and regulations.
6. Storage conditions must comply with EN 60721-3-1(Refer Table 1.4 on the next page)
7. Motor can be stored for up to two years indoor with the following conditions:
    i. Dry
    ii. Dust-free
    iii. No vibration
    iv. Good ventilation
    v. Resistance to extreme weather
    vi. Indoor air does not contain corrosive gas
    vii. Prevent motor vibration and moisture
8. If no dry storage environment is available, the following measures need to be taken:
    i. Wrap the motor with moisture-absorbing material, and then seal the motor.
    ii. Put desiccant in the sealed package; the desiccant needs to be checked and replaced if necessary.
    iii. Check the motor regularly.
9. After long-term storage and removal of the motor, the insulation resistance value may be reduced due to moisture. Before installing the machine, confirm the insulation resistance state of the motor. Use an inspection instrument that meets EN61557. The test must reach 100MΩ after 60 seconds at 1000V_{DC}. If it does not meet the specifications, the motor may be damp. If it is used directly, it may cause insulation damage. You can dehumidify the motor by yourself. The steps are as follows or please contact HIWIN:
    i. Put the motor in the oven, set the temperature to 70℃ (the maximum temperature should not exceed 80℃), take it out after four hours, and put it at room temperature.
    ii. Measure the insulation resistance, if it does not reach 100 MΩ, repeat the process i (at this time, pay attention to whether the insulation resistance has gradually increased, if it cannot be improved, please contact HIWIN).

Table 1.4 Storage conditions

Environmental parameter	Unit	Value
Air temperature	(℃)	-5~40
Relative humidity	(%)	5~85
Absolute humidity	(g/m^3)	1~25
Rate of change of temperature	$(℃/min)$	0.5
Air pressure	(kPa)	70~106
Solar radiation	(w/m^2)	700
Condensation		Not allowed
Formation of ice		Not allowed
Long-term storage conditions		Refer Class 1K3
Store the motor in an environment with good weather protection. (indoor/factory)		
Biological conditions	Class 1B1	
Chemically active substances	Class 1C1	
Mechanically active substances	Class 1S2	
Mechanical conditions	Class 1M2	

1.3.11 Transport precautions

1. Permanent magnets are listed as Dangerous Goods (Magnetized material: UN2807) according to International Air Transport Association (IATA).
2. For products containing permanent magnets, no additional measures on packaging are required to resist the magnetic field in sea freight and inland transportation.
3. When transporting products containing permanent magnets by air, the maximum permissible magnetic field strengths specified by the appropriate IATA Packing Instruction must not be exceeded. Special measures may be required so that these products can be shipped. Above a certain magnetic field strength, such shipments must be labelled in accordance with Packing Instruction 953 from IATA (Please refer below or the latest regulation from IATA.)
   i. Products whose highest field strength exceeds 0.418 A/m (0.525 μT) or 2° of compass deviation, as determined at a distance of 4.6 m from the product, require shipping authorization from the responsible national body of the country from where the product is being shipped (country of origin) and the country where the airfreight company is based. Special measures need to be taken to enable the product to be shipped.
   ii. When shipping products whose highest field strength is equal to or greater than 0.418 A/m (0.525 μT) or 2° of compass deviation, as determined at a distance of 2.1 m from the product, shipment is conducted with regulation of Dangerous Goods Transportation.
   iii. When shipping products whose highest field strength is less than 0.418 A/m (0.525 μT), as determined at a distance of 2.1 m from the product, you do not have to notify the relevant authorities and you do not have to label the product.
4. Shipping originally packed motor components neither has to be disclosed nor marked.
5. Transport conditions must comply with EN 60721-3-2 (Please refer **Table 1.5** on the next page).

Table 1.5 Transport conditions

<table>
<tr><th>Environmental parameter</th><th colspan="2">Unit</th><th>Value</th></tr>
<tr><td>Air temperature</td><td colspan="2">(℃)</td><td>-5~40</td></tr>
<tr><td>Relative humidity</td><td colspan="2">(%)</td><td>5~85</td></tr>
<tr><td>Rate of change of temperature</td><td colspan="2">(℃/min)</td><td>0.5</td></tr>
<tr><td>Condensation</td><td colspan="2"></td><td>Not allowed</td></tr>
<tr><td>Formation of ice</td><td colspan="2"></td><td>Not allowed</td></tr>
<tr><td>Transport condition</td><td colspan="2"></td><td>Class 2K2</td></tr>
<tr><td colspan="4">Transport the motor in an environment with good weather protection (indoor/factory)</td></tr>
<tr><td colspan="2">Biological conditions</td><td colspan="2">Class 2B1</td></tr>
<tr><td colspan="2">Chemically active substances</td><td colspan="2">Class 2C1</td></tr>
<tr><td colspan="2">Mechanically active substances</td><td colspan="2">Class 2S2</td></tr>
<tr><td colspan="2">Mechanical conditions</td><td colspan="2">Class 2M2</td></tr>
</table>

2. Basic Structure of Motor

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2.1 General view

HIWIN torque motor can get its best performance through water cooling. Bearing, position feedback device and other related parts are excluded from shipment. Basic structure of motor is shown in **Figure 2.1.**

- Stator

  Stator in TMRW/TM-2/IM-2 series does contain water cooling channel. The outer casing is made of aluminum alloy or steel, and the inner part is composed of iron core, coils, covered with epoxy. There are two cable outlets on one side, motor power cable and temperature sensor cable. Stator should be installed on the fixed part of customer’s machine.

- Rotor

  The main structure is a steel ring with evenly attached magnets. Rotor should be installed on the rotating part of customer’s machine. Due to its strong magnetic suction, well protection is needed during assembly and handling. To avoid danger, keep it away from magnetic conductors (e.g. iron objects).

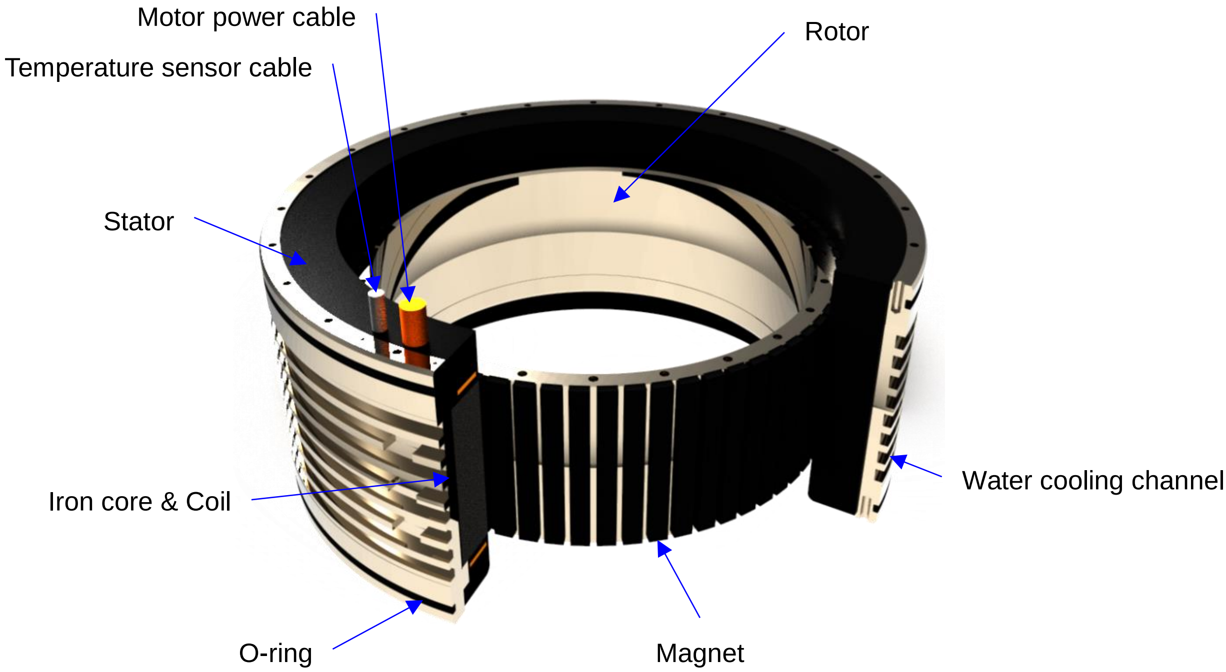


Figure 2.1 Basic structure of torque motor

2.2 Product code

2.2.1 TMRW Series codification

	Motor specification			Function			Characteristic	
	TMRW	**4**	**7**	**L**	**C**	**-**	**X**	**X**

Code	Description
Type:	
TMRW	Torque Motor
External diameter of the stator:	
1	Ø160mm
2	Ø198mm
4	Ø230mm
7	Ø310mm
A	Ø385mm
D	Ø485mm
G	Ø565mm
Rotor (Magnet) height:	
3	30mm
5	50mm
7	70mm
A	100mm
F	150mm
Winding code:	
	Standard
L	Low Back emf
Optional:	
	Standard
C	Customized
Reserved:	
	Standard
XX	Characteristics Code See motor datasheet

2.2.2 TM-2/IM-2 Series codification

Motor specification												Sensor		Cable output			Reserved	
TM	-	2	-	7	5	-	S	D	0	-		0	-	20	V	-	X	X

Type:
TM-2: Torque motor
IM-2 : IM motor

External diameter of the stator:
1 : Ø160mm
2 : Ø198mm
4 : Ø230mm
7 : Ø310mm
A : Ø385mm
D : Ø485mm
G : Ø565mm

Rotor (Magnet) height:
3 :30mm
5 :50mm
7 :70mm
A :100mm
F :150mm

Torque / Speed Characteristics Code
See motor datasheet

Temperature sensor configuration:
0 :PTC130+PTC100+Pt1000 (Standard)
1 :PTC130+PTC100+Pt1000x3
⋮

Cable length:
20 : 2.0m (Standard)
05 : 0.5m
10 : 1.0m
⋮

Cable output style[1]:
S :Straight output
V :Straight output with cable clamp
A :Straight output with cable gland
H :90° output in tangent direction with cable clamp (temp. cable straight output)
P :All cable separate with cable clamp (straight output)
⋮

Reserved:
00 :Standard(without bridge)
03 :Bridge on cable side
⋮

1). Cable output style schematics refer to **Figure 2.2**

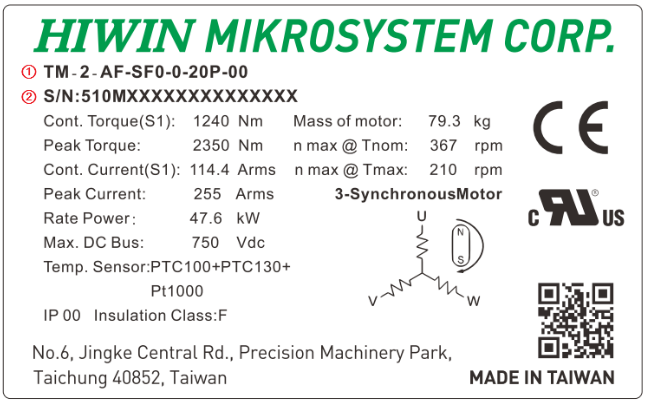
S :Straight output	V :Straight output with cable clamp
	
A :Straight output with cable gland	H :90° output in tangent direction with cable clamp (temp. cable straight output)
	
P :All cable separate with cable clamp (straight output)	Note: The style shown above is schematic diagram, and the shape may be modified in case of design purpose.
	

Figure 2.2 Cable output style

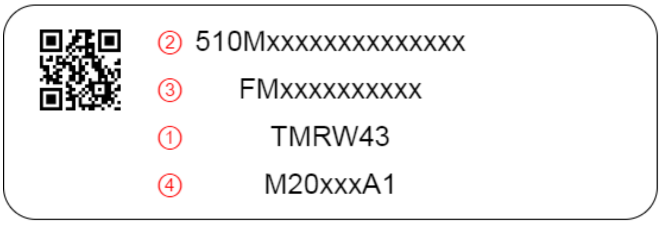
2.3 Logistics Content

Each rotor and stator has the specific mark. 2 name labels and 3 simple labels and 2 O-rings are delivered in the package. And have one magnetic warning sign on the rotor. Here is an example of these labels:

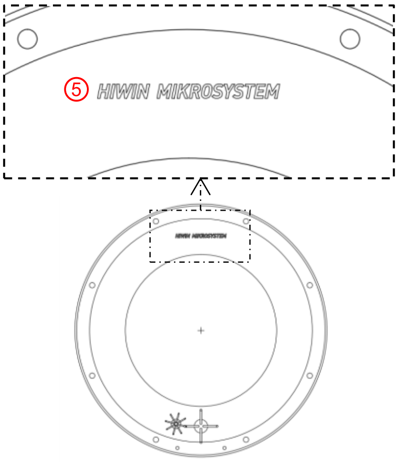
Name label



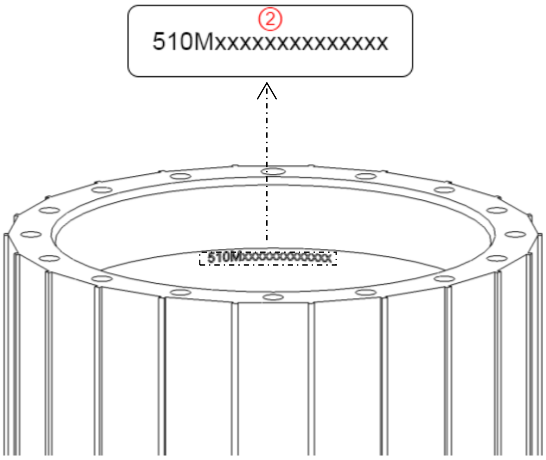
Simple label



Stator mark



Rotor label



① ︰Motor type
② ︰Serial number
③ ︰Article number
④ ︰Drawing number
⑤ ︰Laser engraving trademark

Magnetic warning sign

3. Configuration

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3.1 Torque motor selection

The way to select a suitable motor based on speed, moving distance, and loading inertia is described in the following contents. The basic process for sizing a motor is as below.

Requirement

- Operating environment
- Installation (horizontal or vertical)
- Driving method
- Load conditions (loading inertia, friction and cutting force)
- Speed condition (maximum acceleration and velocity)
- Duty cycle

↓

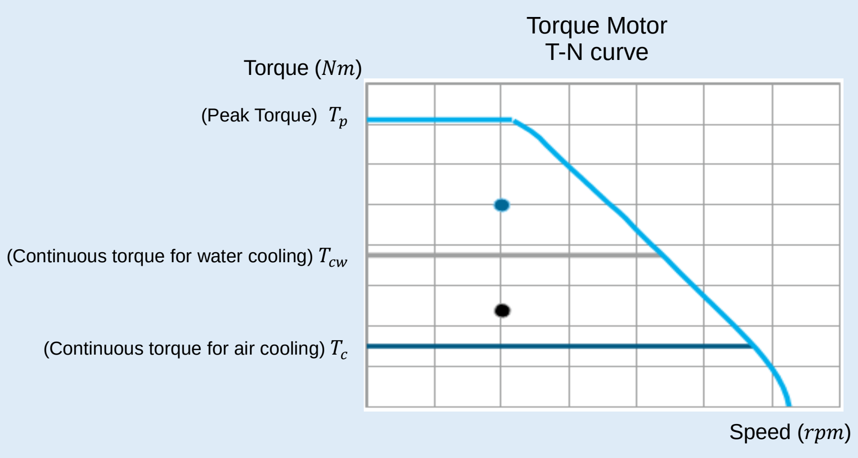
Torque calculation

- Calculate the torque corresponding to the speed under each operation condition
- Calculate equivalent torque

↓

Motor sizing and T-N curve confirmation

- Select the appropriate motor from HIWIN's catalogue in accordance with calculated maximum torque, equivalent torque and speed.
- Ensure the speed and the corresponding torque under all operating conditions are within the range of torque-speed curve of the motor.
- Confirm the equivalent torque is within the continuous torque of the motor.



■ Symbol

φ	Angular displacement (rad)	I_p	Peak current (A_{rms})
t	Moving time (sec)	I_e	Equivalent current (A_{rms})
α	Angular acceleration (rad/s^2)	I_c	Continuous current (A_{rms})
ω	Angular velocity (rad/s)	ω_0	Initial angular velocity (rad/s)
J_L	Load inertia (kgm^2)	m	Loading Mass (kg)
J	Rotor inertia (kgm^2)	R_L	Outside diameter of loading Mass (m)
T_p	Peak torque (Nm)	r_L	Inside diameter of loading Mass (m)
T_c	Continuous torque (Nm)	a_L 、 b_L	Side length of loading Mass (m)
T_i	Inertia torque (Nm)	S	Distance from gravity center to rotary center (m)
K_t	Torque constant (Nm/A_{rms})		

STEP 1 Requirement

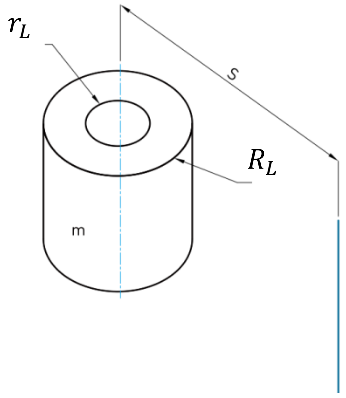
To select a proper motor, the following formula of load inertia and motion must be understood before selection.

Calculation of load inertia

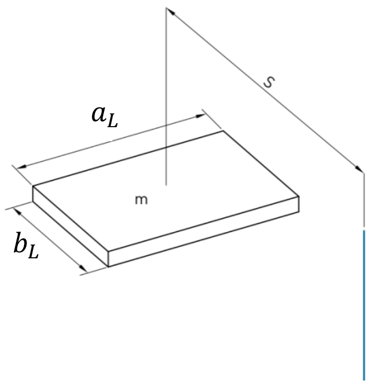
Load inertia can be determined by 3D drawing software or the formula. Basic formula is as below.

moment of inertia of a hollow cylinder: $J_L = m\left(\frac{R_L+r_L}{2} + S^2\right)$

moment of inertia of a rectangular: $J_L = m\left(\frac{a_L+b_L}{12} + S^2\right)$



rotary center



rotary center

Determine motion speed and parameters

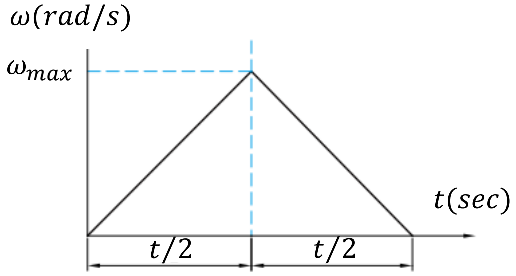
Basic kinematics equations are described as below.

$\omega = \omega_0 + \alpha t \qquad \varphi = \omega_0 t + \frac{1}{2}\alpha t^2$

Where ω is angular velocity, α is angular acceleration, t is moving time and φ is angular displacement. Users can choose two of the four parameters (ω, α, t and φ) as designed parameters. The left two parameters can be calculated by above equations.

※ Motion velocity profile

Motion profiles for torque motor can be classified into "Trapezoidal profile" and "Triangular profile". Trapezoid profile is usually used in scanning applications. Its motion profile can be divided into acceleration, constant velocity and deceleration. The maximum angular acceleration can be determined by the basic kinematics equations mentioned above. Triangle profile is usually used in point-to-point applications. Its motion profile can be divided into acceleration and deceleration, and its motion profile and formula can be simplified as below.



$$\omega_{max} = 2 \times \frac{\varphi}{t} \text{ 或 } \omega_{max} = \sqrt{\alpha \times \varphi}$$

$$\alpha_{max} = \frac{4\varphi}{t^2}$$

STEP 2 Torque calculation

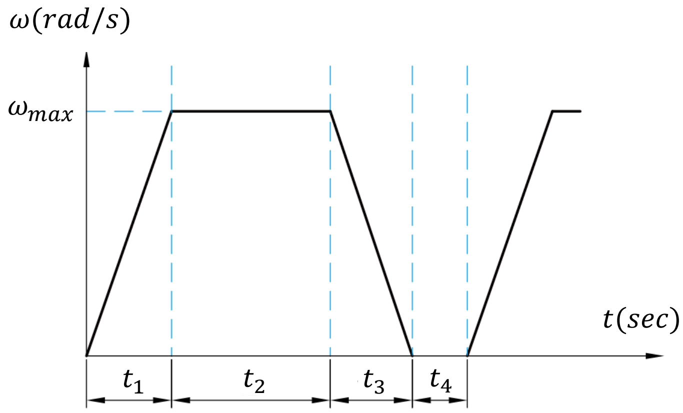
The maximum torque can be calculated by the following equation.

$$T_{max} = (J + J_L) \times \alpha_{max} + T_f = T_i + T_f$$

Where T_i is inertia torque, T_f is the torque caused by friction torque, cutting force or external force.

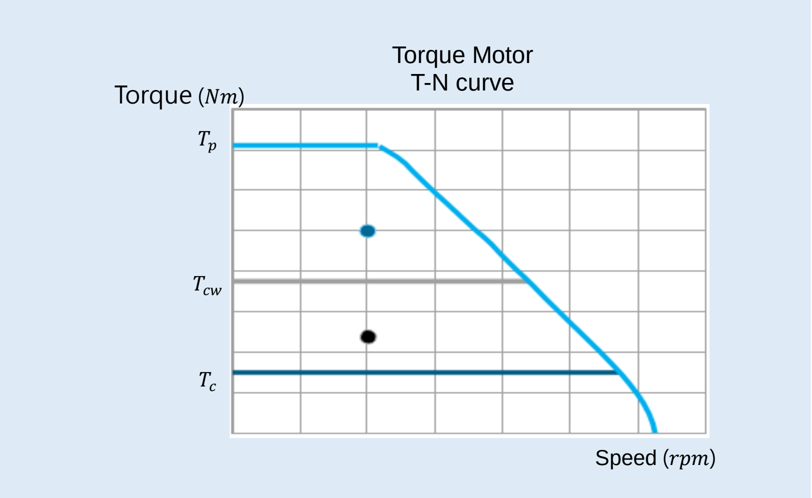
In most cases, the motions are cyclic point-to-point movements. The equivalent torque of a cyclic motion with a dwell time of t_4 second can be calculated as below.

$$T_e = \sqrt{\frac{(T_i+T_f)^2 \times t_1 + T_f^2 \times t_2 + (T_i - T_f)^2 \times t_3}{t_1+t_2+t_3+t_4}}$$



STEP 3 Motor sizing and T-N curve confirmation

With the help of HIWIN's motor specification, users can select the appropriate motor from peak torque and equivalent torque, and ensure speed and torque under all operating conditions is within the range of the motor's T-N curve.



Motor sizing is determined as follows.

$T_{max} < T_p$

$T_e < T_c$

Users need to consider the ratio of equivalent torque and continuous torque. Generally, the ratio (T_e/T_c) is recommended to be within 0.7. Continuous torque for TMRW/TM-2/IM-2 series can be classified into air cooling and water cooling. If the motor is operated with water cooling, the water cooling continuous torque can be taken as the guideline for comparison.

Note:

The torque-speed curve provided in the specification is for a specific voltage, regardless of the speed limit of the bearing and the position feedback system. The customer should also set the maximum speed limit of the overall mechanism when sizing to avoid bearing life or position feedback system failure result in abnormal operation or damage of the motor.

3.2 Thermal calculation

3.2.1 Heat loss

When the motor converts electric energy into kinetic energy, copper loss, iron loss and mechanical loss are inevitable. Copper loss is the loss generated by the resistance when the current flows through the stator coil of the motor. Iron loss, which can be classified into hysteresis loss and eddy current loss, is generated by the conversion of the magnetic field between stator iron core and rotor magnet. As for mechanical loss, it is generally much less than copper loss and iron loss; therefore, it can be ignored.

Copper loss under continuous torque is calculated as below.

$$P_c = \frac{3}{2} R_{25}\{1 + [0.00393(\theta_c - 25)]\} I_c^2$$

P_c=copper loss at coil temperature θ_c $[W]$
R_{25}= line-to-line resistance at coil temperature 25℃ $[\Omega]$
I_c=continuous current at coil temperature θ_c $[A_{rms}]$
θ_c= coil temperature [℃] (120℃ for TMRW series, 130℃ for TM-2/IM-2 series)

Iron loss is mainly caused by the change of magnetic flux during the commutation process and is influenced by the frequency a lot. Since rotational speed is directly proportional to frequency, iron loss will be larger at high speed. However, rotational speed for HIWIN torque motor is low, so iron loss is relatively less than copper loss. Rotational speed value indicated by HIWIN drawing and specification is the maximum peak speed that the motor can reach. Under the continuous operation of high speed, iron loss must calculate extra heat given to rotor. At this time, motor loss increases rapidly. To avoid overheating, users need to appropriately adjust operating conditions or apply heat dissipation on rotor.

Iron loss is mainly generated by eddy current and frequency. The faster the speed is, the more the iron loss will be.

$$P_{Fe} \propto f^2$$

P_{Fe}= iron loss $[W]$
f = frequency $[Hz]$

Definition of frequency：

$$f = \frac{n \cdot p}{60}$$

n = rotational speed $[rpm]$
p = Number of poles pair

Heat loss mainly transmits the loss of coil and iron core to motor outer casing via heat conduction. Take natural air cooling for example. Lost heat source will be transmitted from the surface of outer casing contacted by the air to external environment via heat convection, and from the customer’s installation surface via heat radiation and heat conduction. As for water cooling, lost heat source will be transmitted from center of heat source to cooling water via heat conduction. Since the heat-conduction coefficient of cooling water is much higher than that of air, the effect that heat source transmits to the air via convection can be ignored. TMRW series is available to either water cooling or air cooling while TM-2 and IM-2 series are mainly available to water cooling. Ensure parameters you use fit the specification, and keep coil temperature from exceeding 120℃. (for □M-2 is 130℃). Please contact HIWIN for other applications.

3.2.2 Continuous operating temperature

Steady state temperature of motor coil is determined by the proportion of copper loss and iron loss. When rotational speed is low, iron loss may not be considered. Both total loss and rated continuous torque (T_c) are defined when coil temperature is 120℃. When equivalent torque (T_e) is less than rated continuous torque (T_c), steady state temperature of motor coil under various operating conditions can be known by the following formula.

When operating current is lower than rated current ($I_{eff} < I_c$), the relationship between temperature and torque is as below.

$$\theta_e = \theta_{surr} + \left(\frac{T_e}{T_c}\right)^2 (\theta_c - 25)$$

θ_e= steady state temperature of coil under equivalent torque [℃]
θ_{surr}= ambient temperature [℃] (ambient temperature for air cooling / water temperature for water cooling)
T_e= equivalent torque under actual operation [Nm] (when coil temperature is θ_e)
T_c= rated continuous torque [Nm] ((when coil temperature is θ_c)

3.3 Thermal time constant

The temperature of the coil of the motor is related to the thermal time constant during operation. The thermal time constant is defined as the time required for the temperature difference to reach 63.2% of the difference between the steady-state temperature and the initial temperature (**Figure 3.1**). The time to reach the thermal steady-state is about 5 times the thermal time constant.

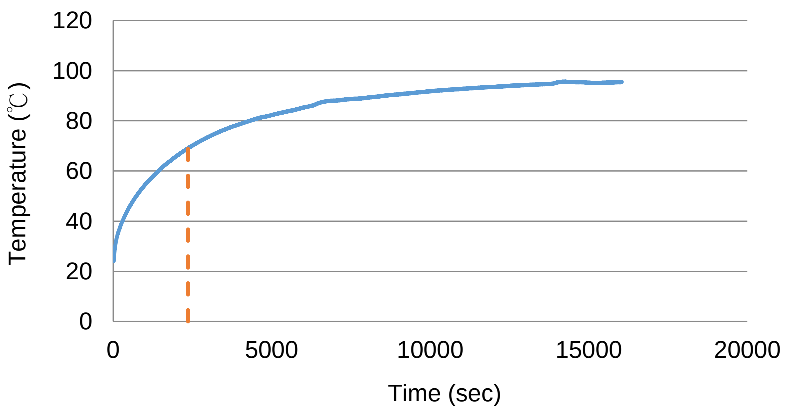


Figure 3.1 Curve of temperature rising

The relationship between thermal time constant and temperature is

$$\theta(t) = \theta_i + (\theta_c - \theta_i) \cdot \left(1 - e^{-\left(\frac{t}{\tau_{th}}\right)}\right)$$

$\theta(t)$= coil temperature [℃] (at the operating time t)

θ_i= initial coil temperature [℃]

t= operating time [sec]

τ_{th}= thermal time constant [sec]

When operating current is between rated current and peak current ($I_c < I_e < I_p$), power off time should be set to cool the motor. The thermal time constant mentioned above can be applied to calculate the time for load cycle. Refer to Section 3.2 to get steady state temperature of coil under equivalent torque(θ_e)through equivalent torque under actual operation(T_e). Then, get the relative maximum operating time via the following formula.

The relationship between steady state temperature of coil under equivalent torque (θ_e) and maximum operating time is

$$t_0 = -\tau_{th} \cdot ln\left(1 - \frac{\theta_c - \theta_i}{\theta_e - \theta_i}\right)$$

t_0= maximum operating time [sec]

Note: Coil temperature (θ_c) here cannot exceed the specification's upper limit. (120℃ for TMRW series,130 ℃ for TM-2/IM-2)

The relationship between coil temperature and power off time is

$$t_b = -\tau_{th} \cdot ln\left(1 - \frac{\theta(t_b) - \theta_c}{\theta_{surr} - \theta_c}\right)$$

$\theta(t_b)$= coil temperature to be cooled [℃] (after power off time t_b)

t_b= power off time [sec]

The time allocation of load cycle during motor operation can be determined by the two formulas above

3.4 Power supply and controller selection

The continuous current, peak current and bus voltage must be considered while selecting a power supply. In addition, the resonance effect which can be induced in motors by some drive systems must be taken into account. Motors are assembled with several individual coils connected in series. Each one of these coils has an inductance in series and a stray capacitance to earth. The LC network obtained possesses a resonant frequency, so when an electrical oscillation is applied to the phase inputs (in particular the PWM frequency), the neutral point of the motor can oscillate with very high amplitudes with respect to earth, and the insulation can be damaged as a consequence of these oscillations. This phenomenon is more pronounced in motors with a large number of poles (such as torque motors).

Under ideal conditions, the 600V_{DC} bus voltage generated by the power supply should be ±300V_{DC} relative to earth. However, in some configurations, the voltage between the buses and earth will have an oscillating voltage, and the peak of the high voltage will be transmitted to the motor. The oscillation between voltage and earth depends on system characteristics. By experience, a system with few axes connected to the bus voltage is less liable to have disturbing oscillations on the bus, but for example in a large machine tool with many axes and several spindles, the oscillations can reach high amplitudes. If the frequency of these oscillations is close to the resonant frequency of the motor, it can lead to over-voltage failures on the neutral point.

The case where the PWM frequency of the controller happens to correspond to the resonant frequency of the motor. In this case, the fundamental harmonic of the PWM frequency is directly exciting the resonant frequency of the motor, and very high voltages are thus obtained on the neutral point. Also, as the PWM voltage is a square wave, it contains odd harmonics (1, 3, 5, 7, etc..) that can also excite the motor resonance. Fortunately, these harmonics have a smaller amplitude that the fundamental.

In another case, it may also lead an over-voltage failure. In this case, the fundamental harmonic of the PWM frequency is directly exciting the resonant frequency of the motor, and very high voltages are thus obtained on the neutral point. In addition, because the PWM voltage is a square wave, it contains odd harmonics (1, 3, 5, 7, etc.) that can also excite motor resonance.

In conclusion, to prevent any failure from occurring, two elements must be considered: the oscillations between the bus voltage and earth and the PWM frequency. If both elements above do not enter into resonance with the motor, then there is no risk for the motor.

When selecting power supply, please check the conditions below:

Peak voltages and dV/dt gradients generated by the power supply must not exceed the values below:

- 300 V_{DC} controllers: 750 V_p(phase to ground), voltage gradient: $8kV/\mu s$.
- 600 or 750 V_{DC} controllers: 800 V_p maximum (at the PWM frequency) and spikes up to 1400 V (earth to peak and for a few μs) and a voltage gradient: 11 $kV/\mu s$.

The cable between the controller and the motor will generate a reflected wave due to the impedance mismatch between the cable and the motor, and the reflected voltage will be superimposed with the subsequent input voltage, causing the voltage to rise. This phenomenon will be more obvious when the motor cable is longer. If the length of the cable between the controller and the motor is longer than 10 m, it is necessary to measure voltages at the motor terminals to ensure they are lower than specified above. If the measured value is greater, a dV/dt filter must be inserted between the controller and the motor for protection.

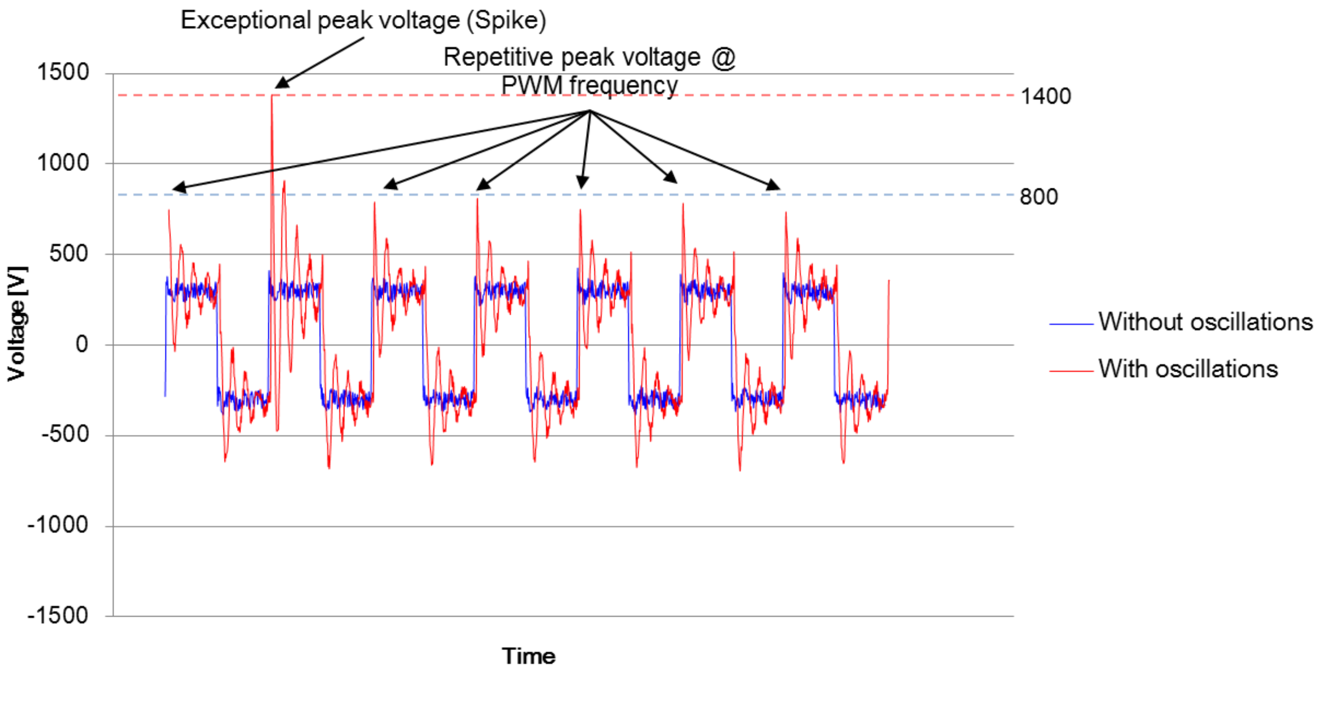


Figure 3.2 Voltage oscillation schematic (600/750 V_{DC} controller)

3.5 Water cooling system calculation

The features of motor indicated in HIWIN torque motor drawing and specification are suitable for water cooling condition, and coolant temperature is 20℃. Taking oil as coolant is also acceptable. Just properly modify the performance of motor based on the features of coolant. The cooling condition indicated in specification: coil temperature should be less than 120℃(130℃ for □M-2) when motor stator continuously operates under continuous torque. If equivalent torque of actual operation is lower than continuous torque indicated in specification, reduce cooling water flow to avoid consuming excess pump. The cooling condition can be properly adjusted based on the following formulas.

Adjust the boundary conditions of water cooling system according to the motor power loss:

When equivalent torque is lower than continuous torque ($T_e < T_c$), get the corresponding coolant flow from the following formulas.

$$P_e = \frac{p_c}{\left(\frac{T_c}{T_e}\right)^2}$$

$$P_e = 69.7 \cdot q_e \cdot \Delta\theta$$

P_e= Total loss of motor under equivalent torque $[W]$

$\Delta\theta$ = Temperature difference between motor inlet and outlet [℃]

q_e= Coolant flow$[l/min]$ (under equivalent torque)

Pressure difference between inlet and outlet (ΔP_{eff}) is related to coolant flow (q)

$$\Delta P_{eff} = \Delta P \cdot \frac{q_e}{q}$$

ΔP_{eff}= Pressure difference between inlet and outlet [bar] (under equivalent torque)

ΔP = Pressure difference between inlet and outlet [bar] (in datasheet)

q = Coolant flow [l/min] (n datasheet)

- **Example**

In model type TMRWAF's specification, the continuous torque (T_c) water cooling condition is 1290 Nm, power loss (P_c) is 8262 W, coolant flow(q) is 23.7 l/min, pressure difference between inlet and outlet(ΔP) is 3 bar. If the used continuous toque is only 600 Nm and the temperature difference between inlet and outlet should be 6℃, what is the coolant flow (q_e) and the pressure difference between inlet and outlet (ΔP_{eff}) in cooling water system? [$v_{water} = 10^{-3}(m^3/kg)$]

$$P_e = \frac{p_c}{\left(\frac{T_c}{T_e}\right)^2} = \frac{8262}{\left(\frac{1290}{600}\right)^2} = 1787(W)$$

$$1787 = 69.7 \times q_e \times 6$$

$$q_e = 4.27(l/min)$$

$$\Delta P_{eff} = \Delta P \cdot \frac{q_e}{q} = 3 \times \frac{4.27}{23.7} = 0.54(bar)$$

The differences between datasheet parameters and user parameters are listed in the following **Table 3.1**.

Table 3.1 Difference between datasheet parameter and user parameter

Parameter (under water cooling condition)	Datasheet	User
Torque (T)	1290 Nm	600 Nm
Power loss (P)	8262 W	1787 W
Temperature difference between inlet and outlet ($\Delta\theta$)	5℃	6℃
Coolant flow (q)	22 l/min	4.27 l/min
Pressure difference between inlet and outlet (ΔP)	3 bar	0.54 bar

3.6 Coolant selection

Coolant needs to be prepared by the user. Anti-corrosion coolant needs to be used for HIWIN torque motor. The design and performance test of HIWIN torque motors are based on pure water. If customers use oil as the coolant, the heat that can be taken away by the same flow rate will be reduced and so will the motor power, otherwise the flow rate should be increased to keep the motor power. Please contact HIWIN for related information.

The coolant must be processed and filtered in advance to avoid blocking the cooling channel. The maximum allowable size of particles in the coolant is 100 microns, and it must not freeze. If untreated water is used, it may cause failure or damage due to deposition, algae growth or formation of slime, and corrosion, such as: reduced thermal conductivity, pressure loss due to cross-sectional area reduction, and blockage of various components. And for water quality, at the least the following requirements must be met:

1. Chloride and sulfate must be less than 100 ppm.
2. The solute of mineral salt must be less than 2000 ppm.
3. 6.5≦pH≦9.5

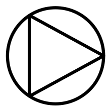
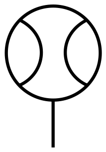
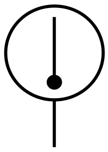
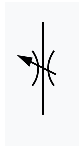
If an anti-corrosion agent is added (the basic raw material is Ethylene Glycol Monoethyl Ether), it must not react with water and the freezing point must be at least -5℃. The anti-corrosion agent must be compatible with the connectors and the materials in the cooling system including the O-ring of the motor. Please confirm with the supplier of the agent! It is generally recommended that the concentration should not exceed 50%.

Apart from oil, adding various solvents to water will also cause its specific heat capacity (C_p) to decrease (please confirm the features with the supplier). It is necessary to reduce the motor power accordingly. For example, when using Glycol as an additive, please refer to the **Table 3.2** below:

Table 3.2 The specific heat capacity of Ethylene Glycol based water solutions at various temperatures

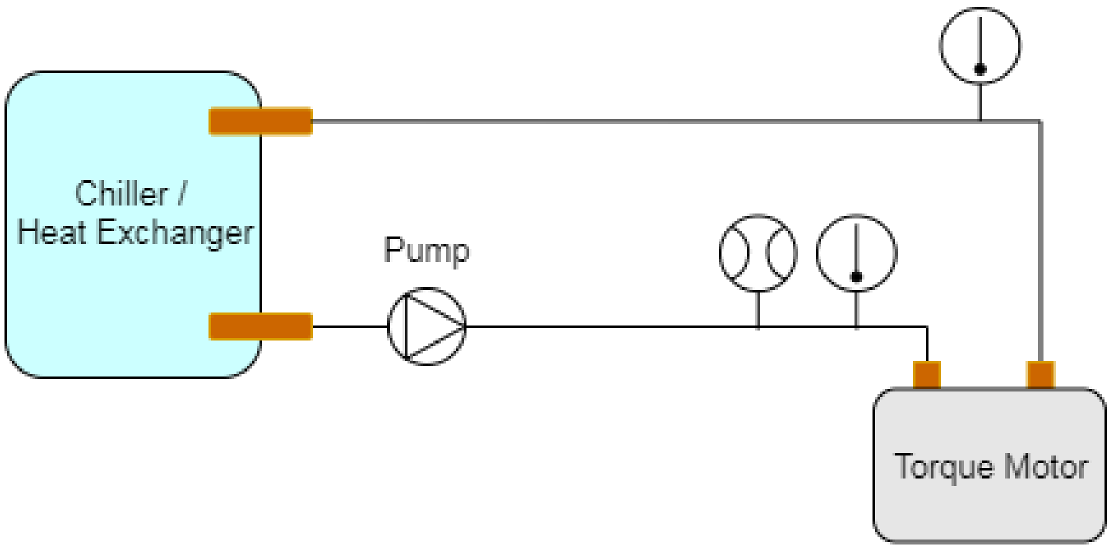
	Specific heat capacity C_p $(KJ/kg\ K)$			
Concentration of Ethylene Glycol (Weight %)	Temperature			
	0℃	10℃	20℃	30℃
0	4.203	4.195	4.189	4.185
10	4.071	4.079	4.087	4.096
20	3.918	3.935	3.951	3.968
30	3.764	3.807	3.807	3.828
40	3.595	3.647	3.647	3.674
50	3.412	3.473	3.473	3.504

3.7 Water coolant diagram

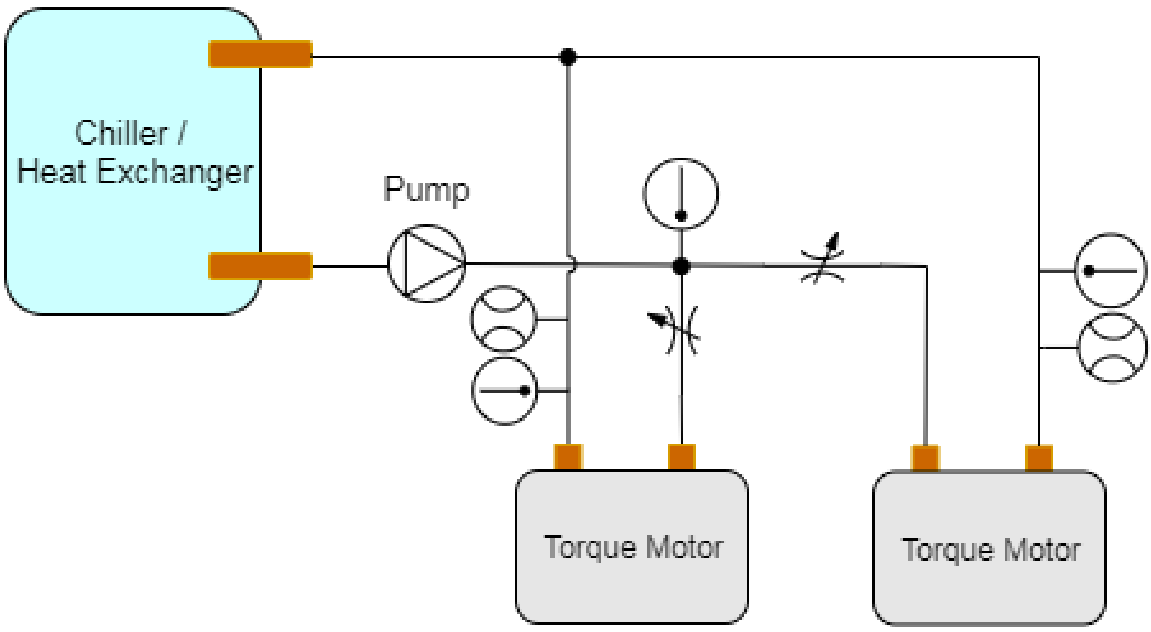
	Pump		Flow Indicator		Thermometer		Flow control (Adjustable)

This section shows simple schematic water cooling diagram:

a. Single torque motor

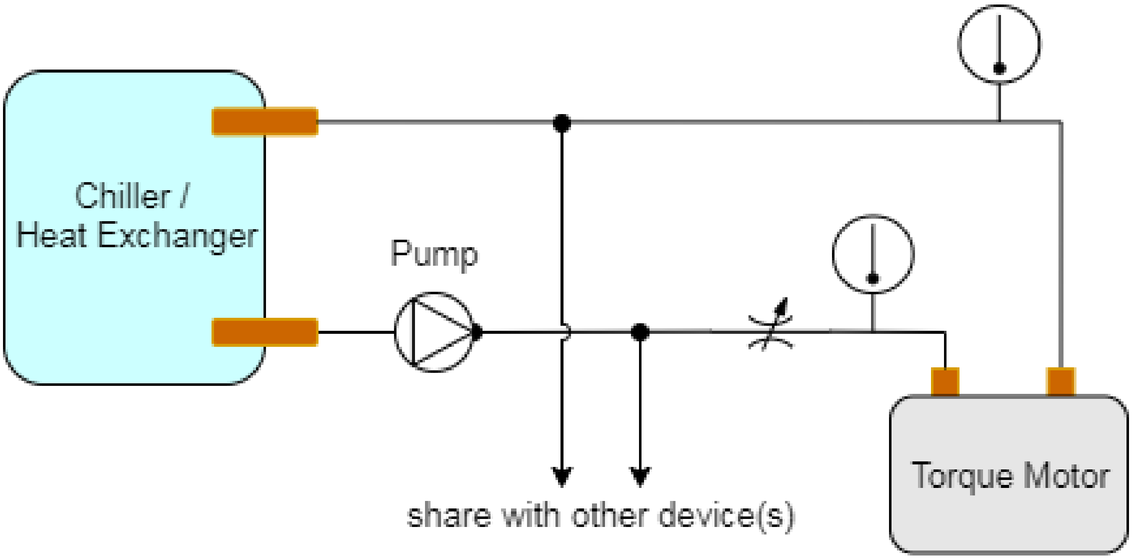


b. Parallel operation



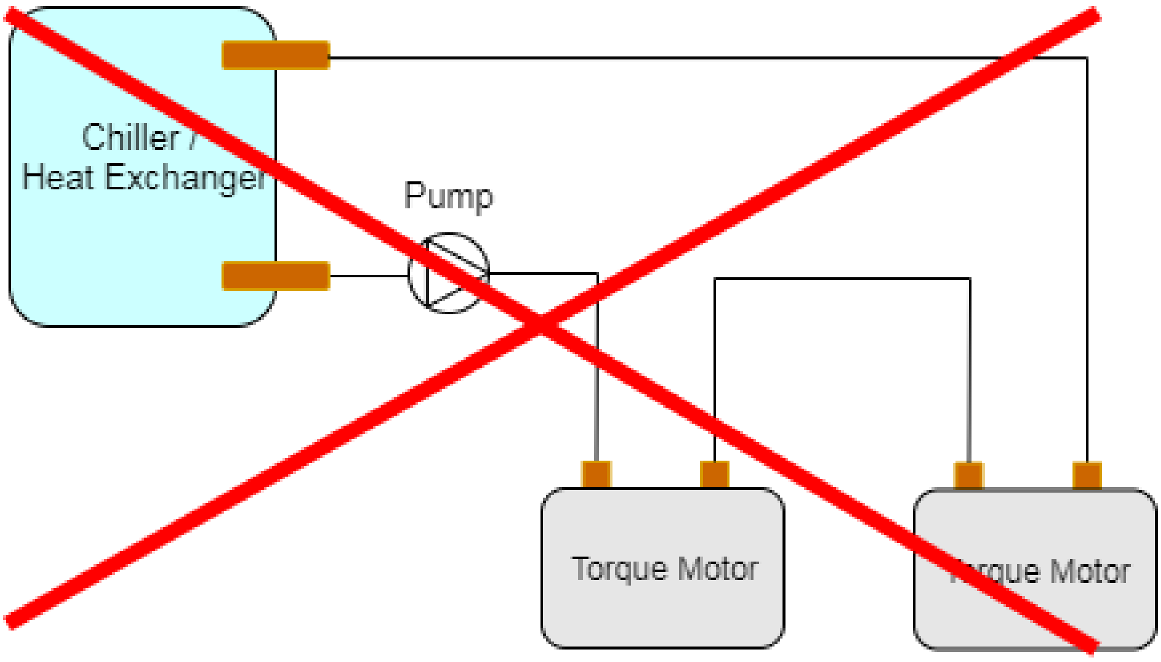
c. Share with other device(s)

In any case, sharing flow with other device should be monitor flow and control it.



d. Serial Circuit

Never do serial circuit!



4. Motor Interface Design

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4.1 Water cooling design

HIWIN torque motor can be cooled by water or air. (TM-2 and IM-2 are only available with water-cool) Water cooling channel is designed on the outer case of stator. O-ring is installed outside the water cooling channels as a leak-proof device. To ensure a good circulation of the coolant for cooling, the design coolant inlet and outlet must be aligned with position on the approved drawing.

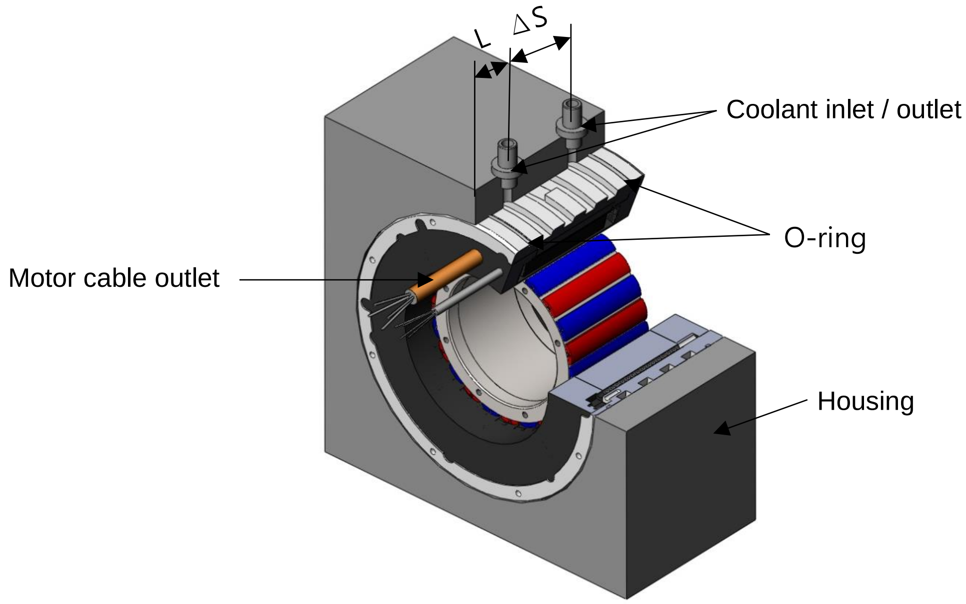


Figure 4.1 Basic structure of HIWIN torque motor

4.1.1 Water cooling channel position

The recommended coolant inlet / outlet position for each series is given as below.

Table 4.1 TMRW series coolant inlet / outlet position

L (mm)	ΔS (mm)				
	20	40	60	90	140
25	TMRW13(L) TMRW43(L)	TMRW15(L) TMRW45(L)	TMRW17(L) TMRW47(L)	TMRW1A(L) TMRW4A(L)	TMRW1F(L) TMRW4F(L)
30	TMRW23(L)	TMRW25(L)	TMRW27(L)	TMRW2A(L)	TMRW2F(L)
35	TMRW73(L) TMRWA3(L)	TMRW75(L) TMRWA5(L)	TMRW77(L) TMRWA7(L)	TMRW7A(L) TMRWAA(L)	TMRW7F(L) TMRWAF(L)
43	TMRWD3(L)	TMRWD5(L)	TMRWD7(L)	TMRWDA(L)	TMRWDF(L)
35	TMRWG3(L)	TMRWG5(L)	TMRWG7(L)	TMRWGA(L)	TMRWGF(L)

Table 4.2 TM-2/IM-2 series coolant inlet / outlet position

L (mm)	ΔS (mm)				
	20	40	60	90	140
25	□M-2-13 □M-2-43	□M-2-15 □M-2-45	□M-2-17 □M-2-47	□M-2-1A □M-2-4A	□M-2-1F □M-2-4F
30	□M-2-23	□M-2-25	□M-2-27	□M-2-2A	□M-2-2F
35	□M-2-73 □M-2-A3	□M-2-75 □M-2-A5	□M-2-77 □M-2-A7	□M-2-7A □M-2-AA	□M-2-7F □M-2-AF
43	□M-2-D3	□M-2-D5	□M-2-D7	□M-2-DA	□M-2-DF
35	□M-2-G3	□M-2-G5	□M-2-G7	□M-2-GA	□M-2-GF

4.1.2 Water cooling channel dimension

Water cooling channel dimension for each series is given in the following table.

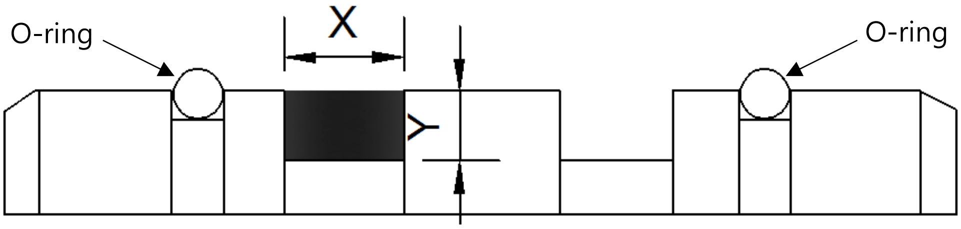


Figure 4.2 Water cooling channel dimension diagram

Table 4.3 TMRW series cooling channel dimension

Type	X (mm)	Y (mm)	Inlet / Outlet inside diameter (mm)	Type	X (mm)	Y (mm)	Inlet / Outlet inside diameter (mm)
TMRW13(L)	8	5	8	TMRWA3(L)	8	5	8
TMRW15(L)	8	5	8	TMRWA5(L)	8	5	8
TMRW17(L)	9	5	8	TMRWA7(L)	9	5	8
TMRW1A(L)	8	5	8	TMRWAA(L)	8	5	8
TMRW1F(L)	9	5	8	TMRWAF(L)	9	5	8
TMRW23(L)	8	5	8	TMRWD3(L)	8	5	8
TMRW25(L)	8	5	8	TMRWD5(L)	8	5	8
TMRW27(L)	9	5	8	TMRWD7(L)	9	5	8
TMRW2A(L)	8	5	8	TMRWDA(L)	8	5	8
TMRW2F(L)	9	5	8	TMRWDF(L)	9	5	8
TMRW43(L)	8	5	8	TMRWG3(L)	8	5	10
TMRW45(L)	8	5	8	TMRWG5(L)	8	5	10
TMRW47(L)	9	5	8	TMRWG7(L)	9	5	10
TMRW4A(L)	8	5	8	TMRWGA(L)	8	5	10
TMRW4F(L)	9	5	8	TMRWGF(L)	9	5	10
TMRW73(L)	8	4	8				
TMRW75(L)	8	4	8				
TMRW77(L)	9	4	8				
TMRW7A(L)	8	4	8				
TMRW7F(L)	9	4	8				

Note: The water cooling inlet and outlet mentioned above must have the smallest inner diameter to ensure the minimum water flow given in the datasheet. The maximum pressure that HIWIN torque motors can withstand is 10 bar.

Table 4.4 TM-2/IM-2 series cooling channel dimension

Type	X (mm)	Y (mm)	Inlet / Outlet inside diameter (mm)	Type	X (mm)	Y (mm)	Inlet / Outlet inside diameter (mm)
□M-2-13	8	5	8	□M-2-A3	8	6	8
□M-2-15	8	5	8	□M-2-A5	8	6	8
□M-2-17	9	5	8	□M-2-A7	9	6	8
□M-2-1A	8	5	8	□M-2-AA	8	6	8
□M-2-1F	9	5	8	□M-2-AF	9	6	8
□M-2-23	8	5	8	□M-2-D3	8	5	8
□M-2-25	8	5	8	□M-2-D5	8	5	8
□M-2-27	9	5	8	□M-2-D7	9	5	8
□M-2-2A	8	5	8	□M-2-DA	8	5	8
□M-2-2F	9	5	8	□M-2-DF	9	5	8
□M-2-43	8	5	8	□M-2-G3	8	5	10
□M-2-45	8	5	8	□M-2-G5	8	5	10
□M-2-47	9	5	8	□M-2-G7	9	5	10
□M-2-4A	8	5	8	□M-2-GA	8	5	10
□M-2-4F	9	5	8	□M-2-GF	9	5	10
□M-2-73	8	4	8				
□M-2-75	8	4	8				
□M-2-77	9	4	8				
□M-2-7A	8	4	8				
□M-2-7F	9	4	8				

Note: The water cooling inlet and outlet mentioned above must have the smallest inner diameter to ensure the minimum water flow given in the datasheet. The maximum pressure that HIWIN torque motors can withstand is 10 bar.

4.1.3 Water cooling channel configuration

■ **Mounted horizontally**

No matter motor cable outlet is facing upward or downward, coolant outlet should be above and coolant inlet should be below. (Defined by the direction of gravity.) Besides, coolant inlet and outlet must be aligned with motor cable outlet (refer to HIWIN approved drawing for motor cable outlet position).

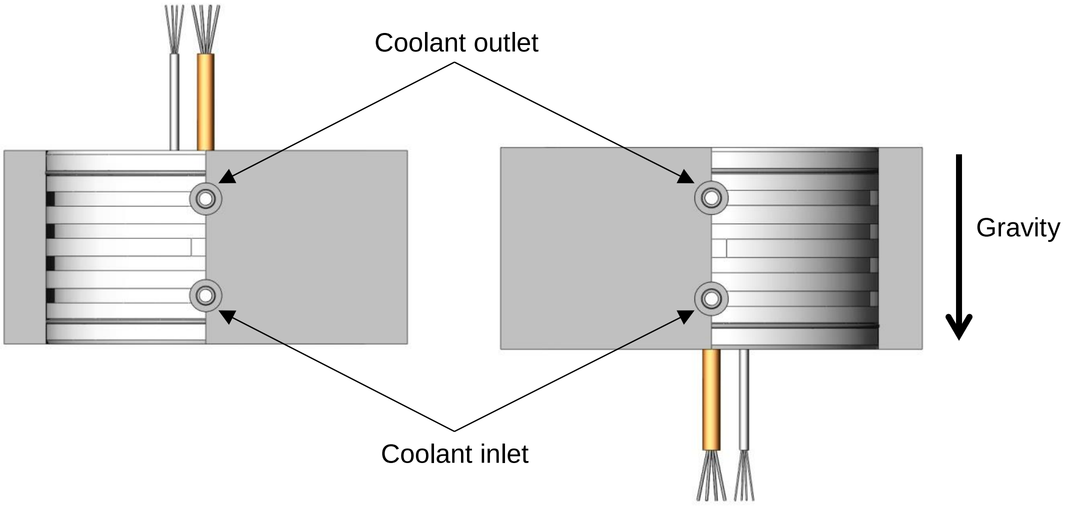


Figure 4.3 Coolant inlet / outlet position when mounted horizontally

■ **Mounted vertically**

Customers can decide coolant inlet / outlet direction. Coolant inlet and outlet must be aligned with motor cable outlet (refer to HIWIN approved drawing for motor cable outlet position).

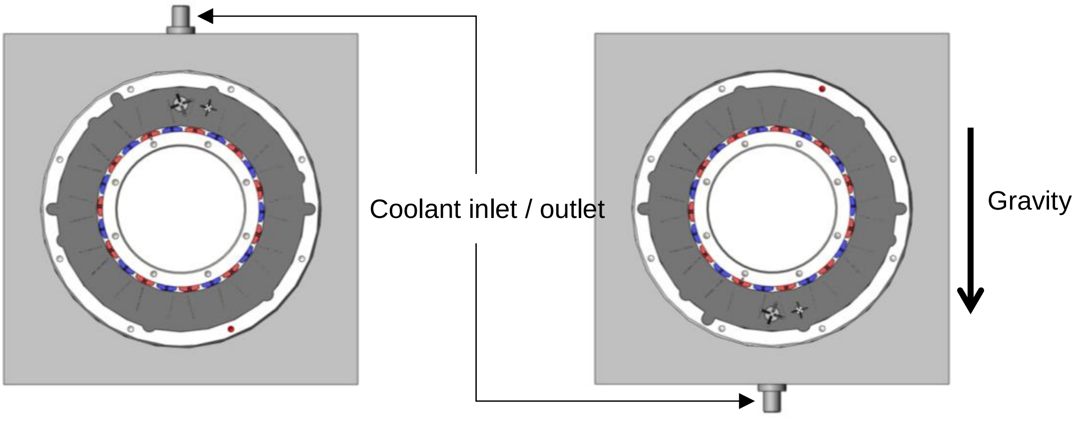


Figure 4.4 Coolant inlet / outlet position when mounted vertically

4.1.4 O-ring features

O-ring features for each series are given in the following **Table 4.5**.

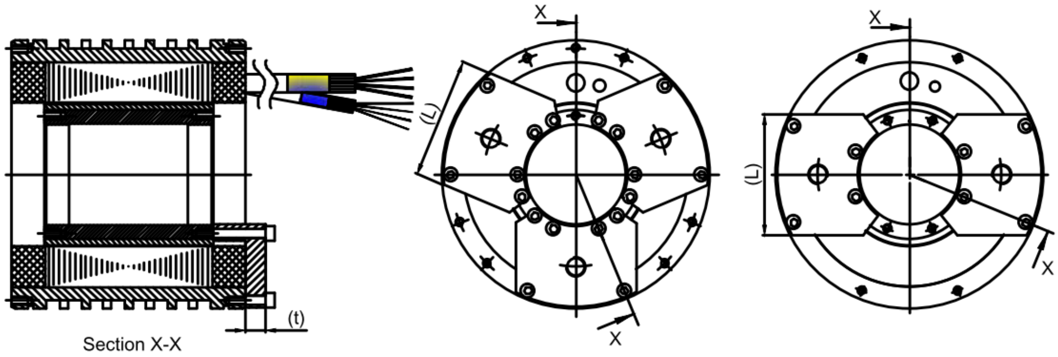
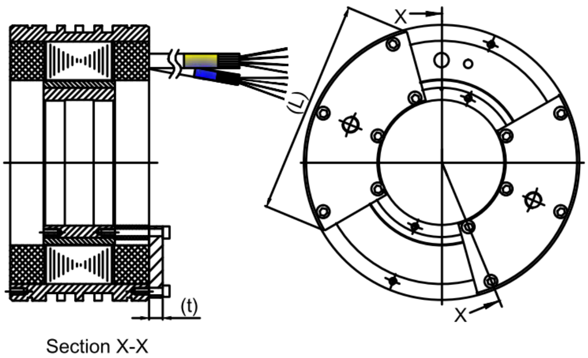
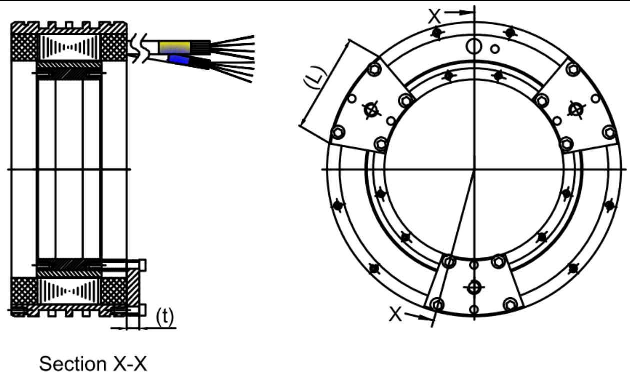
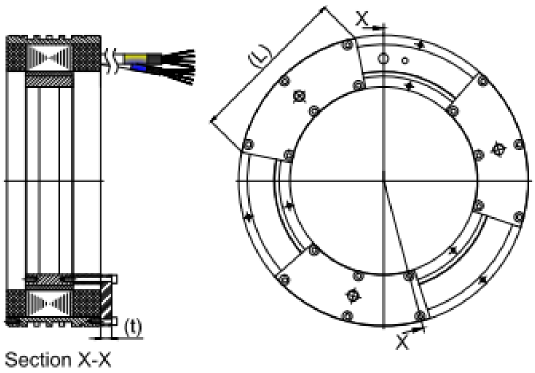
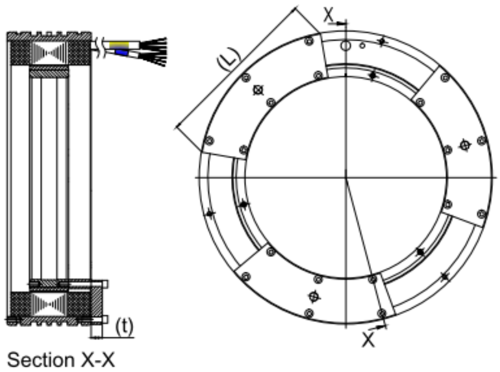
Table 4.5 O-ring features

Type	Material	Shore A	O-ring thickness (mm)	O-ring inside diameter (mm)
TMRW1□/□M-2-1□	VITON	70°	2.62	152.07
TMRW2□/□M-2-2□	VITON	70°	2.62	190.17
TMRW4□/□M-2-4□	VITON	70°	2.62	221.92
TMRW7□/□M-2-7□	VITON	70°	2.5	296
TMRWA□/□M-2-A□	VITON	70°	4	370
TMRWD□/□M-2-D□	VITON	70°	4	465
TMRWG□/□M-2-G□	VITON	70°	4	550

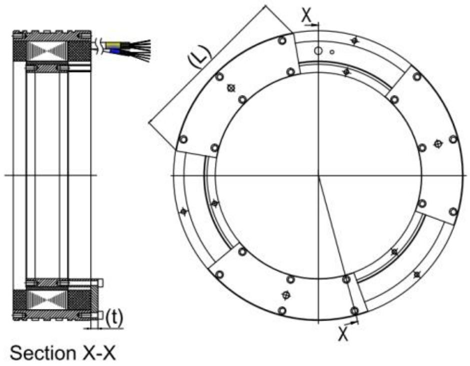
The quality of O-rings shipped by HIWIN is defined in accordance with ISO3601 standards (Series G & Grade N); different brands of Fluor elastomers have different product names, also known as FKM and FPM. It is Viton® with DuPont™ from the United States, Dyneon™ with 3M from the United States, and DAI-EL with Daikin® from Japan. If customers need to replace O-rings by themselves, apart from purchasing directly from HIWIN, they can also contact local suppliers to obtain materials equivalent to Viton. Note that the hardness must be above 70° of Shore A.

4.1.5 Fixture dimension

Fixture dimension for each series is given as below. (The default setting for the shipment of TM-2/IM-2 is to ship the stator and rotor separately. Please contact HIWIN, if shipment with complete assembled motor is required.)

<table>
<tr><th colspan="2">TMRW1 Series</th></tr>
<tr><td colspan="2">
</td></tr>
<tr><th>TMRW2 Series</th><th>TMRW4 Series</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>TMRW7 Series</th><th>TMRWA Series</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

TMRWD Series



TMRWG Series

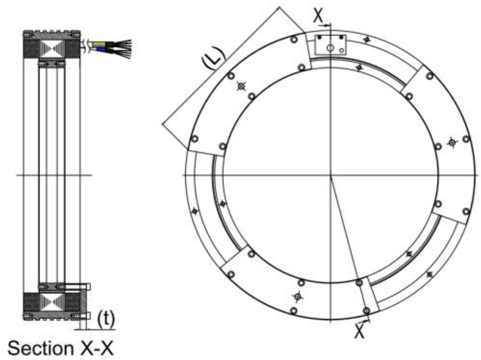


Figure 4.5 Fixture diagram

Table 4.6 Fixture dimension

Motor type	Fixture maximum length: L (mm)	Fixture thickness: t (mm)
TMRW1□	72	12
TMRW2□	151	10
TMRW4□	76	10
TMRW7□	166	12
TMRWA□	205	15
TMRWD□	274	12
TMRWG□	312	12

4.2 Rotor interface design

To prevent magnet interference from affecting motor performance, there should be some space between customer's shaft and rotor magnet. The recommended dimension of outside diameter($\emptyset D$) inside diameter($\emptyset d$) and flatness specification of rotor mounting surface (Flatness A) is given in

Table 4.7, **Table 4.8** 。

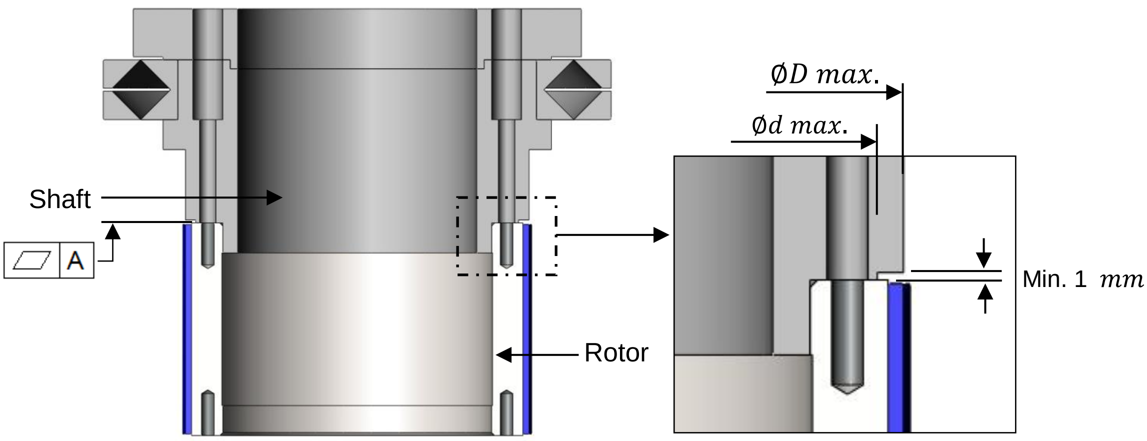
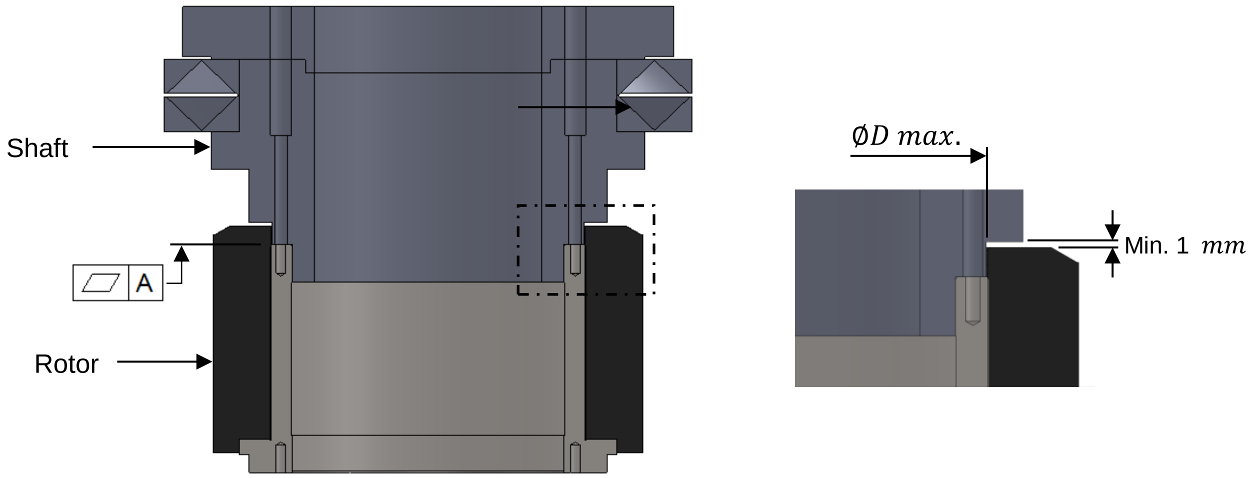


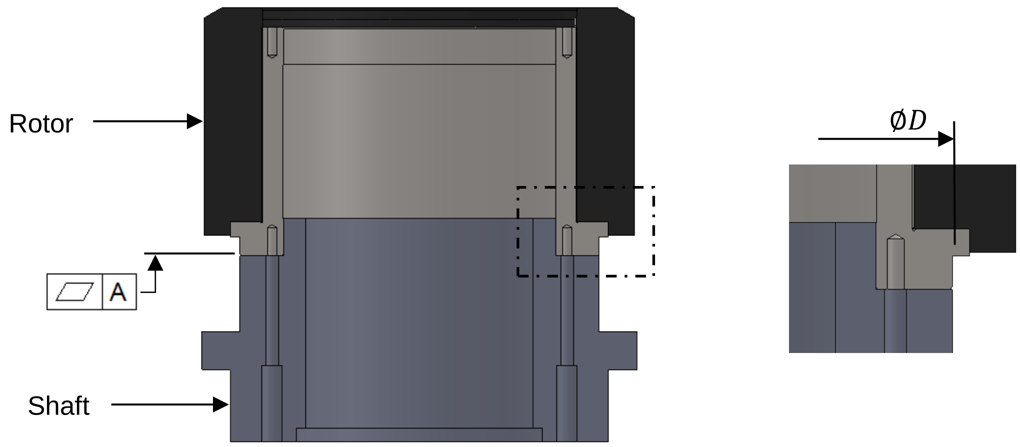
Figure 4.6 Rotor mounting interface (TMRW/TM-2)

Table 4.7 mounting interface suggestion (TMRW/TM-2)

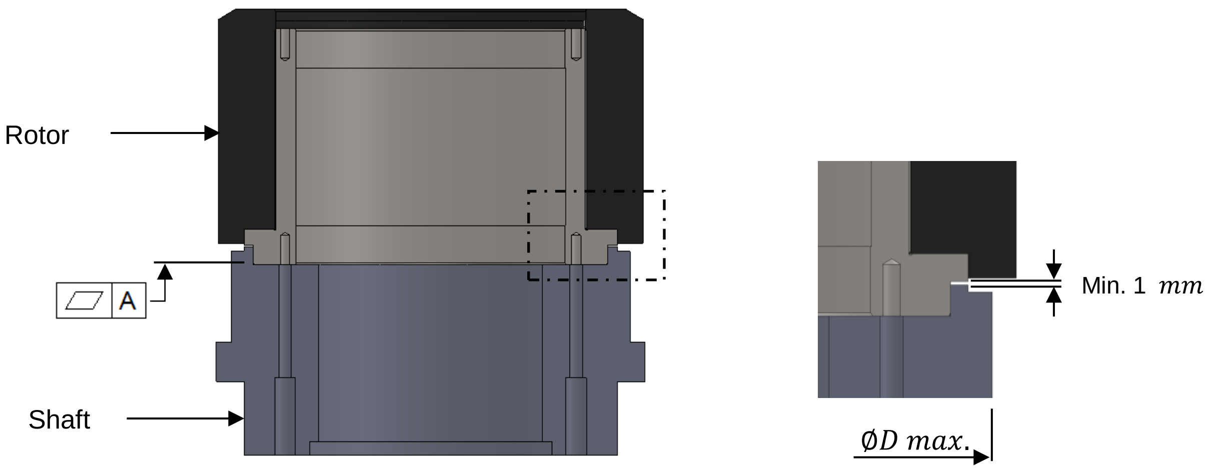
Type	$\emptyset D$ (mm)	$\emptyset d$ (mm)	Flatness A (mm)	Flatness B (mm)
TMRW1□/TM-2-1□	84.5	76.5	0.05	0.05
TMRW2□/TM-2-2□	118	110/108.4	0.05	0.05
TMRW4□/TM-2-4□	168	158.5	0.1	0.1
TMRW7□/TM-2-7□	233	222.5/218.8	0.1	0.1
TMRWA□/TM-2-A□	298	284.5	0.1	0.1
TMRWD□/TM-2-D□	383	370	0.15	0.15
TMRWG□/TM-2-G□	458	447	0.15	0.15



Type A



Type B



Type C

Figure 4.7 Rotor mounting interface (IM-2)

Table 4.8 mounting interface suggestion (IM-2)

Type	$\emptyset D$ (mm)			Flatness A (mm)	Flatness B (mm)
	Type A	Type B	Type C		
IM-2-2□	61.5	86	118	0.05	0.05
IM-2-4□	140	N/A	168	0.1	0.1
IM-2-7□	164.5	190	228	0.1	0.1
IM-2-A□	236.5	264	298	0.1	0.1
IM-2-G□	N/A	420	458	0.15	0.15

4.3 Stator interface design

The recommended tolerance of housing's inside diameter and stator's mounting holes is H7 or H8, and the recommended flatness specification of stator mounting level (Flatness B) is given in **Table 4.7**. Housing is suggested to be chamfered, deburred and rounded (the recommended dimension is shown in **Figure 4.9**) to avoid scratching O-ring and causing water leaking.

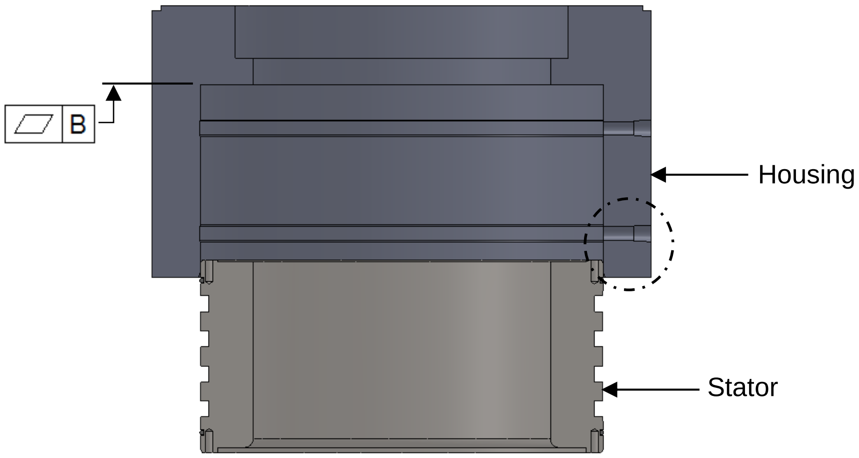


Figure 4.8 Stator mounting interface

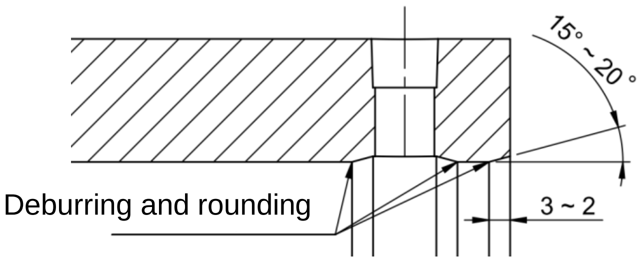


Figure 4.9 Housing mounting interface

4.4 Air gap and assembly concentricity

Air gap, existing between stator and rotor, prevents the motor from any damage during rotation. As long as you follow the standard value of air gap and the requirement of assembly concentricity established in **Figure 4.10** and the **Table 4.9** to **Table 4.11**, the motor will not be interfered during rotation.

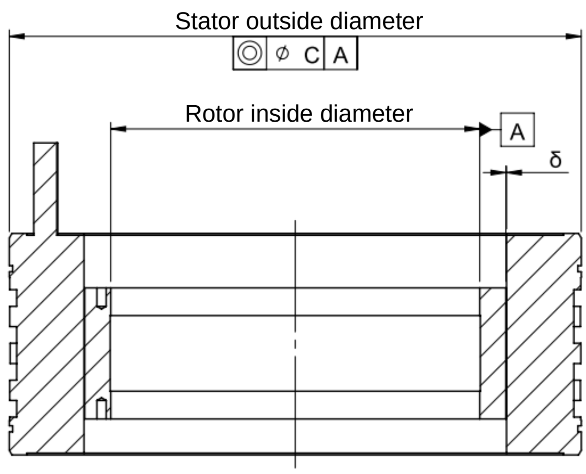


Figure 4.10 Air gap and assembly concentricity diagram

Table 4.9 TMRW series air gap and assembly concentricity dimension

Motor type	Air gap: δ (mm)	Assembly concentricity: C (mm)
TMRW1□	0.5	0.2
TMRW2□	0.5	0.2
TMRW4□	0.5	0.2
TMRW7□	0.5	0.2
TMRWA□	0.6	0.3
TMRWD□	0.6	0.3
TMRWG□	0.6	0.5

Table 4.10 TM-2 series air gap and assembly concentricity dimension

Type	Air gap: δ (mm)	Assembly concentricity: C (mm)
TM-2-1□	0.25	0.1
TM-2-2□	0.25	0.1
TM-2-4□	0.35	0.1
TM-2-7□	0.45	0.1
TM-2-A□	0.60	0.2
TM-2-D□	0.75	0.3
TM-2-G□	0.75	0.3

Table 4.11 IM-2 series air gap and assembly concentricity dimension

Type	Air gap: δ (mm)	Assembly concentricity: C (mm)
IM-2-2□	0.55	0.1
IM-2-4□	0.45	0.1
IM-2-7□	0.70	0.1
IM-2-A□	0.65	0.2
IM-2-G□	0.75	0.3

4.5 Force between stator and rotor

4.5.1 Radial force

When the concentricity of stator and rotor is offset, a radial force is generated between stator and rotor. (As **Figure 4.11**) Value of radial force for each series is given in **Table 4.12.**

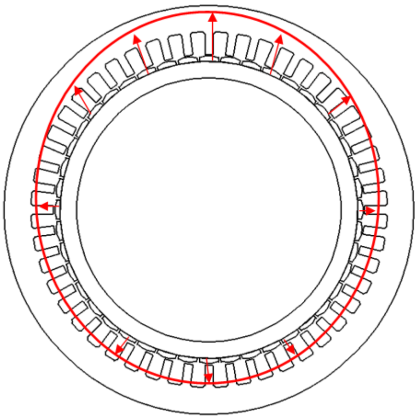


Figure 4.11 Concentricity of stator and rotor is offset

Table 4.12 Value of radial force

Type	Radial force: f (N/mm)	Type	Radial force: f (N/mm)	Type	Radial force: f (N/mm)
TMRW1A	2184	TM-2-1A	2639	IM-2-2A	6684
TMRW2A	2590	TM-2-2A	2924	IM-2-4A	3783
TMRW4A	2946	TM-2-4A	4285	IM-2-7A	9700
TMRW7A	2899	TM-2-7A	4256	IM-2-AA	16390
TMRWAA	3574	TM-2-AA	5809	IM-2-GA	20648
TMRWDA	4350	TM-2-DA	7259	-	-
TMRWGA	5158	TM-2-GA	7582	-	-

Radial force varies by length of iron core.

$$Force = \text{Radial force } f \times \frac{L}{100}$$

L stands for length of iron core. Length of iron core for each series is given as below **Table 4.13.**

Table 4.13 Length of iron core

Type	$L\ (mm)$
TMRW□**3/**□M-2-□3	30
TMRW□**5/**□M-2-□5	50
TMRW□**7/**□M-2-□7	70
TMRW□**A/**□M-2-□A	100
TMRW□**F/**□M-2-□F	150
TMRW□**J/**□M-2-□J	190
TMRW□**K/**□M-2-□K	200
TMRW□**L/**□M-2-□L	210

- **Example**

  Radial force of TMRW7F:

$$Force = TMRW7F\,'s\ f \times \frac{150}{100} = 2899 \times \frac{150}{100} = 4348.5\ N/mm$$

4.5.2 Axial force

When rotor moves toward stator, an axial force is generated between stator and rotor. (As **Figure 4.12**) Max. value of axial force for each series is given in **Table 4.14**. "X" in **Figure 4.12** stands for moving direction.

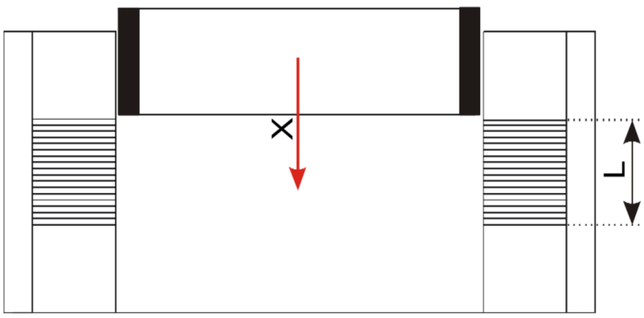


Figure 4.12 Axial offset of the stator and rotor

Table 4.14 Maximum value of axial force

Type	Axial force: $f(N)$	Type	Axial force: $f(N)$	Type	Axial force: $f(N)$
TMRW1□	118	TM-2-1□	131	IM-2-2□	185
TMRW2□	176	TM-2-2□	212	IM-2-4□	216
TMRW4□	300	TM-2-4□	232	IM-2-7□	268
TMRW7□	375	TM-2-7□	364	IM-2-A□	384
TMRWA□	528	TM-2-A□	382	IM-2-G□	480
TMRWD□	944	TM-2-D□	657	-	-
TMRWG□	1335	TM-2-G□	701	-	-

4.6 Screw tightening torque

Screws with a strength class of 12.9 are recommended for fixed screws of stator and rotor. Specification of threaded holes, quantity of threaded holes and screw tightening torque for each series are given in **Table 4.15, Table 4.16.**

Table 4.15 TMRW/TM-2 Screw tightening torque

TMRW Series	TM-2 Series	Specification of threaded holes	Quantity of threaded holes	Screw tightening torque $(kgf - cm)$	Screw tightening torque (Nm)
TMRW13(L) TMRW15(L) TMRW17(L) TMRW23(L) TMRW25(L) TMRW27(L)	TM-2-13 TM-2-15 TM-2-17 TM-2-23 TM-2-25 TM-2-27	M5 x 0.8P x 10DP	8	80	7.85
TMRW1A(L) TMRW1F(L) TMRW2A(L) TMRW2F(L)	TM-2-1A TM-2-1F TM-2-2A TM-2-2F	M5 x 0.8P x 10DP	16	80	7.85
TMRW43(L) TMRW45(L) TMRW73(L) TMRW75(L) TMRW77(L)	TM-2-43 TM-2-45 TM-2-47 TM-2-73 TM-2-75 TM-2-77	M5 x 0.8P x 10DP	12	80	7.85
TMRW47(L) TMRW4A(L) TMRW4F(L) TMRW7A(L) TMRW7F(L)	TM-2-4A TM-2-4F TM-2-7A TM-2-7F	M5 x 0.8P x 10DP	24	80	7.85
TMRWA3(L) TMRWA5(L) TMRWA7(L)	TM-2-A3 TM-2-A5 TM-2-A7	M6 x 1P x 12DP	12	120	11.77
TMRWAA(L) TMRWAF(L)	TM-2-AA TM-2-AF	M6 x 1P x 12DP	24	120	11.77

TMRWD3(L) TMRWD5(L) TMRWD7(L)	TM-2-D3 TM-2-D5 TM-2-D7	M8 x 1.25P x 12DP	12	250	24.52
TMRWDA(L) TMRWDF(L)	TM-2-DA TM-2-DF	M8 x 1.25P x 12DP	24	250	24.52
TMRWG3(L) TMRWG5(L) TMRWG7(L)	TM-2-G3 TM-2-G5 TM-2-G7	M8 x 1.25P x 12DP	12	250	24.52
TMRWGA(L) TMRWGF(L)	TM-2-GA TM-2-GF	M8 x 1.25P x 12DP	24	250	24.52

Table 4.16 IM-2 Screw tightening torque

IM-2 Series	Part	Specification of threaded holes	Quantity of threaded holes	Screw tightening torque $(kgf-cm)$	Screw tightening torque (Nm)
IM-2-23 IM-2-25 IM-2-27	Stator	M5 x 0.8P x 10DP	8	80	7.85
	Rotor	M6 x 1.0P x 12DP	6	120	11.77
IM-2-2A IM-2-2F	Stator	M5 x 0.8P x 10DP	16	80	7.85
	Rotor	M6 x 1.0P x 12DP	12	120	11.77
IM-2-43 IM-2-45 IM-2-47 IM-2-73 IM-2-75 IM-2-77	Stator	M5 x 0.8P x 10DP	12	80	7.85
	Rotor	M6 x 1.0P x 12DP	12	120	11.77
IM-2-4A IM-2-4F	Stator	M5 x 0.8P x 10DP	24	80	7.85
	Rotor	M6 x 1.0P x 12DP	12	120	11.77
IM-2-7A IM-2-7F	Stator	M5 x 0.8P x 10DP	24	80	7.85
	Rotor	M6 x 1.0P x 12DP	24	120	11.77
IM-2-A3 IM-2-A5 IM-2-A7	Stator/Rotor	M6 x 1P x 12DP	12	120	11.77
IM-2-AA IM-2-AF	Stator/Rotor	M6 x 1P x 12DP	24	120	11.77

IM-2-G5 IM-2-G7	Stator/Rotor	M8 x 1.25P x 12DP	12	250	24.52
IM-2-GA IM-2-GF	Stator/Rotor	M8 x 1.25P x 12DP	24	250	24.52

4.7 Direction of rotation

If the motor cable is connected according to **Table 4.18**. The rotor will rotate in clockwise direction (view towards the rotor side without cable outlet, **Figure 4.13**).

Figure 4.13 Illustration of rotational direction of the rotor

4.8 Motor cable

The standard length of the power cable and temperature sensor cable is 2000 $mm \pm 50mm$ (as shown in **Figure 4.14**), and the metal connector is not included. Customers can choose cables with other lengths, with an increment unit of 500 mm, up to 10000 mm (for the case of total length including extension cable longer than 10 meters, please refer to section 3.4).

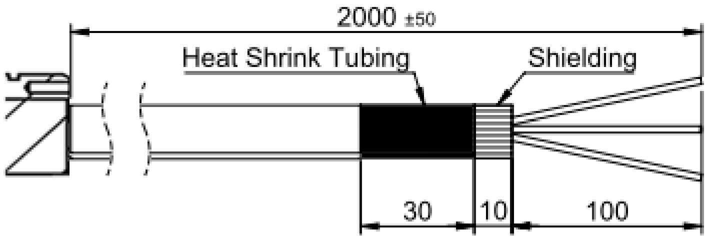


Figure 4.14 Cable specification

4.8.1 Power cable specification

IGUS's Chainflex®(CF27), Chainflex®(CF270), Chainflex®(CF310) and LAPP®'s Olflex® Servo FD 796CP, with UL and CE certificates, are used for power cable. The wire diameter is determined by the value of continuous current under water cooling condition. The relationship between wire diameter and motor type is given in **Table 4.17**.

Note: Power cable contains isolation net. The isolation net must be grounded

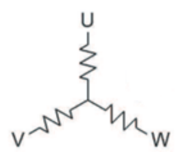
Table 4.17 Relationship between wire diameter and motor type

Cross-sectional area (mm^2)	Type				
1.5	TMRW13(L)	TMRW15(L)	TMRW17(L)	TMRW1A(L)	TMRW1F
	TMRW23(L)	TMRW25(L)	TMRW27(L)	TMRW2A(L)	TMRW2F
	TMRW43	TMRW45	TMRW47	TM-2-13-LA	TM-2-15-LA
	TM-2-17-LA	TM-2-1A-LA	TM-2-1F-LA	TM-2-23-PA	TM-2-25-PA
	TM-2-27-PA	TM-2-2A-PA	TM-2-2F-PA	TM-2-43-LA	TM-2-45-LA
	TM-2-47-LA	TM-2-73-LB	IM-2-23-PA	IM-2-25-PA	IM-2-27-PA
	IM-2-43-LA	IM-2-45-LA			
2.5	TMRW43L	TMRW45L	TMRW47L	TMRW4A	TMRW4F
	TMRW73	TMRW75	TMRW77	TMRW7A	TMRW7F
	TMRWA3	TMRWA5	TM-2-13-SA	TM-2-15-SA	TM-2-17-SA
	TM-2-1A-SA	TM-2-1F-SA	TM-2-23-PB	TM-2-25-PB	TM-2-27-PB
	TM-2-2A-PB	TM-2-2F-PB	TM-2-4F-PA	TM-2-73-PB	TM-2-75-PB
	TM-2-77-PB	TM-2-7A-PB	TM-2-7F-PB	TM-2-A3-PB	TM-2-A5-PB
	IM-2-23-PB	IM-2-25-PB	IM-2-27-PB	IM-2-2A-PB	IM-2-2F-PB
	IM-2-73-SA	IM-2-A3-PB			

4.0	TMRW1FL	TMRW2FL	TMRW4AL	TMRW4FL	TMRW73L
	TMRW75L	TMRW77L	TMRW7AL	TMRW7FL	TMRWA3L
	TMRWA5L	TMRWA7	TMRWAA	TMRWD3	TMRWD5
	TMRWD7	TMRWDA	TMRWG3	TMRWG5	TMRWG7
	TM-2-43-SA	TM-2-45-SA	TM-2-47-SA	TM-2-4A-SA	TM-2-75-SB
	TM-2-77-SB	TM-2-7A-SB	TM-2-7F-SB	TM-2-A3-PC	TM-2-A5-PC
	TM-2-A7-PC	TM-2-AA-PC	TM-2-AF-PC	TM-2-G5-SB	TM-2-G7-SB
	TM-2-GA-SB	IM-2-43-SA	IM-2-45-SA	IM-2-47-SA	IM-2-4A-SA
	IM-2-4F-SA	IM-2-73-SB	IM-2-75-SB	IM-2-77-SB	IM-2-7A-SB
	IM-2-A3-PC	IM-2-A5-PC	IM-2-A7-PC	IM-2-AA-PC	IM-2-G5-SB
	IM-2-G7-SB	IM-2-GA-SB			
6.0	TMRWA7L	TMRWAAL	TMRWAF	TM-2-4A-PB	TM-2-4F-PB
	TM-2-D3-SB	TM-2-D5-SB	TM-2-D7-SB	TM-2-DA-SB	TM-2-DF-SB
	IM-2-2A-PD	IM-2-2F-PD	IM-2-47-SB	IM-2-4A-SB	IM-2-4F-SB
10.0	TMRWAFL	TMRWD3L	TMRWD5L	TMRWD7L	TMRWDAL
	TMRWDF	TMRWG3L	TMRWG5L	TMRWG7L	TMRWGA
	TMRWGF	TM-2-A7-PF	TM-2-AA-PF	TM-2-AF-PF	TM-2-G5-SD
	TM-2-G7-SD	TM-2-GA-SD	TM-2-GF-SD	IM-2-75-SD	IM-2-77-SD
	IM-2-7A-SD	IM-2-7F-SD	IM-2-A5-PF	IM-2-A7-PF	IM-2-AA-PF
	IM-2-AF-PF	IM-2-G5-SD	IM-2-G7-SD	IM-2-GA-SD	IM-2-GF-SD
16.0	TM-2-D3-SD	TM-2-D5-SD	TM-2-D7-SD	TM-2-DA-SD	TM-2-DF-SD
25.0	TMRWDFL	TMRWGAL	TMRWGFL	TM-2-GF-SH	IM-2-AF-SF
	IM-2-GF-SH	IM-2-7F-WD			

The relationship between power cable color and signal is given in Table 4.18

Table 4.18 Relationship between power cable color and signal

Color & Number	Signal	Diagram
Black, No. L1/U	U	
Black, No. L2/V	V	
Black, No. L3/W	W	
Yellow with green	grounding	

4.8.2 Temperature sensor cable specification

IGUS®'s Chainflex® (CF240) is used for temperature sensor cable. There are three temperature sensors in standard specification (Type B), a set of PTC100, a set of PTC120(130), and a Pt1000. Pt1000 contains an ESD protection device, is installed on every phase winding. Temperature sensors used in each Type are given in **Table 4.19**. The cross-sectional area of temperature sensor cable is 0.25 mm^2, and the pin assignment of temperature sensor cable for each type is given from **Figure 4.15** to **Figure 4.17**.

Note : Temperature sensor cable contains isolation net. The isolation net must be grounded.

Table 4.19 Temperature sensors used in each Type

Type	Temperature sensor	Remarks
Type A	PTC120(130) + Pt1000	-
Type B	PTC100 + PTC120(130) + Pt1000	Standard
Type C	PTC120(130) + 3x Pt1000	-

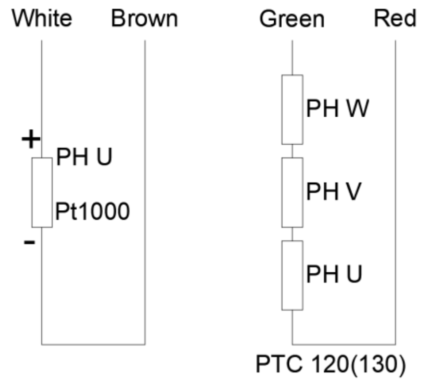


Figure 4.15 Type A

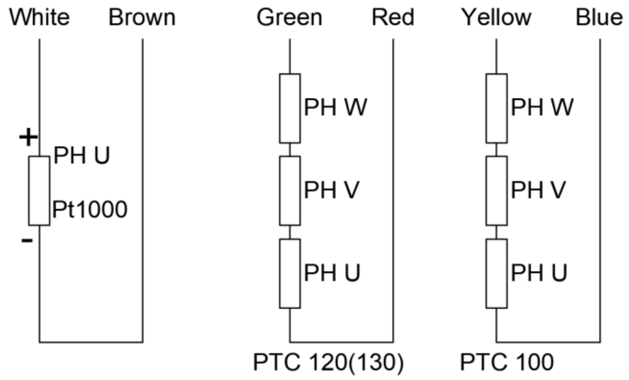


Figure 4.16 Type B

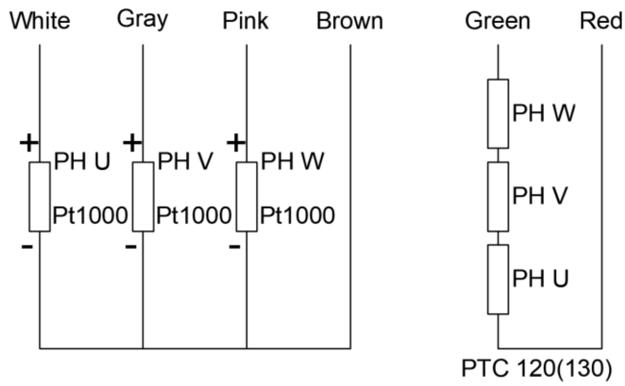
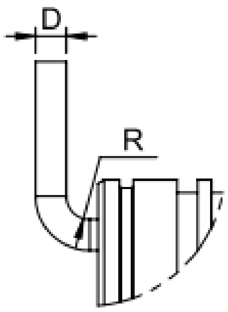


Figure 4.17 Type C

4.8.3 Bending radius of cable

The minimum bend radius of power cable and temperature sensor cable for torque motor is given in the following **Table 4.20**.

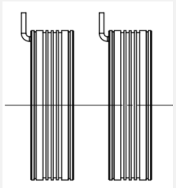
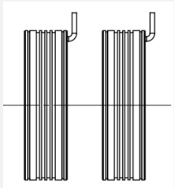
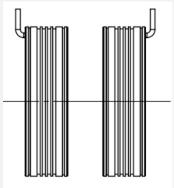
Table 4.20 Bending radius of cable

<table>
<tr><th rowspan="3">Feature</th><th rowspan="3">Diagram</th><th colspan="2">Power cable</th><th>Temperature sensor cable</th></tr>
<tr><th rowspan="2">Olflex® servo FD</th><th>Chainflex® CF27</th><th rowspan="2">Chainflex®</th></tr>
<tr><th>Chainflex® CF270</th></tr>
<tr><td rowspan="2">Min. bending radius of fixed installation</td><td rowspan="4">
</td><td rowspan="2">R= 4 x D</td><td>R= 4 x D</td><td rowspan="2">R= 5 x D</td></tr>
<tr><td>R= 5 x D</td></tr>
<tr><td rowspan="2">Min. bending radius of moving installation</td><td rowspan="2">R= 7.5 x D</td><td>R= 7.5 x D</td><td rowspan="2">R= 10 x D</td></tr>
<tr><td>R= 10 x D</td></tr>
</table>

4.9 Setting of parallel operation

Torque motor can perform parallel operation on the same axis. Follow **Table 4.21** to correctly connect the power cables. The details of wiring for design 1 and design 2 are shown in **Figure 4.19** to **Figure 4.24**.

Table 4.21 Connection of power cables for parallel operation

		Design 1				Design 2	
							
	Drive	Master	Slave	Master	Slave	Master	Slave
1 A TMRW 2 D Series 7 G	U	U	U	U	U	U	V
	W	W	W	W	W	W	W
	V	V	V	V	V	V	U
TMRW4 Series	U	U	U	U	U	U	W
	W	W	W	W	W	W	U
	V	V	V	V	V	V	V
□M-2 Series	U	U	U	U	U	U	U
	W	W	W	W	W	W	V
	V	V	V	V	V	V	W

Pay attention to the following points when driving multiple motors in parallel.

1. To drive the motors in parallel, contact HIWIN Engineering Department.
2. The motors performing parallel operation should be the same type.
3. The phase sequence of back EMF for motors performing parallel operation should be the same.
4. Home position mark on rotor should be aligned with motor cable outlet position (the position error range is ±0.5°), as **Figure 4.18** shows. If the motors are operated at rated load but home position mark is not aligned with outlet position, one of the motors in parallel operation may overload and overheat.
5. Power cable and temperature sensor cable contain isolation net. The isolation net must be grounded.
6. Please contact HIWIN Engineering Department for parameters for parallel design.

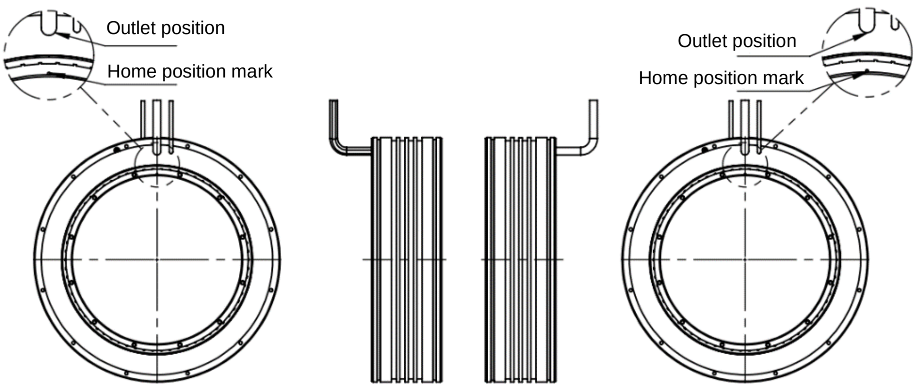
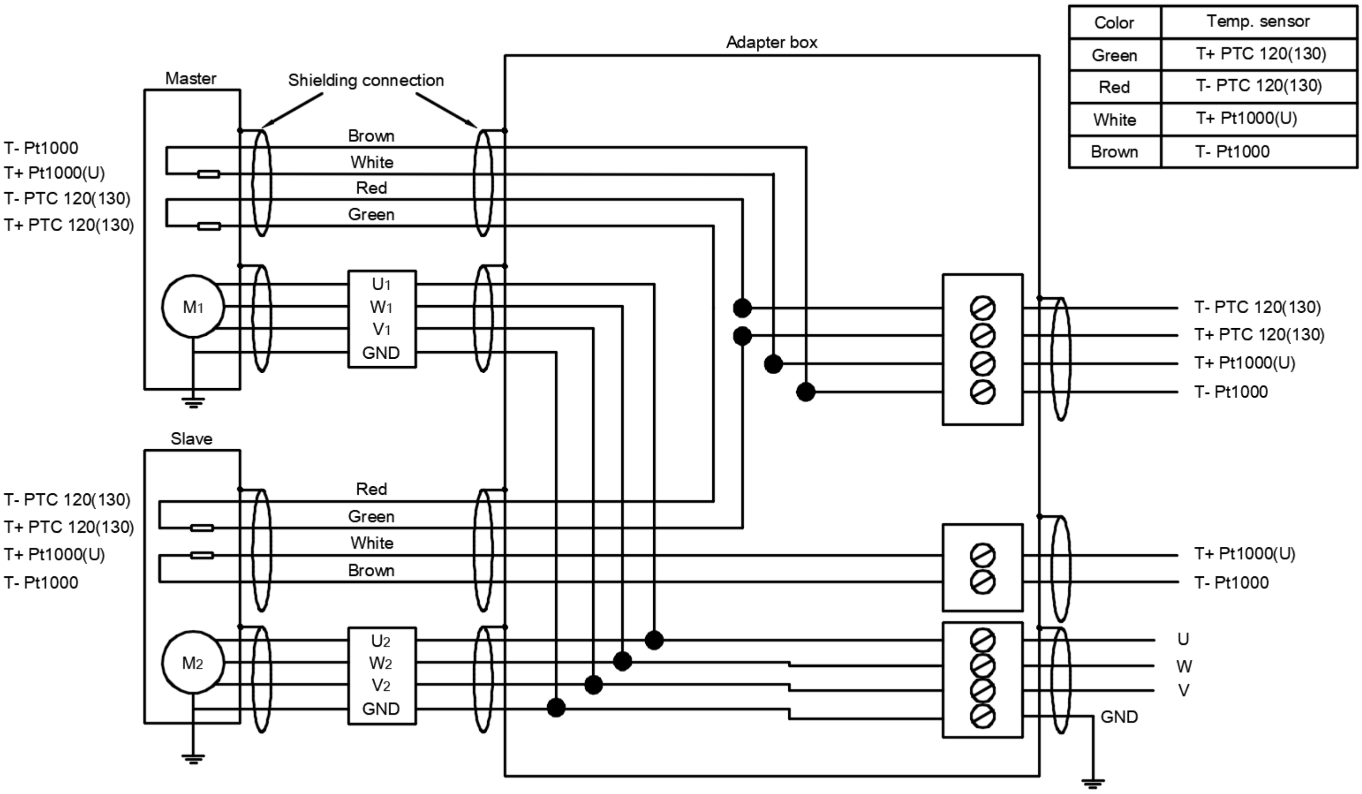
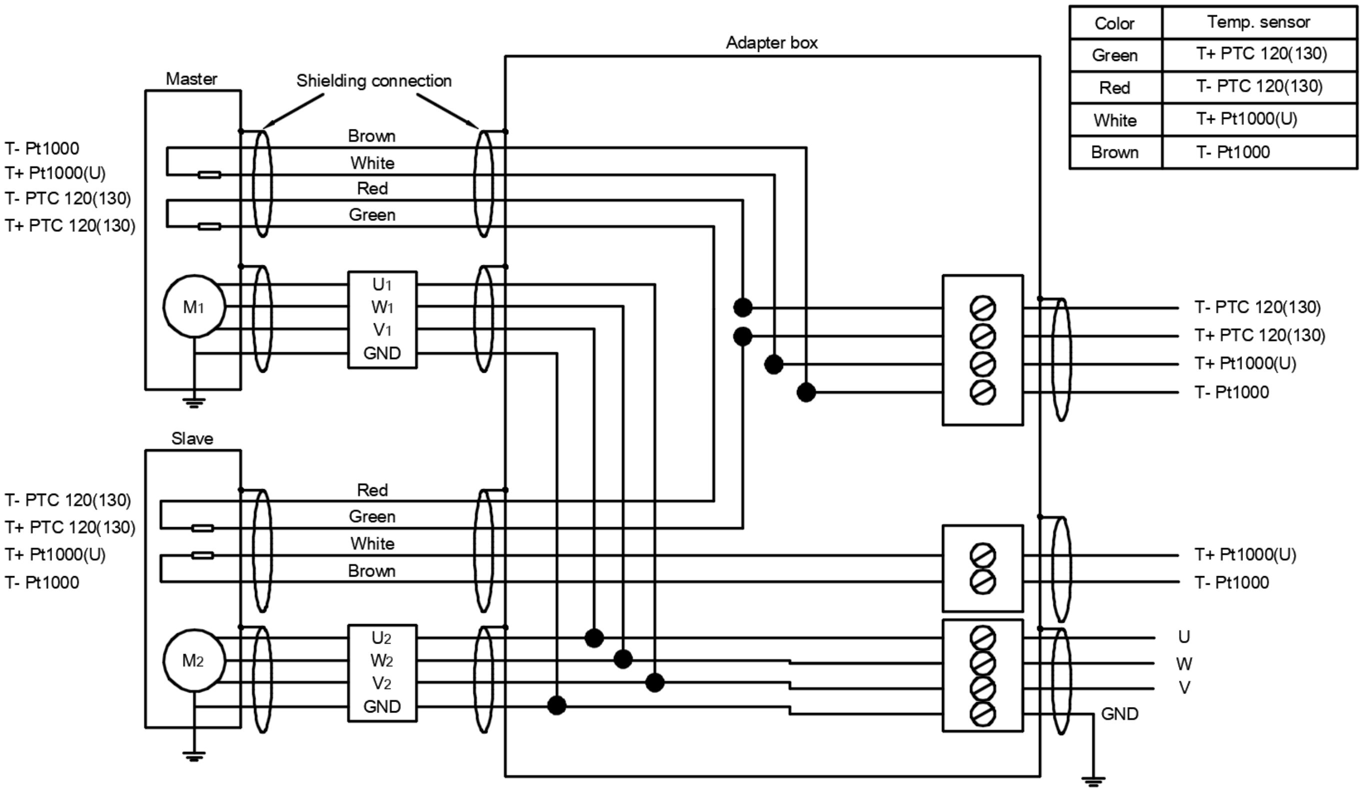


Figure 4.18 Relative position of home position mark and outlet position during parallel operation



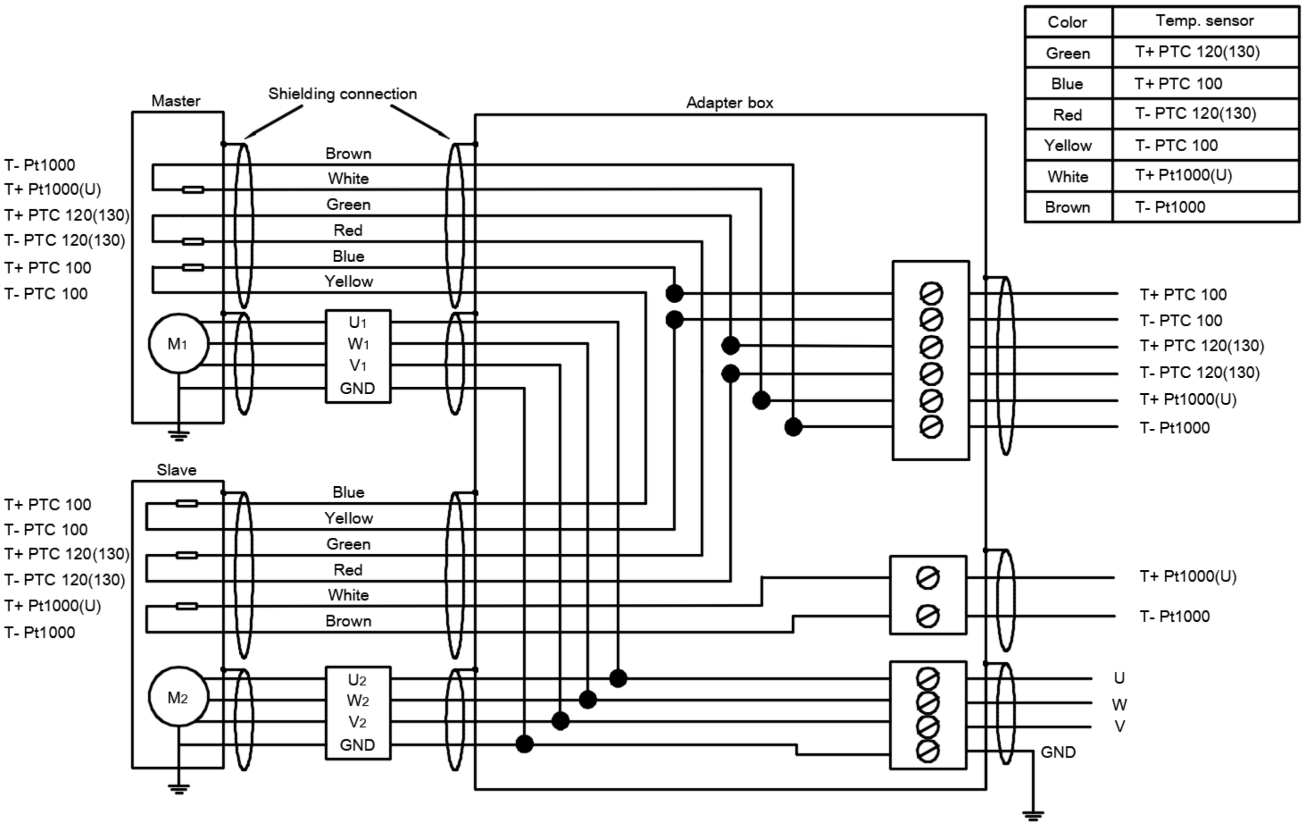
Color	Temp. sensor
Green	T+ PTC 120(130)
Red	T- PTC 120(130)
White	T+ Pt1000(U)
Brown	T- Pt1000

Figure 4.19 Type A (Design 1)



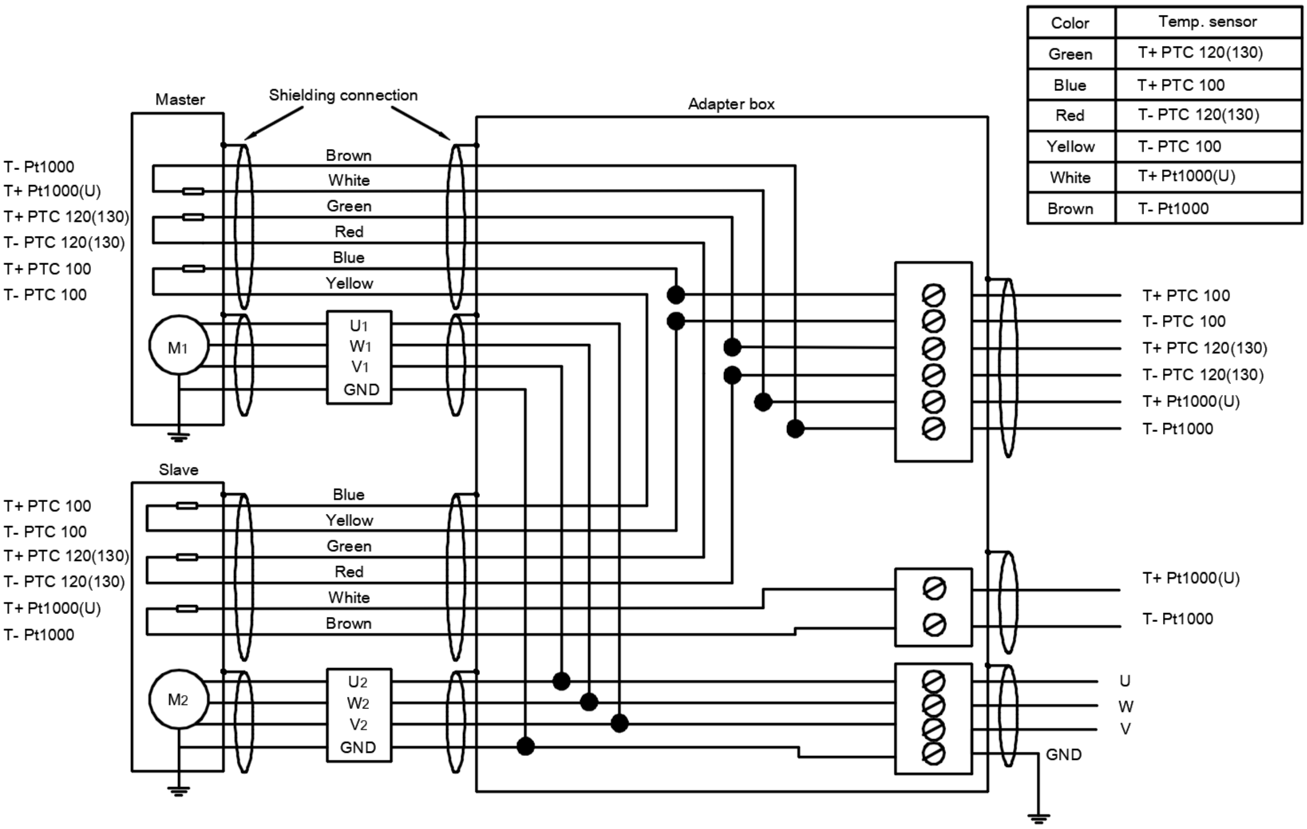
Color	Temp. sensor
Green	T+ PTC 120(130)
Red	T- PTC 120(130)
White	T+ Pt1000(U)
Brown	T- Pt1000

Figure 4.20 Type A (Design 2)



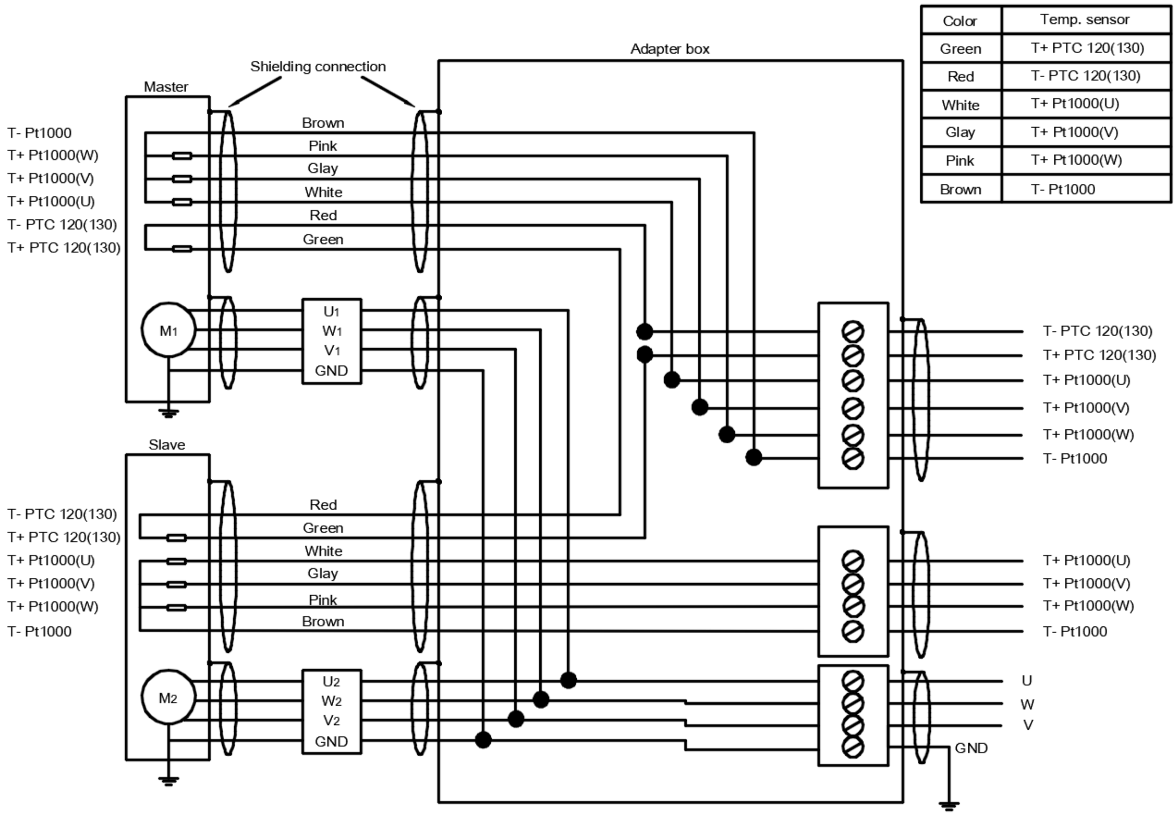
Color	Temp. sensor
Green	T+ PTC 120(130)
Blue	T+ PTC 100
Red	T- PTC 120(130)
Yellow	T- PTC 100
White	T+ Pt1000(U)
Brown	T- Pt1000

Figure 4.21 Type B (Design 1)



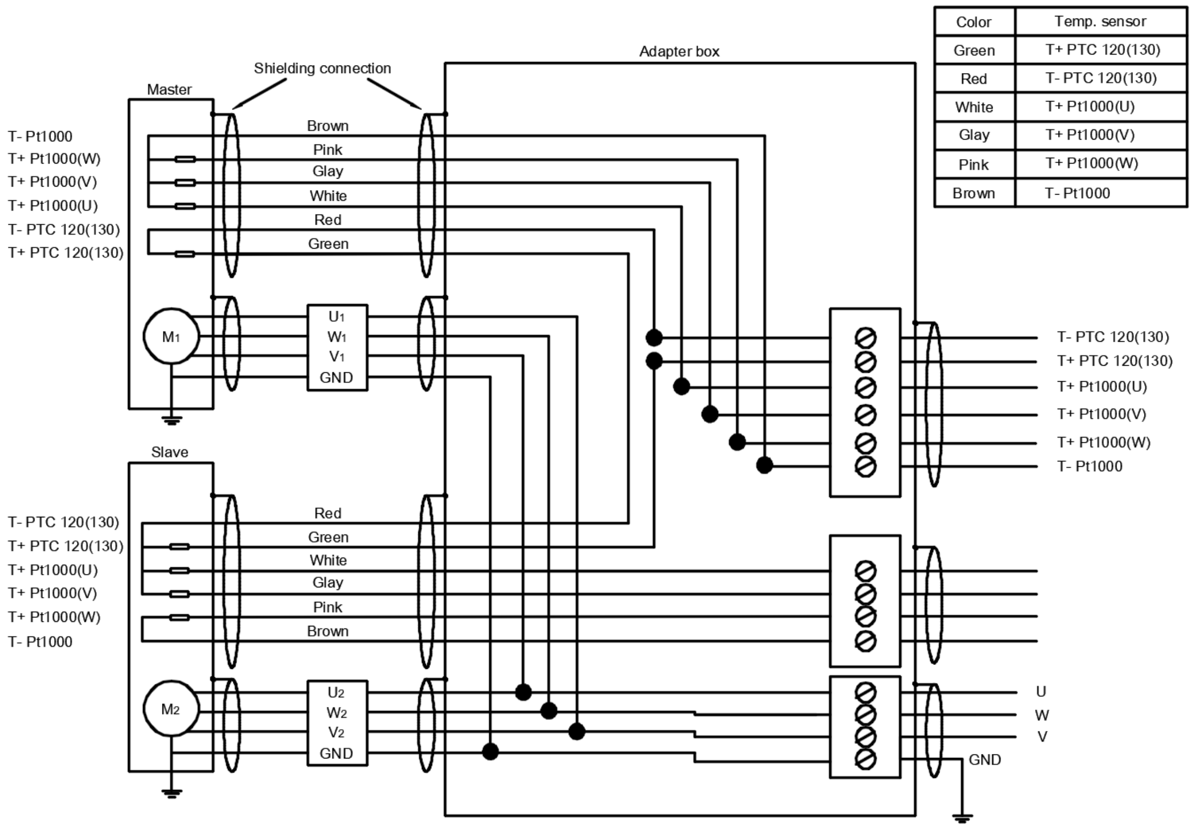
Color	Temp. sensor
Green	T+ PTC 120(130)
Blue	T+ PTC 100
Red	T- PTC 120(130)
Yellow	T- PTC 100
White	T+ Pt1000(U)
Brown	T- Pt1000

Figure 4.22 Type B (Design 2)



Color	Temp. sensor
Green	T+ PTC 120(130)
Red	T- PTC 120(130)
White	T+ Pt1000(U)
Glay	T+ Pt1000(V)
Pink	T+ Pt1000(W)
Brown	T- Pt1000

Figure 4.23 Type C (Design 1)



Color	Temp. sensor
Green	T+ PTC 120(130)
Red	T- PTC 120(130)
White	T+ Pt1000(U)
Glay	T+ Pt1000(V)
Pink	T+ Pt1000(W)
Brown	T- Pt1000

Figure 4.24 Type C (Design 2)

4.10 Temperature sensor

Pt1000 is a platinum resistance temperature sensor (RTD), which is characterized by a resistance value of 1000Ω at 0℃. The corresponding temperature can be converted by measuring the output resistance value. The relationship between resistance and temperature is shown in **Figure 4.25**. The standard relationship between resistance and temperature is as follows:

Temperature range: -200℃ ~ 0℃

$R_\theta = R_0[1 + A\theta + B\theta^2 + C(\theta - 100)\theta^3]$

In temperature range: 0℃ ~ 850℃

$R_\theta = R_0(1 + A\theta + B\theta^2)$

R_0 = 1000 [Ω] C = -4.1830 x 10^{-12} [$℃^{-4}$]

A = 3.9083 x 10^{-3} [$℃^{-1}$] θ = temperature [℃]

B = -5.7750 x 10^{-7} [$℃^{-2}$]

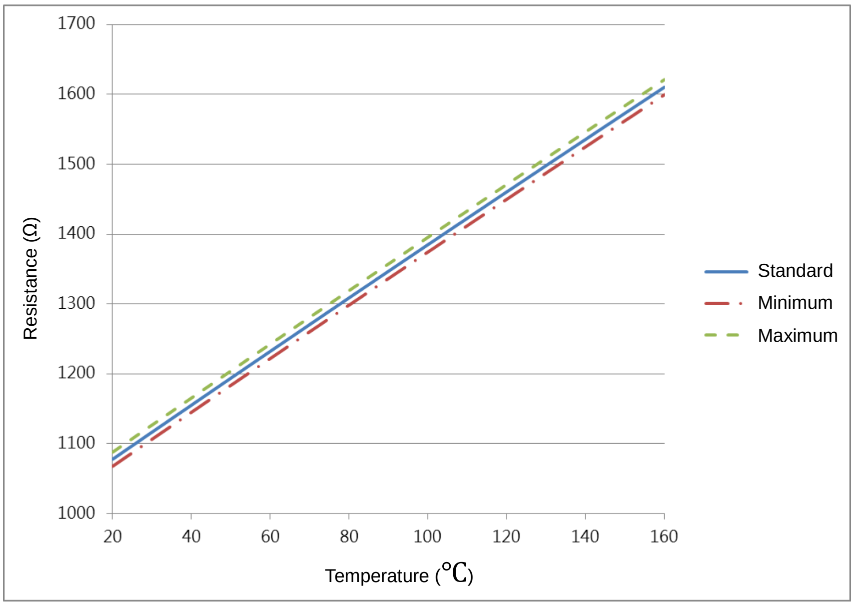


Figure 4.25 Relationship between resistance and temperature (Pt1000)

PTC100 and PTC120(130) are thermistors. Their output resistance changes according to coil temperature. Resistance of PTC100 rises drastically when T_{REF}=100℃, while resistance of PTC120(130) rises drastically when T_{REF}=120(130) ℃. Their features are given in **Table 4.22** and **Figure 4.26**.

Table 4.23 Features of PTC

Features of	Resistance	3 series resistors
20℃<T<T_{REF} - 20K	20Ω~250Ω	60Ω~750Ω
T=T_{REF} - 5K	≦ 550Ω	≦ 1,650Ω
T=T_{REF} + 5K	≧ 1,330Ω	≧ 3,990Ω
T=T_{REF} + 15K	≧ 4,000Ω	≧ 12,000Ω

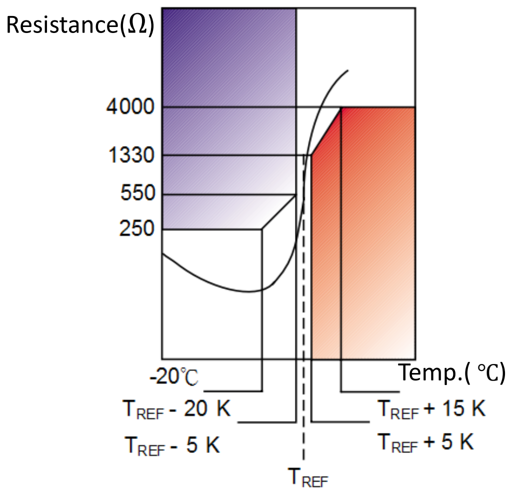


Figure 4.26 Relationship between PTC temperature and resistance

4.10.1 Temperature monitoring and motor protection

To protect the motor windings against thermal damage, every motor is equipped with a triple positive temperature coefficient (PTC) sensor, type SNM120/130 (in accordance with DIN 44082-M180). Since the degree of heating of the individual motor phases can be very different, a PTC sensor is fitted in each phase winding (U, V and W). Each PTC element has a “Quasi-switching” characteristic, i.e. the resistance suddenly increases close to the rated temperature (switching threshold, Figure 4.26). Due to its low heat capacity and good thermal contact with the motor winding, the PTC reacts very quickly to a rise in temperature and, in conjunction with additional protective mechanisms on the control side, ensures reliable motor protection against overload. The PTC elements located in every phase winding in HIWIN motors are wired in series; they connect via two wires.
With TMRW/TM-2/IM-2 there is an additional temperature circuit with positive temperature coefficient (PTC), type SNM100, for redundant use or to distinguish between warning and danger temperatures.

Note:
Motor protection by temperature monitoring alone using PTC elements can be insufficient. This is the case, for example, if the motor is operated with currents above continuous current. HIWIN advises the use of additional protective algorithm on the control side. The calculation of max. operating time with currents above continuous current can be found in **Chapter 3.3**.

4.10.2 Connection to the drive amplifier

The temperature monitoring circuits can normally be connected directly to the drive control. If the protective separation requirements in accordance with EN61800-5-1 are to be fulfilled, the sensors must be connected to the decoupling modules provided by the drive manufacturers.

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5. Thermal Protection Device

5. Thermal Protection Device..5-1
5.1 Features..5-2
5.2 Wiring of temperature module..5-3

Refer to operation manual MT99UE01 for specification, wiring and related description of THPD (thermal protection device).

Figure 5.1 Thermal protection device

5.1 Features

- THPD must be used with HIWIN torque motor.
- It converts three temperature sensor inputs of motor into one analog output and two digital outputs and sends them to controller.
- Real-time temperature monitoring is realized by the delay of software compensation. Even under severe operating conditions, the motor can be prevented from overheating.
- Controller can get the complete information of motor temperature via the following methods.
  Analog temperature output: Pt1000
  Digital warning output: Alarm
  Digital error output: Error

5.2 Wiring of temperature module

If the temperature sensor of the motor is Pt1000, it must be used with THPD-1000-120. The wiring structure diagram is shown below.

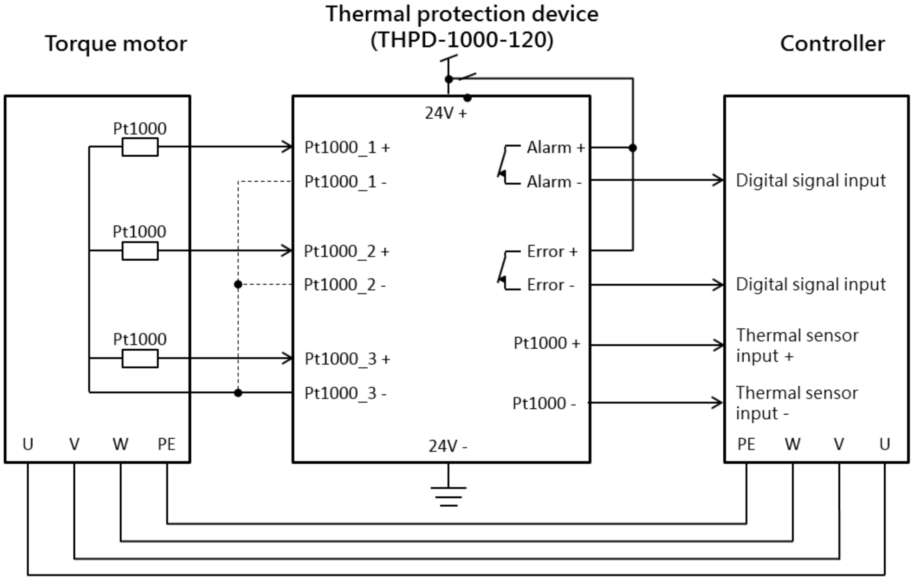

Figure 5.2 Pt1000 wiring diagram

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6. Motor Installation

6. Motor Installation 6-1
6.1 Install stator and rotor together 6-4
6.2 Install stator and rotor separately...6-6

⚠ DANGER!

Danger from electrical voltage!

Before and during assembly, disassembly and repair work, dangerous currents may flow.

- Work may only be carried out by a qualified electrician and with the power supply disconnected!
- Before carrying out work on the linear motor system, disconnect the power supply and protect it from being switched back on!

⚠ DANGER!

Danger from strong magnetic fields!

Strong magnetic fields around torque motor systems pose a health risk to persons with implants (e.g. cardiac pacemakers) that are affected by magnetic fields.

- Persons with implants that are affected by magnetic fields should maintain a safe distance of at least 300 mm from torque motor systems.

⚠ DANGER!

Risk of crushing from strong forces of attraction!

- Assemble the rotors and stators carefully!
- Do not place fingers or objects between the rotors and stators!
- The rotor and magnetizable objects may accidentally attract each other and collide!
- Two rotors may accidentally attract each other and collide!
- The magnetic force of the rotor acting on the object may be as high as several kN, which may cause a certain part of the body to be clamped.
- Do not underestimate the attraction force and operate carefully.
- Wear safety gloves when necessary.
- At least two people are required to cooperate during operation.
- If the assembly steps have not yet reached the installation of the rotor, please place the rotor in a safe and proper place first.
- Never take multiple rotors at once.
- Never place two rotors directly together without any protection.
- Do not bring any magnetizable materials close to the rotor! If the tool must be magnetized, please hold it firmly with both hands and slowly approach the rotor!
- It is recommended to install the rotor immediately after unpacking!
- When installing the stator and rotor, an installation auxiliary device is required to assemble the stator and rotor individually. Please follow the correct method.
- Keep the following tools at hand at any time to release body parts (hands, fingers, feet, etc.) clamped by magnetic force.
  - Hammer made of non-magnetized solid material (about 3Kg)
- Two wedge blocks composed of non-magnetized materials (wedge-shaped sharp angle 10°~15°, minimum height 50mm).

⚠ WARNING!

Danger from heavy loads!

Lifting heavy loads may damage your health.

- Use a hoist of an appropriate size when positioning heavy loads which are over 20 kg!
- Observe applicable occupational health and safety regulations when handling suspended loads!
- Motors with stator and rotor fixture can be hung with hanging holes. The strength of the components should be considered when hanging under any circumstances.

ATTENTION!

Risk of physical damage to watches and magnetic storage media.

Strong magnetic forces may destroy watches and magnetisable data storage media near to the torque motor system! 。

- Do not bring watches or magnetisable data storage media into the vicinity (<300 mm) of the torque motor systems!

ATTENTION!

Damage of the torque motor system!

The torque motor system may be damaged by mechanical loading.

- Do not pull the cable directly.
- No heavy load or sharp object on motor.

There are two ways to install the motor.

- **Install stator and rotor together**

  They are installed with the fixture provided by torque motor, and the fixture position can be either the outlet side or the other side. Before placing an order, customers can consult with HIWIN sales or engineers about the definition of the fixture position. HIWIN will offer drawing for customers to confirm.

- **Install stator and rotor separately**

  Based on the basis of customer's mechanism, a guide tool is designed for installing stator and rotor.

The recommended steps for installation are described as below.

6.1 Install stator and rotor together

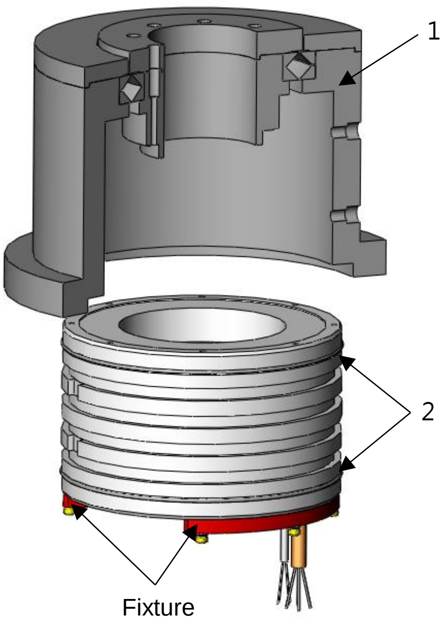
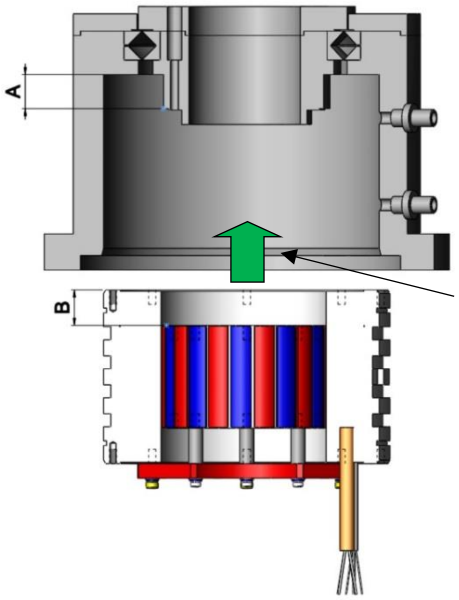
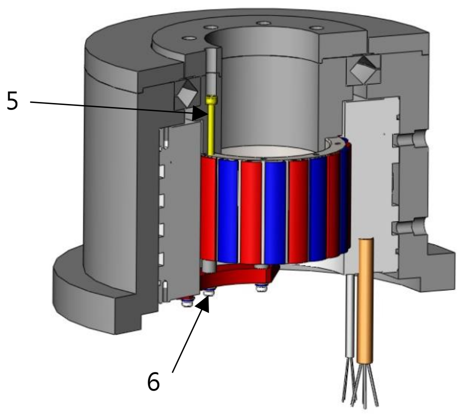
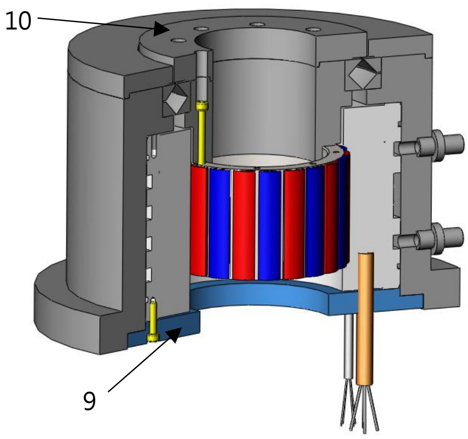
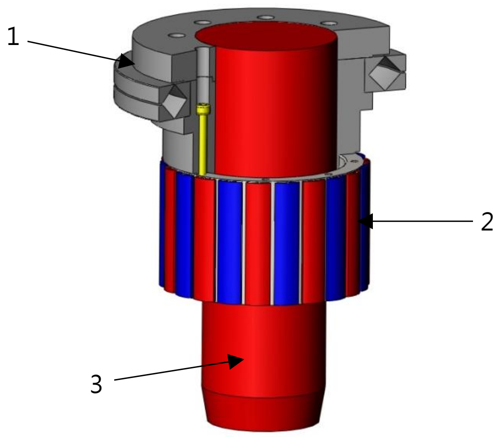
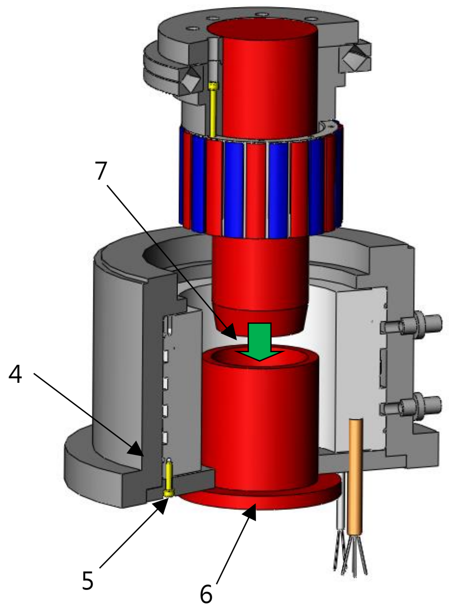
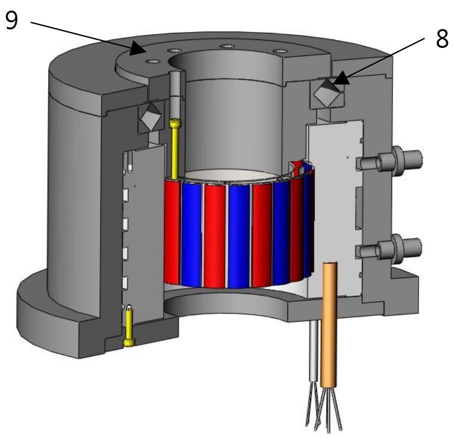
Diagram	Step
	1. Install housing, shaft, and bearing. 2. Install O-ring on stator. **Note: O-ring cannot be twisted.**

Diagram	Step
	3. To ensure that the motor is not influenced by the pull generated by the fixture and the mating parts during the assembly process, measure the space of the shaft (as A shows) and the height of stator and rotor (as B shows). 4. Place the set of stator and rotor (with the fixture) into the housing. Motor cable outlet must be aligned with coolant inlet and outlet. To avoid water leaking, O-ring cannot be damaged (refer to Chapter 4 for the design of housing). Pay attention to rotor's strong magnetic suction. To avoid danger, keep it away from magnetic conductors (e.g. iron objects). **Note: Refer to HIWIN approved drawing for the position of motor cable outlet.**
	5. Fix rotor on shaft. At this time, screw tightening torque is 80 percent of the specification (refer to Section 4.6 for screw tightening torque). 6. Loosen all the screws on the fixture about 1/8 turn. If the space A>B, loosen fixed screws of rotor first. If the space A<B, loosen fixed screws of stator first. 7. Fasten fixed screws of rotor to the specification, totally loosen the screws of fixture, and dismantle the fixture. 8. Ensure the screws are fastened to the specification.
	9. Install bottom plate and fasten fixed screws of stator（refer to Section 0 for screw tightening torque）。 10. Rotate rotating part. Ensure that it rotates smoothly and that no interference occurs. 11. Install the remaining parts, such as connector of coolant inlet / outlet, lower supporting bearing and encoder.

6.2 Install stator and rotor separately

Diagram	Step
	1. Install shaft and bearing. 2. Install rotor on shaft (refer to Section 4.6 for screw tightening torque). 3. Install guide tool on shaft.
	4. Install O-ring on stator. **Note: O-ring cannot be twisted.** 5. Place the set of stator into the housing, and fasten fixed screws of stator (refer to Section4.6. for screw tightening torque). Motor cable outlet must be aligned with coolant inlet and outlet. To avoid water leaking, O-ring cannot be damaged (refer to Chapter 4 for the design of housing). **Note: Refer to HIWIN approved drawing for the position of motor cable outlet.** 6. Install lower guide tool on shaft if it is necessary. 7. Install rotating module on fixed part. To avoid the danger caused by strong magnetic suction between stator and rotor, which may even make the assembly fail, the guide tool must be contacted and combined before the installation.

	8. Fix the bearing and dismantle the guide tool. 9. Check the air gap and assembly concentricity refer to Section 4.4 10. Rotate rotating part. Ensure that it rotates smoothly and that no interference occurs. 11. Install the remaining parts, such as connector of coolant inlet / outlet, lower supporting bearing and encoder.

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7. Maintenance and Troubleshooting

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⚠ DANGER!

Danger from electrical voltage!

Before and during assembly, disassembly and repair work, dangerous currents may flow.

- Work may only be carried out by a qualified electrician and with the power supply disconnected!
- Before carrying out work on the linear motor system, disconnect the power supply and protect it from being switched back on!

⚠ DANGER!

Danger from strong magnetic fields!

Strong magnetic fields around torque motor systems pose a health risk to persons with implants (e.g. cardiac pacemakers) that are affected by magnetic fields.

- Persons with implants that are affected by magnetic fields should maintain a safe distance of at least 300 mm from torque motor systems.

⚠ DANGER!

Risk of crushing from strong forces of attraction!

- Assemble the rotors and stators carefully!
- Do not place fingers or objects between the rotors and stators!
- The rotor and magnetizable objects may accidentally attract each other and collide!
- Two rotors may accidentally attract each other and collide!
- The magnetic force of the rotor acting on the object may be as high as several kN, which may cause a certain part of the body to be clamped.
- Do not underestimate the attraction force and operate carefully.
- Wear safety gloves when necessary.
- At least two people are required to cooperate during operation.
- If the assembly steps have not yet reached the installation of the rotor, please place the rotor in a safe and proper place first.
- Never take multiple rotors at once.
- Never place two rotors directly together without any protection.
- Do not bring any magnetizable materials close to the rotor! If the tool must be magnetized, please hold it firmly with both hands and slowly approach the rotor!
- It is recommended to install the rotor immediately after unpacking!
- When installing the stator and rotor, an installation auxiliary device is required to assemble the stator and rotor individually. Please follow the correct method.
- Keep the following tools at hand at any time to release body parts (hands, fingers, feet, etc.) clamped by magnetic force.
  - Hammer made of non-magnetized solid material (about 3Kg)
- Two wedge blocks composed of non-magnetized materials (wedge-shaped sharp angle 10°~15°, minimum height 50mm).

⚠ WARNING!

Danger from heavy loads!

Lifting heavy loads may damage your health.

- Use a hoist of an appropriate size when positioning heavy loads which are over 20 kg!
- Observe applicable occupational health and safety regulations when handling suspended loads!
- Motors with stator and rotor fixture can be hung with hanging holes. The strength of the components should be considered when hanging under any circumstances.

ATTENTION!

Risk of physical damage to watches and magnetic storage media.

Strong magnetic forces may destroy watches and magnetisable data storage media near to the torque motor system!。

- Do not bring watches or magnetisable data storage media into the vicinity (<300 mm) of the torque motor systems!

Please read all safety instructions before performing motor maintenance

Safety Instruction

1. Obstacle removal and maintenance can only be performed by HIWIN technicians or authorized dealers, and with appropriate protective equipment.
2. Do not perform any maintenance actions while the motor is running. The controller must stop the motor first.
3. Please turn off the power and the main switch of the machine (Please refer to the machine manufacturer's instructions for operation).
4. After the power is turned off, there will be residual voltage in the system. Please wait for sufficient discharge time before disconnecting all power connections.
5. Turn off the cooling system, release the pressure to discharge the cooling liquid and remove the cooling connection (Please refer the instructions of the cooling machine).
6. Disassemble the motors in order.
7. Clean the metal particles on the motor regularly.
8. Regularly check the air gap between the stator and rotor of the motor to keep it clean and undamaged.

HIWIN torque motor is a direct drive system, there will be no wear during operation, but even so, improper operation or incorrect use environment will still shorten the life of the motor or even damage it. It is recommended to conduct measurement and maintenance every quarter:

1. Confirm the flow rate of the cooling system and remove impurities and particles.
2. Measure and eliminate partial blockage of the cooling system.
3. The detection mechanism or electrical connection must not be loosened.
4. Detect possible wear or aging of the cable.

5. Check the air gap between the stator and rotor to confirm that there is no leakage that may cause foreign matter, dust or particles to invade.
6. To test the insulation resistance of the three phases of the motor. It must meet the requirements of 1000V_DC 60 sec>100 MΩ@25℃. If the insulation resistance decreases gradually at the same temperature compared to the previous several measurements, the motor may have begun to age, so special attention should be paid.

7.1 Troubleshooting

Table 7.1 Troubleshooting

Symptom	Cause	Action
Motor cannot be rotated manually without connecting the controller	Mechanical interference	Remove interference
	Motor three-phase short circuit	Fix three-phase short circuit
Motor can't rotate at all.	Wrong cable wiring	Check the cable connected to the controller.
	Current overload	Check whether there are interfering objects and remove them. Fix the brake clamping failure.
	Over temperature protection	Check the over temperature setting of controller
	Abnormal insulation resistance	Measure insulation resistance after cooling Measurement of stator three-phase to ground (U/V/W to PE): 1000V_{DC} 60 sec>100 MΩ@25℃ If it does not reach 100 MΩ, please contact HIWIN
Wrong rotating direction	Wrong encoder setting	Check encoder setting.
	Wrong motor power cable wiring	Interchange the two-phase power cable connected to the controller.
Smell of burning	Abnormal operation of cooling system	Check cooling system.
	Wrong controller setting	Check controller setting.
	Wrong motor parameters setting	Check motor parameters setting.
Abnormal temperature of motor outer casing	Speed is too slow	Use the stall condition when switching frequency<1 Hz
	Abnormal operation of cooling system	Check cooling system.
	Wrong controller setting	Check controller setting.
	Wrong motor parameters setting	Check motor parameters setting.
	Abnormal operation of bearing	Check installation.

Symptom	Cause	Action
Unstable rotation (vibration)	Insulation failure	Check the resistance value of phase/earth is larger than 50 MΩ.
	Wrong encoder installation	Check installation stiffness of encoder.
	Wrong encoder signal	Check encoder grounding and connection.
	Wrong controller setting	Check controller setting.
	Wrong motor parameters setting	Check motor parameters setting.
Hard to rotate or abnormal friction noise	Abnormal installation of rotor	Check installation.
	Unbalanced system	Check the dynamic balance
	Loose system	Fix it tight again
	Foreign object exists in air gap.	Remove foreign object.
Motor generate local high heat (uneven)	Air bubbles blocked in the cooling circuit	Remove air bubbles or increase flow rate to remove air bubbles.
	Incorrect position of inlet and outlet of cooling circuit	Check the inlet/outlet of cooling circuit to fit according to approved drawing.

7.2 HIWIN Torque motor trouble shooting form

In the event a breakdown or error occurs with the torque motor, this form has been designed to help the user to provide HIWIN with the most essential details so that the unit can be troubleshooted and repaired efficiently and effectively. Avoiding any possible and unnecessary downtime. Please ensure the form is filled out in full.

Caution!: Don’t dismount the motor before the all possible required measurements be performed with the motor mounted in machine.

7.2.1 Identification of Motor and machine

Codification: TMRW{ | | }-{ | } /
{ }M-2-{ | }-{ | | }-{ }-{ | | }-{ | }

Serial number of stator(see label):______________________________

Serial number of rotor (see label): ______________________________

Machine designation: ______________________________

Number of axis: ______________________________

Motor in service since (yyyy-mm-dd): ______________________________

Factory location (Country, City): ______________________________

7.2.2 Conditions

Motor liquid cooling:□ No / □ Yes,

Coolant Type:□ Water +___% additive, □ Oil ___ J/(kg·K) ___kg/m³, □ Other ____

Flow rate at the motor input: _____ (l/min)

Fluid used in machine operation: □ No / □ Yes, Type:

Bearing type:

Clamp system inside: □ No / □ Yes, Type: □ Magetic, □ Hydraulic, □ Other ____

7.2.3 Failure situation

Failure description:

What was the status when the motor failed?

☐ during commissioning stage, comments:

____

☐ during Normal operation stage (e.q. turning, milling, stalled), please specify:

____

☐ other operation:

____

Failed axis(swivel, rotary table, brush, …):______________________________________

Failure message form the Controller: □ No / □ Yes, message: _____________________

____

☐ Sudden stop, comments:____

☐ Performance degradation (vibration, ripple, noise), comments:_________________

____

☐ Other, comments:____

____

Did the same failure occur before?

□ No / □ Yes, when exactly(yyyy-mm-dd):__________, failure motor type:____________

7.2.4 NC parameters

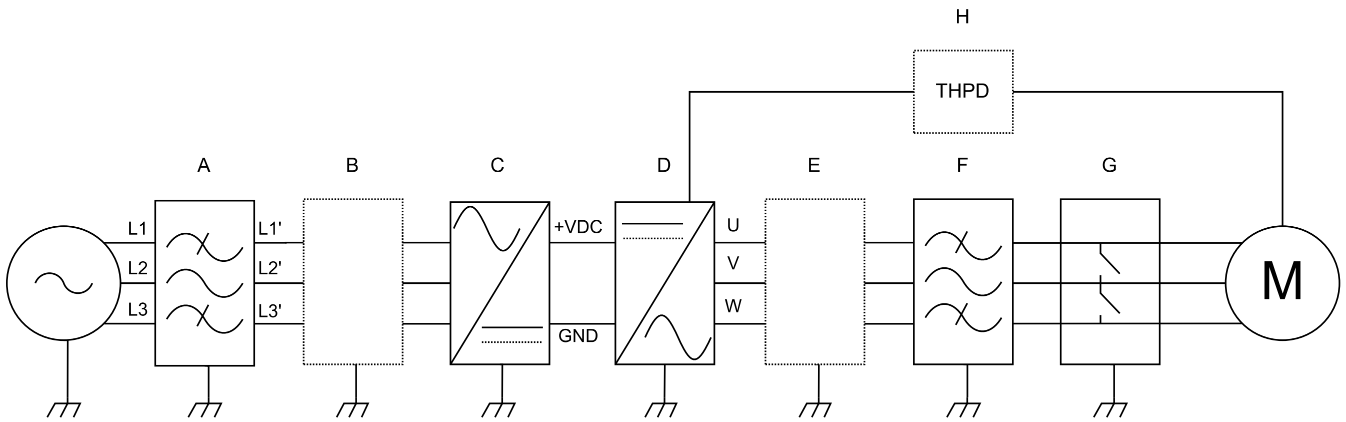
☐ NC(Numerical Control) type: ____

☐ Other comments:____

List all parameters regarding to the motor, or send the corresponding file to HIWIN (in case HIWIN supplied the parameter data sheet for the motor, please send HIWIN this parameter file)

____

____



A. Filter type: □ Harmonic filter □ Regen filter □ EMC filter □ Other type _______ □ No

B. Chokes & Reactors: □ Line reactor □ Commutation choke □ Other type _______ □ No

C. Power supply types: _______

D. Amplifier types: _______

E. Chokes & Reactors: □ dv/dt reactor □ Motor choke □ Other type _______ □ No

F. Filter type: □ dv/dt filter □ sinusoidal filter □ Other type _______ □ No

G. Short circuit relay type: _______, □ No

H. THPD used? □ No / □ Yes

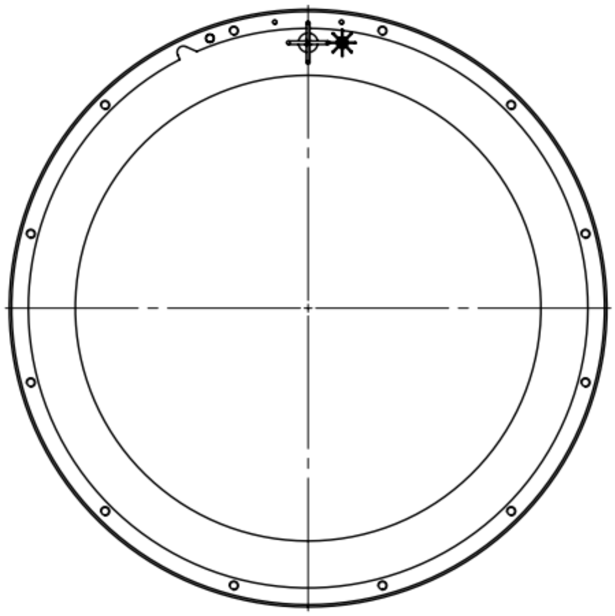
7.2.5 Electrical troubleshooting

Before starting the measurements below, switch off the power, disconnect the phases and wait until motor is cooled down to ambient temperature (25±5℃): (Precaution refer to section 7-1)
Check the entire wiring. Any observed interruptions or loose connection?
□ No / □ Yes, where exactly:____
Measure the resistances between phases: R_{U-V}:________, R_{V-W}: ________, R_{U-W}: ________
Measure the resistance to Ground: R_{U-G}:________, R_{V-G}: ________, R_{W-G}: ________
Measure the resistance of the temperatures sensors:
R_{Pt1000}:1) _____ 2) _____ 3) _____, $R_{PTC100/120/130}$: 1) _____ 2) _____ 3) _____

7.2.6 Visual inspection

In visual inspection below concerns a dismounted motor. (Be sure all measurement on machine have done before dismounted motor, or may disturb the failure scene) (Precaution refer to section 7-1)
Stator inspection:
Any abnormal marks on the stator (inside): □ No / □ Yes
Any abnormal smell on the stator: □ No / □ Yes
Remark the visual marks on the following figures:

- Blisters (draw ○)
- Burn point (draw △)
- Scratch (draw ☰)
- Flange wrinkle (draw ~)



Cables and connections inspection:
Any damage on cables/cable glands/cable connectors: □ No / □ Yes

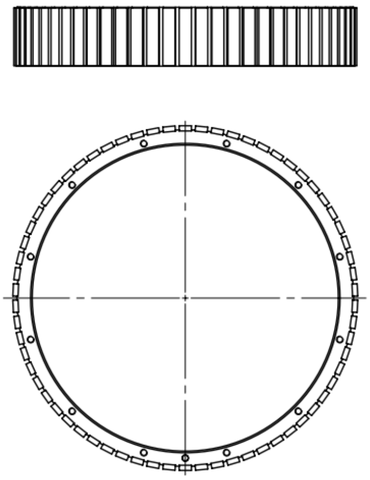
Rotor inspection:

Any abnormal marks on the rotor (outside): □ No / □ Yes

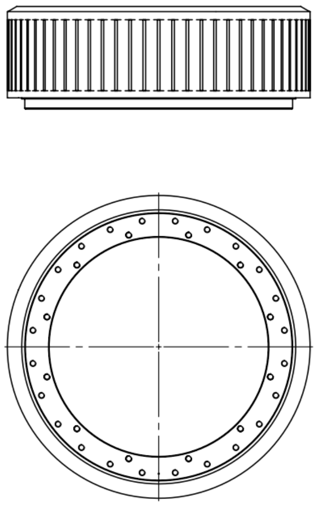
Remark the visual marks on the following figures:

- Flying magnet (draw ○)
- Burn point (draw △)
- Metal shavings (draw ╳)
- Scratch (draw ☰)
- Flange wrinkle (draw ~)

TM-2



IM-2



Is the motor oily or greasy? □ No / □ Yes, comments:______________________________

Is there any metal particles on the magnets: □ No / □ Yes, something like ______________

7.2.7 Appendix

Please share all information with HIWIN to get a better understanding of the problem (photos, NC records, damaged parts). List all the file and parts sent to HIWIN:

____

____

____

____

____

7.2.8 Contact information

Company/Institute/Department: ____

Contact person: ____

Email: ____

Phone: ____

Address: ____

8. Tolerances and Hypotheses of Motor Specifications

8. Tolerances and Hypotheses of Motor Specifications 8-1

8.1 Tolerances..8-2

8.2 Hypothesis of heat transfer 8-2

8.1 Tolerances

Except for the size specifications, there is tolerance of ±10% for all specification value mentioned in the motor specifications. The dimensions without marked tolerance are with general tolerances, except the effective depth of the thread and the positioning pin hole. The tolerance table is shown in the approved drawing.

8.2 Hypothesis of heat transfer

The assumptions of all specifications are based on water cooling and natural air cooling. For other heat dissipation conditions, individual test needs to be conducted for confirmation.

Hypothesis of air cooling condition: ambient temperature around stator/rotor: 20℃;

Hypothesis of water cooling conditions:

- Ambient temperature around the rotor: 20℃
- Inlet water temperature: 20℃
- Temperature difference between inlet and outlet water: 5℃
- External temperature of stator: 22.5℃ on average
- The stator heat exchange characteristics are defined in accordance of the number of water cooling system and the interface design from **Table 4.1**and **Table 4.4**.

9. Decommissioning and disposal

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9.2.1 Disposal of rotors 9-4
9.2.2 Disposal of packaging 9-5

DANGER!

Danger from electrical voltage!

Before and during assembly, disassembly and repair work, dangerous currents may flow.

- Work may only be carried out by a qualified electrician and with the power supply disconnected!
- Before carrying out work on the linear motor system, disconnect the power supply and protect it from being switched back on!

DANGER!

Danger from strong magnetic fields!

Strong magnetic fields around torque motor systems pose a health risk to persons with implants (e.g. cardiac pacemakers) that are affected by magnetic fields.

- Persons with implants that are affected by magnetic fields should maintain a safe distance of at least 300 mm from torque motor systems.

DANGER!

Risk of crushing from strong forces of attraction!

- Assemble the rotors and stators carefully!
- Do not place fingers or objects between the rotors and stators!
- The rotor and magnetizable objects may accidentally attract each other and collide!
- Two rotors may accidentally attract each other and collide!
- The magnetic force of the rotor acting on the object may be as high as several kN, which may cause a certain part of the body to be clamped.
- Do not underestimate the attraction force and operate carefully.
- Wear safety gloves when necessary.
- At least two people are required to cooperate during operation.
- If the assembly steps have not yet reached the installation of the rotor, please place the rotor in a safe and proper place first.
- Never take multiple rotors at once.
- Never place two rotors directly together without any protection.
- Do not bring any magnetizable materials close to the rotor! If the tool must be magnetized, please hold it firmly with both hands and slowly approach the rotor!
- It is recommended to install the rotor immediately after unpacking!
- When installing the stator and rotor, an installation auxiliary device is required to assemble the stator and rotor individually. Please follow the correct method.
- Keep the following tools at hand at any time to release body parts (hands, fingers, feet, etc.) clamped by magnetic force.
  - Hammer made of non-magnetized solid material (about 3Kg)
- Two wedge blocks composed of non-magnetized materials (wedge-shaped sharp angle 10°~15°, minimum height 50mm).

⚠ WARNING!

Danger from heavy loads!

Lifting heavy loads may damage your health.

- Use a hoist of an appropriate size when positioning heavy loads which are over 20 kg!
- Observe applicable occupational health and safety regulations when handling suspended loads!
- Motors with stator and rotor fixture can be hung with hanging holes. The strength of the components should be considered when hanging under any circumstances.

ATTENTION!

Risk of physical damage to watches and magnetic storage media.

Strong magnetic forces may destroy watches and magnetisable data storage media near to the torque motor system! 。

- Do not bring watches or magnetisable data storage media into the vicinity (<300 mm) of the torque motor systems!

ATTENTION!

Damage of the torque motor system!

The torque motor system may be damaged by mechanical loading.

- Do not pull the cable directly.
- No heavy load or sharp object on motor.

9.1 Decommissioning

When disassembling or deactivating the motor, please follow the orders instructed below:

⚠ WARNING!

Risk of injury and material damage

If you do not follow the orders to disassemble or deactivate the motor, it may cause personal injury, death or property damage.

- Please disassemble or deactivate the motor according to the order below:

1. Disconnect the motor power supply and wait for the DC power supply to discharge completely.
2. Wait for the motor to cool down (at least 30 minutes), then turn off all cooling systems and vent the pressure to 0 bar.
3. Remove all power cables, signal cables and cooling tubes.
4. If necessary, isolate all power connections to avoid the risk of electric shock due to voltage generated by the rotating motor during disassembly, or braking torque due to short circuits.
5. Drain all internal coolant and dispose of it properly
6. Clean the foreign matter, debris and dust on the motor.
7. Insert the spacer between the gaps of stator and rotor.
8. When there are fixation plates of stator and rotor or self-designed stator and rotor fixing jigs, use these plates/jigs to fix the stator and rotor.

8-1 If the guiding fixture method is used, it is necessary to confirm that the related fixture and configuration are installed.

9. Remove all the fixings at the machine end. If the stator and rotor are fixed, they can be separated from the machine at the same time; if the guiding method is used, please remove the stator and rotor in the reverse order during assembly. When removing, be careful that the O-ring may be damaged.
10. When removing the O-ring, be careful not to stretch it excessively. Stretching more than 10% may cause permanent damage; it is also not allowed to twist or use sharp tools.
11. Use the original packaging or a safe way to pack and store it correctly.

Note: If replace a new torque motor, it is recommended to use a new O-ring; when the O-ring needs to be replaced, please refer to Chapter 4.1.4 to purchase an appropriate O-ring or purchase it from HIWIN.

9.2 Disposal

Products need to be disposed according to the normal recycling process in accordance with laws and regulations.

⚠ WARNING!

Injury and material damage if not correctly disposed of

If the torque motor or related components (especially the rotor with strong magnets) are not handled correctly, it may cause personal injury, death or property damage.

- Please ensure that the torque motor and related components are disposed of correctly.

Appropriate disposal process:

- The permanent magnets in the rotor assembly must be completely demagnetized.
- The components to be recycled need to be disassembled:
  - Electronic waste (e.g. encoder components, temperature control modules, etc.)
  - Electrical waste (e.g. stator, cables, etc.)
  - Scrap metal alloys (classified by metal)
  - Insulation material
- No mixing with solvents, cold cleaning agents, or residue of paint

9.2.1 Disposal of rotors

Rotors with permanent magnets must be disposed after a specific demagnetization treatment to avoid the danger of subsequent disposal. It is recommended to be disposed of by a professional recycling company.

After disassembling the motor, the rotor must be separately placed in a safe package.

Rotor demagnetization steps:
It needs to be placed in a dedicated non-magnetic oven for baking, and the rotor is placed on a strong and heat-resistant load. During the entire demagnetization process, the temperature in the oven must be at least 310°C (Curie point) for baking for 1 hour, and the exhaust gas generated during the baking should be treated to avoid environmental pollution.
Note: After degaussing and returning to normal temperature, the remaining gauge should be close to 10 Gauss, otherwise it is recommended to continue the above process.

9.2.2 Disposal of packaging

The packaging materials and packaging auxiliary materials used by HIWIN are no problematic materials. Except for wood materials, they can be recycled and reused. Wood materials should be burned.

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10. Technical Terms

9. Technical Terms 9-6

- **Back EMF constant (line-to-line):** K_v $\left(\frac{V_{rms}}{rad/s}\right)$

  The back EMF constant, K_v, is the ratio of the back EMF voltage (V_{rms}) to the motor rotational speed (rad/s) when the magnet is at 25℃. It is created at the movement of the coil in the magnetic field of permanent magnets.

- **Continuous current:** I_c/I_{cw} (A_{rms})

  The continuous current, I_c, is the current that can be continuously supplied to the motor coils at the ambient temperature 25℃, and the final temperature of coil can't exceed 120℃
  (130℃ for □M-2 series). Under this condition, the motor reaches the rating continuous torque T_c; in relation with the continuous current and coil temperature, torque motor will respond to I_c for air cooling and I_{cw} for water cooling

- **Continuous torque:** T_c/T_{cw} (Nm)

  The continuous torque, T_c, is the maximum torque the motor is able to generate continuously at the ambient temperature 25℃ and the final temperature of coil can't exceed 120℃ (130℃ for □M-2 series). This continuous torque correspond to I_c/I_{cw} supplied to the motor; in relation with continuous current and coil temperature, torque motor will respond to T_c for air cooling and T_{cw} for water cooling.

- **Inductance (line-to-line):** L (mH)

  Inductance is defined as inductance measured between lines when the motor operates at the coil temperature 25℃.

- **Resistance at 25℃ (line-to-line):** R_{25} **(Ω)**

  Resistance is defined as resistance measured between lines when the motor operates at the coil temperature 25℃.

- **Motor constant:**K_m $\left(\frac{Nm}{\sqrt{W}}\right)$

  The motor constant, K_m, is defined as the ratio of square root of motor output torque to consumption power when the coils and magnets are at 25℃. The larger motor constant represents the lower power loss when the motor outputs at the specific torque.

- **Number of poles: 2p**

  2p represents the number of poles of the rotor, where p is the number of poles pair.

- **Peak current: I_p (A_{rms})**

  The peak current, I_p, is the current corresponding to torque output of the motor, and the motor temperature reached by current can't demagnetize magnet. Generally speaking, peak current can be granted to supply 1 second when the motor is operating in the normal condition and the input current phase is balanced. And then the motor needs to rest for at least 6 seconds after it reaches the normal temperature to supply peak current. (For more accurate time, please contact HIWIN)

- **Peak torque: T_p (Nm)**

  The peak torque, T_p, is the maximum torque that the motor outputs less than 1 second. Peak current corresponding to the torque cannot demagnetize magnet.

- **Rotor inertia:J (kgm^2)**

  The rotor inertia, J, is the rotary component resists any changes in its state of motion, including changes to its speed and direction. It is related to the shape and mass.

- **Stall condition:**

  When the motor is moving slowly with a control frequency bellowing 1Hz which is produced the uneven power distribution in the individual motor phases.

- **Stall current:I_s/I_{sw} (A_{rms})**

  The stall current, I_s, is the upper limit of current when the motor is at 25℃ and in the stall condition. Depending on the heat dissipation, torque motor will correspond to I_s for air cooling and I_{sw} for water cooling.

- **Stall torque: T_s/T_{sw} (Nm)**

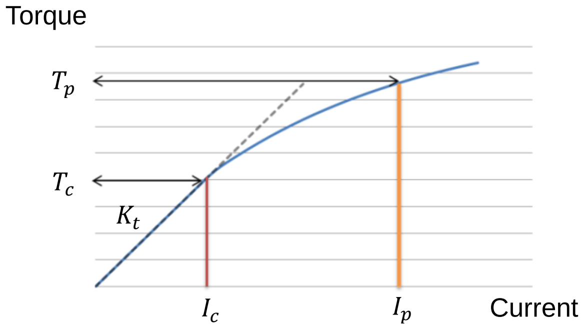
  The stall torque, T_s, is the upper limit of torque when the motor is at 25℃ and in the stall condition. Depending on the heat dissipation, torque motor will correspond to T_s for air cooling and T_{sw} for water cooling.

- **Thermal resistance: R_{th} (K/W)**

  The thermal resistance, R_{th}, is defined as the resistance suffered heat from motor coil to dissipate the environment (consider the natural convection and radiation for air cooling when ambient temperature is at 25℃, and the force water cooling for water cooling when the water is at 25℃). Higher thermal resistance represents the larger temperature difference between the coil and environment under the same heat source.

- **Torque constant:K_t (Nm/A_{rms}) at magnet temperature of 25℃**

  The torque constant, K_t, is ratio between as the motor's output torque per RMS current. Except for TMRW series, output torque and input current shows a linear relationship. The non-linear relationship is due to saturation in the iron core.



- **Maximum speed**

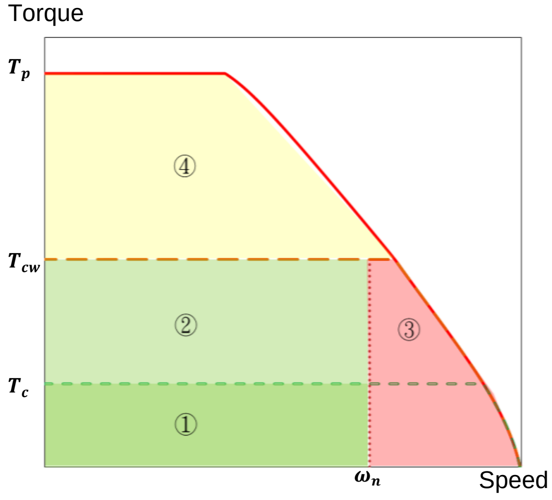
  Maximum speed is defined as maximum speed provided under specific torque (usually continuous torque). There are three conditions to define the maximum speed of torque motor: maximum speed under air-cooling continuous torque, maximum speed under water-cooling continuous torque and maximum speed under peak torque.

- **Rated speed: ω_n (rpm)**

  Rated speed, ω_n, is defined as the speed at which the rotor will not be damaged due to the high temperature of the rotor (>80℃) caused by iron loss when the motor is running continuously without rest; if the speed exceeds this speed, the working cycle must be reduced or additional heat dissipation design must be conducted for rotor. Please refer to the T-N Curve for the explanation of the motor working range.

- **T-N Curve (TM-2)**

  The T-N curve is defined as the comparison chart of the torque and the speed that can be output under a certain input voltage of the motor. Considering the temperature rise of the motor, the figure can be divided into four operating ranges as shown below:



①：When the motor is air-cooled and the torque is less than T_c, it can run continuously below ω_n without break.

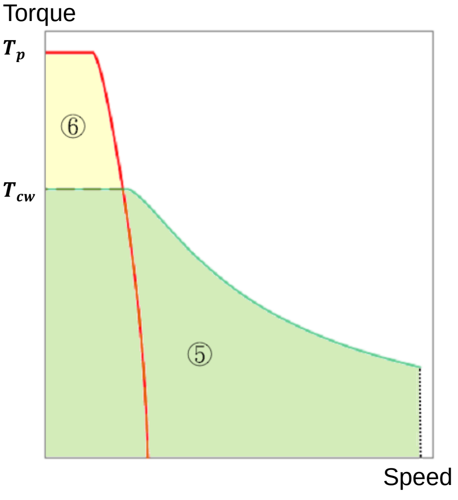
①+②： When the motor is water-cooled and the torque is less than T_{cw}, it can run continuously below ω_n without break.

③： When the motor is air-cooled and the torque is less than T_c or when it is water−cooled and the torque is less than T_{cw}, the speed is greater than ω_n , the duty cycle must be reduced or additional design on rotor heat dissipation must be provided to avoid overheating of the rotor.

④： When the motor is air-cooled and the torque is greater than T_c or when it is water-cooled and the torque is greater than T_{cw}, the duty cycle must be reduced. When T_p is reached, only 1 second output is allowed to avoid overheating of the stator.

- **T-N Curve (IM-2)**

  The T-N curve is defined as the comparison chart of the torque and the speed that can be output under a certain input voltage of the motor. Considering the temperature rise of the motor, the figure can be divided into two operating ranges as shown on next page:



⑤ : When the motor is water-cooled and the torque is less than T_{cw}, it can run continuously below maximum speed in field weakening without break.

⑥ : When it is water-cooled and the torque is greater than T_{cw}, the duty cycle must be reduced. When T_p is reached, only 1 second output is allowed to avoid overheating of the stator.

- **Maximum input voltage (V_{DC})**

  Maximum input voltage is the maximum voltage for the motor operating in the normal environment.

- **Maximum continuous power loss: P_c (W)**

  Maximum continuous power loss is the energy lost when the motor runs continuously under continuous current and the coil temperature is 120℃ (130℃ for □M-2). It mainly converts into heat. In water cooling system, the loss is mostly eliminated by coolant.

- **Maximum pressure difference: Δp (bar)**

  Maximum pressure difference is the maximum value tolerated by the pressure difference between inlet and outlet under water cooling system with pure water. It corresponds to minimum water flow q. If the operating environment is different, pressure difference must be modified by calculation (refer to Section 3.6).

- **Minimum water flow: q (l/min)**

  Minimum water flow is the minimum flow required for normal cooling under water cooling system with pure water. If the operating environment is different, water flow must be modified by calculation (refer to Section 3.6).

- **Temperature difference under maximum power loss: $\Delta\theta$ (℃)**

  Temperature difference under maximum power loss is the temperature difference between inlet and outlet under water cooling system with pure water. Generally, it is defined as 5℃. If the operating environment is different, temperature difference under maximum power loss must be modified by calculation (refer to Section 3.6).

- **Rated power (kW)**

  Rated power is the maximum continuous rated power as specified on the nameplate of the motor.

  In IM-2 Series, the rated power in the field-weakening operation will be higher than normal operation, so the definition of rated power in IM-2 series will be the maximum continuous rated power in the field-weakening operation.

  The schematic as shown as below, the red dot is the maximum continuous rated power in the field-weakening operation