HIWIN®

TMRW Series Torque Motor

Installation Manual

www.hiwinmikro.tw

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1. Introduction

HIWIN TMR(W) series torque motor, with the constitution of a stator and a rotor, can be directly drove 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 Safety symbols

Symbol	Meaning
	Warning of dangerous high voltage!
	Warning of magnetic fields!
	Warning of hot surfaces!
	Environmentally hazardous substance!

1.3 Safety instructions

- ◆ 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.
- ◆ Do not repair the product by yourself when it malfunctions. The product can only be repaired by qualified technician from HIWIN.
- ◆ HIWIN 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 Wiring precautions

- ■ 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.
- ■ Check if the wiring is correct. Incorrect wiring may make the motor operate abnormally, or even cause permanent damage to the motor.
- ■ Select extension cord with isolation net. The isolation net must be grounded.
- ■ Do not connect power cable and temperature sensor cable to the same extension cord.
- ■ Power cable and temperature sensor cable contain isolation net. The isolation net must be grounded.

1.3.2 Operation precautions

- Avoid excessive friction when the motor is running.
- Ensure there is no object in the motion range of the system.
- Before starting the motor, ensure the water cooling system works properly.
- Before starting the motor, ensure the main switch is on.
- Before transmitting electricity, ensure at least one ground wire is connected to all electrical products.
- Do not directly touch motor parts as the motor stops operating.
- 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.
- Do not operate the product in an environment that exceeds its rated load.
- When the motor is running, its temperature must be within the specification.
- If any abnormal odor, noise, smoke, temperature rise or vibration is detected, stop the motor and turn off the power immediately.
- Ambient temperature: +5˚C ~ +40˚C

1.3.3 Maintenance and storage precautions

- Do not store the product in an inflammable environment or with chemical agents.
- Store the product in a place without humidity, dust, harmful gases or liquids.
- Install the product in location with less vibration.
- The storage and transportation temperature of the product: -10˚C ~ +50˚C
- The way to clean the product: wipe with alcohol (70%)
- The way to discard the damaged product: recycle it according to local laws and regulations

2. Motor Basic Structure

TMRW series can get its best performance through water cooling. Bearing, position feedback device and other related parts are excluded from shipment. Motor basic structure is shown in Figure 2.1.

- **Stator**

  Stator in TMR series does not contain water cooling channel, while stator in TMRW series does. The outer casing is made of aluminum alloy or silicon steel, and the inner part is composed of iron core and 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 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).

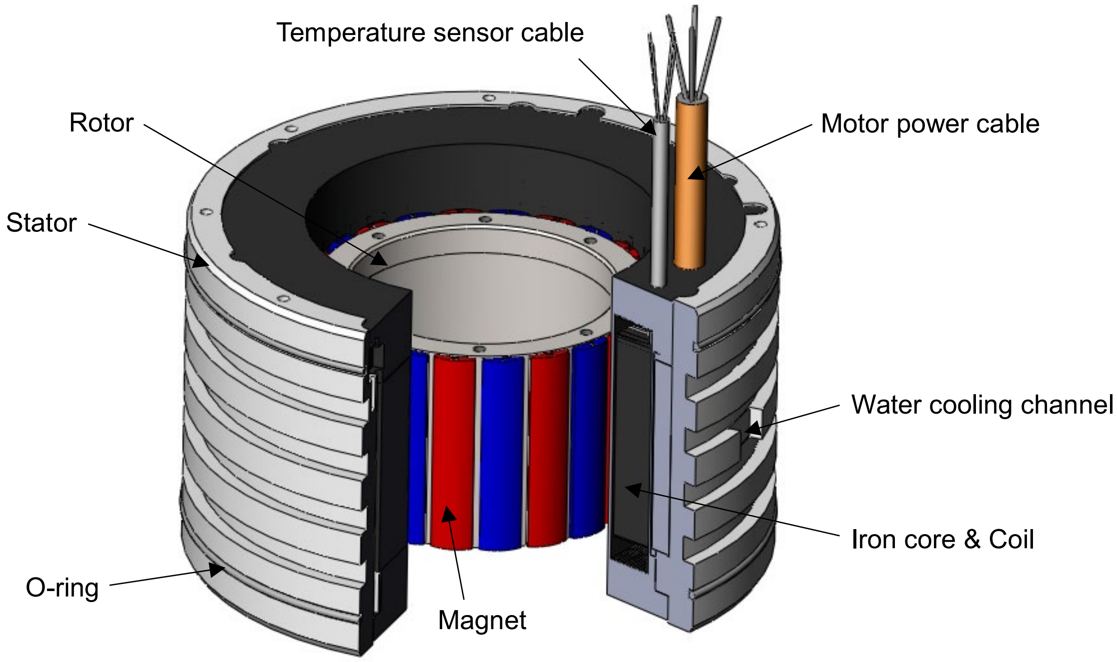


Figure 2.1 Motor basic structure for TMRW series

3. Motor Sizing

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

↓

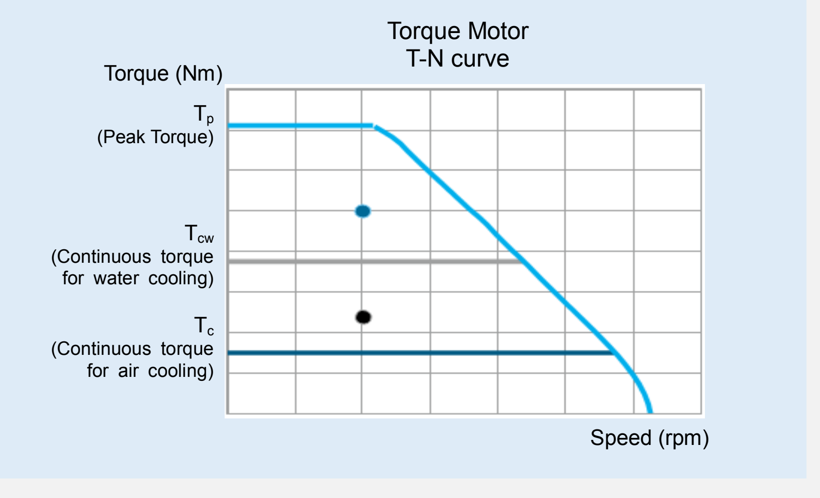
Torque calculation

- 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

θ	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)	ω0	Initial angular velocity (rad/s)
J	Load inertia (kgm^2)	m	Loading Mass (kg)
J_m	Rotor inertia (kgm^2)	R	Outside diameter of loading Mass (m)
T_p	Peak torque (Nm)	r	Inside diameter of loading Mass (m)
T_c	Continuous torque (Nm)	a、b	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

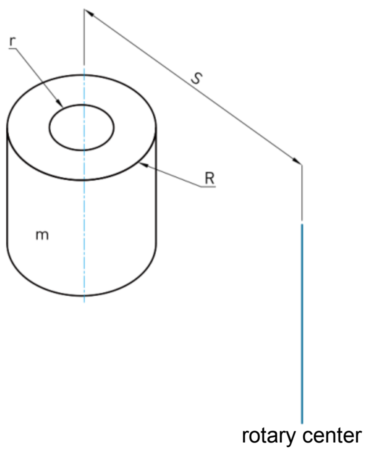
To select a proper motor, the following formula of load inertia and motion must be understood before selection.

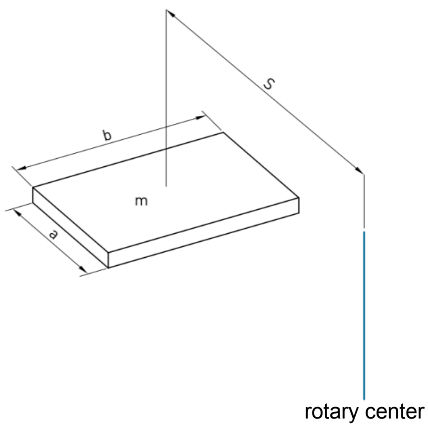
Calculation of load inertia

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

moment of inertia of a hollow cylinder: $J = m\left(\frac{R+r}{2} + S^2\right)$

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





Determine motion speed and parameters

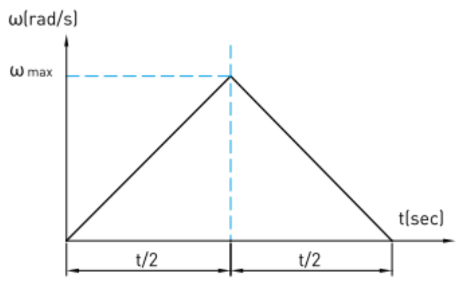
Basic kinematics equations are described as below.

$\omega = \omega_0 + \alpha t \quad \theta = \omega_0 t + \frac{1}{2}\alpha t^2$

Where ω is angular velocity, α is angular acceleration, t is moving time and θ is angular displacement. Users can choose two of the four parameters (ω, α, t and θ) 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 “Trapezoid profile” and “Triangle 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.



$\omega_{max} = 2 \times \frac{\theta}{t}$ or $\omega_{max} = \sqrt{\alpha \times \theta}$

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

STEP 2 Torque calculation

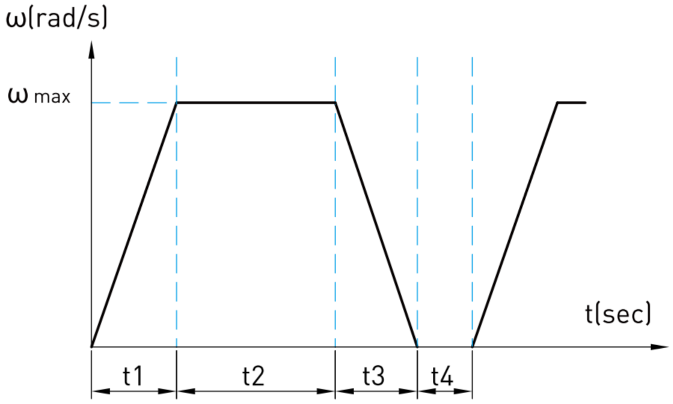
The maximum torque can be calculated by the following equation.

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

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

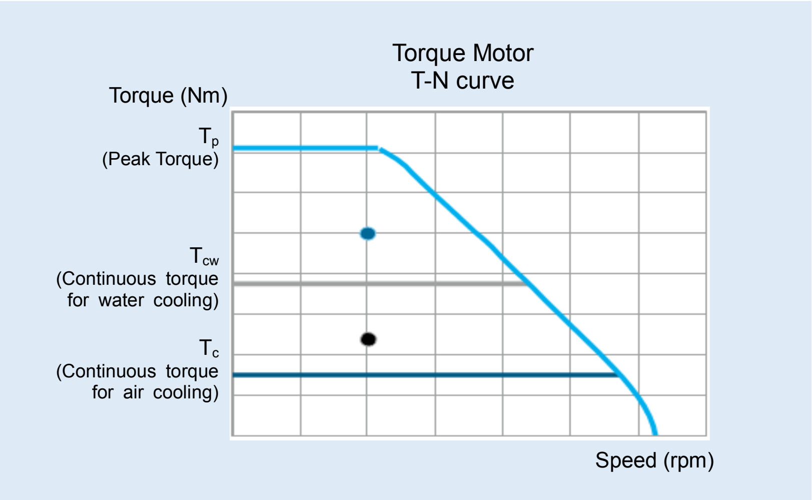
In most cases, the motions are cyclic point-to-point movements. The equivalent torque of a cyclic motion with a dwell time of t_4 second can be calculated as below.

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



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 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.

Peak current I_{max} and effective current I_e can be calculated by bring motor torque constant into the following equation. (To know more about K_t, please refer to Chapter 8.)

$$I_{max} = \frac{T_{max}}{K_t}$$

$$I_e = \frac{T_e}{K_t}$$

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.

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

P_c = copper loss at coil temperature θ_c [W]
R_{25} = line-to-line resistance at coil temperature 25°C [Ω]
I_c = continuous current at coil temperature θ_c [Arms]
θ_c = coil temperature [°C] (120°C for TMRW series; as for TMR series, refer to the drawing)

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, the more the iron loss.

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

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. Ensure parameters you use fit the specification, and keep coil temperature from exceeding 120°C.

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°C. 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.

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

θ_e = steady state temperature of coil under equivalent torque [°C]
θ_{surr} = ambient temperature [°C]
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

During the operation of motor, coil temperature is related to thermal time constant. The definition of thermal time constant is the time that the initial temperature reaches 63% of steady state temperature (as Figure 3.3.1 shows). The time to reach steady state is approximately five times the thermal time constant.

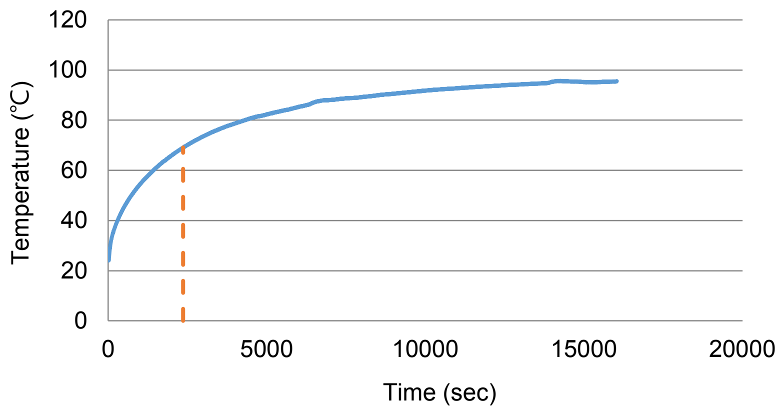


Figure 3.3.1 Curve of temperature rising

The relationship between thermal time constant and temperature is

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

$\theta(t)$ = coil temperature [°C] (at the operating time t)
θ_i = initial coil temperature [°C]
t = operating time [sec]
T_{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

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

t_0 = maximum operating time [sec]

Note: Coil temperature (θ_c) here cannot exceed the specification's upper limit. (120°C for TMRW series; as for TMR series, refer to the drawing)

The relationship between coil temperature and power off time is

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

$\theta(t_b)$ = coil temperature to be cooled [°C] (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 Water cooling system calculation

The features of motor indicated in HIWIN water-cooling motor drawing and specification are suitable for water cooling condition, and coolant temperature is 20°C. 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 under 120°C 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.

$$P_e = \frac{P_c}{\left(\frac{T_c}{T_e}\right)^2} \qquad P_e = 69.7 \cdot q_e \cdot \Delta\theta$$

P_e = Total loss of motor under equivalent torque [W]
$\Delta\theta$ = Temperature difference between motor inlet and outlet [°C]
q_e = Coolant flow [l/min] (under equivalent torque)

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

$$\Delta p_e = \Delta p \cdot \frac{q_e}{q}$$

Δp_e = Pressure difference between inlet and outlet [bar] (under equivalent torque)

Δp = Pressure difference between inlet and outlet [bar] (under equivalent torque)

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

■ Example

In model type TMRWAF's specification, the continuous torque (T_c) in 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°C, what is the coolant flow (q_e) and the pressure difference between inlet and outlet (Δp_e) in cooling water system? [ν_{water} = 10^{-3} (m^3/kg)]

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

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

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

$$\Delta p_e = \Delta p \cdot \frac{q_e}{q} = 3 \times \frac{4.27}{23.7} = 0.54(bar)$$

The differences between datasheet parameters and user parameters are listed in the following table.

Table 3.4.1 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 (Δθ)	5°C	6°C
Coolant flow (q)	22 l/min	4.27 l/min
Pressure difference between inlet and outlet (Δp)	3 bar	0.54 bar

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4. Motor Installation Design

4.1 Water cooling design

TMRW series can be cooled by water or air. 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, coolant inlet and outlet must be aligned with motor cable outlet.

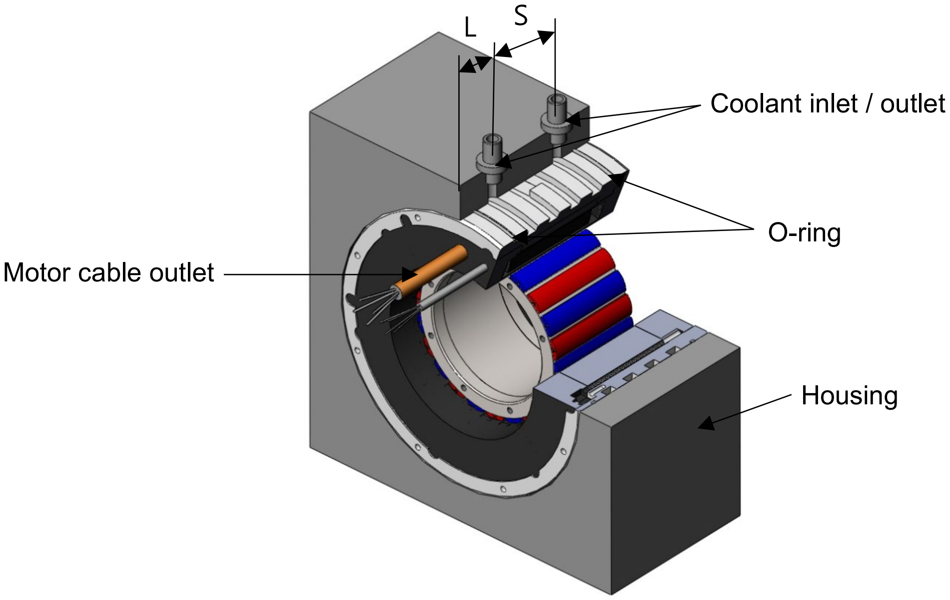


Figure 4.1.1 Motor basic structure for TMRW series

4.1.1 Water cooling channel position

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

Table 4.1.1.1 Coolant inlet / outlet position

L (mm)	S (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)

4.1.2 Water cooling channel dimension

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

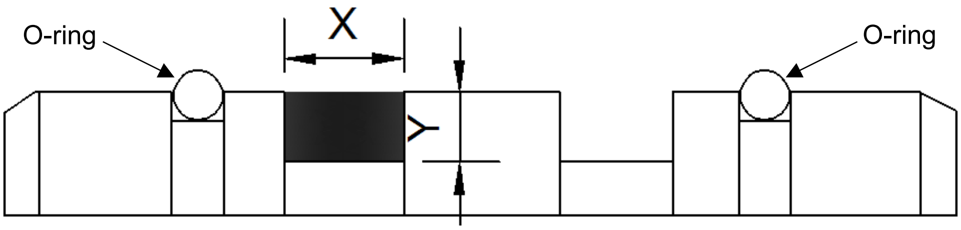


Figure 4.1.2.1 Water cooling channel dimension diagram

Table 4.1.2.1 Water cooling channel dimension

Motor type	X (mm)	Y (mm)	Inlet / Outlet inside diameter (mm)	Motor 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	4.8	10
TMRW45(L)	8	5	8	TMRWG5(L)	8	4.8	10
TMRW47(L)	9	5	8	TMRWG7(L)	9	4.8	10
TMRW4A(L)	8	5	8	TMRWGA(L)	8	4.8	10
TMRW4F(L)	9	5	8	TMRWGF(L)	9	4.8	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				

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. Besides, coolant inlet and outlet must be aligned with motor cable outlet (refer to HIWIN approved drawing for motor cable outlet position).

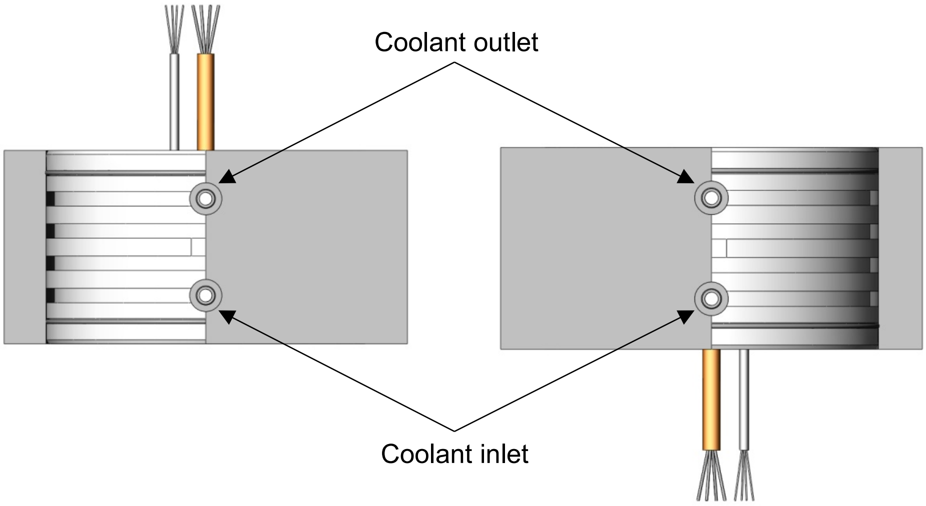


Figure 4.1.3.1 Coolant inlet / outlet position when mounted horizontally

- **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).

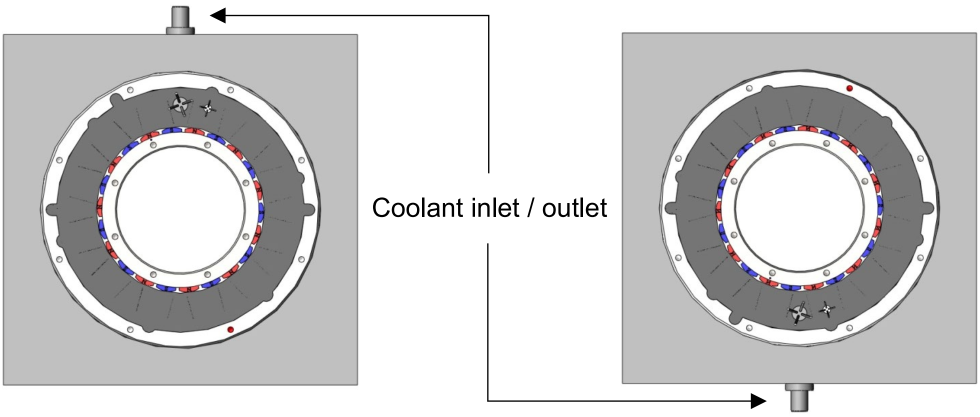


Figure 4.1.3.2 Coolant inlet / outlet position when mounted vertically

4.1.4 O-ring features

O-ring features for each series are given in the following table.

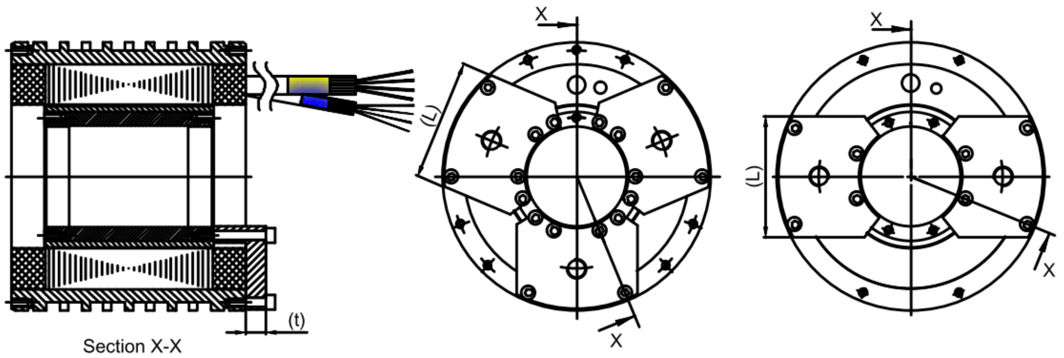
Table 4.1.4.1 O-ring features

Motor type	O-ring type	O-ring thickness (mm)	O-ring inside diameter (mm)
TMRW1□	VITON	2.62	152.07
TMRW2□	VITON	2.62	190.17
TMRW4□	VITON	2.62	221.92
TMRW7□	VITON	2.5	296
TMRWA□	VITON	4	370
TMRWD□	VITON	4	465
TMRWG□	VITON	4	550

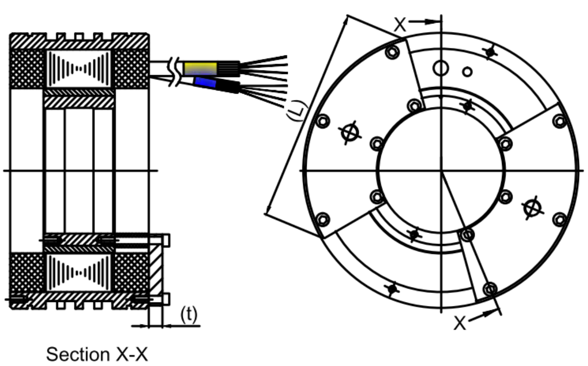
4.1.5 Fixture dimension

Fixture dimension for each series is given as below.

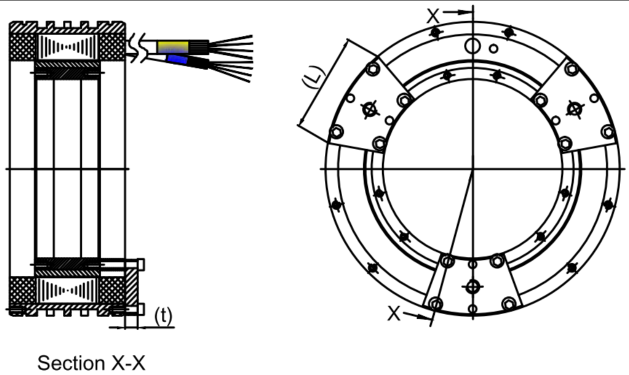
TMRW1 series



TMRW2 series



TMRW4 series



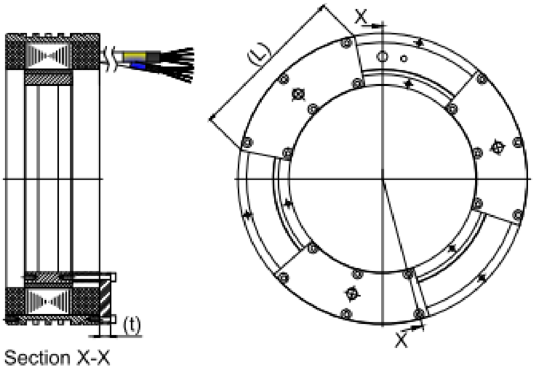
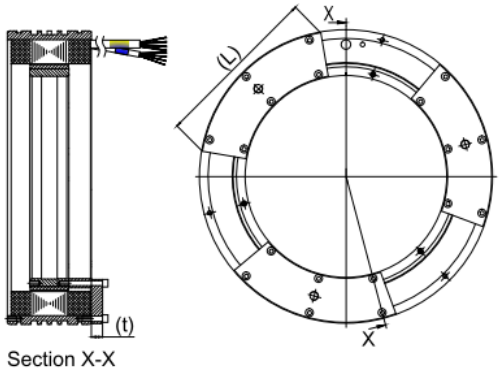
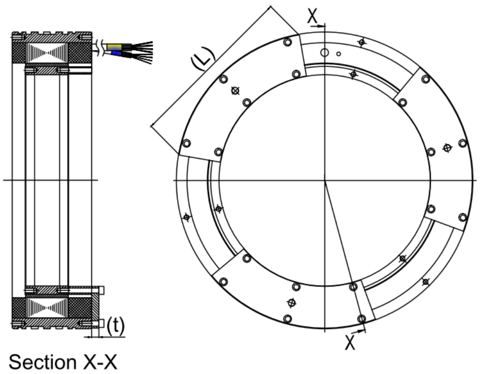
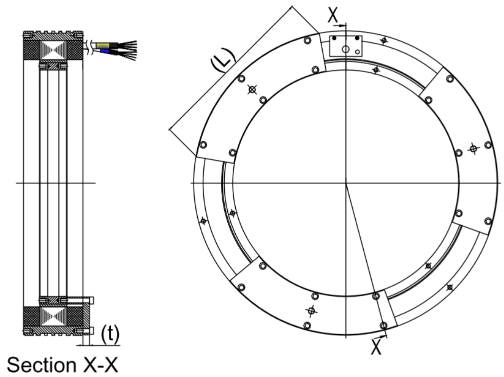
TMRW7 series	TMRWA series
	
TMRWD series	**TMRWG series**
	

Figure 4.1.5.1 Fixture diagram

Table 4.1.5.1 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 installation design

To prevent magnet interference from affecting motor performance, there should be some space between customer's shaft and rotor magnet. The recommended maximum dimension of outside diameter (ΦD), inside diameter (Φd) and flatness specification of rotor mounting surface (Flatness A) is given in Table 4.2.1.

Note: Refer to HIWIN approved drawing for TMR series.

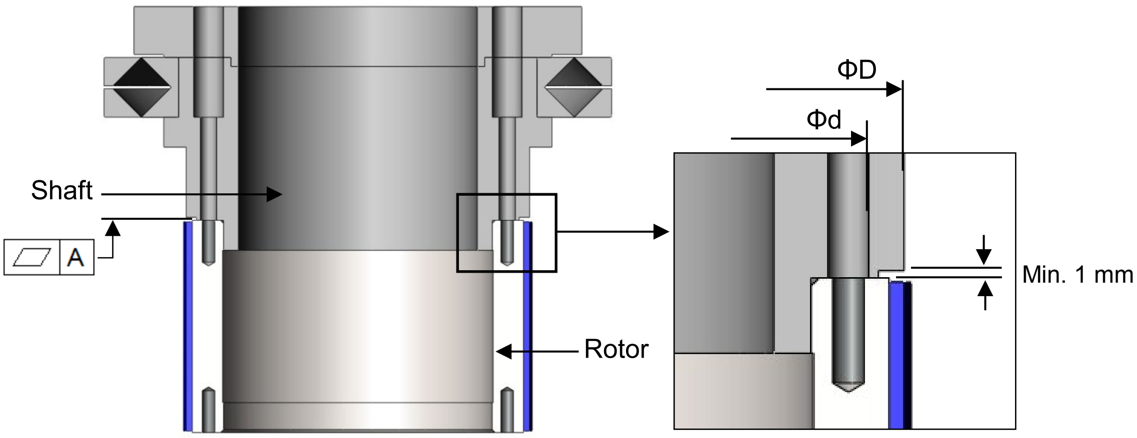


Figure 4.2.1 Rotor mounting level

Table 4.2.1 Rotor mounting level suggestion

Motor type	ΦD (mm)	Φd (mm)	Flatness A (mm)	Flatness B (mm)
TMRW1□	84.5	76.5	0.05	0.05
TMRW2□	118	110	0.05	0.05
TMRW4□	168	158.5	0.1	0.1
TMRW7□	233	222.5	0.1	0.1
TMRWA□	298	284.5	0.1	0.1
TMRWD□	383	370	0.15	0.15
TMRWG□	458	447	0.15	0.15

4.3 Stator installation 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 4.2.1. Housing is suggested to be chamfered (the recommended dimension is shown in Figure 4.3.1) to avoid scratching O-ring and causing water leaking.

Note: Refer to HIWIN approved drawing for TMR series.

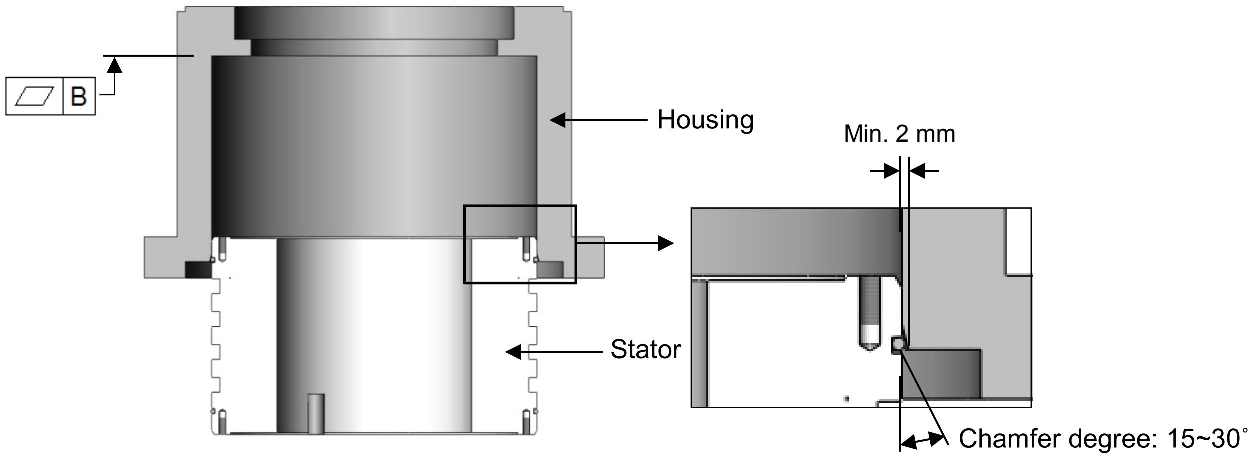


Figure 4.3.1 Stator mounting level

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 Table 4.4.1, the motor will not be interfered during rotation.

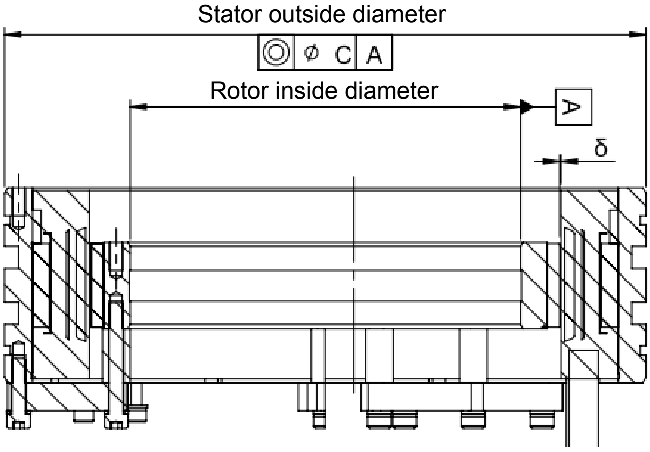


Figure 4.4.1 Air gap and assembly concentricity diagram

Table 4.4.1 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

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. Value of radial force for each series is given in Table 4.5.1.1.

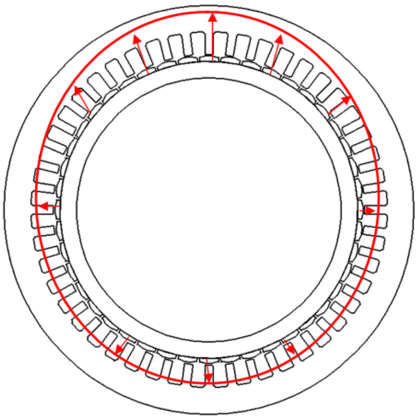


Figure 4.5.1.1 Concentricity of stator and rotor is offset

Table 4.5.1.1 Value of radial force

Motor type	Radial force: f (N/mm)
TMRW1A	2184
TMRW2A	2590
TMRW4A	2946
TMRW7A	2899
TMRWAA	3574
TMRWDA	4350
TMRWGA	5158

Radial force varies by length of iron core.

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

“L” stands for length of iron core. Length of iron core for each series is given as below.

Table 4.5.1.2 Length of iron core

Motor type	L (mm)
TMRW□3	30
TMRW□5	50
TMRW□7	70
TMRW□A	100
TMRW□F	150
TMRW□J	190
TMRW□L	210

- **Example**

Radial force of TMRW7F:

$$Force = \text{TMRW7A's } f \times \frac{150}{100} = 2899 \times \frac{150}{100} = 4348.5\ \text{N}/mm$$

4.5.2 Axial force

When rotor moves toward stator, an axial force is generated between stator and rotor. Value of axial force for each series is given in Table 4.5.2.1. “X” in Figure 4.5.2.1 stands for moving distance, and its unit is millimeter (mm).

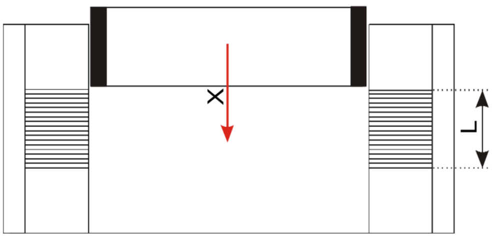


Figure 4.5.2.1 Rotor moves toward stator

Table 4.5.2.1 Maximum value of axial force

Motor type	Axial force: f (N/mm)
TMRW1□	118
TMRW2□	176
TMRW4□	300
TMRW7□	375
TMRWA□	528
TMRWD□	944
TMRWG□	1335

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 4.6.1.

Table 4.6.1 Screw tightening torque

Motor type	Specification of threaded holes	Quantity of threaded holes	Screw tightening torque (kgf-cm)
TMRW13(L) TMRW15(L) TMRW17(L) TMRW23(L) TMRW25(L) TMRW27(L)	M5 x 0.8P x 10DP	8	80
TMRW1A(L) TMRW1F(L) TMRW2A(L) TMRW2F(L)	M5 x 0.8P x 10DP	16	80
TMRW43(L) TMRW45(L) TMRW73(L) TMRW75(L) TMRW77(L)	M5 x 0.8P x 10DP	12	80
TMRW47(L) TMRW4A(L) TMRW4F(L) TMRW7A(L) TMRW7F(L)	M5 x 0.8P x 10DP	24	80
TMRWA3(L) TMRWA5(L) TMRWA7(L)	M6 x 1P x 12DP	12	120
TMRWAA(L) TMRWAF(L)	M6 x 1P x 12DP	24	120
TMRWD3(L) TMRWD5(L) TMRWD7(L)	M8 x 1.25P x 12DP	12	250
TMRWDA(L) TMRWDF(L)	M8 x 1.25P x 12DP	24	250
TMRWG3(L) TMRWG5(L) TMRWG7(L)	M8 x 1.25P x 12DP	12	250
TMRWGA(L) TMRWGF(L)	M8 x 1.25P x 12DP	24	250

4.7 Motor cable

The standard length of power cable and temperature sensor cable is 2000mm±50mm (as Figure 4.7.1 shows), excluding the metal connector of the outlet. Customers can choose other lengths. 1 m is taken as a unit, up to 8 m.

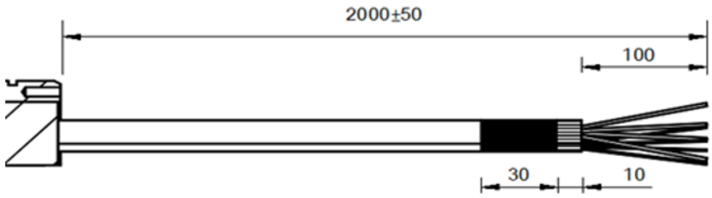


Figure 4.7.1 Cable specification

4.7.1 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 the following table.

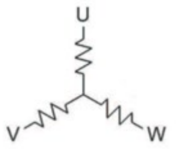
Note: Power cable contains isolation net. The isolation net must be grounded.

Table 4.7.1.1 Relationship between wire diameter and motor type

Cross-sectional area (mm^2)	Motor type				
1.5	TMRW13(L)	TMRW15(L)	TMRW17(L)	TMRW1A(L)	TMRW1F
	TMRW23(L)	TMRW25(L)	TMRW27(L)	TMRW2A(L)	TMRW2F
	TMRW43	TMRW45	TMRW47		
2.5	TMRW43L	TMRW45L	TMRW47L	TMRW4A	TMRW4F
	TMRW73	TMRW75	TMRW77	TMRW7A	TMRW7F
	TMRWA3	TMRWA5			
4.0	TMRW1FL	TMRW2FL	TMRW4AL	TMRW4FL	TMRW73L
	TMRW75L	TMRW77L	TMRW7AL	TMRW7FL	TMRWA3L
	TMRWA5L	TMRWA7	TMRWAA	TMRWD3	TMRWD5
	TMRWD7	TMRWDA	TMRWG3	TMRWG5	TMRWG7
6.0	TMRWA7L	TMRWAAL	TMRWAF		
10.0	TMRWAFL	TMRWD3L	TMRWD5L	TMRWD7L	TMRWDAL
	TMRWDF	TMRWG3L	TMRWG5L	TMRWG7L	TMRWGA
	TMRWGF				
25.0	TMRWDFL	TMRWGAL	TMRWGFL		

The relationship between power cable color and signal is given in Table 4.7.1.2.

Table 4.7.1.2 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	

4.7.2 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 SNM100, a set of SNM200 and a Pt1000 or KTY84-130. Pt1000 or KTY84-130, which contains an ESD protection device, is installed on every phase winding. Temperature sensors used in each type are given in Table 4.7.2.1. The cross-sectional area of temperature sensor cable is 0.25 mm^2, and the connection of temperature sensor cable color for each type is given from Figure 4.7.2.1 to Figure 4.7.2.3.

Note 1: Since the supplier no longer produces temperature sensor KTY84-130, it will be replaced by Pt1000.
Note 2: Temperature sensor cable contains isolation net. The isolation net must be grounded.

Table 4.7.2.1 Temperature sensors used in each type

Type	Temperature sensor	Remarks
Type A	SNM120 + Pt1000 or KTY84	-
Type B	SNM100 + SNM120 + Pt1000 or KTY84	Standard
Type C	SNM120 + 3x Pt1000 or 3x KTY84	-

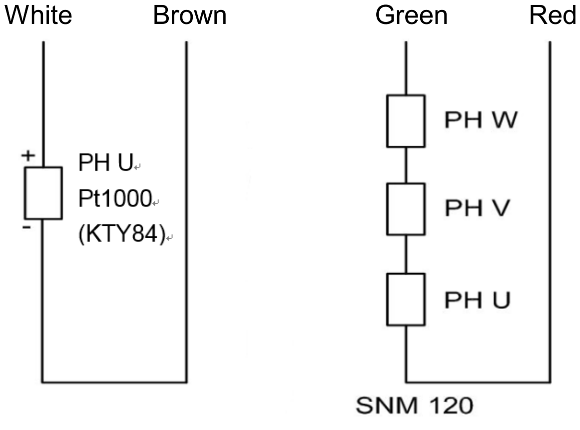


Figure 4.7.2.1 Type A

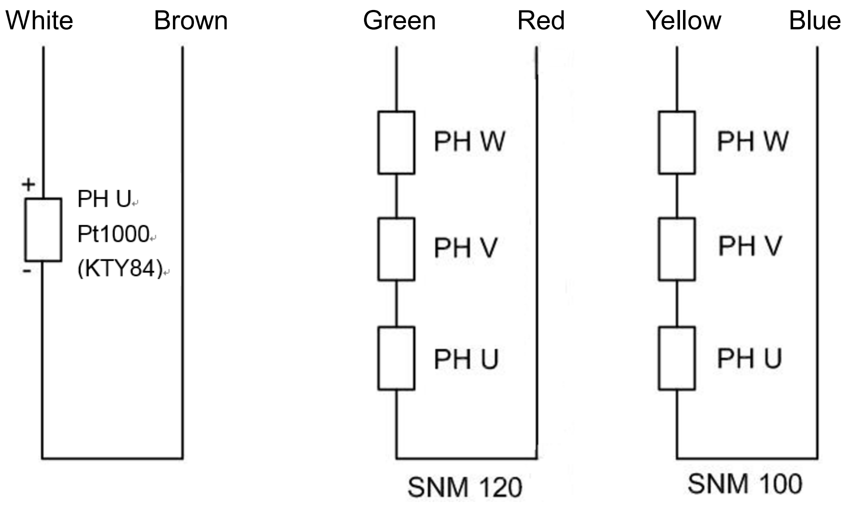


Figure 4.7.2.2 Type B

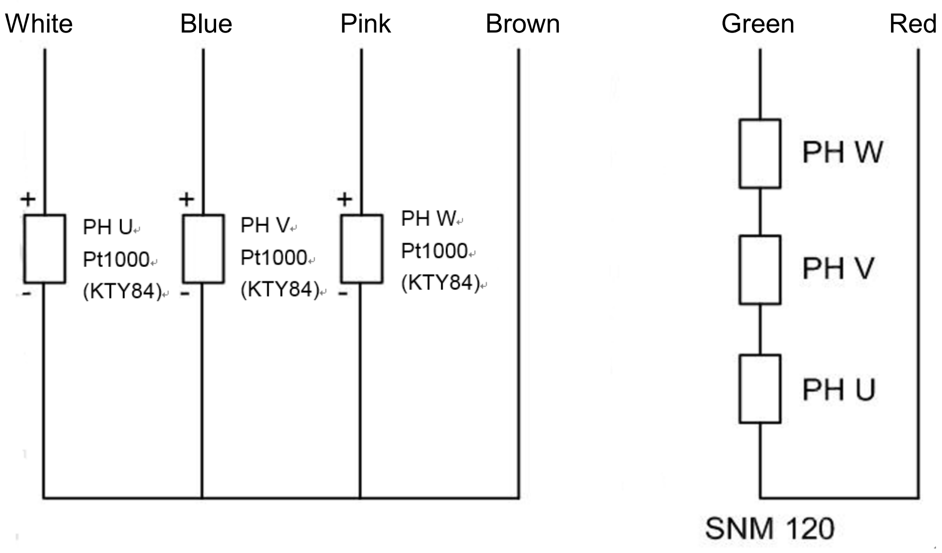
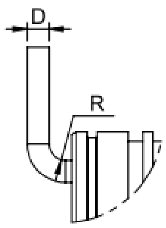


Figure 4.7.2.3 Type C

4.7.3 Bend radius of cable

The minimum bend radius of power cable and temperature sensor cable for TMRW series is given in the following table.

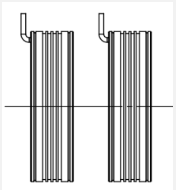
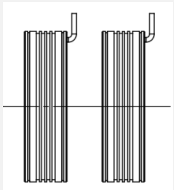
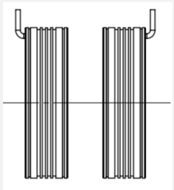
Table 4.7.3.1 Bend radius of cable

Feature	Diagram	Power cable		Temperature sensor cable
		Olflex servo FD	Chainflex CF27	Chainflex
			Chainflex CF270	
Min. bend radius of fixed installation		R= 4 x D	R= 4 x D	R= 5 x D
			R= 5 x D	
Min. bend radius of moving installation		R= 7.5 x D	R= 7.5 x D	R= 12 x D
			R= 10 x D	

4.8 Parallel operation design

Torque motor can perform parallel operation on the same axis. Follow Table 4.8.1 to correctly connect the power cables. The details of wiring for condition 1 and condition 2 are shown in Figure 4.8.2 to Figure 4.8.7.

Table 4.8.1 Connection of power cables for parallel operation

		Condition 1				Condition 2	
							
	Drive	Master	Slave	Master	Slave	Master	Slave
TMRW 1A / 2D / 7G Series	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

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 4.8.1 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. To get the parallel information of TMR series, contact HIWIN Engineering Department.

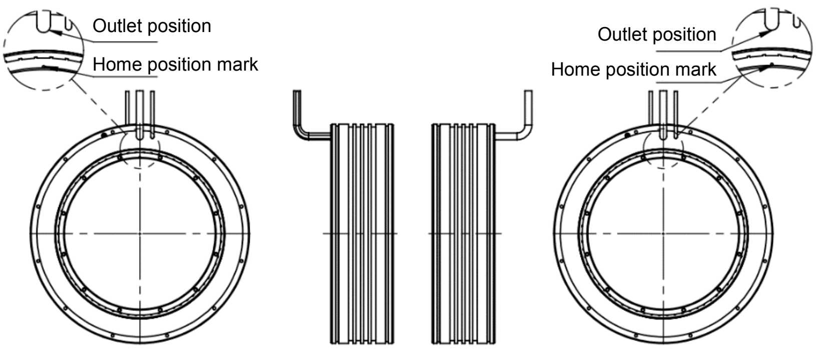


Figure 4.8.1 Relative position of home position mark and outlet position during parallel operation

Color	Temp. sensor
Green	T+ PTC 120 °C
Red	T- PTC
White	T+ Pt1000(KTY 84)(U)
Brown	T- Pt1000(KTY 84)

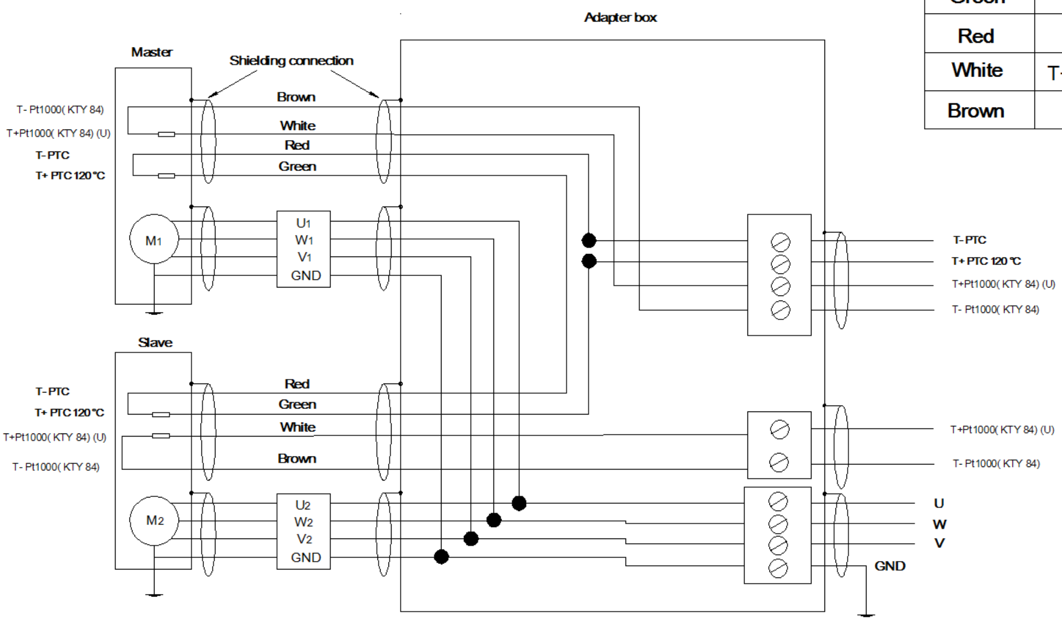


Figure 4.8.2 Type A (Condition 1)

Color	Temp. sensor
Green	T+ PTC 120 °C
Red	T- PTC
White	T+ Pt1000(KTY 84)(U)
Brown	T- Pt1000(KTY 84)

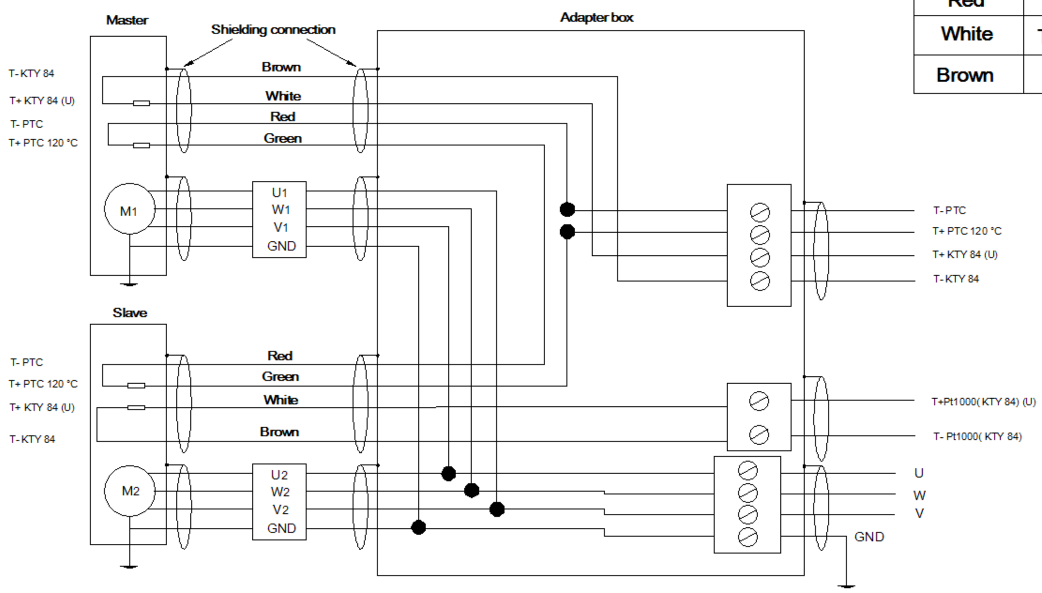


Figure 4.8.3 Type A (Condition 2)

Color	Temp. sensor
Green	T+ PTC 120 °C
Blue	T+ PTC 100 °C
Red	T- PTC 120 °C
Yellow	T- PTC 100 °C
White	T+ Pt1000(KTY 84)(U)
Brown	T- Pt1000(KTY 84)

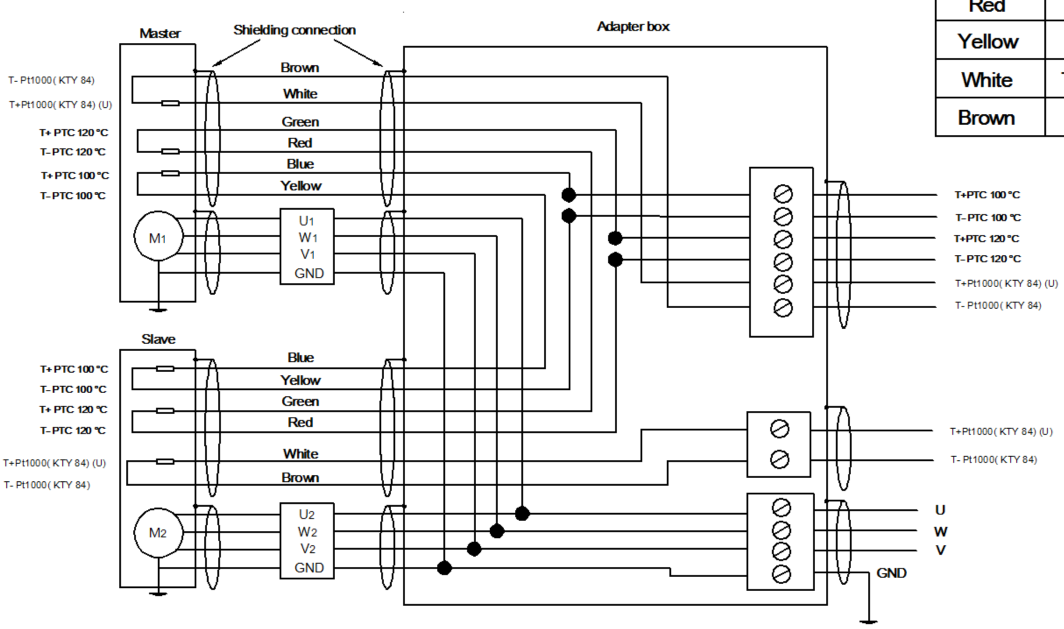


Figure 4.8.4 Type B (Condition 1)

Color	Temp. sensor
Green	T+ PTC 120 °C
Blue	T+ PTC 100 °C
Red	T- PTC 120 °C
Yellow	T- PTC 100 °C
White	T+ Pt1000(KTY 84)(U)
Brown	T- Pt1000(KTY 84)

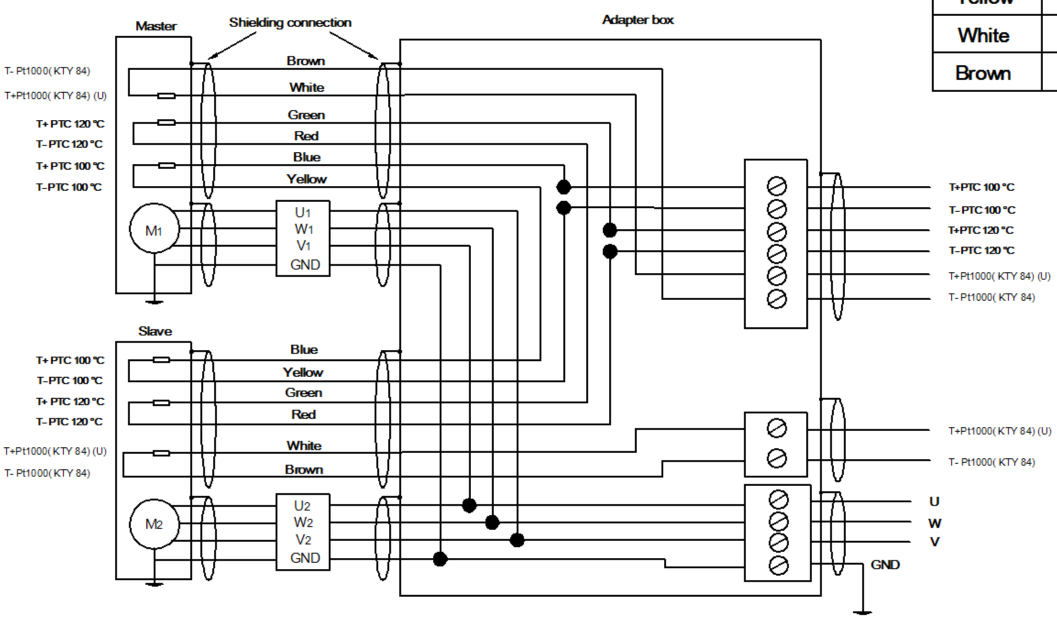


Figure 4.8.5 Type B (Condition 2)

Color	Temp. sensor
Green	T+ PTC 120 °C
Red	T- PTC
White	T+ Pt1000(KTY 84)(U)
Blue	T+ Pt1000(KTY 84)(V)
Pink	T+ Pt1000(KTY 84)(W)
Brown	T- Pt1000(KTY 84)

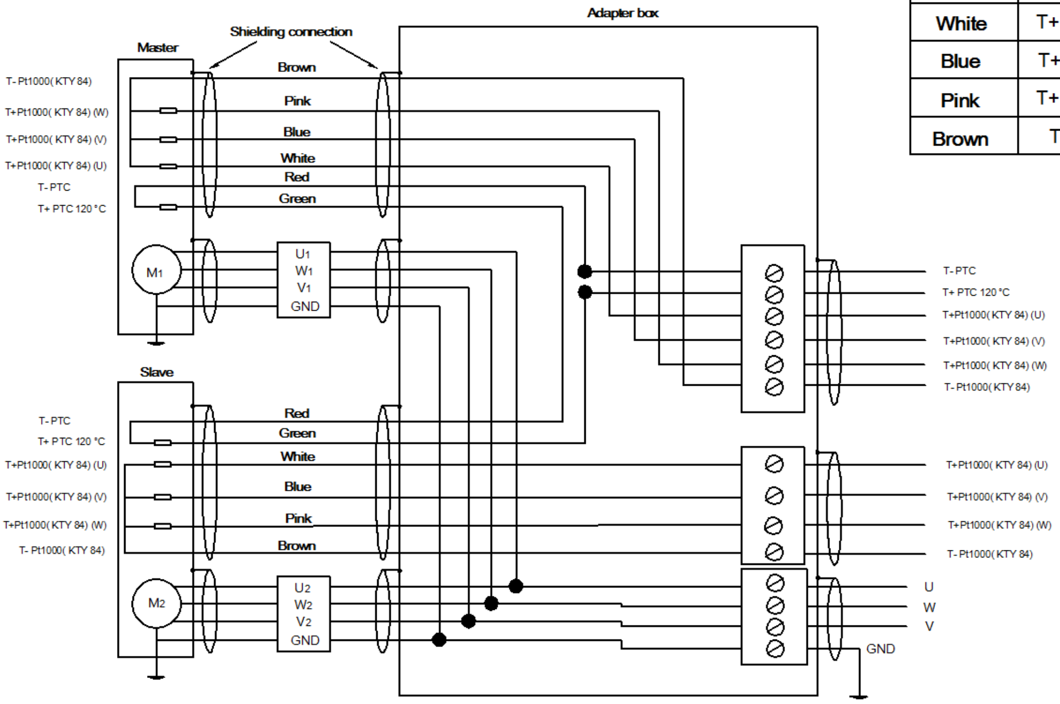


Figure 4.8.6 Type C (Condition 1)

Color	Temp. sensor
Green	T+ PTC 120 °C
Red	T- PTC
White	T+ Pt1000(KTY 84)(U)
Blue	T+ Pt1000(KTY 84)(V)
Pink	T+ Pt1000(KTY 84)(W)
Brown	T- Pt1000(KTY 84)

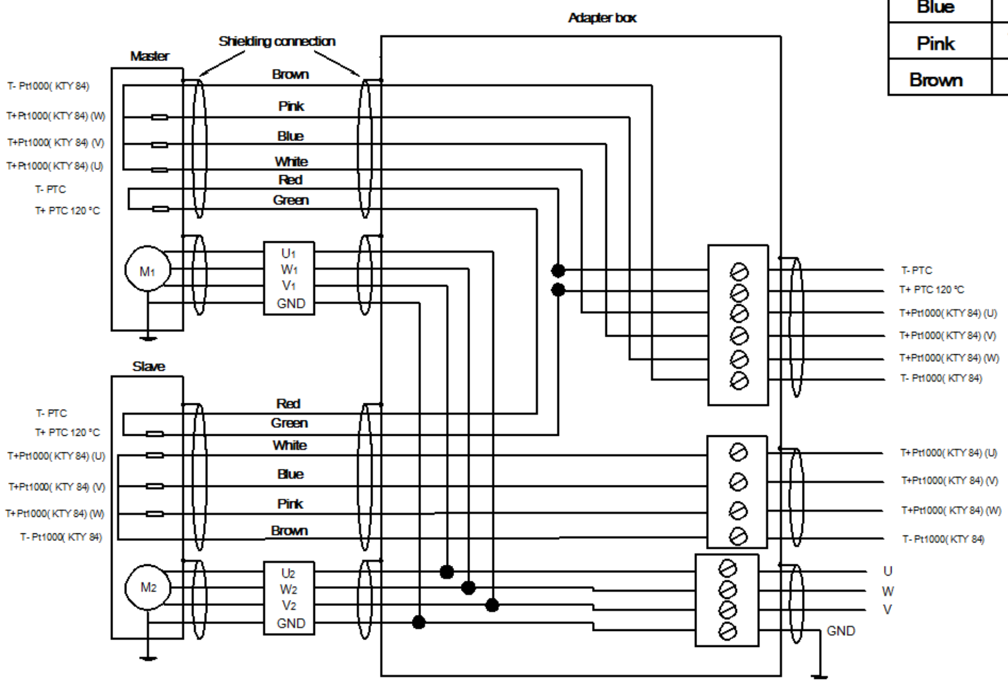


Figure 4.8.7 Type C (Condition 2)

4.9 Temperature sensor

KTY84-130, a type of silicon temperature sensor, can measure output resistance to get the actual temperature. Its features are given in Table 4.9.1, and the relationship between resistance and temperature is shown in Figure 4.9.1.

Table 4.9.1 Features of temperature sensor KTY84-130

Symbol	Parameter	Condition	Minimum	Standard	Maximum	Unit
R_{100}	Resistance under 100°C	$I_{(out)}$=2mA	970	-	1030	Ω
R_{250}/R_{100}	Resistance ratio	T=250°C & 100°C	2.111	2.166	2.221	Ω
R_{25}/R_{100}	Resistance ratio	T=25°C & 100°C	0.595	0.603	0.611	Ω

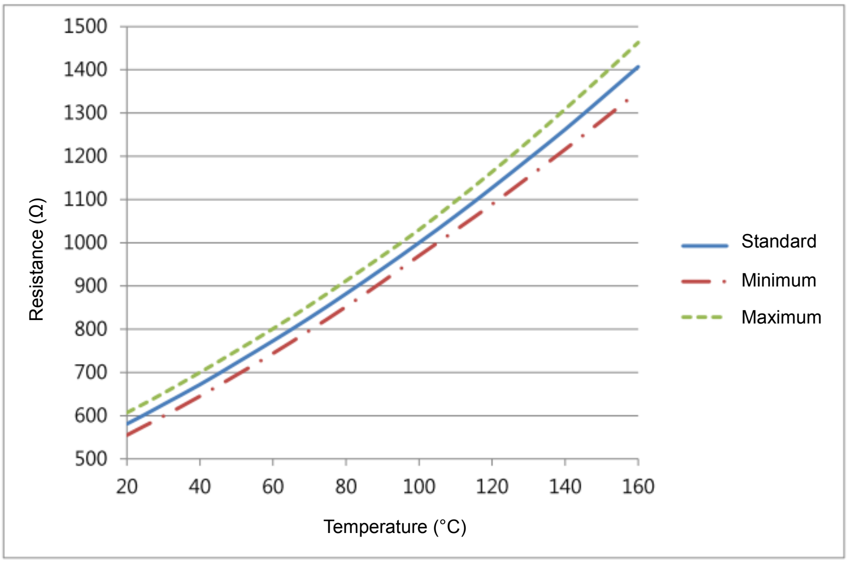


Figure 4.9.1 Relationship between resistance and temperature (KTY84-130)

Pt1000, a type of platinum resistance temperature sensor (RTD) with a resistance value of 1000Ω at 0°C, can measure output resistance to get the actual temperature. The relationship between resistance and temperature is shown in Figure 4.9.2, and the standard formulas between resistance and temperature are given as below.

Temperature range: -200°C ~ 0°C

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

Temperature range: 0°C ~ 850°C

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

R_0 = 1000 [Ω]   A = 3.9083 x 10^{-3} [$°C^{-1}$]

B = -5.7750 x 10^{-7} [$°C^{-2}$]   C = -4.1830 x 10^{-12} [$°C^{-4}$]   θ = operating temperature [°C]

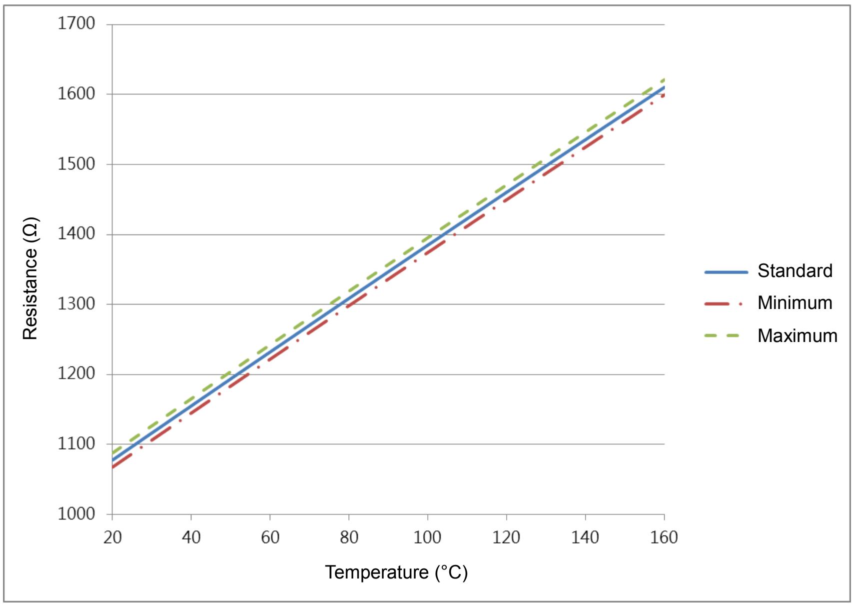


Figure 4.9.2 Relationship between resistance and temperature (Pt1000)

SNM100 and SNM120 are thermistors. Their output resistance changes according to coil temperature. Resistance of SNM100 rises drastically when T_{REF} = 100°C, while resistance of SNM120 rises drastically when T_{REF} = 120°C. Their features are given in Table 4.9.2 and Figure 4.9.3.

Table 4.9.2 Features of SNM

Temperature	Resistance
20℃<T<T_{REF} - 20K	20Ω~250Ω
T=T_{REF} - 20K	≦ 550Ω
T=T_{REF} + 5K	≧ 1,330Ω
T=T_{REF} + 15K	≧ 4,000Ω

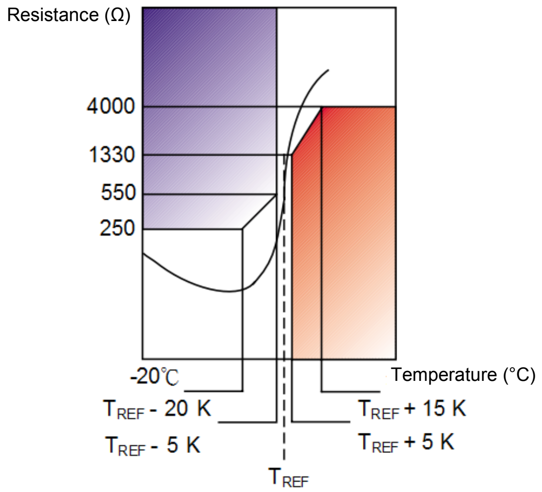


Figure 4.9.3 Relationship between PTC temperature and resistance

5. Thermal Protection Device

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

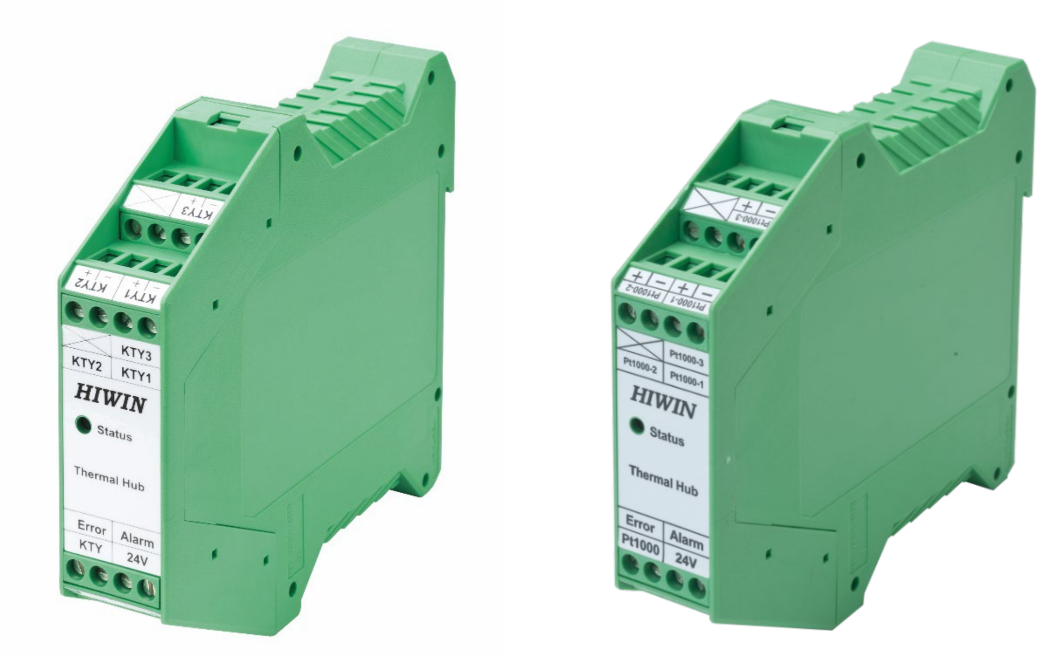


Figure 5.1 Thermal protection device

5.1 Features

- THPD must be used with HIWIN TMRW / TMRI series motor.
- It converts three temperature sensor inputs of motor into one analog output and two digital outputs and send 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.
- Due to its type, the specification of temperature sensor input can be classified into KTY84-130 and Pt1000.
- Controller can get the complete information of motor temperature via the following methods.

  Analog temperature output: KTY84-130 or Pt1000

  Digital warning output: Alarm

  Digital error output: Error

5.2 Wiring of temperature module

Match temperature sensor KTY84-130 with THPD-130-120. Match temperature sensor Pt1000 with THPD-1000-120. The wiring diagrams are as below.

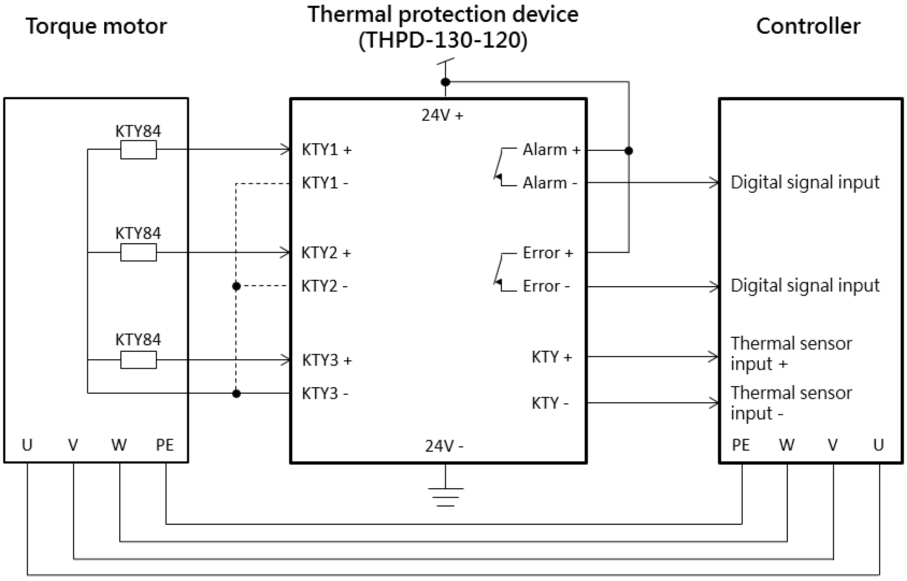


Figure 5.2.1 KTY84-130 wiring diagram

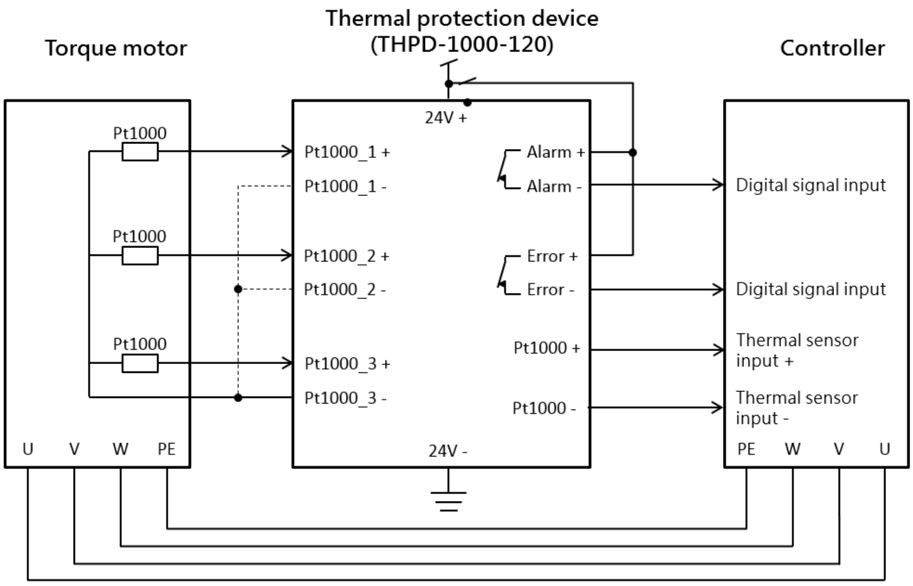


Figure 5.2.2 Pt1000 wiring diagram

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6. Motor Installation

There are two ways to install the motor.

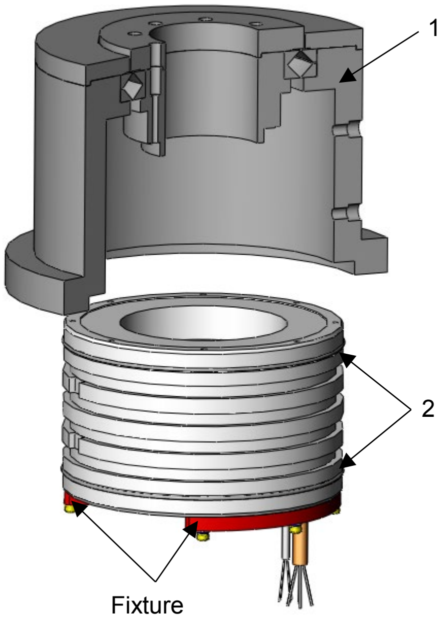
- **Install stator and rotor together**
  They are installed with the fixture provided by HIWIN, and the fixture position can be either the outlet side or the other side. Before placing an order, customers can consult with HIWIN sales or engineers about the definition of the fixture position. HIWIN will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

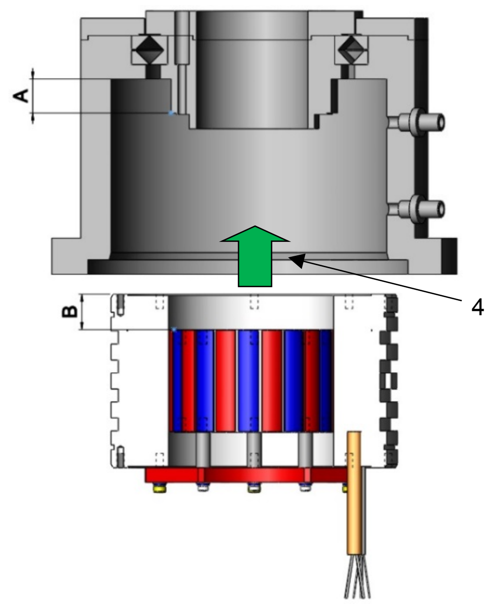
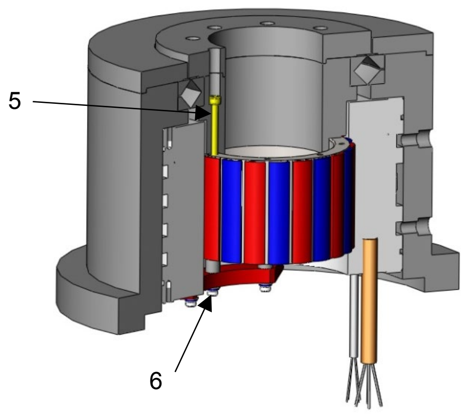
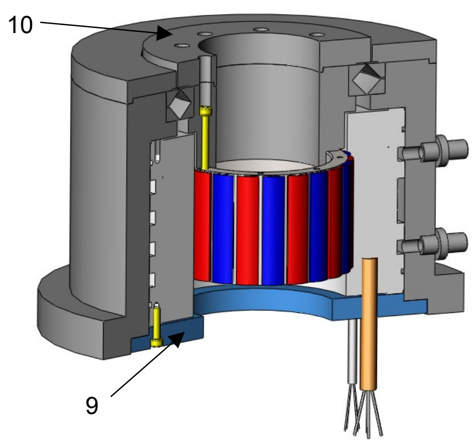
- **Install stator and rotor separately**
  Based on the basis of customer's mechanism, a guide tool is designed for installing stator and rotor.

The recommended steps for installation are described as below.

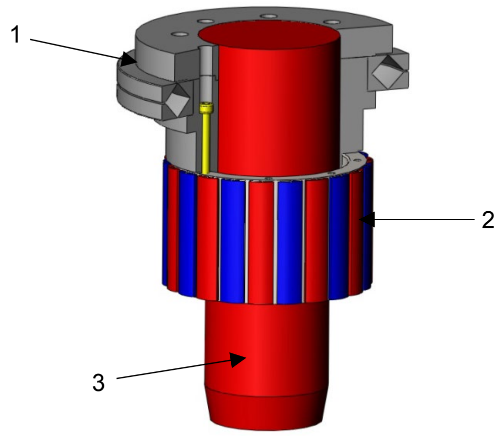
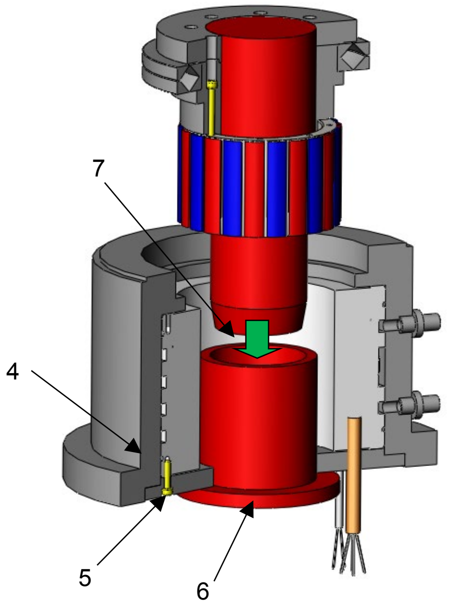
Note: Here takes water-cooling motor for example. As for installing TMR series, ignore the water-cooling related instructions.

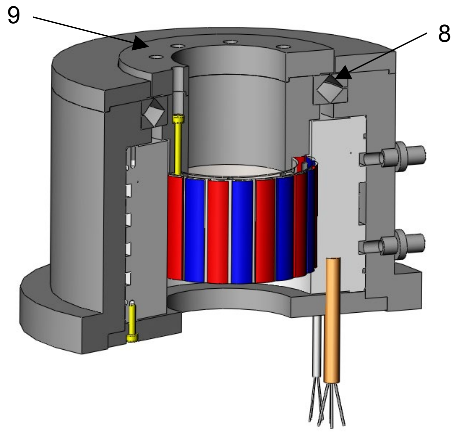
6.1 Install stator and rotor together

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

<table>
<tr><td>
</td><td>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.</td></tr>
<tr><td>
</td><td>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.</td></tr>
<tr><td>
</td><td>9. Install bottom plate and fasten fixed screws of stator (refer to Section 4.6 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.</td></tr>
</table>

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 Section 4.6 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. Rotate rotating part. Ensure that it rotates smoothly and that no interference occurs. 10. Install the remaining parts, such as connector of coolant inlet / outlet, lower supporting bearing and encoder.

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7. Troubleshooting

Table 7.1 Troubleshooting

Symptom	Cause	Action
Motor cannot rotate at all.	Wrong cable wiring	Check the cable connected to the controller.
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	Abnormal operation of cooling system	Check cooling system.
	Wrong controller setting	Check controller setting.
	Abnormal operation of bearing	Check installation.
Unstable rotation (vibration)	Insulation failure	Check the resistance value of phase/earth is larger than 50MΩ.
	Wrong encoder installation	Check installation stiffness of encoder.
	Wrong encoder signal	Check encoder grounding and connection.
	Wrong controller setting	Check controller setting.
Hard to rotate or abnormal friction noise	Abnormal installation of rotor	Check installation.
	Foreign object exists in air gap.	Remove foreign object.

8. Technical Terms

■ **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°C. 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°C, and the final temperature of coil can't exceed 100°C (120°C for TMRW series). Under this condition, the motor reaches the rating continuous torque T_c; in relation with the continuous current and coil temperature, TMRW series 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°C and the final temperature of coil can't exceed 100°C (120°C for TMRW series). This continuous torque corresponds to I_c/I_{cw} supplied to the motor; in relation with the continuous current and coil temperature, TMRW series 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°C.

■ **Resistance at 25°C (line-to-line): R_{25} (Ω)**

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

■ **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°C. 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 maximum 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 then need to ensure it reaches the normal temperature to supply peak current.

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

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

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

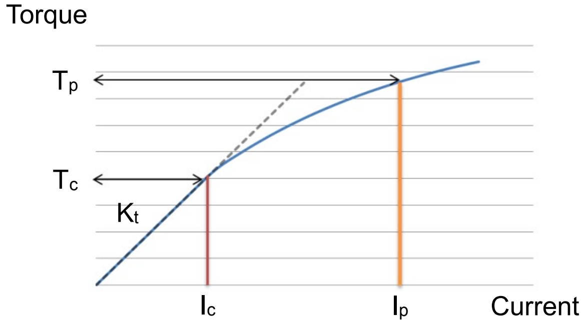
  The stall torque, T_s, is the upper limit of torque when the motor is at 25°C and in the stall condition. Depending on the heat dissipation, TMRW series will correspond to T_s for air cooling and T_{sw} for water cooling.

- **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°C, and the force water cooling for water cooling when the water is at 25°C). 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})**

  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 water-cooling motor: maximum speed under air-cooling continuous torque, maximum speed under water-cooling continuous torque and maximum speed under peak torque.

- **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°C. 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 3.4).

- **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 3.4).

- **Temperature difference under maximum power loss: Δθ (K)**

  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°K. If the operating environment is different, temperature difference under maximum power loss must be modified by calculation (refer to Section 3.4).