零差云控®

eRob Rotary Actuator User Manual

Version 3.37

Build Robot Fast

What's New

0.1 eRob Rotary Actuator User Manual Version 3.37 Update

0.1.1 NEW Content

(1) NEW Definition for Maximum Output Rotational Speed;
(2) NEW Installation Guide Item;
(3) NEW Chapter 19 content added regarding the hyperlink to firmware download and firmware update software user manual;
(4) NEW Section 24.2 pulse direction control mode output shaft actual position feedback reading instruction;

0.1.2 Content Enhancement

(1) Enhanced Section 5.3 Pin Layout image illustration;

0.1.3 Content Removal

(1) Removed Chapter 19 instructions on how to use the old firmware update tool;

Content Modification Markings

0.2 New Content

The new content in this document of the current version is marked with a blue strip and ★ symbol.

Example:

★ Thank you for choosing ZeroErr's eRob series rotary actuator module. We appreciate your trust and confidence in our product. To ensure your satisfaction and enhance your user experience, we have carefully designed this user manual to provide you with all the necessary information for operating and maintaining your eRob rotary actuator module.

0.3 Enhanced Content

The enhanced content in document of the current version is marked with a green strip and Δ symbol.

Example:

Δ If you have any questions or encounter any issues while using eRob rotary actuator module, please do not hesitate to reach out to our customer support team. We are here to assist you and provide timely assistance to ensure that you have a smooth and enjoyable experience.

Record of Revisions

Version	Iteration	Description	Date
3.34.2	1	Symbols and terminology improvements in compliance with ISO80000; Image improvement; Page layout improvements; Header and footer improvements; Hyper link functionality added; Content improvements; Equation improvements; Removed Chapter2. Packaging and Accessories.	2023/11/27
3.35	2	New content added, content discrepancy error fixed, removed outdated content.	2024/01/05
3.36	3	New content added.	2024/01/31
3.37	4	New content added, content discrepancy error fixed, removed outdated content.	2024/01/31

SAFETY GUIDE

Before installing, operating, maintaining, or inspecting this product, please be sure to read this SAFETY GUIDE and fully understand the information provided in this user manual and appendices before using the product. Mishandling the eRob rotary actuator module may cause harm to personnel or damage to property. Therefore, it is essential that the operator read and understand this manual thoroughly.
It is recommended to keep this manual in a readily accessible location for easy reference during operation and maintenance of the product.

It is crucial to follow the SAFETY GUIDE outlined in this manual.

0.4 NOTATION

Symbol	Definition
	**DANGER:** This indicates an imminently hazardous electrical usage situation which, if not avoided, could result in death or serious injury.
	**DANGER:** This indicates an imminently hazardous situation which, if not avoided, could result in death or serious injury.
	**WARNING:** This indicates a potentially hazardous electrical situation which, if not avoided, could result in personal injury or serious equipment damage.
	**WARNING:** This indicates a potentially hazardous situation which, if not avoided, could result in personal injury or serious equipment damage.
	**WARNING:** This indicates a hot surface that can create a hazard, which if touched, could result in personal injury.
	**CAUTION:** This refers to a situation which, if not avoided, could result in equipment damage.

0.5 Please Adhere to the Following Guidelines to Avoid Personal Injury:

DANGER:

1. Set Appropriate Protection Limits:
Avoid any incorrect target command when operating the rotary actuator in torque mode. Set appropriate protection limits on the host controller and the servo driver, including position limit, speed limit and current limit.

2. Perform Risk Assessment:
Machine manufacturers must perform risk assessment on machine and take appropriate measures to ensure unexpected movements will not result in any personal injury or property damage. More demands may be placed on professionals after risk assessment.

3. Assembly Precautions:
Make sure the rotary actuators are properly and securely in place without the danger of accidental falls. Our company is not responsible for any damage caused by abnormal operation.

WARNING:

1. Conduct the Initial Test Without Load:
Put rotary actuator trial run under a no-load condition. (Do not connect to drive shaft).

WARNING:

1. Beware of Hot Surfaces:
During operation of the motors, depending on their ingress protection level, the surfaces can be very hot. The surface temperature will exceed $85°C$, beware of minor burns. Measure the temperature and wait until the motor cools below $40°C$ before touching it.

2. Keep Module Suspended:
The eRob module have passed strict power consumption testing before leaving the factory. The module generates heat due to friction, oil agitation loss, and brake power consumption, even when there are no load. The compact design and smooth surface of the Rob module may not be sufficient to dissipate the heat generated when it is not mounted (e.g. placed on the desktop), resulting in an increase in surface temperature. This could trigger temperature protection and pose a risk of high-temperature burns. For detailed information on the power consumption during no load operation, please refer to Chapter 25.

If this product is used in environments where human safety or material losses are at stake, it is crucial to install safety devices that can prevent accidents even if the output control is disabled due to damage.

0.6 Please Adhere to the Following Guidelines to Avoid eRob Damage:

WARNING:

1. Do Not Plug or Unplug Power Cable While Power ON:
Please make sure to perform wiring and inspection tasks only after confirming that the Power LED indicator light has turned off by itself.

2. Do Not Plug or Unplug CAN Cable While Power ON:
Since the electrical level of the CAN_GND at both ends of the host controller and the actuator may be different when they are not wired, the voltage difference between the CAN_GND at both ends will cause damage to the CAN interface at the moment of connection.

3. Do Not Plug or Unplug RS485 Cable While Power ON;
Due to the possible difference in the ground potential between the master controller and the eRob module when not connected, upon connection, the voltage difference between the two ground points may lead to damage to the RS485 interface.

NOTE: It is important to note that the process of plugging and unplugging cables while the power is on should include the power from power supply, debugger, and controller. This means that all three components need to be powered OFF during the cable connection or disconnection process.

4. Connect Power Terminals Properly and Securely:
Refer to Section 5.9

5. Ground Module Housing:
If the eRob rotary actuator housing is not properly grounded, it may cause the housing to accumulate charge and become charged. For details, refer to Chapter 6.

6. Use ZeroErr's Proprietary Multi-Turn eRob Battery:
A rotary actuator with multi-turn counting function will have an extra battery being packaged in the box, which has a stable voltage, a temperature range of -55°*C*~85°*C*, and a normal working life of more than 10 years. The battery is also available on our website: https://en.zeroerr.cn/products/accessories/battery. Do not use other batteries other than ZeroErr proprietary multi-turn counting battery. We do not offer technical support for other batteries. Typically, each multi-turn eRob module is designed to operate with a single battery, which ensured both convenience and reliability during wiring procedure. It is important to note that if an attempt is made to modify a single battery setup to supply power to multiple eRob modules simultaneously, ZeroErr cannot be held responsible for any potential consequences arising from this modification and the associated rewiring.

7. Adhere to Voltage and Current Limits:
Comply with technical data and specifications (nameplate and documentation). Exceeding the permissible voltage value or current value will damage the motor and appear abnormal phenomenon, such as overheating.

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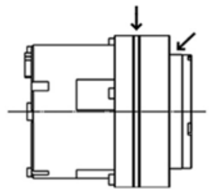
WARNING:

1. Pay Attention to the Rust-Prone Parts:
The material in the area indicated by the arrow in the image below is susceptible to rust. Therefore, when conducting installation operations, it is crucial to exercise caution and take necessary precautions. This includes wearing gloves to protect your hands and applying an anti-rust treatment to prevent corrosion and ensure the longevity of the material.



2. Do Not Exceed the Permissible Torque:
Please do not exceed the momentary permissible maximum torque when applying torque. Otherwise, it may result in loosening of fasteners, shaking, or damage, leading to product failure. When directly attaching to the output shaft, such as a robotic arm, colliding with the arm can cause damage and loss of control over the output shaft.

3. Do Not Disassemble Assembled Products:
This product is a high-precision device and must be installed and calibrated by professionals. It is strictly prohibited to disassemble or reassemble the assembled product. Reassembling the product may result in the loss of its original performance. Any product failures resulting from improper use will void the product warranty.

4. Do Not Modify the Module Assembly:
The product is a combination of various components, and its performance cannot be guaranteed when used in conjunction with other kits or components not intended for it. Any product malfunction resulting from improper use will result in the loss of warranty coverage. It is important to use the product as intended and avoid altering or mixing its components to ensure optimal performance and warranty protection.

5. Do Not Alter the Warranty Label:
Removing the tamper-proof warranty label on this product will result in the loss of warranty coverage for the product.

6. Use the Module in the Specified Environment:

① The product has an IP54 protection rating.

② Extreme operating temperature: -40~70°C
(At extremely low temperatures, joint friction will increase significantly, resulting in higher operating currents. At high temperatures, over-temperature alarm protection and shut-off actions may be triggered.)

③ General Operating temperature: 0~60°C;

④ Storage temperature: -30~60°C;
Using low-temperature grease will improve the operational resistance of the module in low temperatures. For detailed model specifications, please refer to Section 2.1.

⑤ Operating and storage humidity: 20%~80%RH (non-condensing);

⑥ Avoid exposure to dust, metal particles, corrosive gases, flammable gases, oil mist, and similar substances.

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WARNING:

7. Handle the Module with Care:
Avoid using hammers or forcefully striking any components or assemblies. Additionally, take precautions to prevent cracks or dents caused by accidental drops or impacts. Damaging the product in such a way can compromise its integrity, leading to performance issues and potential malfunctions. Handle the product with care to ensure its longevity and proper functionality.
8. Transportation:
Ensure that the personnel handling the transportation of the module do not bear excessive weight on their bodies, and maintain the original packaging during transportation. Use appropriate transportation equipment and adhere to all regional and national transportation guidelines. Our company is not responsible for any damages caused during transportation.
9. Operation Precaution:
The ZeroErr module is equipped with several outstanding features. However, incorrect operation or mishandling of its principles or structure can not only hinder its performance but also potentially result in malfunctions and damage. When using the module, it is vital to pay particular attention to the following:
① Avoid using the joint module in applications where there is a risk of dropping or falling. Even if there are no visible external damages, internal stress accumulation can weaken its fatigue strength. Therefore, it is advisable not to use the module if it has been dropped.

0.7 Please Adhere to the Following Guidelines to Avoid Performance Issues:

WARNING:

The following actions may cause performance issues:
1. Failure to tighten the screws according to the specified torque standards or not using a diagonal method to tighten them.
2. Operating the product on a wooden table.
3. Running the joint module on a movable platform (such as an improperly secured base).
4. Installing the eRob module in a plastic or 3D-printed housing may effect heat dissipation, leading to overheating of the eRob module.

WARNING:

1. Each eRob rotary actuator has undergone strict jitters and noise tests before delivery. If it fails to meet expected operation results, please reinstall it strictly in accordance with Chapter 18.
2. Mount the robot on a sufficiently solid surface without vibration (such as steel plates).

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WARNING:

3. Even when opting for a rotary actuator model with EtherCAT communication, it is highly recommended to connect and preserve the joint CAN communication line within the entire system. It is also advisable to pre-configure the joint CAN ID (as outlined in Section 6.2) in order to facilitate subsequent debugging processes. This includes troubleshooting, parameter adjustments, firmware upgrades, and other tasks related to individual joints. Retaining the joint CAN communication line enables efficient and effective debugging procedures throughout the system's operation.

CAUTION:

1. Suspended and No-Load Operation:
eRob rotary actuator will also generate heat when running under no-load condition. The temperature of the rotary actuator which has not been installed actually will gradually increase due to nowhere for heat diffusion, until the temperature protection is triggered. Please test with caution. Overheating is not an actuator fault under a suspended high-speed continuous operation. Install the rotary actuator normally, and additional cooling components are not required.
2. Oil churning noise reminder:
After the eRob rotary actuator rests horizontally in the axial direction for a period, there will be a slight oil churning noise due to the uneven distribution of grease sedimentation when running at a speed above 80% of the rated speed. The sound will disappear naturally when the distribution of grease gets even after the rotary actuator runs for about 5 minutes. The characteristics of the noise are:
(1) It appears when running at a high speed after keeping in a static state to cool down;
(2) The noise in the vertical state is lower than that of in the horizontal state;
(3) The noise at high temperature is lower than that of when the temperature is low;
(4) The noise at a low speed is lower than that of at a high speed;
(5) It will disappear naturally after running for about 5 minutes. This noise is not an actuator fault, please rest assured to use.

0.8 Maintenance:

WARNING:

1. Enhanced Protection for Specialized Industries:
Within the eRob module, lubricating grease is well-contained with effective seals at the input shaft and various joints. While these seals typically meet IP65 standards for general industrial use, it is advisable to consider additional external protective casings if deploying the product in specific sectors like food, medical, or pharmaceutical industries.
2. Grease Replacement in eRob Modules:
The lubricating grease within the eRob module does not require replacements, and the SWG does not allow for grease changes.

0.9 Disposal Information:

	WARNING: **1. Module Disposal must comply with industrial waste standards:** Please ensure that the product is disposed of as industrial waste and in compliance with relevant regulations and guidelines.

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Symbols and Abbreviations

α	angular acceleration/deceleration
η_t	the efficiency of SWG transmission
ω	output angular velocity
ω_θ	output angular velocity measured in °/s
ω_{rad}	output angular velocity measured in rad/s
ω_t	target speed (angular velocity)
θ	position angle
θ_{in}	angle of wave generator input shaft
θ_{out}	angle of flexspline output shaft
AAB	Armature Actuated Brake
$Acc.$	Acceleration
AKA	Also Known As
C_0	basic static load rating
C_{10}	basic dynamic load rating
CCW	Counterclockwise
D	diameter
DC	Direct Current
$D_{Circular\ Spline}$	the circular spline diameter
$Dec.$	Deceleration
$D_{Output\ Shaft}$	the output shaft diameter
$ECAT$	EtherCAT
E_{FED}	error caused by flexspline elastic deformation
$e.g.$	for example
E_{in}	the transmission error of input shaft
E_{ITG}	error caused by input teeth gap
E_k	kinetic energy
E_M	error caused by manufacture
E_{out}	error caused by circular spline elastic deformation
$etc.$	and so forth
E_{WGD}	error caused by wave generator deformation
F	force
$F_{a,max}$	maximum axial load
$F_{r,max}$	maximum radial load
GR	Gear ratio
I	electrical current
$I_{a,\ motor}$	the actual current input of motor
IP	Ingress Protection
ISO	International Organization for Standardization
K_e	voltage constant of torque motor AKA back EMF constant
K_m	Moment Stiffness
K_T	the torque constant
$K_{T,\ eRob}$	the eRob module torque constant
$K_{T,\ motor}$	the motor torque constant

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L_a	axial load length
L_h	life measured in hours
L_n	life of L_{10} or L_{50}
$L_{Output\ Shaft}$	the thickness of output shaft flange
L_r	radial load length
M_c	permissible moment load
M_{max}	maximum moment of force
m_G	SWG gear ratio
N	the amount of revolutions
n	rotational speed
n_a	the actual maximum rotational speed output by the rotary actuator
n_{avg}	average SWG input / motor output rotational speed
N/A	Not Applicable
$NASA$	National Aeronautics and Space Administration
n_c	output rotational speed measured in counts/s
n_m	motor / SWG input rotational speed
n_o	SWG output rotational speed
N_{out}	the amount of eRob output rotation
n_r	the rated maximum output rotational speed
n_{RPM}	output rotational speed measured in RPM
n_t	motor rated rotational speed used for module rated torque testing (2000RPM)
OD	Outer Diameter
P_c	current encoder position
$P_{encoder}$	encoder position
p_{input}	the amount of external input pulses
P_s	single-turn encoder position
R	offset length
RPM	Revolutions Per Minute
SI	International System of Units
SWG	Strain Wave Gear
t	time
T	torque
t_α	acceleration/deceleration time
T_a	the actual torque output by the rotary actuator module
T_{avg}	average load torque on the SWG output side
T_{out}	the eRob output torque
T_r	the rated torque output by the eRob module
V_{DC}	DC voltage
V_{in}	the actual voltage supplied to the rotary actuator module
V_r	the rated input voltage of the eRob module

Chapter 1 Overview

1.1 About This Manual

This manual provides information on the operation parameters, range of safety, application methods, safety precautions, and other details of the eRob series robot joints developed, designed, and manufactured by Zeroerr Control Co., Ltd; Please read the manual carefully before performing any operation.

1.2 Introductions of the eRob Series Modules

The eRob series rotary actuator module is an innovative product introduced by ZeroeErr. It is designed to provide a standardized solution for rotary actuation in robotics applications. The module incorporates ZeroeErr's proprietary servo driver and absolute value encoder technologies, which have been refined over the years through extensive customer service experience.
The primary objective of the eRob series is to streamline and accelerate the development of robots while prioritizing safety. By offering a pre-integrated and pre-tested rotary actuator module, ZeroeErr aims to simplify the integration process for robot developers. This standardized approach eliminates the need for extensive custom design and integration, reducing both development time and costs.
The eRob series rotary actuator modules by ZeroeErr offer a range of models, including the eRob70, eRob80, eRob90, eRob110, eRob142, eRob170, and more. These models are meticulously crafted to provide precise performance and feature a compact structure.
Each eRob rotary actuator module is designed to be a comprehensive solution, incorporating essential components within its small form factor. These components include a servo driver with integrated temperature sensor, absolute encoder for motor, multi-turn absolute encoder for output, frameless brushless torque motor, armature actuated friction brake(AAB), high precision strain wave gears(SWG) AKA Harmonic Drive, and more, as depicted in Figure 1-1.

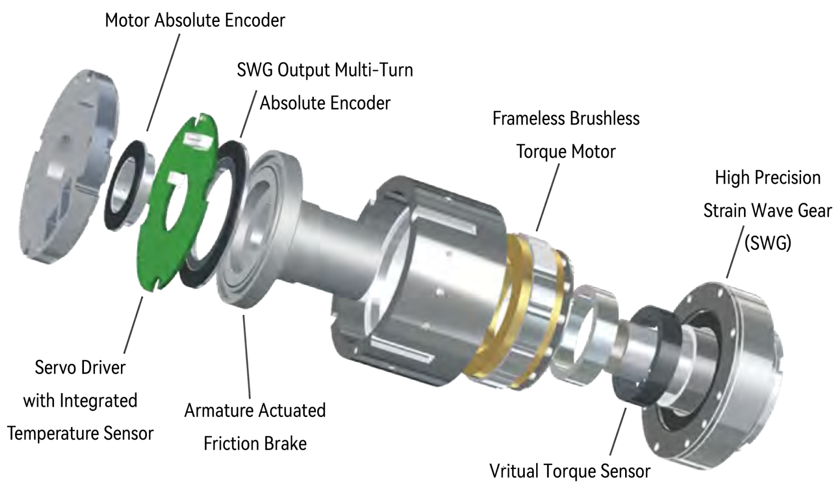


Figure 1-1 Exploded View of An I-Type eRob Rotary Actuator Module

By integrating all these components, the eRob series eliminates the need for customers to invest time and effort in selecting, designing, purchasing, and assembling multiple mechanical and electronic devices from scratch. This simplifies the development process and accelerates time to market for robotic applications.

Chapter 2 eRob Rotary Actuator Module Specifications

The model code of the eRob series rotary actuator modules and instructions to read them are explained below (as shown in Figure 2-1).

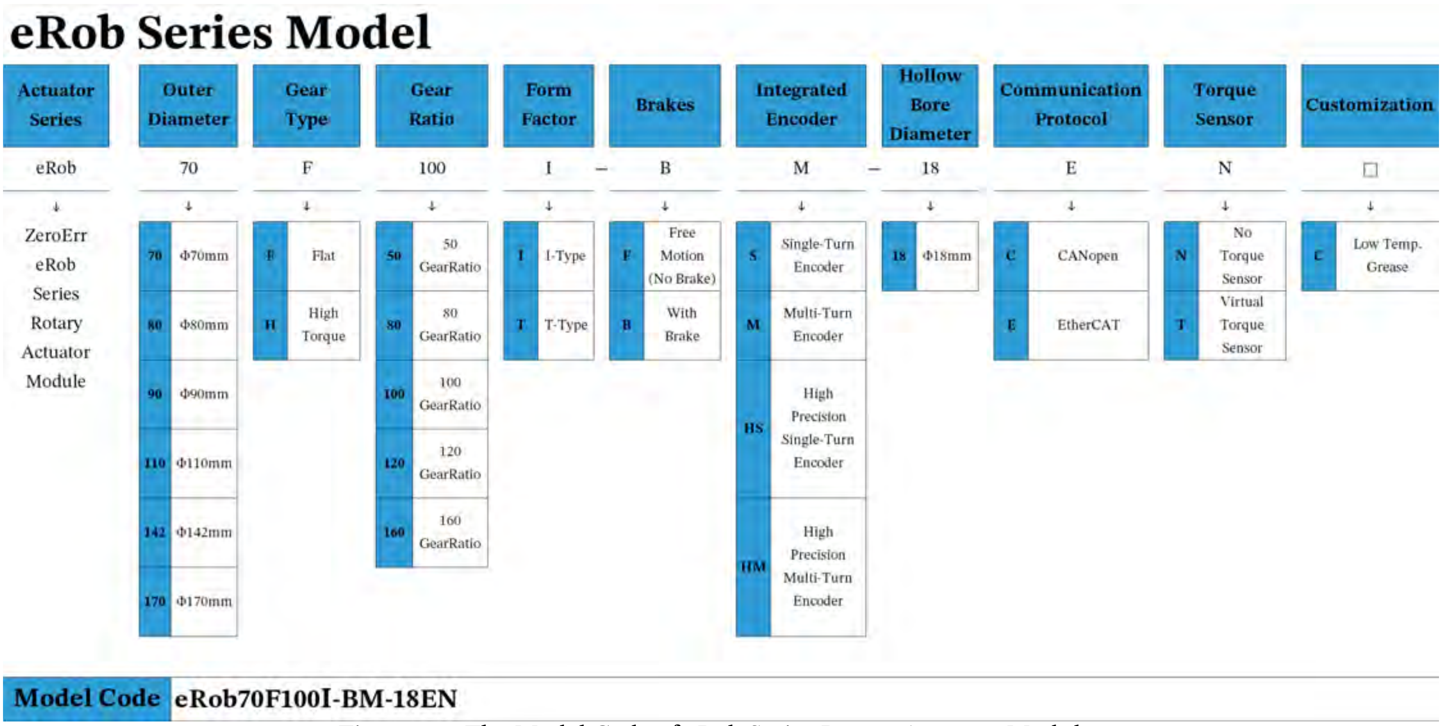


Figure 2-1 The Model Code of eRob Series Rotary Actuator Modules

2.1 Understanding the eRob Model Code Definitions

Model Example:

eRob	70	F	100	I	-	B	M	-	18	E	N	□
(1)	(2)	(3)	(4)	(5)	-	(6)	(7)	-	(8)	(9)	(10)	(11)

(1) Actuator Series: ZeroErr eRob Series Rotary Actuator Module.

(2) Outer Diameter(OD): The outer diameter measured in millimeters (mm) of the I-Type eRob modules. The T-Type eRob modules has a larger outer diameter; for more information regarding the size of the modules, please refer to the detail drawings of the module.

(3) Gear Type: Indicate which type of strain wave gear is equipped with the module.

F	Indicates the eRob module is equipped with the SHD series flat strain wave gear. The eRob module with this type of strain wave gear is shorter and lighter.
H	Indicates the eRob module is equipped with the SHF series strain wave gear. The eRob modules with this type of strain wave gear have more power, rotational speed, and load capacity.

(4) Gear Ratio(GR): The gear ratio of the eRob module is determined by the number of teeth on the flexspline and circular spline of the strain wave gear. For every complete revolution of the output, the input (torque motor) will rotate the gear ratio + 1 number of times.

(5) Form Factors: ZeroErr currently offers eRob series rotary actuators in two form factors: the I-type and T-type. These rotary actuators share identical parameters, such as torque, speed, and size, except for one key difference: the module housing. This distinction in module housing provides customers with flexibility in selecting the most suitable actuator type for their specific application, ensuring seamless integration while maintaining consistent performance across both variants.

I-type	The module aligns its housing with the its axis, resembling the shape of the letter "I".
T-type	The module features a housing configuration perpendicular to the actuator's axis, forming a "T" shape.

(6) Brakes: Some of the eRob rotary actuator module incorporates an armature actuated friction brake that offers a seamless and vibration-free stop and start. This mechanism enables the eRob module to initiate movement from a standstill, even under full load conditions. Furthermore, during operation, the mechanism operates silently without any grinding or audible noise during rotation. The robust design of the friction brake allows the eRob module to withstand heavy-load emergency stops while operating at full speed, ensuring reliable performance and safety in critical situations.

F	Indicates the eRob module does not have a brake.
B	Indicates the eRob module is equipped with a brake.

(7) Integrated Encoders: The output encoder configurations for the eRob joint are as follows:

S	Single-Turn Absolute Value Encoder: This encoder provides the absolute angle value at the output, but it does not record the number of complete rotations when power is lost and then restored. In other words, after a power loss and restart, it reverts to the single-turn value, regardless of the number of turns made during normal powered operation.
M	Multi-Turn Absolute Value Encoder: This encoder provides the absolute angle value at the output, and it record the number of complete rotations when power is lost and then restored. In other words, after a power loss and restart, it remembers the number of turns made during normal powered operation. The multi-turn function needs a multi-turn battery packaged in the accessories kit.
HS	High-Precision Single-Turn Absolute Value Encoder: Similar to the HM version, the HS configuration features a high-precision single-turn absolute value encoder. It also includes calibrated encoders after installation, compensating for assembly errors and elastic deformation errors. The HS version provides high absolute accuracy and is suitable for applications requiring precise positioning.
HM	High-Precision Multi-Turn Absolute Value Encoder: The output encoder in this configuration is a high-precision multi-turn absolute value encoder. It is equipped with calibrated encoders after installation, compensating for assembly errors and elastic deformation errors caused by different loads. This version offers high absolute accuracy and is suitable for applications that demand precise positioning.

Both the HM and HS models offer a resolution capability of 20 bits, with a repeatability/absolute accuracy of ±7/±15 arcsec*.

The standard model, on the other hand, has a resolution of 19 bits, with a repeatability/absolute accuracy of ±10/±25 arcsec*.

The standard version is typically sufficient for common industrial robots and automation industry requirements. However, if you have more demanding requirements for absolute positioning accuracy, it is recom-

mended to opt for the HM/HS versions.
*Note: For more details regarding the accuracy, please refer to: en.zeroerr.cn/accuracy

(8) Hollow Bore Diameter: Hollow bore diameter measured in millimeter (mm).

(9) Communication Protocol: There are two primary types of communication protocols available for the eRob: EtherCAT (abbreviated as E) and CANopen (abbreviated as C). These protocols enable seamless communication between the eRob and other devices in a networked system. Additionally, both type of the eRob supports the Modbus protocol when connected with to the RS485 interface.

C	Indicates the eRob module support CANopen communication protocol.
E	Indicates the eRob module support EtherCAT communication protocol.

(10) Torque Sensor: The torque sensor in the "T" models is achieves through the calculation of the angular value difference between the two absolute value encoders integrated in the module. For comprehensive information on the torque sensor feature and its implementation, please refer to Chapter 22. This chapter will provide in-depth details and insights into the workings and benefits of the torque sensing feature in the eRob series rotary actuator modules.

N	Signifies an eRob module without torque sensing capability.
T	Signifies an eRob module with torque sensing capability.

(11) Customization: Customization options.

C	Optional Low-Temperature Grease*.

*For more details, please refer to the "eRob High and Low Temperature Reliability Test Report" at en.zeroerr.cn/temperature

2.2 The Specifications of eRob Modules

The Specifications of eRob Series Rotary Actuator Modules are shown in Table 2-1.

Table 2-1 The Specifications of eRob Series Rotary Actuator Modules

Model	SWG Model & GR	Peak Start Stop Torque	Permissible Maximum Torque with Average Load	Rated Torque	Permissible Maximum Momentary Torque	Maximum Output Rotational Speed	Torque Motor Rated Power	SWG Output Side Inertia	SWG Output Side Mass	Without Brake: SWG Input Side Inertia	Without Brake: SWG Input Side Mass	Without Brake: OD × Length	Without Brake: Total Mass	With Brake: SWG Input Side Inertia	With Brake: SWG Input Side Mass	With Brake: OD × Length	With Brake: Total Mass
		Nm	Nm	Nm	Nm	RPM	W	$g \cdot mm^2$	kg	$g \cdot mm^2$	kg	mm	kg	$g \cdot mm^2$	kg	mm	kg
eRob70F	SHD 14-50	12	4.8	3.7	23	60	75	54030	0.13	43656	0.15	70 × 60.4	0.77	46885	0.16	70 × 67.7	0.83
	SHD 14-80	16	7.7	5.4	35	37.5											
	SHD 14-100	19	7.7	5.4	35	30											
eRob70H	SHG 14-50	23	9	7	46	60	100	69717	0.17	47767	0.18	70 × 75.3	0.87	50996	0.19	70 × 75.3	0.93
	SHG 14-80	30	14	10	61	37.5											
	SHG 14-100	36	14	10	70	30											
	SHG 14-120	36	14	10	70	25											
eRob80H	SHG 17-50	44	34	21	91	60	146	150085	0.25	67408	0.26	80 × 84.2	1.19	70637	0.27	80 × 84.2	1.25
	SHG 17-80	56	35	29	113	37.5											
	SHG 17-100	70	51	31	143	30											
	SHG 17-120	70	51	31	112	25											
eRob90H	SHG 20-50	73	44	33	127	60	300	297466	0.36	139057	0.41	90 × 98.9	1.75	147025	0.43	90 × 98.9	1.87
	SHG 20-80	96	61	44	165	37.5											
	SHG 20-100	107	64	52	191	30											
	SHG 20-120	113	64	52	191	25											
eRob110H	SHG 25-50	127	72	51	242	60	750	715482	0.58	277434	0.7	110 × 115.2	2.88	285402	0.72	110 × 115.2	3.06
	SHG 25-80	178	113	82	332	37.5											
	SHG 25-100	204	140	87	369	30											
	SHG 25-120	217	140	87	395	25											
	SHG 25-160	229	140	87	408	18.75											
eRob142H	SHG 32-50	281	140	99	497	40	1000	2589596	1.21	1244894	1.33	142 × 133.9	6.49	1273287	1.37	142 × 133.9	6.7
	SHG 32-80	395	217	153	738	25											
	SHG 32-100	433	281	178	841	20											
	SHG 32-120	459	281	178	892	16.7											
	SHG 32-160	484	281	178	892	12.5											
eRob170H	SHF 40-50	402	196	137	686	40	1000	6679752	2.02	1517148	1.66	170 × 144.9	9.29	1545541	1.7	170 × 144.9	9.5
	SHF 40-80	519	284	206	980	25											
	SHF 40-100	568	372	265	1080	20											
	SHF 40-120	617	451	294	1180	16.7											
	SHF 40-160	647	451	294	1180	12.5											

Universal Specification	Input Voltage: 48V (±10%); Hollow Bore Diameter: 18mm; IP-Rating: IP54; Brake Type: Armature Actuated Friction Brake.
Optional Configuration	Communication Protocol: EtherCAT / CANopen / Modbus; Output-Side Encoder Resolution: 19 Bit, Repeatability/Accuracy: ±10/±25 arcsec*; Output-Side Encoder Resolution: 20 Bit, Repeatability/Accuracy: ±7/±15 arcsec; Optional Low Temperature Grease.

Please note that the specifications provided above are subject to slight variations in different product versions, and for precise and specific specifications, it is recommended to refer to the detailed drawings of each model and version; Furthermore, for detailed information regarding accuracy, please consult the following link: en.zeroerr.cn/about us/certificates & patents.

* 1 arcsec = 1/60 arcmin = 1/3600 degree = 4.848 μrad

2.2.1 Output-Side (Load) Specifications

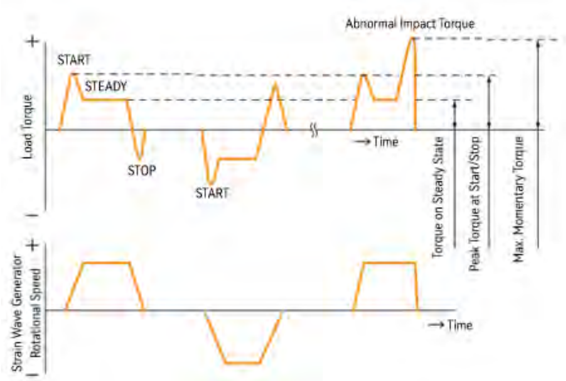


Figure 2-2 Example of Load Pattern

(1) **Permissible Peak Start Stop Torque (as shown in Figure 2-2):**
During startup and stopping, due to the rotational inertia of the load, there may be a load acting on the actuator module that exceeds the normal torque. The values in the eRob specification table represent the permissible value of the peak torque in such situations.

(2) **Permissible Maximum Torque with Average Load:**
When there are variations in the load torque and input rotational speed, it is necessary to calculate the average value of the load torque. The values in the eRob specification table represent the permissible value at the average load torque. If the average load torque exceeds the values specified in the eRob specification table, it can lead to premature degradation of lubricants and abnormal gear wear due to heat generation. Please pay close attention to this.

(3) **Rated Torque:**
This information specifies the maximum continuous load torque that is allowed when the input motor rotational speed is 2000RPM.

(4) **Permissible Maximum Momentary Torque (as shown in Figure 2-2):**
Apart from the usual load torque and the load torque during startup and stopping, there may be unforeseen external impact torques. It is important to note that the maximum value of the impact torque must not exceed the Permissible Maximum Momentary Torque specified in the eRob specification table. This is crucial to ensure the proper functioning and longevity of the eRob module. Exceeding the permissible limits can result in mechanical stress, potential damage to the module, and compromised performance. Therefore, it is essential to carefully consider and account for these factors to maintain optimal operation and prevent any undesirable consequences.

★

(5) **Maximum Output Rotational Speed:**
The Maximum Output Rotational Speed is the maximum speed the SWG can output on the load bearing end, the motor rotational speed at this moment is at it’s rated rotational speed, as shown in Section 25.2.2. The relation between the output torque and the output rotational speed is shown in Section 25.4

2.2.2 Input-Side (Motor) Specifications

(1) **Torque Motor Rated Power:**
The the highest power input allowed to supplied to the motor without damaging the motor.

(2) **Input-Side SWG Inertia**

(3) **Input-Side SWG Mass**

The specification mentioned above are only applicable to the latest version, and there may be slight differences in different product versions. For more details, as well as 2D drawings and 3D models, for further information and downloads, please visit the official website: en.zeroerr.cn

2.2.3 Difference Between Single-Turn and Multi-Turn Encoders

(1) **Multi-Turn Encoder**
For multi-turn encoders (with multi-turn memory function), they require the installation of a battery and can retain multi-turn information even when power is disconnected.

(2) **Single-Turn Encoder**

On the other hand, single-turn encoders (without multi-turn memory function) do not have this capability.

To determine whether a module is single-turn or multi-turn, you can check if the ”Multi-Turn” option in the ”Encoder” interface is check in the ”eRunner” software. There are differences in both the hardware and software aspects between Single-Turn and Multi-Turn modules.

2.2.4 Communication Protocol Supported

(1) **CANopen** (Model eRobxxxxxxxx-xx-18**C**x) Supports:
- CANopen
- CAN-custom
- Modbus (RTU/ASCII)

(2) **EtherCAT** (Model eRobxxxxxxxx-xx-18**E**x) Supports:
- EtherCAT
- CAN-custom
- Modbus (RTU/ASCII)

CAN-custom and Modbus-ASCII are proprietary communication protocols developed by our company. The communication protocol used between our PC debugging software "eTunner"(connection method please refer to YouTube Tutorial) and the rotary actuator is CAN-custom. On the other hand, EtherCAT and CANopen follow the standard CiA402 control protocol, but they differ in terms of their communication physical layer interfaces.

Chapter 3 Power Input of The eRob Rotary Actuator Module

3.1 Power Supply Voltage and Rated Current Value

When the power supply is powered with 48V DC (the factory default permissible minimum bus voltage is 44V, and the permissible maximum bus voltage is 55V), the drive will trigger an over-voltage fault when the detected voltage exceeds 55V, and when the detected voltage is less than 44V, it will result in an under-voltage alarm.
The rated current of an rotary actuator is shown in Table 3-1.

Table 3-1 Rated Current of Each Rotary Actuator Model

Model	Voltage (V)	Current (A)
eRob70F	48±10%	1.91
eRob70H	48±10%	2.55
eRob80H	48±10%	3.4
eRob90H	48±10%	6.7
eRob110H	48±10%	18.9
eRob142H	48±10%	22
eRob170H	48±10%	22

3.2 Permissible Maximum Input Voltage

The permissible maximum voltage of eRob power interface is DC60V. If the input voltage exceeds 60V, it will easily cause drive failure. The input voltage waveform when the eRob is supplied power abnormally is as shown in Figure 3-2a. Note that when powering on the eRob with switching power supply or storage battery (connect the power output side to the miniature circuit breaker and then connect to the eRob power interface), there may be an over-voltage shock (>60V) when turning on the switch and powering on. It should be connected an electrolytic capacitor (reference specification: 1000uF, 100V) in parallel behind the miniature circuit before powering on the rotary actuator to avoid the overshoot of input voltage at the moment of powering on (as shown in Figure 3-1), and input voltage waveform when the eRob is supplied power normally after connecting an electrolytic capacitor is shown in Figure 3-2b.

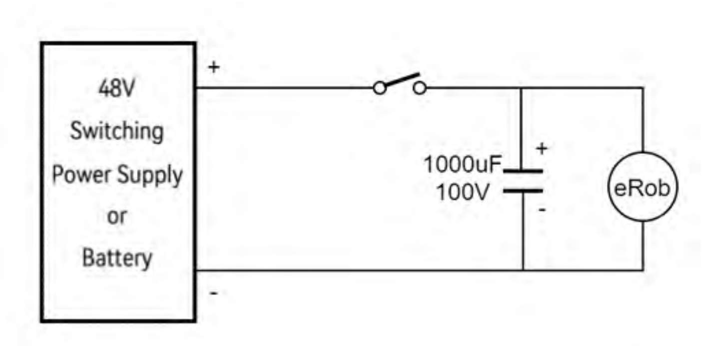
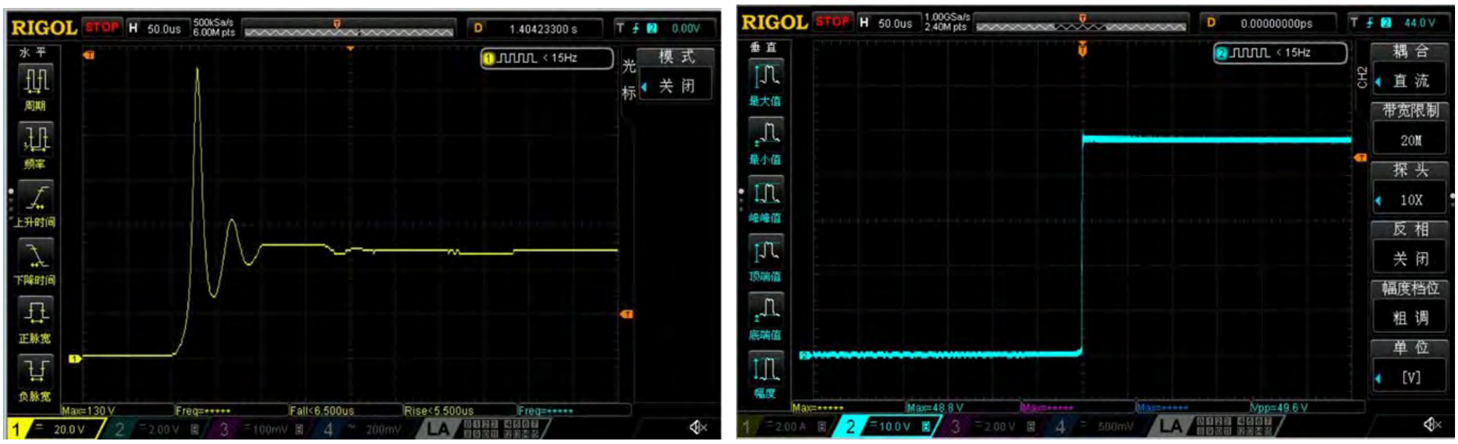


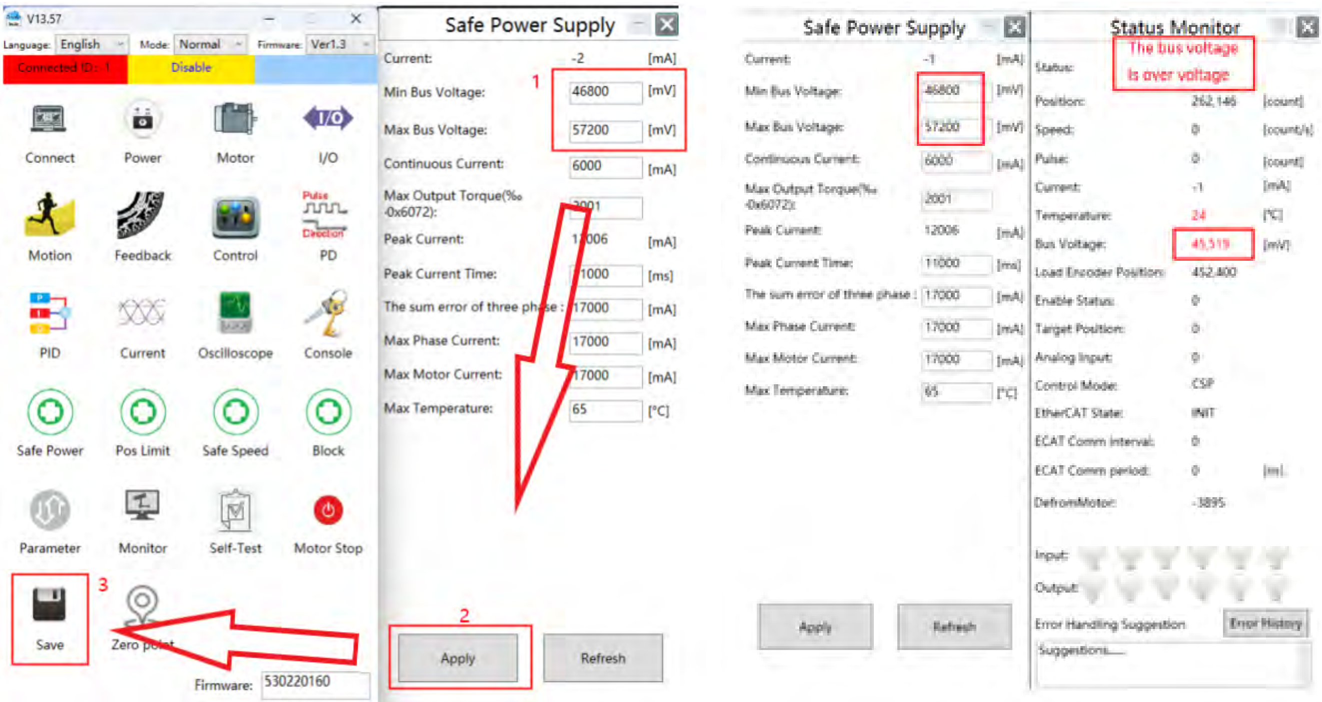
Figure 3-1 Wiring Diagram of Electrolytic Capacitor in Parallel with Power Supply



(a) Abnormal Power Input Voltage Waveform ($V_{max} = 130V > 60V$)   (b) Normal Power Input Voltage Waveform ($V_{max} = 48.8V < 60V$)

Figure 3-2 Power Input Related Diagrams

When powering on with the battery (lithium battery or other storage battery), the back electromotive force (back EMF) has no influences on the eRob because the back EMF generated in regenerative braking process charges the battery directly. Therefore, no actions for back-EMF are required. However, it needs to modify the permissible maximum/minimum voltage in "Safe Power" in eTunner. Following is the modification method. When the battery voltage exceeds 48V, such as powering on with DC52V battery, it needs to modify the permissible maximum bus voltage to 57.2V (52V×110% , the percentage can be modified according to the actual situation, but it is not recommended to set the value over 60V), and modify the permissible minimum bus voltage to 46.8V (52V × 90% , the percentage can be modified according to the actual situation). Apply and save the parameters after configuration, as shown in Figure 3-3a When the detected voltage exceeds the permissible maximum bus voltage 57.2V, the eRob will not be enabled, and there will be an error report ("The bus voltage is overvoltage") and shutdown (as shown inFigure 3-3b, the detected voltage is 57.802V).



(a) Example of Using DC52V Power Supply   (b) "The bus voltage is overvoltage" Error Message

Figure 3-3 eRunner Over-Voltage Error Example

3.3 Permissible Minimum Input Voltage

The permissible minimum input voltage of eRob rotary actuator with brakes is shown in Table 3-2.

The permissible minimum input voltage of the eRob without brakes is 19.5V.

When the input voltage is lower than the permissible minimum input voltage, the eRob will fail to work normally.

The correlation between the actual maximum rotational speed of the eRob and the input voltage is as below:

Table 3-2 The Permissible Input Voltage of Rotary Actuators with Brakes

Model	Voltage (V)
eRob70F	24
eRob70H	24
eRob80H	24
eRob90H	48
eRob110H	48
eRob142H	48
eRob170H	48

$$n_a = n_r \times \frac{V_{in}}{48V} \tag{3.1}$$

Symbol	Definition	Unit
n_a	The actual maximum rotational speed output by the rotary actuator.	RPM
n_r	The rated maximum output rotational speed, as shown in Table 2-1.	RPM*
V_{in}	The actual voltage supplied to the rotary actuator module.	V

* To convert the rotational speed to angular velocity, please refer to Chapter 12.1.

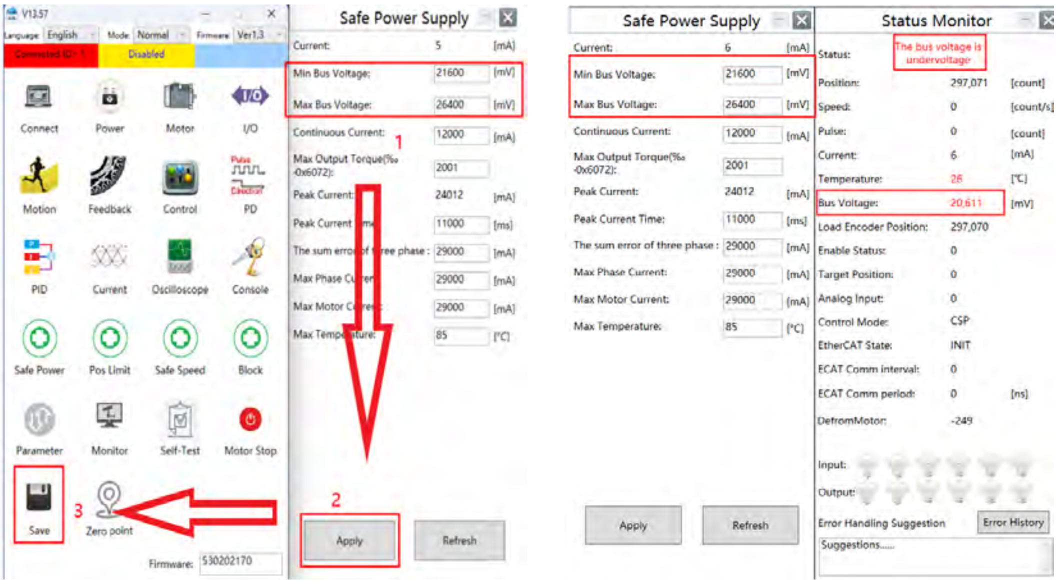
When the input voltage is lower than the rated voltage, the actual max. rotational speed will be reduced, but the toque performance will not be reduced.

$$V_{in} \le V_r \quad \Rightarrow \quad \begin{cases} n_a \le n_r \\ T_a = T_r \end{cases}$$

Symbol	Definition	Unit
V_{in}	The actual voltage supplied to the rotary actuator module.	V
V_r	The rated input voltage of the eRob module, as shown in Table 2-1.	V
n_a	The actual maximum rotational speed output by the rotary actuator.	RPM
n_r	The rated maximum output rotational speed, as shown in Table 2-1.	RPM
T_a	The actual torque output by the rotary actuator module.	Nm
T_r	The rated torque output by the rotary actuator module, as shown in Table 2-1.	Nm

Since the factory default permissible minimum bus voltage is 44V, when using a voltage below 44V, the permissible minimum bus voltage needs to be manually modified (set in "Safe Power" interface in eTunner). For example, when powering with DC24V, the permissible minimum bus voltage should be modified to 21.6V. (24V×90%, and the percentage can be modified according to the actual situation); The permissible maximum bus voltage should be modified to 26.4V (24V×110%, and the percentage can be modified according to the actual situation). Apply and save the parameters after configuration, as shown in Figure 3-4a When the detected voltage is below permissible minimum bus voltage 21.6V, the eRob rotary actuator cannot be enabled and an error will be reported ("The bus voltage is undervoltage"), and the eRob will shut down ,as shown in Figure 3-4b (the detected current voltage is 20.611V).

Note: There is no regenerative braking circuit of the eDriver inside the eRob rotary actuator, so the related parameters of regenerative braking have no effect on the eRob rotary actuator.



(a) Example of Using DC24V Power Supply (b) ”The bus voltage is undevoltage” Error Example

Figure 3-4 eRunner undervoltage example

Chapter 4 Rotary Actuator Positive Rotation Direction

In face of the output shaft of harmonic gear, the positive rotation direction of eRob rotary actuator is as shown in Figure 4-1, which is counterclockwise (CCW) rotation direction. The rotation direction can not be modified. The eRob rotation direction is determined by the direction of the target command which can be modified by controller.

Figure 4-1 Positive Rotation Direction of Rotary Actuator

Chapter 5 Electrical Interface and Status Indicator LED

5.1 Indicator LED Function

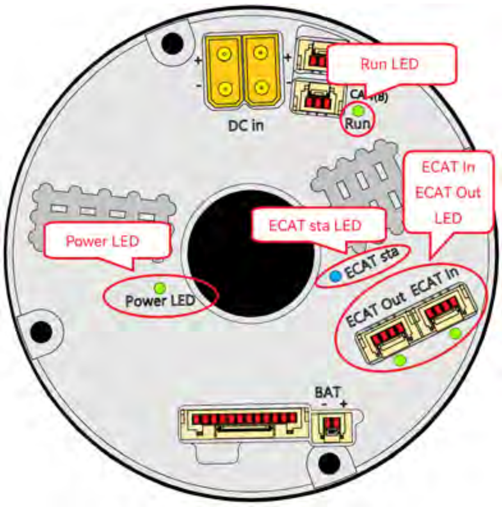
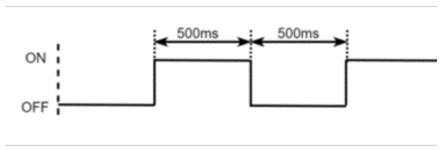


Figure 5-1 eRob Module LED Illustration

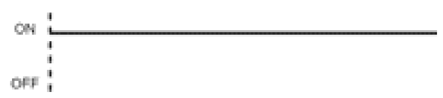
(1) **Run LED**

System Operation Indication.

LED Status	Green light flashes.
LED Status Figure	

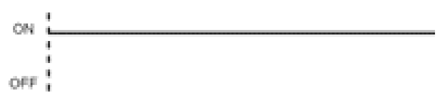
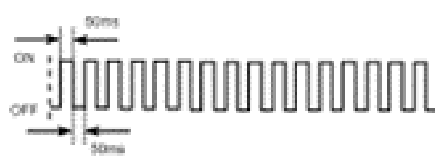
(2) **Power LED**

Bus power connection indication.

LED Status	Green light is always on.
LED Status Figure	

(3) **ECAT In LED**

EtherCAT In is used to connect the ECAT Out port of previous eRob slave or master controller.

ECAT Communication Connection Status	LED Status	LED Status Figure
Communication cable is not connected and the EtherCAT (COE) controller does not start.	Light is off	
Communication cable is connected, but data communication is not performed.	Green light is always on.	
Data communication is in progress.	Green light flashes quickly.	

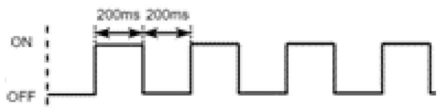
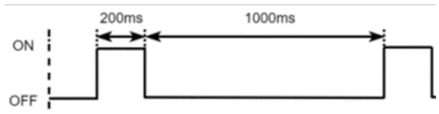
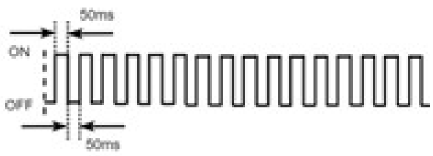
(4) **ECAT Out LED**

EtherCAT Out is used to connect the ECAT In port of slave of the next eRob.

ECAT Communication Connection Status	LED Status	LED Status Figure
Communication cable is not connected and the EtherCAT (COE) controller does not start.	Light is off	
Communication cable is connected, but data communication is not performed.	Green light is always on.	
Data communication is in progress.	Green light flashes quickly.	

(5) **ECAT sta LED**

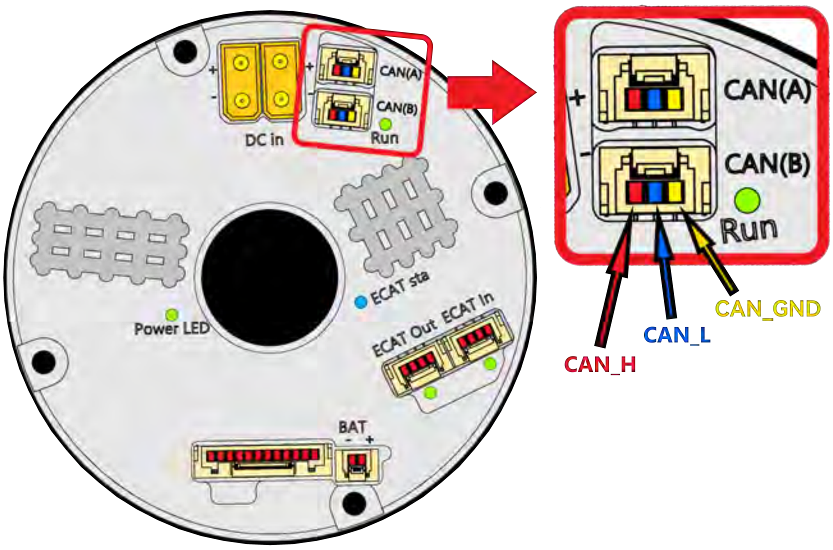
Indicates the state of the EtherCAT status machine.

ECAT Communication Connection Status	LED Status	LED Status Figure
INIT status	Light is off	
PREOP status	Blue light flash	
SAFEOP status	Blue light flashes once, and $Time_{off}$ >$Time_{on}$	
OP status	Blue light is always on	
OP status	Blue light flashes quickly.	

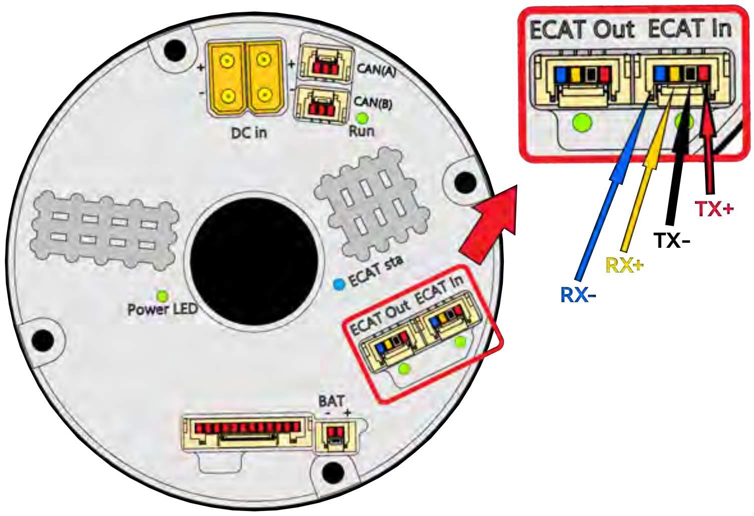
Note: Please refer to *Section 4.3* in *eRob CANopen and EtherCAT User Manual* for the details about the

EtherCAT status machine.

5.2 CAN Communication Interface

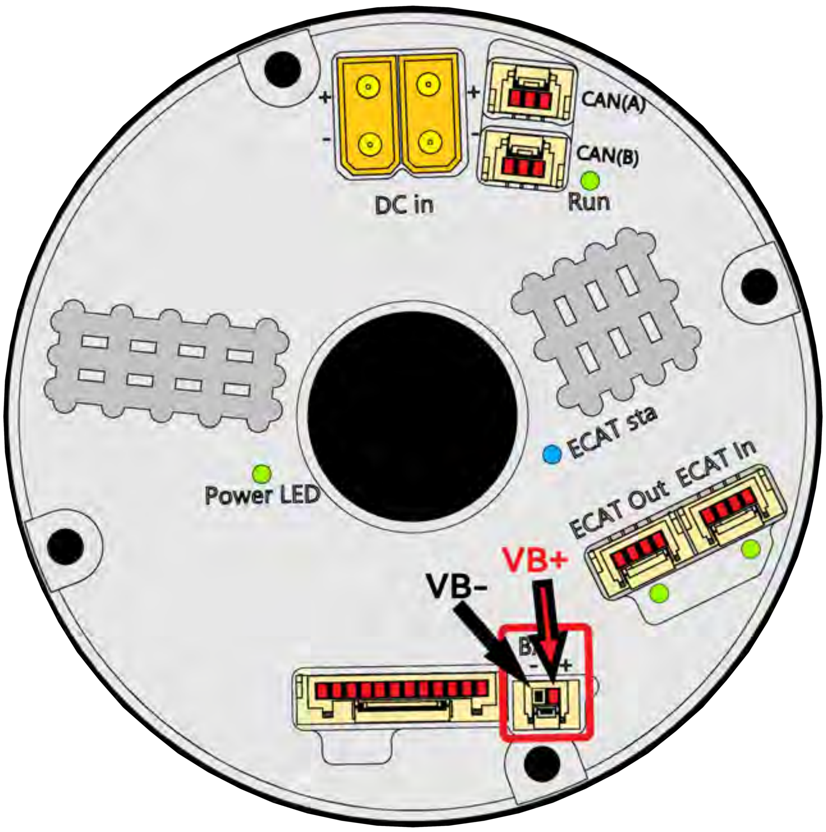
<table>
<tr><th>Pin</th><th>Terminal Label</th><th colspan="2">Terminal Function</th></tr>
<tr><td>1</td><td>CAN_H</td><td colspan="2" rowspan="2">CAN Network Signal</td></tr>
<tr><td>2</td><td>CAN_L</td></tr>
<tr><td>3</td><td>CAN_GND</td><td colspan="2">CAN Network Ground</td></tr>
<tr><th colspan="3">Pin Layout</th><th>Connector</th></tr>
<tr><td colspan="3">
</td><td>
</td></tr>
<tr><th colspan="3">Header Information</th><th>Connector Information</th></tr>
<tr><td colspan="3">Model: BM03B-GHS-TBT</td><td>Manufacturer: JST
Housing Model: GHR-03V-S
Contact Model: SSHL-002T-P0.2</td></tr>
<tr><td colspan="4">Specification: JST Top Entry Single Row 3Pin 1.25mm Pitch Disconnectable Crimp Style Connector</td></tr>
</table>

5.3 EtherCAT Communication Interface

<table>
<tr><th></th><th colspan="2">ECAT In</th><th colspan="2">ECAT Out</th></tr>
<tr><th>Pin</th><th>Terminal Label</th><th>Terminal Function</th><th>Terminal Label</th><th>Terminal Function</th></tr>
<tr><td>1</td><td>ECAT In_RX-</td><td>EtherCAT
Input Signal Reception-</td><td>ECAT Out_RX-</td><td>EtherCAT
Output Signal Reception-</td></tr>
<tr><td>2</td><td>ECAT In_RX+</td><td>EtherCAT
Input Signal Reception+</td><td>ECAT Out_RX+</td><td>EtherCAT
Output Signal Reception+</td></tr>
<tr><td>3</td><td>ECAT In_TX-</td><td>EtherCAT
Input Signal Transmission-</td><td>ECAT Out_TX-</td><td>EtherCAT
Output Signal Transmission-</td></tr>
<tr><td>4</td><td>ECAT In_TX+</td><td>EtherCAT
Input Signal Transmission+</td><td>ECAT Out_TX+</td><td>EtherCAT
Output Signal Transmission+</td></tr>
<tr><th colspan="3">Pin Layout</th><th colspan="2">Connector</th></tr>
<tr><td colspan="3">
</td><td colspan="2">
</td></tr>
<tr><th colspan="3">Header Information</th><th colspan="2">Connector Information</th></tr>
<tr><td colspan="3">Model: BM04B-GHS-TBT</td><td colspan="2">Manufacturer: JST
Housing Model: GHR-04V-S
Contact Model: SSHL-002T-P0.2</td></tr>
<tr><td colspan="5">Specification: JST Single Row 4Pin 1.25mm Pitch Disconnectable Crimp Style Connector</td></tr>
</table>

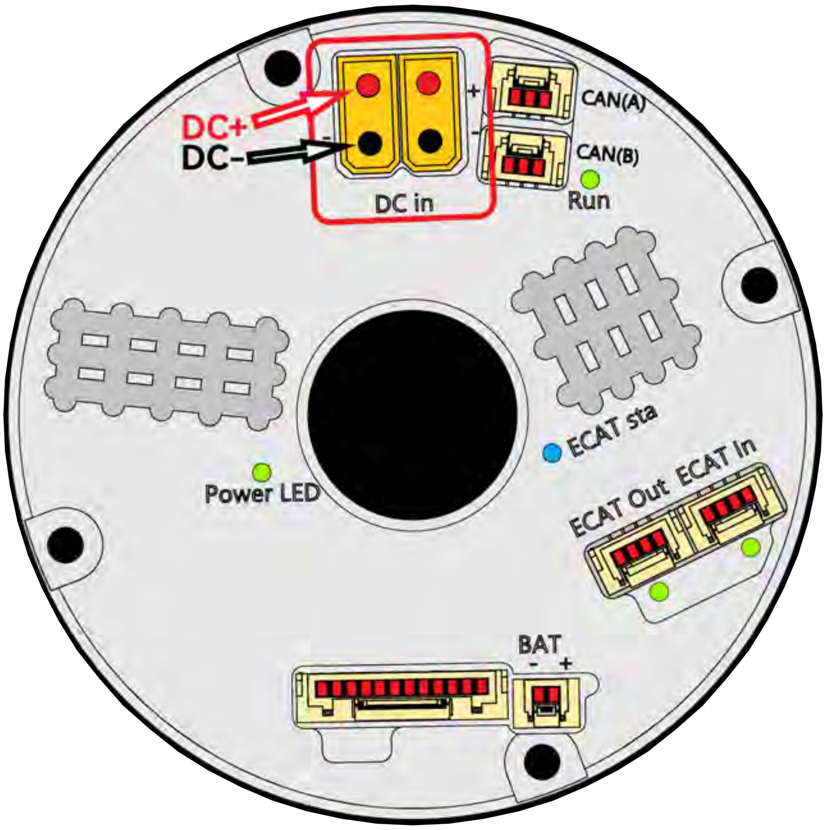
Note: CANopen version rotary actuators (model: eRobxxxxxxxx-xx-18**C**x) do not have this interface.

5.4 Multi-Turn Power Supply Battery Interface

<table>
<tr><th>Pin</th><th>Terminal Label</th><th colspan="2">Terminal Function</th></tr>
<tr><td>1</td><td>VB+</td><td colspan="2">Battery Positive</td></tr>
<tr><td>2</td><td>VB-</td><td colspan="2">Battery Negative</td></tr>
<tr><th colspan="3">Pin Layout</th><th>Connector</th></tr>
<tr><td colspan="3">
</td><td>
</td></tr>
<tr><th colspan="3">Header Information</th><th>Connector Information</th></tr>
<tr><td colspan="3">Model: BM02B-GHS-TBT</td><td>Manufacturer: JST
Housing Model: GHR-02V-S
Contact Model: SSHL-002T-P0.2</td></tr>
<tr><td colspan="4">Specification: JST Single Row 2Pin 1.25mm Pitch Disconnectable Crimp Style Connector</td></tr>
</table>

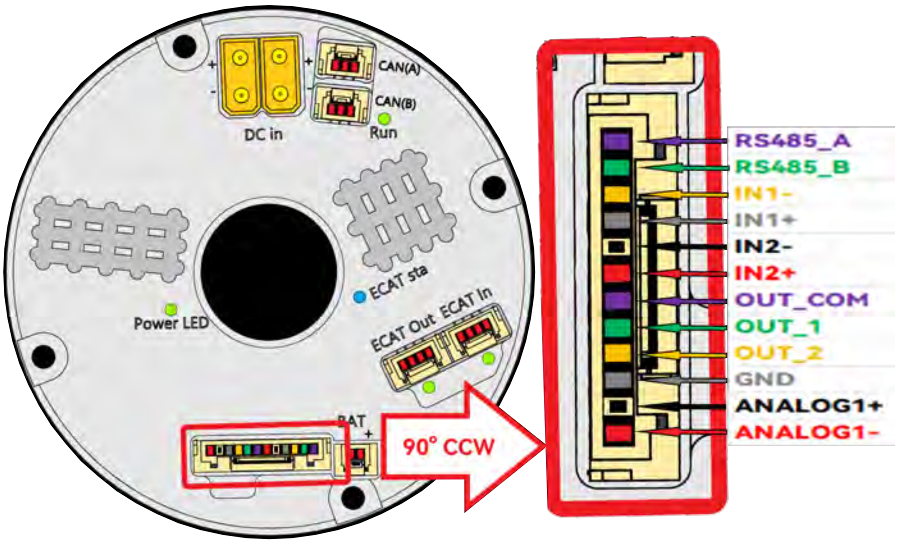
Note: Single-turn rotary actuators (model: eRobxxxxxxxxx-x**S**-18xx) do not have this interface. More details for multi-turn battery instruction, please refer to Chapter 11.

5.5 48V Power Supply Interface

<table>
<tr><th>Pin</th><th>Terminal Label</th><th>Terminal Function</th></tr>
<tr><td>1</td><td>DC+</td><td>Power Supply Positive</td></tr>
<tr><td>2</td><td>DC-</td><td>Power Supply Negative</td></tr>
<tr><th colspan="2">Pin Layout</th><th>Connector</th></tr>
<tr><td colspan="2">
</td><td>


</td></tr>
<tr><th colspan="2">Header Information</th><th>Connector Information</th></tr>
<tr><td colspan="2">Model: XT30UPB-M</td><td>Manufacturer: AMASS
Model: XT30U-F</td></tr>
<tr><td colspan="3">Specification: AMASS Top Entry 2Pin 5mm Pitch Straight Pin Connector With 2mm Pin Length</td></tr>
</table>

5.6 I/O Signal Terminal

<table>
<tr><th>Pin</th><th>Terminal Label</th><th>Terminal Function</th></tr>
<tr><td>1</td><td>RS485-A</td><td>RS485 COM Interface DATA+</td></tr>
<tr><td>2</td><td>RS485-B</td><td>RS485 COM Interface DATA-</td></tr>
<tr><td>3</td><td>IN1- / Pulse- /STOA-</td><td rowspan="2">Digital Input DIn1 /
Pulse Command Signal / STOA</td></tr>
<tr><td>4</td><td>IN1+/ Pulse+ /STOA+</td></tr>
<tr><td>5</td><td>IN2- /Dir- /STOB-</td><td rowspan="2">Digital Input DIn2 /
Pulse Command Direction / STOB</td></tr>
<tr><td>6</td><td>IN2+ /Dir+ /STOB+</td></tr>
<tr><td>7</td><td>OUT_COM</td><td>Programmable output signal ground</td></tr>
<tr><td>8</td><td>OUT_1</td><td>Programmable digital output 1</td></tr>
<tr><td>9</td><td>OUT_2</td><td>Programmable digital output 2</td></tr>
<tr><td>10</td><td>GND</td><td>Signal ground</td></tr>
<tr><td>11</td><td>ANALOG1+</td><td>Analog signal input +
(input range -10V ~+10V)</td></tr>
<tr><td>12</td><td>ANALOG1-</td><td>Analog signal input-
(input range -10V ~+10V)</td></tr>
<tr><th colspan="2">Pin Layout</th><th>Connector</th></tr>
<tr><td colspan="2">
</td><td>
</td></tr>
<tr><th colspan="2">Header Information</th><th>Connector Information</th></tr>
<tr><td colspan="2">Model: BM12B-GHS-TBT</td><td>Manufacturer: JST
Housing Model: GHR-12V-S
Contact Model: SSHL-002T-P0.2</td></tr>
<tr><td colspan="3">Specification: JST Top Entry Single Row 12Pin 1.25mm Pitch Disconnectable Crimp Style Connector</td></tr>
</table>

5.7 Cable Specification Explanation

Table 5-2 eRob Rotary Actuator Module Wire Specification

Model	COM Port	Wire Count × Port Count	Wire Recommendation Cross-Section Area (mm^2)	Wire Recommendation AWG#	Wire Connection Reserve Height (mm)
Universal Specification	CAN COM Port: CAN(A) & CAN(B)	3P×2	0.05~0.13	30~26	10
	EtherCAT COM Port: ECAT In & ECAT Out	4P×2	0.05~0.13	30~26	10
	I/O Port	12P×1	0.05~0.13	30~26	10
	Multi-Turn Func. Battery Port: BAT	2P×1	0.05~0.13	30~26	10
eRob70	48V Power Input Port: DC In	2P×2	0.5	20	15
eRob80		2P×2	0.75	19	15
eRob90		2P×2	1	18	15
eRob110		2P×2	1.25	17	15
eRob142		2P×2	1.5	16	15
eRob170		2P×2	1.5	16	15

5.8 Force Instruction of Connector

The permissible tensile force of connection between JST terminal and wire is shown in Table 5-3, and the tensile test is shown in Figure 5-2a.

Table 5-3 Permissible Tensile Force of Connection Between JST Terminal and Wire

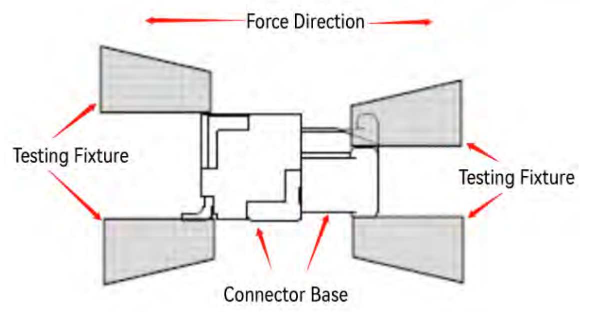
AWG	Standard Value (N)	Actual Value (N)
AWG #26	≥ 20	33 ~ 39
AWG #28	≥ 10	21 ~ 26
AWG #30	≥ 5	14 ~ 18

The permissible tensile force of the male/female head buckles of JST connector are shown in Table 5-4, and the tension testing is shown in Figure 5-2b. Do not unplug the wiring terminal directly from the interface. Loose the buckle first, and then pull it out gently. Pulling out terminal directly may cause the buckle breakage and unstable connection.

Table 5-4 Permissible Tensile Force of Male/Female Connector Connecting to Buckle

Pin Number	2 ~ 3	4 ~ 6	7 ~ 9	10 ~ 15
Min. Value (N)	10	12	15	20

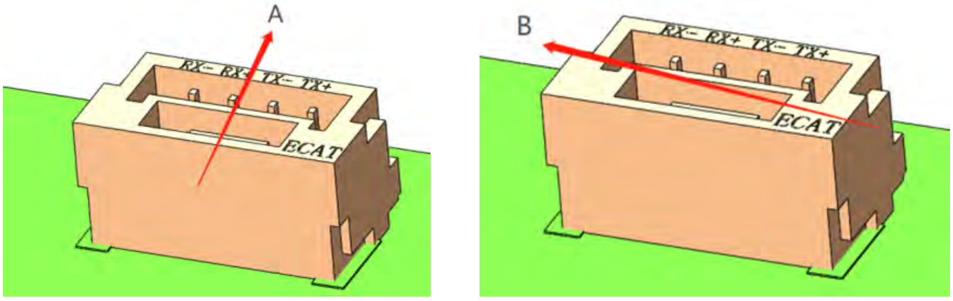
(a) Tension Testing of Connection Between JST Terminal and Wires



(b) Tension Testing of the Male/Female Head Buckles of Connector

Figure 5-2 Tension Testing Illustrations

The bases of four type of connectors are all GHS-TBT type, and the sizes of the four solder discs are the same. Therefore, the permissible thrust force of A-direction is no more than 3N, and the permissible thrust force of B-direction is no more than 4.2N. as shown in Figure 5-3a and Figure 5-3b



(a) A-Direction Force GHS-TBT Connector Housing

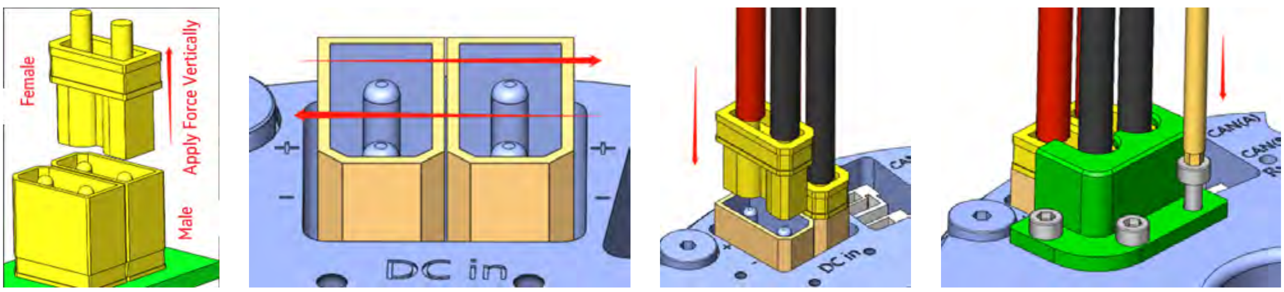
(b) B-Direction Force GHS-TBT Connector Housing

Figure 5-3 Direction of Force Applied on GHS-TBT Connector Housing

5.9 Force Instruction of Power Terminal

(1) When pulling in or pulling out the power plug, please plug and unplug the power terminal female head in vertical direction, as shown in Figure 5-4a. The tensile force limit of power terminal male head in vertical direction is about 170N, and in horizontal direction is about 0.4Nm. Do not shake the power terminals from side to side at any time. As shown in Figure 5-4b, shaking from side to side may cause the power terminals to fall off easily.

(2) To avoid the power terminals fall off or the power terminal is in poor connection caused by vibration, pulling or other factors during operation, it is necessary to install plug retainers after connecting the power terminals. The installation steps are:
  (1) Weld the power cable to the power terminal female head;
  (2) Insert the power terminal female head, as shown in Figure 5-4c;
  (3) Install the plug retainer and lock it firmly, as shown in Figure 5-4d.



(a) Plug and Unplug in Vertical Direction

(b) Do Not Shake Power Terminal from Side-to-Side

(c) Plug Female Power Terminal

(d) Plug Retainer Installation

Figure 5-4 Direction of Force Applied on GHS-TBT Connector Base

NOTE: (1) **Screw Size**

The locking screws of plug retainers are M1.6×4. The plug retainers and locking screws are packaged into the rotary actuator accessories kit.

(2) **Warranty**

The warranty of eRob does not apply if the eRob installed without plug retainers subjected to vibration, pulling or other factors causing the power terminals fall off or power terminals is in poor connection to ignition and further causing eRob occurs irreversible damage.

Chapter 6 Cable Wiring Among Rotary Actuators

Cable wiring among rotary actuators is as shown in Figure 6-2. EtherCAT networking adopts direct wiring mode. Connect the RJ45 network port of the master controller to ECAT In port of the first eRob (Slave1), and connect the ECAT Out port of the first eRob (Slave1) to the ECAT In port of the next eRob and so on. The corresponding eRob network port pin sequence of the RJ45 network port is as shown in Figure 6-1. Connect CAN networking cables according to port definitions, and the CAN port of the two adjacent eRobs can be connected in random order. Refer to Section 6.1 for the wiring method of the power supply; refer to Section 6.2 for the CAN/CANopen communication wiring, and refer to Section 6.3 for the EtherCAT communication wiring.

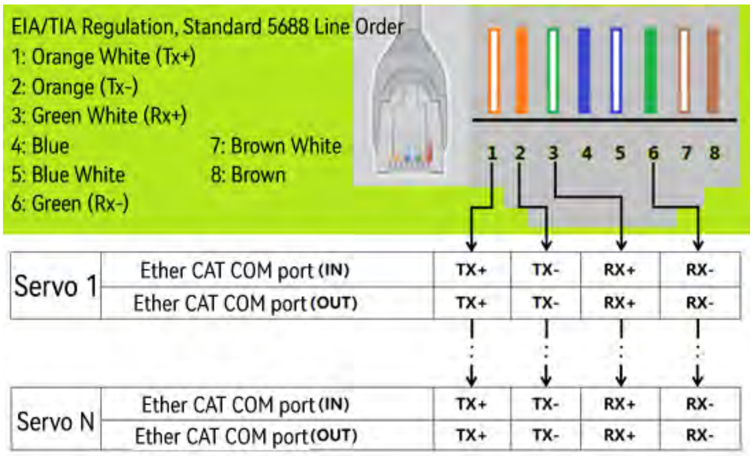


Figure 6-1 EtherCAT Networking Connection Mode

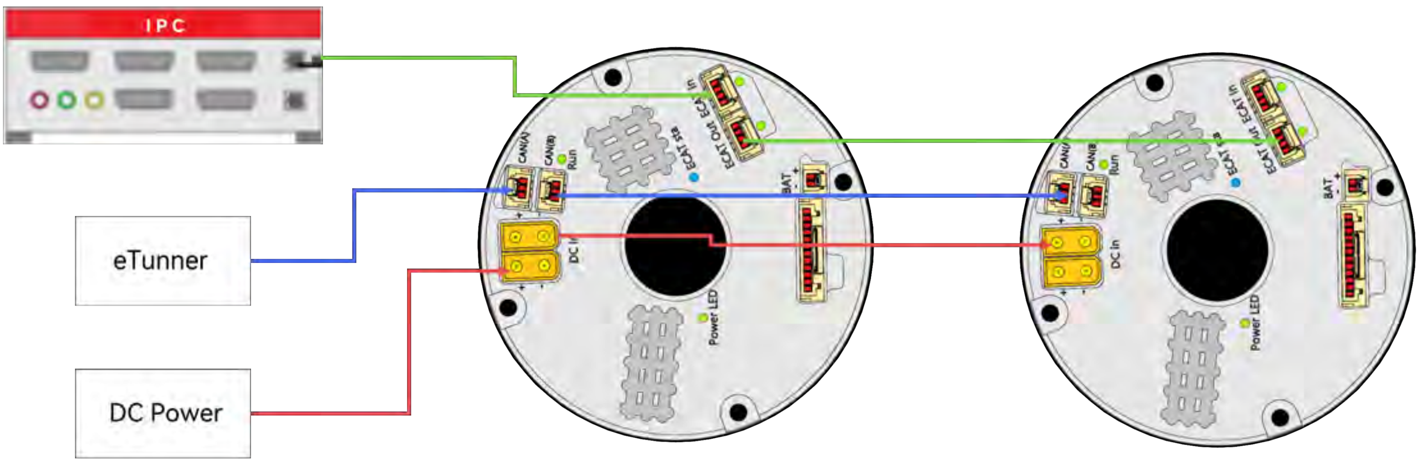


Figure 6-2 Cable Wiring Among Rotary Actuators Illustration

6.1 Power Supply Wiring Illustration

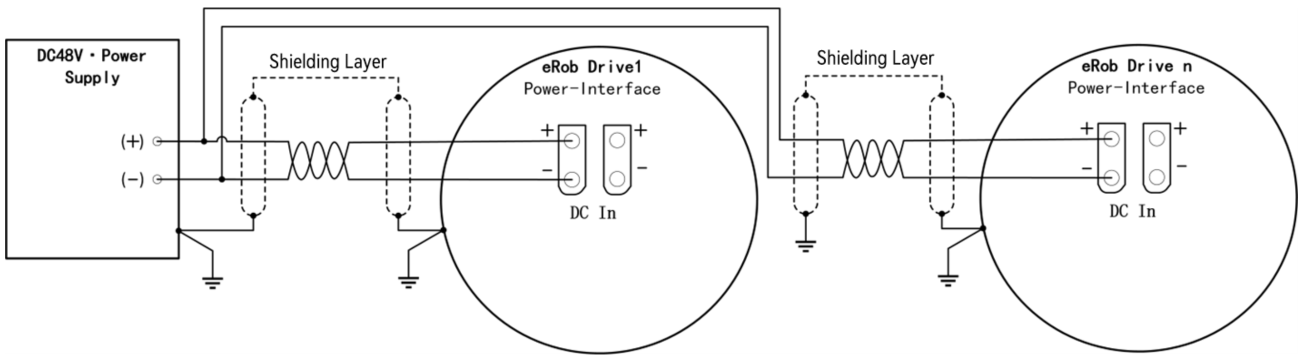
There are three power wiring methods for the eRob modules: direct wiring for single eRob, tree topology wiring, and chain topology wiring (as shown in Figure 6-3a, Figure 6-3b and Figure 6-3c). Under the condition of applying multiple eRobs which are powered by 48V, according to the actual test results of the pressure drop of each eRob, the recommended order of adopting the three wiring modes is:

(1) **Direct Wiring Mode (as shown in Figure 6-3a)**
the best mode, minimum wiring resistance, minimum pressure drop of wire consumption, suitable for high-power eRob;

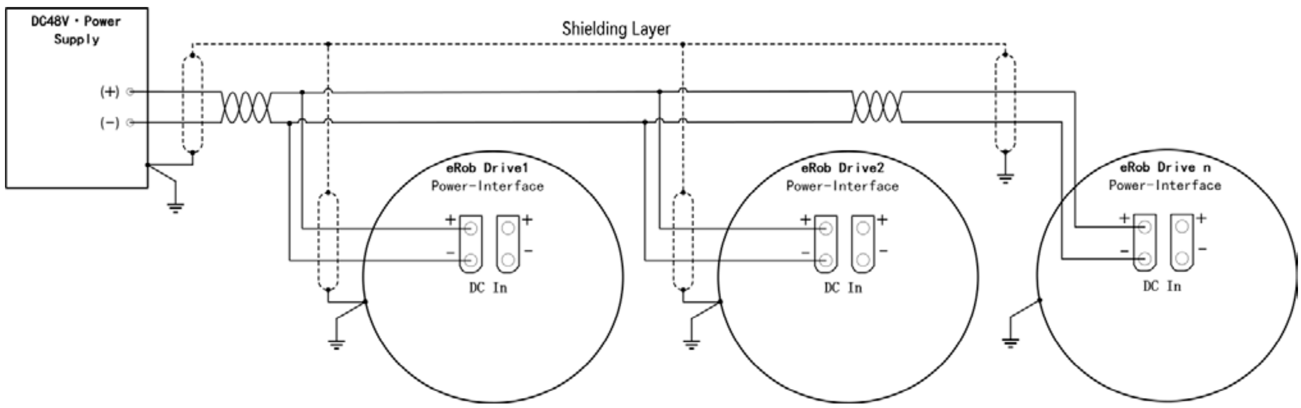
(2) **Tree Topology Wiring Mode (as shown in Figure 6-3b)**
the better mode;

(3) **Chain Topology Wiring Mode (as shown in Figure 6-3c)**
the good mode, larger wiring resistance, larger pressure drop of wire consumption, suitable for low-power eRob .

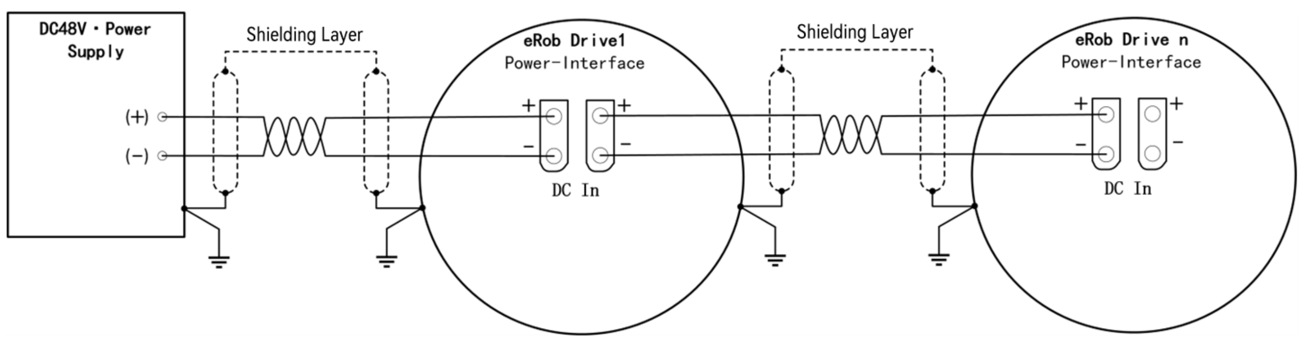
CAUTION:
Please use direct wiring for single eRob method when using eRob90/110/142/170. Otherwise, it is easily to appear error reports of the too low bus voltage and too high bus voltage during running.
Do not connect other electrical devices in series. Other electrical devices may cause unpredictable voltage drop or voltage rise and cause a failure.



(a) Direct Wiring of Single Rotary Actuator Diagram



(b) Tree Topology Wiring Diagram



(c) Chain Topology Wiring Diagram

Figure 6-3 Wiring Diagrams

6.1.1 Examples of Collaborative Robot Power Wiring

3 kg Payload Collaborative Robot Arm Example(as shown in Figure 6-4):

Note: Due to the adoption of a chain topology connection, it is recommended to use specific power cable specifications for each axis to ensure optimal performance and reliable power transmission.

(1) **DC48V → J1 axis**
For the connection between the DC48V power supply output and the J1 axis, it is highly recommended to use power cables with a minimum cross-sectional area of $\geq 1mm^2$ (18AWG). This ensures sufficient power delivery and minimizes power losses.

(2) **J1 → J3 axis**
Similarly, for the connection between J1 and J3 axes, it is advised to use power cables with a minimum cross-sectional area of $\geq 1mm^2$ (18AWG) to maintain efficient power transfer and prevent voltage drops.

(3) **J3 → J5 axis**
When connecting J3 to J5 axes, it is recommended to use power cables with a minimum cross-sectional area of $\geq 0.75mm^2$ (19AWG) to meet the power requirements and ensure stable power transmission.

(4) **J5 → J6 axis**
Lastly, for the connection between J5 and J6 axes, it is recommended to use power cables with a minimum cross-sectional area of $\geq 0.5mm^2$ (20AWG) to ensure reliable power transmission.

By following these cable specifications, you can ensure proper power distribution and minimize potential issues related to power supply, thereby optimizing the overall performance of the system.

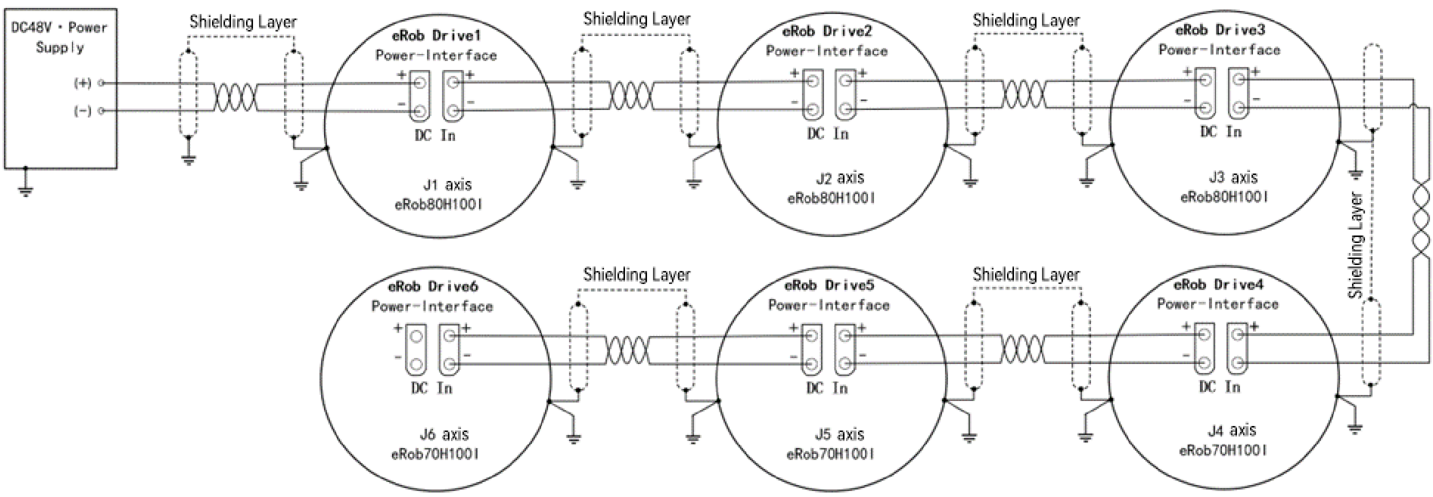


Figure 6-4 3kg payload collaborative robot power wiring diagram example

5 kg Payload Collaborative Robot Arm Example(as shown in Figure 6-5):

Note: Due to the adoption of a chain topology connection, it is recommended to use specific power cable specifications for each axis to ensure optimal performance and reliable power transmission.

(1) **DC48V → J1 axis**
For the connection between the DC48V power supply output and the J1 axis, it is highly recommended to use power cables with a minimum cross-sectional area of ≥1.5mm^2 (16AWG). This ensures sufficient power delivery and minimizes power losses.

(2) **J1 → J3 axis**
Similarly, for the connection between J1 and J3 axes, it is advised to use power cables with a minimum cross-sectional area of ≥1.5mm^2 (16AWG) to maintain efficient power transfer and prevent voltage drops.

(3) **J3 → J5 axis**
When connecting J3 to J5 axes, it is recommended to use power cables with a minimum cross-sectional area of ≥0.75mm^2 (19AWG) to meet the power requirements and ensure stable power transmission.

(4) **J5 → J6 axis**
Lastly, for the connection between J5 and J6 axes, it is recommended to use power cables with a minimum cross-sectional area of ≥0.5mm^2 (20AWG) to ensure reliable power transmission.

By following these cable specifications, you can ensure proper power distribution and minimize potential issues related to power supply, thereby optimizing the overall performance of the system.

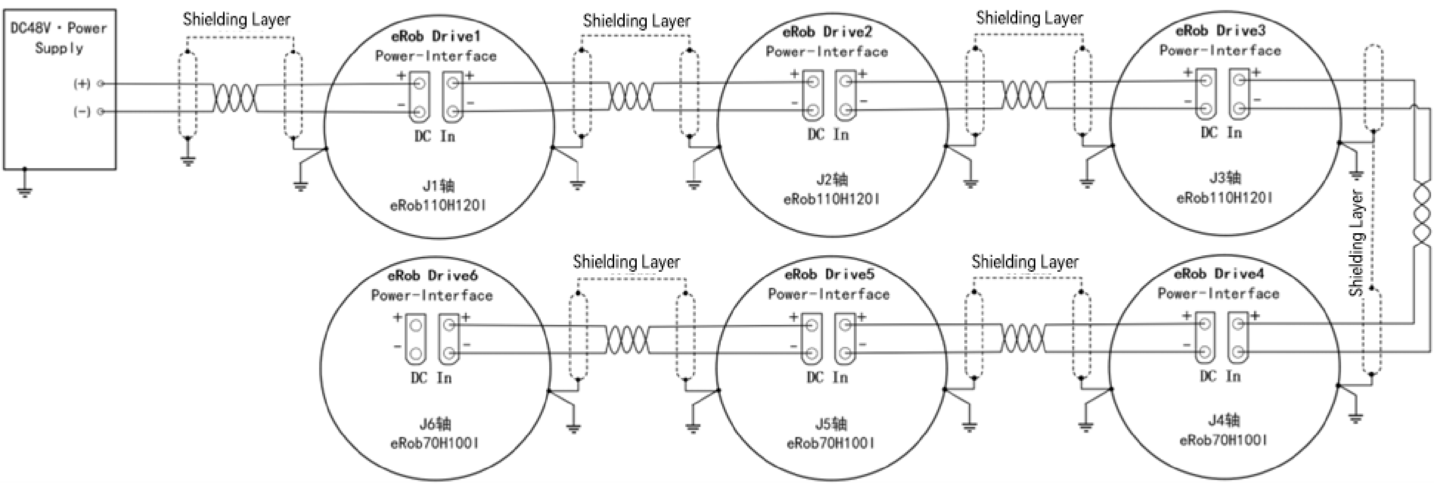


Figure 6-5 5kg payload collaborative robot power wiring diagram example

10 kg Payload Collaborative Robot Arm Example(as shown in Figure 6-6):

Note: Due to the adoption of both single-axis direct connection and chain topology connection, it is recommended to use specific power cable specifications for each axis to ensure optimal performance and reliable power transmission.

(1) **DC48V → J1 & J2 & J3 axis**
For the connection between the DC48V power supply output and the axes J1, J2, and J3, it is recommended to use power cables with a minimum cross-sectional area of ≥1.5mm² (16AWG). This ensures sufficient power delivery and minimizes power losses.

(2) **J3 → J5 axis**
When connecting J3 to J5 axes, it is advised to use power cables with a minimum cross-sectional area of ≥1mm² (18AWG) to maintain efficient power transfer and prevent voltage drops.

(3) **J5 → J6 axis**
Similarly, for the connection between J5 and J6 axes, it is recommended to use power cables with a minimum cross-sectional area of ≥0.75mm² (19AWG) to ensure reliable power transmission.

If the DC48V power supply output is connected to the axes J1, J2, and J3 using branch terminals (such as a two-in, six-out configuration), then for the connection between the DC48V power supply output and the terminal input, it is recommended to use power cables with a minimum cross-sectional area of ≥3mm² (12AWG).

By following these cable specifications, you can ensure proper power distribution and minimize potential issues related to power supply, thereby optimizing the overall performance of the system.

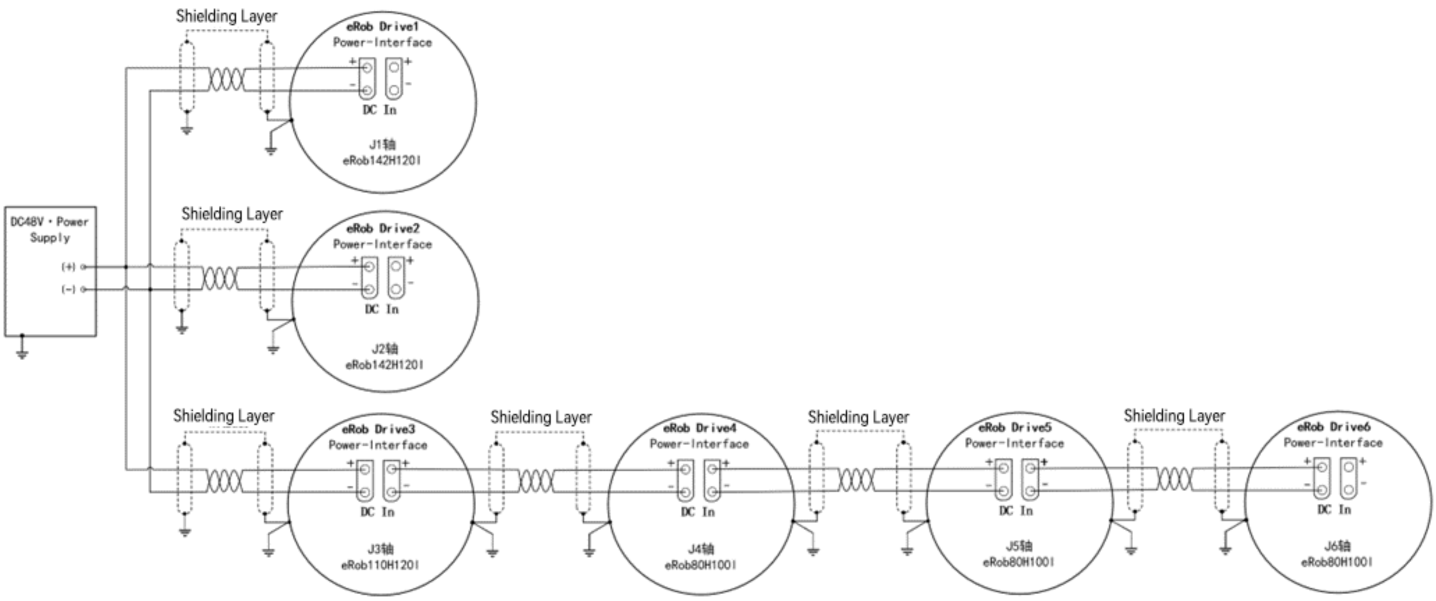


Figure 6-6 10kg payload collaborative robot power wiring diagram example

20 kg Payload Collaborative Robot Arm Example(as shown in Figure 6-7):

Note: Due to the adoption of both single-axis direct connection and chain topology connection, it is recommended to use specific power cable specifications for each axis to ensure optimal performance and reliable power transmission.

(1) **DC48V → J1** & **J2** & **J3 axis**
For the connection between the DC48V power supply output and the axes J1, J2, and J3, it is recommended to use power cables with a minimum cross-sectional area of ≥1.5mm² (16AWG). This ensures sufficient power delivery and minimizes power losses.

(2) **DC48V → J4 axis** & **J4 → J5 axis**
When connecting J3 to J5 axes, it is advised to use power cables with a minimum cross-sectional area of ≥1.25mm² (17AWG) to maintain efficient power transfer and prevent voltage drops.

(3) **J5 → J6 axis**
Similarly, for the connection between J5 and J6 axes, it is recommended to use power cables with a minimum cross-sectional area of ≥1mm² (18AWG) to ensure reliable power transmission.

If the DC48V power supply output is connected to the axes J1, J2, J3 and J4 using branch terminals (such as a two-in, six-out configuration), then for the connection between the DC48V power supply output and the terminal input, it is recommended to use power cables with a minimum cross-sectional area of ≥6mm² (9AWG).
By following these cable specifications, you can ensure proper power distribution and minimize potential issues related to power supply, thereby optimizing the overall performance of the system.

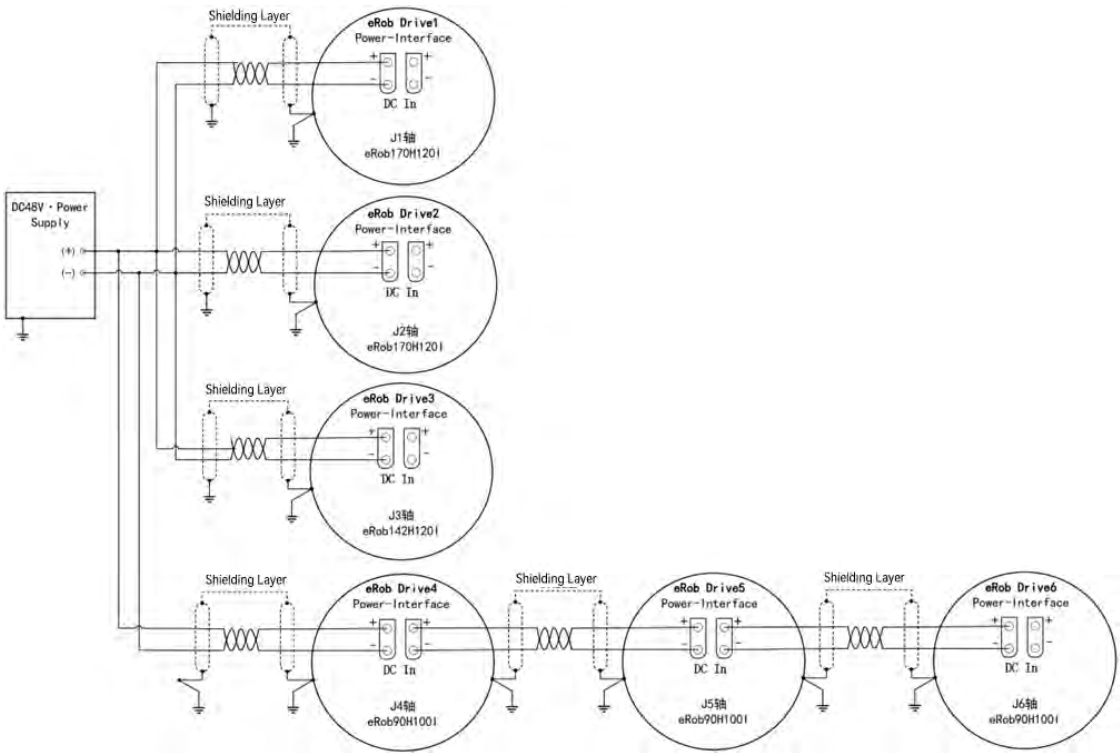
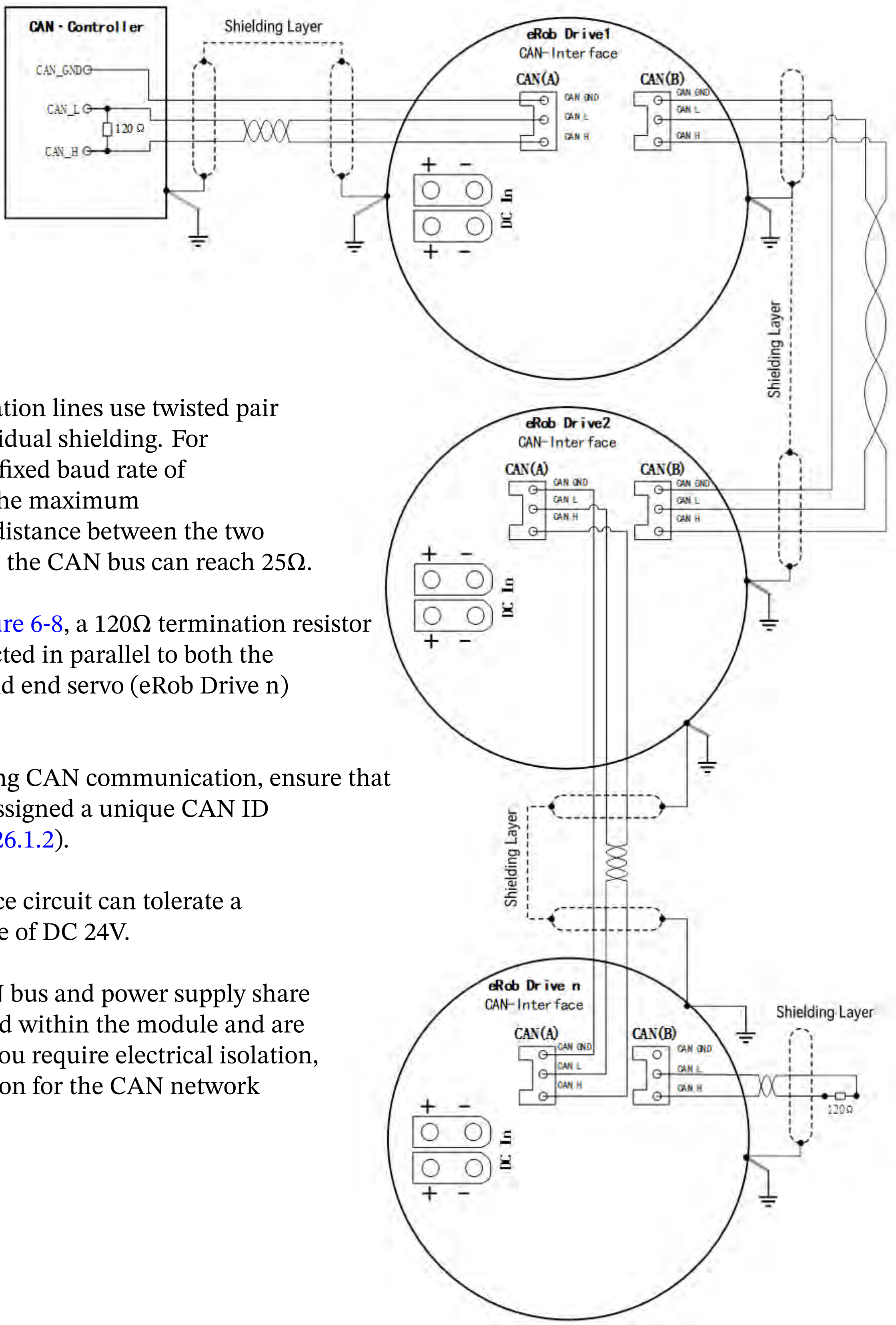


Figure 6-7 20kg payload collaborative robot power wiring diagram example

6.2 CAN/CANopen Communication Wiring Diagram (as shown in Figure 6-8)



NOTES:

(1) CAN communication lines use twisted pair cables with individual shielding. For eRob modules, a fixed baud rate of 1Mbps is used. The maximum communication distance between the two farthest nodes on the CAN bus can reach 25Ω.

(2) As shown in Figure 6-8, a 120Ω termination resistor should be connected in parallel to both the controller-end and end servo (eRob Drive n) CAN interfaces.

(3) Before establishing CAN communication, ensure that each module is assigned a unique CAN ID (refer to Section 26.1.2).

(4) The CAN interface circuit can tolerate a maximum voltage of DC 24V.

(5) The module CAN bus and power supply share a common ground within the module and are non-isolated. If you require electrical isolation, please add isolation for the CAN network in your circuit.

Figure 6-8 CAN/CANopen communication wiring diagram

6.3 EtherCAT Communication Wiring Diagram (as shown in Figure 6-9)

NOTES:

(1) EtherCAT communication lines use twisted pair cables with individual shielding.

(2) Even if you choose a module with EtherCAT communication, it is still recommended to connect and retain the module CAN communication lines in the overall system. It is also advised to set the module CAN ID in advance (refer to Chapter 6.2). This enables convenient debugging of individual module in the entire system (without disassembling the casing) during subsequent debugging processes, including troubleshooting, parameter modification, firmware upgrades, etc.

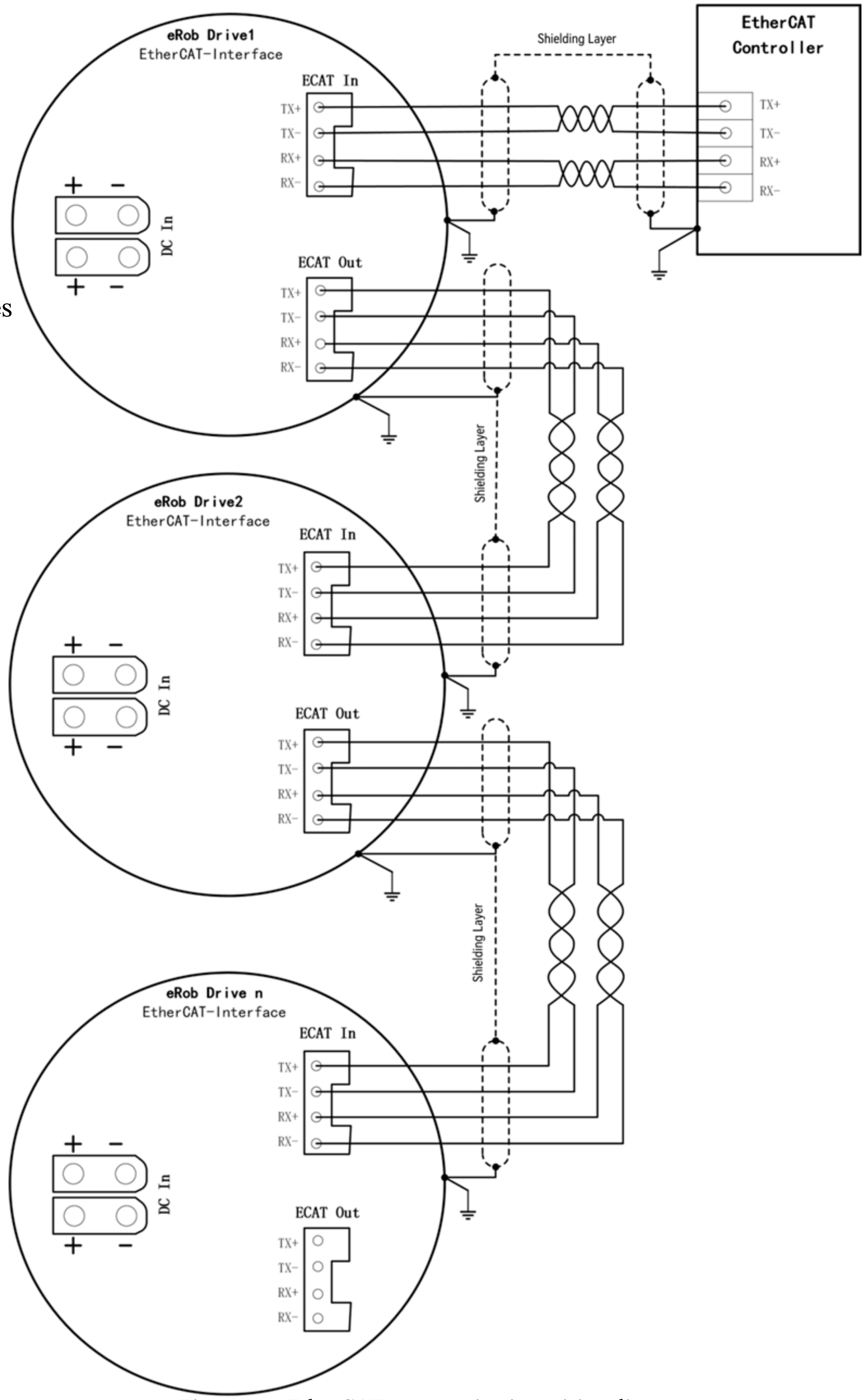


Figure 6-9 EtherCAT communication wiring diagram

6.4 Modbus-RTU Communication Wiring Diagram(as shown in Figure 6-10)

The Modbus-RTU communication interface is the RS485 communication interface of the I/O terminal of the eRob rotary actuator. The MODBUS master system and the MODBUS slave system can create a multi-point connection bus network. The wiring diagram is shown in Figure 6-10. For details on the use of the Modbus-RTU communication protocol, please refer to the *eRob Modbus-RTU User Manual*.

Notes:

(1) The Modbus-RTU communication lines use twisted pair cables with individual shielding.

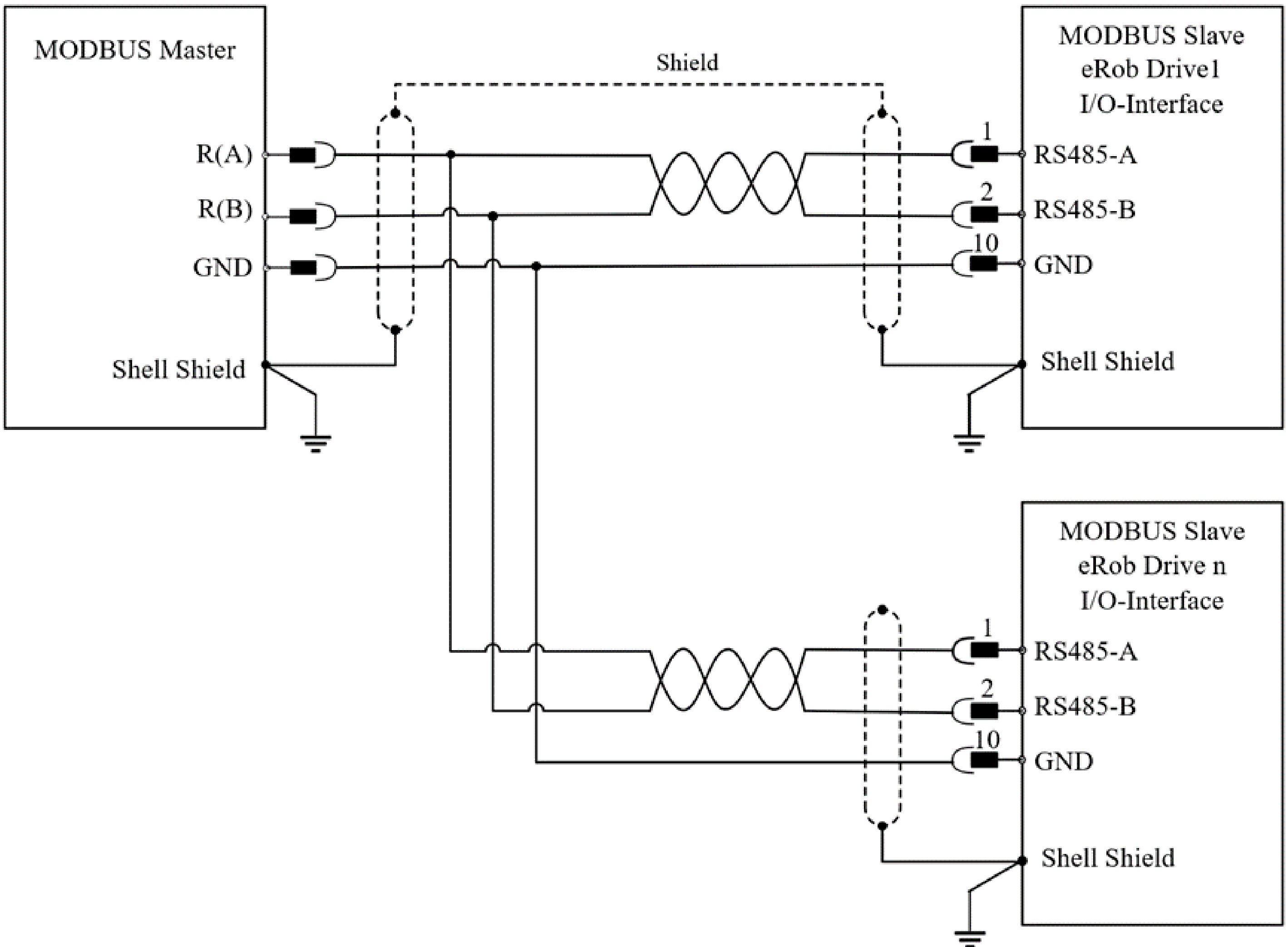


Figure 6-10 Modbus-RTU communication wiring diagram

6.5 I/O Signal Terminal Wiring Diagram

(1) **Universal digital input DI terminal (as shown in Figure 6-11):**

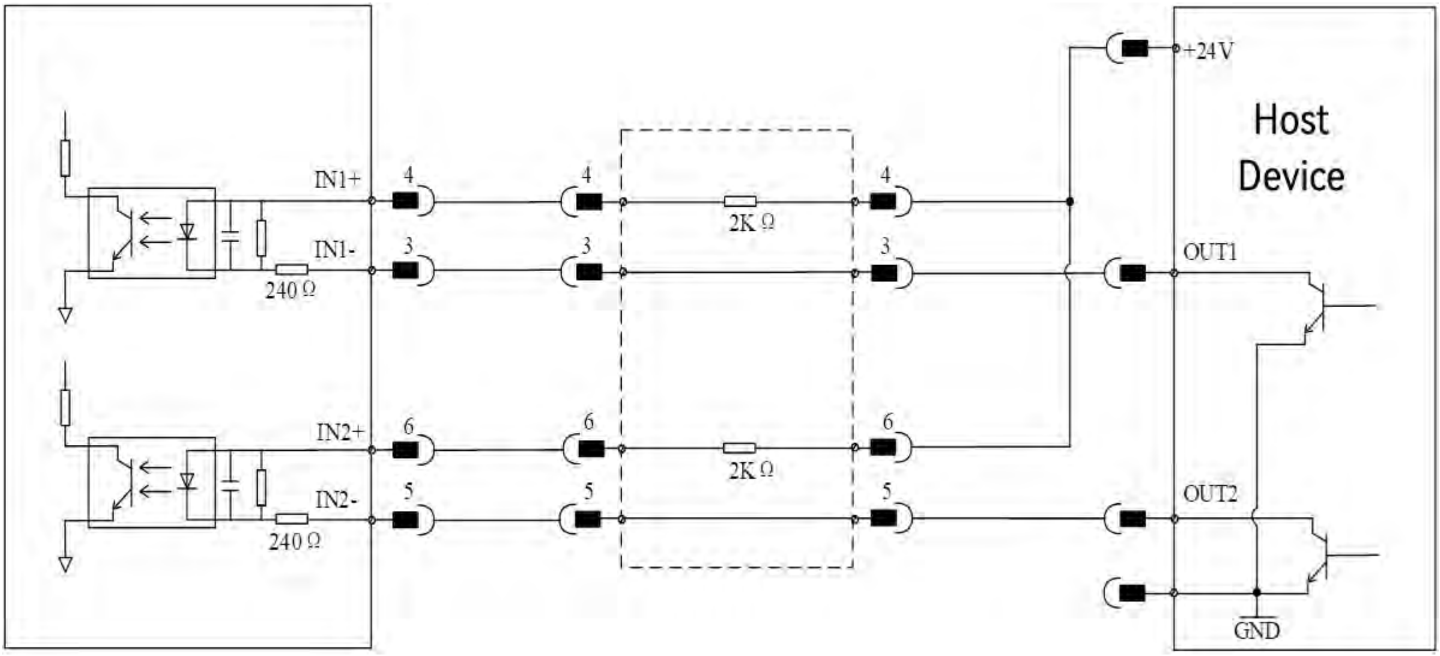


Figure 6-11 Universal digital input DI terminal wiring diagram

(2) **Safe Torque Off (STO) function terminal (as shown in Figure 6-12):**

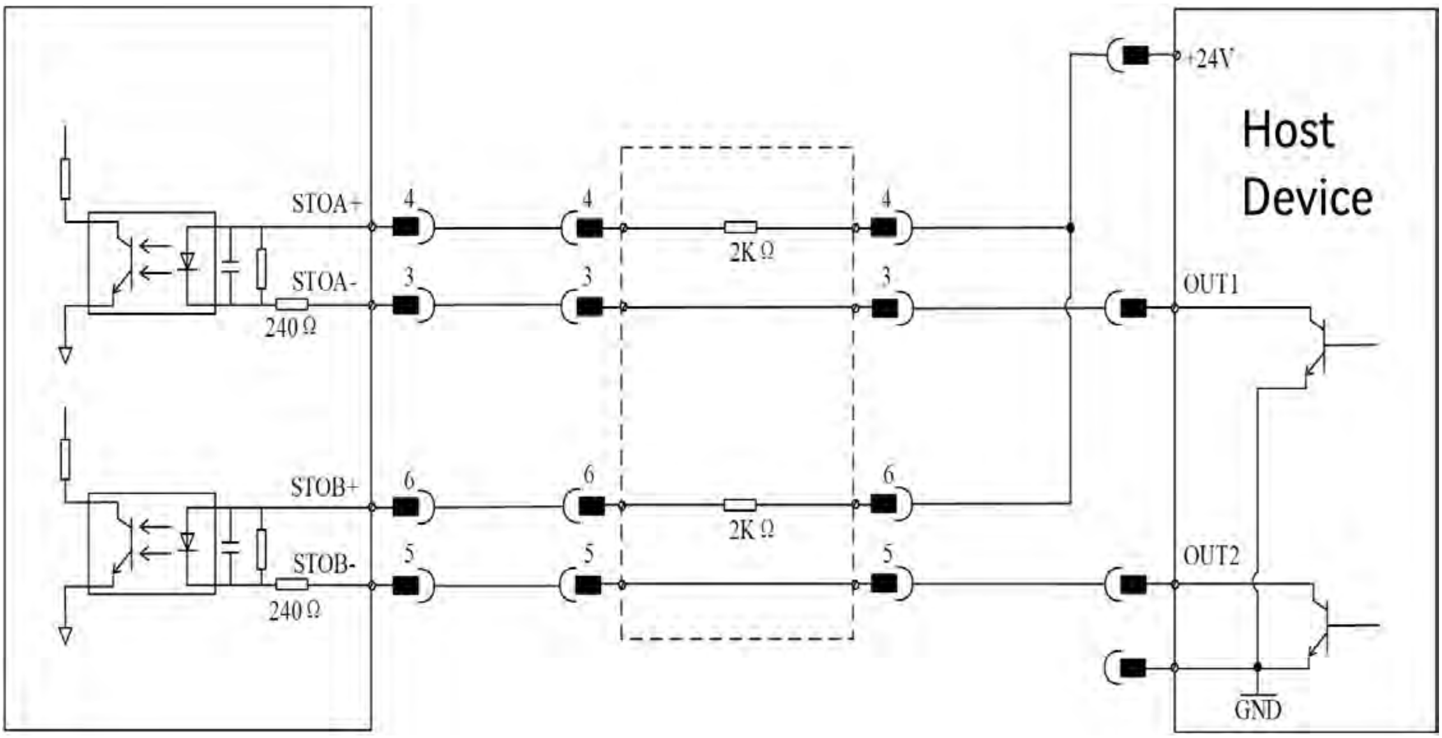


Figure 6-12 Safe torque off (STO) terminal wiring diagram

(3) **Pulse direction control terminal**

(1) **5V difference mode (as shown in Figure 6-13):**

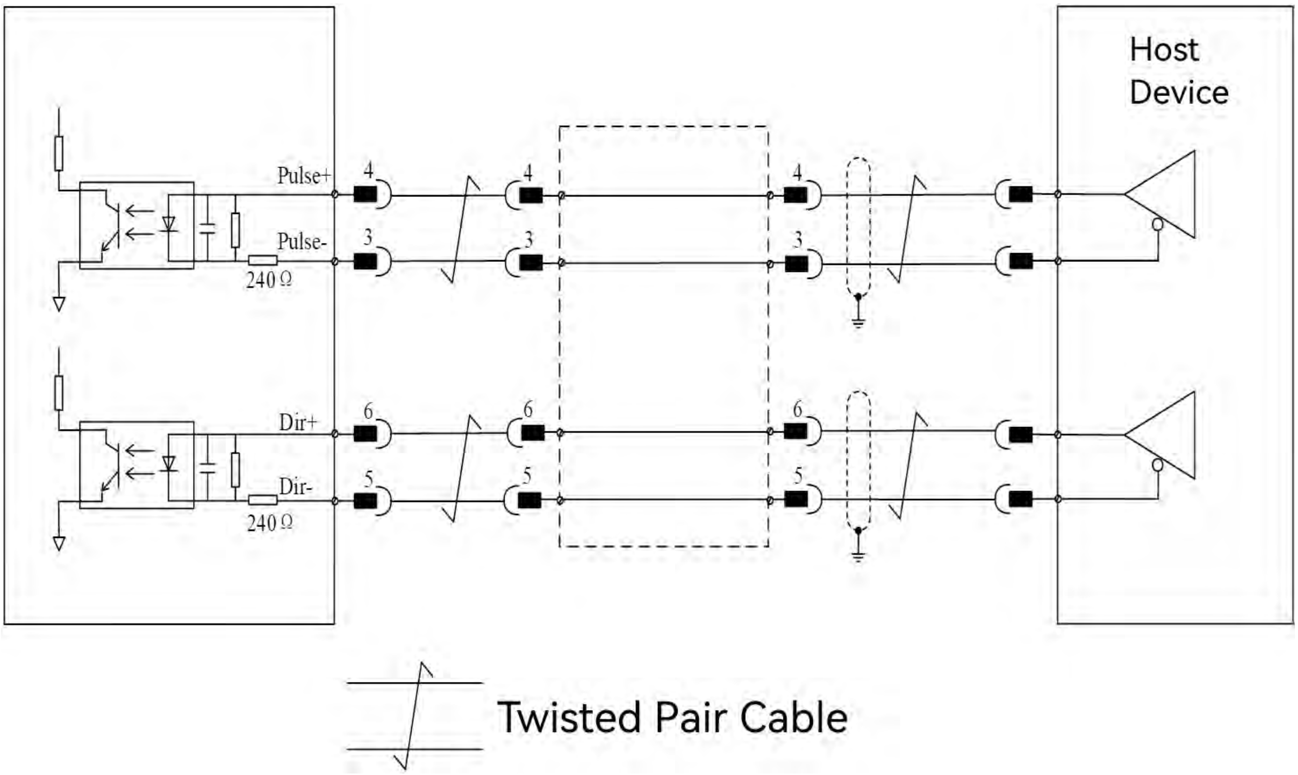


Figure 6-13 5V difference pulse command input terminal wiring diagram

(2) **Open collector mode (as shown in Figure 6-14):**

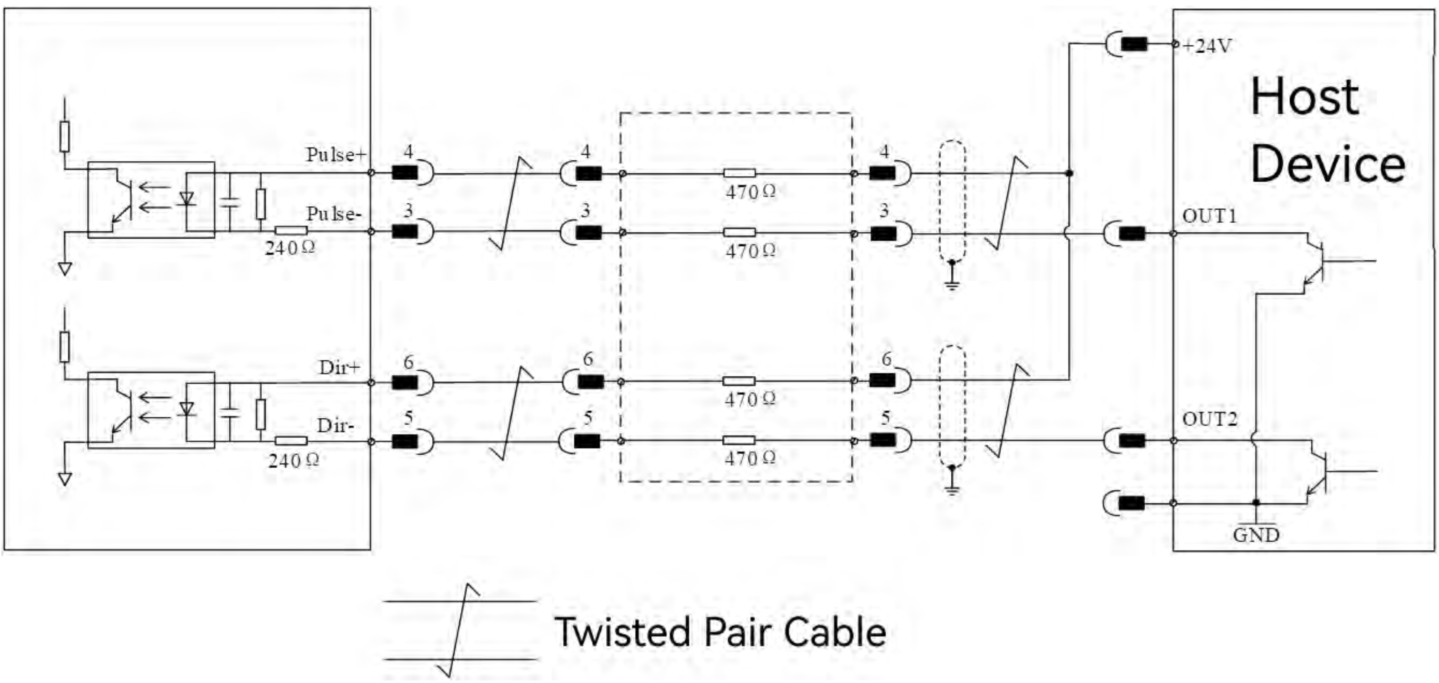


Figure 6-14 Open collector pulse command input terminal wiring diagram

(4) **Digital output DO terminal (as shown in Figure 6-15):**

The permissible maximum voltage and current capacity of the optical

- Voltage: DC30V (Max.)
- Current: DC50mA (Max.)

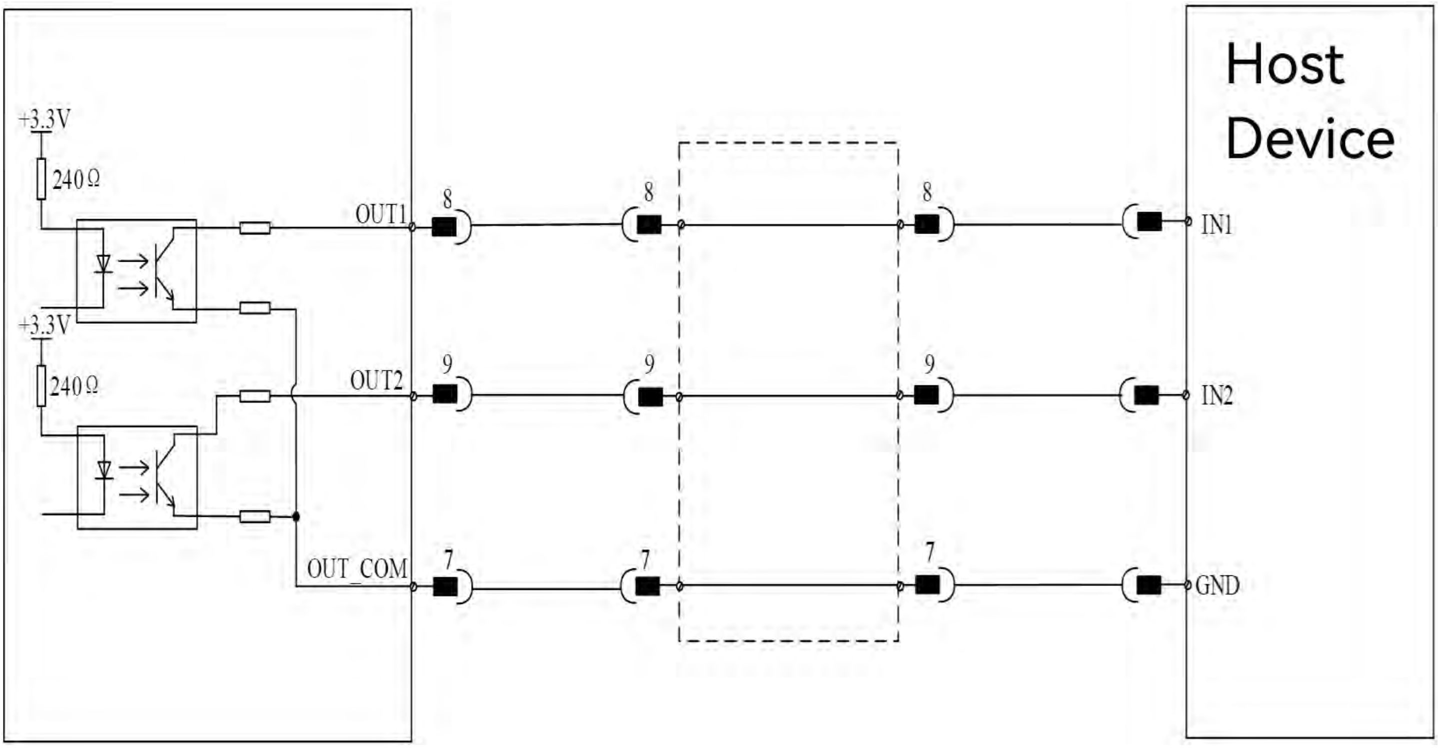


Figure 6-15 Digital output DO terminal wiring diagram

Chapter 7 Brake Instruction

7.1 Instruction and Caution

(1) The Brake does not need to be powered separately. Connect power to the DC power interface of eRob and the brake will be powered. For the eRob power supply voltage, please refer to Chapter 3.
(2) eRob brake can be used as a static holding brake.
(3) eRob brake can withstand dynamic brake impact under the operating condition of low load (<10% max. torque) and low rotational speed (<10% max. rotational speed), but frequent use as dynamic brake should be avoided.
(4) Failure, accident, and emergency stop triggered under the condition of high rotational speed and heavy load will cause the brake to be closed and cause permanent damage to motion components. Avoid running eRob under high rotational speed and heavy load conditions during application development or debugging.
(5) There is a risk that the brake will not work properly if the eRob is exposed to a strong magnetic environment. Therefore, magnetic shielding measures should be taken for eRob.
(6) When it is necessary to rotate the eRob in rare emergency situations (for example, the power is failure or do not want to use the power supply), the eRob can be forced to rotate by external force. The torque required for each model is shown in Table 7-1.
(7) When the eRob is powered normally, enabling it will release the brake, and disabling it will engage the brake. The time of activating the brake is about 150ms. It is recommended that the minimum control interval from enabling the brake to disabling the brake is 300ms. After enabling, please wait at least 500ms before sending any motion command, Please refer to *Section 5.1* of the *eRob CANopen and EtherCAT User Manual* for more detail.

Warning: Rotating rotary actuators by eternal force can be only used in emergency and it may damage the rotary actuators.

Table 7-1 Torque Value of External Force Required for Rotation of eRob (Nm)

Gear Ratio \ Model	eRob70F	eRob70	eRob80	eRob90	eRob110	eRob142	eRob170
50	35	35	65	125	125	200	300
80	56	56	104	200	200	320	480
100	70	70	130	250	250	400	600
120	-	84	156	300	300	480	720
160	-	-	-	-	400	640	960

7.2 Brake Lifespan

7.2.1 Brake Opening and Closing Times

The brakes used in each module have been sampled for more than 100,000 times of suction test, and all performance parameters are normal after the suction life test is over.

7.2.2 The Amount of Forcible Drags While Brake Engaged

The brakes can withstand occasional forced dragging. Before leaving the factory, each brake will undergo more than 1,000 cycles of forced dragging tests when it is closed, and all performance parameters are normal.

However, the braking torque of the brake is greater than the rated torque of the gear (after the gear ratio is converted), and the reducer may be damaged before the brake when forced to drag. For the life of the harmonic gear, please refer to Chapter 23. The braking torque of each actuator module is as follows Table 7-2.

Table 7-2 Braking torque value of each eRob models (Nm)

Model	eRob70F	eRob70	eRob80	eRob90	eRob110	eRob142	eRob170
Braking Torque (Nm)	0.7 < T < 2		1 < T < 2.5	2.5 < T < 4		4 < T < 8	6 < T < 10

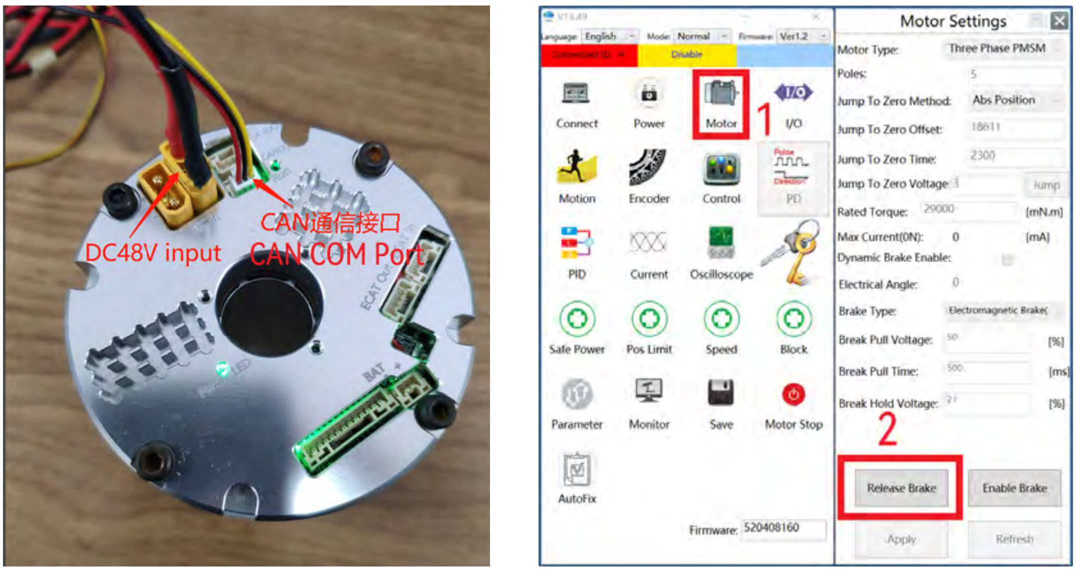
7.3 Method for Forcibly Releasing the Brake (Non-Enabled State)

When the eRob power supply is functioning properly, and there is a need to manually rotate the joint while the motor is not enabled, you can follow the procedure in this section to release the brake individually and rotate the joint with a smaller external force.

Note: Ensure that the machine is stopped and the motor is not enabled before performing the brake release operation. After releasing the brake, the braking force is disengaged, and there is no braking torque. If there is a load gravity torque at the output end of the joint, it will not be able to maintain the position lock state. Please make sure to support the load or unload part of the load before releasing the brake to prevent it from falling.

7.3.1 PC Software Operation

Step 1: As shown in Figure 7-1a, install a computer with PC software eTunner, connect eRob CAN communication interface through USB CAN Debugger, and then supply the eRob with proper power, as shown in Figure 7-1a.



(a) CAN wiring (b) Connect PC and release brake

Figure 7-1 Wiring and Operation Illustration

Step 2: Open eTunner PC software and enter into the PC main interface. Click "Motor", the"Motor Settings" interface will pop up, as shown in Figure 7-1b.

Table 7-3 CAN Control Message of Brake

Function	COB-ID	Message
Release Brake	641	01 4F
	5C1	3E
Enable Brake	641	01 00 00 00 00 00
	5C1	3E

Note: The communication mode between PC and servo communication is CAN communication, so brake can also be operated by sending CAN messages. Please refer to *eRunner User Manual* for message protocol.

Take servo ID=1 as an example, sending messages are as shown in Table 7-3.

7.3.2 EtherCAT Operation

Step 1: As shown in Figure 7-2, install a computer with master software (TwinCAT3) or other master controllers with EtherCAT communication, connect to eRob ECAT communication interface via cables, and then supply proper power for the eRob.

Figure 7-2 EtherCAT wiring

Step 2: Take TwinCAT3 master station as an example, visit "Release Brake" parameter object "4602h (Release brake)" and enter value "1" through SDO, operation methods are shown in Figure 7-3, click "Device 2 (EtherCAT)", click "Drive1(ZeroErr Driver)", click "CoE-Online", pull down to find the object "4602", double left-click the parameter object, the "Set Value Dialog" interface will pop up, enter value "1" in the "Dec", and finally click "OK" , the brake is in release status (free brake), and if value "0" is entered, the brake is in close status(with brake).

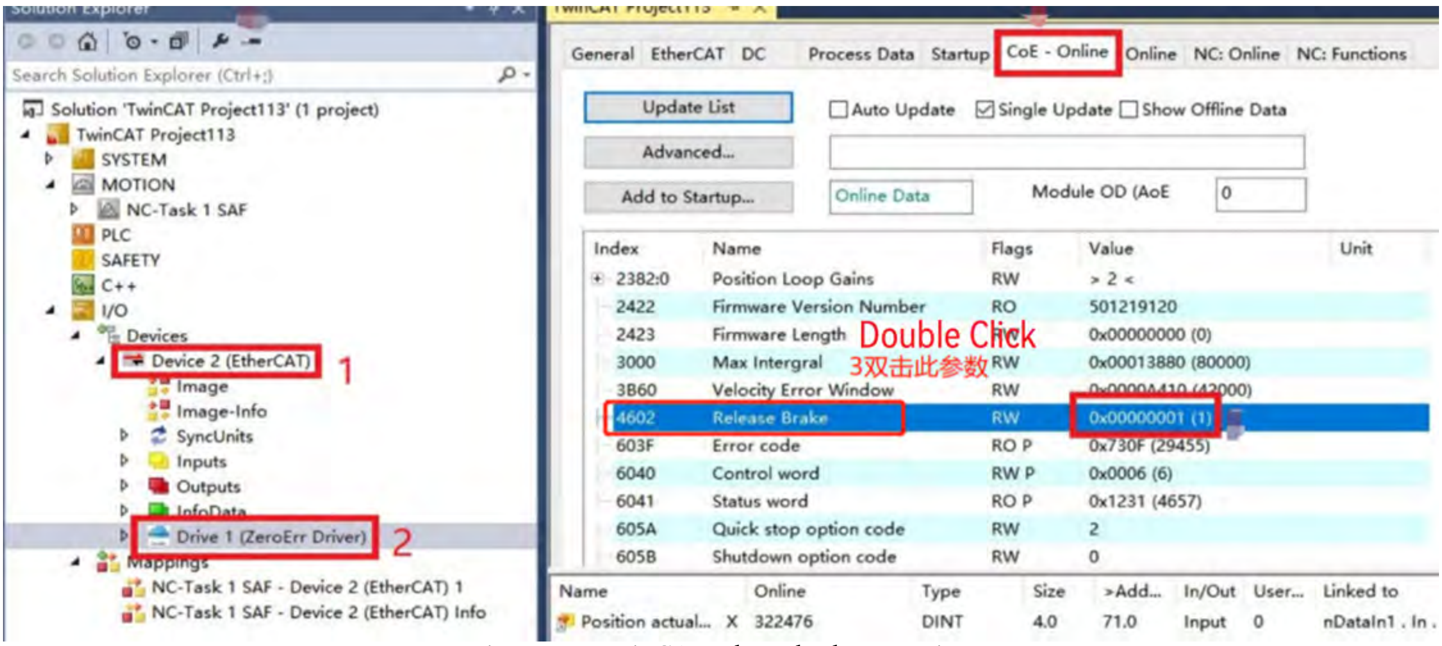


Figure 7-3 TwinCAT release brake operation

7.3.3 CANopen Operation

Step 1: As shown in Figure 7-4, connect the master controller with CANopen communication to the eRob CANopen communication interface the same hardware interface as CAN communication hardware interface, and then supply eRob with proper power.

Figure 7-4 CAN wiring

Step 2: Master controller sends CANopen message to operate brake. Refer to *Chapter 3* of *eRob CANopen and EtherCAT User Manual* for message protocol. Take servo ID=1 as an example, sending messages are as shown in Table 7-4.

Table 7-4 CANopen Control Message of Brake

Function	COB-ID	Message
Release Brake	601	23 02 46 00 01 00 00 00
	581	60 02 46 00 00 00 00 00
Enable Brake	601	23 02 46 00 00 00 00 00
	581	60 02 46 00 00 00 00 00

7.4 Abnormal Brake Judgment

The brake is abnormal when one of the below conditions occurs:

(1) When the eRob rotary actuator with rated load is not powered on, it slips and cannot be maintained.

(2) Powering on an eRob with DC48V separately and the eRob is in a no-load static status. After 6 seconds of power-on and no operation, the output current of the power supply exceeds the normal value (refer to Table 7-5), and then use the host computer to click to release the brake (Please refer to Section 7.3.1 for details of the operation steps) After 3 seconds, the output current of the power supply exceeds the normal value (refer to Table 7-5).

Table 7-5 eRob Module Power Supply Current when Powered on Separately

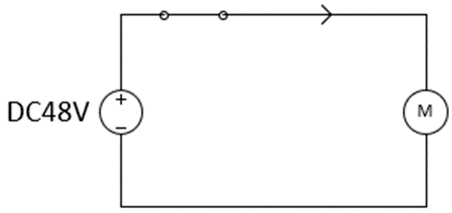
Model	Power Current After 6 Seconds of Power-On and No Operation (mA)	Power Current After 3 Seconds of Releasing the Brake (mA)
eRob70	35~60	70~120
eRob80	35~60	90~120
eRob90	35~60	175~210
eRob110	35~60	175~210
eRob142	35~60	150~180
eRob170	35~60	150~180

Chapter 8 Kinetic Energy Recovery

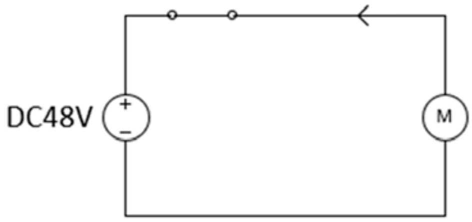
8.1 Analysis of the Cause of Kinetic Energy Recovery

When the rotary actuator is powered by a 48V switching power supply, its simplified circuit loop is equivalent to that shown in Figure 8-1a and Figure 8-1b.

As shown in Figure 8-1a, when it works properly, the power supply supplies power to the load (motor) and outputs electric energy. As shown in Figure 8-1b, when the load is decelerating, the circuit loop is in the process of kinetic energy recovery. That is, the motor works as a generator, the kinetic energy is converted into electrical energy feedback, and the reverse current continuously charges the capacitor at the power supply end to increase the voltage. Since the recovered kinetic energy (power) is proportional to torque × rotational speed ($E_k \propto (T \times n)$), the speed gets faster, the load gets greater, and the recovered kinetic energy (power) gets higher. When the power supply voltage rises to a value which is greater than the value of the permissible maximum bus voltage set by the drive, the servo will report errors and stop when the bus voltage is too high.



(a) During Normal Operation



(b) During Decelerating Operation

Figure 8-1 Circuit Illustrations for Different Operation

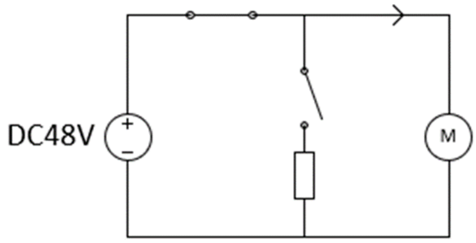
8.2 Solution

There are three processing methods for kinetic energy recovery:

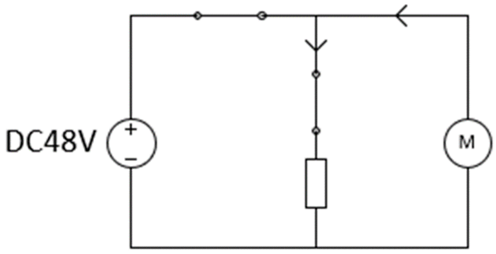
(1) Add leak resistor
(2) Add super capacitor
(3) Add storage battery

8.2.1 Add Bleeder Resistor

When the rotary actuator is powered on with a 48V switching power supply, the working circuit with adding leak resistor can be simplified and equivalent to Figure 8-2a and Figure 8-2b.



(a) Resistor is Disconnected when V_{DC}<51V



(b) Resistor is Connected when V_{DC}>53V

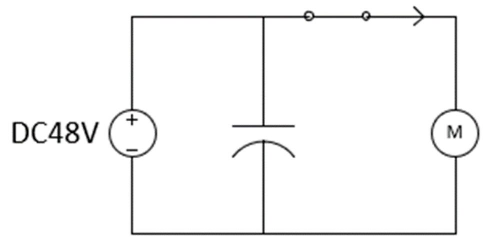
Figure 8-2 Bleeder Resistor Circuit Illustration

The function of adding leak resistor is that when the circuit loop is in kinetic energy recovery processing, the excess energy is dissipated through the resistor, thereby avoiding the power supply voltage spike in the process of the kinetic energy feedback. However, the leak resistor cannot be connected to the circuit for a long time, otherwise more heat will be generated continually, resulting in device damage, circuit failure or unnecessary current consumption. Therefore, it is recommended to design a reliable control logic of connecting leak resistor . For example, when setting the permissible maximum bus voltage setting value of the drive to 55V and the permissible minimum bus voltage setting value to 44V, the control logic of connecting the leak resistor can be designed as that when the resistor is connected during V_{DC}>53V (as shown in Figure 8-2b, the excess power is dissipated through the resistor at this time), and when the resistor is disconnected during V_{DC}<51V (as shown in Figure 8-2a, the power supply only outputs power to the motor at this time).

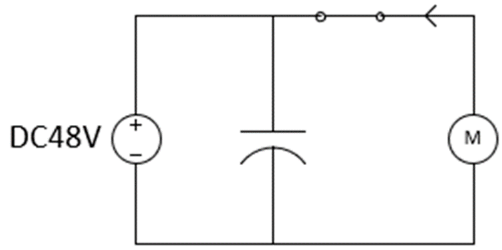
8.2.2 Add Super Capacitor

The super capacitor with large capacitance and fast charging characteristics can be used to absorb and recover kinetic energy. The working circuit can be simplified and equivalent to Figure 8-3a and Figure 8-3b.

As shown in Figure 8-3a, switching power supply and the super capacitor supply power to the load (motor) and output electric energy at the same time when it works normally. As shown in Figure 8-3b, kinetic energy is converted into electric energy feedback and the super capacitor quickly charges to recover part of the kinetic energy when the load is decelerating, thereby avoiding quick supply voltage spike and realizing the effect of the supply voltage fluctuating within the range of safe voltage.



(a) Super Capacitor is Discharging



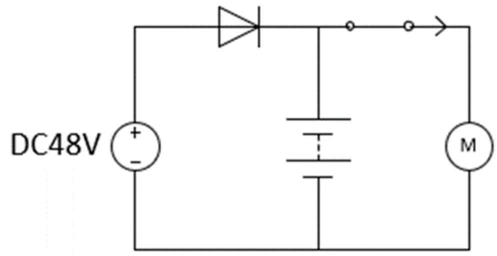
(b) Super Capacitor is Charging

Figure 8-3 Super Capacitor Circuit Illustration

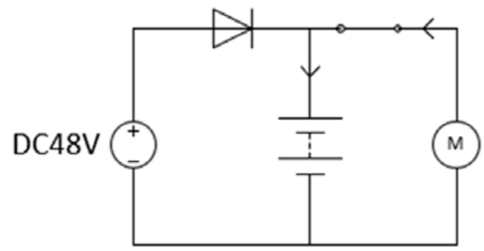
8.2.3 Add Storage Battery

Storage battery is used to charge and absorb kinetic energy recovery, whose circuit can be simplified and equivalent to Figure 8-4a and Figure 8-4b.

Similar to the principle of super capacitors, switching power supply and storage battery can supply power to the load (motor) and output electric energy at the same time (as shown in Figure 8-4a) when it works normally. As shown in Figure 8-4b, the kinetic energy is converted into electric energy feedback, and the kinetic energy is recovered by charging the storage battery when the load is decelerating.



(a) Switching Power Supply add Storage Battery



(b) Storage Battery Charges

Figure 8-4 Storage Battery Circuit Illustration

Chapter 9 Encoder and Position Feedback

9.1 Encoder Resolution and Single-Turn Position Feedback

Rotary actuator is built-in dual absolutes encoders to achieve dual loop position control, including a single-turn absolute encoder for motor with 17-bit resolution and a single-turn absolute encoder for output shaft with 19-bit resolution. (The multi-turn resolution of rotary actuator with multi-turn function is 16 bit)

Encoder resolution refers to the position number outputted by one rotation of the rotary actuator. For example, the encoder resolution of the output shaft is 19 bit, that is, the position number outputted by one rotation of the shaft is 2^{19}; The single-turn position feedback of 19-bit resolution is 0~524287, which will jump from 0 to 524287 if the actuator moves in the opposite direction at the 0 position. On the contrary, the position feedback will jump from 524287 to 0 if the actuator moves in the positive direction at the 524287 position.

Calculation Example

Calculate the encoder position corresponding to the single-turn angle(19 bit), if the position angle is 20°:

$$P_{encoder} = \frac{\theta}{360} \times 524288 \qquad (9.1)$$

$$P_{encoder} = \frac{20°}{360} \times 524288$$

$$P_{encoder} = 29127$$

Symbol	Definition	Unit
$P_{encoder}$	Encoder position.	counts
θ	Position angle.	degree

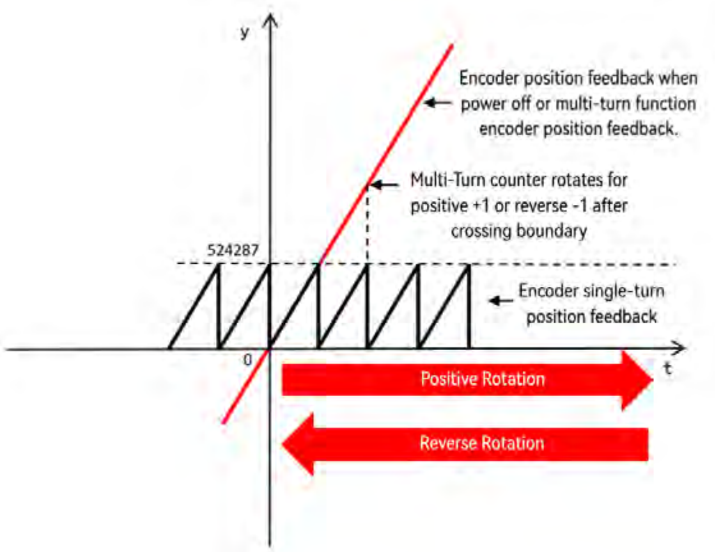


Figure 9-1 Position Feedback

9.2 Position Feedback of Rotary Actuator

When the encoder single-turn position jumps at the boundary position, the rotary actuator will count the multi-turn turns. As shown in Figure 9-1, the encoder boundary positions with 19-bit resolution are 0 and 524287; The position feedback will jump from 524287 to 0 if it rotates in the positive direction, and the multi-turn turns +1; On the contrary, the position feedback will jump from 0 to 524287 if it rotates in the opposite direction, the multi-turn turns -1.
The current position calculation formula:

$$P_c = N \times resolution + P_s \tag{9.2}$$

Symbol	Definition	Unit
P_c	Current encoder position	count
N	The amount of rotation	N/A
P_s	Single-turn encoder position	count

Rotary Actuator Position Feedback Acquisition:

(1) Read object index 6064h (actual position, unit: pulse) via EtherCAT or CANopen bus. According to the above position calculation formula, it can be seen that:

$$6064h\ value = N \times resolution + P_s \tag{9.3}$$

Symbol	Definition	Unit
N	The amount of rotation	N/A
P_s	Single-turn encoder position	count

(2) In eTunner, read the position feedback of rotary actuator via the "Position" displayed in the "Monitor" interface; the singleturn position feedback corresponds to the "Motor Encoder" and "Load Encoder" displayed in the "Encoder" interface, as shown in Figure 9-2a and Figure 9-2b.

(a) Encoder (b) Position

Figure 9-2 The eTunner Reads the Position Feedback

9.3 Position and Cautions of Rotary Actuator with Single-Turn Function

Adjust the output shaft position of reducer before installation of rotary actuator equipped with singleturn encoder to ensure no overshoot of output singleturn encoder boundary position (0 and 524287) within the operation range. Otherwise, the multi-turn count will be lost after powering off and restarting to operate, then the actuator position feedback will become the output encoder singleturn position.

9.4 Position and Cautions of Rotary Actuator with Multi-Turn Function

The rotary actuators with multi-turn encoder do not need to adjust the output shaft position of reducer to match the mechanical zero position before installation. Noted that the 3.6V multi-turn power supply battery needs to be installed before using the multi-turn rotary actuator, and then click "Reset Load Encoder" in "Encoder" interface to clear the multi-turn battery errors (The operation method is shown in Figure 9-3). If you intend to use the multi-turn eRob module as a single-turn model (i.e., not connected to the 3.6V multi-turn power supply battery), please be aware that the multi-turn module will generate an error upon each power-off and restart. To resolve this issue, users can clear the error by writing 0x80 to the control word (address 6040h) and then enable the eRob module. During operation, please ensure that the device operates within the single-turn range and does not surpass the boundaries of the output-side single-turn encoder (0 and 524287). Failure to comply may result in the loss of multi-turn counting after a power-off restart, causing the position feedback to revert to the single-turn encoder's position at the output side.

NOTE:

(1) The multi-turn eRob should be equipped with a battery during the first use, then click "Reset Load Encoder" to clear multi-turn error reports.

(2) If encoder battery alarms occur during operation, click "Reset Load Encoder" to clear multi-turn error reports after troubleshooting.

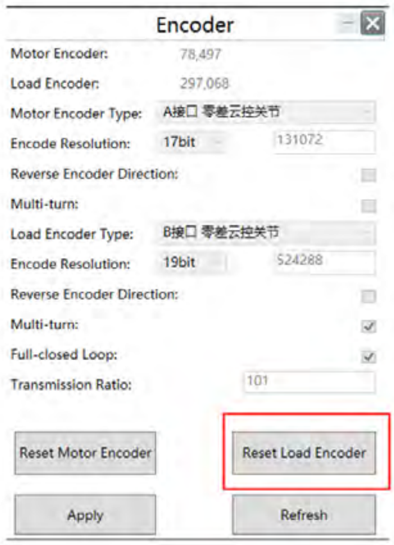


Figure 9-3 Load Encoder Reset Operation

9.5 Instruction of Zero Position Calibration Function

9.5.1 Zero Position Calibration Function of Single-Turn Rotary Actuator

Due to the installation method, when the singleturn rotary actuator operates with the zero position defined by the user and reaches the maximum motion range, the position feedback value may exceed the boundary value (0 or 524287). The user can set the zero position to 262144 by using zero position calibration function thereby ensuring the maximum motion range the single-turn eRob rotary actuator is −175°~175° and the position feedback value is within the singleturn position range as shown in Figure 9-4.

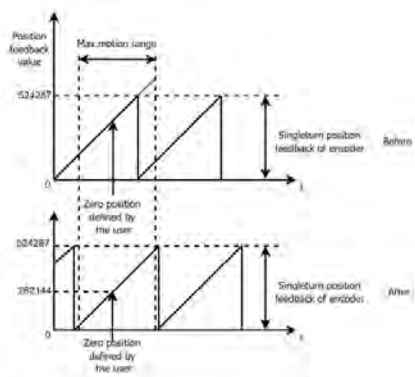


Figure 9-4 Comparison Figures of Before/After Zero Position Calibration of Single-Turn eRob

Connect eTunner, make the eRob move to the zero position defined by the user. Refer to Chapter 14 for detailed steps. The flow diagram for zero position calibration of singleturn eRob is as shown in Figure 9-5.

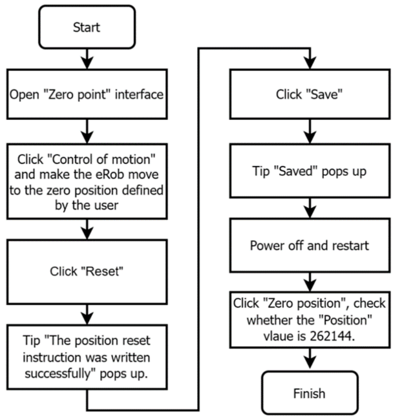


Figure 9-5 Flow Diagram of Zero Position Calibration of Single-Turn eRob

The steps for using zero position calibration function of singleturn eRob are as shown in Figure 9-6. When the save command is completed, power off and restart. Open the "Zero point" interface, when current "Position" value is 262144, the setting is successful.

NOTE: Mechanical zero calibration function of singleturn eRob in the latest eTunner should match firmware of X3071220X or above.

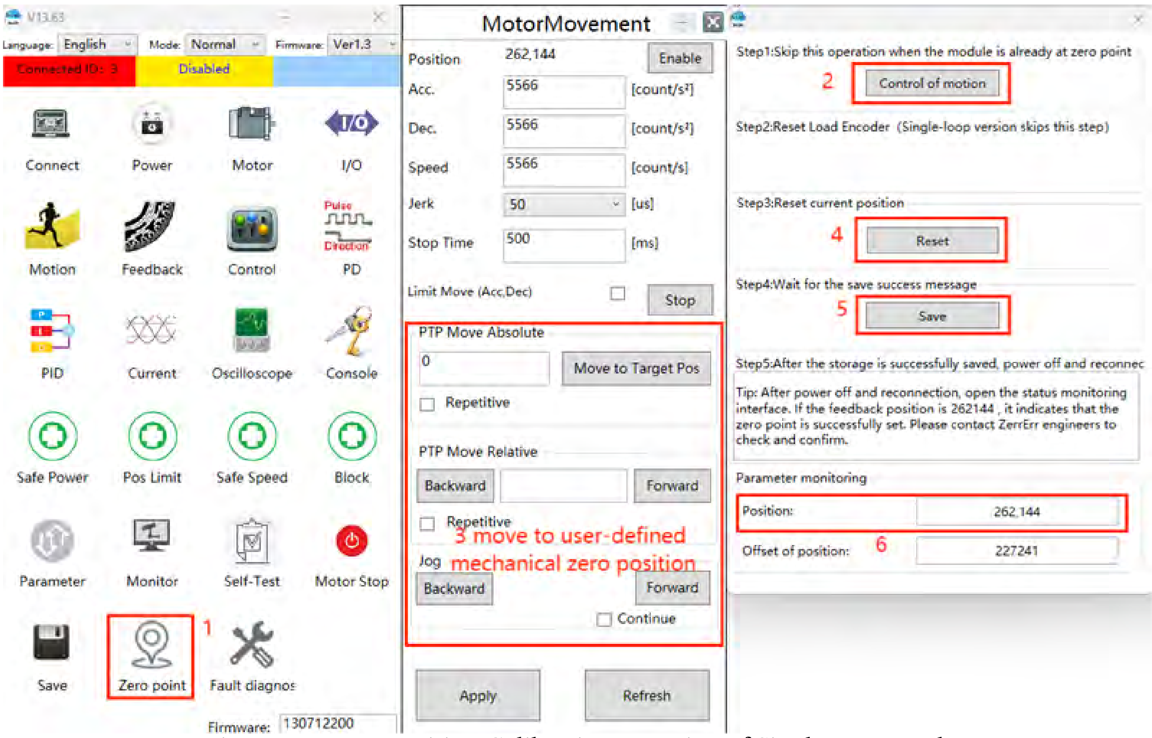


Figure 9-6 Zero Position Calibration Function of Single-Turn eRob

9.5.2 Zero Position Calibration Function of Multi-Turn Rotary Actuator

The multi-turn eRob user can use zero position calibration function to set the zero position (0~524287) flexibly according to the actual situation. The default zero position value is 262144, as shown in Figure 9-7.

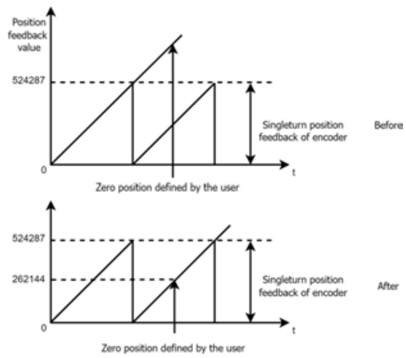
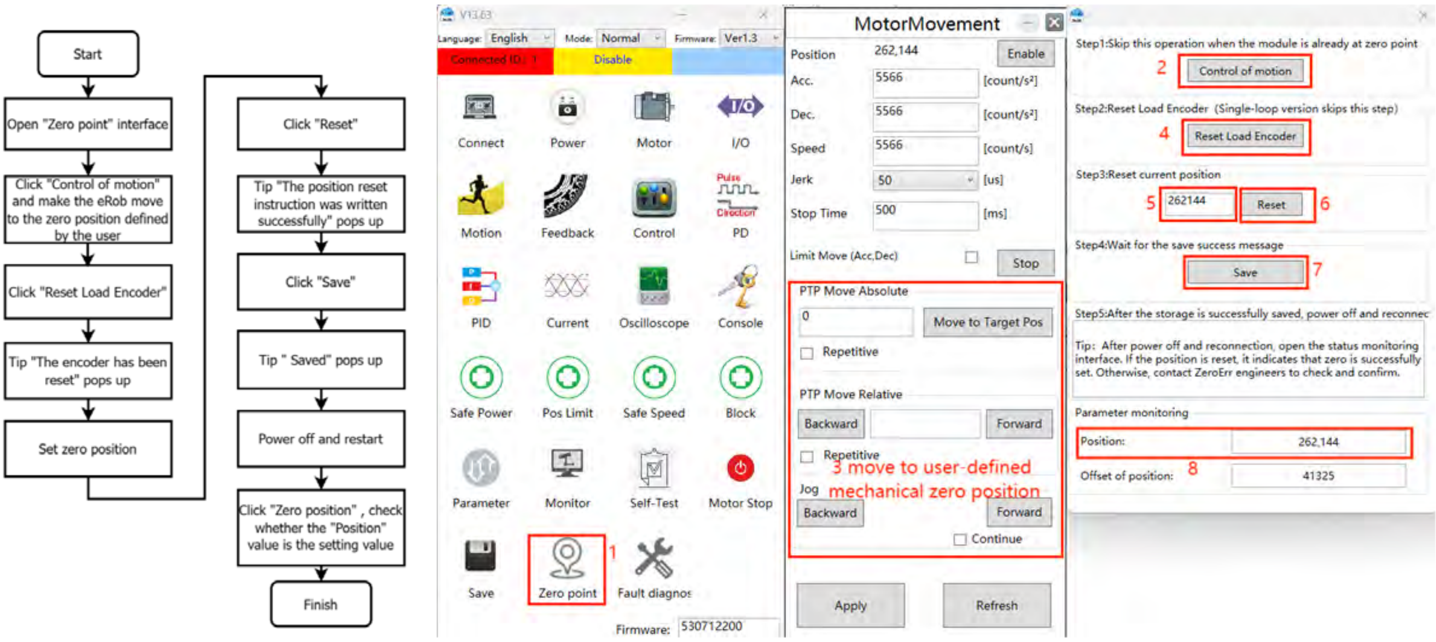


Figure 9-7 Comparison Figures of Before/After Zero Position Calibration of Multi-Turn eRob

Connect eTunner and make the eRob move to the zero position set by the user. Refer to Chapter 14 for detailed steps.The flow diagram for zero position calibration of multi-turn eRob is as shown in Figure 9-8a.

The steps for using zero position calibration function of multi-turn eRob are as shown in Figure 9-8b. When the save command is completed, power off and restart. Open the "Zero point" interface, when the setting value is displayed in current "Position" , the setting is successful.

NOTE: Mechanical zero calibration function of multi-turn eRob in the latest eTunner should match firmware of X3071220X or above.



(a) Flow Diagram for Zero Position Calibration of Multi-Turn eRob

(b) Zero Position Calibration Function of Multiturn eRob

Figure 9-8 Zero Position Calibration

9.6 Instruction of Position Protection Function

The rotary actuators are configured with the default parameters of position protection as shown in Figure 9-9. The user can use the “Pos Limit” function to limit the actual motion range of the eRob, preventing the eRob from operating beyond the actual permissible maximum motion range which may cause device collision or the wire connection damage between rotary actuators.

For example: the operation range is ±15°, the encoder position corresponding to the mechanical zero position (0°) is 262144, that is ,

Lower limit set value: 262144 - 21846 = 240298

Upper limit set value: 262144 + 21846 = 283990

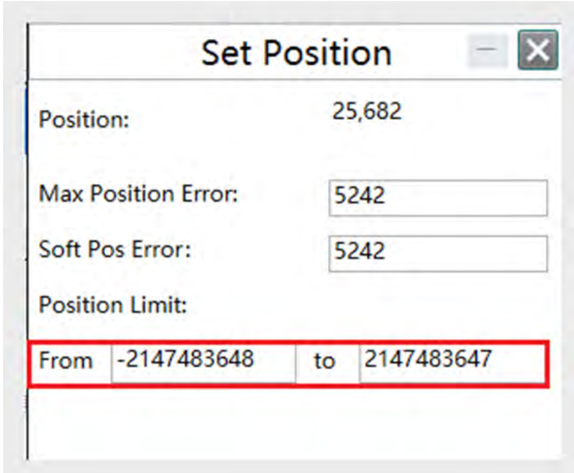


Figure 9-9 The Default Parameter of Position Protection

Setting method via eTunner is as shown in Figure 9-10. Open the “Safe Position” interface, set “Position Limit” from (lower limit set value) to (upper limit set value); then click “Apply” and “Save”.

Position protection parameters can also be set via EtherCAT or CANopen bus. The object index of position limit protection parameter is “$607D_h$”, enter lower limit set value “$607D_h$: 01_h”, enter upper limit set value “$607D_h$: 02_h”, and then enter save command “65766173_h”. (enter other value is invalid and the read-back value is “0”; when the read-back value is “1”, it means the save command is in execution; the read-back value is “2”, it means the save command is completed).

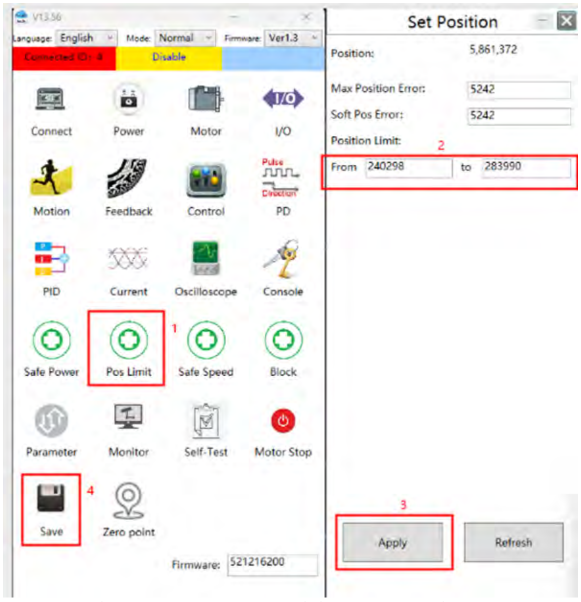


Figure 9-10 Set Position Protection

Table 9-1 The effects of position limitations in different operating modes

6060_h Set Value	Operation Mode	Position Limit Effect
0x01	Profile Position Mode	If the target position ($607A_h$) sent by the master station controller exceeds the position limit, the driver will use the limit position as the internal target position for motion trajectory planning. It will decelerate to 0 at the profile deceleration rate (6084_h) before reaching the limit and stop at the limit position, continuously outputting position-holding torque. At this time, the driver will only execute target position ($607A_h$) commands within the position limit range.
0x04	Profile Torque Mode	When the actual position (6064_h) reaches or exceeds the position limit, the driver immediately shuts off the power to the motor, but the brake does not engage. At this point, both the motor actual current (6078_h) and the torque actual value (6077_h) become zero, and no position holding torque is outputted. It is important to note that the eRob module remains enabled during this time, and it may continue to move due to inertia and gravity acting on the load. In this situation, the driver will only execute target torque (6071_h) commands that move the eRob module in the direction within the position limit range.
0x08	Cyclic Synchronous Position Mode	When the position actual value (6064_h) reaches or exceeds the position limit, the driver will rapidly decelerate and come to a stop, return to the limit position and continuously outputting position holding torque. During this time, the driver will only execute target position ($607A_h$) commands within the range of the position limit.
0x0A	Cyclic Synchronous Torque Mode	When the actual position (6064_h) reaches or exceeds the position limit, the driver will immediately cut off the power to the motor, but the brake will not engage. As a result, both the motor actual current (6078_h) and the torque actual value (6077_h) will be set to zero, and no position holding torque will be outputted. It is important to note that during this time, the joint remains in the enabled state, and it may continue to move due to inertia and gravity acting on the load. In such cases, the driver will only execute target torque (6071_h) commands that move the joint in the direction towards the position limit range.

Chapter 10 Multi-Turn Power Supply Battery Instruction

10.1 Function of Battery

When the rotary actuator with multi-turn is powered off, it provides working power for the load multi-turn encoder to count the multi-turn position value and avoid rotary actuators and other devices losing zero position.

10.2 Cautions on Battery Usage

Cautions on multi-turn power supply battery usage:

(1) Do not change the wiring sequence of the original battery, and do not vigorously pull the battery wires;
(2) Do not use wires or other conductive media to directly connect to the positive and negative terminals of the battery;
(3) The wiring terminal of the original battery is only suitable for the multi-turn power supply battery interface of rotary actuators in our company. Pay attention to the correct connecting direction. Fix the battery to prevent the terminals from being pulled and shaken after insertion;
(4) Reset the load encoder after the first installation of the battery or replacement of a new battery (the reset operation method is shown in Section 9.4). When replacing the battery, do not pull out the connector terminal directly. Pull the terminal front end snaps to release the buckle, and then gently pull it out.

Note: More details for safety cautions, please refer to Appendix A.

10.3 Power Consumption of Multi-Turn Encoder

According to the test (ambient temperature: 25°C), on the condition that a single multi-turn battery (initial voltage: 3.67V) supplies power to a rotary actuator (with multi-turn function), the current consumption is $4\mu A$ when the rotary actuator with 48V input power is not powered on; and the current consumption is $0\mu A$ when the rotary actuator with 48V input power is powered on. Figure 10-1 shows the discharge characteristic curve of multi-turn battery at 25°C. According to the calculation of 1mA discharge curve, a battery can supply 250 rotary actuators, and the battery requires discharging continuously for at least 1000h when voltage drops to 3.2V. According to the calculation of $25\mu A$ discharge curve, a battery can supply power for 6 actuators; and the battery requires discharging continuously for at least 50,000h (about 5.7 years) when voltage drops to 3.2V. It can be estimated that a battery powers a rotary actuator ($4\mu A$ discharge) when voltage drops to 3.2V, it requires discharging continuously for at least 300,000h (about 34.2 years).

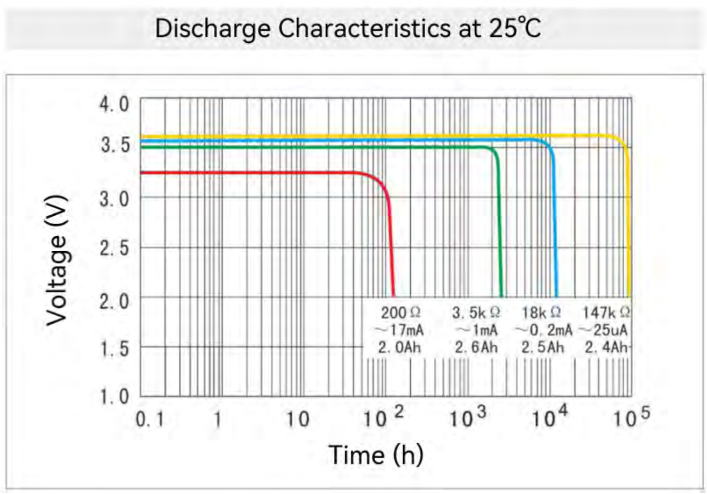


Figure 10-1 Discharge Characteristics of multi-turn battery at 25°C

10.4 Battery Related Errors Handling

Refer to Table 10-1 for the battery related errors handling.

Table 10-1 Query Table for Battery Related Errors Handling

Error Codes Reported by 0x603F	Messages	Direct Causes	Possible Causes	Troubleshooting
0x730D	Battery Warning Error[*1]	Load encoder multi-turn battery keeps holding voltage lower than warning voltage 3.15V.	1. The battery is normally consumed to low voltage warning. 2. Use wrong battery. 3. Abnormal battery circuit leads to fast consumption.	1. Replace batteries with new ones and perform correct reset operation[*2]. 2. Replace batteries with correct ones and perform correct reset operation. 3. Check cables, replace batteries with new ones and perform correct reset operation.
0x730F	Battery Voltage is Too Low	Load encoder multi-turn battery keeps holding voltage lower than working voltage 3.05V.	1. After the battery is consumed to trigger the low voltage warning, continue consuming to trigger the voltage warning error. 2. Use a wrong battery. 3. The battery circuit is in poor contact. 4. The battery is not connected.	1. Replace batteries with correct ones and perform the correct reset operation. 2. Replace the correct batteries and perform the correct reset operation. 3. Check cables, replace batteries with new ones and perform correct reset operation. 4. Install the batteries and perform a correct reset operation.
0x7314	Power-Off Status Detected	When load encoder multi-turn battery keeps holding voltage higher than the working voltage 3.05V. Under this condition, load encoder has been replaced the battery.	1. Load encoder has been replaced the battery. 2. Load encoder battery wiring is too loose.	1. Perform correct reset operation. 2. Check load encoder wiring and perform correct reset operation.
0x7374	Multi-Turn Position Error			

***1** Multi-turn data will not be lost when the rotary actuator reports a battery warning error.

***2** The correct reset operation is shown in Figure 9-4. Connect to eTunner, open “Encoder” interface and click “Reset Load Encoder”.

Chapter 11 Multi-Turn Encoder Battery Under-Voltage Warning

Status instruction:

(1) Battery status: "0" indicates the battery power supply voltage of the encoder is lower than 3.05V, "1" indicates the battery voltage of the encoder is normally powered, and "×" means arbitrary state.

(2) 48V status: "0" indicates the rotary actuator is not supplied power with 48V, and "1" indicates the rotary actuator is supplied power with 48V.

11.1 The Status when 48V Power Supply Switch from OFF to ON (0 -> 1)

Case 1: Description: In the previous state, there were no reported errors, and the module started up without any issues. During the current startup, there are no error reports from CAN and EtherCAT, indicating a smooth and error-free initialization process.

	Previous Status	Startup
Battery	1	1
48V	1	0 → 1
Status	OK	OK

Case 2: Description: Under the condition that the previous status was in arbitrary status, when the actuator was started, the battery was dead. The CAN and EtherCAT are started this time with reporting multi-turn power failure alarm error, the multi-turn is lost, but the servo drive can be enabled.

	Previous Status	Startup
Battery	×	1
48V	1	0 → 1
Status	×	NG

Case 3: Description: Under the condition that there were no error reports in previous status, pull out the battery with 8 seconds (the capacitor discharge takes time, which can be quickly discharged by both terminals of short-circuiting) and then insert the battery back before the actuator starts. CAN and EtherCAT are started with reporting "multi-turn power-off alarm" this time, then the multi-turn is lost, but the servo drive can be enabled.

	Previous Status	Before Startup	Startup
Battery	1	1 → 0 → 1	1
48V	0	0	0 → 1
Status	OK	OK	NG

11.2 The Status When the 48V Power Supply Has Been Activated (1)

Case 1: Description: If the current status is normal, no error will be reported under arbitrary status when operating. CAN and EtherCAT will not report errors, the multi-turn value will not be lost.

	Current Status	Startup Status
Battery	1	×
48V	1	1
Status	OK	OK

11.3 The Status When 48V Power Supply from Startup to Close to Startup (1 -> 0 -> 1)

Case 1: Description: If the current status is normal at startup, and the battery voltage drops below 3.05V under startup condition, CAN and EtherCAT will not report any errors, and the multi-turn value will not be lost. When the rotary actuator restarts, CAN and EtherCAT will not report "multi-turn power-off alarm", and the multi-turn will be lost, but the servo drive can be enabled.

	Current Status	Startup Status	Restart the Rotary Actuator
Battery	1	$1 \to 0$	0
48V	1	1	$1 \to 0 \to 1$
Status	OK	OK	NG

Case 2: Description: If the current status is normal at startup, and the battery voltage drops below 3.05V under startup condition, CAN and EtherCAT will not report any errors, and the multi-turn value will not be lost. When the rotary actuator restarts, CAN and EtherCAT will not report the "multi-turn battery with low voltage" error, and the multi-turn is lost, but the servo drive can be enabled.

	Current Status	Startup Status	Restart the Rotary Actuator
Battery	1	$1 \to 0 \to 1$	1
48V	1	1	$1 \to 0 \to 1$
Status	OK	OK	NG

Chapter 12 Strain Wave Gear Analysis

12.1 Gear Ratio Analysis

12.1.1 Output Rotational Speed Calculation

The rotary actuator output side is outputted after the motor passed through the gear, and the conversion from motor speed(n_m) to the output speed(n_o) needs to be calculated by the gear ratio(m_G). The formula is:

$$n_o = \frac{n_m}{(m_G + 1)} \tag{12.1}$$

Symbol	Definition	Unit
n_o	SWG output rotational speed	RPM
n_m	motor / SWG input rotational speed	RPM
m_G	SWG gear ratio*	N/A

* The reason why dividing by $(m_G + 1)$ is related to the gear installation method, that is, the input is wave generator; the output is circular spline; and the fixation of installation is flexspline.

12.1.2 About Speed Setting and Angular Velocity Conversion

There are two encoders in a rotary actuator, encoder for motor (17 bit) and encoder for output shaft (19 bit). The rotary actuator runs with dual loop position control, so the way to set the operating speed is setting the output rotational speed directly. The speed feedback is the rotational speed feedback of the output. As shown in Figure 12-1.

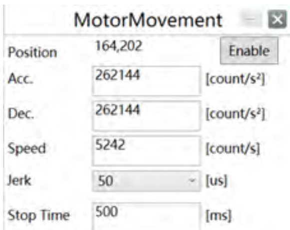


Figure 12-1 Speed Setting Interface

(1) The conversion formula between eRob rotational speed (n_c) (unit: count/s) and rotational speed (n_{RPM}) (unit: RPM): (524288 is the resolution of 19-bit encoder in the output shaft)

$$n_{RPM} = \frac{n_c}{524288} \times 60 \tag{12.2}$$

Symbol	Definition	Unit
n_{RPM}	output rotational speed	RPM
n_c	output rotational speed	counts/s

(2) The conversion formula between eRob rotational speed (n_c) (unit: count/s) and angular velocity (ω_θ) (unit: °/s):

$$\omega_\theta = \frac{n_c}{524288} \times 360 \tag{12.3}$$

Symbol	Definition	Unit
ω_θ	output angular velocity	$°/s$
n_c	output rotational speed	counts/s

(3) The conversion formula between eRob rotational speed (n_c) (unit: count/s) and angular velocity (ω_{rad}) (unit: rad/s):

$$\omega_{rad} = \frac{n_c}{524288} \times 2\pi \tag{12.4}$$

Symbol	Definition	Unit
ω_{rad}	output angular velocity	rad/s
n_c	output rotational speed	counts/s

(4) Set angular acceleration/deceleration (α): It is recommended to set the acceleration/deceleration time (t_α) ≥0.3s. The acceleration time is the required time for the eRob to reach the target speed from 0. The deceleration time is the required time for the eRob to reach 0 from the target speed(ω_t). The relationship between ω_t and t_α:

$$\alpha = \frac{\omega_t}{t_\alpha} \tag{12.5}$$

Symbol	Definition	Unit
α	angular acceleration/deceleration	$°/s^2$, rad/s^2
ω_t	target speed (angular velocity)	$°/s$, rad/s
t_α	acceleration/deceleration time	second

(5) The max. rotational speed for each model of eRob is as shown in Table 12-1.

Table 12-1 Max. Rotational Speed of Each Model of eRob

Model	Gear Ratio m_G	Max. Output Rotational Speed n_c (counts/s)	Max. Output Rotational Speed n_{RPM} (RPM)	Max. Output Angular Velocity ω_θ (°/s)	Recommended Acc. / Dec. Time t_α (seconds)
eRob70F	50	524288	60	360	≥0.3
	80	327680	37.5	225	≥0.3
	100	262144	30	180	≥0.3
eRob70H	50	524288	60	360	≥0.3
	80	327680	37.5	225	≥0.3
	100	262144	30	180	≥0.3
	120	218453	25	150	≥0.3
eRob80H	50	524288	60	360	≥0.3
	80	327680	37.5	225	≥0.3
	100	262144	30	180	≥0.3
	120	218453	25	150	≥0.3
eRob90H	50	524288	60	360	≥0.3
	80	327680	37.5	225	≥0.3
	100	262144	30	180	≥0.3
	120	218453	25	150	≥0.3
eRob110H	50	524288	60	360	≥0.3
	80	327680	37.5	225	≥0.3
	100	262144	30	180	≥0.3
	120	218453	25	150	≥0.3
	160	163840	18.75	112.5	≥0.3
eRob142H	50	349525	40	240	≥0.3
	80	218453	25	150	≥0.3
	100	174763	20	120	≥0.3
	120	145927	16.7	100.2	≥0.3
	160	109227	12.5	75	≥0.3
eRob170H	50	349525	40	240	≥0.3
	80	218453	25	150	≥0.3
	100	174763	20	120	≥0.3
	120	145927	16.7	100.2	≥0.3
	160	109227	12.5	75	≥0.3

Chapter 13 PC Connection and Debugging

Step 1: Wiring the USB CAN Debugger, do not connect PE, connect L to CAN_L, connect G to GND, connect H to CAN_H, switch 1 or 2 to ON in R DIP switch, and do not move the other one, then connect the debugger to the rotary actuator. As shown in Figure 13-1.

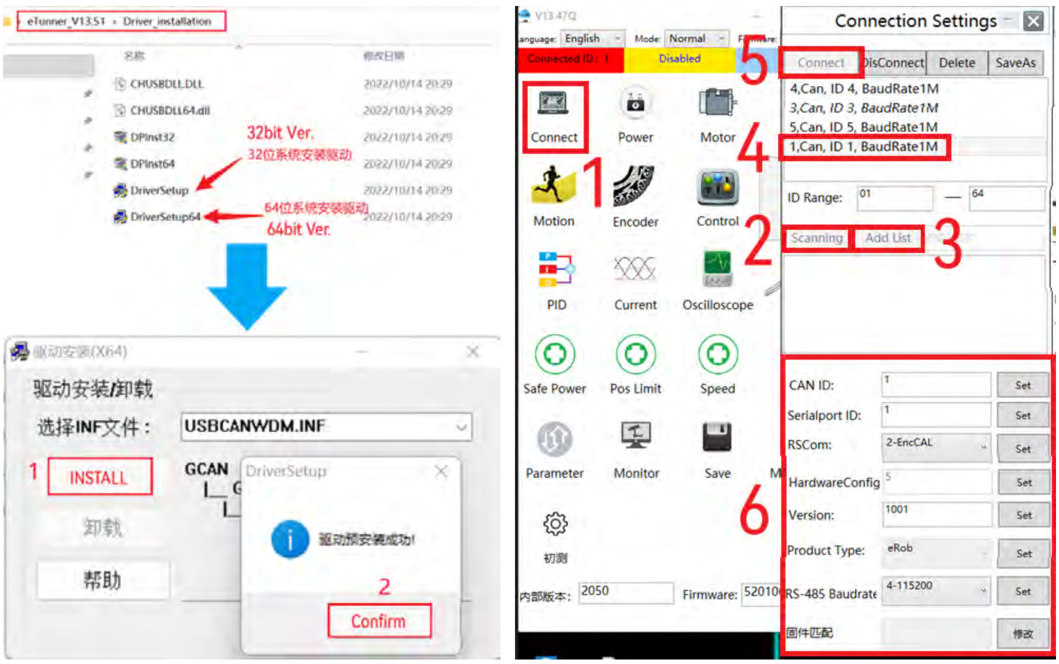
Figure 13-1 CAN Debugger Interface

Step 2: Install "USBCANWDM.INF". Download the latest eTunner software in ZeroErr official website, unzip the compressed package and open eTunner_ V13.51 \ Driver _installation.
Then double click the DriveSetup program to install the drive (as shown in Figure 13-2a).

Step 3: Open the software and follow the steps below to connect the actuator as shown in Figure 13-2b.

(1) Click "Connect" to open "Connect Settings"interface.
(2) Click "Scanning" to test, wait for Scanning finish.
(3) Click "Add List".
(4) Click the device has been added.
(5) Click "Connect".
(6) Connect successfully and display CAN ID parameters etc.

Note: The equipment has been added, just need to repeat step 4, 5, and 6 in Step3.



(a) Debugger Driver Installation (b) Debugger Driver Installation
Figure 13-2 PC Connection and Debugging

Chapter 14 Trial Run for Rotary Actuator

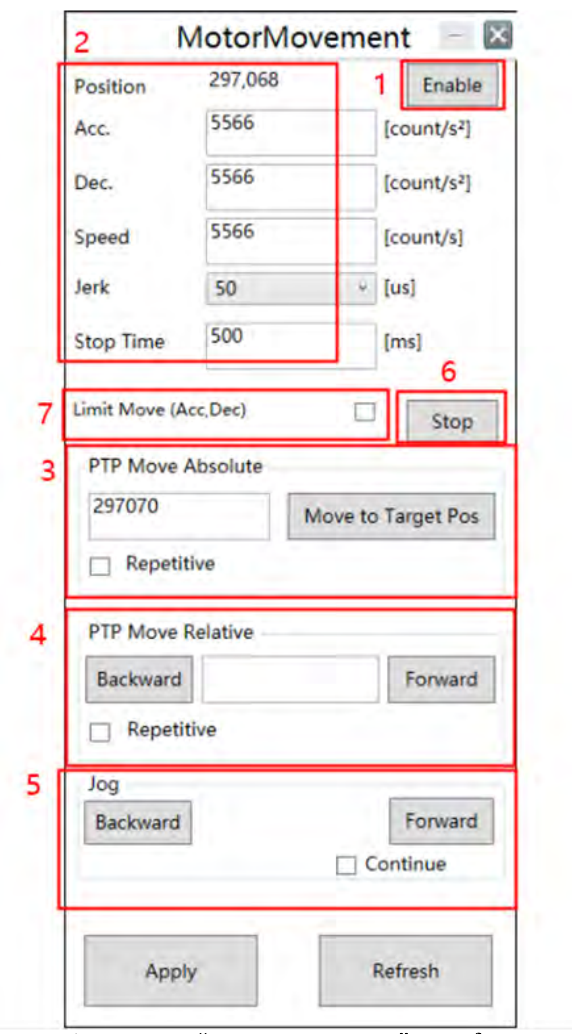


Figure 14-1 "MotorMovement" Interface

Interface Introduction:

(1) Click "Enable". The motor is enabled, and the brake is released automatically.

(2) The current "Position" value is displayed and set the "Speed" which takes the encoder resolution as the unit. The "Jerk" is the time for the eRob achieves the set acceleration from 0 (The larger the setting value, the closer to the S-type speed curve; the smaller the setting value, the closer to the T-type speed). The default setting is 50us. The "Stop Time" is the dwell time when setting point-to-point reciprocating motion.

(3) Set a target position and make the motor move to there. Tick "Repetitive" and make the motor move back and forth between the current position and target position.

(4) Set the relative motion displacement value, make the motor move forward or backward by a set displacement value. Tick "Repetitive" and make the motor operate the reciprocating motion at the current position with the set displacement.

(5) Do not tick "Continuous" and click "Forward" and "Backward' to make the motor move; click "Continuous", click "Forward" and "Backward" to make the motor to move continuously.

(6) Decelerate with the set "Dec" to stop. Although the motion is stopped, the motor is not disabled and the brake keeps releasing.

(7) Speed limit function: When "Limit Move (Acc, Dec)" is ticked, the rotary actuator motion is limited by the "Acc.", "Dec", "Speed limit" (set in "MotorMovement" interface) and "Max Motor Speed" (set in the "Speed" interface). When "Limit Move (Acc, Dec)" is not ticked, the actuator motion is only limited by the "Max Motor Speed" set in the "Safe Speed" interface.

Steps for No-Load Trial Run of the Motor:

(1) Check the "Speed" does not exceed the permissible maximum speed in "Speed" interface. It is recommended to set a lower speed operation at the beginning.

(2) Click "Enable" before moving and confirm that the brake is released (there will be a "click" sound when the brake is released).

(3) Click "Forward" in the "Repetitive", the motor moves forward, and observe the operation status of the motor.

(4) Click "Stop", the motor will decelerate and stop.
(**Note:** Do not directly click "Motor Stop" on the main interface during operation).

(5) Click "Motor Stop" (as shown in Figure 14-2) in the main interface of the software, the motor is disabled and the brake works. The trial run is finished.

Figure 14-2 "Motor Stop" Button on the Main Interface of the Software

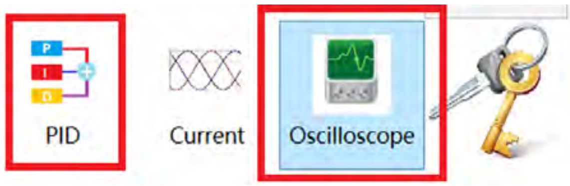
Chapter 15 PID Tuning with Load

After loading, tune the PID of speed loop and position loop. First, open the "Oscilloscope" and "PID" on the main interface of the host computer, and click the icons as shown in Figure 15-1a.

Note:

1. Before performing PID tuning, please ensure that the parameters shown in Figure 15-1b are set correctly. On the control mode interface, set "Operation Mode" to "Position Control" and "Control Source" to "0-Not Used". The settings should be made while the joint is in the enabled state (click the "Motor Stop" button on the main interface to enable the joint). After setting the parameters, click the "Apply" button at the bottom of the interface to take effect immediately; otherwise, the joint will not operate.

2. Before performing PID tuning, it is recommended to adjust the load position to an appropriate location. For example, if the joint is horizontally installed (with the output shaft axis parallel to the ground), the load position should be adjusted to a vertical position as much as possible (i.e., the load force arm direction is perpendicular to the ground). After adjusting the load position, you can proceed with PID tuning.



(a) PID settings and Oscilloscope in Main Interface

(b) Control Mode Interface Parameter Setting

Figure 15-1 Settings Illustration

15.1 Speed Loop Adjustment

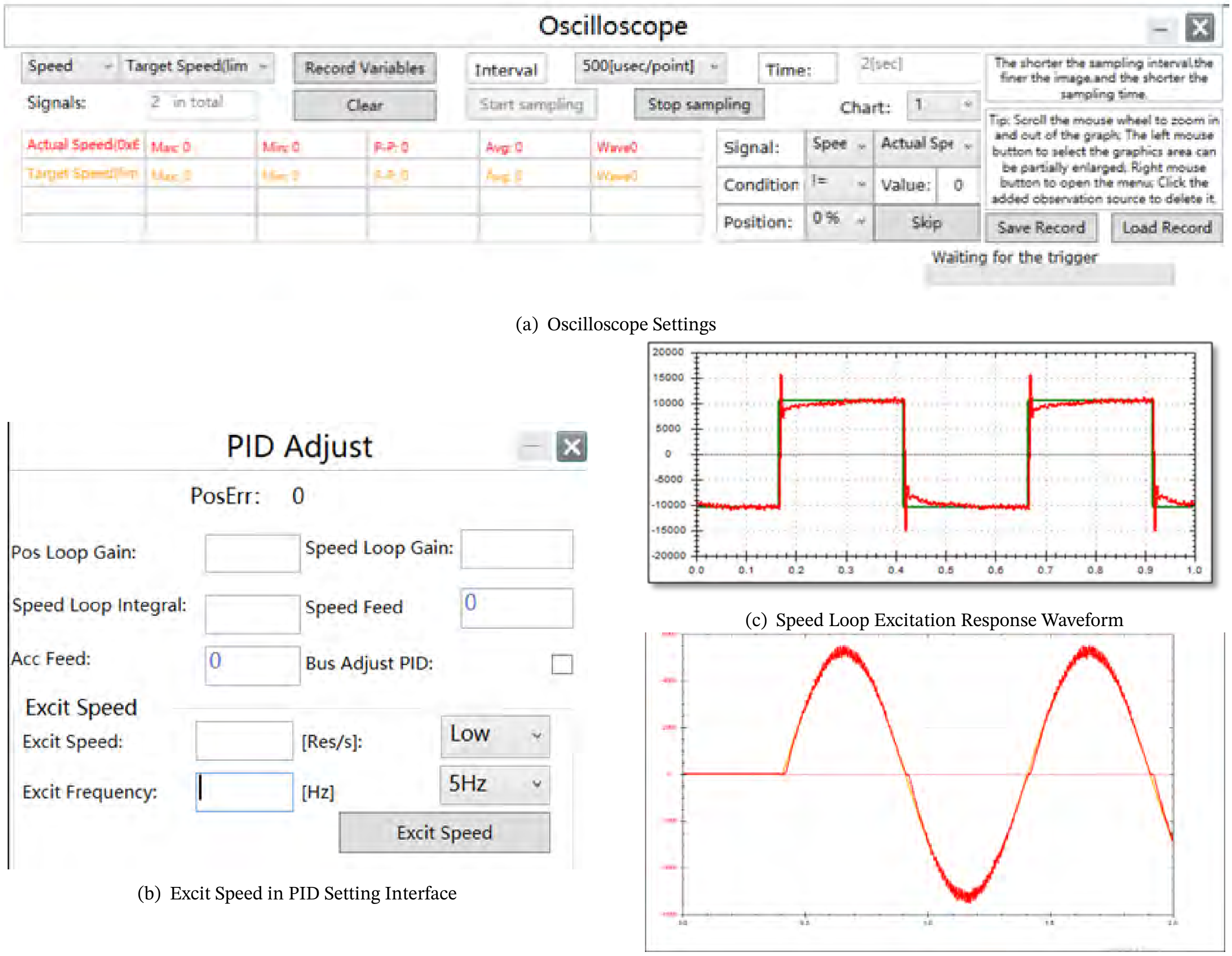
(1) First, select the "Target Speed (limiting amplitude)" and " Actual Speed" as "Signals" in the oscilloscope interface; the "Interval" is "500 $\mu sec/point$", the "Time" is "2 sec". The "Target Speed (limiting amplitude)" is used as the "Signal", the "Condition" is "≠" and "Position" select "0%", click "Start sampling" to make the oscilloscope in the status of "Waiting for triggering", as shown in Figure 15-2a.

(2) Set "Excit Frequency" of speed loop in "PID Adjust" interface as shown in Figure 15-2b, the recommended value is 1Hz. The "Excit Speed" is generally set to 524288/Gear Ratio; Tune PID from the original basic value. Click "Excit Speed"; at the moment, the motor will response following the excit speed and the oscilloscope will collect data.

(3) Adjust "Speed Loop Gain" first, and it is acceptable that the waveform is without excessive oscillation. Then adjust "Speed Loop Integral", the value does not need to be set too large, which can eliminate oscillation properly. The final waveform should be close to the one as shown in Figure 15-2c.

(4) Click "Motor Stop" after the completion of adjustment. Click "Apply" in the left bottom of PID Adjust interface, then click "Save" in the main interface to save parameters (save command will be completed after about 3 seconds), thereby avoiding reverting into original parameters after the drive restarts.

(5) The speed loop excitation type can be set to sine wave excitation, and the resulting waveform should resemble the waveform shown in Figure 15-2d.



(a) Oscilloscope Settings

(b) Excit Speed in PID Setting Interface

(c) Speed Loop Excitation Response Waveform

(d) Speed Loop Sine Wave Excitation Waveform

Figure 15-2 Speed Loop Adjustment

15.2 Position Loop Adjustment

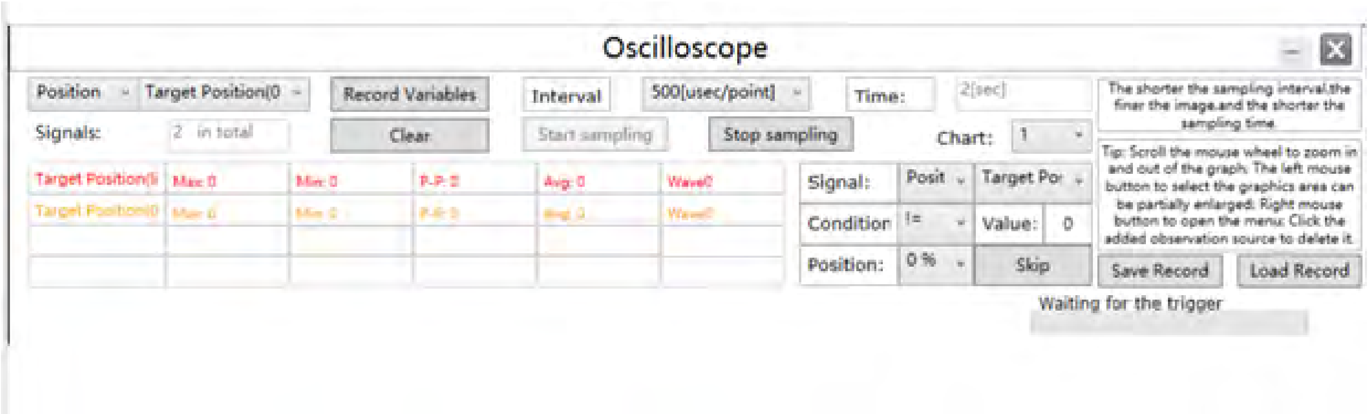
(1) Select “Target Position (limiting amplitude)” and “Position” as the “Signals” in oscilloscope interface, the “Interval” is “500 $\mu sec/point$””, the “Time” is “2 sec”; use “Target Position (limiting amplitude)” as “Signal”, and “Condition” is “$\neq$” and “Position” select “0%”, then click “Start sampling” to make oscilloscope in the status of “Waiting for the trigger”, as shown in Figure16-5.

(2) Set “Excit Frequency” in PID Adjust interface as shown in Figure 15-3b, the recommended value is 1Hz. The “Excit Position” is generally set to 52428/gear ratio; adjust PID from the original basic value. Click “Excit Position”; at the moment, the motor will response following the excit position and the oscilloscope will collect data.

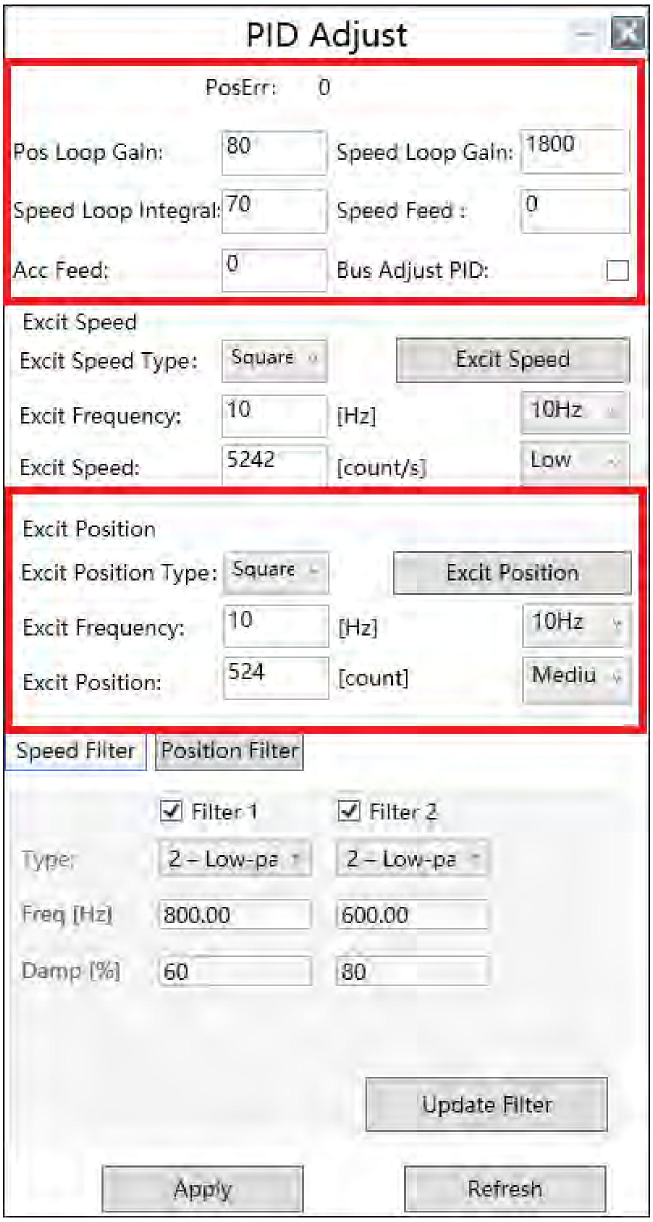
(3) Adjust “Pos Loop Gain”, the final waveform should be close to the one shown in Figure 15-3c.

(4) Click “Motor Stop” after the completion of adjustment. Click “Apply” in the left bottom of “PID Adjust” interface, then click “Save” in the main interface to save parameters (save command will be completed after about 3 seconds), thereby avoiding reverting into original parameters after the drive restarts.

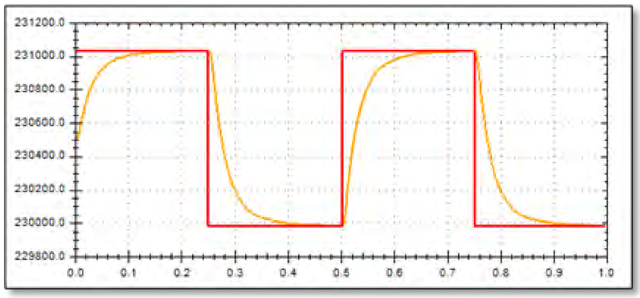
(5) The position loop excitation type can be set to sine wave excitation, and the resulting waveform should resemble the waveform shown in Figure 15-3d.



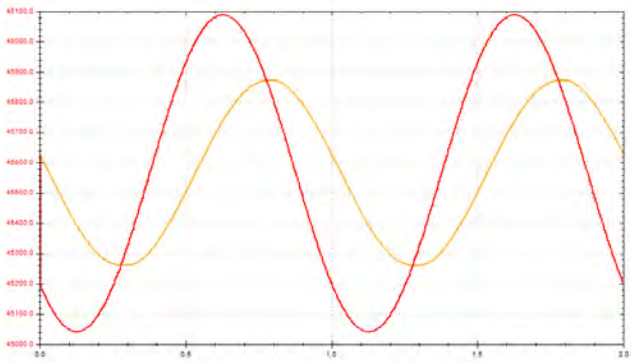
(a) Oscilloscope Settings



(b) Excit Position in PID Setting Interface



(c) Position Loop Excitation Response Waveform



(d) Position Loop Excitation Response Waveform

Figure 15-3 Position Loop Adjustment

15.3 EtherCAT Dynamically Modify PID Function

In addition to being modified by the PC, the PID parameters can also be modified dynamically through the EtherCAT. First, tick “Bus Adjust PID” in “PID Adjust” interface as shown in Figure 15-3c, then click “Apply” and “Save”, otherwise the modification will be invalid. Then, visit 2381_h: 01_h (speed loop gain), 2381_h: 02_h (speed loop integral), and 2382_h: 01_h (position loop gain) through SDO to dynamically modify PID parameters (Current loop parameters are not available to modify. They are factory settings, do not need to be modified).

Attentions on Using Bus Adjust PID: Tick “Bus Adjust PID” first when EtherCAT modify PID parameter function is needed, otherwise the function cannot be used.
If the operation of using PC to modify PID parameters is needed after using EtherCAT to modify PID parameters, please follow the operation steps below to avoid the PC modifying PID operation from not taking effect and becoming a value between the original value and the target value :

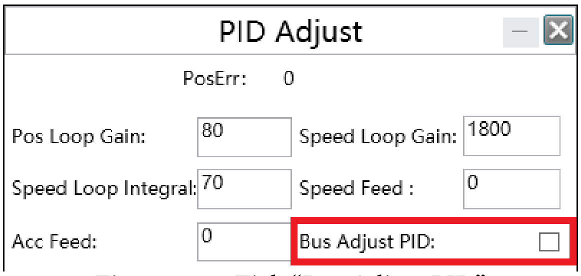


Figure 15-4 Tick “Bus Adjust PID”

(1) Untick “Bus Adjust PID”;
(2) Tick “Apply” and “Save”
(3) Reenter into “PID Adjust” interface and modify the PID parameters.

For more info regarding EtherCAT dynamically modifies PID function and the description of the related object dictionary, please refer to *Section 8.2* in *eRob CANopen and EtherCAT User Manual*.

Chapter 16 Special Function Introduction

16.1 PDO Dynamic Configuration

In the predefined list of eDriver series PDO mapping, 0x1A00/0x1600 mapping TxPDO/RxPDO supports any mapping configuration (the total number of configurable PDO bytes is up to 80 bytes), including but not limited to:

(1) TxPDO:
- 6041_h
- 6064_h
- $606C_h$
- 6061_h
- etc.

(2) RxPDO:
- 6040_h
- $607A_h$
- 6065_h
- 6060_h
- etc.

Note: Due to the characteristics of the ESC chip, if you need to configure an 8-bit length object index (such as 6060_h/6061_h), you need to configure an empty 8-bit (bit8) at the same time to align with 2 bytes (16bit).More details about PDO mapping list description, please refer to *Chapter 3* in *eRob CANopen and EtherCAT User Manual*.

16.2 PID Control Function of Variable Integral Upper Limit

Access parameter ID: 97 (decimal) through CAN can proceed reading and writing operations on "Speed Loop Integral Upper Limit" parameters (parameter properties: INT32, not saved to flash, can be read and written, unit: mA) and also can modify parameters while the rotary actuator is running.

Function Instructions:

(1) Setting integral upper limit to 0 can eliminate the accumulated speed loop integral value.

(2) Restoring integral limit value to the original set value will cause shock. Therefore, it is recommended to increase the value gently (the increased appropriate value of each cycle depends on the actual smoothness of operation, and it is recommended to increase from small value to large value to see the actual effect).

(3) PID control of variable integral upper limit can not only eliminate the integral being 0, but also can properly change integral upper limit, which makes the servo running more stable and allows a larger proportional gain and quicker response speed.

Chapter 17 Permissible Forces in All Directions

17.1 Moment of Force Calculation

Maximum Moment of Force(M_{max}) Calculation Formula is as below:

$$M_{max} = F_{r,max}(L_r + R) + (F_{a,max} \times L_a) \tag{17.1}$$

Symbol	Definition	Unit	Reference
M_{max}	Max. Moment of Force	Nm	
$F_{r,max}$	Max. Radial Load	N	Figure 17-1
$F_{a,max}$	Max. Axial Load	N	Figure 17-1
L_r	Radial Load Length	m	Figure 17-1
L_a	Axial Load Length	m	Figure 17-1
R	Offset Length	m	Figure 17-1

NOTE: Make sure $M_{max} \leq M_c$

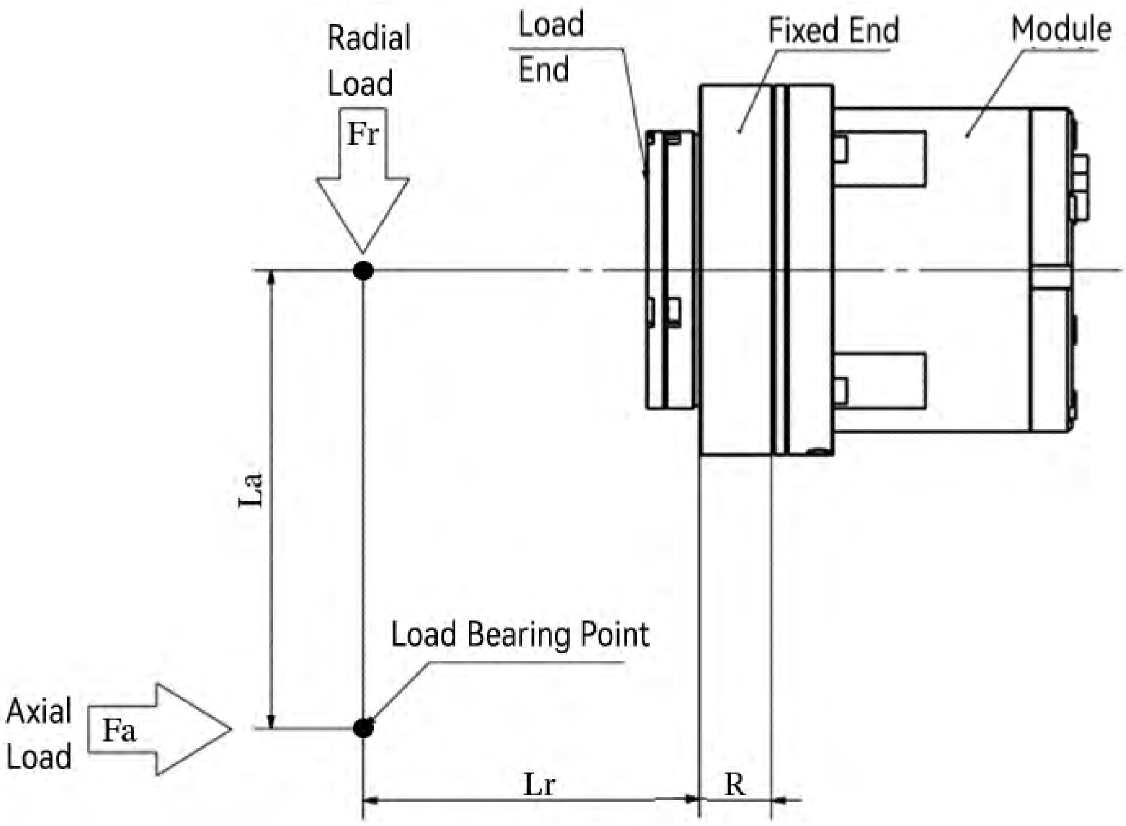


Figure 17-1 External Load Influence Diagram

The Permissible Moment Load (M_c) of each actuator model is shown in Table 17-1.

Table 17-1 Permissible Moment Load(M_c) of Each Actuator Model

Model	Offset (R)	Permissible Moment (M_c)	
	m	Nm	kgf
eRob70F	0.0111	37	3.8
eRob70H	0.0217	74	7.6
eRob80H	0.0239	124	12.6
eRob90H	0.0255	187	19.1
eRob110H	0.0296	258	26.3
eRob142H	0.0364	580	59.1
eRob170H	0.044	849	86.6

Example: For an eRob70H module, with the following condition:

$L_a = 0.2m, \quad L_r = 0.5m, \quad F_{r,max} = 50N, \quad F_{a,max} = 30N.$

First acquire the Permissible Moment Load from Table 17-1:

$R = 0.0217m,\ M_c = 74Nm.$

Apply the conditions into the Formula 17.1

$$M_{max} = 50 \times (0.5 + 0.0217) + 30 \times 0.2$$
$$M_{max} = 32.085Nm$$

The calculation result is $M_{max}(32.085Nm) \leq M_c(74Nm)$, so it meets the usage requirements of bending.

17.2 Roller Bearing Specification

Table 17-2 Roller Bearing Specifications of Each Actuator Model

Model	Basic Dynamic Load Rating (C_{10})		Basic Static Load Rating (C_0)		Permissible Moment (M_c)		Moment Stiffness (K_m)	
	$\times 10^2 N$	kgf	$\times 10^2 N$	kgf	$N \cdot m$	$kgf \cdot m$	$\times 10^4 \frac{N \cdot m}{rad}$	$\frac{Kgf \cdot m}{arcmin}$
eRob70F	29	296	43	438	37	3.8	7.08	2.1
eRob70	58	590	86	880	74	7.6	8.5	2.5
eRob80	104	1060	163	1670	124	12.6	15.4	4.6
eRob90	146	1490	220	2250	187	19.1	25.2	7.5
eRob110	218	2230	358	3660	258	26.3	39.2	11.6
eRob142	382	3900	654	6680	580	59.1	100	29.6
eRob170	433	4410	816	8330	849	86.6	179	53.2

Basic Dynamic Load Rating (C_{10}):
AKA Catalog Load Rating or Basic Load Rating or Basic Dynamic Rated Load, is defined as the radial load that causes 10% of a group of bearings to fail at the rated life of 100 million revolutions.

Basic Static Load Rating (C_0):
AKA Basic Static Rated Load, The static load applied at the central position of the contact area between the

rotating element and the raceway, which is $4kN/mm^2$.

Permissible Moment Load (M_c):
The maximum moment of force that can be applied to the output side bearing. Within this specified range, the bearing should be able to maintain its rated performance and operate reliably.

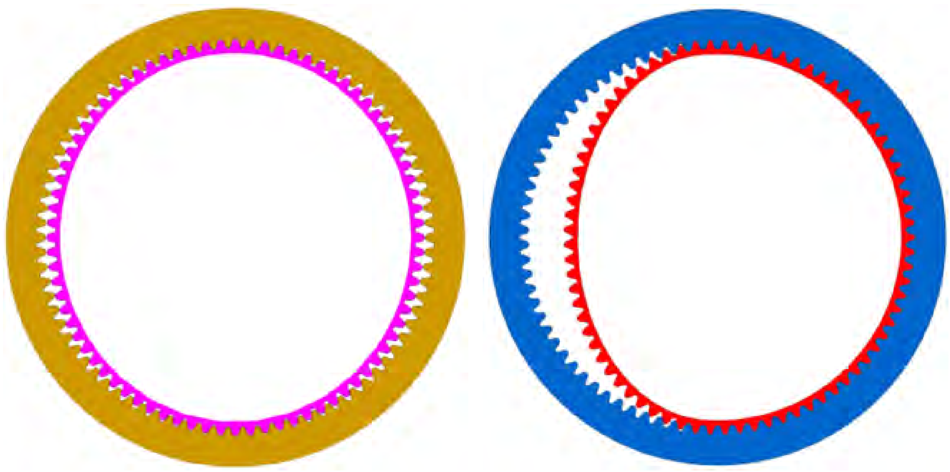
Moment Stiffness (K_m):
The moment stiffness value of the crossed roller bearing on the rotary actuator module, moment per unit angular (radian). The values shown are mean values.

17.3 Ratcheting Torque

When the rotary actuator is subjected to excess impact torque during operation, the engagement of the teeth between the circular spline and the flexspline may be put momentarily out of alignment instead of damaging the flexspline. This phenomenon is called "ratcheting", and the torque is called "ratcheting torque" (see values in Table 17-3). Operating without fixing ratcheting will result in earlier abrasion of the teeth and shorter life of the wave generator bearing due to the effect of the grinding powder generated by ratcheting.

Table 17-3 Ratcheting Torque Values of Each Models (unit: Nm)

GR \ Model	eRob70F	eRob70	eRob80	eRob90	eRob110	eRob142	eRob170
50	88	88	150	220	450	980	1800
80	-	110	200	350	680	1400	2800
100	84	84	160	260	500	1000	2100
120	-	-	120	240	470	980	1900



(a) Correct Engagement of Teeth (b) The Engagement of the Teeth is Out of Alignment
Figure 17-2 Strain Wave Gear Teeth Alignment Illustration

Figure 17-2a shows the correct engagement of teeth. When ratcheting happens, the teeth may not be correctly engaged and become out of alignment as shown in Figure 17-2b. Continue to operate in this condition will generate vibration and damage the flexspline.

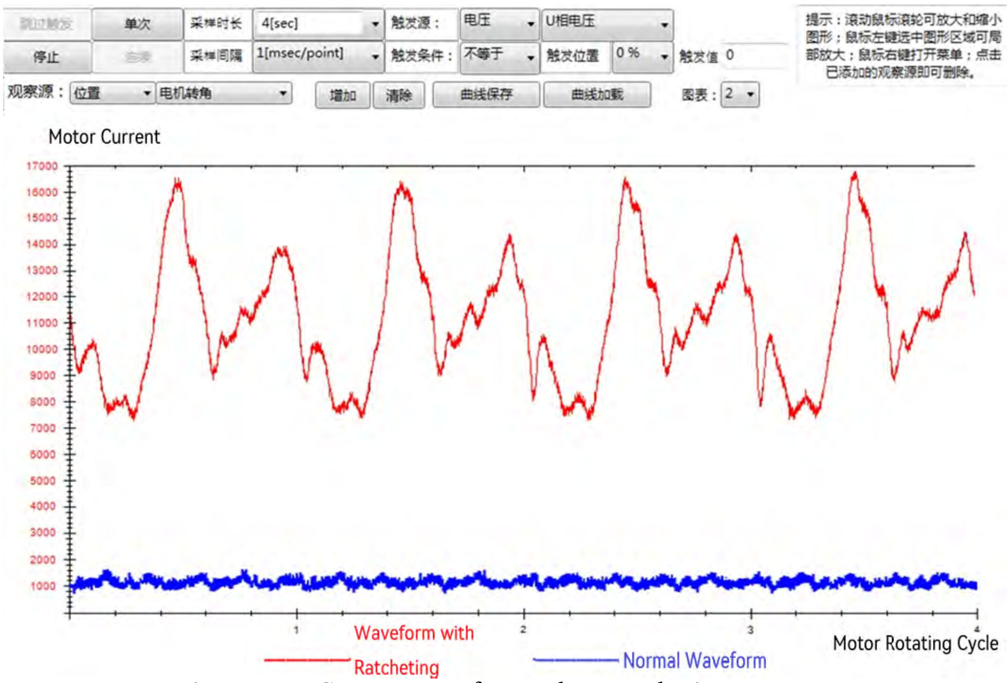
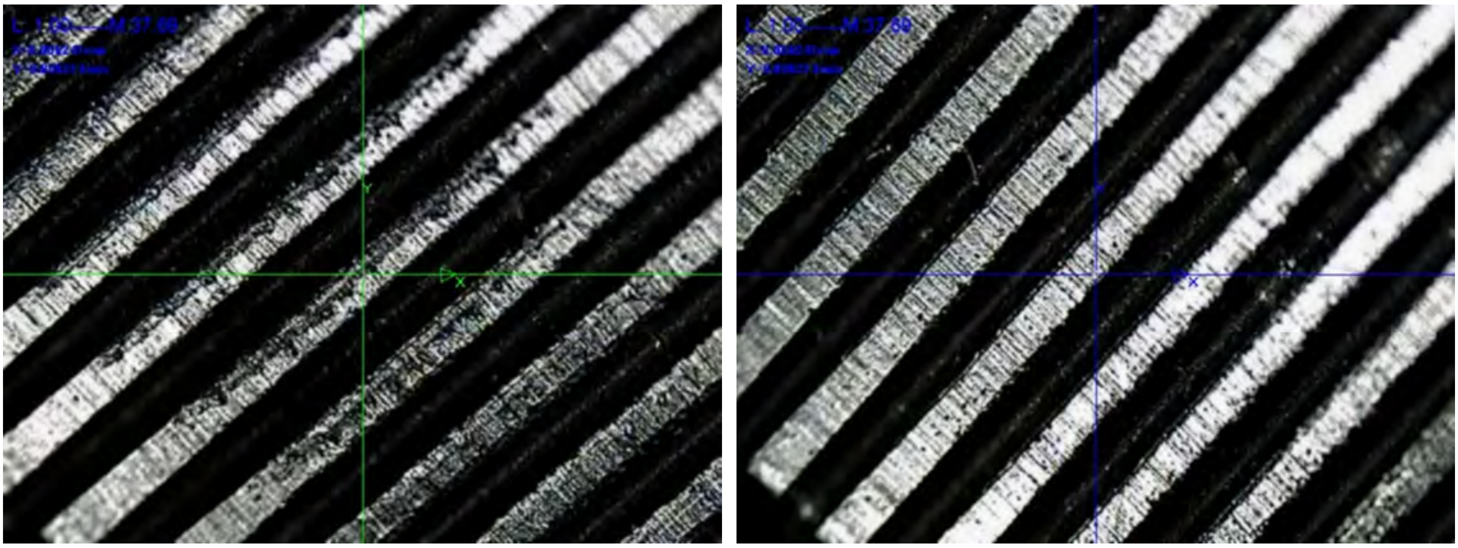


Figure 17-3 Current Waveform When Ratcheting Happens

Taking eRob90H100I as an example, operating at a speed of 5242count/s when ratcheting (motor rotational speed is 1r/s at this moment) (when serious ratcheting is caused, operating the actuator with no- load may also result in alarm) , using oscilloscope to collect the current waveform of the motor (as shown in Figure 17-3, set motor current and motor corner as the “Signal” sources ; sampling “Interval” is 1ms ; sampling “Time” is 4s.), will result in a large current fluctuation. When serious ratcheting happens, operating the rotary actuator with load will generate alarm, such as excess current, motor struck protection, position error exceeded, speed error exceeded, and power temperature being too high etc. The rotary actuator can no longer be used after ratcheting.

Once a ratcheting happens one time, the teeth tips are worn as shown in Figure 17-4a and Figure 17-4b shows the normal teeth tips. Once ratcheting happens more than two times, the torque value will be lowered.



(a) The Tips of the Teeth are Worn (b) The Normal Teeth Tips

Figure 17-4 Strain Wave Gear Teeth

Chapter 18 Rotary Actuator Installation Requirements

18.1 Seam Allowance Requirement of Flange Connection

The seam allowance in load must be buckled on the designated position as shown in Figure 18-1. The seam allowance length for specific actuator is shown in Table18-1. The flange mating face is not allowed to have protrusions such as flash; pay attention to the orifice protrusions, flash etc., which can be caused by drilling easily. The design of flange must be equipped with a vacant space in 0.3 Ød depth. Rotary actuator output shaft cannot afford force within Ød range (as shown in Figure 18-1). The damage of rotary actuator caused by output shaft bearing forces within Ød range due to customers' improper flange design is not covered by the warranty.

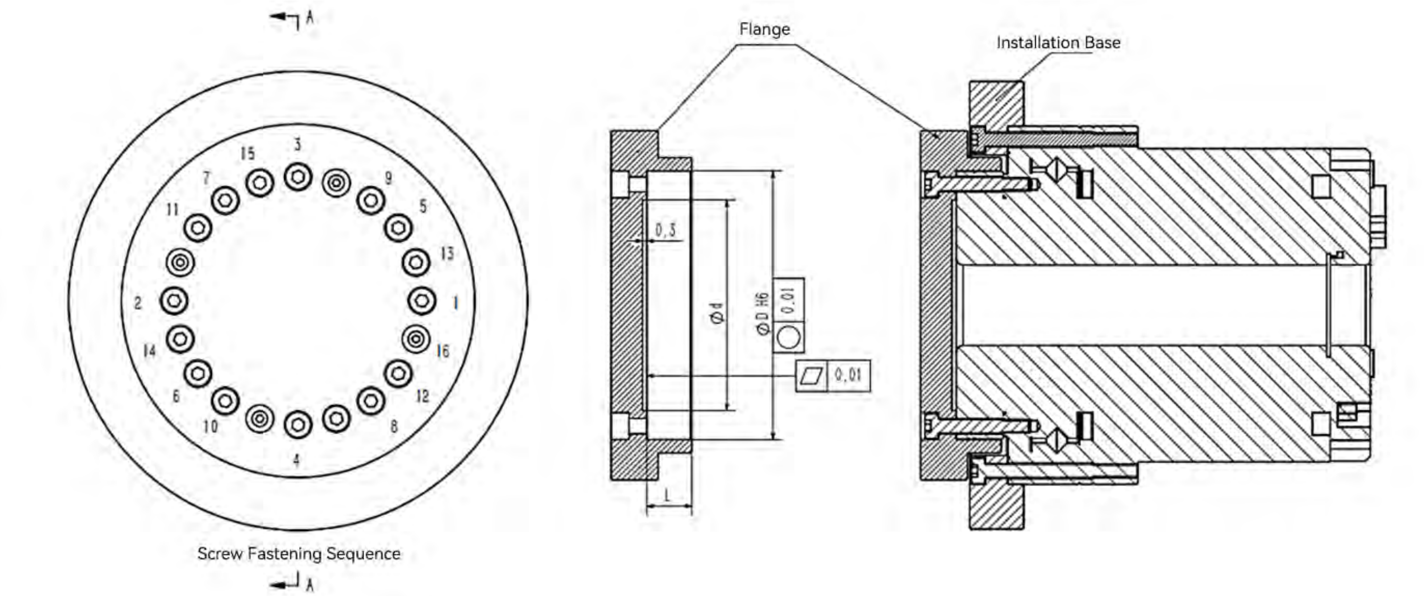


Figure 18-1 Rotary Actuator Installation

Table 18-1 Seam Allowance Parameters

Model	D_{Output} (mm)	$D_{Circular\ Spline}$ (mm)	$L_{Output\ Shaft}$ (mm)	D (mm)	L (mm)	d (mm)	Seam Allowance Roundness	Seam Allowance Flatness
eRob70F	Ø48.6	$Ø49^{0}_{-0.016}$	3	$Ø49^{+0.016}_{0}$	4.5	Ø38.3	0.01	0.01
eRob70H	Ø49.6	$Ø50^{0}_{-0.016}$	4	$Ø50^{+0.016}_{0}$	6	Ø39	0.01	0.01
eRob80H	Ø59.6	$Ø60^{0}_{-0.019}$	5	$Ø60^{+0.019}_{0}$	7	Ø49	0.01	0.01
eRob90H	Ø69.6	$Ø70^{0}_{-0.019}$	5	$Ø70^{+0.019}_{0}$	7	Ø56	0.01	0.01
eRob110H	Ø84.6	$Ø85^{0}_{-0.022}$	5	$Ø85^{+0.022}_{0}$	7	Ø70	0.01	0.01
eRob142H	Ø109.6	$Ø110^{0}_{-0.022}$	7	$Ø110^{+0.022}_{0}$	9	Ø91	0.01	0.01
eRob170H	Ø134.6	$Ø135^{0}_{-0.025}$	7	$Ø135^{+0.025}_{0}$	10	Ø102	0.01	0.01

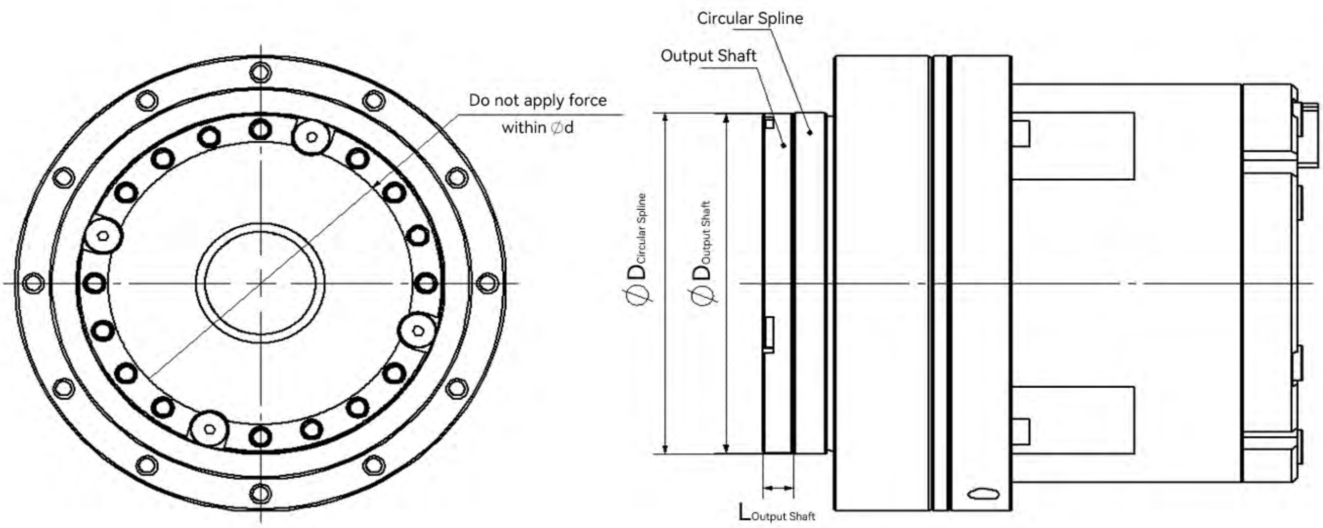


Figure 18-2 Rotary Actuator Installation

Note:

(1) Fail to follow the installation requirement of the eRob output end connecting flange may cause the output shaft to deform, then the torque sensor cannot work properly even cause irreversible damage.

(2) The Loutput shaft length requirement is to ensure:

  (1) the radial positioning accuracy of the output flange;

  (2) the load moment is transmitted through the output flange seam allowance to the precision cross roller bearing that directly supports the external load.

(3) The roundness and flatness of the customer's load flange seam allowance should be as close as possible to the required values. Excessive roundness or flatness will lead to uneven force on the output end of the eRob, which will lead to abnormal noise or vibration of the eRob.

18.2 Screw Locking Method

Use diagonal method to tighten screws. The first step is to turn screws to the bottom without tightening it. The second step is to slightly tighten screws via the diagonal method. The third step is to use torque wrench to tighten screws via the diagonal method.

18.3 Screw Torque Standard

Refer to Table 18-2 for screw locking force.

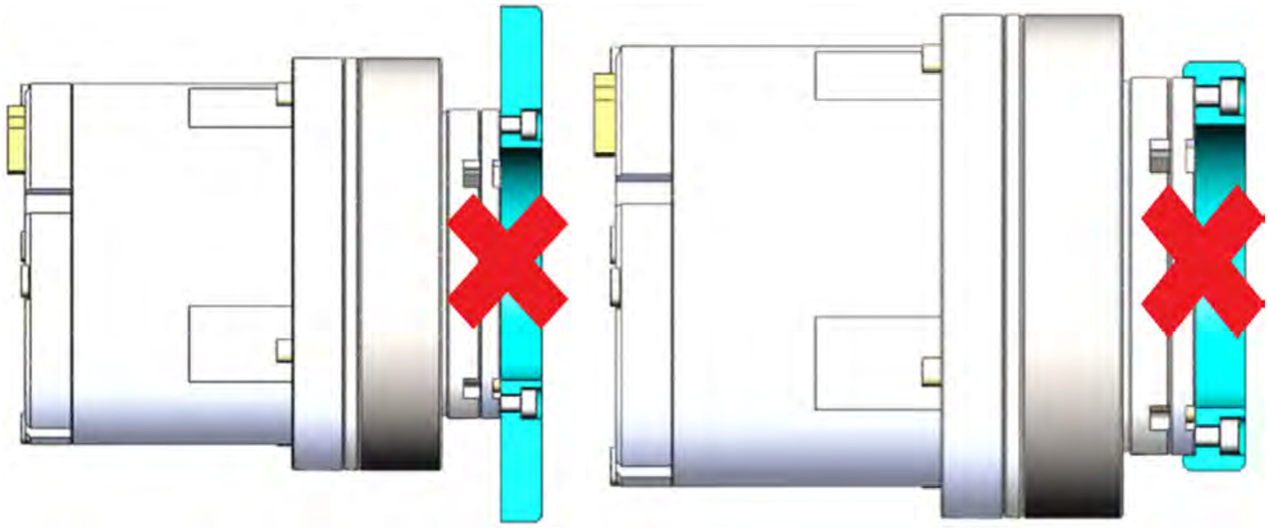
Screw Strength Class: level 12.9

Table 18-2 Screw Locking Torque

Screw Model	M3	M4	M5	M6
Locking Torque	2 Nm	4 Nm	9 Nm	15 Nm
Note	The premise is that the material on the female thread side can withstand the screw locking torque.			

18.4 Common Improper Installation

(1) Positioning deficiency, only have plane installation. As shown in Figure 18-3a.
(2) Insufficient positioning depth, fail of efficient positioning. As shown in Figure 18-3b.



(a) Lack of Positioning Seam Allowance (b) Insufficient Positioning Seam Allowance Depth

Figure 18-3 Common Improper Installation

(3) Flange protrusion caused by drilling. As shown in Figure 18-4.

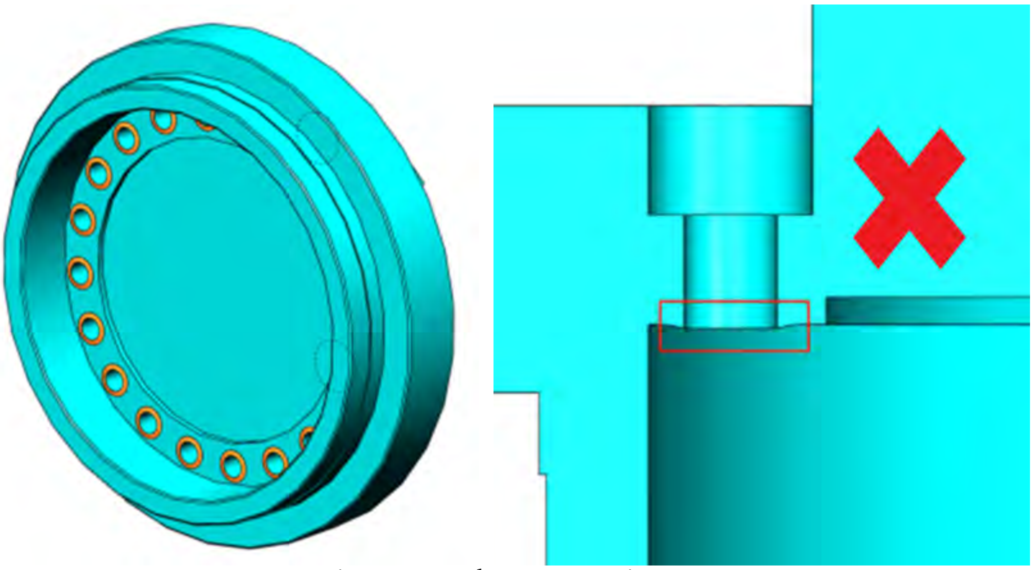


Figure 18-4 Flange Protrusion

(4) The flatness is out of tolerance due to poor processing. As shown in Figure 18-5.

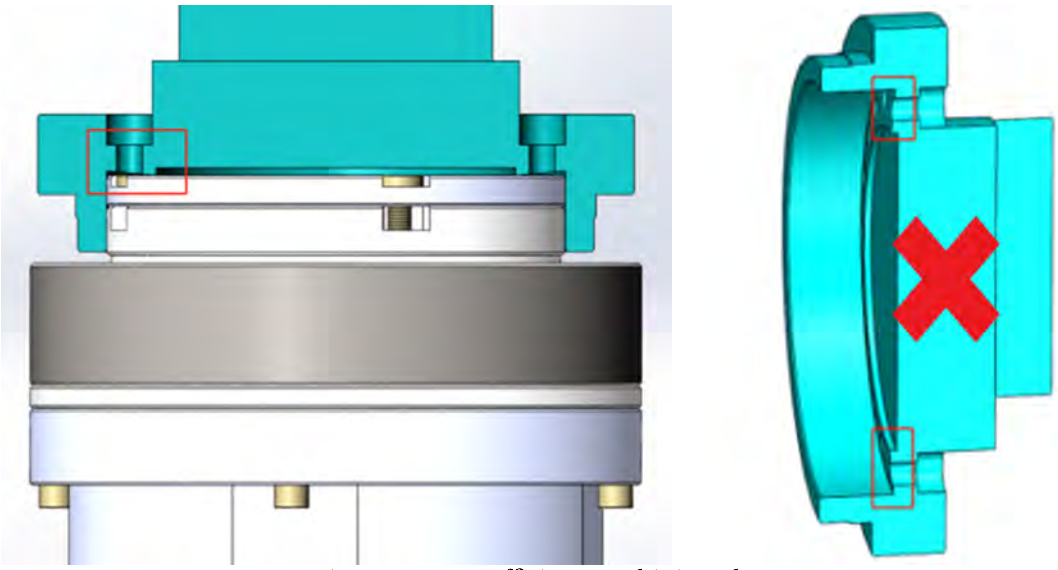


Figure 18-5 Insufficient Machining Flatness

(5) The improper installation will affect the force of the joint, as shown in Figure 18-6: Since the joint is equipped with precision cross roller bearing to directly support external loads, the improper installation method does not transmit the force of the output flange to the cross roller bearing, but to the bolts that fix the motor casing.

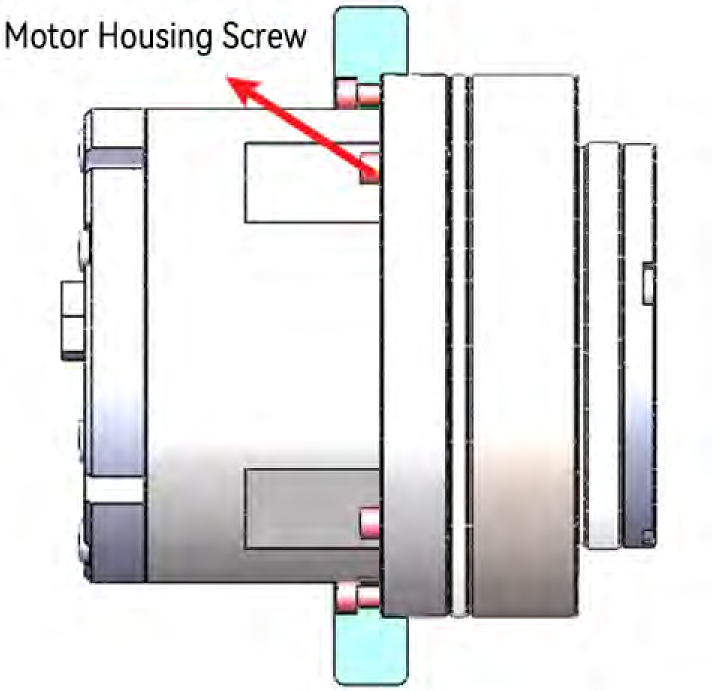


Figure 18-6 Improper Installation
(Fail to transmit the force of the output flange to the cross roller bearing)

If you need to lock the joint from the fixed end of the motor casing, please refer to Figure 18-7 and to ensure that the tightening torque of the bolts and nuts is sufficient (refer to Table 18-2), and both are locked simultaneously with the same torque but in different directions.

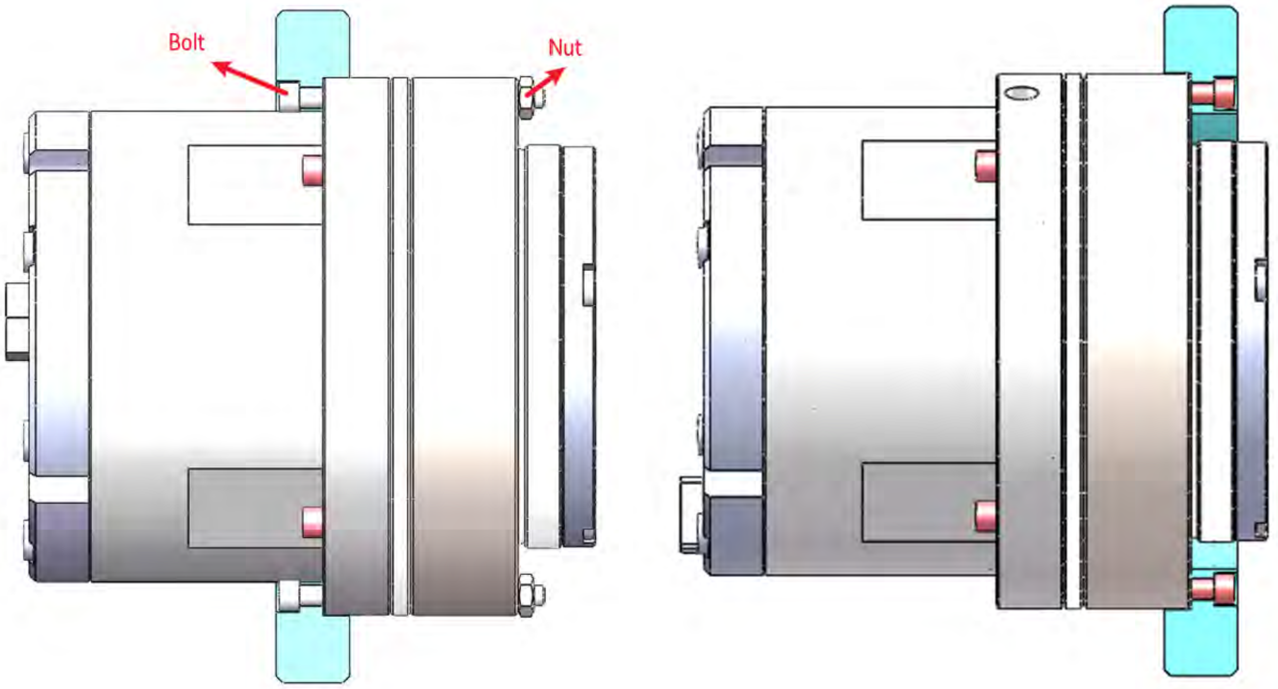


Figure 18-7 Insufficient Machining Flatness

Each eRob rotary actuator has undergone strict jitters and noise tests before delivery. Exceptions like jitters and noise will occur if the eRob cannot meet the installation requirements.

★

(6) The installation of the eRob module does not require the addition of external bearings. As shown in Figure 18-8, the eRob module is equipped with integrated cross-roller bearings that can withstand both radial and axial loads. The load-bearing capacity of the eRob module should be checked according to Chapter 17. Adding external bearing support can lead to situations where the installation dimensions are exceeded, resulting in abnormal noises, vibrations, jitter, jamming, and bending of the eRob module.

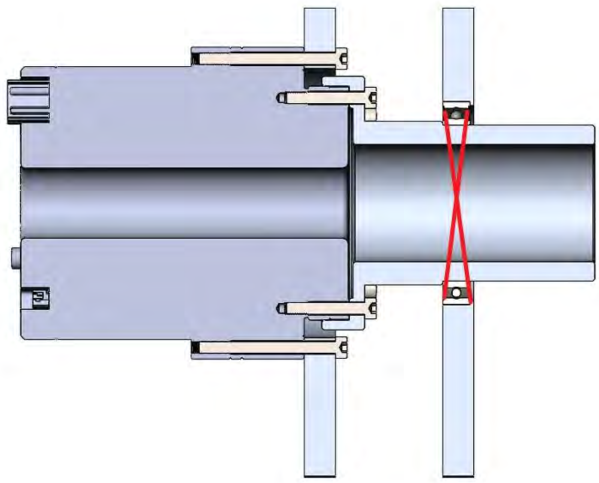


Figure 18-8 No External Bearings Required for eRob Module Installation

Each eRob module undergoes rigorous jitter and noise testing before leaving the factory. If it

★ does not meet the installation requirements, it may exhibit abnormal jitters and noises.

18.5 Pre-Installation Cleaning Advisory

Ensure the mounting face is thoroughly cleaned before installation to prevent any interference caused by metal chips, thread glues, sealants, particles, or dust accumulation. Failure to achieve a clean mounting face may result in unreliable fits, leading to jitters and noise during operation.

Chapter 19 Firmware Version Upgrade

Definition rules of firmware version of rotary actuator are as shown in Figure 19-1.

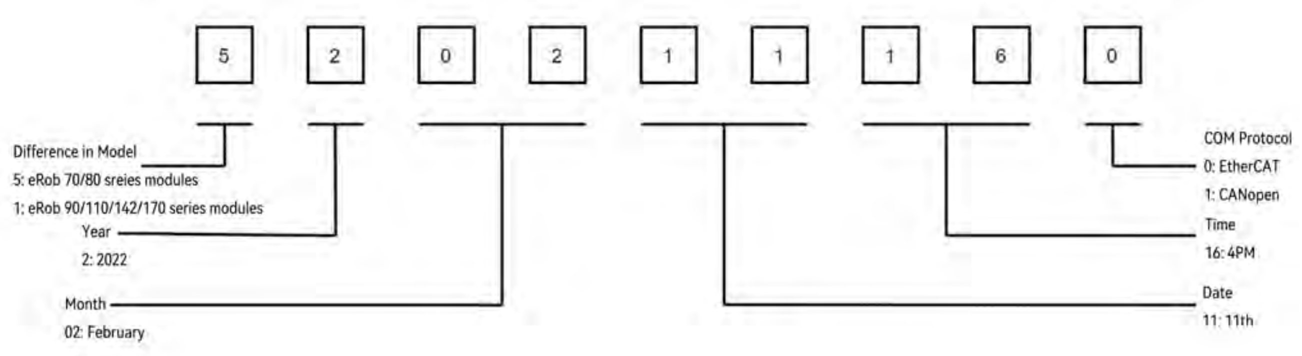


Figure 19-1 Definition rules of firmware version of rotary actuators

★

For more information regarding the Firmware Versions,
please visit our official website: en.zeroerr.cn/support/firmware-version

For more information regarding the Firmware Update Tool, i.e., the CAN_Update_Tool,
please refer to our CAN_Update_Tool User Manual

Chapter 20 Restoring Factory Parameter Function

The operation steps of restoring factory parameters are as shown in Figure 20-1.

(1) Connect eTunner (refer to YouTube Tutorial) and then click "Parameter", the "Upload and Download" window pops up.

(2) Click "Reset parameters" and wait until the progress bar is completed. Click "Confirm" in the "Tips" window as shown in Figure 20-1.

(3) Power off and restart, reconnect in the "eTunner" software, confirm the parameters are restored. Then click "Save" to save the restored parameters.

Note:

(1) The restoring factory parameter function can be used only when part of parameters or all the parameters are lost due to unexpected power failure during the process of saving parameters.

(2) When applying restoring factory parameter function, please confirm that rotary actuators are equipped with the latest official version (firmware version number is X2040816X or the later firmware versions, and the eRob must be delivered after April 8, 2022). Actuators delivered before this date cannot support this function.

(3) In the case of "Note (1)" but not meeting the conditions of "Note (2)", please promptly contact our technical support engineers for confirmation.

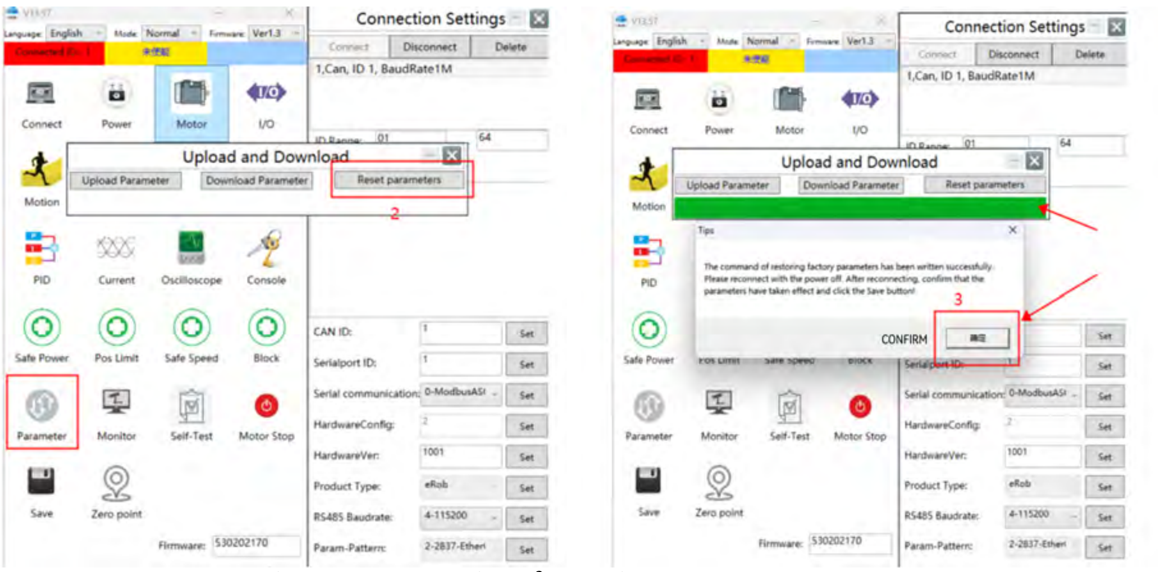


Figure 20-1 Operation of Restoring Factory Parameters

Chapter 21 Safe Torque Off (STO) Function Instruction

Safe torque off (STO) function is used under the conditions of emergency stop and prevention of unexpected start-up. When STO signal is triggered, the motor power will be turned off and the brake will be enabled, but the drive power does not need to be disconnected.

Figure 21-1 Wiring Figure

Note:

(1) More details for STO wiring figures, please refer to Figure 6-12 STO terminal connection in Section 6.5. The rotary actuator can support two STO branch circuits (STOA and STOB). When only one branch circuit is configured, connect STOA interface.

21.1 STO Function Configuration

As shown in Figure 23-1, install a computer with eTunner, connect CAN communication interface of rotary actuator via USB CAN Debugger, connect 12P I/O wiring terminal and I/O signal interface, then supply proper power for rotary actuator.

21.1.1 One STO Branch Circuit Function Configuration

As shown in Figure 21-2, connect eTunner, enter control interface, select “0-None” in “Control Source”. Then enter “I/O Settings” interface to set STO function configuration (pay attention to check “Status Monitor” interface. Only when it displays “Disable”, can the function modification be allowed.)

Set DIn01 to “STOA”, set STO configuration to “2-One of STO”, click apply and save in sequence. Wait about 3 seconds, it will be prompted that the save demand is completed. Then STO one branch circuit configuration is completed.

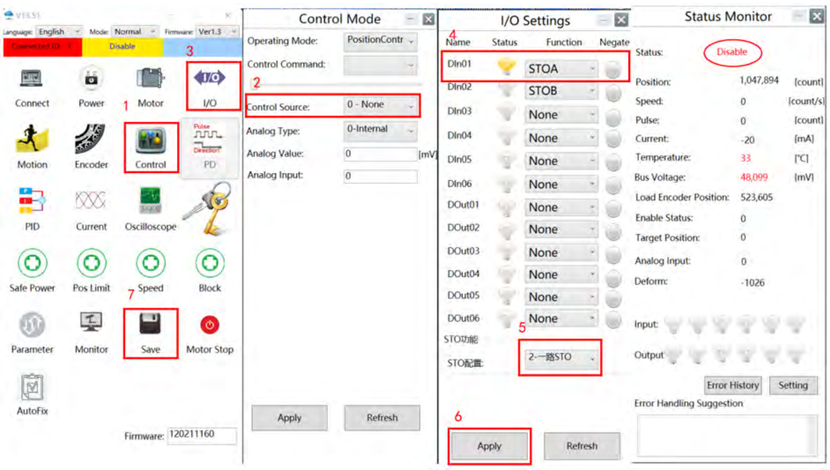


Figure 21-2 One STO branch circuit function configuration steps

21.1.2 Two STO Branch Circuits Function Configuration

As shown in Figure 21-3, Connect eTunner, enter “Control Mode” and select “0-None” in “Control Source”. Then enter “I/O Settings” interface to set STO function configuration (pay attention to check status monitor interface. Only when it displays “Disable”, can the function modification be allowed.)

Set DIn01 to “STOA”, set DIn02 to “STOB”, set STO configuration to “3- Two of STO”, click apply and save in sequence. Wait about 3 seconds, it will be prompted that the save command is completed. Then STO two branch circuits configuration is completed.

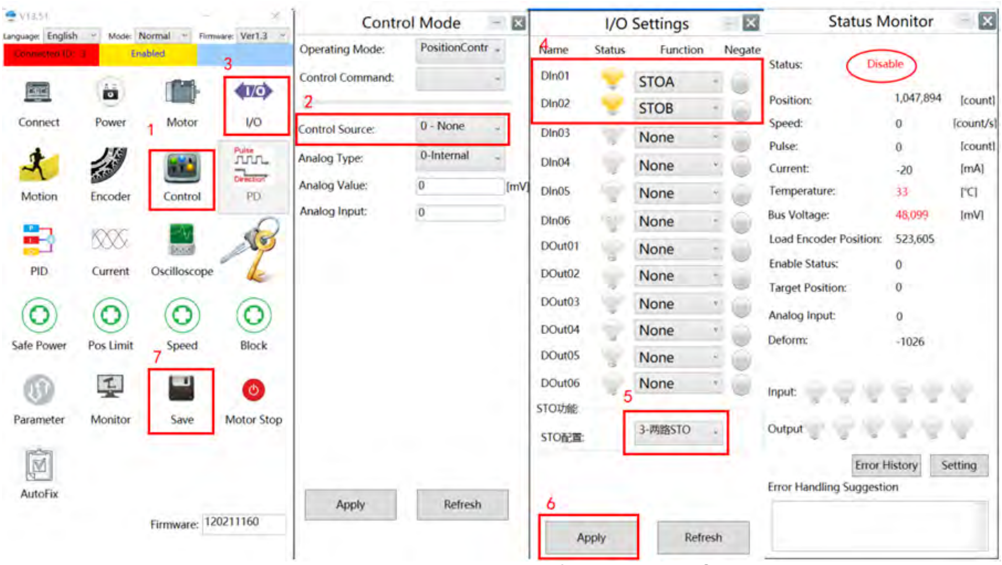


Figure 21-3 Two STO branch circuits function configuration steps

Chapter 22 Virtual Torque Sensor

(1) The transmission equation of SWG under ideal conditions:

$$\theta_{out} = \frac{\theta_{in}}{m_G} \tag{22.1}$$

Symbol	Definition	Unit
θ_{out}	Angle of flexspline output shaft. Measured by encoder for output shaft, and the resolution is 19 bit.	°, rad
θ_{in}	Angle of wave generator input shaft. Measured by encoder for motor, and the resolution is 17 bit.	°, rad
m_G	SWG gear ratio.	N/A

(2) The actual transmission equation of SWG:

$$\theta_{out} + E_{out} = \frac{\theta_{in}}{m_G} + E_{in} \tag{22.2}$$

Symbol	Definition
E_{in}	The transmission error of input shaft.
E_{out}	Error caused by circular spline elastic deformation.

The error value is so small that it can be ignored.

$$E_{in} = E_{FED} + E_{WGD} + E_{ITG} + E_M \tag{22.3}$$

Symbol	Definition
E_{FED}	Error caused by flexspline elastic deformation.
E_{WGD}	Error caused by wave generator deformation.
E_{ITG}	Error caused by input teeth gap.
E_M	Error caused by manufacture.

When compared with E_{FED}, E_{WGD}, and E_{ITG}, the E_M is very small and can be ignored.
Define variable $\Delta\theta$ (let $\Delta\theta = E_{in}$, represented by the object dictionary 0x2241) represents the total torsional angle of the SWG.

$$\Delta\theta = (\theta_{out} \times m_G) - \theta_{in} \tag{22.4}$$

Symbol	Definition	Unit
θ_{in}	Angle of wave generator input shaft. Measured by encoder for motor, and the resolution is 17 bit.	Resolution
θ_{out}	Angle of flexspline output shaft. Measured by encoder for output shaft, and the resolution is 19 bit.	Resolution
$\Delta\theta$	Calculated using Formula 22.4, and the resolution is 17 bit.	Resolution

The sampling period of both encoders is 50 μs, and both $\Delta\theta$ (0x2241) and calculated torque value (0x3B69) are calculated immediately after the encoder samples. Therefore, the bandwidth of $\Delta\theta$ and calculated torque value mainly depends on the communication cycle of EtherCAT or CANopen for 0x2241 and 0x3B69.

Table 22-1 Dual Encoder Difference

Index	0x2241	Object	Variation	Name	Dual Encoder Difference ($\Delta\theta$)
Sub-index	PDO Mapping	Read-write Operation	Data Format	Unit	Description
0x00	TxPDO	Read Only	INT32	Resolution	Mapped to the dual encoder difference on the motor side, the resolution is 17 bits. Taking eRob80H100 as an example, the relationship between $\Delta\theta$ dual encoder difference and load end torque at standstill is shown in Figure 22-1

Table 22-2 Calculated Torque Value

Index	0x3B69	Object	Variation	Name	Calculated Torque Value
Sub-index	PDO Mapping	Read-write Operation	Data Format	Unit	Description
0x00	TxPDO	Read Only	INT32	mNm	Calculated torque value based on the dual encoder scheme. Only for eRob with virtual torque sensor (model: eRobxxxxxxxx-xxx-18x**T**).

Note: Installation without obeying requirements of mounting flange in output shaft (for details, refer to Chapter 18) may cause output shaft deformation and cause the torque sensor cannot properly work even cause an irreversible damage.

The correlation between the difference value 0x2241h and the torque value 0x3B69h of the dual encoder can be obtained by combining the characteristics of the rigidity and hysteresis curve of the SWG, as shown in Figure 22-2.

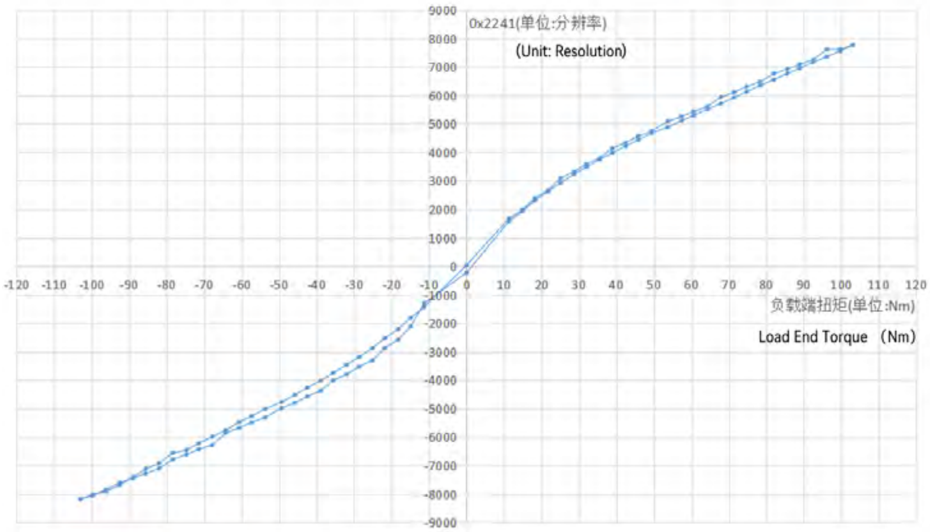


Figure 22-1 Relationship Curve Between Dual Encoder Difference and Load End Torque at Standstill

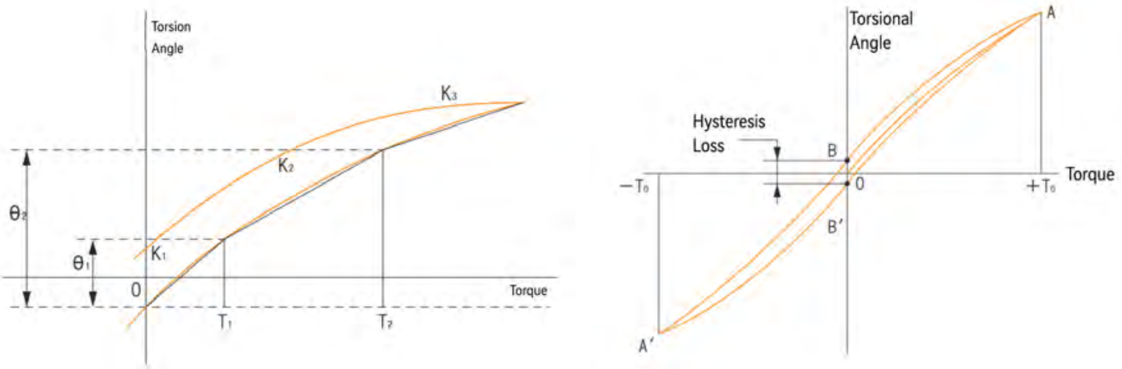


Figure 22-2 Hysteresis and Rigidity Curve of The Strain Wave Gear

Reference: *HarmonicDrive General Catalog.pdf*

Table 22-3 Dual Encoder Difference and Load End Torque Relationship Test Data Sheet at Standstill

Load End Torque	Dual Encoder Difference (Avg.)	Load End Torque (Nm)	Dual Encoder Difference (Avg.)
0.000	-230	0.000	37
11.327	1583	-11.327	-1433
14.903	1935	-14.903	-1815
18.218	2305	-18.218	-2211
21.794	2629	-21.794	-2530
25.109	2935	-25.109	-2871
28.685	3240	-28.685	-3188
32.000	3490	-32.000	-3462
35.576	3756	-35.576	-3746
38.891	3977	-38.891	-4018
42.467	4220	-42.467	-4262
45.782	4439	-45.782	-4512
49.358	4680	-49.358	-4770
53.756	4888	-53.756	-5018
57.331	5109	-57.331	-5265
60.647	5299	-60.647	-5472
64.222	5512	-64.222	-5756
67.884	5716	-67.884	-5988
71.459	5931	-71.459	-6219
74.775	6137	-74.775	-6463
78.350	6353	-78.350	-6563
82.011	6556	-82.011	-6917
85.587	6766	-85.587	-7115
88.902	6955	-88.902	-7396
92.478	7165	-92.478	-7677
96.139	7357	-96.139	-7914
99.715	7565	-99.715	-8017
103.030	7773	-103.030	-8185
99.715	7620	-99.715	-8062
96.139	7620	-96.139	-7839
92.478	7244	-92.478	-7596
88.902	7086	-88.902	-7432
85.587	6926	-85.587	-7279
82.011	6766	-82.011	-7100
78.350	6481	-78.350	-6784
74.775	6314	-74.775	-6616
71.459	6115	-71.459	-6434
67.884	5945	-67.884	-6281
64.222	5602	-64.222	-5850
60.647	5439	-60.647	-5674
57.331	5254	-57.331	-5483
53.756	5092	-53.756	-5314
49.358	4747	-49.358	-4986
45.782	4566	-45.782	-4797
42.467	4337	-42.467	-4564
38.891	4141	-38.891	-4363
35.576	3801	-35.576	-4007
32.000	3595	-32.000	-3802
28.685	3324	-28.685	-3534
25.109	3097	-25.109	-3304
21.794	2671	-21.794	-2869
18.218	2392	-18.218	-2575
14.903	1985	-14.903	-2122
11.327	1678	-11.327	-1299

Chapter 23 Life of Rotary Actuator

The life of rotary actuator is determined by the lifetime of the SWG. Lifetime of the SWG depends on the life of wave generator bearing. It can be calculated by rotational speed and load torque just as with a general ball bearing lifetime calculation.

Table 23-1 Rotary Actuator Life

Series Name	Life	
	eRobxxF	eRobxxH
L_{10} (10% damage probability)	7,000 hr	10,000 hr
L_{50} (Average Lifetime)	35,000 hr	50,000 hr

Note: Life is based on rated rotational speed and rated torque from the ratings.

Calculation formula for life (L_h) by actual operation condition

$$L_h = L_n \times (\frac{T_r}{T_{avg}})^3 \times (\frac{n_t}{n_{avg}}) \tag{23.1}$$

Symbol	Definition
L_h	Life measured in hours.
L_n	Life of L_{10} or L_{50}.
T_r	The Rated Torque Output by the eRob Module.
T_{avg}	Average Load Torque on the SWG Output Side.
n_t	Motor Rated Rotational Speed Used for Module Rated Torque Testing (2000RPM).
n_{avg}	Average SWG Input / Motor Output Rotational Speed.

Reference: *HarmonicDrive General Catalog.pdf*

Note: Use eRob series rotary actuator within the range of "Normal operation area". Using it beyond "Normal operation area" may result in damaging eRob series rotary actuator earlier than usual. Lubricant life such as for abrasion on the tooth surface is not taken into consideration in the graph described above.

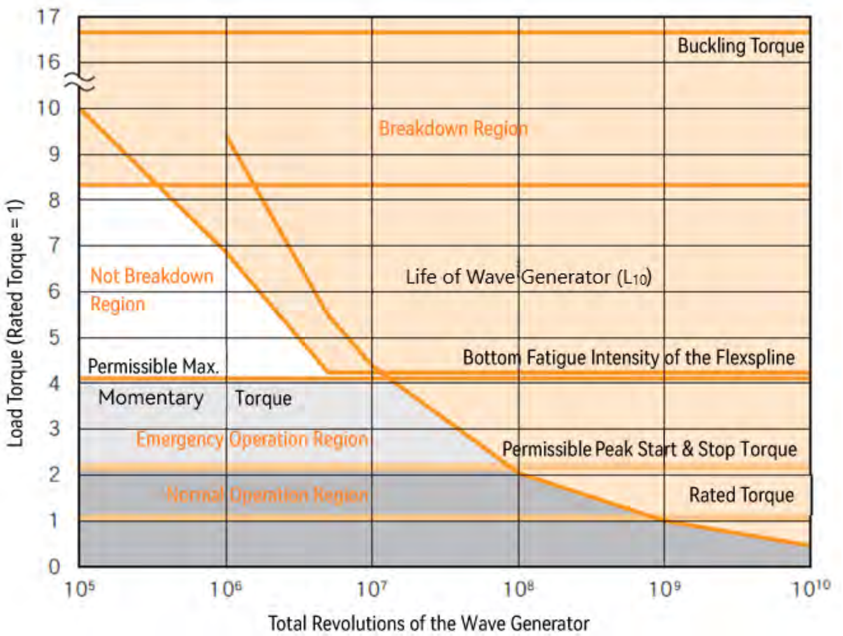


Figure 23-1 Relationship Between Strength and Lifetime of the Rotary Actuator

Chapter 24 Instruction of Pulse Direction Control Mode

eRob rotary actuator supports pulse direction control mode which can control the motion of eRob by inputting pulse signal and direction signal externally.

Note:

(1) Only EtherCAT version rotary actuator is equipped with the interface of pulse direction control mode (Model:eRobxxxxxxxx-xx-18**E**x).

(2) The wiring of pulse direction control mode refers to Figure 6-13 and Figure 6-14 in Section 6.5.

24.1 Parameter configuration of pulse direction control mode

Steps for Parameter Configuration of Pulse Direction Control Mode The steps for parameter configuration of pulse direction control mode are as shown in Figure 24-1.

(1) Connect eTunner and enter the "PD Set" interface where the user can monitor the number of pulses received by the eRob.

(2) Tick "Pulse direction control mode" to activate the function.

(3) Configure the "direction of pulse"

- "0" indicates pulse-direction positive logic: the motion direction of the eRob is the same as that of external input pulse.
- "1" indicates pulse-direction inverse logic : the motion direction of the eRob is opposite to that of external input pulse.

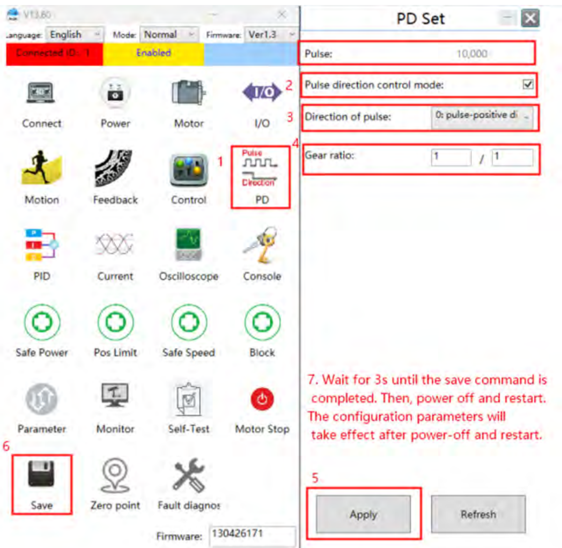


Figure 24-1 Parameter configuration of pulse direction control mode

(4) Configure Gear Ratio

$$N_{out} = p_{input} \times \frac{m_G}{524288} \tag{24.1}$$

Symbol	Definition
N_{out}	The amount of eRob output rotation.
p_{input}	The amount of external input pulses.
m_G	SWG Gear Ratio.

The numerator and denominator of the gear ratio are configured as 1 by default, that is, 1 pulse is input from the outside, the eRob moves 1 encoder position (count). If the user wants to configure the external input of 1000 pulses to make the eRob rotates 1 circle, the gear ratio needs to be configured to 524288/1000.

(5) Click "Apply".

(6) Click "Save".

(7) Wait for 3s until the save command is completed. Then, power off and restart. The configuration parameters will take effect after power-off and restart.

Configure the I/O Port to Send Enable Command Users can configure I/O port to send enable command in the "I/O settings" of eTunner. The setting steps are as shown in Figure 24-2.

(1) Connect the PC and open the "I/O settings" interface.
(2) Set "DIn03" to "Enable".
(3) Tick "Inverse" of DIn03.
(4) Click "Apply" and the motor is enabled.
(5) Click "Save".
(6) Wait for 3s until the save command is completed. Then, power off and restart. The configuration parameters will take effect after power-off and restart.

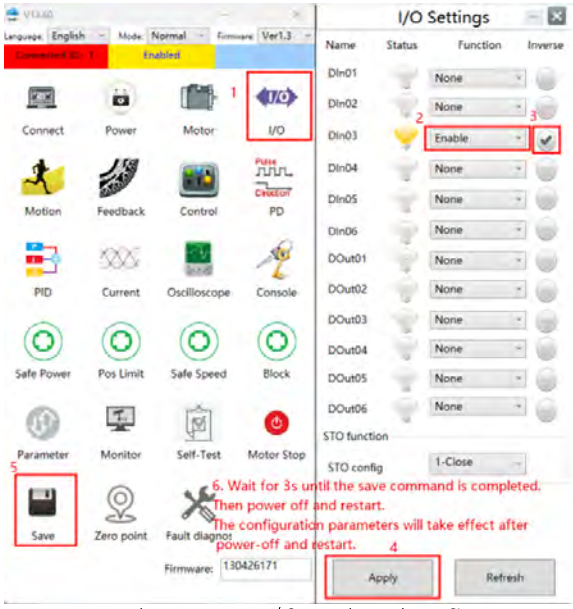
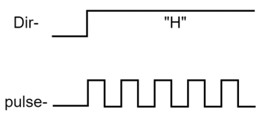
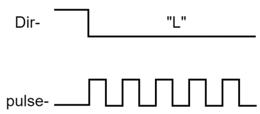
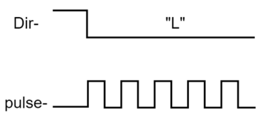
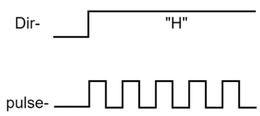


Figure 24-2 I/O settings in PC

24.2 Pulse direction motion control

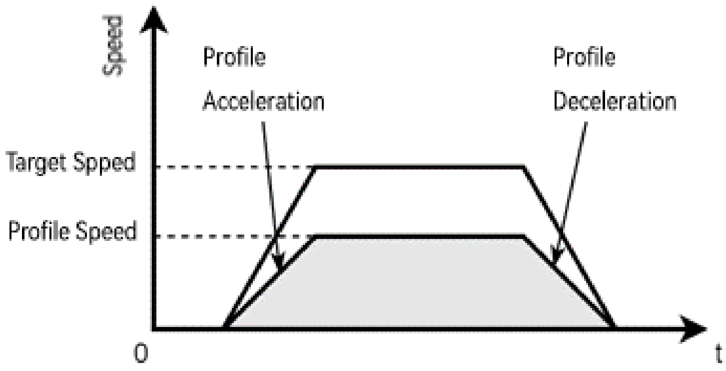
After the parameter configuration of pulse direction control is completed, the eRob will be enabled automatically when powering on. At this time, send pulse direction signal to the eRob, the eRob will start to move while receiving the external pulse direction signal. The pulse direction control command is as shown in Table 24-1.

Table 24-1 Pulse direction command

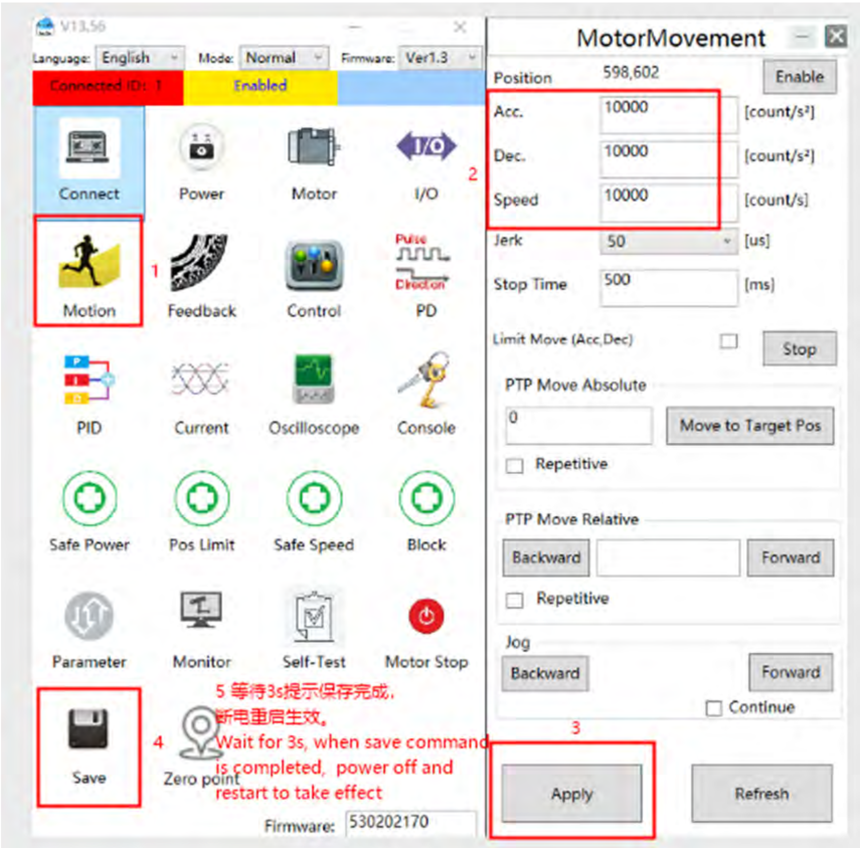
Command	Pulse Direction Logic	Motor Positive Rotation	Motor Positive Rotation
Begin Direction Command	Positive Logic	 Dir- "H" pulse-	 Dir- "L" pulse-
Begin Direction Command	Inverse Logic	 Dir- "L" pulse-	 Dir- "H" pulse-

The user can control the motion position and speed of the eRob by adjusting the number and the frequency of external pulses sent. The position of the eRob is equal to the number of pulses received by the eRob. The motion speed of eRob is limited by the motion parameters, as shown in Figure 24-3a.

(1) When the target speed of the eRob is greater than the profile speed, the eRob operates at the profile speed.
(2) When the target speed of the eRob is less than the profile speed, the eRob operates at the target speed.



(a) Motion of the eRob is limited by motion configuration



(b) Motion parameter configuration

Figure 24-3 Motion Related Illustration

The user can reduce the external pulse sending frequency or configure a greater profile speed so that the target speed of eRob is less than the profile speed, thereby making the eRob operate at the target speed. The motion parameter configuration is as shown in Figure 24-3b.

★ When using Pulse Direction control mode, the Output Shaft Actual Position can be determined via the CAN or RS485 communication interface:

(1) **CAN Interface**

The output shaft actual position can be determined by sending & receiving data messages via the CAN communication interface using CAN-custom communication protocol. For detailed instructions, please refer to the eRunner User Manual Chapter 7

Take servo ID=1 as an example.

Table 24-2 CAN-Custom Messages for Reading Output Shaft Actual Position

COB-ID	Message	Description
641	00 02	Read output shaft actual position
5C1	00 15 8A 06 3E	Return output shaft actual position

(2) **RS485 Interface**

★

The output shaft actual position can be determined by sending & receiving data messages via the RS485 communication interface using Modbus communication protocol. For detailed instructions, please refer to the eRob Modbus RTU User Manual

Take servo ID=1 as an example.

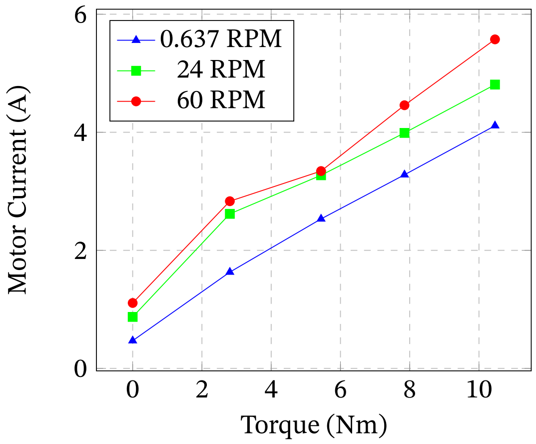
Table 24-3 Modbus Messages for Reading Output Shaft Actual Position

Direction	Message	Comment
Send→	01 03 00 66 00 02 24 14	Read output shaft actual position
Receive←	01 03 04 00 15 8A 06 0C 95	Return output shaft actual position

Chapter 25 Output Characteristic Curve

25.1 eRob Motor Current, Output Torque, Rotational Speed Curves

The following are the motor current, output torque, rotational speed curves and test parameters of some eRob models. The motor current is the actual motor current. For details, please refer to Table 25-3 Motor actual current (0x6078).

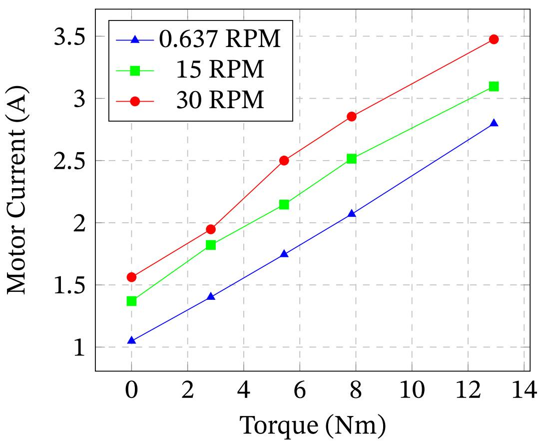


(a) Plot

Motor Current / Output Torque / Rotational Speed	0 Nm	2.806 Nm	5.440 Nm	7.849 Nm	10.463 Nm
0.637 RPM	0.469 A (39 °C)	1.631 A (41 °C)	2.532 A (39 °C)	3.280 A (36 °C)	4.111 A (40 °C)
24 RPM	0.872 A (40 °C)	2.618 A (42 °C)	3.272 A (38 °C)	3.989 A (37 °C)	4.808 A (41 °C)
60 RPM	1.108 A (40 °C)	2.832 A (37 °C)	3.343 A (41 °C)	4.458 A (39 °C)	5.574 A (43 °C)

(b) Parameter

Figure 25-1 eRob70H50I Motor Current, Output Torque, Rotational Speed Curve

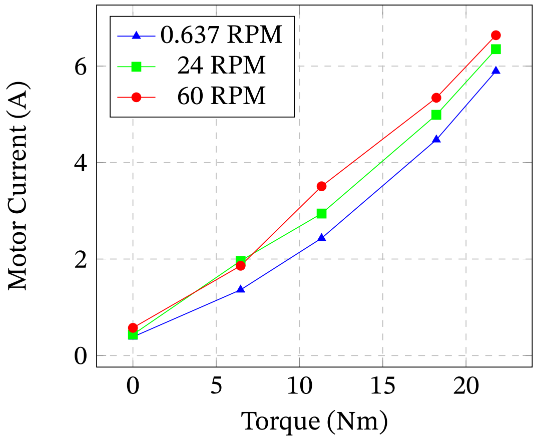


(a) Plot

Motor Current / Output Torque / Rotational Speed	0 Nm	2.826 Nm	5.440 Nm	7.849 Nm	12.922 Nm
0.637 RPM	1.049 A (37 °C)	1.402 A (36 °C)	1.745 A (36 °C)	2.069 A (36 °C)	2.797 A (36 °C)
15 RPM	1.370 A (40 °C)	1.821 A (39 °C)	2.146 A (38 °C)	2.515 A (39 °C)	3.096 A (41 °C)
30 RPM	1.562 A (39 °C)	1.947 A (36 °C)	2.500 A (35 °C)	2.854 A (35 °C)	3.475 A (38 °C)

(b) Parameter

Figure 25-2 eRob70H100I Motor Current, Output Torque, Rotational Speed Curve

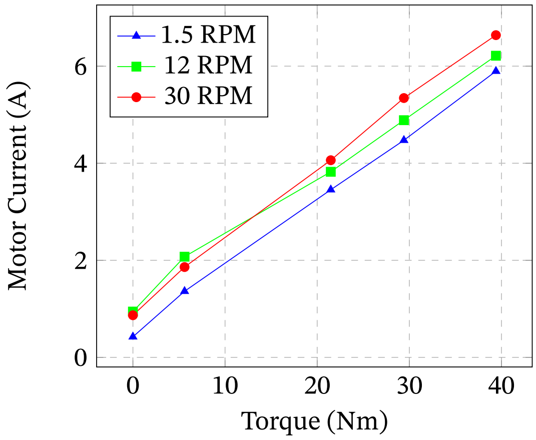


(a) Plot

Motor Current / Output Torque / Rotational Speed	0 Nm	6.465 Nm	11.327 Nm	18.218 Nm	21.794 Nm
0.637 RPM	0.386 A (40 °C)	1.362 A (37 °C)	2.432 A (42 °C)	4.473 A (40 °C)	5.896 A (38 °C)
24 RPM	0.435 A (39 °C)	1.963 A (38 °C)	2.943 A (43 °C)	4.990 A (40 °C)	6.350 A (38 °C)
60 RPM	0.574 A (40 °C)	1.861 A (40 °C)	3.508 A (38 °C)	5.343 A (41 °C)	6.639 A (40 °C)

(b) Parameter

Figure 25-3 eRob80H50I Motor Current, Output Torque, Rotational Speed Curve

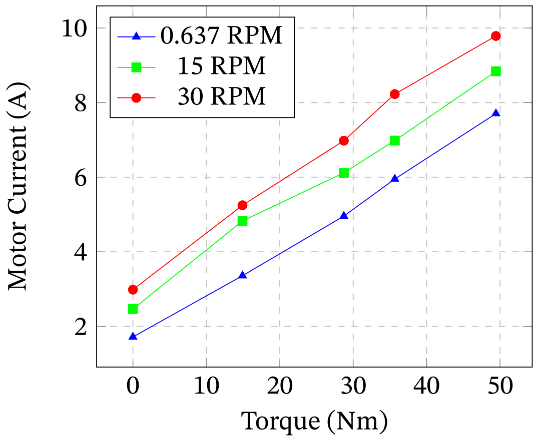


(a) Plot

Motor Current / Output Torque / Rotational Speed	0 Nm	5.604 Nm	21.475 Nm	29.409 Nm	39.398 Nm
1.5 RPM	0.424 A (38 °C)	1.362 A (41 °C)	3.454 A (38 °C)	4.473 A (40 °C)	5.896 A (41 °C)
12 RPM	0.944 A (40 °C)	2.075 A (38 °C)	3.824 A (42 °C)	4.887 A (42 °C)	6.215 A (40 °C)
30 RPM	0.868 A (41 °C)	1.861 A (39 °C)	4.062 A (44 °C)	5.343 A (42 °C)	6.639 A (40 °C)

(b) Parameter

Figure 25-4 eRob80H100I Motor Current, Output Torque, Rotational Speed Curve

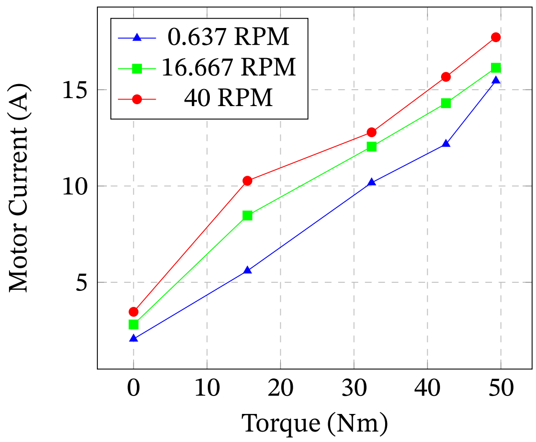


(a) Plot

Motor Current / Output Torque / Rotational Speed	0 Nm	14.923 Nm	28.726 Nm	35.664 Nm	49.437 Nm
0.637 RPM	1.716 A (44 °C)	3.358 A (42 °C)	4.957 A (44 °C)	5.951 A (39 °C)	7.705 A (43 °C)
15 RPM	2.464 A (45 °C)	4.826 A (42 °C)	6.117 A (44 °C)	6.982 A (40 °C)	8.838 A (40 °C)
30 RPM	2.984 A (44 °C)	5.247 A (42 °C)	6.978 A (44 °C)	8.228 A (39 °C)	9.787 A (38 °C)

(b) Parameter

Figure 25-5 eRob90H100I Motor Current, Output Torque, Rotational Speed Curve

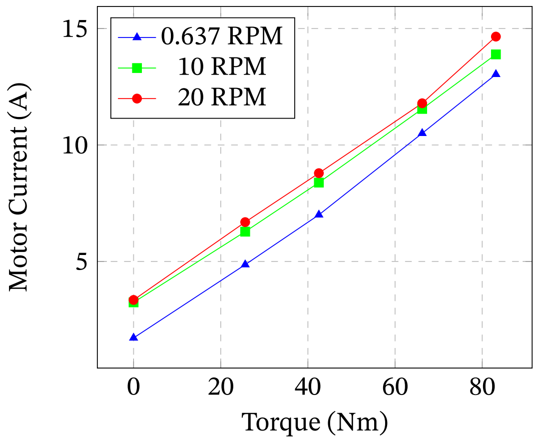


(a) Plot

Motor Current / Output Torque / Rotational Speed	0 Nm	15.498 Nm	32.404 Nm	42.519 Nm	49.320 Nm
0.637 RPM	2.059 A (39 °C)	5.596 A (39 °C)	10.173 A (40 °C)	12.173 A (41 °C)	15.466 A (41 °C)
16.667 RPM	2.808 A (39 °C)	8.468 A (39 °C)	12.044 A (41 °C)	14.301 A (42 °C)	16.140 A (43 °C)
40 RPM	3.465 A (40 °C)	10.272 A (38 °C)	12.789 A (39 °C)	15.667 A (40 °C)	17.725 A (42 °C)

(b) Parameter

Figure 25-6 eRob110H50I Motor Current, Output Torque, Rotational Speed Curve

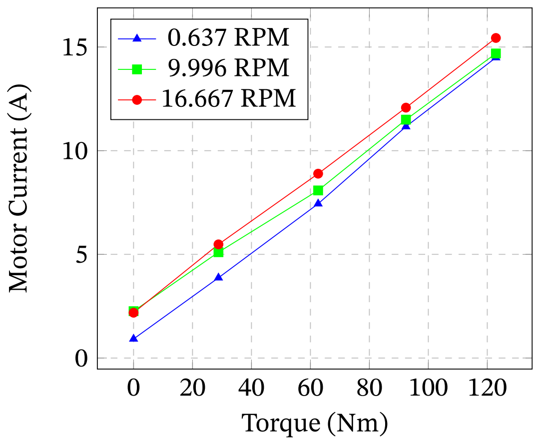


(a) Plot

Motor Current / Output Torque / Rotational Speed	0 Nm	25.609 Nm	42.519 Nm	66.222 Nm	83.142 Nm
0.637 RPM	1.716 A (35 °C)	4.862 A (35 °C)	7.001 A (37 °C)	10.501 A (40 °C)	13.033 A (39 °C)
10 RPM	3.243 A (38 °C)	6.279 A (36 °C)	8.385 A (38 °C)	11.548 A (39 °C)	13.890 A (41 °C)
20 RPM	3.347 A (41 °C)	6.688 A (36 °C)	8.790 A (38 °C)	11.791 A (40 °C)	14.653 A (41 °C)

(b) Parameter

Figure 25-7 eRob110H100I Motor Current, Output Torque, Rotational Speed Curve

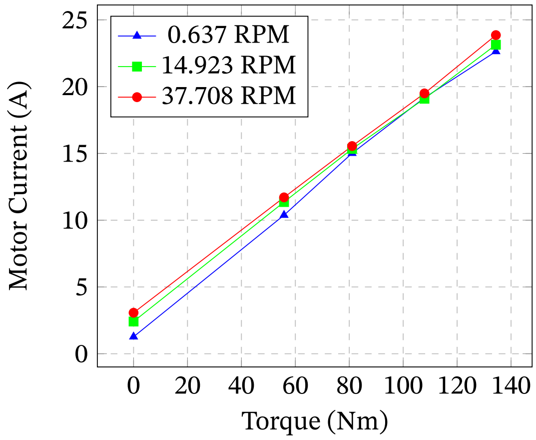


(a) Plot

Motor Current / Output Torque / Rotational Speed	0 Nm	28.803 Nm	62.621 Nm	92.407 Nm	122.929 Nm
0.637 RPM	0.920 A (38 °C)	3.870 A (40 °C)	7.440 A (38 °C)	11.161 A (40 °C)	14.488 A (40 °C)
9.996 RPM	2.260 A (41 °C)	5.103 A (39 °C)	8.083 A (40 °C)	11.497 A (42 °C)	14.688 A (39 °C)
16.667 RPM	2.185 A (41 °C)	5.482 A (39 °C)	8.891 A (41 °C)	12.076 A (42 °C)	15.436 A (38 °C)

(b) Parameter

Figure 25-8 eRob110H120I Motor Current, Output Torque, Rotational Speed Curve

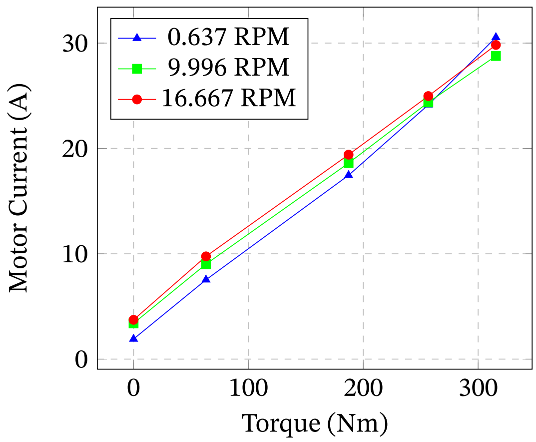


(a) Plot

Motor Current / Output Torque / Rotational Speed	0 Nm	55.804 Nm	81.043 Nm	107.886 Nm	134.383 Nm
0.637 RPM	1.269 A (41 °C)	10.377 A (37 °C)	15.012 A (41 °C)	19.168 A (42 °C)	22.632 A (39 °C)
14.923 RPM	2.412 A (40 °C)	11.359 A (38 °C)	15.337 A (43 °C)	19.094 A (42 °C)	23.137 A (38 °C)
37.708 RPM	3.068 A (40 °C)	11.708 A (40 °C)	15.550 A (43 °C)	19.494 A (41 °C)	23.858 A (39 °C)

(b) Parameter

Figure 25-9 eRob142H50I Motor Current, Output Torque, Rotational Speed Curve



(a) Plot

Motor Current / Output Torque / Rotational Speed	0 Nm	63.059 Nm	187.186 Nm	256.616 Nm	315.476 Nm
0.637 RPM	1.908 A (36 °C)	7.531 A (41 °C)	17.455 A (42 °C)	24.139 A (40 °C)	30.545 A (42 °C)
9.996 RPM	3.399 A (38 °C)	9.018 A (40 °C)	18.606 A (40 °C)	24.374 A (43 °C)	28.779 A (40 °C)
16.667 RPM	3.734 A (38 °C)	9.755 A (40 °C)	19.410 A (39 °C)	24.971 A (41 °C)	29.825 A (40 °C)

(b) Parameter

Figure 25-10 eRob142H120I Motor Current, Output Torque, Rotational Speed Curve

The transfer function block diagram of motor current to output torque is as shown in Figure 25-11.

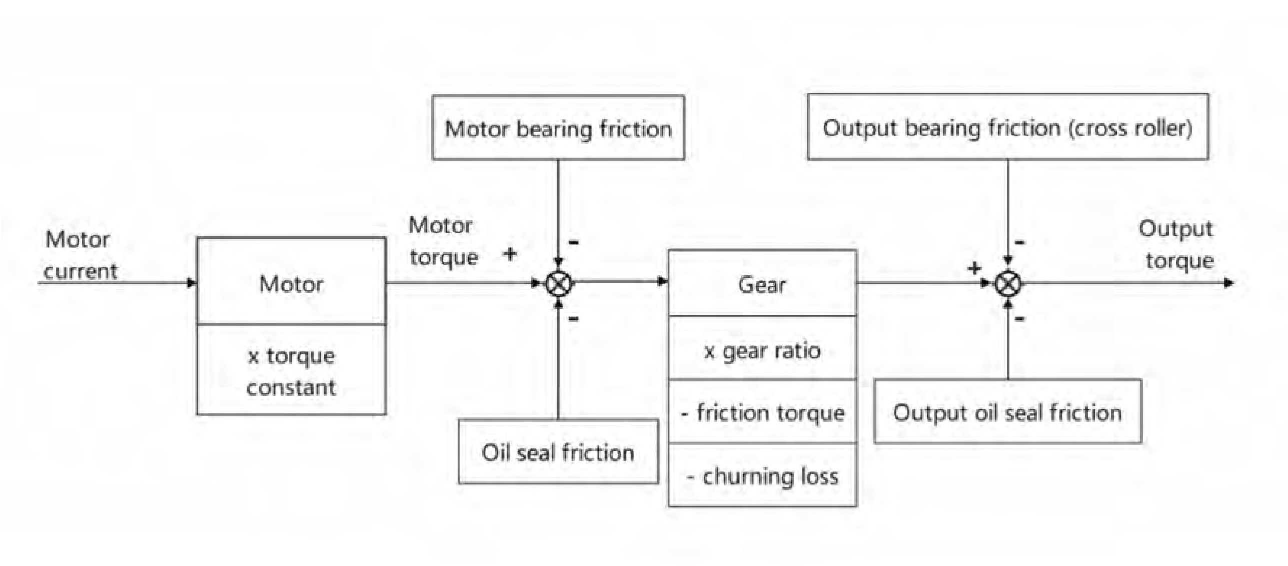


Figure 25-11 Transfer function block diagram of motor current to output torque

Therefore, the motor needs efficient initial current to obtain the output torque.

Meanwhile, all friction torques have different dynamic friction and static friction.

The contact stress of sealing components is different at different temperature (The rigidity of rubber components changes).

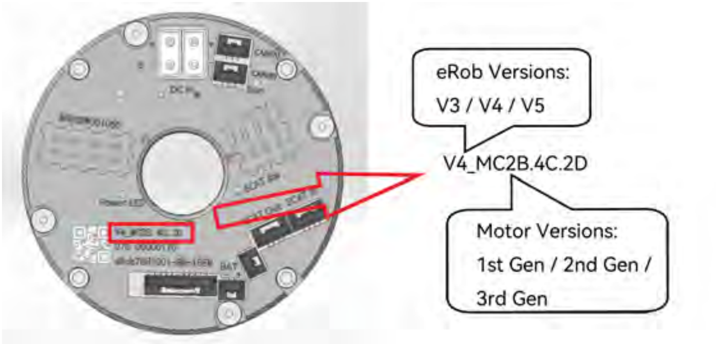


Figure 25-12 eRob Rotary Actuator Version Identification

Temperature also causes differences in the viscosity coefficient of the grease. Thermal expansion and contraction change in size, the higher the temperature, the lower the torque constant of the motor.

Inherent tolerances of the component sizes create different contact stresses at the seal. The viscosity coefficient is the same, the churning loss is nearly proportional to the square of the rotational speed.

Under the combined effect of the above factors, the transfer function of the harmonic reducer is not an ideal lossless model, and the relationship between the motor current and the output torque is also nonlinear.

On the whole, when the load is equal, the lower the temperature, the higher the speed, and the more current the motor needs.

25.2 eRob Rotary Actuator Motor Parameter

25.2.1 eRob Rotary Actuator Version Identification

As shown in Figure 25-12.

25.2.2 Motor Parameter

Table 25-1 eRob Rotary Actuator Motor Parameter Sheet

eRob Model	eRob70F	eRob70		eRob80		eRob90		eRob110			eRob142		eRob170	
eRob Ver. / Motor Spec.	V3_MC2	V3_MC1	V4_MC2	V3_MC1	V4_MC2 V5_MC2	V3_MC1	V3_MC2	V3_MC1	V4_MC2	V6_MC2	V3_MC1	V4_MC2	V3_MC1	V3_MC2
№ of poles	16	10	16	10	16	10	16	10	16	16	10	10	10	10
DC Link Voltage $U_{DC,\ motor}$ (DC Link)	48	48	48	48	48	48	48	48	48	48	48	48	48	48
Rated Power $P_{r,\ motor}$ (W)	75	100	100	200	146	400	293	750	750	723	1000	1000	1000	1000
Rated Torque $T_{r,\ motor}$ (Nm)	0.24	0.32	0.32	0.64	0.45	1.27	0.85	2.4	2.39	2.3	4.78	4.78	4.78	4.78
Rated Speed $n_{r,\ motor}$ (RPM)	3000	3000	3000	3000	3100	3000	3300	2000	3000	3000	2000	2000	2000	2000
Rated Current $I_{r,\ motor}$ (A)	1.91	3.3	2.55	6.9	3.4	11	6.7	20	18.6	18.9	26	22	26	22
Maximum Torque $T_{m,\ motor}$ $(N \cdot m)$	0.72	0.96	0.96	1.92	1.25	3.81	2.55	7.2	7.17	6	15	14.3	15	14.3
Maximum Current $I_{m,\ motor}$ (A)	5.9	11	7.8	16.8	10.88	29	21.44	40	61	50	56	71	56	71
Resistance line-line $R_{L,\ motor}$ (Ω)(±10%)	3.87	1.75	2	0.7	0.76	0.22	0.31	0.119	0.093	0.084	0.069	0.059	0.069	0.059
Inductance line-line $L_{L,\ motor}$ (mH)(±20%)	2.54	2.5	2.46	1.362	1.32	0.6	0.86	0.2	0.2	0.16	0.37	0.38	0.37	0.38
Voltage Constant $K_{e,\ motor}$ (V/kRPM)(±5%)	8	8.42	8.3	8.36	8.1	8.43	8.3	8.65	8	8.1	12.2	13.5	12.2	13.5
Torque Constant $K_{T,\ motor}$ (Nm/A)	0.134	0.075	0.132	0.101	0.134	0.088	0.14	0.112	0.132	0.134	0.153	0.22	0.153	0.22

NOTE: Please note that the motor parameters shown in Table 25-1 are the factory parameters of the motor. The rated torque of the motor is not equal to the rated torque of the module. The rated torque value of the motor is suited for general robot model calculation use only. The rated torque of the eRob module is based on the rated torque of the SWG gearbox. These two values (eRob module rated torque & motor rated torque) are not equal, and for the rated torque of the eRob module, please refer to Section 2.2.

Furthermore, it is important to understand that the rated current in the driver have no correlation with the rated torque of the module. The rated current in the driver is set based on the allowable heat capacity of the entire module.

The calculation formula of eRob torque constant (Nm/A) and output torque (Nm) :

(1) eRob Torque Constant (usually 50%~70%. The efficiency curve is shown in Figure 25-13)

$$K_{T,\ eRob} = K_{T,\ motor} \times m_G \times \eta_t \tag{25.1}$$

Symbol	Definition
$K_{T,\ eRob}$	The eRob module torque constant.
$K_{T,\ motor}$	The motor torque constant. (as shown in Table 25-1).
m_G	SWG Gear Ratio. (as shown in Table 2-1).
η_t	The efficiency of SWG transmission. (as shown in Figure 25-13).

(2) eRob Output Torque (can be obtained by the object dictionary 0x6078. The description of the object dictionary 0x6078 is shown in Table 25-2.)

$$T_{out} = K_{T,\ eRob} \times I_{a,\ motot} \tag{25.2}$$

Symbol	Definition
T_{out}	The eRob output torque.
$K_{T,\ eRob}$	The eRob module torque constant.
$I_{a,\ motor}$	The actual current input of motor.

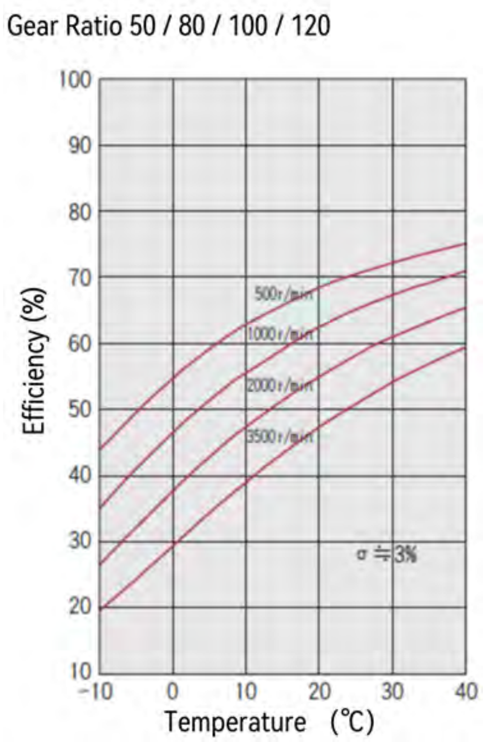


Figure 25-13 Efficiency at Rated Torque

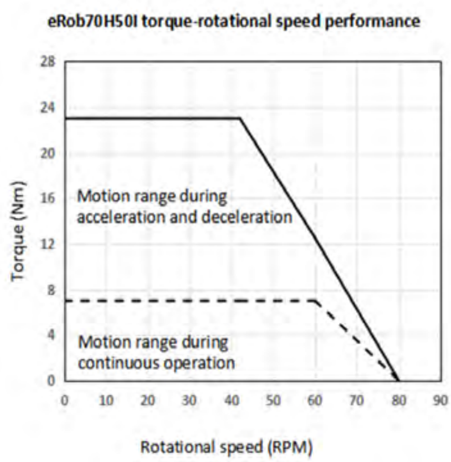
Table 25-2 Motor Actual Current (0x6078)

Index	0x6078	Object	Variation	Name	Motor Actual Current
Sub-index	PDO Mapping	Read-write Operation	Data Format	Unit	Description
0x00	TxPDO	Read Only	INT16	1‰	The motor actual current is the value obtained by calculating the sum of momentary three-phase current value of the motor when sampling. It is displayed by the permillage of the rated current (obtained by object dictionary 0x6075). $I_{motor\ actual} = 0x6078\ value \times \frac{(0x6075\ value)}{1000}$

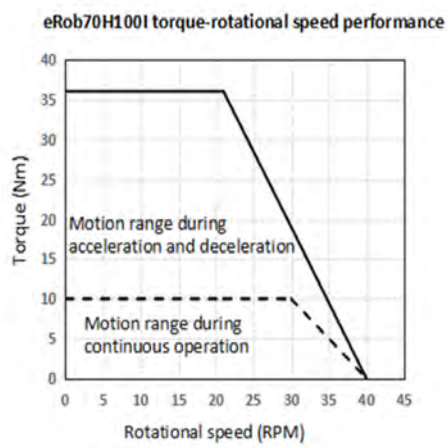
Table 25-3 Rated Current (0x6075)

Index	0x6075	Object	Variation	Name	Rated Current
Sub-index	PDO Mapping	Read-write Operation	Data Format	Unit	Description
0x00	NO	Read/Write	UDINT32	mA	This object index corresponds to the “Continuous current” in “Safe Power” interface in eTunner.

25.3 eRob Torque, Rotational Speed Curves

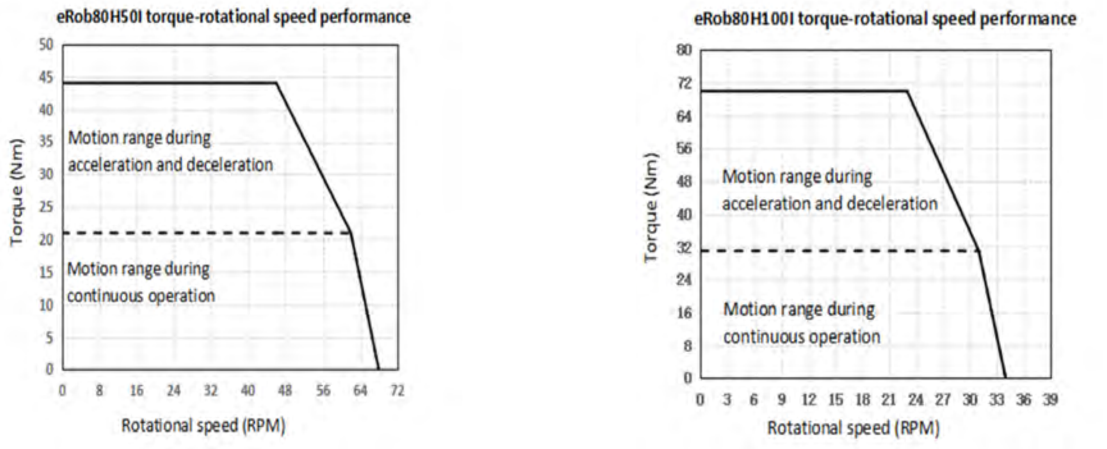


(a) eRob70H50I



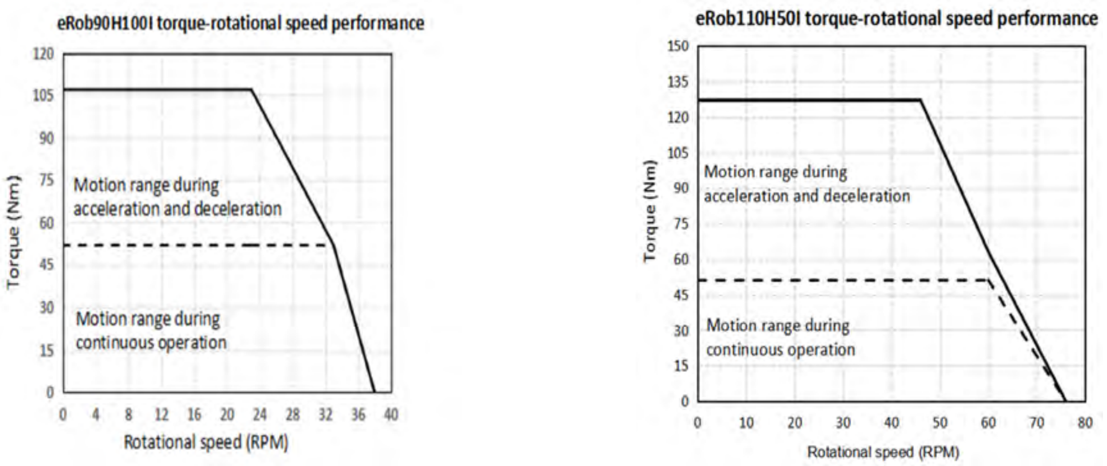
(b) eRob70H100I

Figure 25-14 eRob Torque, Rotational Speed Curve



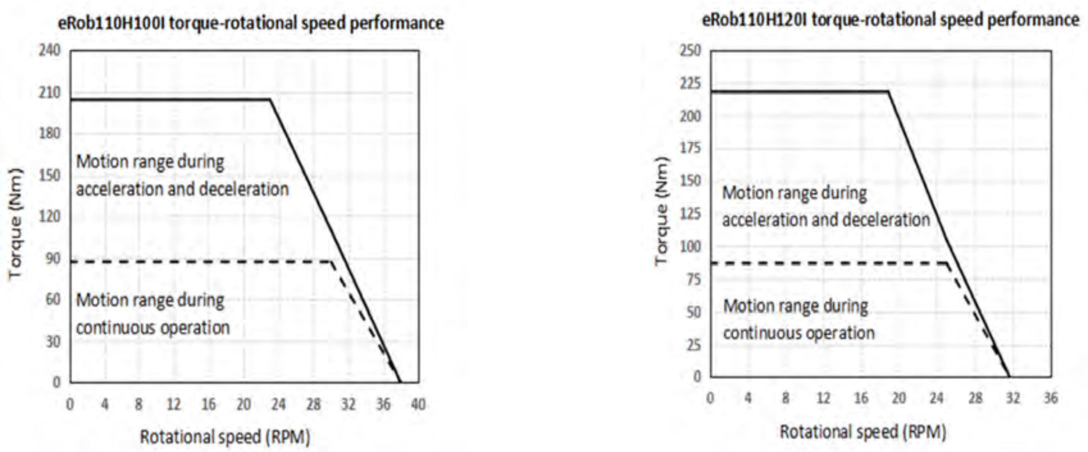
(a) eRob80H50I (b) eRob80H100I

Figure 25-15 eRob Torque Rotational Speed Curve



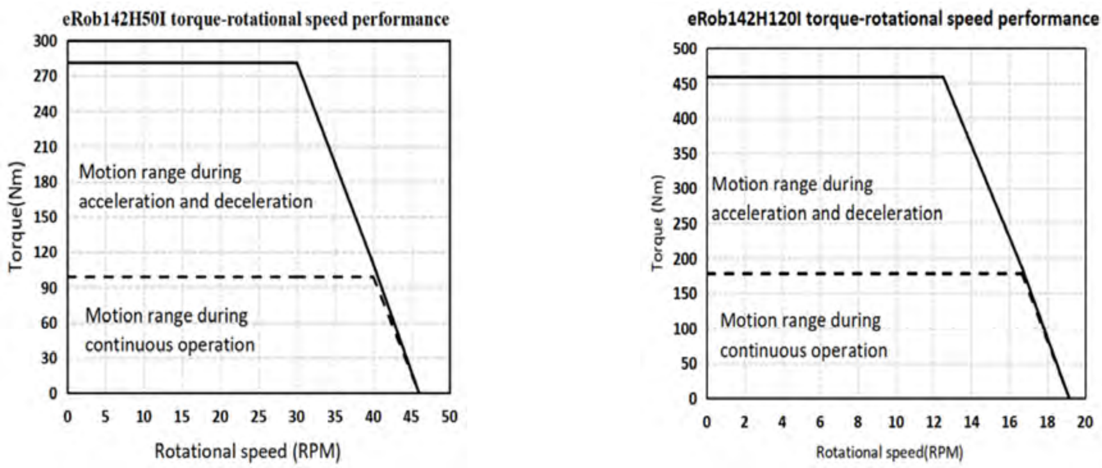
(a) eRob90H100I (b) eRob110H50I

Figure 25-16 eRob Torque Rotational Speed Curve



(a) eRob110H100I (b) eRob110H120I

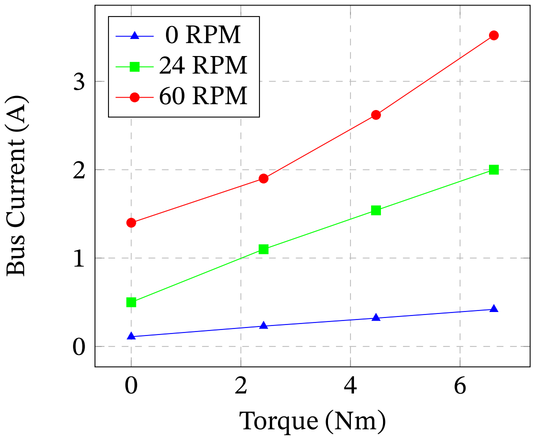
Figure 25-17 eRob Torque Rotational Speed Curve



(a) eRob142H50I (b) eRob142H120I

Figure 25-18 eRob Torque Rotational Speed Curve

25.4 eRob Module Bus Current, Output Torque, Rotational Speed Curves

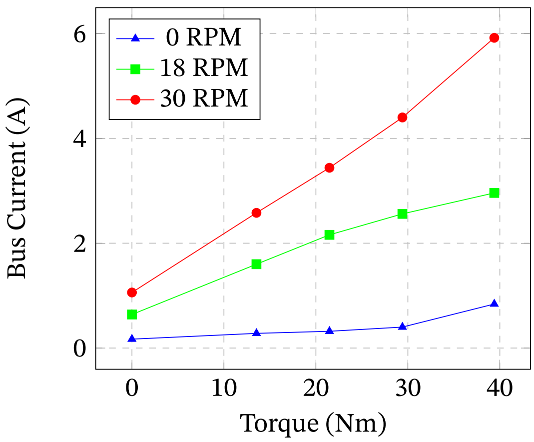


(a) Plot

Bus Current \ Output Torque / Rotational Speed	0 Nm	2.415 Nm	4.466 Nm	6.617 Nm
0 RPM	0.11 A (39 °C)	0.23 A (41 °C)	0.32 A (39 °C)	0.42 A (38 °C)
24 RPM	0.50 A (40 °C)	1.10 A (42 °C)	1.54 A (38 °C)	2.00 A (37 °C)
60 RPM	1.40 A (40 °C)	1.90 A (37 °C)	2.62 A (41 °C)	3.52 A (39 °C)

(b) Parameter

Figure 25-19 eRob70H50I Bus Current, Output Torque, Rotational Speed Curve

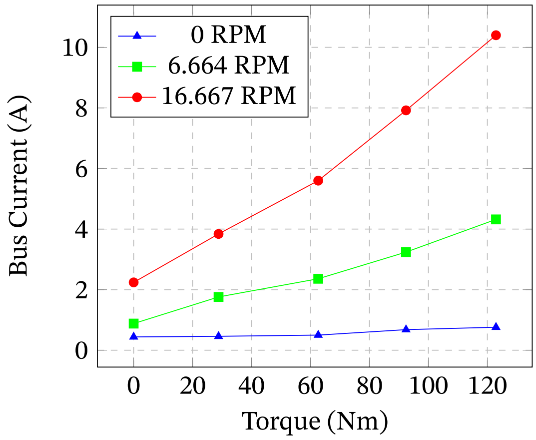


(a) Plot

Bus Current \ Output Torque / Rotational Speed	0 Nm	13.539 Nm	21.475 Nm	29.409 Nm	39.398 Nm
0 RPM	0.17 A (38 °C)	0.28 A (41 °C)	0.32 A (38 °C)	0.40 A (40 °C)	0.84 A (41 °C)
18 RPM	0.64 A (40 °C)	1.60 A (38 °C)	2.16 A (42 °C)	2.56 A (42 °C)	2.96 A (40 °C)
30 RPM	1.06 A (41 °C)	2.58 A (39 °C)	3.44 A (44 °C)	4.40 A (42 °C)	5.92 A (40 °C)

(b) Parameter

Figure 25-20 eRob80H100I Bus Current, Output Torque, Rotational Speed Curve

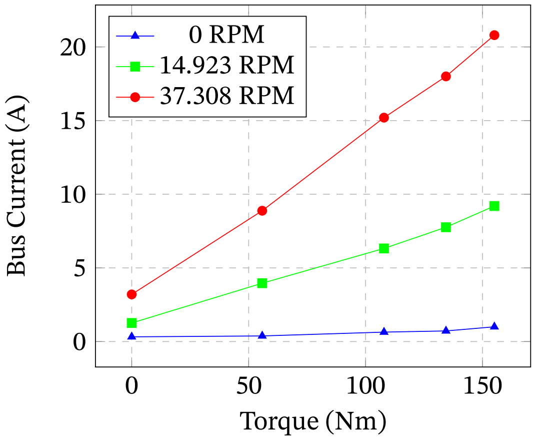


(a) Plot

Bus Current \ Output Torque / Rotational Speed	0 Nm	28.803 Nm	62.621 Nm	92.407 Nm	122.929 Nm
0 RPM	0.44 A (35 °C)	0.46 A (35 °C)	0.50 A (37 °C)	0.68 A (40 °C)	0.76 A (39 °C)
6.664 RPM	0.88 A (38 °C)	1.76 A (36 °C)	2.36 A (38 °C)	3.24 A (39 °C)	4.32 A (41 °C)
16.667 RPM	2.24 A (41 °C)	3.84 A (36 °C)	5.60 A (38 °C)	7.92 A (40 °C)	10.40 A (41 °C)

(b) Parameter

Figure 25-21 eRob110H120I Bus Current, Output Torque, Rotational Speed Curve

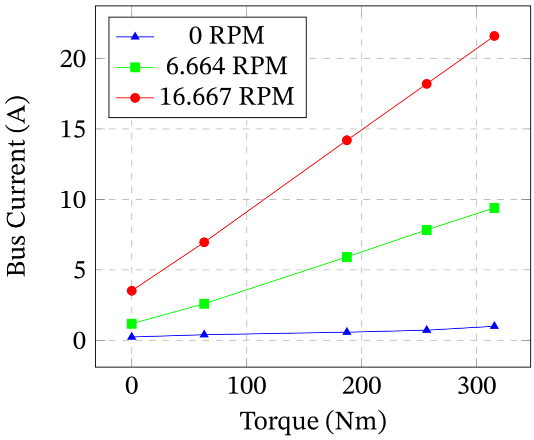


(a) Plot

Bus Current \ Output Torque / Rotational Speed	0 Nm	55.804 Nm	107.886 Nm	134.383 Nm	155.084 Nm
0 RPM	0.32 A (41 °C)	0.38 A (37 °C)	0.64 A (41 °C)	0.72 A (42 °C)	1.00 A (39 °C)
14.923 RPM	1.26 A (40 °C)	3.96 A (38 °C)	6.32 A (43 °C)	7.76 A (42 °C)	9.20 A (38 °C)
37.308 RPM	3.20 A (40 °C)	8.88 A (40 °C)	15.20 A (43 °C)	18.00 A (41 °C)	20.80 A (39 °C)

(b) Parameter

Figure 25-22 eRob142H50I Bus Current, Output Torque, Rotational Speed Curve



(a) Plot

Bus Current \ Output Torque / Rotational Speed	0 Nm	63.059 Nm	187.186 Nm	256.616 Nm	315.476 Nm
0 RPM	0.24 A (36 °C)	0.40 A (41 °C)	0.58 A (42 °C)	0.72 A (40 °C)	1.00 A (42 °C)
6.664 RPM	1.18 A (38 °C)	2.60 A (40 °C)	5.92 A (40 °C)	7.84 A (43 °C)	9.40 A (40 °C)
16.667 RPM	3.52 A (38 °C)	6.96 A (40 °C)	14.20 A (39 °C)	18.20 A (41 °C)	21.60 A (40 °C)

(b) Parameter

Figure 25-23 eRob142H120I Bus Current, Output Torque, Rotational Speed Curve

Chapter 26 Troubleshooting Instruction

Table 26-1 Troubleshooting and Solutions

Problem Classification	Alarm Prompt or Phenomenon	Possible Causes	Solutions
CAN Communication Abnormality	RUN LED indicator does not light up	1. Incorrect power supply used. 2. Excessive voltage at the eRob's 48V power input, causing hardware failure.	1. Use a 48VDC power supply and pay attention to the polarity. 2. It is recommended to use our proprietary ePower power supply.
	RUN LED indicator is normal, but clicking the "Connection Test" button in the PC prompts: please check if the driver is powered on.	1. The CAN interface of the joint is not properly connected with the USBCAN debugger. 2. Strong current is fed into the CAN interface, causing partial components of the CAN interface to burn out and communication to be interrupted.	1. Check the CAN wiring order to ensure a good connection. 2. Check the resistance of the CAN interface.
	The PC connection test recognizes fewer CAN IDs than the actual number of connections.	1. There are slave devices on the CAN bus with the same CAN ID.	1. Connect each axis separately, reset the CAN IDs to ensure unique IDs.
	After connecting to the PC, the data displayed on the status monitoring interface fluctuates abnormally.	1. There are slave devices on the CAN bus with the same CAN ID. 2. The wiring of the joint's CAN port does not match the wiring of the USBCAN debugger's port.	1. Connect each axis separately, reset the CAN IDs to ensure unique IDs. 2. Check the wiring of the joint's CAN port with the USBCAN debugger to ensure a one-to-one correspondence.
EtherCAT Communication Abnormality	Ethernet port indicator does not light up Ethernet port indicator flashes for a while and then stops flashing.	1. Poor wiring of the EtherCAT bus; 2. Hardware failure of the eRob's PCB.	1. Check the wiring order and connectivity of the network cable to ensure a good connection.

26.1 Troubleshooting Steps for Abnormal CAN Communication

26.1.1 "Check whether the drive is powered on" window pops up when click "connect" for test in the host computer

According to the following steps to check when the host computer cannot be connected as shown in Table 26-1.

(1) **Check "Run LED" indicator status of eRob rotary actuator.**
When the eRob runs normally, the "Run LED" indicator is breathing and flashing. If the operation status is abnormal, the CAN communication cannot be connected.

(2) **Check the voltage and the wiring of the power supply when "Run LED" indicator status is abnormal.**
  (1) Check the positive and negative wiring sequence of the power supply, please refer to Section 6.1.
  (2) The voltage of power supply is DC24V 48V when the eRob works properly (For the permissible minimum input voltage, please refer to Section 3.3. Use a multi-meter to measure the voltage, check whether the voltage is within the voltage range.
  (3) Power off the power. Then connect the oscilloscope to measure waveform outputted by voltage at the moment of powering on. Check whether there is overvoltage phenomenon (>60V). Please refer to Section 3.2.

(3) **"Check whether the drive is powered on" window pops up when click "connect" for test in the host computer when "Run LED" indicator status is abnormal, check CAN wiring.**

  (1) Power off the eRob. Check the wiring between CAN interface and USBCAN debugger of the eRob, please refer to Chapter 13. Make sure that the crimp terminals of the debugger and the CAN wire cores are connected effectively, the wiring sequence is correct, and the wires are conductive.

  (2) Unplug and plug the USB wires. Make sure the effective connection between USB wires, USB-CAN debugger and computer USB interface.

  (3) Power off and restart the PC, click "Connect" for test. Check whether the PC identifies CANID normally.

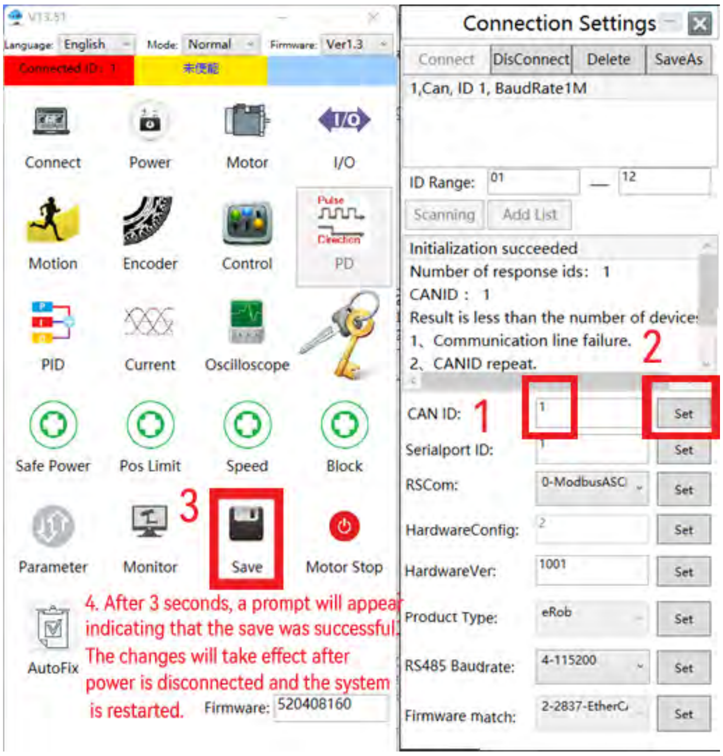
(4) **If the host computer still reminds that "Check the driver is powered on", power off the rotary actuator and use a multimeter to measure the CAN interface resistance value of rotary actuator.**

The normal resistance measurement value of CAN_L to CAN_GND is about 61KΩ~65KΩ, and the normal resistance measurement value of CAN_H to CAN_GND is about 61KΩ~65KΩ. The normal measurement value is as shown in Figure 26-1a. The abnormal resistance measurement value is as shown in Figure 26-1b. The resistance measurement value of CAN_L to CAN_H is about 2KΩ.

If the resistance value is abnormal, please confirm whether the CAN wire is plugged or unplugged when powering on during operation. Plugging or unplugging CAN wire when it is powered will easily damage to CAN interface.

(a) Normal CAN communication resistance measurement value

(b) Abnormal CAN communication resistance measurement value



(c) CANID modification steps

Figure 26-1 CAN Communication

26.1.2 The number of CANID identified by the host computer connection test is less than the actual CANID number of connection

(1) Check the wiring between the eRob CAN interface and the USB CAN Debugger, and the wiring of the CAN interface between the eRob rotary actuators (please refer to Chapter 14). Make sure the wire correspondence is in sequence and the wires are conductive.

(2) Power off the eRob, and use the USB CAN Debugger to connect each eRob respectively. Then power on the eRob, connect to the host computer, and open the "Connection Settings" interface. Reset CANID (The steps are shown in Figure 26-1c) to make sure the ID of each rotary actuator is unique.

(3) Power off the eRob, and re-cascade the CAN bus networking (refer to Section 6.2). Then power the eRob and open the connection interface in the host computer to reconnect the test

26.1.3 The data displayed on "Status Monitor" interface jumps abnormally when the host computer is connected.

(1) Check the wiring between the CAN interface of the eRob and the USB CAN Debugger, and the wiring of the CAN interface between eRob rotary actuators (please refer to Chapter 13 and Section 6.2). Make sure the wire correspondence is in sequence and the wires are conductive.
(2) Power off the eRob, and use the USB CAN Debugger connect each eRob respectively. Then power the eRob, connect to the host computer and open the "Connection Settings" interface. Reset CANID (The steps are as shown in Figure 26-1c) to make sure the ID of each rotary actuator is unique.
(3) Power off the rotary actuator, and re-cascade the CAN bus networking (refer to Section 6.2). Then power the eRob and open the "Connection Setting" interface in the host computer to reconnect the test.

26.2 Troubleshooting Steps for Abnormal EtherCAT Communication

(1) Please provide the brand and model of the EtherCAT master controller you are using, so that our technical support engineer can confirm if it is within the compatible range.
(2) Check the EtherCAT master controller and ensure it is functioning properly.
(3) Check the status of the "Run LED" indicator on the eRob module.
When the eRob is operating normally, the "Run LED" indicator should be in a breathing flashing state. If the indicator is not in the expected state, it may indicate a problem with the EtherCAT communication connection. Please refer to Section 5.1 for more details.
(4) If the status of the "Run LED" indicator is abnormal, check the power supply voltage and wiring:
    (1) Verify the correct polarity of the power supply connections. Refer to the Section 6.1 for guidance.
    (2) Make sure the joint is powered within the range of DC24V~48V (refer to Section 3.3). Use a multimeter to measure the output voltage of the power supply and ensure it falls within this range.
    (3) Disconnect the power supply and use a physical oscilloscope to measure the voltage output waveform when the power switch is turned on. Confirm if there is any over-voltage impact (above 60V) as described in Section 3.2.
(5) If the power supply is normal and the "Run LED" is flashing correctly after power-up, but the "ECAT In LED" or "ECAT Out LED" is not lit, further check the EtherCAT wiring:
    (1) Verify the wiring order of the EtherCAT communication cable. Refer to the Section 6.3 and use a multimeter to confirm the connectivity. Ensure the wiring order is correct, and the cables are securely fixed without any looseness.
    (2) Refer to Section 5.1 reconfirm the indicator LED status of the module. If the EtherCAT indicator LED is not lit, check for any loose connections on the module's EtherCAT interface.
(6) If all the above checks are normal, perform a complete power cycle by turning off the entire system, then power on the eRob module first and the controller second. Wait for the controller to finish initializing before confirming the communication connection.
Refer to eRob CANopen and EtherCAT User Manual *Section 5.1* for the operation sequence from power-on to servo enable.
(7) Perform a cross-validation test by replacing the EtherCAT communication cable from a normal eRob module to the malfunction eRob module, then follow step 6 to confirm if the EtherCAT communication is restored to normal.

26.3 Troubleshooting Steps for Motor Stalling Error

For the reasons and handling instructions related to motor stalling error, please refer to *Section 7.2.10.* of the *eRob CANopen and EtherCAT User Manual*. You can follow the steps below for troubleshooting:

(1) Confirm whether the load torque of the connected output shaft of the joint module that triggered the error exceeds the maximum permissible value specified in Section 25.1. Please avoid exceeding this maximum value.
(2) Check for any interference between the connected part of the joint module's output shaft and the external components, and eliminate any potential external interference.
(3) Use the self-check function in the eTunner_V13.70 PC software to perform self-diagnostic tests and check if the module parameters and motion status are normal.

Note: Ensure that the module is in an unloaded state during the self-diagnostic test. If the module is not unloaded, only retrieve the module information without conducting the full test. If the error is displayed on the status monitoring interface of the eTunner software, clear the error by clicking the enable button on the motion interface, then click the motor stop button on the main interface before performing the self-diagnostic test. Refer to our official YouTube video: "Self Test Function of eTunner" for detailed instructions on using the self-check function. After the test, check the test data (stored in folder path: eTunner_V13.70\Self_check_report), which can assist in analysis.

(4) Provide separate DC48V power supply to the joint module. With the joint in an unloaded and stationary state, enter the motor settings interface of the eTunner software and click the release brake button (refer to Section 7.3 for detailed steps). Check whether the power output current exceeds the normal value after 3 seconds (refer to Table 7.4).
(5) If all the above checks are normal and the motor stalling error still persists, please contact our technical support for remote confirmation.

26.4 Troubleshooting Steps for The Velocity Error Exceeds the Limit Value (Error HEX:0x8400, DEC:33792)

The reasons and handling instructions for the "Velocity Error Exceeds the Limit Value" can be found in the eRob CANopen and EtherCAT User Manual *Section 7.2.19. 0x8400(33792): Velocity Error Exceeds the Limit Value*. Please refer to this manual for detailed information. You can follow the steps below for troubleshooting:

(1) Please verify whether the load torque of the eRob module's output shaft connection exceeds the "Permissible Maximum Torque with Average Load" specified in Section 2.2. It is important not to exceed this maximum value during usage.
(2) Check for any interference between the output shaft connection of the eRob module and the external components (load). Use a feeler gauge to ensure that the installation clearance of the module's output end is within the normal range and eliminate any potential external interference.
(3) Confirm whether the speed and acceleration of the target instruction trajectory planned by the main station controller exceed the maximum speed and acceleration specified in Table 12-1. It is crucial not to exceed this maximum value during usage.
(4) Please verify if the "Max Motor Speed" set in the eTunner_V13.70 software "Safe Speed" interface is too low. If the "Max Motor Speed" setting is lower than the speed sent via the master controller, it can result in Velocity Error Exceeds the Limit Value.
(5) Utilize the "Self-Test" function in the eTunner_V13.70 software to perform self-diagnostic tests and ensure that the module parameters and motion status are normal.

Note: Ensure that the module is in an unloaded state during the self-test. If the module is not unloaded, do not initiate full test, only retrieve the module information without conducting the full test. If an error is displayed in the "Monitor" interface of the eTunner software, clear the error by clicking the "Enable" button in the "Motion" interface, then click the "Motor Stop" button in the main interface before proceeding with the self-diagnostic test.
The instruction to utilize the self-test function of the eTunner, please refer to the YouTube Tutorial

Video.
The test result will be saved to file path: eTunner_V13.70\Self_check_report, these data can assist the analysis process.

(6) Open the “Fault diagnosis” function of eTunner_V13.70 host computer, replicate the fault and data collection will be triggered. The oscilloscope will automatically collect relevant data (including target position 0x607A, actual velocity 0x606C, motor current, etc.) and plot the curve. You can save the curve and send it to our technical support for further analysis.

(7) If all the above checks are normal and the velocity error still exceeds the limit value, please contact our technical support for remote confirmation.

Chapter 27 About Rigidity

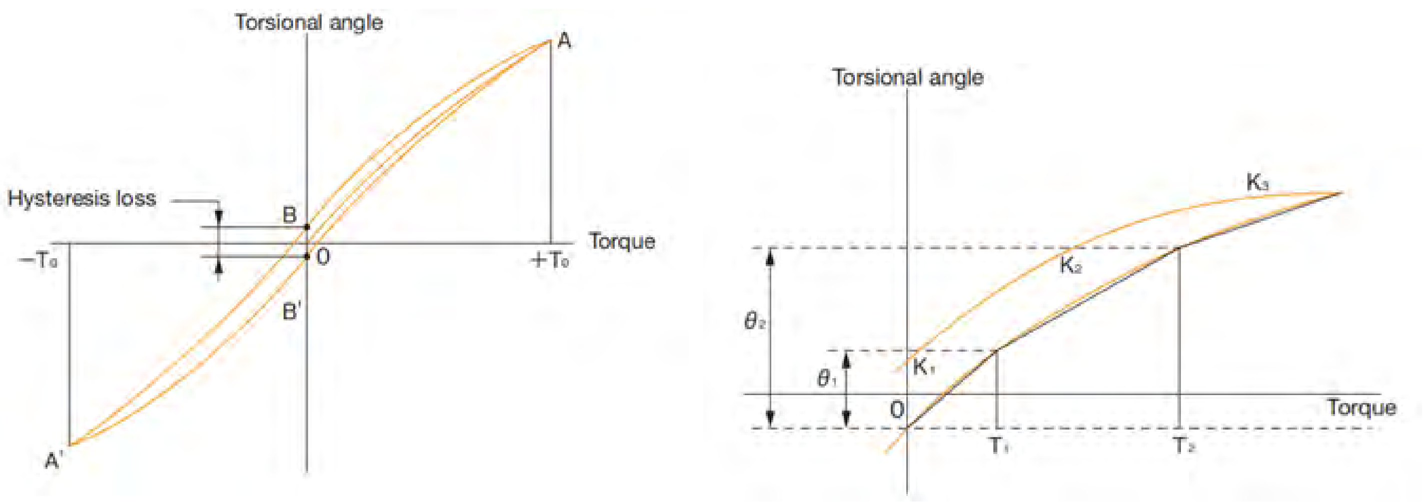
27.1 Rigidity

Fixing the input side (wave generator) and applying torque to the output side (flexspline) generates torsion almost proportional to the torque on the output side.

Figure 27-1a shows the torsional angle quantity on the output side when the torque applied on the output side starts from 0, increases up to $+T_0$ and decreases down to -T_0. This is called the "Torque-torsional angle diagram", which normally draws a loop of 0—A—B—A'—B'—A. The slope described in the "Torque-torsional angle diagram" is represented as the spring constant for the rigidity of eRob rotary actuators (unit:Nm/rad).

As shown in Figure 27-1b, this "Torque-torsional angle diagram" is divided into 3 partitions, and the spring constants in the area are represented as K_1, K_2 and K_3.

K_1 — The spring constant when the torque changes from 0 to T_1.
K_2 — The spring constant when the torque changes from T_1 to T_2.
K_3 — The spring constant when the torque changes from T_2 to T_3.



(a) Torque-torsional angle diagram (b) Partitioning of spring constant diagram

Figure 27-1 Diagrams

References: *Harmonic Drive General catalog.*

Table 27-1 Partitioning of Spring Constant

Item \ Model			eRob70F	eRob70	eRob80	eRob90	eRob110	eRob142	eRob170
T_1		Nm	2	2	3.9	7	14	29	54
		kgfm	0.2	0.2	0.4	0.7	1.4	3	5.5
T_2		Nm	6.9	6.9	12	25	48	108	196
		kgfm	0.7	0.7	1.2	2.5	4.9	11	20
GR 50	K_1	$\times 10^4$ Nm	0.29	0.34	0.81	1.3	2.5	5.4	10
		kgfm/arcmin	0.085	0.1	0.24	0.38	0.74	1.6	3
	K_2	$\times 10^4$ Nm	0.37	0.47	1.1	1.8	3.4	7.8	14
		kgfm/arcmin	0.11	0.14	0.32	0.52	1	2.3	4.2
	K_3	$\times 10^4$ Nm	0.47	0.57	1.3	2.3	4.4	9.8	18
		kgfm/arcmin	0.14	0.17	0.4	0.67	1.3	2.9	5.3
	θ_1	$\times 10^4$ Nm	6.9	5.8	4.9	5.2	5.5	5.5	5.2
		kgfm/arcmin	2.4	2	1.7	1.8	1.9	1.9	1.8
	θ_2	$\times 10^4$ Nm	19	16	12	15.4	15.7	15.7	15.4
		kgfm/arcmin	6.4	5.6	4.2	5.3	5.4	5.4	5.3
GR >80	K_1	$\times 10^4$ Nm	0.4	0.47	1	1.6	3.1	6.7	13
		kgfm/arcmin	0.12	0.14	0.3	0.47	0.92	2	3.8
	K_2	$\times 10^4$ Nm	0.44	0.61	1.4	2.5	5	11	20
		kgfm/arcmin	0.13	0.18	0.4	0.75	1.5	3.2	6
	K_3	$\times 10^4$ Nm	0.61	0.71	1.6	2.9	5.7	12	23
		kgfm/arcmin	0.18	0.21	0.46	0.85	1.7	3.7	6.8
	θ_1	$\times 10^4$ Nm	5	4.1	3.9	4.4	4.4	4.4	4.1
		kgfm/arcmin	1.7	1.4	1.3	1.5	1.5	1.5	1.4
	θ_2	$\times 10^4$ Nm	16	12	9.7	11.3	11.1	11.6	11.1
		kgfm/arcmin	5.4	4.2	3.3	3.9	3.8	4	3.8

27.2 Torsional Quantity Calculation Example

Take eRob110H100I-BM-18EN as an example to calculate the angular displacement (θ).

(1) **When the load torque is extremely small (T_{L1}=2.9 Nm)**
As the torque is T_1 or less, angular displacement θ_{L1} is represented as follows.

$$\theta_{L1} = \frac{T_{L1}}{K_1} \tag{27.1}$$

$$\theta_{L1} = \frac{2.9}{3.1 \times 10^4}$$

$$\theta_{L1} = 9.4 \times 10^{-5} rad\ (0.33 arc\ min)$$

(2) **When the load torque is extremely small (T_{L2}=39 Nm)**
As the torque between T_1 and T_2, angular displacement θ_{L2} is represented as follows.

$$\theta_{L2} = \theta_1 + \frac{T_{L2} - T_1}{K_2} \tag{27.2}$$

$$\theta_{L2} = 4.4 \times 10^{-4} + \frac{39 - 14}{5.0 \times 10^4}$$

$$\theta_{L2} = 9.4 \times 10^{-4} rad\ (3.2 arc\ min)$$

The total angular displacement when the load is applied the other way round will be double the quantity obtained above plus the backlash quantity.

Note: Note that the angular displacement indicates the value of the each eRob rotary actuator only. The angular displacement of the output shaft is not included.

27.3 Hysteresis Loss

As shown in Figure 27-1a, when the torque is applied up to the rated value and is brought back to “0”, the torsional angle does not become absolutely “0”, and a small amount remains (B—B’). This is called hysteresis.

Table 27-2 Hysteresis loss quantity for each eRob model

Gear Ratio	Model / Unit	eRob70F	eRob70	eRob80	eRob90	eRob110	eRob142	eRob170
50	$\times 10^4\ rad$	7.3	5.8	5.8	5.8	5.8	5.8	5.8
	$arc\ min$	2.5	2.0	2.0	2.0	2.0	2.0	2.0
>50	$\times 10^4\ rad$	5.8	2.9	2.9	2.9	2.9	2.9	2.9
	$arc\ min$	2.0	1.0	1.0	1.0	1.0	1.0	1.0

27.4 Backlash

As hysteresis loss is mainly generated by internal abrasion, it is hardly generated, and only a small allowance is represented in the diagram when the torque is extremely small. This quantity is expressed as the backlash quantity.
As the allowance of the tooth engagement is suppressed to “0” for the gear, the backlash quantity is caused by the clearance of the connection of mechanical structures.

Chapter 28 Instructions for Back-Driving eRob by External Force

(1) The actuator can be rotated with a small external force under the condition of motor disabled and the brake released separately (please refer to Section 7.3 for more details), because there is still friction and the magnetic induction force produced by motor dragging and the magnetic induction force is that the greater the rotation speed, the greater the resistance, so it is necessary to apply a torque with the help of a certain force arm to rotate the joint.

(2) Use the torque mode (CST mode or PT mode), set the target torque (object dictionary 0x6071) to 0, and then enable the actuator. At this time, the external force required to rotate the actuator by external force is smaller than that of releasing the brake alone.

(3) If you want to further reduce the drag force, the usual method is to first identify the friction force and load gravity of the actuator through the drag teaching function of the controller, and then send commands to the actuator through the torque feed-forward (object dictionary 0x60B2) to compensate the friction force and load gravity.

(4) You can use the torque sensor of the actuator (please refer to Chapter 22) as a feedback of the external force, and after the calculation and processing of the force by the controller, send commands to the actuator through the torque feed-forward (object dictionary 0x60B2) for compensation.

Note: Note: For the instructions of CST mode and PT mode, refer to *Chapter 5* of *eRob CANopen and EtherCAT User Manual*, and for the object dictionary description, refer to *Section 8.2* of *eRob CANopen and EtherCAT User Manual*.

Appendix A Safety Precautions for Multi-Turn Encoder Battery

(1) Do not place the battery at random to prevent short circuit.
(2) Do not heat or place the battery in an environment of 100°C.
(3) Do not charge the battery.
(4) Do not disassemble and dissect the battery.
(5) Do not use the positive and negative electrodes in reverse connection with the electrical equipment.
(6) Do not use a soldering iron directly on the battery surface to solder or contact other high-temperature objects.
(7) Do not perform various environmental and safety tests such as extrusion and impact without any protective conditions.
(8) Do not put the battery into water or use or store it in a humid environment without protection.
(9) Do not use the battery in the equipment without setting the cut-off voltage point. After reaching the cut-off voltage point, it must be removed from the equipment immediately to prevent the deep discharge of continuous current operation.
(10) Do not use the battery if you find any heat, odor, discoloration, deformation or other abnormality in the battery during use or storage.
(11) Dispose of the used battery in accordance with local environmental regulations, buried deep in the ground or thrown into salt water.
(12) Rinse with plenty of water and seek medical treatment immediately if the liquid inside the battery splashes on the skin, eyes and clothes.
(13) Do not use and store battery in the place with static electricity.
(14) Store battery in an environment where the temperature does not exceed 30°C and the relative humidity is 45% ~ 75%.
(15) Store battery away from heat sources, away from corrosive gas environments, and avoid direct sunlight, and ensure that the storage area is clean, cool, dry and ventilated.
(16) Keep battery in their original packaging when not in use, and the batteries should not be piled up after removing the packaging.
(17) Protect battery from sunlight, fire, rain, water and corrosive substances during transportation.
(18) Limit the shock and vibration during transportation and handling to a minimum.
(19) Place battery away from the engine when the battery is transported long-distance by ship; Do not leave in an unventilated environment for a long time in summer.

Appendix B Error Codes and Suggestions

Please refer to *Section 7.2 Device Error* in *eRob CANopen and EtherCAT User Manual* for more details.

Appendix C Warranty

C.1 Warranty Period and Scope

(1) Within a period of 7 days from the day following the customer's receipt of the product, in the event of non-human-induced performance failure, subject to confirmation by the ZeroErr Control Co.,Ltd After-Sales Service, the customer shall be entitled to initiate a return procedure. The customer is required to furnish a valid purchase receipt and return the invoice upon making the return. In cases where complimentary items were provided, they shall also be returned in conjunction with the product.
(2) From 8 days to 365 days after the customer's receipt of the product, upon verification by the ZeroErr Control Co.,Ltd After-Sales Service that the issue pertains to an inherent quality fault of the product, priority replacement service shall be granted. It is to be noted that this product undergoes a series of stringent factory tests, and the company reserves the right to decline the customer's requests for return or exchange in cases where the issue does not originate from an inherent quality fault of the product.
(3) Provided that the product is operated, used, and maintained in accordance with the specifications, instructions, and manuals, all products shall be warranted for a period of one year (”Warranty Period”) from the date of delivery. Furthermore, this warranty strictly pertains to the specific product. Any additional losses arising from the product malfunction, as well as costs associated with equipment assembly or disassembly, shall not fall within the purview of this company's responsibility. If a malfunction occurs within the aforementioned warranty period due to manufacturing defects attributable to this company, this company shall assume the responsibility of repairing or replacing the product.

C.2 Non-Warranty Provisions

The following circumstances shall be excluded from the warranty coverage:
(1) Exceeding the warranty period as stipulated in the warranty terms.
(2) Unauthorized disassembly of the module or tampering with the integrity of tamper-evident labels.
(3) Occurrence of product abnormalities subsequent to destructive testing, such as extreme temperature variations, humidity exposure, overloading, submersion, electromagnetic compatibility (EMC) testing, vacuum testing, and similar assessments.
(4) Product damage or destruction resulting from improper utilization deviating from the user manual's prescribed instructions.
(5) Detachment, loosening, melting, or poor contact of the power interface; detachment or loosening of the communication interface, and similar issues.
(6) Slippage of threaded installation interfaces or broken screws.
(7) Substantial impact damage characterized by external damage exceeding dimensions of 3mm in any direction, accompanied by protrusion or depression greater than 0.02mm.
(8) Collisions occurring during loaded or unloaded utilization.
(9) Damage or destruction arising from improper operation, maintenance, installation, modification, testing, or other forms of unauthorized utilization.
(10) Conventional mechanical wear and tear unrelated to quality faults.
(11) Damage resulting from abnormal working conditions, including but not limited to falls, impacts, liquid ingress, severe collisions, and similar scenarios.
(12) Damage caused by acts of nature such as floods, fires, lightning strikes, earthquakes, or other force nature events.
(13) Damage resulting from the application of torque exceeding specified permissible maximum levels.

(14) Use of non-original genuine products from ZeroErr Control Co.,Ltd or inability to provide a legitimate purchase receipt.
(15) Other malfunctions or damage arising from product design, technology, manufacturing, quality-related issues, or similar factors.

Should any of the aforementioned circumstances arise, the customer shall bear the associated costs accordingly.

Declaration

Our product is not designed or intended for use outside the environmental limitations and operating parameters expressly stated on the product's datasheet. Products are not designed or intended for use in medical, military, aerospace, automotive or oil, gas applications or any safety-critical applications where a failure of the product could severe serious environmental or property damage, personal injury, or death. Any use in such applications must be specifically agreed to seller in writing and is subject to such additional terms as the seller may impose in its sole discretion. Use of products in such applications is at buyer's own risk, and buyer will indemnify and hold harmless seller and its affiliates against any liability, loss, damage, or expense arising from such use. Information contained in this datasheet was derived from product testing under controlled laboratory conditions and data reported thereon is subject to the stated, then to tolerances and variations, or if none are stated, then to tolerances and variations consistent with usual trade practices and testing methods. The product's performance outside of laboratory conditions, including when one or more operating parameters is at its maximum range, may not conform to the product's datasheet. Further, information in the product's datasheet does not reflect the performance of the product in any application, end-use or operating environment buyer or its customer may put the product to. Seller and its affiliates make no recommendation, warranty, or representation as to the suitability of the product for buyer's application, use, end-product, process, or combination with any other product or to any results buyer or its customer might obtain in their use of the product. Buyer should use its own knowledge, judgment, expertise, and testing in selecting the product for buyer's application, and-use and/or operating environment, and should not rely on any oral or written statement, representation, or samples made by seller or its affiliates for any purpose. Except for the warranties expressly set forth in the seller's terms and conditions of sale, seller makes no warranty express or implied with respect to the product, including any warranty of merchantability or fitness for any particular purpose, which are disclaimed and excluded. All sales are subject to seller's exclusive terms and conditions of sales which, where the seller is another person, are available on request, and in each case, are incorporated herein by reference, and are exclusive terms of sale. Buyer is not authorized to make any statements or representations that expand the environmental limitations and operating parameters of the products, or which imply permitted usage outside of that expressly stated on the datasheet or agreed to in writing by seller.
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