AirExo-2 Installation Guide

***AirExo*-2** Team https://airexo.tech/airexo2/

A. Overview

We introduce ***AirExo*-2**, an updated low-cost exoskeleton system for large-scale in-the-wild demonstration collection. By transforming the collected in-the-wild demonstrations into pseudo-robot demonstrations, our system addresses key challenges in utilizing in-the-wild demonstrations for downstream imitation learning in the real world.

In this guide, we will introduce how to assemble ***AirExo*-2** for a pair of *Flexiv Rizon robotic arms with Robotiq 2F-85 grippers*. For other types of robots, you can modify the structure according to your own setup.

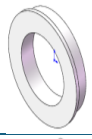
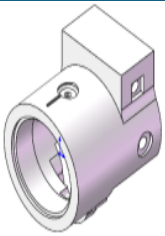
B. Requirements

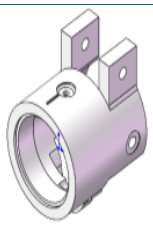
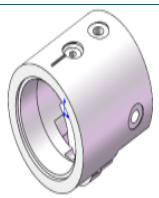
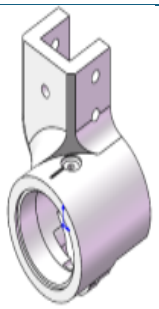
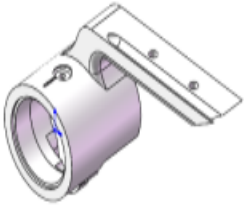
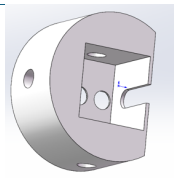
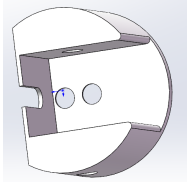
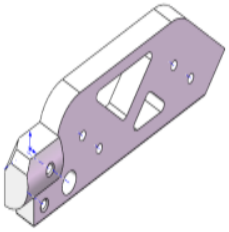
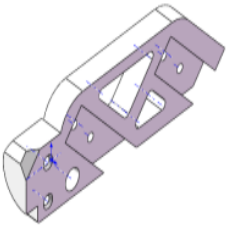
The parts of ***AirExo*-2** have relatively high 3D printing requirements compared to previous version. For optimal part accuracy, it is recommended to use **a 3D printer with an AMS system** and **easily removable support material** to achieve smooth support surfaces. For reference, we use the **Bambu Lab X1C printer** with **PLA-CF** and **Support for PLA/PETG** filament for fabrication.

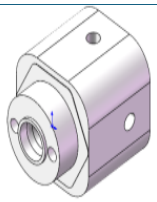
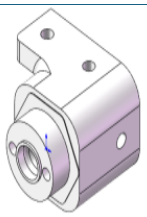
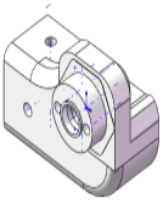
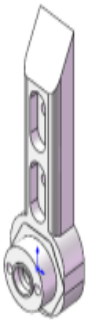
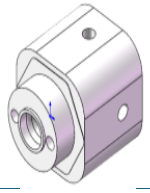
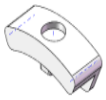
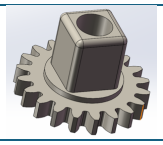
C. Component List

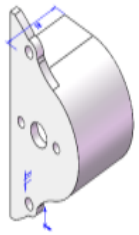
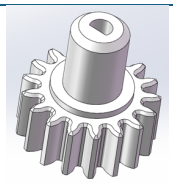
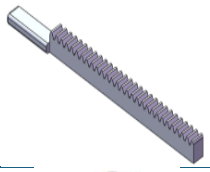
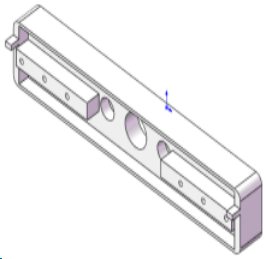
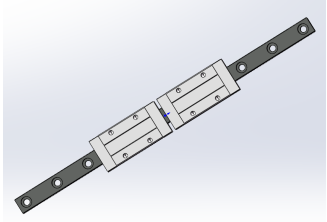
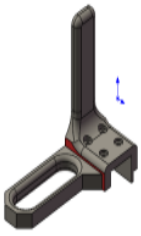
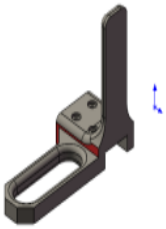
In the following table, we list all components used in ***AirExo*-2** with the detailed descriptions.

Tab. I. The component list of ***AirExo*-2**.

Part	File Name	Photo	Descriptions
Link	*link_1* *link_2* *link_3* *link_4* *link_5* *link_7*		Every link connects two consecutive joints and is made from cut 20x20 European standard aluminum profiles. The link length can be adjusted based on the exoskeleton's required size. The labels in the file indicate the correspondence between links and joints.
Bearing	*Bearing*		Flange bearings, model F6805ZZ, are used in pairs for each joint to connect the joint's rotating shaft to the joint body.
Joint Body	*BaseJointBody* **(joint 1)**		The joint body is named with a number indicating the corresponding joint. It connects to the joint's rotating shaft via *Bearing* and attaches to the aluminum profile link through the *LinkHolder*.

	Joint26Body **(joint 2&6)**		The joint body is named with a number indicating the corresponding joint. It connects to the joint's rotating shaft via *Bearing* and attaches to the aluminum profile link through the *LinkHolder*.
	Joint35Body **(joint 3&5)**		The joint body is named with a number indicating the corresponding joint. It connects to the joint's rotating shaft via *Bearing* and attaches to the aluminum profile link through the *LinkHolder*.
	Joint4Body **(joint 4)**		The joint body is named with a number indicating the corresponding joint. It connects to the joint's rotating shaft via *Bearing* and attaches to the aluminum profile link through the *LinkHolder*.
	Joint7Body **(joint 7)**		The joint body is named with a number indicating the corresponding joint. It connects to the joint's rotating shaft via *Bearing* and attaches to the aluminum profile link through the *LinkHolder*.
Link Holder	*LinkHolder1* **(joint 1&3&5)**		It is mounted on the *JointBody* to connect the joint with the aluminum profile *Link*.
	LinkHolder2 **(joint 2&4&7)**		It is mounted on the *JointBody* to connect the joint with the aluminum profile *Link*.
	BaseLinkHolder1		*BaseLinkHolder* and *BaseLinkHolder2* work together to connect the *BaseJointBody* to the *BaseLink*.
	BaseLinkHolder2		*BaseLinkHolder* and *BaseLinkHolder2* work together to connect the *BaseJointBody* to the *BaseLink*.

Joint Pivot	*StraightJointPivot* **(joint 1&3&5)**		It is the upper part of the joint's rotating shaft, and it connects directly to the *Link*.
	Joint2Pivot **(joint 2)**		It is the upper part of the joint's rotating shaft, and it connects directly to the *Link*.
	Joint4Pivot **(joint 4)**		It is the upper part of the joint's rotating shaft, and it connects directly to the *Link*.
	Joint6Pivot **(joint 6)**		It is the upper part of the joint's rotating shaft, and it connects directly to the *Link*.
	Joint7Pivot **(joint 7)**		It is the upper part of the joint's rotating shaft, and it connects directly to the *Link*. It is actually the same as *StraightJointPivot*. However, the parts are separated to facilitate future compatibility with the inhand camera mount.
Clutch	*Clutch*		A friction block that works with *JointLimit* to achieve angle limiting and damping adjustment.
Joint Limit	*JointLimit*		It is used for angle limiting and damping adjustment. It connects to the *JointPivot* with M4x25 screws. You can modify the limit for different joint angle ranges.
Encoder	*EncoderGear*		*EncoderGear* and *JointGear* together are used for transmission from joint movement to the encoder.
	JointGear		*EncoderGear* and *JointGear* together are used for transmission from joint movement to the encoder.
	Encoder	-	The model for the encoder. This should be purchased instead of 3D-printed.

	EncoderHolder		It is used for mounting the encoder, which is then secured to the *JointBody*.
Gripper	*GripperGear*		The gripper gear.
	Rack		The gripper rack
	Handle		The gripper handle
	GripperBody		The gripper body, connecting the handle and the *Rail*.
	Rail		A linear guide rail (**BMN9H-2-L190-ZF-C-E5**), mounted on the *GripperBody*, enabling the gripper's opening and closing motion.
	LeftFinger		The left and right fingers of the gripper, mounted on the *Rail*.
	RightFinger		The left and right fingers of the gripper, mounted on the *Rail*.

Besides 3D printed components, there are several components to be prepared.

1. **Encoders**. There are two ways to purchase the encoders:
   (1) Buy it through this address. Leave a comment of "AirExo, dual RS485, 4pin 0.8mm wire".
   (2) If you happen to have a Chinese colleague, you can ask them for help and order at this address, and then ship it to you. I would recommend this approach as it is cheaper (~$400 for 16 encoders). The former approach is more expensive because it is actually sold by a distributor.
2. **Wires**. We use 4pin 0.8mm wires of 20cm~30cm to connect the encoders together. Thanks to the updated design, now we do not need to wrap the wires with heat shrink tube like the original *AirExo*. However, please also be careful during assembly to prevent wire compression and abrasion.
3. **Fasteners**. We provide a fastener list in Tab. II as follows.

Tab. II. The fastener list of ***AirExo*-2**.

Type	Number	Notes
M5*10	16	For base installation.
M5*40	2	
M5*50	2	
M3*10 self-tapping	28	For encoder installation: connecting *EncoderHolder* and *JointBody*
M2*6	28	For encoder installation: connecting *Encoder* and
M4*24	28	For joint rotating shaft installation
M5*12	60	For joint installation: connecting links and joints
M5*20	30	
M4*10 flat-hat, self-tapping	14	For joint installation: securing *Clutch*.
M3*18	12	For gripper installation: securing *Rail* to *GripperBody*
M3*6	16	For gripper installation: securing *LeftFinger* and *RightFinger*
M5*18	4	For the 6th link installation: securing *Joint6Pivot* and *Joint7Body*
M6*16	4	For gripper installation: securing *Handle*
M5 T-type nut European standard 20x20	several	
M4 square nut	several	
M3 square nut	several	

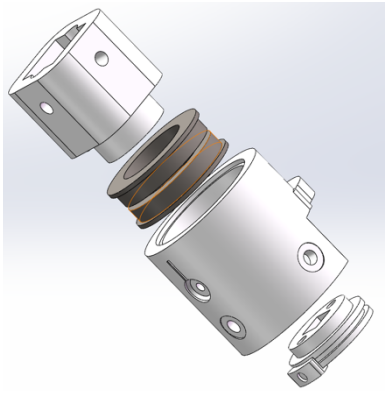
4. **Adhesives**. Since the component is not under load, any fast-drying adhesive can be used.

D. Joint

Although ***AirExo*-2** joints are in various forms, there are essentially only two types in terms of installation: **I-shaped joints** and **L-shaped joints**. The key difference between them lies in how the joint connects to the link.

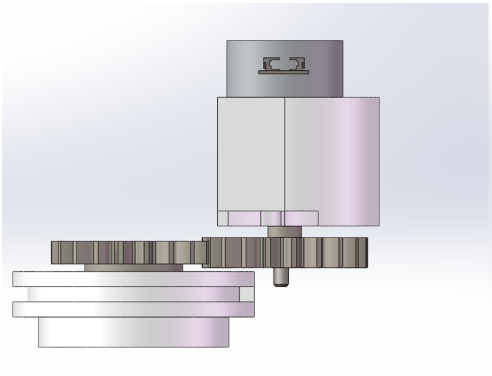
Below, we will first explain the installation of the **I-shaped joint**.

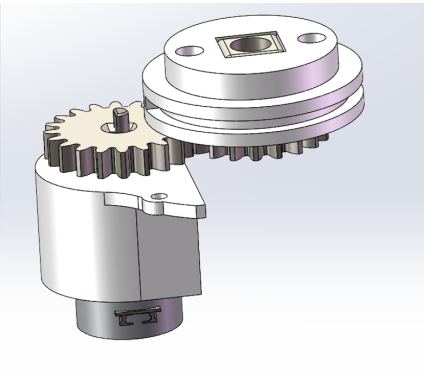
First, press two flange bearings into the housings of the joint structure (*JointBody* and *JointPivot*). Then, insert the upper and lower parts of the rotating shaft into the housing with the bearings installed. **Make sure to insert the lower part together with the friction block**, as it will be difficult to add the friction block later.

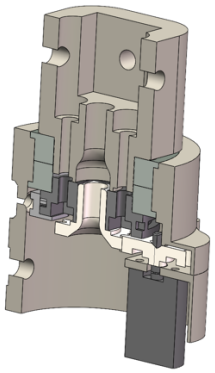


Once in place, secure the assembly with M4 x 25mm screws at the top and bottom to ensure strength. Then, use an M4 flat-head self-tapping screw through the side mounting hole to secure the friction block—adjusting the screw's pressure changes the shaft's damping.

After completing these steps, you can proceed with encoder installation.

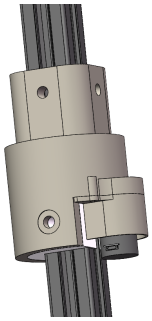


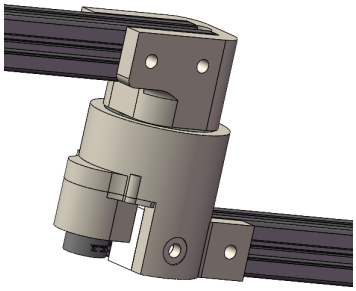




The encoder is driven by gears. The square-shaft gear fits into the square hole on the lower part of the rotating shaft. After securing the encoder to its mounting bracket, another gear is installed onto the rotating shaft. Finally, both components are assembled into the housing to achieve transmission.

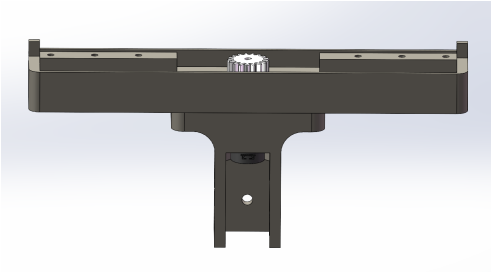
Next, a connector for the aluminum profile is used to mount the link. The link is installed using the standard aluminum profile assembly method. The L-shaped joint follows the exact same installation process as the I-shaped joint for the main assembly. The only difference is that it requires a different type of *LinkHolder* to connect to the joint. The final results are shown in the images below.



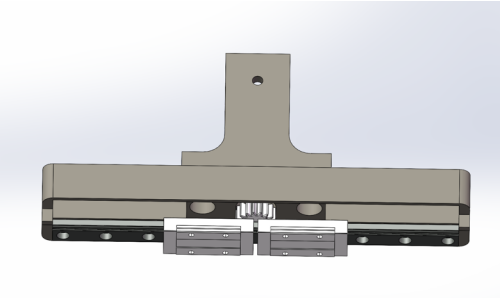


E. Gripper

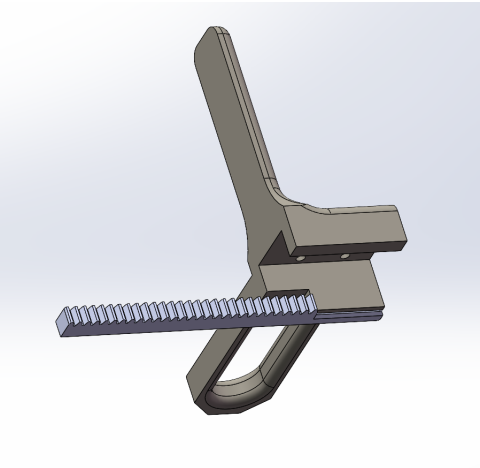
Next, we explain the gripper installation process. First, install the encoder onto the gripper’s main bracket, then mount the drive gear.



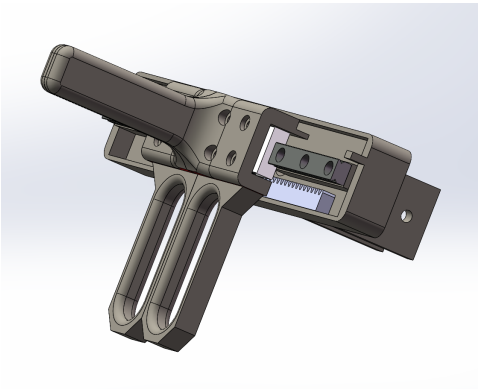
Once this step is complete, the linear guide rail can be installed.



Next, install the gripper fingers, which are bonded to the drive rack using adhesive.

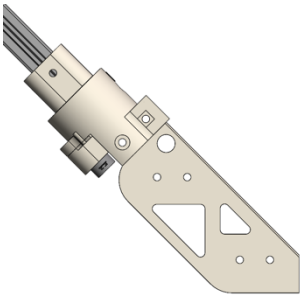


After the adhesive bonding is complete, use M3x6 screws to directly tighten the gripper fingers onto the linear guide rail's slider. The final installation result is shown as follows.



F. Base

The base link holder consists of two clamping shell pieces (*BaseLinkHolder & BaseLinkHolder2*). First, snap the shells together around the BaseJoint and insert the screws without fully tightening them. Then, position the **aluminum profile** in place and tighten all screws at once to complete the installation. During assembly, avoid over-tightening the screws before adjusting the aluminum profile's position to allow for fine-tuning. Once the position is correct, fully tighten the screws.



Mobile Base. The mobile base is consists of several European standard 30x30 / 30x60 / 60x60 aluminum profiles. Follow the provided assembly file to assemble them together.

G. Modification Tips

If you want to modify ***AirExo*-2** to accommodate your own dual-arm robot, here are several modification tips:

A. Obtain the full parameters of your dual-arm robot, including the length of each link, the distance between two robot base, *etc.* Then modify the link length of ***AirExo*-2** according to your own robot's specifications. This step is crucial to obtain a 1:1 exoskeleton of your robot.
B. Different 3D printers may have different tolerances. Since the bearing needs to be pressed into a 3D printed part, it would be better to understand the tolerance of the 3D printer you're using before printing, and then adjust the corresponding dimensions of the part accordingly. Make sure to set up proper supports and position the parts optimally during printing to achieve the best accuracy and strength.

H. Contact Us

For hardware issues, please contact us via e-mail:

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