User Manual
End Effector

Group 07
Document Version 1.0

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Contents

1 Preface

1.1 Target Audience

This document is intended for integrators who design and install complete robot applications. Personnel working with the end-effector are expected to have the following expertise:

- Basic knowledge of mechanical systems
- Basic knowledge of electronic and electrical systems
- Basic knowledge of the robot system

1.2 Intended Use

The end-effector is designed for grabbing objects, installed on the end effector of a robot, typically used in pick and place applications.

1.3 Safety Notice

A risk assessment is required for each application the end-effector is a part of. It is important that all safety instructions are followed. The safety instructions are limited to the end-effector only, and do not cover the safety precautions of a complete application.

Below are some (but not all) potentially dangerous situations.

- Entrapment of fingers between the sliding rail and the body.
- Entrapment of fingers between the rail and/or vertical stabilizer and the body.
- Objects falling out of the end-effector e.g. due to misalignment of robot arm or high acceleration from robot arm.

2 Getting Started

2.1 Mounting

The end-effector is attached to the robot arm using a **welding neck flange**, following the ISO 9409-1 standardized mounting interface. Proper alignment is ensured through the use of suitable screws positioned on a pitch circle diameter.

Mounting Parameters (ISO 9409-1)

- d_1 : 37.5 (Pitch Circle Diameter)
- N : 4 (Number of threaded holes)
- d_4 : M6 (Thread size of holes)

2.2 Operation

2.2.1 Communication with PC

The end-effector communicates the following information with the robot controller PC:

- **Angle:** Angle between the end-effector and the object to be picked.
- **Distance:** Distance between the end-effector and the object to be picked.

The robot controller is expected to ensure proper alignment and positioning of the end-effector for successful gripping operation.

2.2.2 Picking the Object

Once proper alignment and positioning is ensured, the **pick** command must be issued to the end-effector by the robot controller PC.

Once the command is given, the following steps will take place:

- **Suction:** The vacuums will activate and suction will hold the object against the suction pad.
- **Raising:** The suction pad will rise up, lifting the side of the object.
- **Rail:** The rail will slide under the object.
- **Top Support:** The vertical stabilizer will move down onto the object, providing further stabilization.
- **Remove Suction:** Suction will be removed once the object is stable.

2.2.3 Transporting the Object

The robot arm is responsible for transporting the object to the correct destination and ensuring correct alignment.

2.2.4 Placing the Object

Once proper alignment and positioning is ensured, the **place** command must be issued to the end-effector by the robot controller PC.

Once the command is given, the following steps will take place:

- **Rail:** The sliding rail will move out from under the object, resting the object at the target location.
- **Top Support:** The top support will raise and the object will be completely released by the end-effector.

2.3 Mechanical Dimensions

2.3.1 Fork

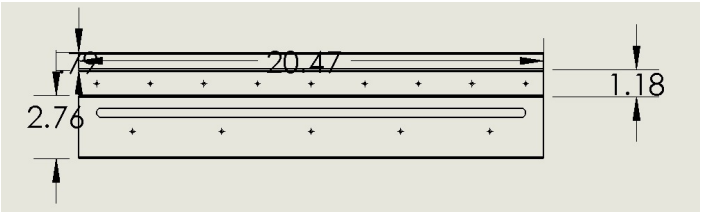

Figure 1: Fork Dimensions

2.3.2 Base Flange

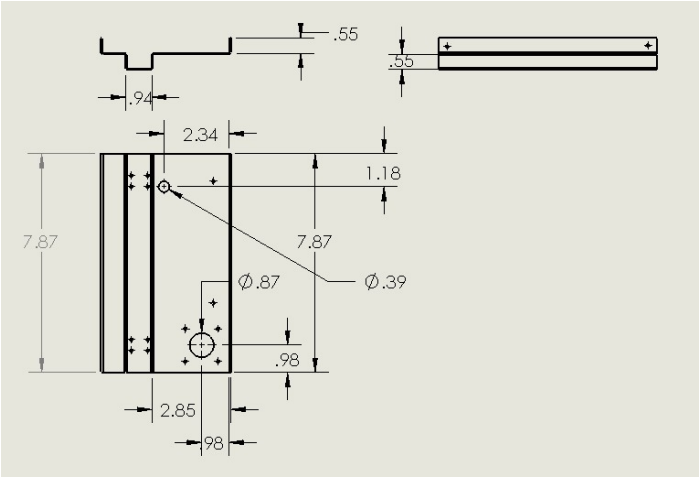

Figure 2: Base Flange Dimensions

2.3.3 Outer Cover

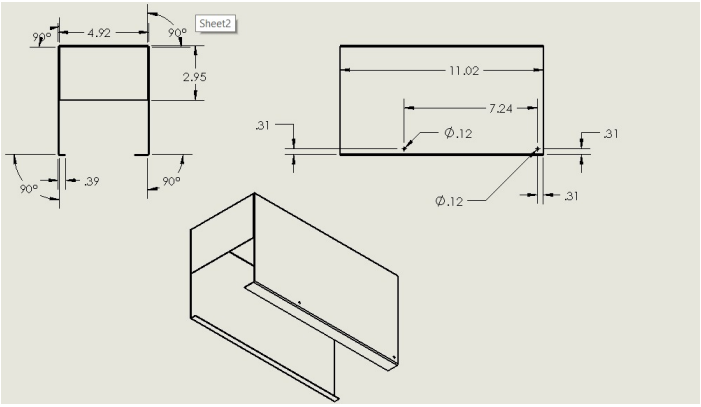

Figure 3: Outer Cover Dimensions

2.3.4 Back Plate

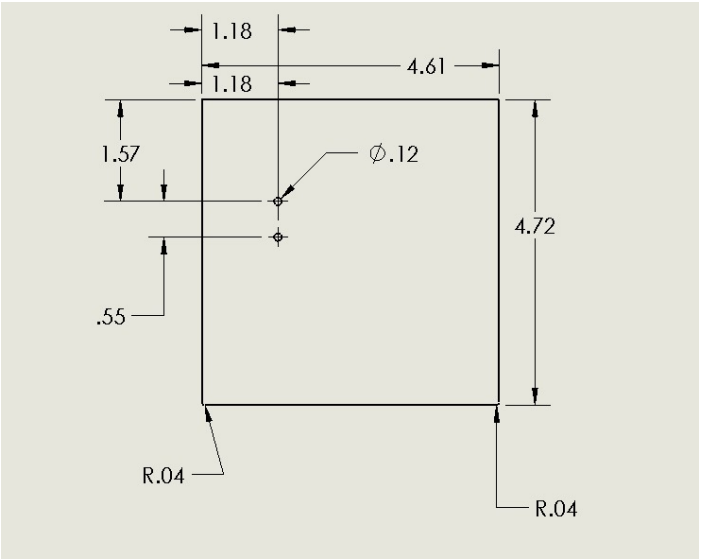

Figure 4: Back Plate Dimensions

2.3.5 Front Plate

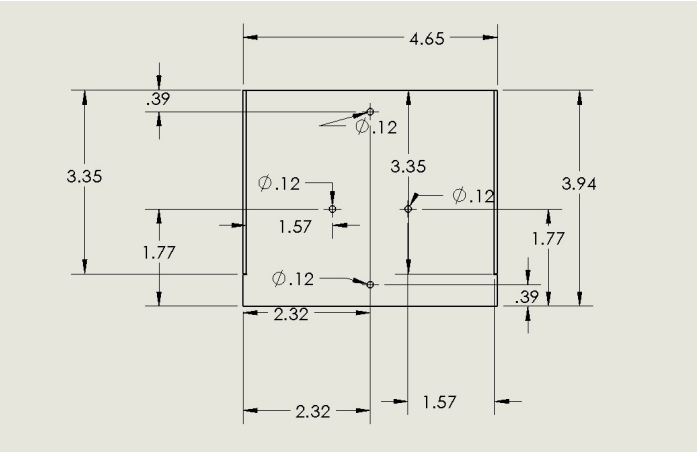

Figure 5: Front Plate Dimensions

2.3.6 Gear wheel and Rack

- **Pinion Gear:**
  - Module: 1 mm
  - Teeth: 20
  - Pitch Diameter: 20 mm
  - Bore: 5mm (D-type with cut at 4.5mm)
- **Rack:**
  - Module: 1 mm
  - Face width: $\geq$ 10 mm
  - Length: 500 mm

2.4 Load Capacity

The end-effector has an operational capacity of 1kg uniformly weighted boxes. Exceeding the weight limit may result in structural failure and/or injury.

2.5 Connections

2.5.1 Pneumatic Connections

Guide the connections for the solenoids and the vacuum suction pads through the groove cut into the base.

Connect 4mm PU tubes from the two double solenoids to the single rod and double rod pistons (each piston must have two tubes.) Connect 4mm tubes from the single solenoid to the suction cups.

Connect the vacuum to the single solenoid and compressor the the two double solenoids using 6mm PU tubes. The solenoid tubes and vacuum tubes must be connected to a compressor with the following specifications.

2.5.2 Power Supply

The gripper is designed to operate with a 24V DC power supply. Ensure the power source is regulated and within the specified voltage range for safe and reliable operation. Guide the power supply through the same groove in the base.

Table 1: Pneumatic Specifications

Parameter	**Value**
Pressure	6 bar
Air Supply Tube Diameter	Ø12 mm
Airflow (including vacuum)	40 l/min
Minimum Air Quality	ISO 8573-1:2010 7 : 4 : 4

3 Control Commands

The end-effector is controlled via UART communication with the host system (typically a PC or microcontroller). The following commands must be transmitted over UART to initiate the respective operational sequences. The communication protocol uses 8 data bits, no parity, and 1 stop bit (8N1), as shown in Figure 6.

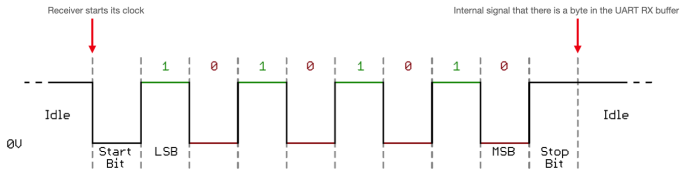

Figure 6: UART Protocol: 8 data bits, 1 stop bit

3.1 Pick Command

To initiate the picking sequence, transmit the command `CMD_GRIPPER_PICK`. This command autonomously executes the full gripping and lifting process. No further step-by-step commands are required.

3.2 Place Command

To initiate the release sequence, transmit the command `CMD_GRIPPER_RELEASE`. This will fully execute the object release process, including the lowering and unclamping actions.

3.3 Debug Commands

For system-level debugging and verification, the following individual control commands can be used. These allow manual actuation of subsystems for testing. **Warning:** Ensure the workspace around the end-effector is clear before issuing debug commands to avoid damage or injury.

- `CMD_TOP_GRIPPER`
- `CMD_FORK`
- `CMD_VACUUM_GRIPPER`
- `CMD_VACUUM_UP`

4 Assembly Instructions

Follow the steps outlined below to correctly assemble the end-effector. All fasteners specified are M3 unless otherwise stated.

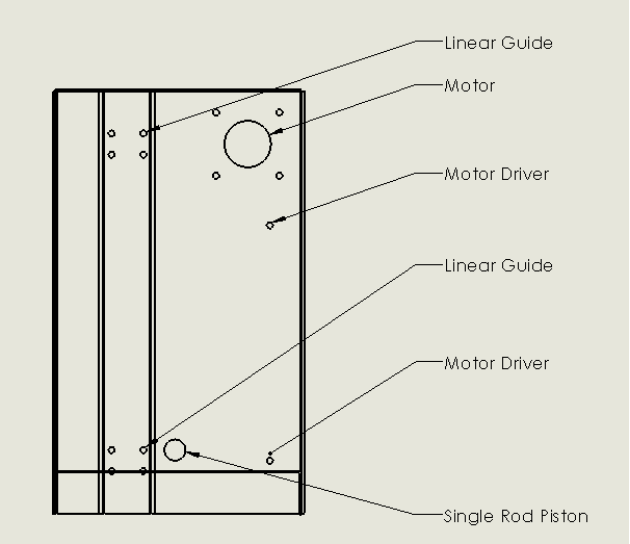

Figure 7: Top View - Base

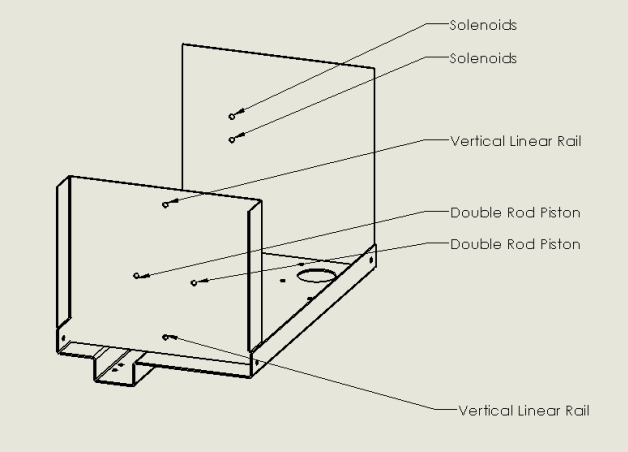

Figure 8: Dimetric View - Base

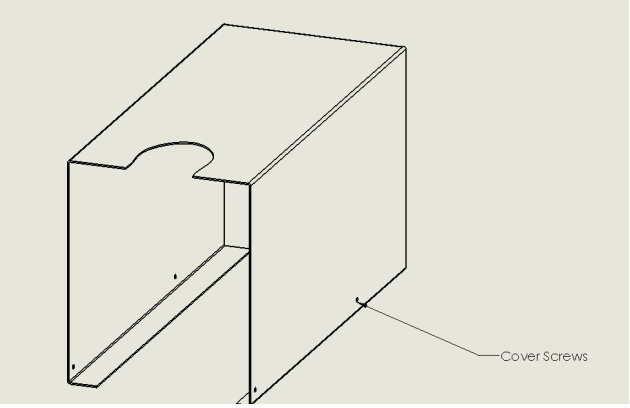

Figure 9: Cover

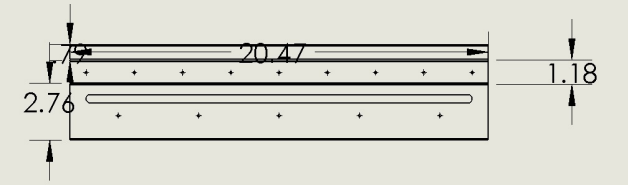

Figure 10: Fork

4.1 Motor Mounting

Secure the motor to the base using four 1/4-inch M3 screws and M3 nuts. Ensure that the motor shaft extends downward through the designated central opening in the base.

4.2 Installation of Linear Guides and Rail

Attach the linear guides to the underside of the base using four 1/4-inch M3 screws inserted from the top side. The alignment slot of the linear guide must correspond precisely with the groove on the base. After installation, insert the linear rail into the linear guide track.

4.3 Fork Assembly

Position the assembled base and linear rail onto the fork component, aligning the end holes of the rail with the predrilled mounting holes on the fork groove. Secure the linear rail to the fork using three 1/4-inch M3 screws and M3 nuts. Mount the rack to the underside of the fork using three M3 screws and nuts, inserted from the top side. Install the gear wheel onto the motor shaft, ensuring proper engagement with the rack teeth to allow smooth linear motion. Once complete, insert the lower fork section into the upper fork structure. Align the screw holes and fasten them using four 1/4-inch M3 screws.

4.4 Vertical Rail and Top Support

Fix the vertical linear rail to the base using two M3 screws and nuts, fastened from the inside. Couple the linear guide to the top support bracket, and slide the vertical rail into the guide channel to complete the vertical axis assembly.

4.5 Solenoids and Piston Installation

Mount the double and single solenoids to the rear panel of the base using two 4-inch M3 screws and M3 nuts. Secure the double-rod pneumatic cylinder to the front of the base using two 1/2-inch M3 screws and nuts. Attach the single-rod pneumatic piston to the base using a 12 mm bolt from underneath. Fix the top support to the piston shaft to complete the actuator assembly.

4.6 Motor Driver

Fasten the motor driver horizontally to the base using two 1/4-inch M3 screws and M3 nuts. Ensure that the back plate faces outward and the terminal connectors face upward.

4.7 PCB Integration

Install the PCB standoffs to the base and mount the PCB using eight 1/4-inch M3 screws and M3 nuts.

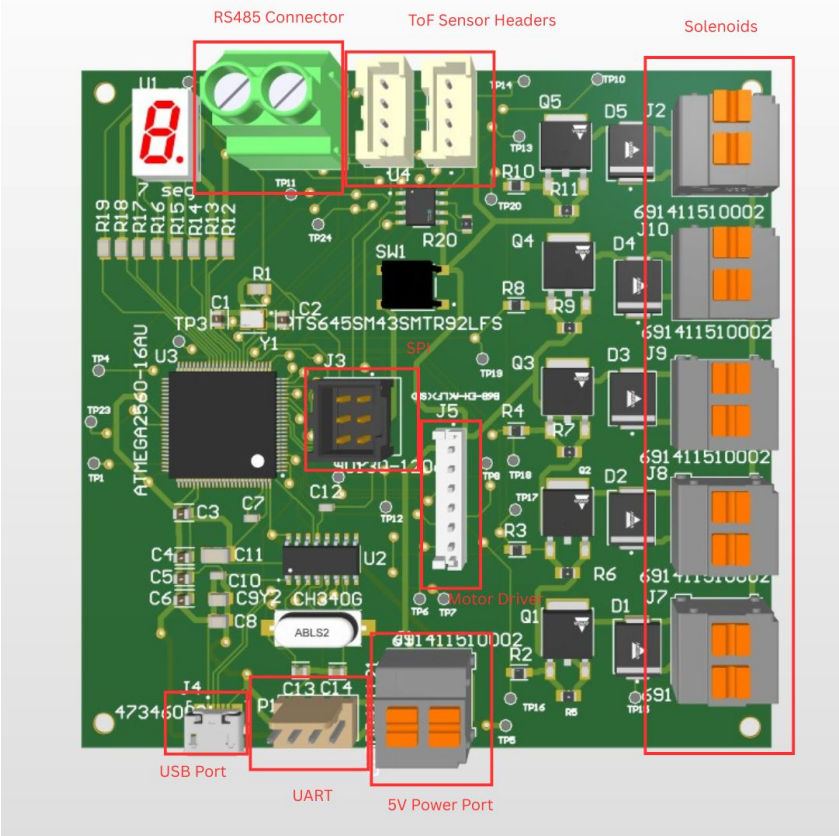

Figure 11: Main Connectors Annotation

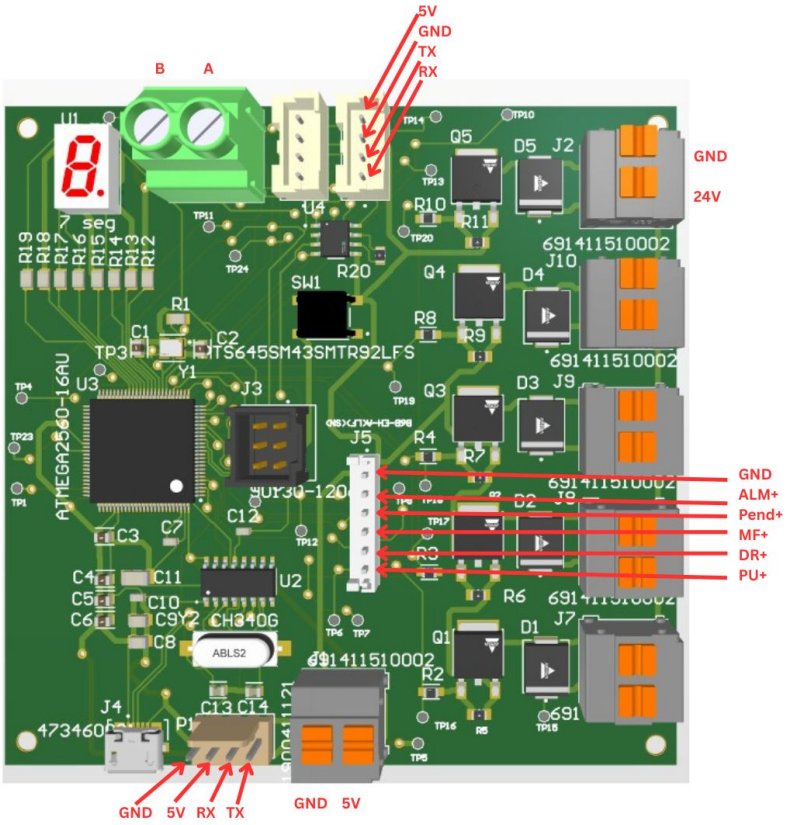

Figure 12: Pin Mapping

Refer to the annotated 3D PCB view for identifying the correct headers. Carefully install the ToF sensor and motor driver module onto the designated connectors as labeled. Ensure that each module is connected to its respective header—UART, SPI, solenoid, ToF, and motor driver—as shown in the pin mapping. Double-check the orientation and pin alignment to match the annotated pin assignments. Incorrect connections may result in malfunction or hardware damage.

4.8 Suction Plate Installation

Secure the suction plate to the top of the double-rod piston using two 1/4-inch M3 screws and M3 nuts. Connect the 4mm tubes to the suction cups and route them over the top and through the groove in the base.

4.9 Electrical and Pneumatic Routing

Neatly route all electrical wires and pneumatic tubing through the designated groove channel in the base.

4.10 Final Assembly and Mounting

Place the top enclosure over the base and secure it using four M3 screws and nuts. Finally, attach the fully assembled end-effector to the robot arm flange using a 6 mm screw and nut.

Once completed, the end effector should look similar to the following images:

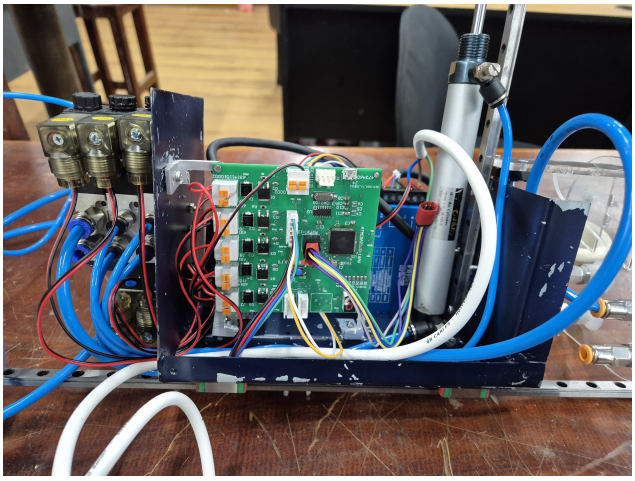

Figure 13: Final Assembly

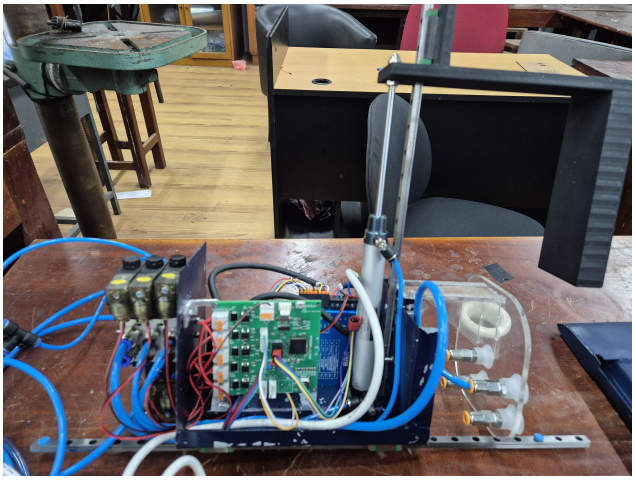

Figure 14: Final Assembly

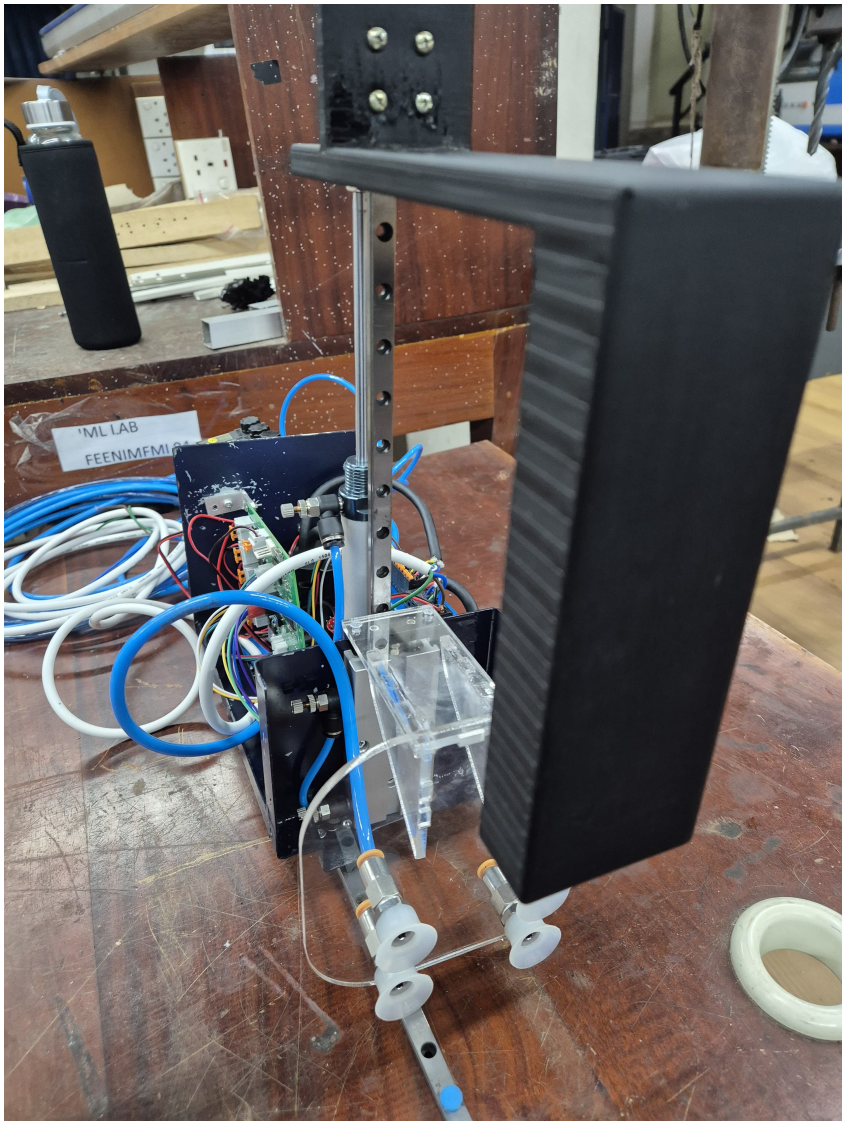

Figure 15: Final Assembly

5 Maintenance Guidelines

This section outlines the preventive maintenance procedures required to ensure the long-term reliability and performance of the end-effector. All maintenance activities should be logged with date, technician name, and observations.

5.1 Closed-Loop Stepper Motor and Gear Mechanism

Interval: Every 250 operating hours or monthly (whichever comes first)

- Perform visual inspection for dust, debris, and oil contamination.
- Check axial and radial play in the motor shaft. Replace bearings if excessive movement is detected.
- Inspect gear teeth and rack for signs of wear, backlash, or misalignment.
- Apply high-performance synthetic gear lubricant to the gear teeth and rack.
- Conduct encoder feedback diagnostics to verify closed-loop accuracy.

5.2 Linear Guides and Rail

Interval: Every 100 operating hours

- Clean linear guideways with lint-free cloth and reapply lithium-based grease.
- Inspect for abnormal noise or resistance during linear motion; verify alignment and smoothness.
- Use dial indicator or laser alignment tools to detect rail deflection or misalignment.

5.3 Pneumatic Solenoids and Cylinders

Interval: Weekly visual inspection, full functional test every 200 cycles

- Inspect PU tubing for cracks, brittleness, or leaks.
- Verify actuation of all three double solenoids and both pistons (single and double rod) via manual override.
- Conduct air leak test using soap solution or ultrasonic leak detector.
- Check piston rods for surface pitting or sticking; re-lubricate or replace seals as necessary.
- Validate response time and holding pressure using a calibrated pneumatic test bench.

5.4 Vacuum Plate Assembly

Interval: Biweekly

- Check for airtight seals and vacuum pressure drop using a digital vacuum gauge.
- Inspect suction cups for deformation or wear; replace if rigidity is compromised.
- Clean contact surfaces to maintain optimal grip efficiency.

5.5 PCB and Electrical Components

Interval: Monthly

- Inspect PCB for discoloration, corrosion, or loose connectors.
- Check signal continuity and voltage outputs using a multimeter or oscilloscope.
- Verify motor driver thermal state under load; ensure proper heat dissipation.
- Ensure no cable insulation degradation near high-vibration areas.

5.6 Top Support and Vertical Linear Rail

Interval: Every 200 cycles or bi-monthly

- Inspect linear motion and guide block alignment with vertical rail.
- Ensure top support fasteners are tightened to specification.
- Check the coupling between the top support and single rod piston for wear or instability.

5.7 General Preventive Maintenance

- Ensure all fasteners are tightened.
- Remove dust and particulates using compressed air or vacuum cleaning.
- Update firmware and perform diagnostics using onboard tools as per controller documentation.
- Record all maintenance actions in the maintenance logbook or digital system.

Note: Always disconnect electrical and pneumatic power before performing maintenance. Use personal protective equipment (PPE) in accordance with safety protocols.

6 Technical Specifications

Table 2: Technical specifications of the End-Effector.

Technical Data	**Min**	**Typical**	**Max**	**Units**
Compressor Pressure		8		Bar
Vacuum Pressure	60		80	%
Operating voltage		24		V DC
Power Rating			72W	W
Maximum Current			3	A
Ambient operating temperature	5		50	°C
Storage temperature	0		60	°C
Product weight		6		kg