Anteater Dynamics Robotic Arm Proof of Concept Test Procedures

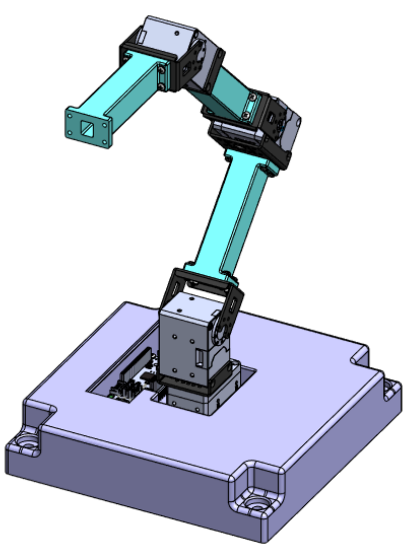
Rev NC
3/5/25

Introduction

The purpose of the test is to isolate the two primary systems of the robotic arm, the linkages and the end-effector, and verify that both systems can actuate as designed given specific code input. The test is designed to not require extra components to be designed, as all tests are conducted using a proof of concept model that will be incorporated into the final product.

The proof of concept model does not exhibit the full seven degrees of freedom and is rather limited to four degrees of freedom to simplify software requirements while verifying that the servos can actuate consecutively to achieve desired movement. The end effector is evaluated separately from the linkage as its own assembly to eliminate any load from the linkage when conducting tests to calibrate and tune kinematic software.

The results from the test will be used to inform any revisions to the robot programming which may be needed and to demonstrate viability of the bespoke end-effector design.



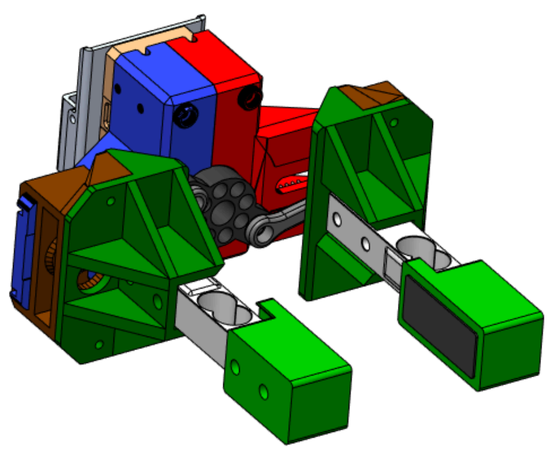


Fig 1. CAD Models of Four Degree of Freedom Linkage PoC (Left) and End-Effector Assembly Poc (Right)

Test Items

Functional Requirements

(A) Base Actuator

FRA-1: The base actuator shall rotate 360 degrees without binding

FRA-2: The base shall provide a stable and secure mounting platform capable of supporting the linkage throughout movement

(B) Arm Linkage

FRB-3: The arm linkage shall articulate as dictated by software input

(C) End Effector

FRC-1: The end effector shall pick up small household objects

FRC-2: The end effector shall sense gripping forces

Ref: Preliminary Design Review Presentation Slide 9

Design/Assembly Specifications

- Manufactured parts exhibit the correct desired fits when assembled without interference
- All hardware is compatible and screws exhibit the correct fit for the specified holes

Features to Be Tested

This section and the following offer a high level user overview of features to be tested (and not to be tested in the following section) and assigns perceived risk levels to each respective feature. Feature risk level indicates the importance to the function of the final product and anticipated challenges with implementation. Features given a low risk level have been excluded from the test.

Features	**Risk Level**
Base Stability	Medium
End Effector Actuation	Medium
Load Cell Force Output	High
Servo Articulation	Medium
Servo Kinematic Rigidity	High

Features Not to Be Tested

Features	**Risk Level**
Linkage Arm and Bracket Rigidity	Low
End Effector Load Capacity	Low
7 DoF Movement	Low

Linkage and bracket rigidity is described as low risk due to existing validation through static finite element analysis. Simulation results show load bearing capacities of both the linkage arms and brackets exceeds the maximum potential load, including a load factor of 2, by several orders of magnitude.

The end effector load capacity has not undergone prior evaluation, however the robotic arm can operate and demonstrate usefulness even if full load capacity is not achieved. In addition, load capacity of the end effector depends on the servo rigidity of a full linkage, and cannot be fully characterized by the existing proof of concept model.

The proof of concept model used for testing only exhibits four degrees of freedom in linkage arm movement, rather than the full seven degrees of freedom. The integration risk of adding the remaining three degrees of freedom is low, as a test validating the efficacy of four degrees of freedom will also serve to validate the potential for extra mobility.

Test Equipment

Item No.	Quantity	Item name	Unit Price	Total Price
2.1	2	DYNAMIXEL XC430-T240BB-T	$119.90	$239.80
2.2	2	DYNAMIXEL XL430-W250-T	$49.90	$99.80
2.3	1	DYNAMIXEL 2XL430-W250-T	$129.90	$129.90
2.4	1	DYNAMIXEL XM430-W350-T	$269.90	$269.90
2.5	1	OpenRB-150 Embedded Controller	$24.90	$24.90
3.1	2	FR12-S102K Set	$19.00	$38.00
3.2	4	FR12-H101K Set	$40.60	$162.40
3.3	1	FR12-S101K Set	$28.60	$28.60
3.4	1	Custom Frame 02		$0.00
3.5	1	Custom Frame 01		$0.00
1.0	3	Linkage Arms		$0.00
1.1	1	End Effector Plastic Set (OpenX)		$0.00
1.2	2	Custom Load Cell Holder		$0.00
1.3	2	Custom Pad Holder		$0.00
1.4	2	1kg Load Cell (YZC-133) + Amp	$4.79	$9.58

Fig 2. BOM for Proof of Concept Assemblies

Other Test Materials:

- Laptop w/ Arduino IDE
- USB cable
- Stopwatch
- Measuring tape
- Stress Ball
- Wood block

Procedures

L-T1 Rotational Verification (FRA-1)

This test validates the robot's ability to actuate rotational movement about its central axis. Base stability, servo rigidity, and software integration are analyzed through the test results.

1. Connect Linkage PoC to laptop via USB to OpenRB-150 Controller
2. Load software for test L-T1.1 in Arduino IDE and execute code
    a. Code shall direct linkage PoC to rotate the base XC-430 servo 360 degrees while maintaining the first linkage in the upright position
3. Designated tester shall record the time from when the code is ran to the completion of one full rotation of the XC-430 servo using a stopwatch
4. Repeat Step 3 five times and record. Note PoC ability to execute code as desired.
5. Load software for test L-T1.2 in Arduino IDE and execute code
    a. Code should direct linkage PoC to rotate the base XC-430 servo 360 degrees while maintaining the first linkage at an angle 30 degrees from normal
6. Designated tester shall record the time from when the code is ran to the completion of one full rotation of the XC-430 servo using a stopwatch
7. Repeat Step 6 five times and record. Note PoC ability to execute code as desired.

L-T2 Linkage Extension (FRB-3)

This test validates the robot's ability to exhibit kinematic motion actuating all servos rotating about the X and Y axes. Base stability, servo rigidity, and software integration are analyzed through the test results.

1. Connect Linkage PoC to laptop via USB to OpenRB-150 Controller
2. Load software for test L-T2.1 in Arduino IDE and execute code
    a. Code shall direct linkage PoC to navigate to starting position where linkage one is normal to the base, linkage two is normal to linkage one, and linkage three is normal to linkage two
    b. From starting position, linkage PoC shall sequentially extend linkage three colinear to linkage two, extend linkage two colinear to linkage one, rotate linkage one parallel to base, hold position
3. Designated tester shall record the time from when the code is run to the completion of one full trial using a stopwatch. Verify linkage parallelism and servo rigidity using calipers to measure distance between linkage arm and testing surface at center of each linkage arm.
4. Repeat Step 3 five times and record. Note PoC ability to execute code as desired.

EE-T1 End Effector Grip (FRC-1, FRC-2)

This test validates the robot's ability to grab objects using the end-effector and receive load feedback through the load cells. Load cell integration, gripper ability, end-effector mechanics, and software integration are analyzed through the test results.

1. Connect End Effector PoC to laptop via USB to OpenRB-150 Controller
2. Load software for test EE-T1.1 in Arduino IDE and execute code
    a. Code shall direct end-effector PoC to starting positions with clamps fully opened. Code shall actuate end effector to close clamps around object, returning load cell feedback on applied force in Newtons. When load cell feedback stabilizes, code shall dictate end-effector servo to stop movement and hold the position for 30 seconds.
3. Place deformable stress ball in between end-effector PoC clamps
4. Execute code and record load cell feedback using Arduino IDE
5. Repeat steps 3-4 five times, returning stress ball to original position before each test
6. Place wooden cube in between end-effector PoC clamps
7. Execute code and record load cell feedback using Arduino IDE
8. Repeat steps 6-7 five times, returning stress ball to original position before each test