Metro Sliding Doors Project

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University: German International University
Course: Mechatronics Lab (MCTR704)
Project No.: [9]
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Overall assembly render

3D Views: Representative render integrated below.

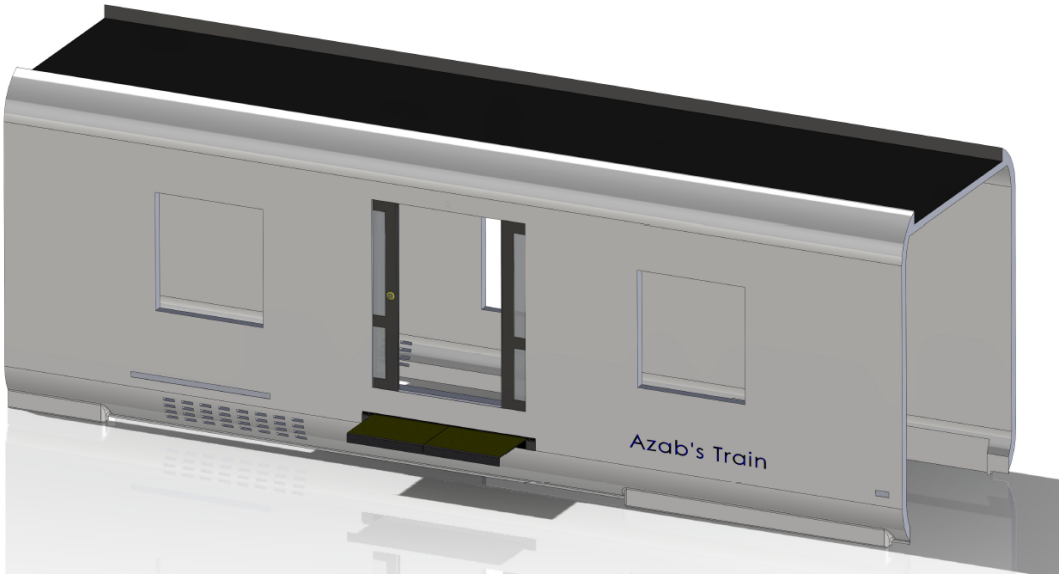

Figure 1: Overall assembly isometric view.

1 Project Description (Milestone Requirement)

This section addresses items (a)–(e) of the milestone description. It establishes functional understanding prior to detailed CAD work.

1.1 (a) Functional Overview

The **Metro Sliding Doors** system provides controlled passenger access between the platform and the train interior using a simplified three-actuator pneumatic architecture:

1. **Door Actuator Cylinder (DC)**: a single long-stroke pneumatic cylinder (approx. 850 mm stroke) driving both door leaves via a dual rack / single pinion mechanism. *Extended = Doors Open*, *Retracted = Doors Closed*.
2. **Lock Linear Solenoid (LS)**: a compact linear actuator (approx. 100 mm stroke) providing mechanical locking. Sequence: it actuates (extends) briefly to disengage the lock prior to door motion, then returns (retracts) to a neutral standby while the door completes travel; re-engagement occurs after verified closure.
3. **Platform Gap Filler (GF1)**: a platform gap-filling module/actuator that deploys concurrently with door opening and retracts during door closing (per datasheet GF1-50-2.pdf). *Extended = Gap Filler Deployed*, *Retracted = Gap Filler Retracted*.

Sensors and Safety Logic:

- **Reed switches** on the door actuator confirm fully open and fully closed positions (end-of-stroke). Optional mid-travel can be added later.
- **Capacitive sensors (doorway/edge)**: verify unobstructed closure. If an obstruction is detected by the capacitive sensors during a closing sequence, the system immediately commands a reopen (DC extend, GF1 extend) while keeping the lock solenoid disengaged to avoid pinch hazards.
- Status indicators (Red = Locked/Inactive, Green = Active/Unlocked) reflect system readiness.

- Interlocks ensure the door cannot begin opening unless the lock solenoid has completed its unlock pulse.

Core functions:

- Provide smooth synchronized bi-directional sliding using one primary actuator.
- Enforce lock-before-motion safety and obstruction detection auto-reopen.
- Present clear status via indicators and sensor-driven logic.
- Support emergency stop: system vents; doors hold or reopen per fail-safe policy (final choice: *fail-safe open on obstruction while closing*).
- Simplify maintenance by reducing actuator count (one main door cylinder instead of two).

1.2 (b) Workpiece Description

The **workpiece** is the *passenger passage aperture* governed by two coupled sliding leaves.

- Clear opening width (aperture): *TODO (e.g., 1400 mm)*
- Each leaf nominal coverage: half aperture + overlap allowance (seal) *(compute after selecting frame profile)*
- Door leaf height: *TODO (e.g., 2000 mm)*
- Door actuator stroke: $\approx$ **850 mm** (matches travel needed for full open)
- Gap filler travel: **per GF1-50-2 datasheet** (see GF1-50-2.pdf)
- Lock solenoid stroke: $\approx$ **100 mm** (sufficient for pawl withdrawal)
- Construction: Aluminum perimeter frame + tempered glass insert (light neutral tint) *(confirm thickness, e.g., 6–8 mm)*

Color coding draft: Frame (RAL 9006), glass (clear), safety / edge trim (high-visibility yellow). Final selection pending ergonomic review.
NOTE: Insert detailed elevation with stroke annotation and rack/pinion centerline.

Dimensional Drawing Placeholder (Front Elevation + Stroke Marks) – TODO

1.3 (c) Operating Sequence

High-level sequence (mapping: DC Extended = Doors Open, GF1 Extended = Gap Filler Deployed, LS Extended = Unlock Pulse):

Step 1: **Idle Locked**: System inactive. DC Retracted (doors closed), GF1 Retracted (gap filler retracted), LS Retracted (lock engaged). Red ON.

Step 2: **Unlock Pulse**: Activation pressed. LS Extends briefly to withdraw lock pawl; Green ON. LS then retracts to standby (pawl held clear mechanically).

Step 3: **Dwell Open**: DC Extended, GF1 Extended. Timer or passenger flow condition decides closing initiation.

Step 4: **Closing**: Close command (Master). DC Retracts; GF1 Retracts. Capacitive sensors must remain clear (no detection). If an obstruction is detected, sequence aborts and the system returns to Opening (auto-reopen).

Step 5: **Closed + Relock**: Reed Closed confirms stroke end. Capacitive sensors confirm *no detection*. LS may perform a short confirm pulse (optional) or remain retracted if passive latch design. Red or Green status per armed state policy.

Interlocks and Safety:

- Door motion blocked until initial unlock pulse complete.
- Obstruction (capacitive detection during closing) forces immediate DC re-extend + GF1 re-extend (fail-safe reopen) and inhibits relock.
- Emergency stop vents air: choose policy (recommended: hold position if mid-travel, else reopen if safe). To finalize after pneumatic circuit design.
- Closing command restricted to Master panel; Opening allowed from Master or Slave (local).

1.4 (d) Additional Components for Full Operation

Beyond base actuators, system integrates:
Actuators and Motion:

- 1x Long-stroke pneumatic double-acting cylinder (dual rack door motion) with end cushioning.
- 1x Platform Gap Filler (GF1) actuator/module (per GF1-50-2.pdf).
- 1x Short-stroke linear solenoid / pneumatic cylinder (lock).

Valves and Air Prep:

- 3x Solenoid-operated 5/2 directional valves (one per actuator) or integrated manifold.
- FRL unit (Filter-Regulator-Lubricator) + main shutoff valve + pressure gauge.
- Quick exhaust valves (optional) for faster closing.

Sensors:

- Reed switches on door cylinder (Open/Closed) + optional mid-travel.
- Capacitive proximity sensors (KI5002-02) positioned at doorway edges (obstruction + closed verification). See KI5002-02_DE-DE.pdf.
- Proximity or limit sensing for gap filler deployed/retracted (optional if correlated to door cylinder).
- Lock solenoid end-of-stroke confirmation (optional micro-switch).
- Panel pushbuttons: Open (Master/Slave), Close (Master), Activate, Emergency Stop.
- Indicator lights: Green (Ready/Active), Red (Locked/Inactive).

Sensors and Placement

- **Capacitive proximity sensor (KI5002-02):**
  - Model: KI5002-02 (capacitive).
    Datasheet: KI5002-02_DE-DE.pdf
  - Use: end-position or presence detection on door/slider elements where non-contact sensing is preferred.
  - Placement: mount on frame with adjustable bracket; detect a target plate on the moving member at both ends.
- **Subminiature Basic Switch (OMRON SS series):**
  - Offers High Reliability and Security — OMRON's best-selling micro switches of a wide variety from 0.1A to 10.1A.
    Datasheet: en-ss.pdf

- Use: mechanical end-of-stroke confirmation for lock pawl engagement or hard-limit detection on carriages.
- Placement: position so the actuator/lever is toggled only at the intended final position; include overtravel allowance per datasheet.

extitNotes: 24 VDC supply, choose PNP vs NPN to match controller. Use shielded cable for capacitive/analog lines and provide proper strain relief.

1.5 (e) System Understanding Emphasis

Prior to CAD work, verify: sizing of cylinders vs required stroke (half door travel), force calculations (friction + inertia), rail selection load rating, lock mechanism sequence timing, and sensor mapping to control logic. **DO NOT** finalize 3D design until force/stroke assumptions are validated.
NOTE: Insert preliminary engineering calculations (force, stroke, timing) here.

Engineering Calculation Placeholder (Forces / Stroke / Timing) – TODO

Mechanical Actuation Mechanism

Transmission architecture:

- **Dual Rack / Single Pinion**: Two parallel racks rigidly fixed to the respective door leaves engage a central pinion mounted on a shaft supported by bearings.
- **Single Door Cylinder Coupling**: The long-stroke cylinder couples to Rack A via a clevis + carriage. Extension drives Rack A forward, rotating the pinion and simultaneously translating Rack B in the opposite direction, yielding symmetric door motion.
- **Platform Gap Filler (GF1)**: Integrated module/actuator that deploys to bridge the platform/train gap when doors open, and retracts during closing, synchronized with door motion per control logic.
- **Lock Linear Solenoid**: Acts on a pawl/keeper interface. A brief extension withdraws the pawl (unlock pulse). Prompt retraction minimizes exposure and readies the mechanism for re-locking upon verified closed state.
- **Guidance**: Each door leaf rides on a lower rail using four rollers (2 leading, 2 trailing) for load distribution and reduced friction; upper guidance optional for anti-sway.
- **Sensing**: Reed switches (door cylinder ends), capacitive sensors (obstruction + closed verification), optional micro-switch on lock solenoid.

Benefits: Reduced actuator count, synchronized motion, clear sensing points, compact upper compartment packaging. Gap filler integrates with door timing to improve passenger safety at the platform/train interface. **Mechanism Figures:**

2 SolidWorks 3D Mechanical Design Guidelines (Adapted)

Design will mirror real hardware implementation. Key project-specific guidelines adapting milestone points:

- Ground-seated frame with vertical uprights supporting upper cylinder compartment.

Figure 2: Door mechanism: opened (left) vs. closed (right) showing rack-pinion engagement.

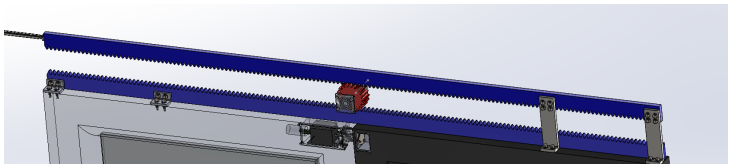

Figure 3: Dual racks connected to door leaves driven by single actuator.

- All pneumatic hardware (valves, FRL, tubing routing) contained within or on rear of frame, not protruding into passenger path.
- Frame width sized by aperture + rail assemblies; height sized by door leaf + clearance + cylinder compartment depth.
- Reserved mounting plane for future control panel (Milestone 2) on side column.
- Clear delineation of stages: (Input = Unlock + Activate), (Operation = Open/Close door motion), (Delivery = Secured locked state ready for next cycle).
- Cylinder orientation strictly horizontal; lock cylinder orthogonal or vertical depending design choice (to finalize).
- Use linear guide rails for door translation; bearings for any rotating shafts (if conversion mechanism used).
- Support layers: base chassis, mid rail support, upper actuator compartment.
- Door position tracking via reed switches; optional mid-stroke sensor mount features integrated.

NOTE: Insert 3D views (isometric, front, side) of assembled model.

3D Isometric View Placeholder – TODO

3D Exploded View Placeholder – TODO

3 Design For Manufacturing (DFM) Report

DFM ensures each custom part is feasible with available processes. Provide per-part manufacturing notes and 2D drawings.

Manufacturing Assumptions

- Frame members: standard rectangular steel/aluminum profiles cut to length, drilled.
- Mounting plates: laser-cut sheet metal (specify alloy, thickness), bent where required.

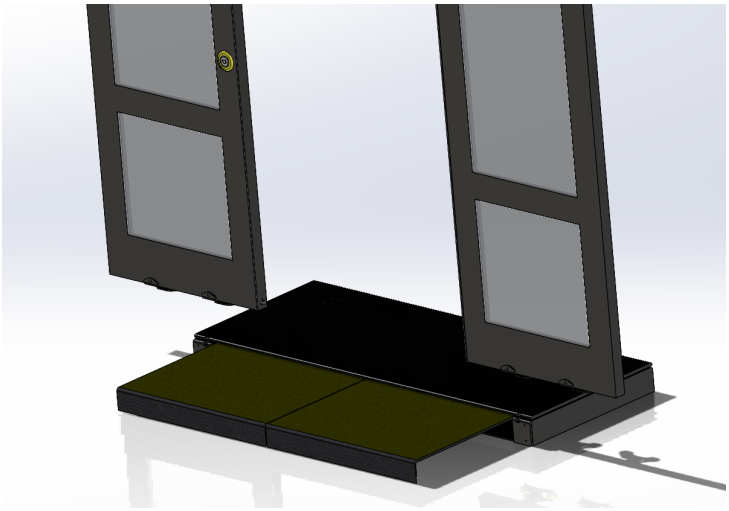

Figure 4: Platform gap filler deployment (GF1 extended).

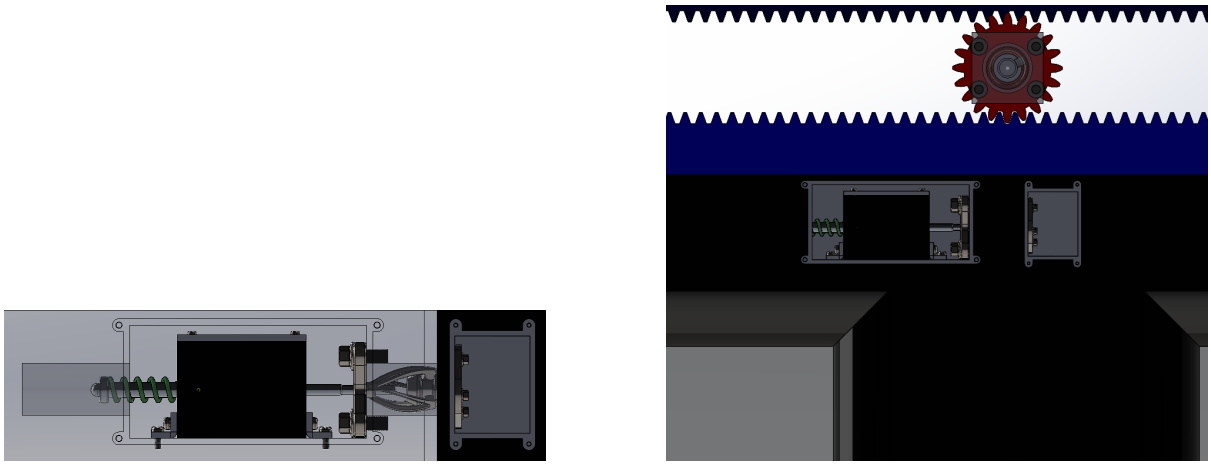

Figure 5: Locking mechanism: closed position and mounting location.

- Lock pawl: CNC milled or laser-cut + heat-treated (if wear critical).
- Brackets: sheet metal with flange bends, hole patterns for cylinder clevis.
- Rails: purchased linear guide assemblies (COTS).

DFM Part Table (Preliminary)

oprule Part	Name	Material / Specs (Draft)	Process	Drawing Ref.
1	Base frame upright	*Alu/Steel profile, cut length*	Saw cut + drill	*FIG TBD*
2	Upper actuator plate	*Alu sheet t=5 mm*	Laser cut + bend	*FIG TBD*
3	Rack mounting bracket	*Steel t=4 mm*	Laser cut + bend	*FIG TBD*
4	Door roller carriage	*Alu machined + bearings*	CNC + assembly	*FIG TBD*
5	Pinion shaft support	*Steel*	Turn + mill	*FIG TBD*
6	Lock pawl	*Steel (HT optional)*	Laser cut + finish	*FIG TBD*
7	Metro slider bracket	*Alu t=3 mm*	Laser cut + bend	*FIG TBD*
8	Valve manifold plate	*Alu t=6 mm*	Laser cut	*FIG TBD*

oprule Part	Name	Material / Specs (Draft)	Process	Drawing Ref.
...	...	...	...	...

NOTE: Insert each 2D technical drawing (dimensions, tolerances) following the table.

2D Drawing Set Placeholder – TODO

4 Design For Assembly (DFA) Report

Focus: minimize assembly time, ensure accessibility, reduce fastener count, enable maintenance.

Assembly Strategy

- Modular subassemblies: Frame, Door Panels on Carriages, Actuator Compartment (cylinders + valves), Lock Mechanism, Sensor Harness.
- Fastener standardization: prioritize M6 socket head and self-locking nuts *(verify)*.
- Accessibility: sliding panels removable without disturbing cylinder alignment.
- Cable/pneumatic routing channels integrated in upright profiles.
- Exploded views to illustrate sequence and tool clearance zones.

NOTE: Insert exploded subassembly views and annotated assembly sequence list.

Exploded Subassembly Views Placeholder – TODO

5 Mechanical Component List

Comprehensive inventory per milestone instructions.

oprule No.	Name	Description / Function	Qty	Notes / Datasheet Ref.
1	Door actuator cylinder (DC)	Drives both doors via dual rack (Extended=Open)	1	Stroke 850 mm (confirm)
2	Platform Gap Filler (GF1)	Deploys to bridge platform gap (Extended=Deployed)	1	See GF1-50-2.pdf
3	Lock linear solenoid (LS)	Unlock pulse + relock pawl	1	Stroke 100 mm (confirm)
4	5/2 solenoid valve (DC)	Controls door actuator	1	Voltage *TODO*
5	5/2 solenoid valve (GF1)	Controls gap filler actuator (if pneumatic)	1	Voltage *TODO*
6	5/2 solenoid valve (LS)	Controls lock actuator / solenoid driver	1	Voltage *TODO*
7	FRL unit	Air preparation	1	Model *TODO*
8	Pressure regulator + gauge	Pressure monitoring	1	Range *TODO*
9	Reed switches (door)	End-position sensing (Open/Closed)	2	Door cylinder barrel
10	Capacitive proximity sensors (KI5002-02)	Obstruction + closed path check	1 set	See KI5002-02_DE-DE.pdf

oprule No.	Name	Description / Function	Qty	Notes / Datasheet Ref.
11	Door roller carriages	Support door leaves	2	Bearings *TODO*
12	Door panels (leaves)	Barrier components	2	Material *TODO*
13	Rack assemblies	Linear motion transfer	2	Module *TODO*
14	Pinion + shaft	Converts rack linear motion	1	Gear data *TODO*
15	Lock pawl	Mechanical lock interface	1	Hardened? *TODO*
16	Strike plate	Pawl engagement surface	1	*TODO*
17	Indicator lights (Green)	Status active	2	Voltage *TODO*
18	Indicator lights (Red)	Status inactive	2	Voltage *TODO*
19	Master panel buttons	Open / Close / Activate	3	Type *TODO*
20	Slave panel button	Local Open	1	Type *TODO*
21	Emergency stop	Safety shutdown	1	Standard *TODO*
22	Tubing (various diam.)	Pneumatic connections	As req.	Diameters *TODO*
23	Fittings (elbow, T)	Air routing	Set	Count *TODO*
24	Fasteners (M6/M8)	Structural joints	Set	Spec *TODO*
25	Cable / pneumatic duct	Routing mgmt	As req.	Length *TODO*
26	Valve manifold plate	Mount valves	1	Material *TODO*
...	...	...	...	...

NOTE: Attach PDF datasheets for all purchased components in Appendix (placeholder below).

Datasheets Appendix Placeholder – TODO

6 Pneumatic Position-Step Diagram

Sequence states for three actuators: DC (Door Cylinder), GF1 (Gap Filler), LS (Lock Solenoid). **Legend:** EXT = Extended, RET = Retracted. Capacitive sensors supervise obstruction during closing.

oprule Step	DC (Doors)	GF1 (Gap Filler)	LS (Lock)	Event / Sensor Condition
0 Idle Locked	RET (Closed)	RET (Retracted)	RET (Locked)	System inactive (Red ON)
1 Unlock Pulse	RET	RET	EXT (Unlock)	Activate pressed (Green ON), LS pulse then returns RET
2 Opening	EXT (Opening)	EXT (Deploying)	RET	Open command; position sensors transition; capacitive sensors ignored
3 Fully Open	EXT (Open)	EXT (Deployed)	RET	Door open confirm; dwell timer start
4 Closing	RET (Closing)	RET (Retracting)	RET	Close command; capacitive sensors monitored for obstruction
5 Closed / Relock	RET (Closed)	RET (Retracted)	RET (Locked)	Door closed confirm; capacitive sensors clear; lock state confirmed

oprule Step	DC (Doors)	GF1 (Gap Filler)	LS (Lock)	Event / Sensor Condition
OB Obstruction	EXT (Re-open)	EXT (Re-deploy)	RET	Capacitive obstruction during closing triggers immediate reopen

NOTE: The time diagram above mirrors the tabular sequence.

7 Milestone Deliverables Checklist

- Updated project description (single-cylinder dual-rack architecture) – *Revised*
- 3D views of mechanical design – *Cover render inserted; exploded view pending*
- Mechanical component list – *Reworked for 3 actuators*
- DFM report + 2D drawings – *Framework ready; drawings pending*
- DFA report with exploded views – *Framework ready; views pending*
- Pneumatic position-step diagram – *Updated table; graphic pending*
- Sensor + safety logic (capacitive + reed) – *Documented*
- Mechanism and lock figures – *Inserted*
- SolidWorks 3D design files – *To include in ZIP upon completion*

8 Appendix

A. Datasheets

NOTE: Insert PDFs (referenced externally) or summary tables for each purchased component.

Datasheet Collection Placeholder – TODO

B. Engineering Calculations

NOTE: Force sizing for cylinders, friction coefficients, air consumption estimates.

Calculation Sheets Placeholder – TODO

C. Risk and Safety Notes

Preliminary safety considerations: pinch points at door edges, emergency stop circuit design, pneumatic pressure limits. Detailed FMEA optional in later milestone.
NOTE: Insert safety assessment here.

Figure 6: Left: door roller wheel set. Right: door control/open button concept.

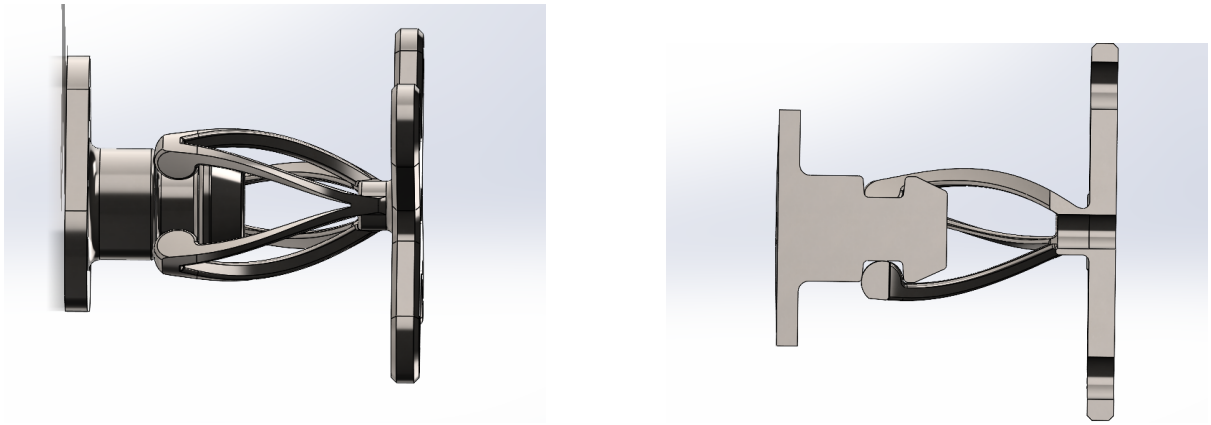

Figure 7: Locking mechanism detailed views: showing engagement geometry.

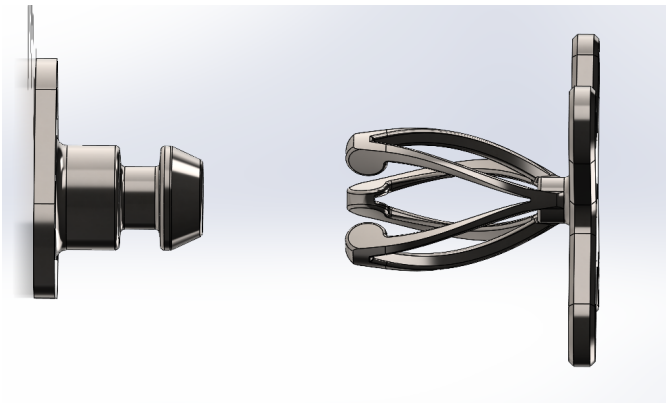

Figure 8: Locking mechanism unlatched (isolated)

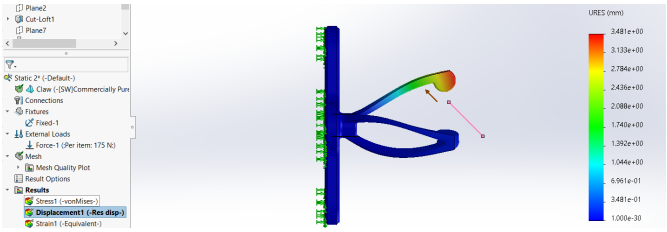

Figure 9: Stress analysis (von Mises) of locking claw under peak load

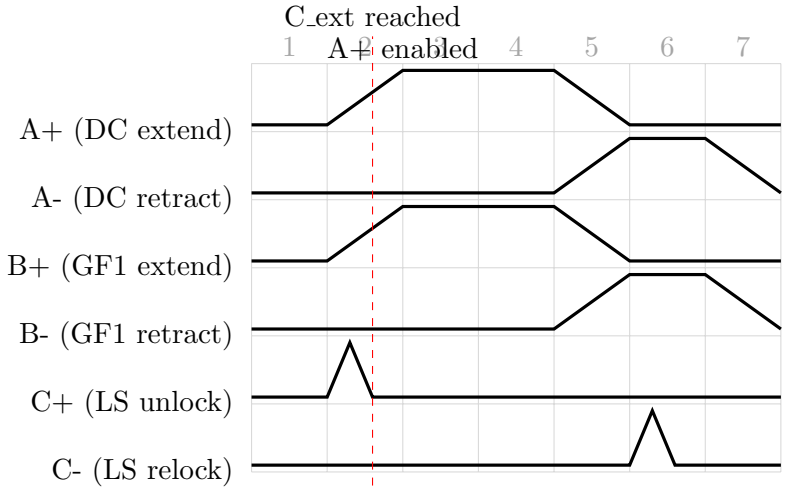

Figure 10: Pneumatic position diagram (normal): A+/B+ during opening, A-/B- during closing. Interlock: A+ rises only after C is fully extended (C_ext). GF1 = gap filler.

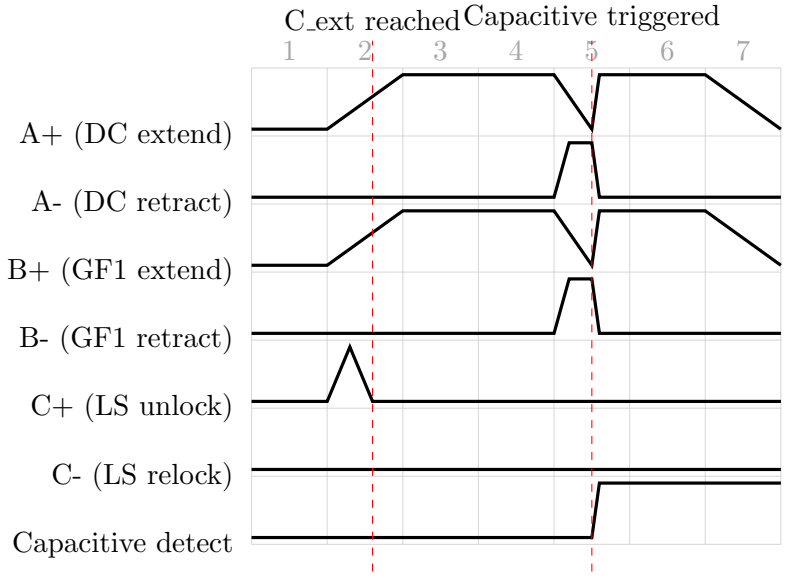

Figure 11: Obstruction/human-detected variant: Capacitive trigger during closing causes immediate re-open (A+/B+ high again) and inhibits relock (C- stays low). A+ remains interlocked to C_ext for any new opening. GF1 = gap filler.