



# Metro Sliding Doors Project

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## Cover Page

**University:** German International University

**Course:** Mechatronics Lab (MCTR704)

**Semester:** Berlin Winter 2025

**Project Title:** Metro Sliding Doors

**Project No.:** [ 9 ]

**Instructor/Supervisor:** *TODO*

**NOTE:** Insert logo / project representative photo here.



Overall assembly render

extbf3D Views: Representative render integrated below. ableofcontents



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. **Metro Slider Cylinder (MSC)**: an auxiliary medium-stroke cylinder (approx. 425 mm stroke) that deploys a secondary sliding element/cover concurrently with door opening and retracts during door closing. *Extended = Slider Open, Retracted = Slider Closed*.

extbfSensors 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.
- **IR Beam (Door-to-Door)**: verifies unobstructed closure. If the beam is broken during a closing sequence, the system immediately commands a reopen (DC extend, MSC 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 (Transferred Object) Description

The **workpiece** is the *passenger passage aperture* governed by two coupled sliding leaves. extbf- Preliminary dimensional assumptions (validate in Milestone 2):

- 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)
- Metro slider stroke:  $\approx$  **425 mm** (about half of main door travel)
- 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.

extbfNOTE: 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, MSC Extended = Slider Open, LS Extended = Unlock Pulse):

- Step 1: **Idle Locked:** System inactive. DC Retracted (doors closed), MSC Retracted (slider closed), 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: **Opening:** Command Open. DC Extends driving racks; MSC Extends simultaneously. IR beam monitored but ignored for opening. Reed Open switch triggers at end-of-stroke.
- Step 4: **Dwell Open:** DC Extended, MSC Extended. Timer or passenger flow condition decides closing initiation.

Step 5: **Closing**: Close command (Master). DC Retracts; MSC Retracts. IR beam must remain clear. If IR obstruction occurs, sequence aborts and system returns to Opening (auto-reopen).

Step 6: **Closed + Relock**: Reed Closed confirms stroke end. IR beam *clear* condition verified. 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 (IR beam break during closing) forces immediate DC re-extend + MSC 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:  
extbfActuators and Motion:

- 1x Long-stroke pneumatic double-acting cylinder (dual rack door motion) with end cushioning.
- 1x Medium-stroke pneumatic double-acting cylinder (metro slider).
- 1x Short-stroke linear solenoid / pneumatic cylinder (lock).

extbfValves 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.

extbfSensors:

- Reed switches on door cylinder (Open/Closed) + optional mid-travel.
- IR beam pair across doorway (obstruction + closed verification).
- Reed or proximity sensor for metro slider extended/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).

extbfMechanical Guidance:

- Linear rails or roller track assemblies for door leaves.
- Linkage brackets coupling cylinder rod to carriage.
- Locking pawl and strike plate assembly.

extbfSafety / Enclosure:

- Protective upper compartment housing cylinders and valves.
- Panel enclosure (added in Milestone 2) reserved space in frame design.

## 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.

extbfNOTE: Insert preliminary engineering calculations (force, stroke, timing) here.

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

## Mechanical Actuation Mechanism (Updated)

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.
- **Metro Slider Cylinder:** Independently mounted; its extension deploys the metro slider panel (auxiliary cover or secondary barrier) in synchrony with door opening for staged access. Retraction during closing maintains clearance.
- **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), IR beam (obstruction + closed verification), optional micro-switch on lock solenoid.

Benefits: Reduced actuator count, synchronized motion, clear sensing points, compact upper compartment packaging. extbfMechanism Figures:

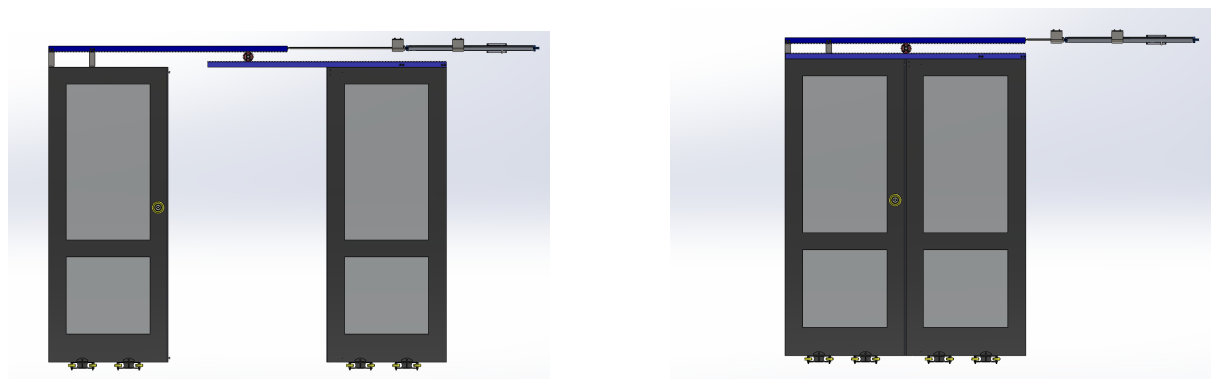


Figure 2: Door mechanism: opened (left) vs. closed (right) showing rack-pinion engagement.

## 2 SolidWorks 3D Mechanical Design Guidelines (Adapted)

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

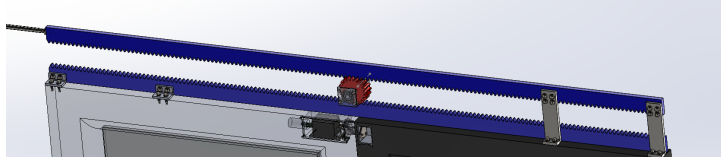


Figure 3: Dual racks connected to door leaves driven by single actuator.

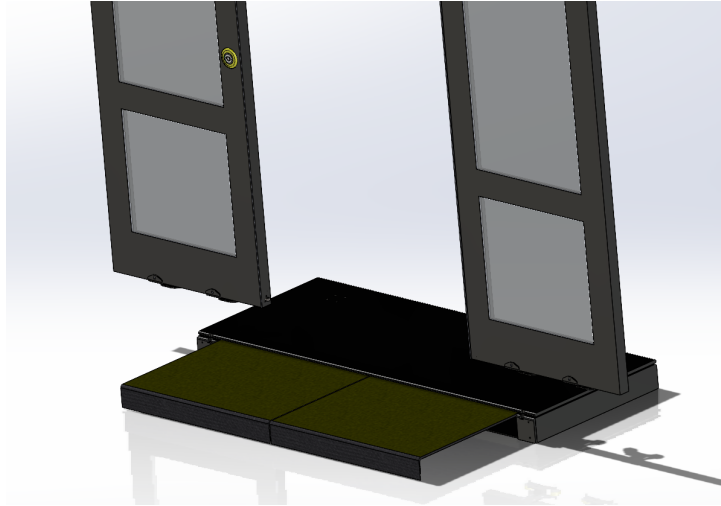


Figure 4: Metro slider secondary panel actuation (MSC extended).

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

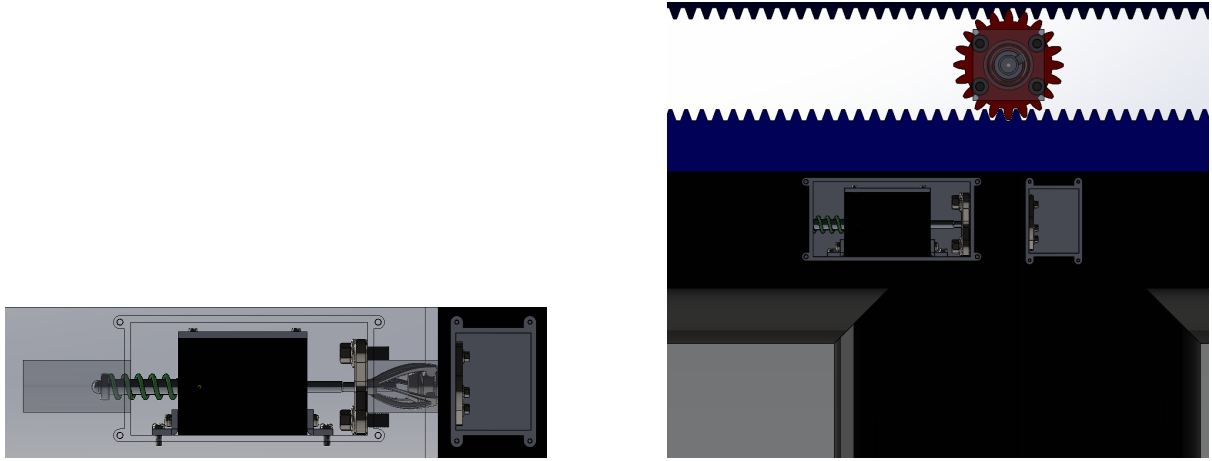


Figure 5: Locking mechanism: closed position and mounting location.



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

## 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.
- 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).

extbfDFM Part Table (Preliminary)

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



| oprule<br>Part | Name | Material / Specs<br>(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<br>No. | Name                        | Description / Function                          | Qty   | Notes / Datasheet<br>Ref. |
|---------------|-----------------------------|---|-------|---------------------------|
| 1             | Door actuator cylinder (DC) | Drives both doors via dual rack (Extended=Open) | 1     | Stroke 850 mm (confirm)   |
| 2             | Metro slider cylinder (MSC) | Secondary slider deployment (Extended=Open)     | 1     | Stroke 425 mm (confirm)   |
| 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 <i>TODO</i>       |
| 5             | 5/2 solenoid valve (MSC)    | Controls metro slider                           | 1     | Voltage <i>TODO</i>       |
| 6             | 5/2 solenoid valve (LS)     | Controls lock actuator / solenoid driver        | 1     | Voltage <i>TODO</i>       |
| 7             | FRL unit                    | Air preparation                                 | 1     | Model <i>TODO</i>         |
| 8             | Pressure regulator + gauge  | Pressure monitoring                             | 1     | Range <i>TODO</i>         |
| 9             | Reed switches (door)        | End-position sensing (Open/Closed)              | 2     | Door cylinder barrel      |
| 10            | IR beam sensor pair         | Obstruction + closed path check                 | 1 set | Range <i>TODO</i>         |

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

**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), MSC (Metro Slider Cylinder), LS (Lock Solenoid). **Legend:** EXT = Extended, RET = Retracted.

| oprule Step       | DC (Doors)    | MSC (Slider)  | LS (Lock)    | Event / Sensor Condition                                 |
|-------------------|---------------|---------------|--------------|--|
| 0 Idle Locked     | RET (Closed)  | RET (Closed)  | 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 (Opening) | RET          | Open command; reed switches transition; IR ignored       |
| 3 Fully Open      | EXT (Open)    | EXT (Open)    | RET          | Door open reed ON; dwell timer start                     |
| 4 Closing         | RET (Closing) | RET (Closing) | RET          | Close command; IR beam monitored for obstruction         |
| 5 Closed / Relock | RET (Closed)  | RET (Closed)  | RET (Locked) | Door closed reed ON; IR beam clear; lock state confirmed |
| OB Obstruction    | EXT (Re-open) | EXT (Re-open) | RET          | IR beam broken during closing triggers immediate reopen  |

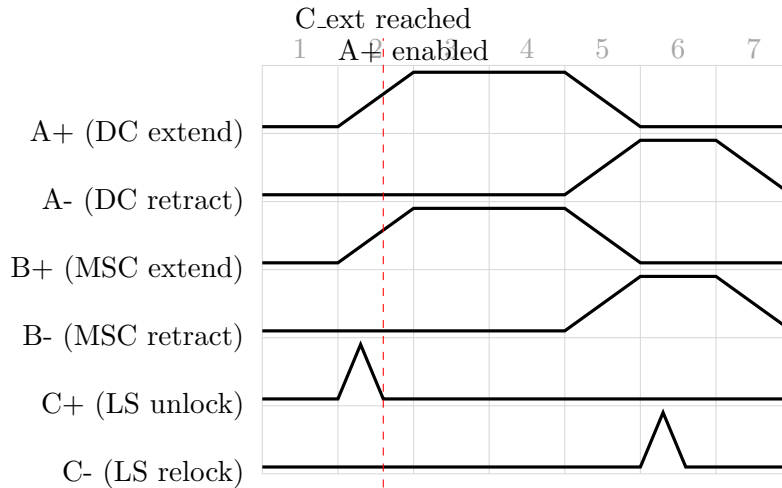


Figure 7: Pneumatic position diagram (normal): A+/B+ during opening, A-/B- during closing. Interlock: A+ rises only after C is fully extended (C\_ext).

extbfNOTE: The time diagram above mirrors the tabular sequence.

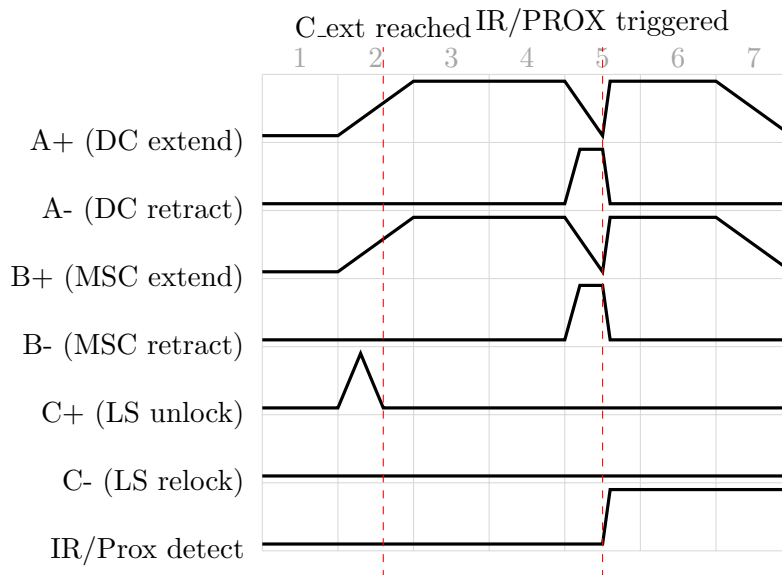


Figure 8: Obstruction/human-detected variant: IR/Prox trigger during closing causes immediate re-open (A+/B+ high again) and inhibits relock (C- stays low). A+ remains interlocked to C\_ext for any new opening.

## 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 (IR + 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.