Critical Design Review

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Automation Technology

Workgroup: University of Cagliari

University of Cassino and Southern Latio

This document is the Critical Design Review of the technical competence ‘Automation Technology.
Its details the complete design of the pneumatic/electropneumatic test bed..

Version: 3.0

Date: June 18th, 2025

Visit https://misceproject.eu/ for more information.

Index of contents

Index of figures

Index of tables

1.1 Scope

This document presents the detailed design of the pneumatic/electropneumatic test bed control platform developed in the framework of MISCE project.

The final objective is to use the developed platform in the practical lectures of engineering degrees to contribute to the technical competence:

A1. Automation Technology

which related skills are (see Table I):

Table I. Skills of Automation Technology

S1.1.	To know the main electric/pneumatic and hydraulics elements
S1.2.	To be able to design the functional behavior of the system
S1.3.	To be able to understand the technical documentation of a project/product
S1.4.	To program the functional behavior of the device
S1.5.	To debug the final planned behaviour of the system

1.2 Preliminary definition

This experimental test-bed (portable version of the TB1) is a compact and transportable solution developed for teaching purposes, especially designed for flexible and dynamic laboratory environments.
It represents a "take-away" version of the initial test-bed, retaining all the essential functionalities while improving mobility and facilitating fast deployment.

It is composed of:

- n.1 Siemens PLC of type 1215C;
- n.1 Siemens HMI of type Comfort Basic;
- n.1 Ethernet cable for PLC/PC communication;
- Digital I/O terminals for external connection;
- External pneumatic/electropneumatic system (connected via standard cables);
- n.1 Laptop with TIA Portal software for programming, monitoring, and simulation.

Figure 1. Suitable experimental test bed realized

This proposal requires the realized test bed or the use of the Digital Twin environment simulation environment by using the software (in this case Autosim-200) that allows the simulation of the behaviour of the movement.

So compared to Test Bench 1, Test Bench 2 offers the great advantage of portability: being a "take-away" version, it can be easily transported and connected to various electromechanical systems — even older setups — making it highly versatile and adaptable to different learning environments.

1.3 Technical requirements

The main strength of this new test bench lies in its compact design and high portability, which allow it to be easily integrated into various laboratory setups and educational environments. Its modular structure enables connection with a wide range of electromechanical systems, even older ones, making it an adaptable and reusable teaching tool. This flexibility, combined with its clear pneumatic and electrical interface, makes it particularly suitable for hands-on training in PLC programming and industrial automation principles.

1.3.1 Actuation of a single acting pneumatic cylinder

The actuation of the single effect pneumatic cylinder is well-known on teaching activities related to automation technology It consists of a single effect pneumatic cylinder, a 5/2 (five ways, two positions) electro-pneumatic valve with pneumatic actuation and a 3/2 (three ways, two positions) electro-pneumatic valve with mechanical actuation. The movement of the pneumatic cylinder can be controlled also by means of one button or via a PLC (see Figure 2).

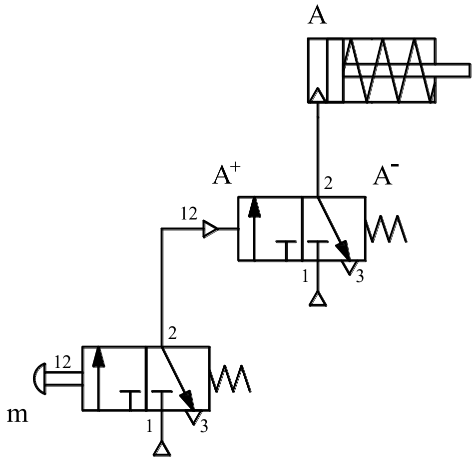


Figure 2. Actuation of single acting pneumatic cylinder

The main advantage of this test bed is related to the possibility to be used widely in different academic activities. In addition, the behaviour of the cylinder is well-know and easy to be achieved and offers a very illustrative way to introduce in all the skills of automation technology.

List of components used:

n.1 Single-acting cylinder;
n.1 Push button (3/2 unistable valve with manual actuation);
n.1 3/2 unistable pneumatically operated power valve.

Functional test:

 By pressing the start button m, the control signal A+ is activated, with the consequent release of the piston of cylinder A;

 when the start button m is released, the control signal A− is activated, with the consequent retraction of the piston of cylinder A. The activation of the control signal A− is determined by the presence of the return spring, with consequent emptying of the rear chamber of the cylinder.

1.3.2 Actuation of a double effect pneumatic cylinder

The actuation of the double effect pneumatic cylinder is well-known on teaching activities related to automation technology. It consists of a double effect pneumatic cylinder, a 5/2 (five ways, two positions) electro-pneumatic valve with electric actuation and a two electric push button. The movement of the pneumatic cylinder can be controlled by means of two button or via a PLC. The control objective of this platform is to control the position of the ball over the beam (see Figure 3).

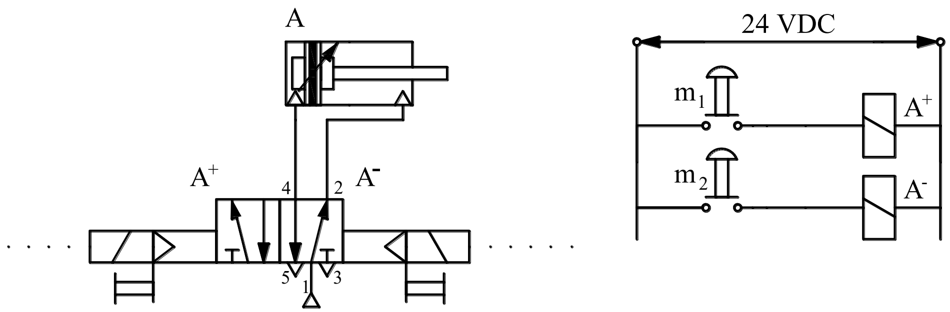


Figure 3. Double effect pneumatic cylinder

This device shall also include the electronics part and the control equipment to command the behaviour of the cylinder by means of electronic board (e. g. Arduino, Raspberry, PLC etc.).

This exercises complements the pneumatic/electropneumatic test bed adding a more functionality in a basic control approach.

List of components used:

- n.1 Double-acting cylinder;
- n.1 5/2 bistable power solenoid valve with pneumatic pilot;
- n.2 m_1 and m_2 electric buttons.

Functional test:

- By pressing and releasing the start button m_1, the control signal A^+ is activated and the piston of cylinder A comes out;
- By pressing the m_2 start button, the control signal A^- is activated and the piston of cylinder A is retracted.

1.3.3 Diagram of Movement-Phase

In order to create a suitable “Movement-Phase” displacement, by using the previous reported experimental platform, will be possible to create all type of required/desired movement/phase diagram. The control objective is to create all possible combination of movement of the cylinder by mean of the experimental/Numerical (digital Twin) Platform (see Figure 4).

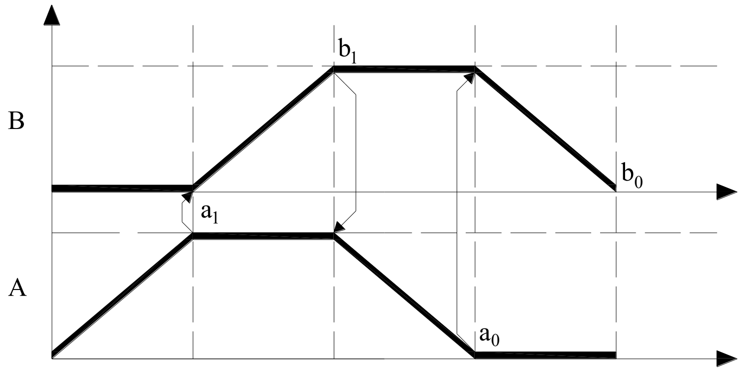


Figure 4. Generation of a suitable “Movement-Phase” displacement

This experimental platform complements the aforementioned by adding a more complex capability.

Using the same hardware set-up it is possible to generate different cycles. It is important to note that compared to the previous two cases, there is no change in the pneumatic and electrical connections; In fact, the only thing that varies is the program downloaded to the controller's memory.

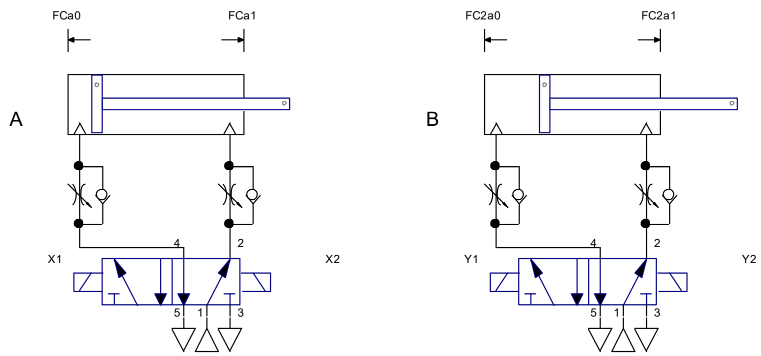


Figure 5. Electro pneumatic connection (physical connection)

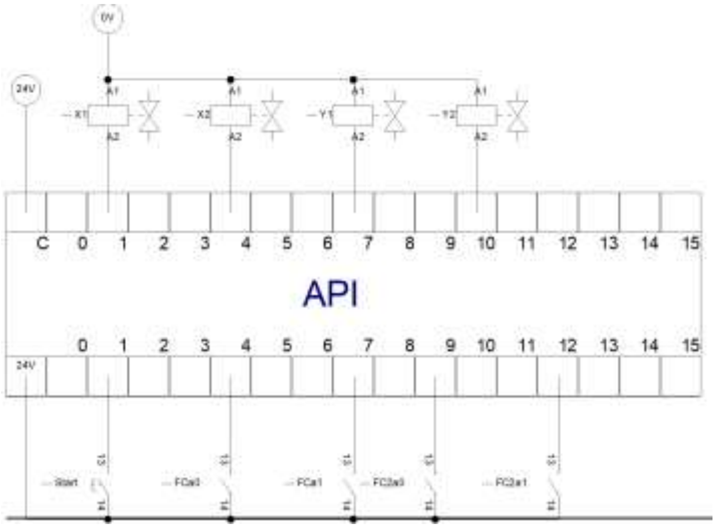


Figure 6. PLC connection (simulation software)

The references of the A and O commands to the consensus and command signals are shown in the following table:

Table II. Command/Consent Matches with Variables Used in the Software

End Stroke		software Variable		Command		Software Variable
a_0		i4 (end stroke a0)		A^+	VAX1	o1
a_1		i7 (end stroke a1)		A^-	VAX2	o4
b_0		i9 (end stroke a0)		B^+	VAY1	o7
b_1		i12 (end stroke a1)		B^-	VAY2	o10
m		i1 (Start)		Memory		u100

2 Hardware Design

The hardware design includes some functional parts that can be easily acquire in the market.

2.1 Functional Parts

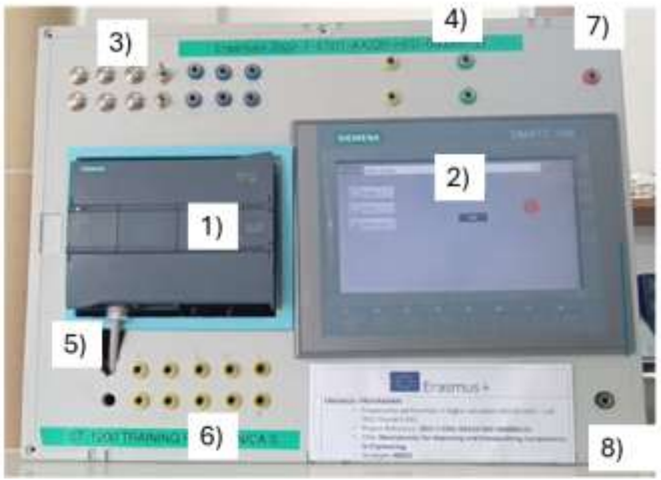
The hardware design includes functional components that are easily available and accessible for educational purposes. In this case, the following functional elements have been selected:

- n.1 Siemens PLC of type 1215C;
- n.1 Siemens HMI of type Comfort Basic;
- Digital Input;
- Analogic Input;
- n.1 Ethernet cable for PLC/PC communication;
- Output;
- n.1 24V DC power supply connection (red wire) for powering the PLC, HMI, and I/O devices;
- n.1 Ground (GND) connection (black wire) for the common return path in the electrical circuits;
- External pneumatic/electropneumatic system (connected via standard cables);
- n.1 Laptop with TIA Portal software for programming, monitoring, and simulation.

As a result, three experimental activities and a digital twin numerical activity have been developed. These activities range from the basic control of a pneumatic actuator to the management of more complex system operations.

2.2 Mechanical Design

The hardware design includes functional components that are easily available and accessible for educational purposes. In this case, the following functional elements have been selected:



1. n.1 Siemens PLC of type 1215C;
2. n.1 Siemens HMI of type Comfort Basic;
3. Digital Input;
4. Analogic Input;
5. n.1 Ethernet cable for PLC/PC communication;
6. Output;
7. n.1 24V DC power supply connection (red wire) for powering the PLC, HMI, and I/O devices;
8. n.1 Ground (GND) connection (black wire) for the common return path in the electrical circuits.

Figure 7. Test bed scheme

Figure 8 TB2 in operation

3 Software Design

The software has been designed to be usable by any user (professors/students). This type of software will require the license, or will be possible to use for a limited time to use the trial version.

In this way, the PLC S71200 has been programmed using its TIA Portal Software, https://www.siemens.com) and a numerical simulation application has been designed by using autosim 200 (https://www.smctraining.com).
Both applications are available in any desktop or laptop computer. Figure 10 illustrates the software architecture.

3.1 Autosim-200 Software

The code of the Autosim-200 software is available, under demand, in MISCE project webpage.
The software has been designed and reported in Fig. 9.

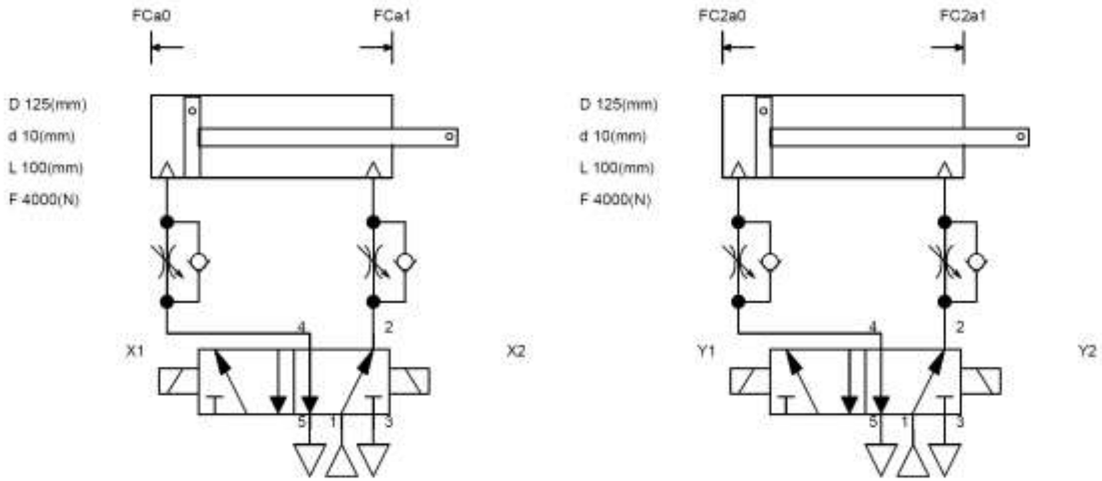


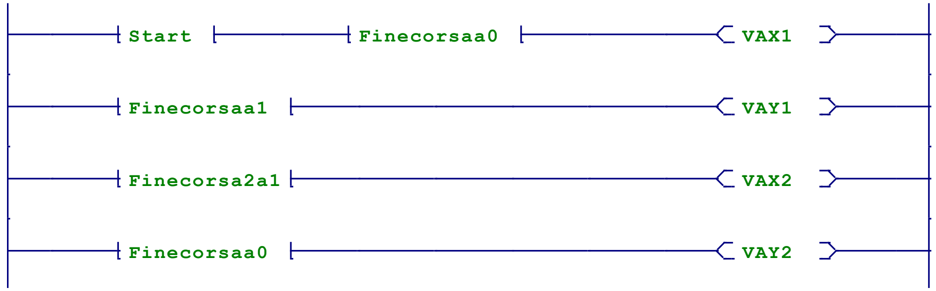
Figure 9 Scheme of the software connections

3.2 Ladder Software

The code of the Autosim-200 software is available, under demand, in MISCE project webpage.

The Ladder software program has been designed and reported in Tab. III.

Table III. Ladder program used in the Software



Ladder diagram of the PLC control program in order to obtain that movements: A^+, B^+, A^-, B^-.