Critical Design Review

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Automation Technology

Workgroup: University of Cagliari

Universidad de Castilla-La Mancha

University of Cassino and Southern Latio

Universitat Politècnica de València

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

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

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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 can be widely used for teaching purposes. It is composed of:

- n.1 Siemens PLC of type 1215C;
- n.6 3/2 electrically operated monostable valves for each cylinder (2 per cylinder);
- n.3 Double-acting pneumatic cylinders (A, B, C);
- n.6 magnetic proximity sensors mounted on cylinders (2 for each cylinder: a0/a1, b0/b1, c0/c1).

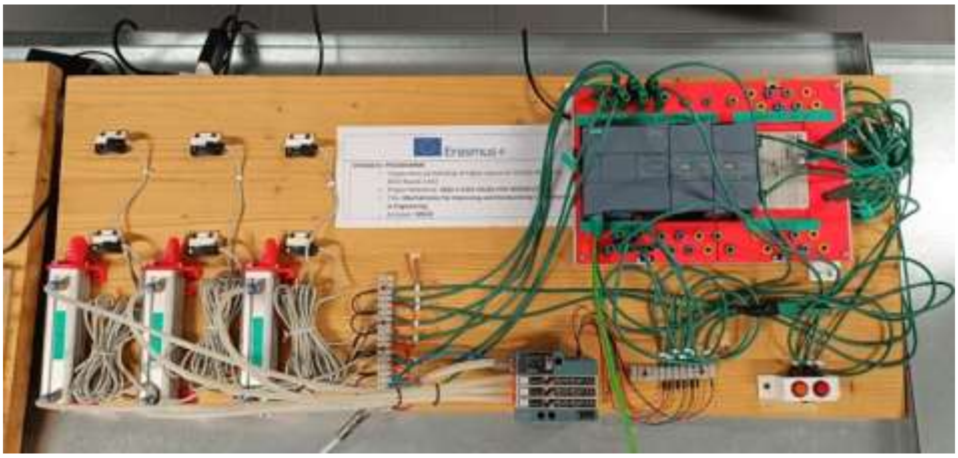


Figure 1. Suitable experimental test bed realized

This system is similar to previous platforms in terms of cylinder actuation and sensor setup, but it differs in the specific valve configuration and control logic used. The use of a Digital Twin simulation environment (e.g., using software like Autosim-200) allows for the simulation of cylinder behavior and movement patterns.

The main advantage of this test bed is its versatility in different academic activities. Additionally, the behavior of the cylinders is well-known and easy to replicate, offering an effective and illustrative way to introduce key concepts of automation technology.

On the other hand, the main drawback lies in the limitations of this basic actuation system, where the cylinder movement is controlled by a spring return mechanism, leaving out more complex aspects of movement control.

1.3 Technical requirements

The main advantage of this test bed is its wide applicability in various academic activities. Additionally, the behavior of the cylinder is well understood and easy to replicate, offering an illustrative way to introduce key concepts in automation technology.

1.3.1 Actuation of a double effect pneumatic cylinder

The actuation of the double-acting pneumatic cylinder is widely used in teaching activities related to automation technology. It consists of a double-acting pneumatic cylinder, a 3/2 (three-way, two-position) electro-pneumatic valve with electric actuation, and two electric push buttons. In this new test bench, each cylinder (A, B, C) is controlled by two 3/2 monostable solenoid valves, one for extending the cylinder and the other for retracting it. The movement of the pneumatic cylinder can be controlled either by the push buttons or via a PLC. The control objective of this platform is to manage the position of the ball over the beam (see Figure 2).

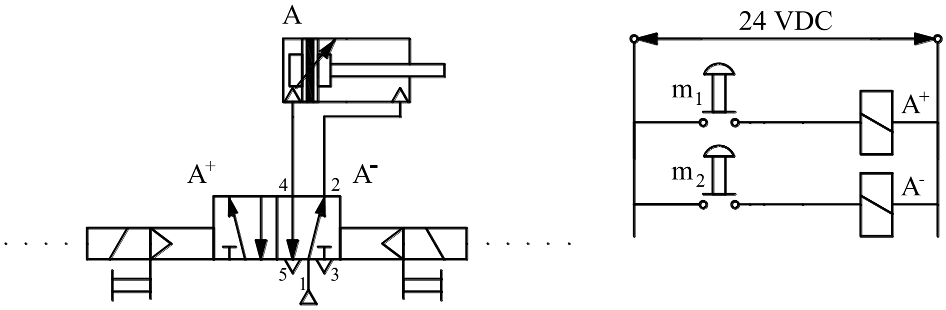


Figure 2. Double effect pneumatic cylinder

This device also includes the electronics and control equipment to manage the cylinder's behavior via an electronic board (e.g., Arduino, Raspberry Pi, PLC, etc.). This exercise complements the pneumatic/electropneumatic test bed by adding more functionality to a basic control approach, with a particular focus on velocity regulation and more advanced control strategies compared to previous systems.

List of components used:
• n.1 Double-acting cylinder;
• n.2 3/2 monostable solenoid valves with electric actuation for each cylinder;
• n.2 electric push buttons (m1 and m2).

Functional test:

- By pressing and releasing the start button m1, the control signal A+ is activated, and the piston of cylinder A extends.;
- By pressing the m2 start button, the control signal A− is activated, and the piston of cylinder A retracts.

1.3.2 Diagram of Movement-Phase

To create a suitable “Movement-Phase” displacement using the previously described experimental platform, it will be possible to generate all types of required/desired movement/phase diagrams. The control objective is to create all possible combinations of cylinder movements using the experimental/numerical (Digital Twin) platform (see Figure 3).

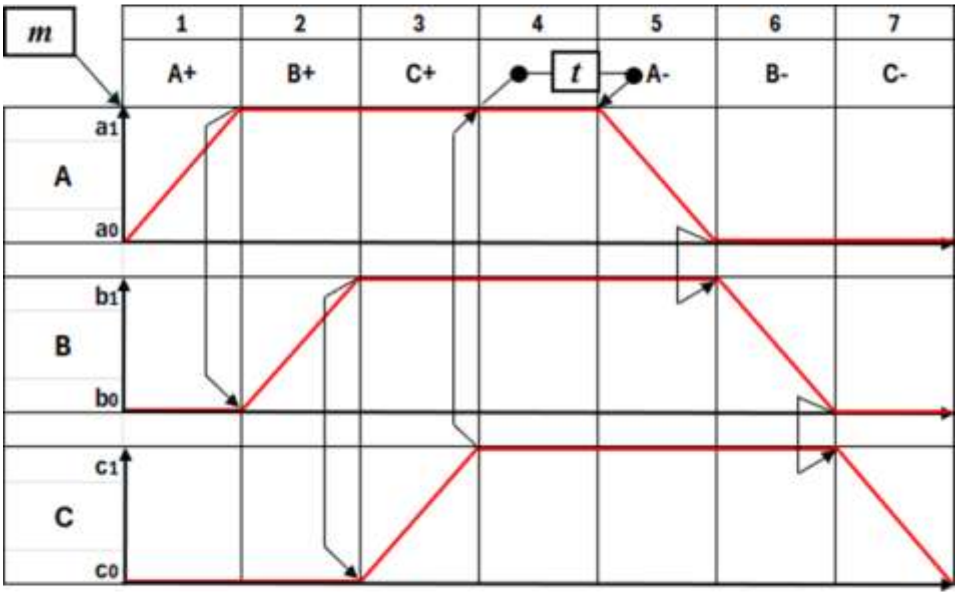


Figure 3 Generation of a suitable “Movement-Phase” displacement

This experimental platform enhances the previous system by adding more complex capabilities. Using the same hardware setup, it is possible to generate different cycles. It is important to note that, compared to the previous cases, there is no change in the pneumatic and electrical connections. The only difference is the updated control logic and the program downloaded to the controller's memory, which allows for more advanced control and sequencing.

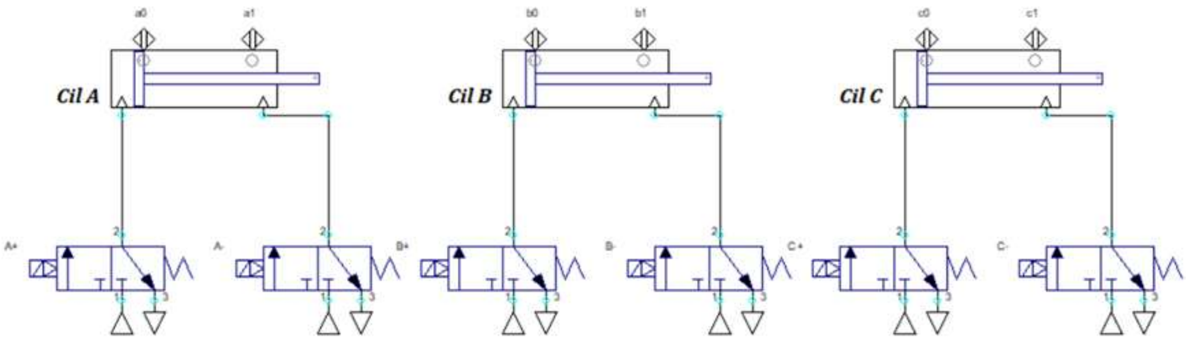


Figure 4 Electro pneumatic connection (physical connection)

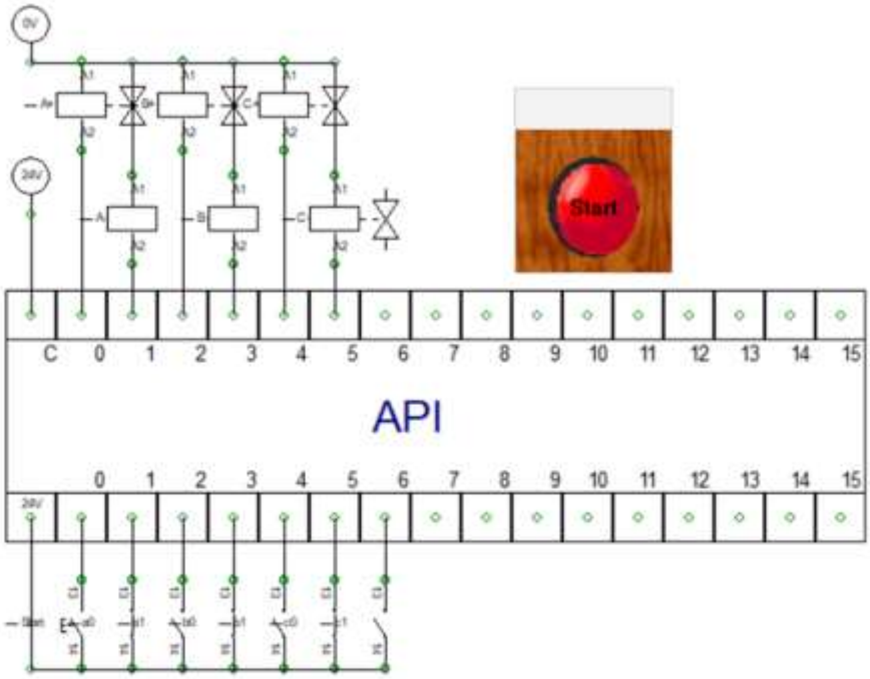


Figure 5 PLC connection (simulation software)

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

Simboli	Variabili
Start	i0
a0	i1
a1	i2
b0	i3
b1	i4
c0	i5
c1	i6
A+	o0
A-	o1
B+	o2
B-	o3
C+	o4
C-	o5

2 Hardware Design

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

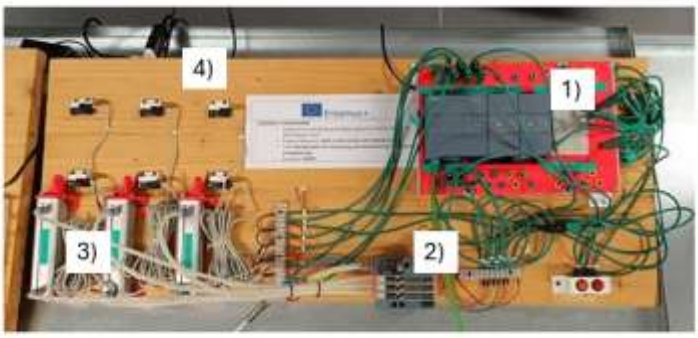
2.1 Functional Parts

The hardware design includes some functional parts that shall be easy to find and to acquire by the teaching professionals. In this case, the following functional elements have been selected or printed:

- n.1 Siemens PLC of type 1215C;
- n.6 3/2 electrically operated monostable valves for each cylinder (3/2 single-valve valves with electric drive (2 for each cylinder);
- n.3 Double-acting pneumatic cylinders (A, B, C);
- n.6 magnetic proximity sensors mounted on cylinders (2 for each cylinder: a0/a1, b0/b1, c0/c1).

2.2 Mechanical Design

The hardware design includes some functional parts that shall be easy to find and to acquire by the teaching professionals. In this case, the following functional elements have been selected or printed:



1. n.1 Siemens PLC of type 1215C;
2. n.6 3/2 electrically operated monostable valves for each cylinder (3/2 single-valve valves with electric drive (2 for each cylinder);
3. n.3 Double-acting pneumatic cylinders (A, B, C);
4. n.6 magnetic proximity sensors mounted on cylinders (2 for each cylinder: a0/a1, b0/b1, c0/c1).

Figure 6 Test bed scheme

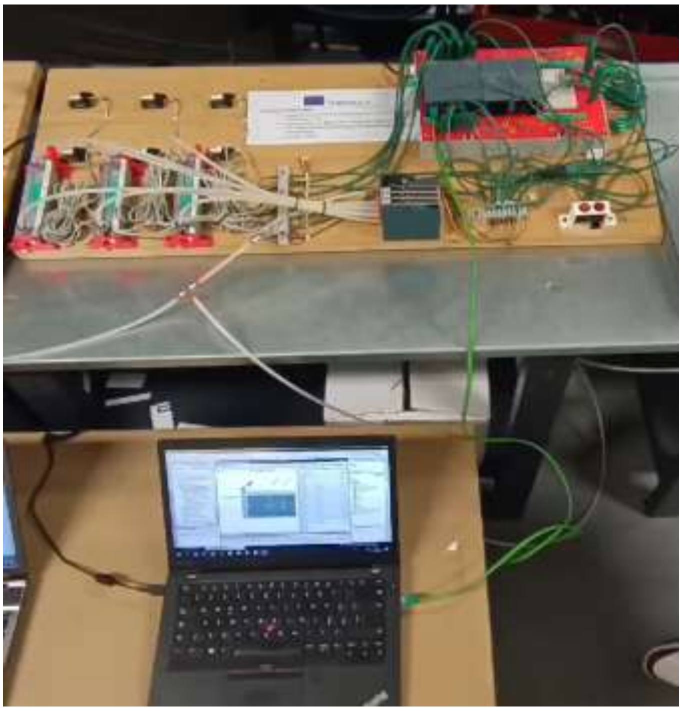


Figure 7 Test bed in operation

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.

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.

3.1 Autosim-200 Software

The software has been designed and reported in Fig. 8. Autosim-200 software is available, under demand, in MISCE project webpage

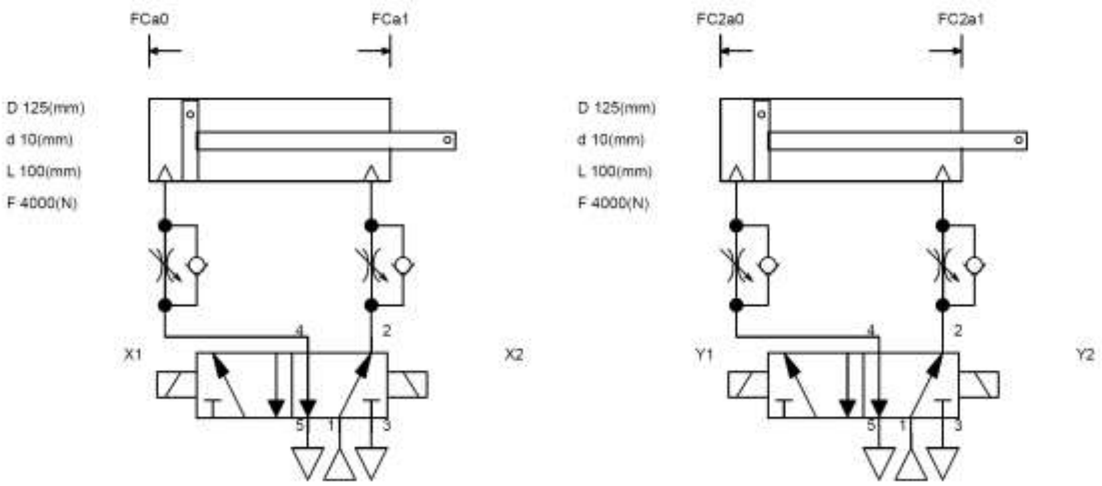


Figure 8. Scheme of the software connections

3.1.1 Grafcet

To complete the developed model, the logical sequence of the electro-pneumatic circuit was represented using a GRAFCET diagram (see Table III) created with the *autoSIM-200* software. This tool allows for a clear definition of the system's operational phases and transition conditions, facilitating functional verification of the control logic. The following table shows the representative GRAFCET of the implemented work cycle.

Table III. Grafcet