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 has been specifically designed for automation training purposes and can be effectively used for developing practical skills related to pneumatics and PLC programming. It is composed by:

- n.1 Siemens PLC of type 1215C;
- n.2 5/2 single-solenoid electrically operated directional control valves (for cylinders A and B);
- n.2 3/2 single-solenoid electrically operated monostable valves (for cylinder C, manifold-mounted);
- n.3 Double-acting pneumatic cylinders (A, B, C).

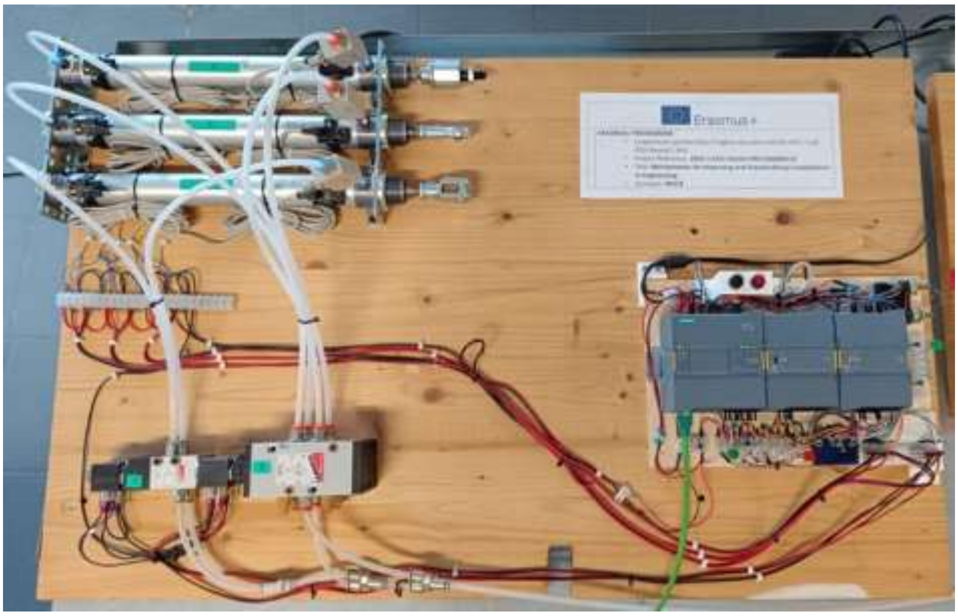

Figure 1. Suitable experimental test bed realized

This test bed can be used both in physical form and through the simulation environment (e.g., AutoSIM-200) thanks to its clear logic structure and modular signal arrangement. Its main strength lies in the clarity of the automation sequence: the behavior of the cylinders is straightforward and suitable to teach the fundamentals of electropneumatics, PLC-based control, and sequence programming.

Unlike other simplified benches, this system does not rely on spring-return actuation, allowing full control over both extension and retraction of all actuators, making it suitable even for synchronized or cyclic control exercises. However, it remains a foundational system and may not cover more advanced topics like pressure regulation, sensor fusion, or proportional control.

1.3 Technical requirements

The main advantage of this new test bed lies in its use for automation training activities involving sequences of multiple actuators. The platform integrates three double-acting pneumatic cylinders, which enables students to work on more complex logic scenarios compared to simple actuation systems.
The logical behavior of the actuators is intuitive and well-suited for educational purposes, particularly

for the development of skills in electropneumatics, sensor integration, and PLC-controlled automation.

1.3.1 Actuation of a double effect pneumatic cylinder

The actuation system is composed of three double-acting pneumatic cylinders (A, B, and C), each of which can be fully controlled in both directions. The cylinders A and B are managed by 5/2 monostable electro-pneumatic valves, while cylinder C is controlled via a pair of 3/2 electrically actuated monostable valves configured as a flip-flop circuit. (see Figure 2).

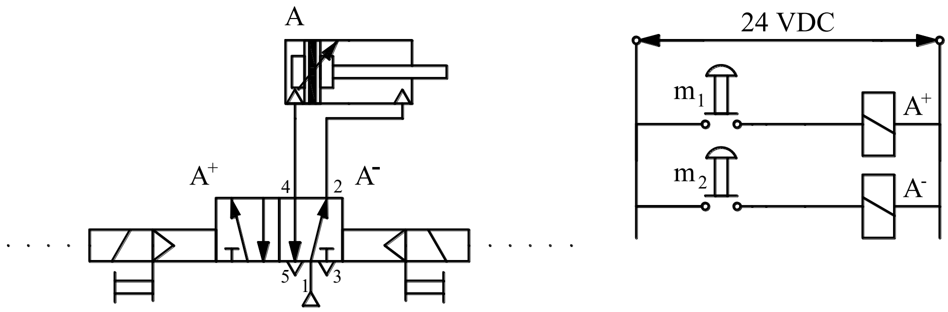

Figure 2. Double effect pneumatic cylinder

Each actuator is equipped with two position sensors (for extended and retracted positions), and the entire system is managed by a PLC (e.g., Siemens S7-1200). The user can start the cycle through a single monostable push button, while the sequence of movements is executed automatically by the logic programmed in the PLC.

This test bed includes:

- n.3 Double-acting pneumatic cylinders (A, B, C);
- n.2 5/2 single-solenoid directional valves (for A and B);
- n.2 3/2 monostable valves for flip-flop control of cylinder C;
- n.6 magnetic position sensors (a0, a1, b0, b1, c0, c1);
- n.1 electric push button (cycle start);
- n.1 Siemens S7-1215C PLC.

Functional test (automatic sequence):

- When the push button is pressed, cylinder A extends (a0 → a1);
- Once in position, cylinder B extends (b0 → b1);
- Then, cylinder C extends (c0 → c1);
- When all three cylinders are extended, all are retracted simultaneously;
- The next two phases include a repetition of simultaneous extension and retraction, completing a 6-step cycle.

1.3.2 Diagram of Movement-Phase

To generate the desired movement/phase diagram with this experimental platform, all types of required displacements can be achieved. The control objective is to create all possible combinations of cylinder movements using the experimental/numerical (Digital Twin) platform (see Figure 3).

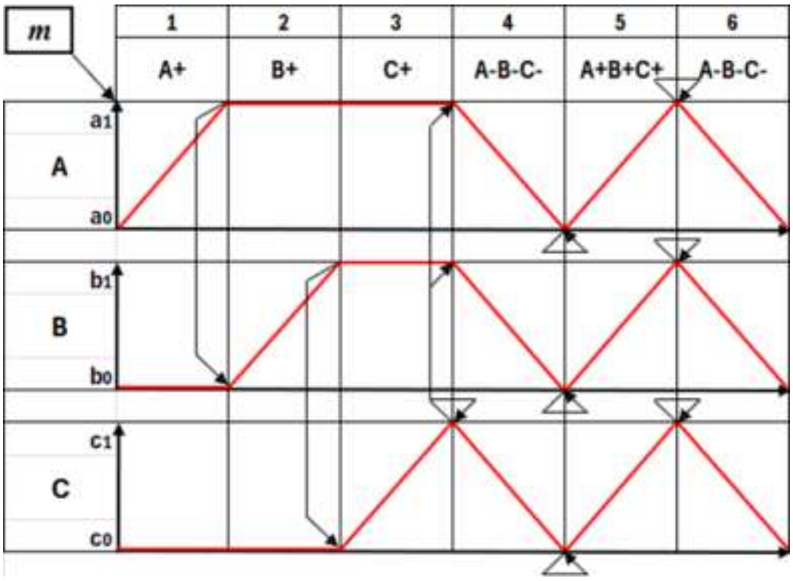

Figure 3. Generation of a suitable “Movement-Phase” displacement

This experimental platform adds more advanced capabilities, allowing for the generation of different cycles. By using the same hardware setup, various cycles can be configured without changing the pneumatic and electrical connections. The only variation is in the program loaded into the controller’s memory.

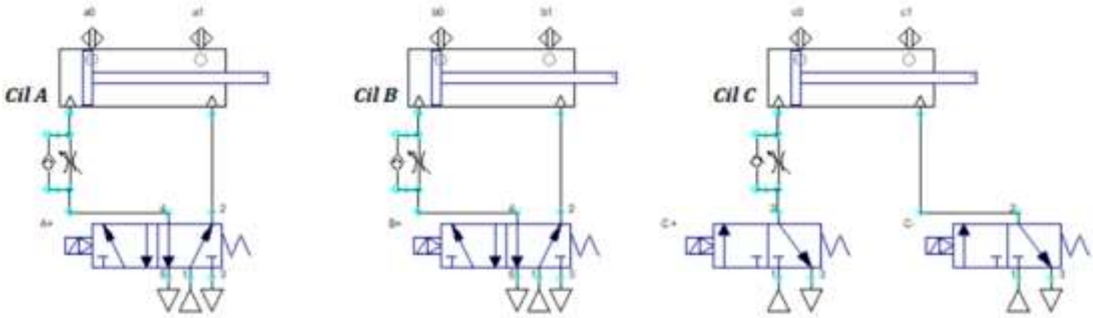

Figure 4. Electro pneumatic connection (physical connection)

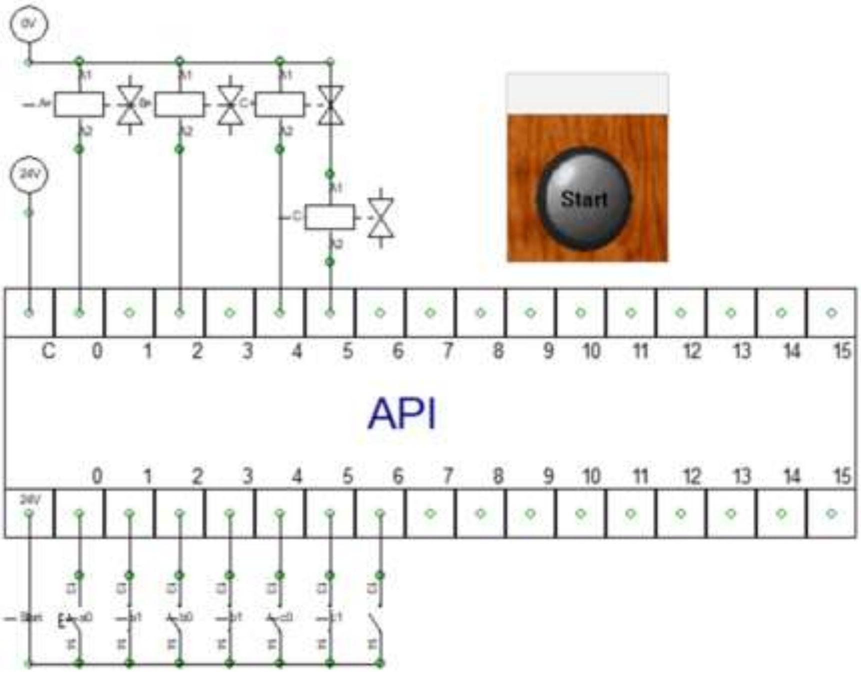

Figure 5. PLC connection (simulation software)

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
B+	o2
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.2 5/2 single-solenoid electrically operated directional control valves (for cylinders A and B);
- n.2 3/2 single-solenoid electrically operated monostable valves (for cylinder C, manifold-mounted);
- n.3 Double-acting pneumatic cylinders (A, B, C).

2.2 Mechanical Design

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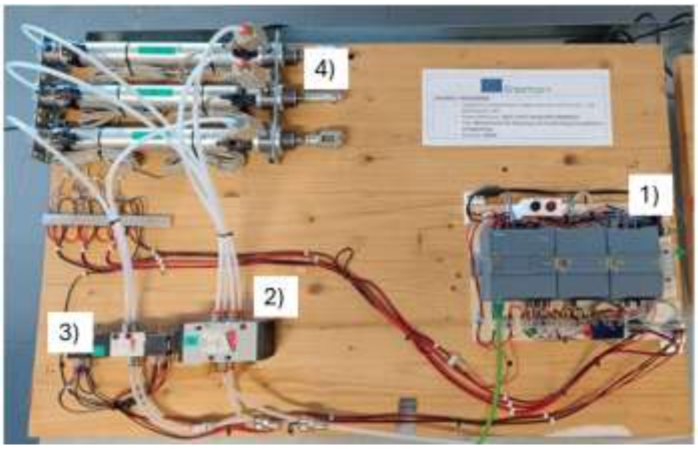

1. n.1 Siemens PLC of type 1215C;
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3. n.2 3/2 single-solenoid electrically operated monostable valves (for cylinder C, manifold-mounted);
4. n.3 Double-acting pneumatic cylinders (A, B, C).

Figure 6. Test bed scheme

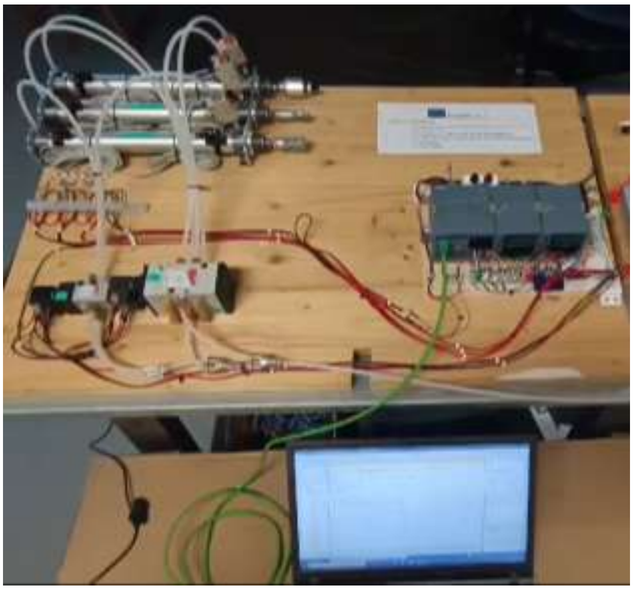

Figure 7 Test bed in operation

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. The code of the

Autosim-200 software is available, under demand, in MISCE project webpage

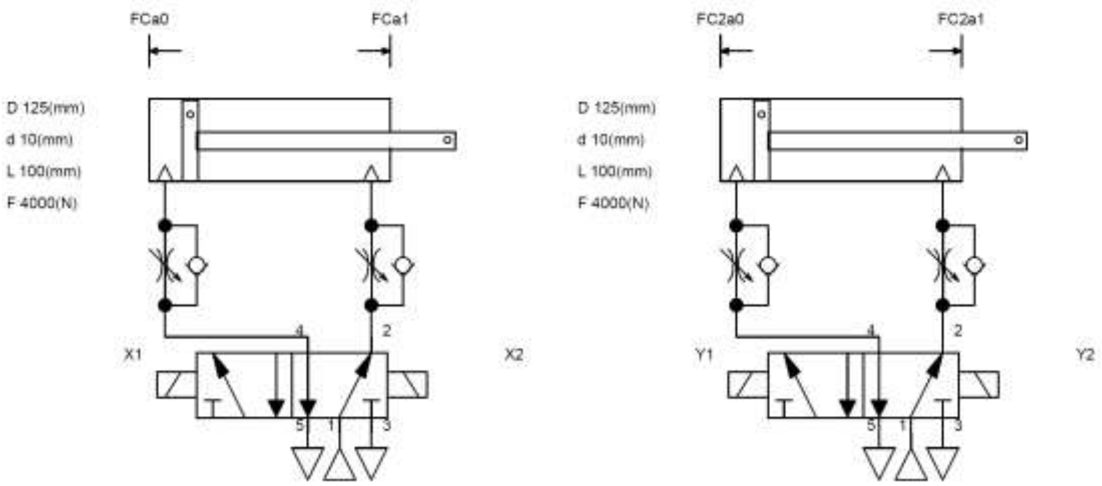

Figure 8. Scheme of the software connections

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