Research regarding Electro-Pneumatic Systems with Pneumatic Motor

Lecturer Dr. eng. **Iulian Claudiu DUȚU[1],** Dr. eng. **Tiberiu AXINTE[2,*],**
Dipl. Eng. **Lidia CALANCEA[2],** Dipl. Eng. **Cătălin FRĂȚILĂ[2],**
Dipl. Eng. **Mihai DIACONU[2],** Dipl. Eng. **Remus COJOCARU[3]**

[1] Politehnica University of Bucharest, Romania

[2] Research Center for Navy, Romania

[3] Princess Cruises, USA

*tibi_axinte@yahoo.com

Abstract: *In this paper, we study electro-pneumatic systems with air motors. Besides the pneumatic motors, the cylinders are the actuators which are the most used in electro-pneumatic systems. The study of pneumatic and electro-pneumatic circuits is performed in the FluidSim from Festo. At the beginning, we make simple pneumatic systems with single or two air motors. We continue with simple and complex electro-pneumatic systems that have air motors. The pneumatic motors are generally used for the development of the following installations: pump drivers, conveyor drivers, mixing equipment, pharmaceutical packaging, tension devices, hose reels, winches, hoists, turntables, etc.*

Keywords: *FluidSim, pneumatic, electrical, systems, air motor*

1. Introduction

A pneumatic motor (an air motor) is a type of motor that does mechanical work by expanding compressed air. The air motors generally convert the compressed air energy to mechanical work through either linear or rotary motion.
The air motor was first applied to the field of transportation from Challiot (France) in 1840.
In research, the pneumatic motor can be used for electro-pneumatic arm development.

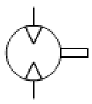
Symbol	Description
	The pneumatic motors are categorized into the groups of piston motors, turbines, gear motors and sliding vane motors.

Fig. 1. The pneumatic motor

The pneumatic motors can be piston air motors or vane air motors.

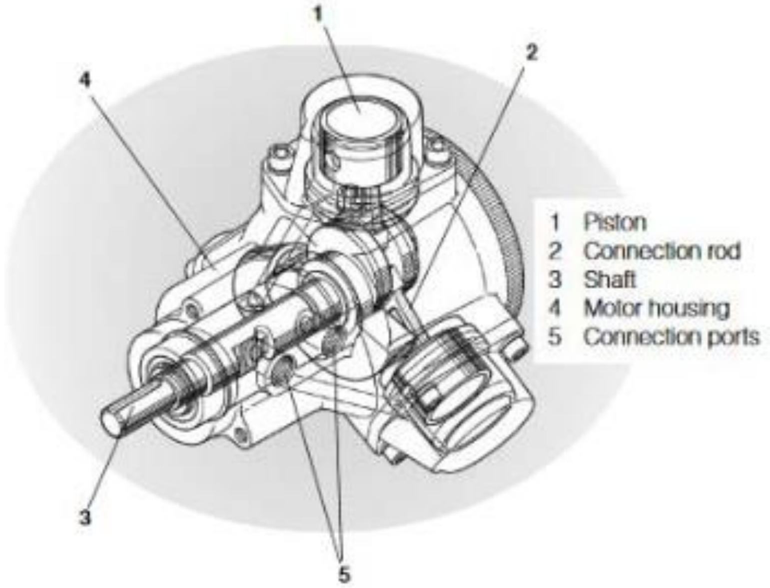


Fig. 2. Radial air motor. Components.

The main components of radial air motor, [1]:

- Piston;
- Connection rod;
- Shaft;
- Motor housing;
- Connection ports.

The relationship that defines the equilibrium of torque in rotary drive is, [2]:

$$M_{PV} - M_{ext} - \mathrm{f} \cdot \omega - \mathrm{I} \cdot \varepsilon = 0 \quad (1)$$

Where:

- M_{PV} - pressure and swept volume dependent torque.
- M_{ext} - external torque.
- f - friction.
- ω- angular velocity.
- I – moment of inertia.
- ε – angular acceleration.

The pressure and swept volume dependent torque is:

$$M_{PV} = \frac{(P_1 - P_2) \cdot V}{2 \cdot \pi} \quad (2)$$

- P_1 – initial pressure;
- P_2 – final pressure;
- V – volume.

2. The pneumatic motor in circuits

An air motor is a type of motor which does mechanical work by expanding compressed air, [3].

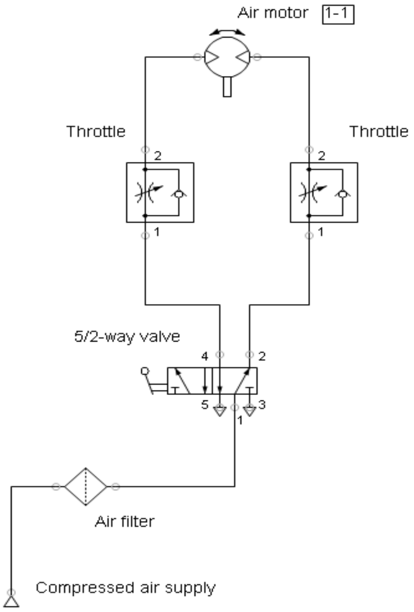


Fig. 3. Pneumatic system with an air motor. Scheme 1.

The pneumatic system with the air motor 1-1 has the following components:

Description	**Number of components**
Air motor	1
Throttle	2
5/2-way valve	1
Air filter	1
Compressed air supply	1

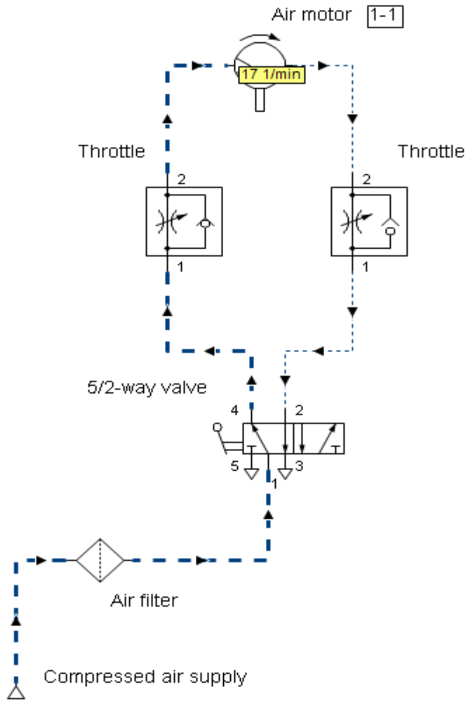


Fig. 4. Pneumatic system with an air motor. Simulation.

The pneumatic system opens if the lever is pushed from 5/2-way valve. In our case, the volumetric flow rate in the air motor 1-1 is 17 l/min, Fig. 4.

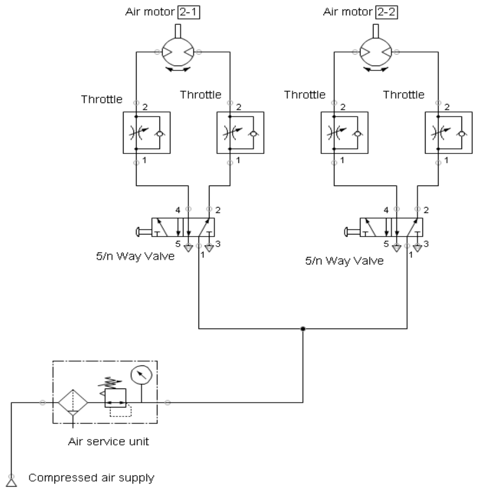


Fig. 5. Pneumatic system with two air motors. Scheme 2.

The pneumatic system with two air motors: 2-1 and 2-2, in scheme 2, has the following devices:

Description	**Number of components**
Air motor	2
Throttle	4
5/2-way valve	2
Air service unit	1
Compressed air supply	1

The two air motors are independent. They can start at the same time or successively. The shafts rotate in a different direction. Therefore, they can rotate clockwise or counterclockwise, [4].
At air motor 2-1, the shaft rotates clockwise. However, at the air motor 2-2, the shaft rotates counterclockwise, Fig. 6.

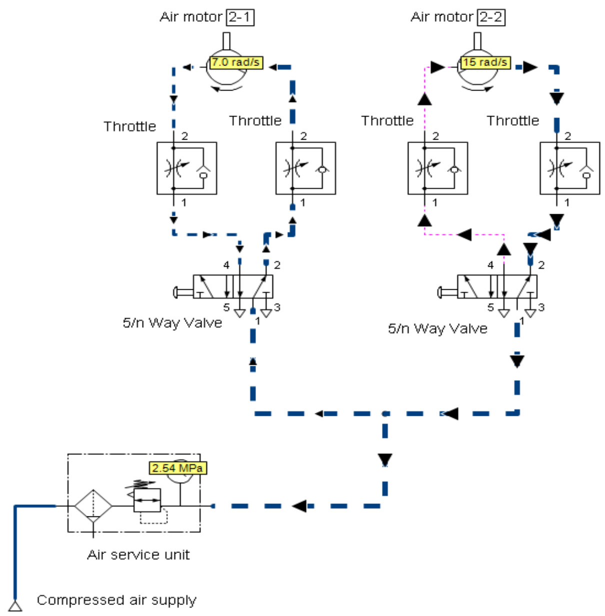


Fig. 6. Pneumatic system with two air motors. Simulation.

The air service unit pressure gauge indicates 2.54 MPa. Rotational speed from the air motor 2-1 is $\omega_{2-1} = 7\ rad/s$ and rotational speed from the air motor 2-2 is $\omega_{2-2} = 15\ rad/s$, Fig. 6.

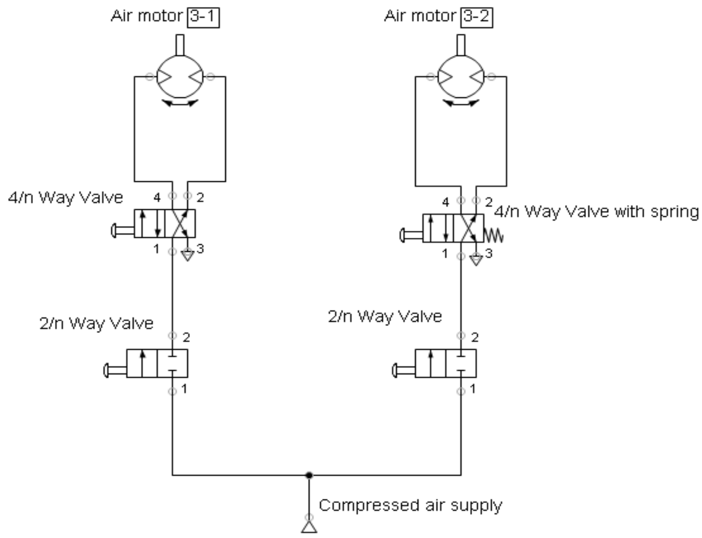


Fig. 7. Pneumatic system with two air motors. Scheme 3.

The pneumatic system with two pneumatic motors air motors: 3-2 and 3-1, in scheme 3, has the following devices:

Description	Number of components
Air motor	2
4/n way valve	1
4/n way valve with spring	1
2/n way valve	2
Compressed air supply	1

The directional control valves type 2/n way valve are safety devices, Fig. 7.

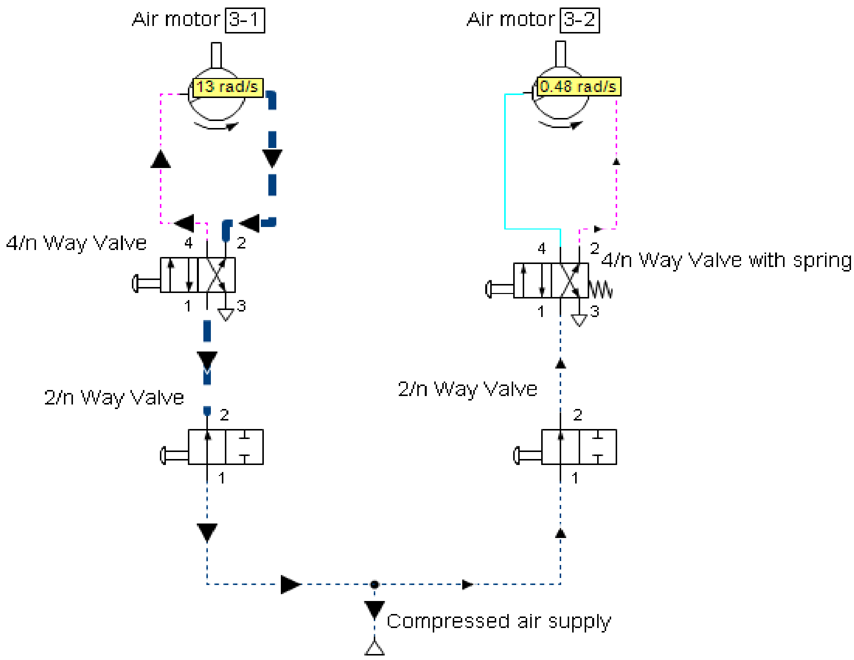


Fig. 8. Pneumatic system with two air motors. Simulation.

Rotational speed from pneumatic motors are represented by two diagrams, Fig. 9

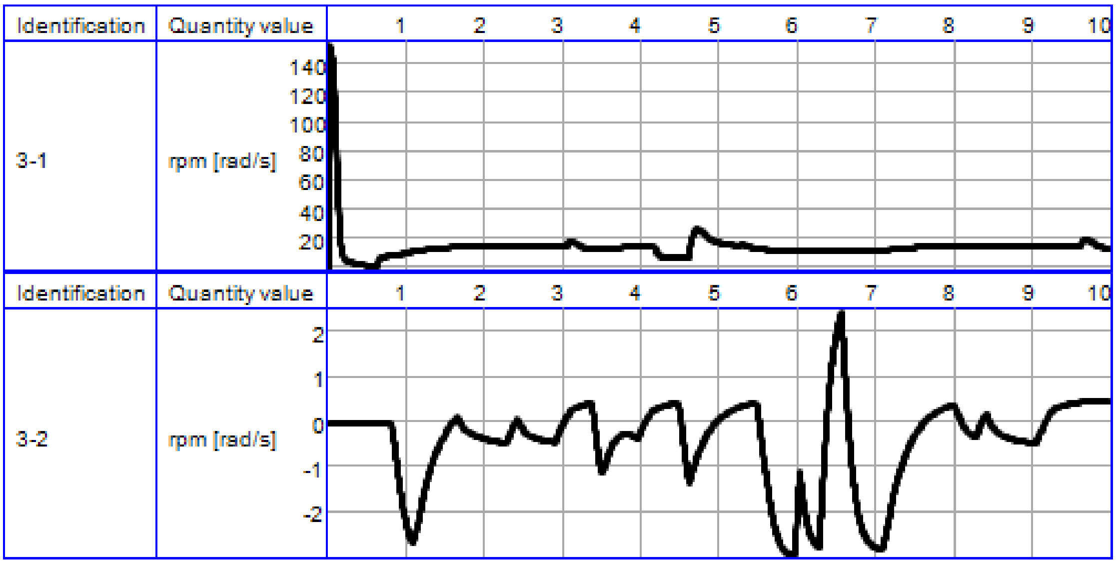


Fig. 9. Scheme 3. Diagrams of the pneumatic motors.

The diagrams of the two pneumatic motors do not resemble each other at all, Fig. 9.

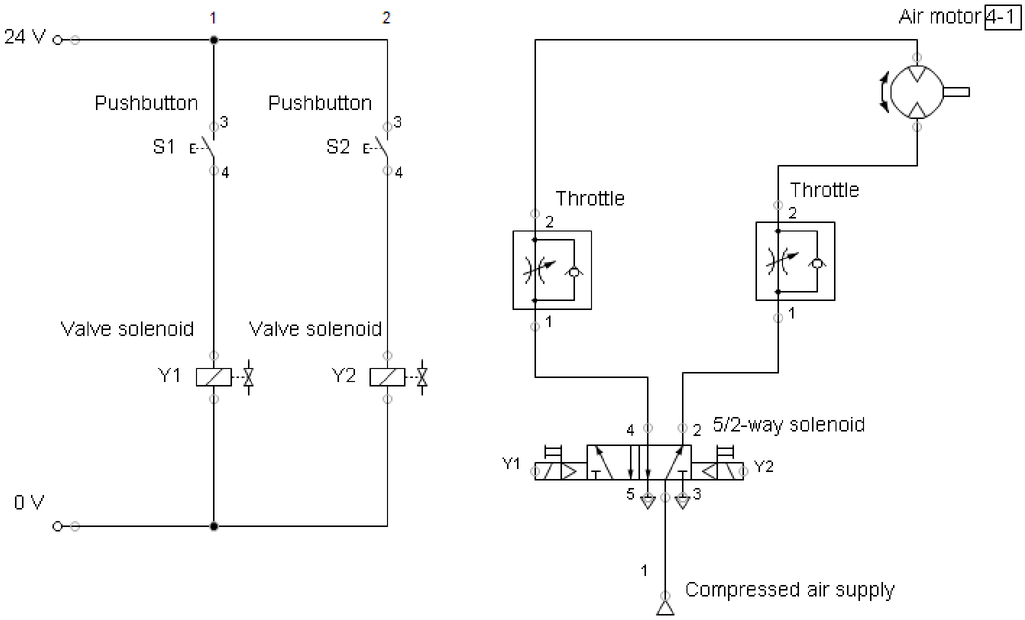


Fig. 10. Electro-pneumatic system with an air motor. Scheme 4.

Scheme 4 represents the first electro-pneumatic circuit in the manuscript. The devices used in the electro-pneumatic system are:

- Pneumatic devices:

Description	**Number of components**
Air motor	1
Throttle	2
5/2 way solenoid	1
Compressed air supply	1

➢ Electrical devices:

Description	**Number of components**
Solenoid valve	2

If we press the S1 button, the shaft rotates counterclockwise. The rate of rotation for the S1 button is $\omega_{4-1\,a} = 3.1\ rad/s$, Fig. 11.

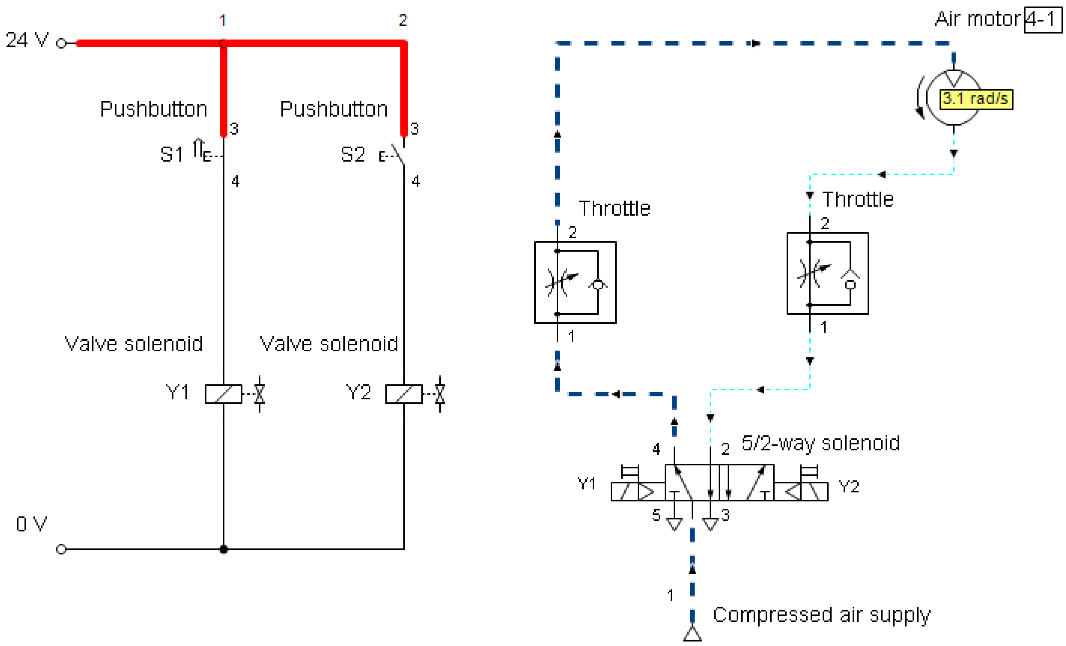


Fig. 11. Counterclockwise rotation shaft. Scheme 4.

After that, we press the S2 button; the shaft rotates clockwise. The rate of rotation for the S2 button is $\omega_{4-1\,b} = 3.1\ rad/s$, Fig. 12.

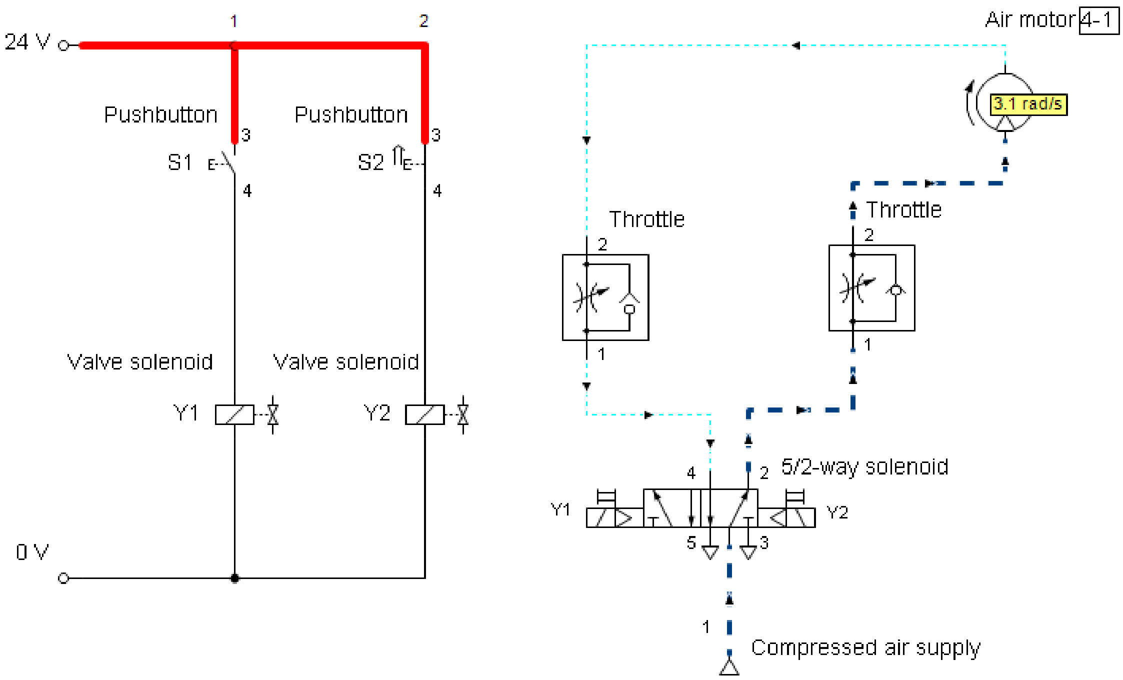


Fig. 12. Clockwise rotation shaft. Scheme 4.

The rotational speed in both directions are equal, [5].
For the pneumatic motor 4-1: $\omega_{4-1\,a} = \omega_{4-1\,b} = 3.1\ rad/s$, Fig. 11 and Fig. 12.

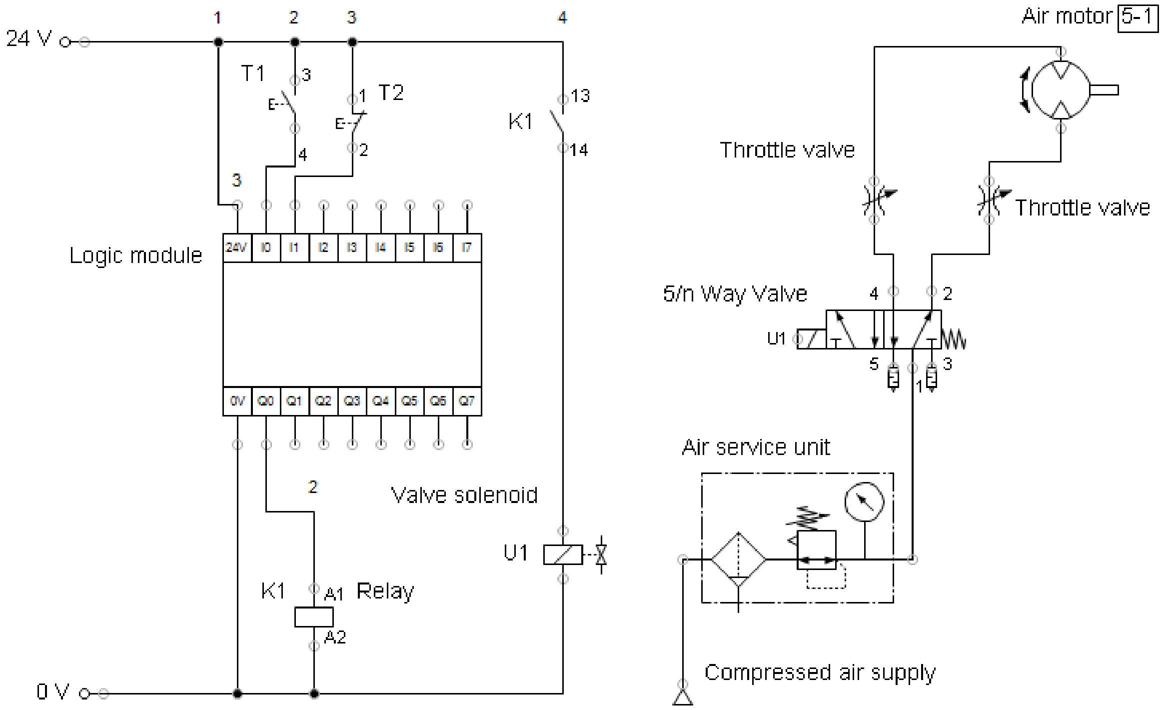


Fig. 13. Electro-pneumatic system with an air motor and logic module. Scheme 5.

At scheme 5, the logic module is introduced in the electrical one, Fig. 13.
The main parts of scheme 5 are:

- Pneumatic parts

Description	Number of components
Air motor 5-1	1
Throttle valve	2
5/2 way valve	1
Air service unit	1
Compressed air supply	1

- Electrical parts

Description	Number of components
Solenoid valve	1
Relay	1
Logic module	1

However, in logic modules there are two digital components from digital technology: latching relay and NOT, Fig. 14.

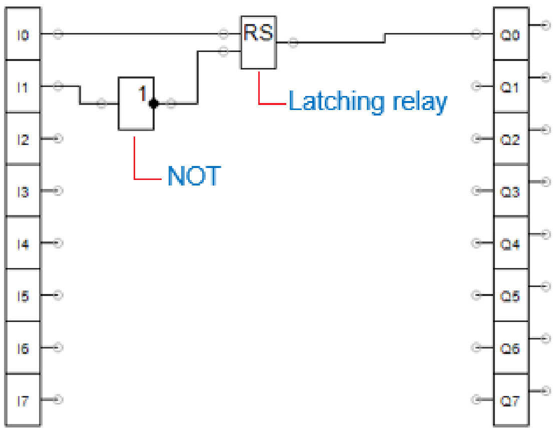


Fig. 14. Components parameters of logic module. Scheme 5.

The electro-pneumatic system shown in scheme 4 opens when the T1 button is pressed. In this case, the shaft from air motor 5-1 rotates counterclockwise. The rotational speed is $\omega_{5-1\,a} = 1.5\ rad/s$. The pressure gauge from the air service unit indicates 0.399 MPa, Fig. 15.

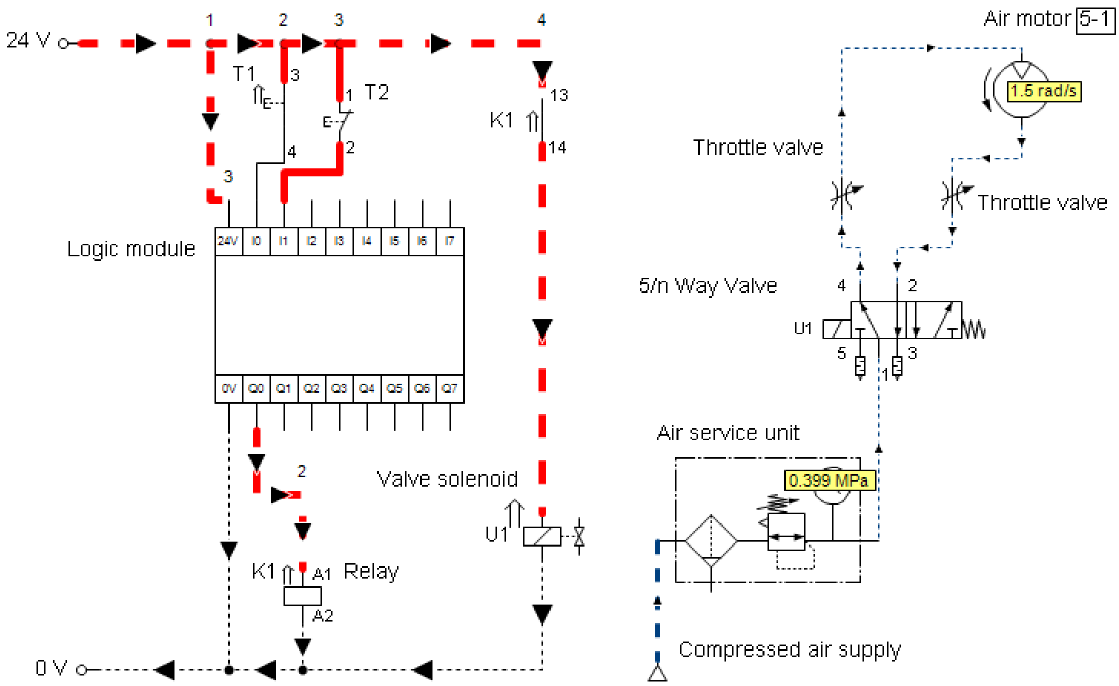


Fig. 15. Counterclockwise rotation shaft .Scheme 5.

However, to try to change the direction of the air motor 5-1, one must press T2 button.
In this case, the shaft from the air motor rotates clockwise, [6].
The rotational speed is $\omega_{5-1\,b} = 1.7\ rad/s$, Fig. 16.

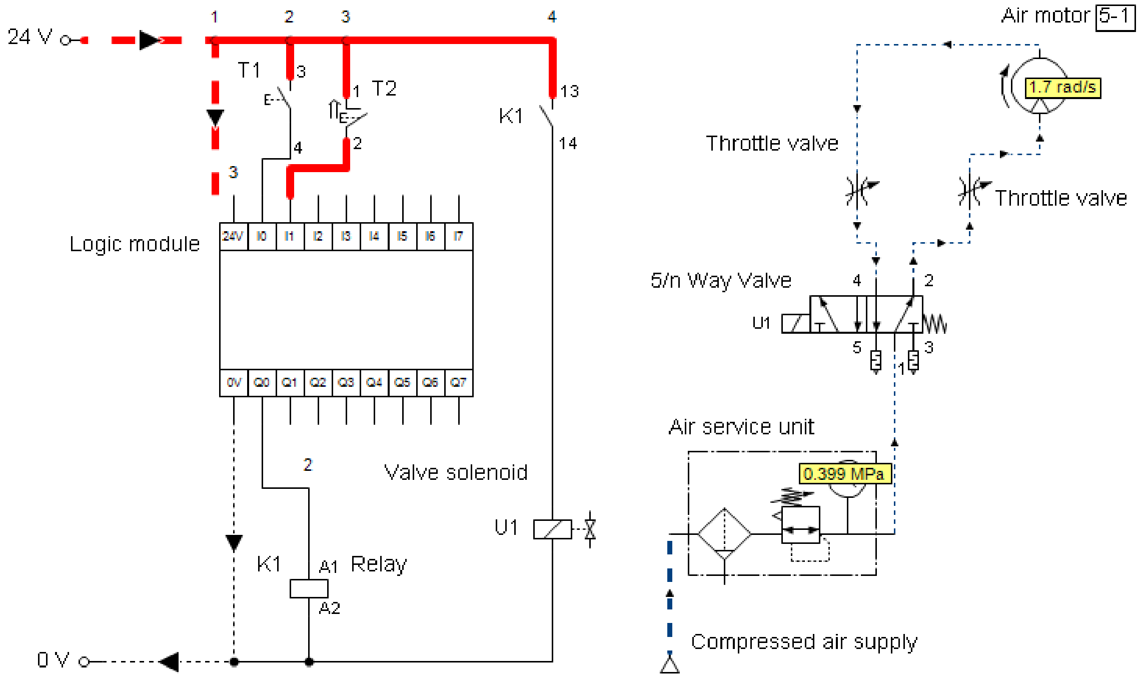


Fig. 16. Clockwise rotation shaft. Scheme 5.

3. Conclusions

The advantages of pneumatic motors are the following: non-electrical sparking, cool running, mounting flexibility, capability to operate in all positions and variable directions.
Some electro-pneumatic systems use mini air motors in small installations.
The electro-pneumatic systems that use air motors are operated in safety conditions for operators.
The high rotation speed for shafts from air motors can lead to increased productivity if it is used in industry.
From this perspective, the determination of such characteristics is very useful and the created pneumatic models can be used in technical research.
The pneumatic motors from Festo are efficient alternatives to electric motors. Their air motors provide excellent horsepower and easily adjusted controls.
In the future, we will try to develop electro-pneumatic schemes that use several types of actuators, meaning air motor with cylinder or semi-rotary actuator.

References

[1] Dvorak, L., K. Fojtasek, and V. Rehacek. "Experimental equipment for measuring of rotary air motors parameters." *EPJ Web of Conferences* 143, DOI: 10.1051/epjconf/201714302019 (2017): 02019.
[2] www.festo.com.
[3] Panaitescu, M., M. Dumitrescu, and F. V. Panaitescu. "Indoor air quality monitoring universal device." *IOP Conference Series: Materials Science and Engineering* 916 (2020): 012081.
[4] Dumitrache, C.L., and D. Deleanu. "Sloshing effect, Fluid Structure Interaction analysis." *IOP Conference Series: Materials Science and Engineering* (2020): 012030.
[5] Curca, E., R. Damian, O. Radu, and V. Rosca. "Modeling and simulation of hydro-acoustic signal propagation in the Romanian Black Sea coast." *IOP Conference Series: Earth and Environmental Science* 172 (2018): 012015, DOI: 10.1088/1755-1315/172/1/012015.
[6] Degeratu, M. *Dimensional analysis, similarity and modeling. Guide for applications in fluid mechanics and hydraulics / Analiză dimensională, similitudine și modelare. Îndrumar pentru aplicații în mecanica fluidelor și hidraulică*. Bucharest, Publishing House of the Romanian Academy of Scientists (AOSR), 2015.