# Study of Electro-Pneumatic Circuits with Magnetic Proximity Switches

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***Abstract:*** *In this paper, we study electro-pneumatic systems with magnetic proximity switches. Besides, magnetic proximity switches are sensors compatible with T-Slot. These sensors with LED Indicator have the following characteristics: supply voltage 24 V dc, minimum operating is -40$^0$C and maximum operating temperature is +85$^0$C. The study of pneumatic and electro-pneumatic circuits is performed using the software FluidSim from Festo. In the first part, we make simple pneumatic circuits with one cylinder or two pneumatic cylinders. We continue with simple and complex electro-pneumatic schemes that have magnetic proximity switches.*

***Keywords***: *FluidSim, pneumatic, electrical, scheme, circuit, magnetic, proximity, switch*

## 1. Introduction

The pneumatic cylinder is an important device in the pneumatic circuit. Pneumatic cylinders are composed of several types, [1]:

- Rod cylinders, Fig. 1.
- Rodless cylinders.
- Tandem cylinders, high force cylinders and multi-position.
- Clamping cylinder.
- Stop and separator cylinder.
- Guided cylinder.

**Fig. 1.** Rod cylinder

The following relation defines the equilibrium of forces within the cylinder:

$$P_1 \cdot S_1 - P_2 \cdot S_2 = m \cdot a + F_E + F_F + F_S + F_W \tag{1}$$

Where:

- $P_0$ – excess pressure at connection 0;
- $P_1$ – excess pressure at connection 1;

- $S_0$ – effective piston area at the side of connection 0;
- $S_1$ – effective piston area at the side of connection 1;
- m – moving cylinder mass;
- a – acceleration of the moving cylinder mass;
- $F_E$ – the user defined force;
- $F_F$ – friction for the user defined force;
- $F_S$ – the spring force of cylinders with spring return;
- $F_W$ – the counteracting force of gravity during the extension.

As the atmospheric pressure remains the same for the complete cylinder, [2], the pressures are specified as excess pressures, Fig. 2.

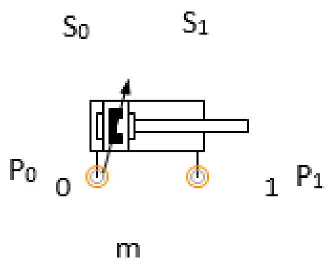



**Fig. 2.** Scheme of pneumatic cylinder

The simple pneumatic circuit of this paper consists of five devices, Fig. 3.
These pneumatic devices are:

1) Compressed air supply;
2) 3/2 – way valve with pushbutton (normally open);
3) Throttle check valve;
4) Pressure gauge;
5) Single acting cylinder.

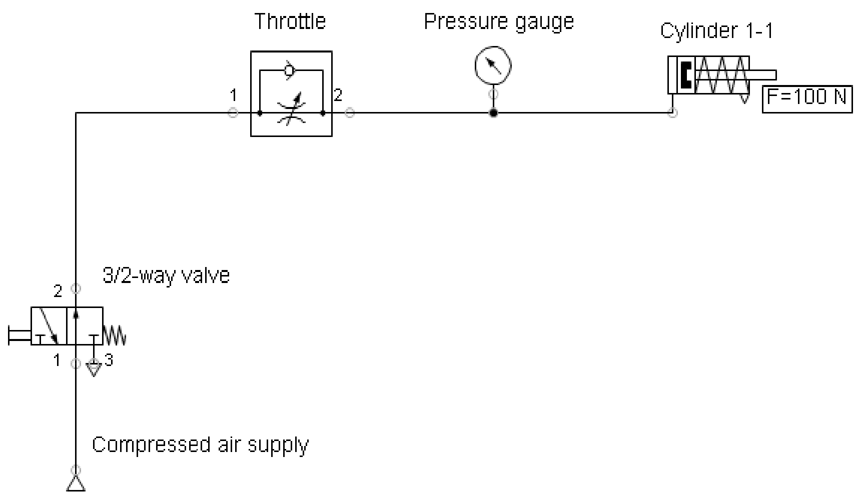



**Fig. 3.** Pneumatic circuit with cylinder

If force $F_E$ = 100 N, when the piston is to middle distance, the pressure is P = 0.574 MPa, Fig. 4.

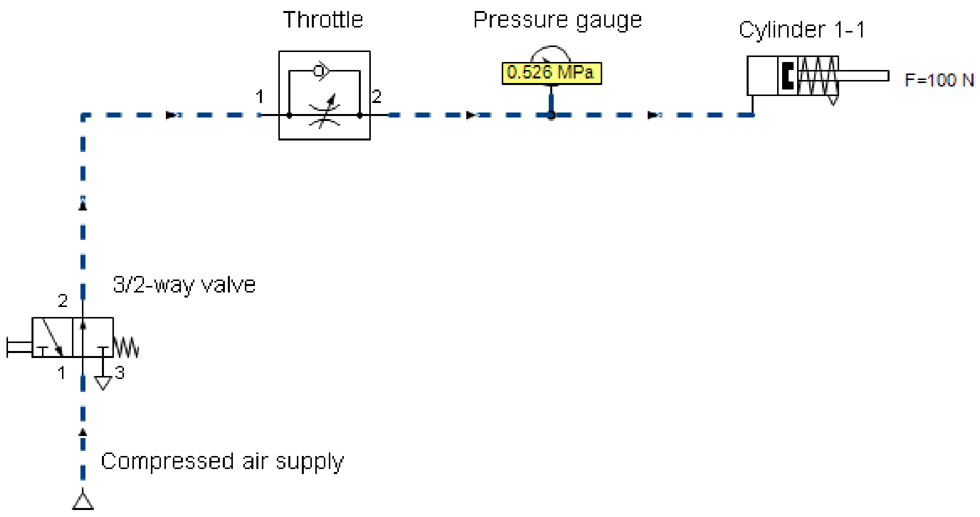



**Fig. 4.** Open pneumatic circuit with cylinder

Second pneumatic circuit is made of two cylinders that have in common air service unit and compressed air supply, Fig. 5.
The cylinder 2-1 is single acting and the cylinder 2-2 is double acting, Fig. 5.
The following devices are in cylinder 2-1, [3]:

- Throttle – one piece;
- 3/2 way valve – one piece.

The following devices are in cylinder 2-2:

- Throttle – two pieces;
- 5/n way valve – one piece.

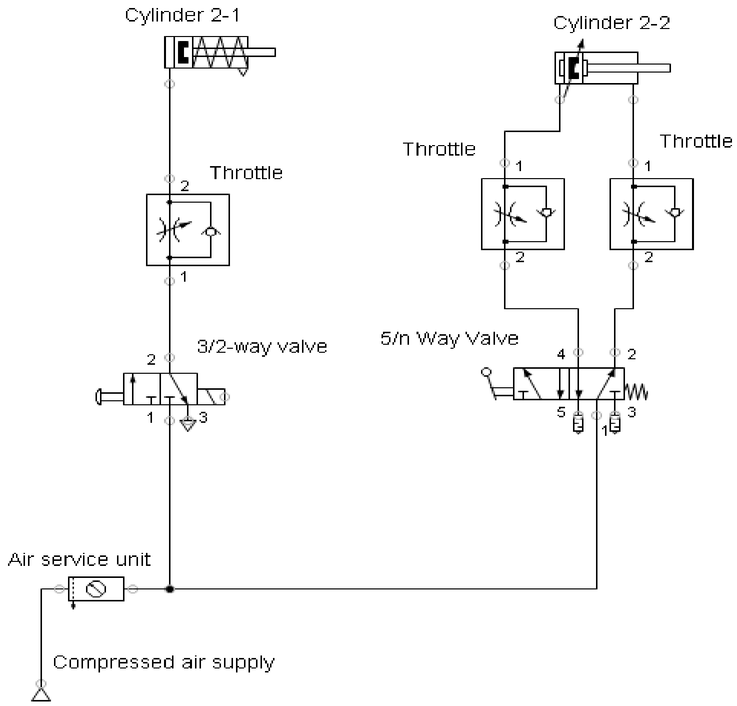



**Fig. 5.** Pneumatic installation with two cylinders

When we press the button from 3/2 way valve, then only the cylinder 2-1 opens. However, if we push the lever from the 5/n way valve, only cylinder 2-2 opens, Fig. 6.

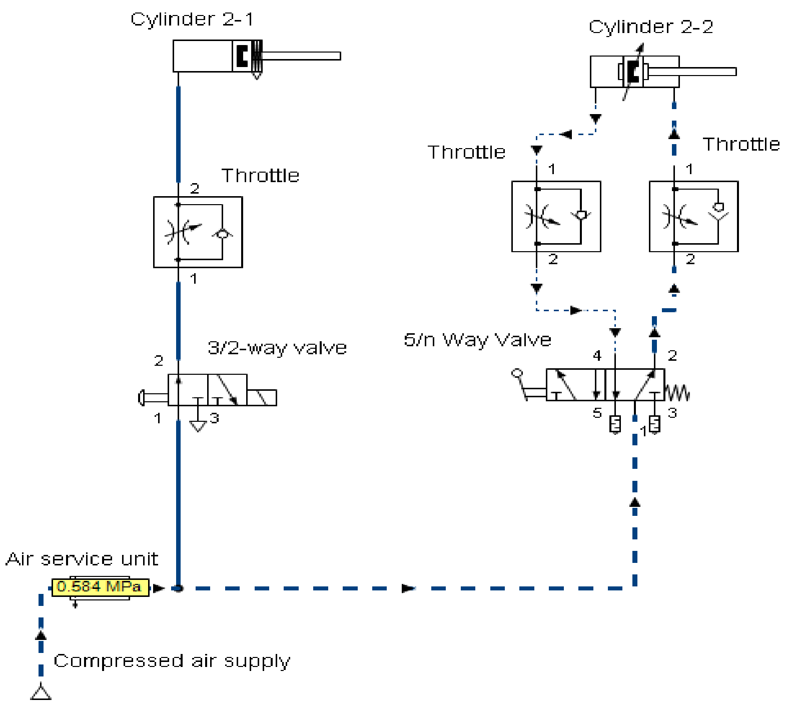



**Fig. 6.** Open pneumatic installation with two cylinders

## 2. Magnetic proximity switch

Proximity sensors are used for binary feedback of the piston position of pneumatic actuators. These sensors are used in electro-pneumatic circuits.
The main types of proximity sensors switch are: magnetic, capacitive, optical and inductive, [4].
In this paper, we study only electro-pneumatic circuits with magnetic proximity switches, Fig 7.

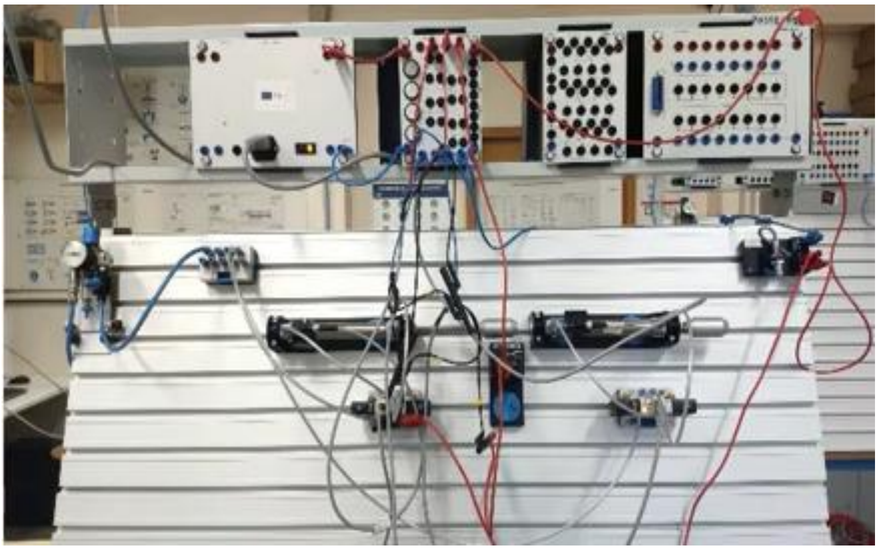


**Fig. 7.** Electro-pneumatic circuit with magnetic proximity switch

Magnetic proximity switches are sensors that detect the magnetic field of the piston magnet field or reed contact, Fig. 8.

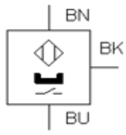
**Fig. 8.** Magnetic proximity switch

In magnetic proximity switch, there exists Faraday's law. The equation for Faraday's law is:

$$\epsilon = -\frac{\Delta\Phi_M}{\Delta t}N \qquad (2)$$

Where:

- ε - induced voltage;
- $\Delta\Phi_N$ – change in magnetic flux;
- Δt – change in time;
- N – number of loops.

| Description | Symbol |
|---|---|
| Magnetic proximity switches are mounted at the desired switching positon in the T-slot or circumferential slot of the cylinder and output a standardized 24 V switching signal when the piston magnetic field is detected. |   |

In the electric part of the circuit, the magnetic proximity switch is connected with relay, Fig. 9.

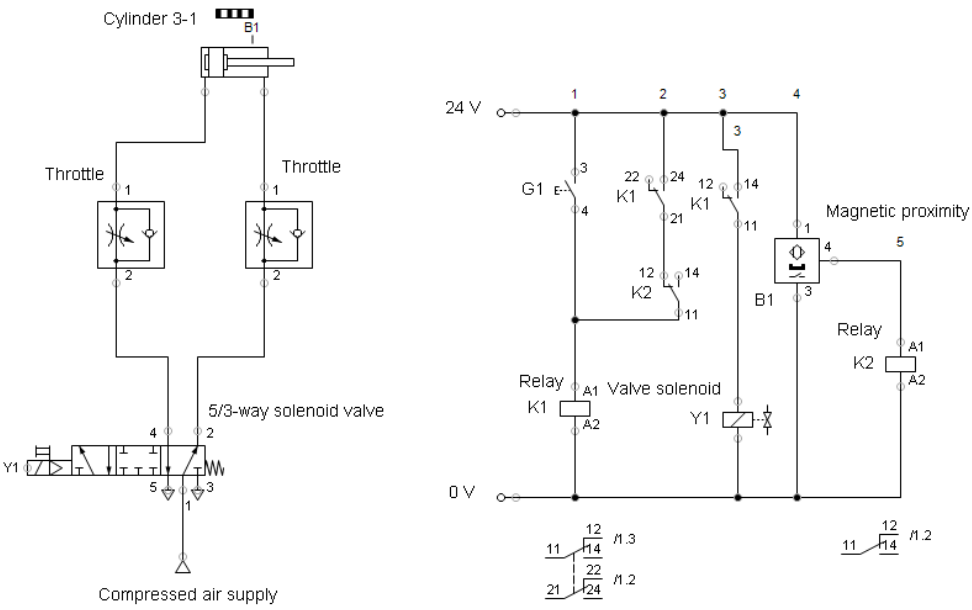



**Fig. 9.** Electro-pneumatic circuit with magnetic proximity switch

We must press the G1 button to open the electro-pneumatic circuit, Fig. 10.

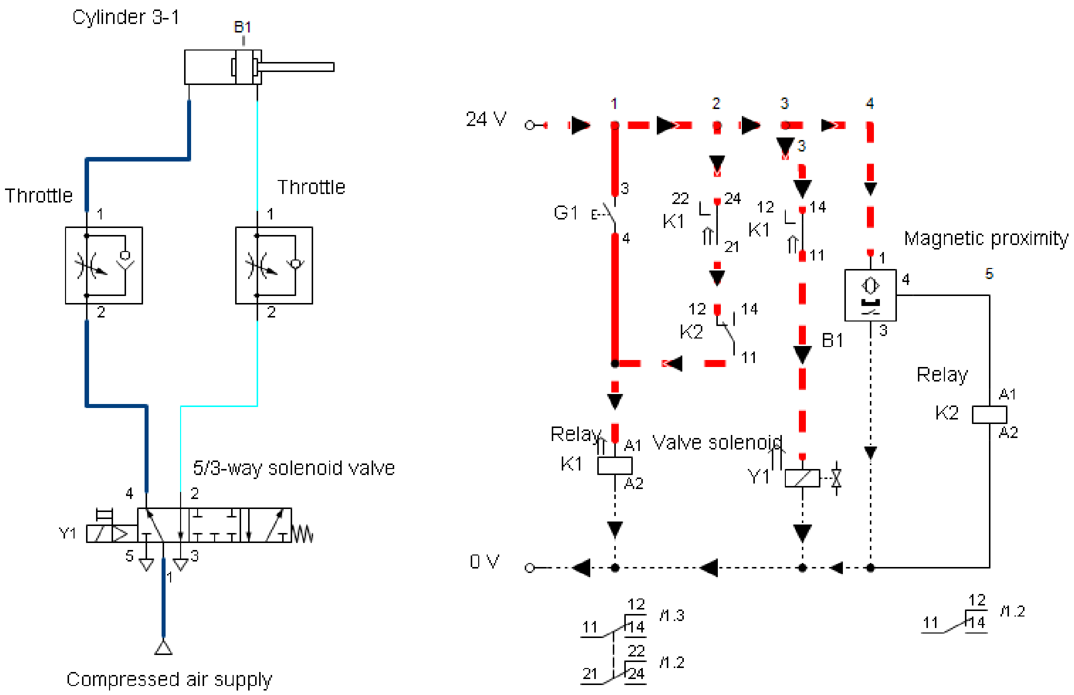



**Fig. 10.** Open electro-pneumatic circuit with magnetic proximity switch

We add a lamp to the electro-pneumatic installation, [5].
When we open the circuit, the light comes on, Fig. 11.

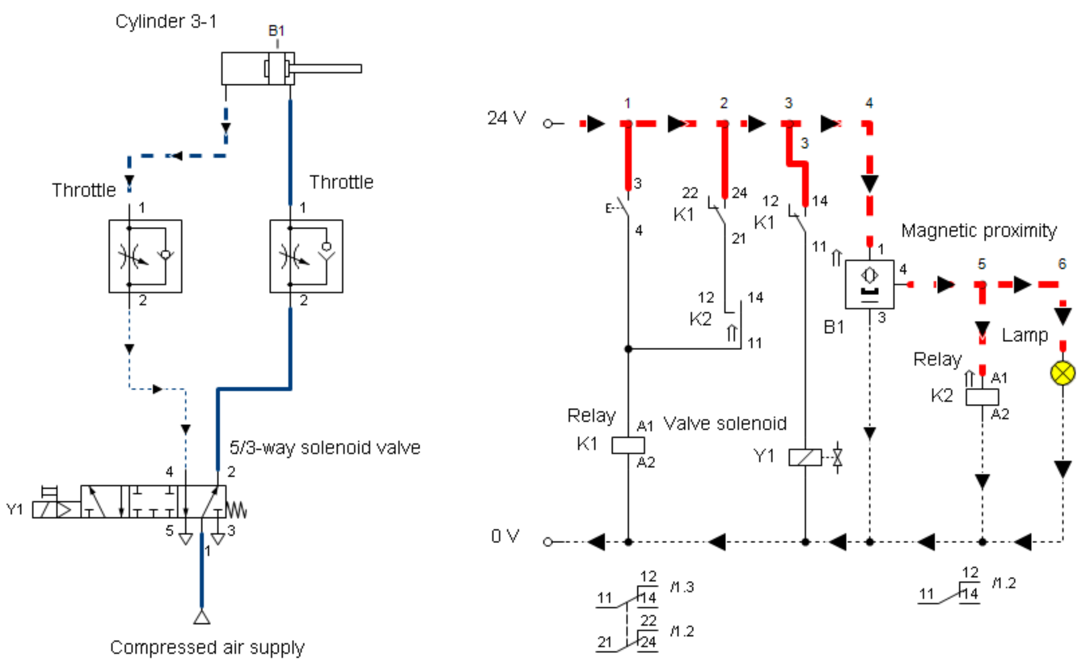



**Fig. 11.** Electro-pneumatic circuit with lamp

The penultimate electro-pneumatic circuit has three way valves, of which one is 5/n way valve and two are 3/n way valves, Fig. 12.

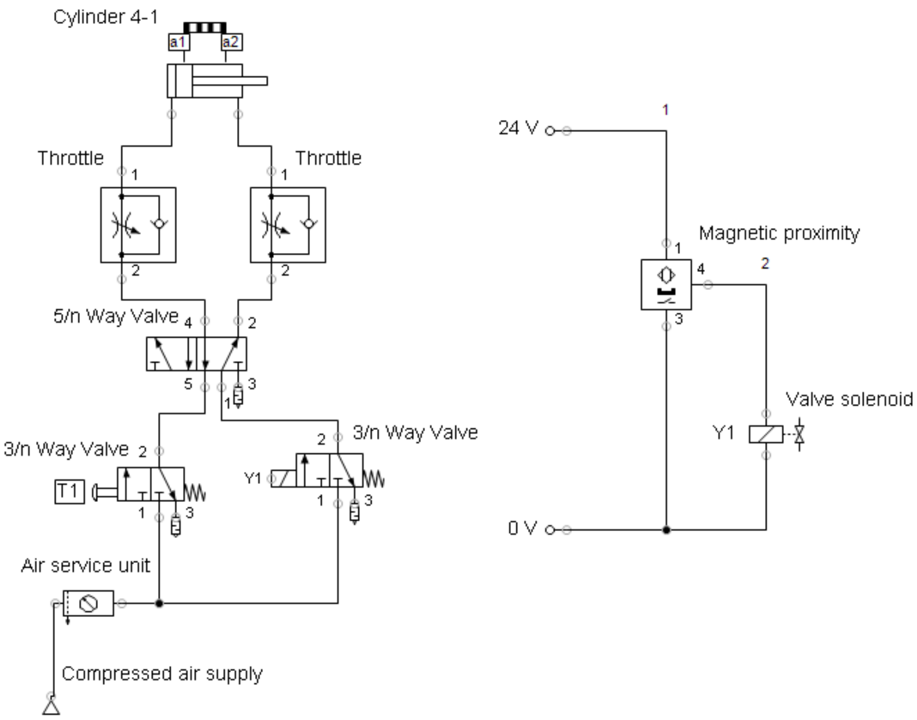



**Fig. 12.** Electro-pneumatic circuit with three way valves

The electrical circuit is made only of magnetic proximity switch and a solenoid valve, Fig. 12.

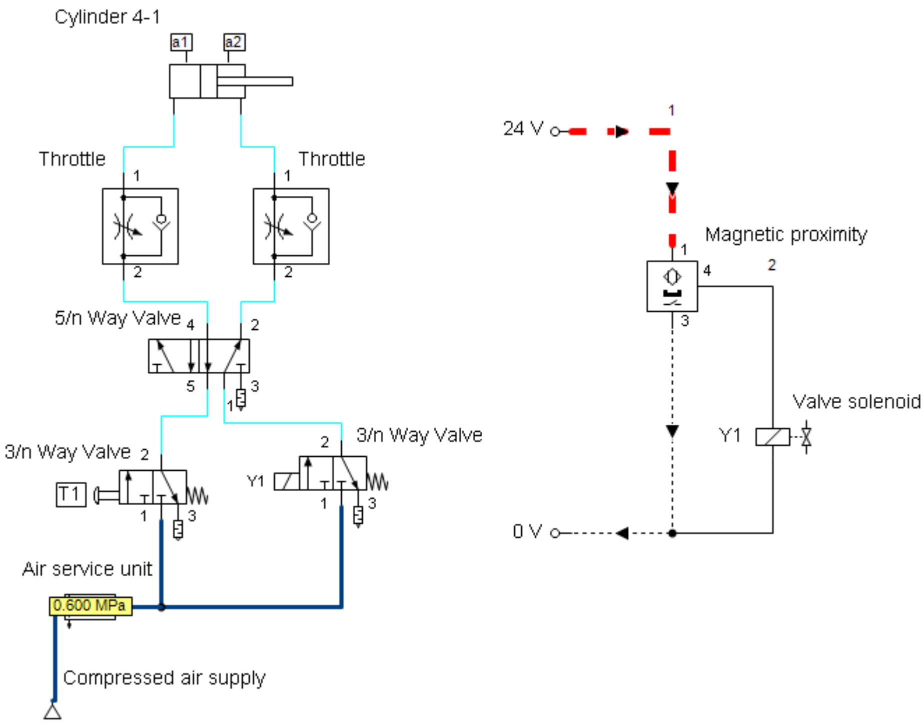



**Fig. 13.** Open electro-pneumatic circuit with three way valves

The electro-pneumatic installation opens if the T1 button on the 3/n way valve is pressed, Fig. 13. Thus, the piston of the cylinder 4-1 moves from point a1 to point a2. Then the piston returns to point a1, Fig. 13.

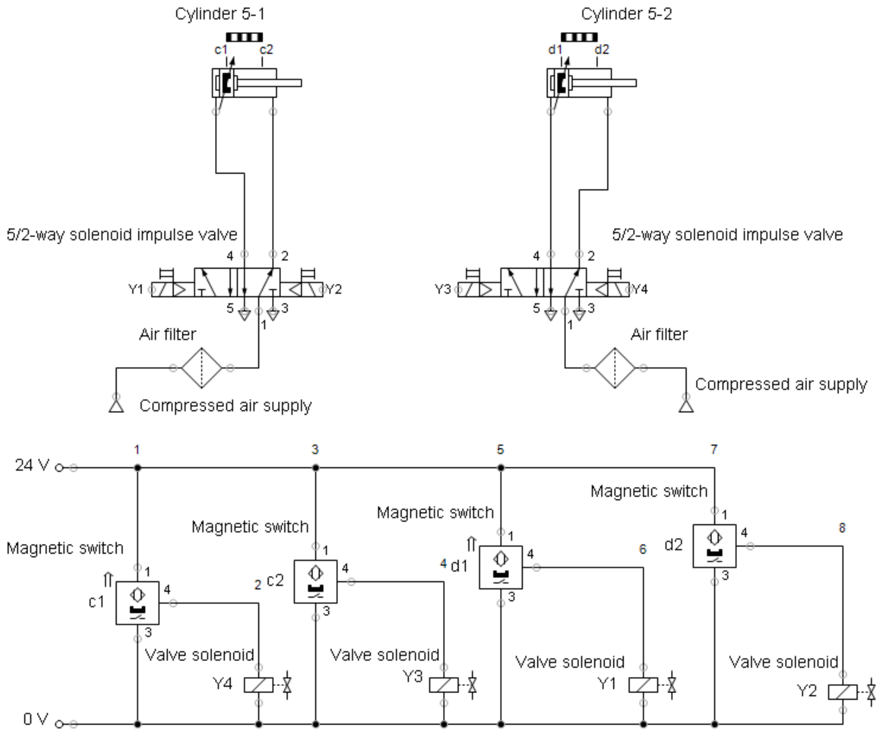



**Fig. 14.** Electro-pneumatic circuit with four magnetic proximity switches

In order to make an electro-pneumatic installation from two double acting cylinders, we must use four magnetic switches, Fig. 14.

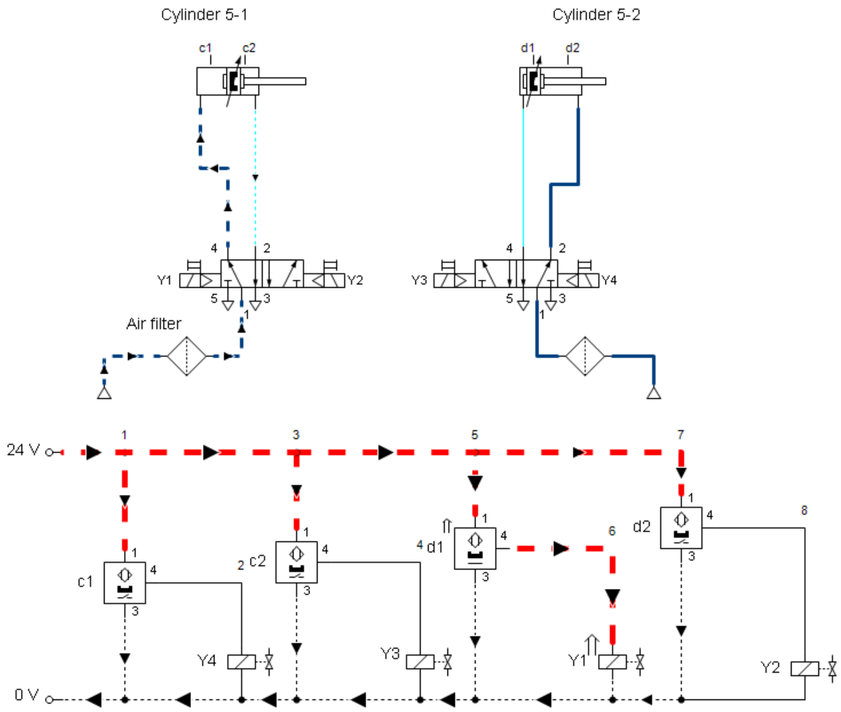



**Fig. 15.** Open electro-pneumatic circuit with four magnetic proximity switches

The pistons are moved automatically from the two cylinders. Thus, there are four steps for the pistons to reach the starting, Fig. 15.

These steps are:

I. From the cylinder 5-1 the piston moves from point c1 to point c2, [6].
II. After the piston in cylinder 5-1 reaches point c2, immediately starts the piston in cylinder 5-2 from point d1 to point d2.
III. When the piston from cylinder 5-2 reaches point d2, the piston from cylinder 5-1 returns from c2 to point c1.
IV. Finally, when the piston from cylinder 5-1 reaches point c1, the piston from cylinder 5-2 returns and reaches point d1, [7].

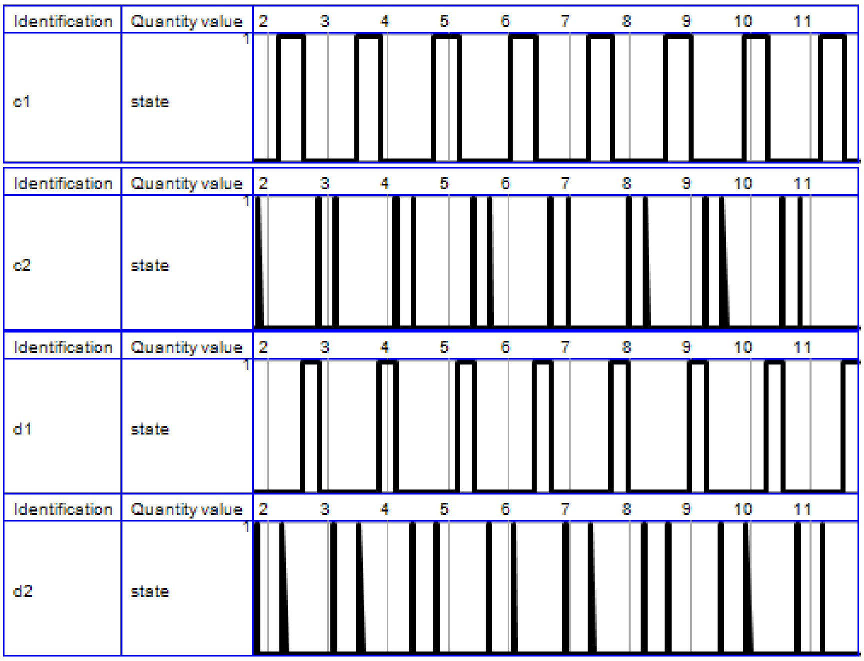



**Fig. 16.** Diagrams of magnetic proximity switches

## 3. Conclusions

If magnetic proximity switches are introduced in the electro-pneumatic installations, a lower energy consumption is achieved. The magnetic proximity switches are devices that are easily mounted and changed in electrical circuits.
Pneumatic cylinders are connected to magnetic proximity switches. In this case, the pneumatic cylinders are harder to wear.
For complex electro-pneumatic installations, it is recommended to install magnetic proximity switches together with relay or solenoid valve.

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