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Design & Simulation of Electro-Pneumatic System Using PLC Automation Studio

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بسم الله الرحمن الرحيم

(و قل اعملوا فسيرى الله عملكم و رسوله والمؤمنون وستردون

الى عالم الغيب والشهادة فينبئكم بما كنتم تعملون)

صدق الله العليّ العظيم

DEDICATING

To my family who supported me all the time

To everyone tries to make this world better

Gratidude

Thanks to our greatest God for completing the project
Thanks to my family for their support
Thanks to my supervisor doctor majid for his patience & guidance

Abstract

This project presents a study of the Electro-Pneumatic Control System and its design using PLC, As well as an introduction to it's used in applications with mentioned few of those applications, also types of circuits that use this kind of control system and we will have one type of these circuits which will be discussed in details in chapter Three and the design of an electro-pneuamtic system with PLC with its simulation while at chapter four there will be conclusion of what we've understand when using such type of control system.

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CHAPTER-ONE

INTRODUCTION

1. INTRODUCTION:-

The automation systems that use electro-pneumatic technology are formed by mainly three kinds of elements: actuators or motors, sensors or buttons and control elements like valves.

Most of the control elements used to execute the logic of the system were substituted by the PLC (Programmable Logic Controller) [1], (a program stored in the central unit of a computer determines the execution of operations in function of the state of the controlled variables. The commands written by an electronic programmer or by a microcomputer) [2]. Sensors and switches are plugged as inputs and the direct control valves for the actuators are plugged as outputs. An internal program executes all the logic necessary to the sequence of the movements, simulates other components like counter, timer and control the status of the system [1].

With the use of the PLC, the project wins agility, because it is possible to create and simulate the system as many times as needed. Therefore time can be saved, risk of mistakes reduced and complexity can be increased using the same elements [1].

A conventional PLC, that is possible to find on the market from many companies, offers many resources to control nor only pneumatic systems, but all kinds of system that uses electrical components. The PLC can be very versatile and robust to be applied in many kinds of application in the industry or even security system and automation of buildings [1].

1.1 Electro –Pneumatic Systems:-

The most used pneumatic actuation systems are electrically controlled systems. These systems are called electro-pneumatic actuation systems [2].

Electro-pneumatic control system is a combination of electrical unit and pneumatic control unit both in one unit. A number of electro-pneumatic elements are used in electro-pneumatic controls. In electro-pneumatic circuits solenoid operated directional control valves, limit switches and pressure switches are used [4].

On an automation system one can find three families of components, which are sensors, valves and actuators [1]. A solenoid is used in pneumatic valves to act as the actuating element.

An adequate technique is needed to project the logic circuit to integrate all the necessary components and execute the sequence of movements properly.

For a simple direct sequence of movement an intuitive method can be used [1], but for indirect or more complex sequence the intuition can generate a very complicated circuit and signal mistakes. It is necessary than to use another method that can save time of the project, make a clean circuit, can eliminate occasional signal overlapping and redundant circuits.

The present method is called step-by-step or algorithmic [3], it is valid for pneumatic and Electro-pneumatic, the method consists of designing the systems based on standard circuits made for each change on the state of the actuators, and these changes are called steps.

The first part is to design those kinds of standard circuits for each step, the next task is to link the standard circuits and the last part is to connect the control elements that receive signals from sensors, switches and the previous movements, and give the air or electricity to the supply lines of each step [1].

1.2 Advantages of Electro-Pneumatic Systems:-

A number of arguments recommend the use of such systems:

- The system allows easy automation of complex industrial processes.
- The high speed of signal transmitting and processing leads to the significant enhancement of the productivity of the automation system.
- Electric equipment costs less than pneumatic equipment.
- Significant loads are controlled with a reduced control signal.
- The loading gauge of the control equipment is reduced.
- Electronic programmers and process computers are used for the control of the system [2].

1.3 Disadvantages of Electro-Pneumatic Systems:-

- The systems use two supply units (pneumatic and electric).
- Functioning is not allowed in flammable environments, in environments subjected to hazard of explosion or in high humidity conditions.
- Hazard of electrocution is present [2].

CHAPTER – TWO

Electro-Pneumatic Control System

2.1 Introduction-

Electro-pneumatics is successfully used in many areas of industrial automation. Production, assembly and packaging systems worldwide are driven by Electro-pneumatic control systems [16]. The change in requirements together with technical advances has had a considerable impact on the appearance of controls. In the signal control section, Electro-pneumatic controllers have the following advantages over pneumatic control systems:

1. Higher reliability (fewer moving parts subject to wear)
2. Lower planning and commissioning effort, particularly for complex controls
3. Lower installation effort, particularly when modern components such as valve terminals are used
4. Simpler exchange of information between several controllers.

Electro-pneumatic also used for remotely controlled system where a few sensors are added to assure the safe operation [17].

2.2 Applications:-

There are so many industry application of electro pneumatic system, these applications can be divided into:-

1. Temperature control [5].
2. Transportation (cement powder, grain and other materials) [6].
3. Packaging [7].
4. Filling as in figure (1)

5. Level gauging [8].
6. Printing as in figure (2).

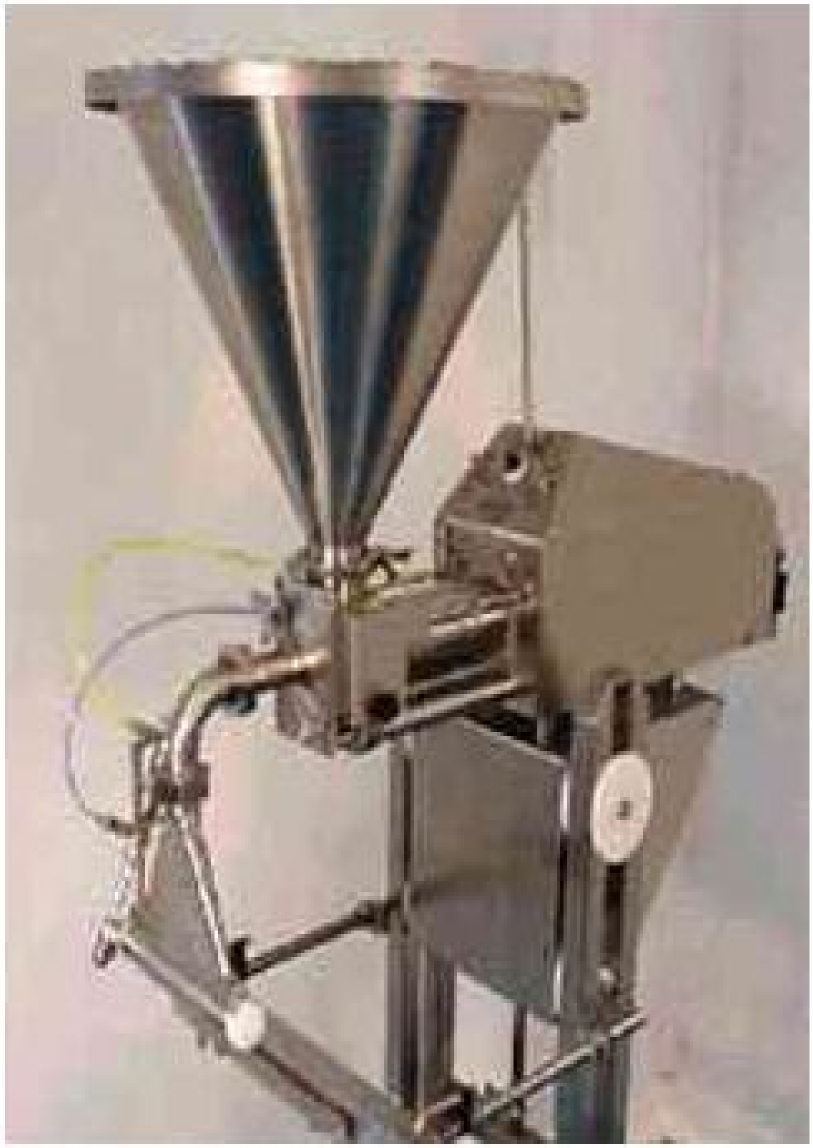


Figure (1): Electro-Pneumatic filling Machine for liquids, creams, semi-solids [14].

Figure (2): Electro-Pneumatic Printing Machine [9].

2.3 Sequential Circuit:-

By sequencing a number of pneumatic cylinders, various machining and tooling operations may easily be obtained in a machine. By using this technique, the cylinders can be actuated one after another in sequences like clamping, feeding and ejecting (or) lifting, pushing and clamping (or) in various other combinations. The electro-pneumatic circuit utilizing this technique is known as automatic sequencing circuit. Correct sequence of motion of each cylinder and the respective cycle time, should be carefully studied before designing such a circuit.

So, Process control electro-pneumatics is also called as sequencing. It means performing number of actions one after another which follows each other in a simple order or with an order determined by sensors [10].

2.3.1 Case Study 1

The circuit below is a closed loop circuit. When the solenoid is activated, current is supplied to valve A+, cylinder A extends (on) to the a+ position and current is obtained from the sensor at the a+ position and supplied to valve B+ and so on.

A+ B+ C+ A- B- C-

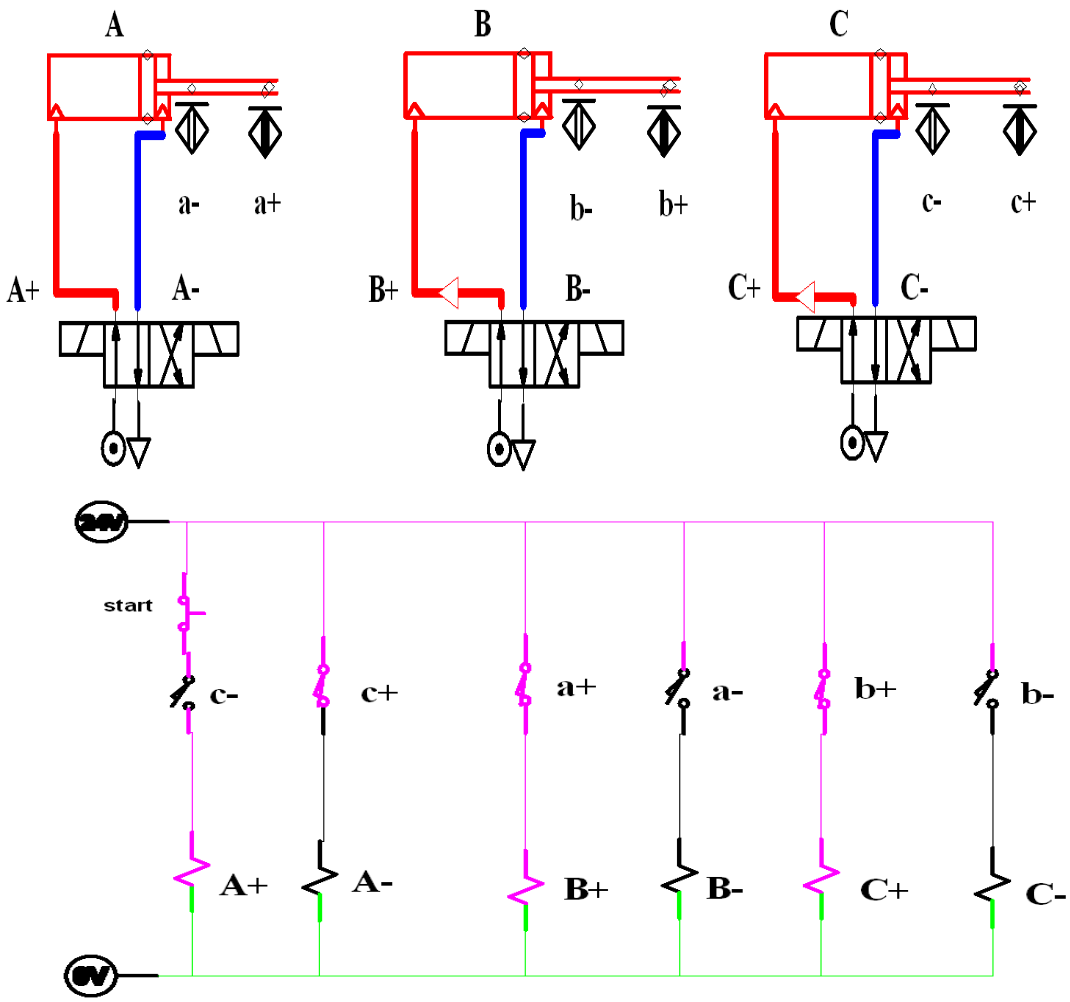


Figure (3): Sequential Circuit for Case Study 1

The sequences that can be made in this way are limited and only work if the actuators are switched off in the same order that they are switched on, Otherwise we get pilot pressure to both sides of the same DCV at the same time. When this happens a standard valve will not move and the sequence stops [11].

2.3.2 Case Study 2

Consider the circuit below:

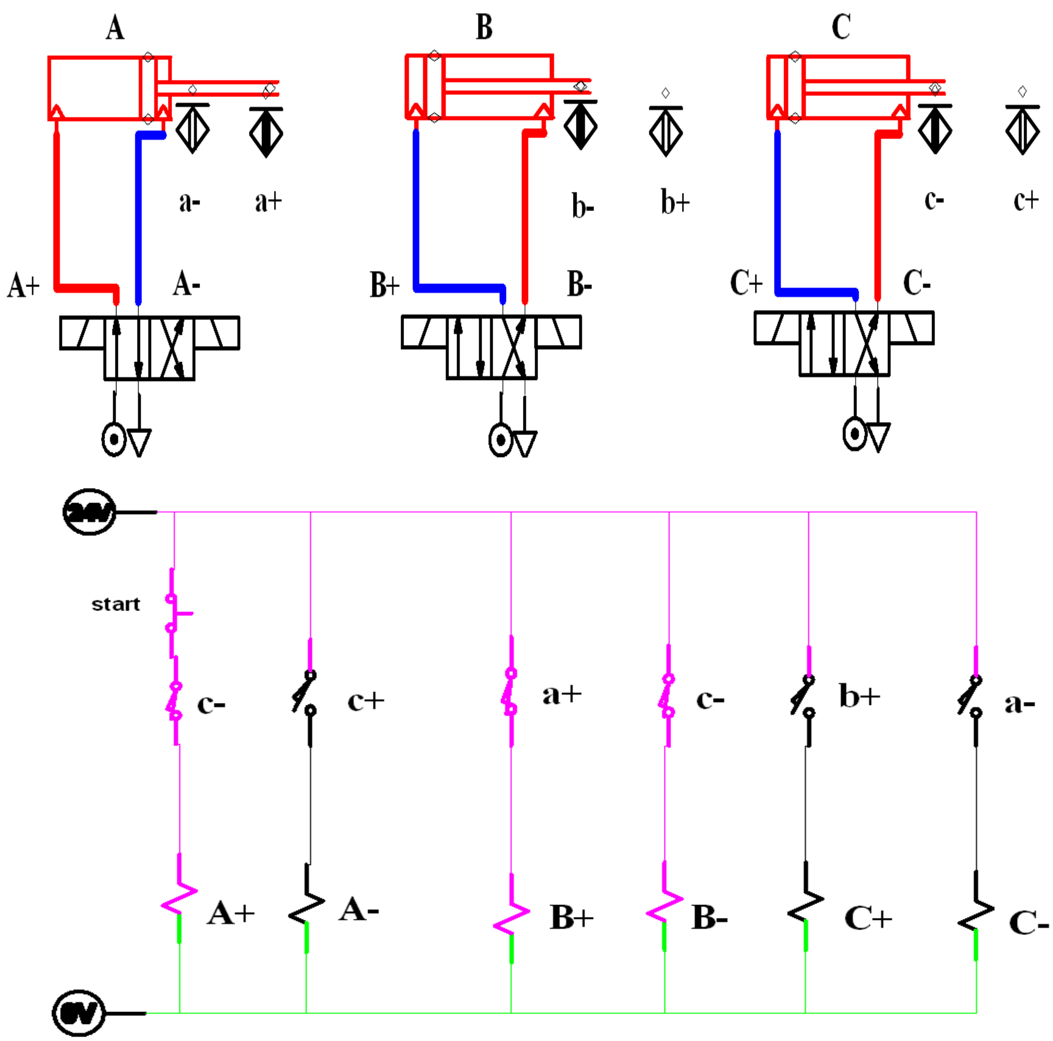


Figure (4): Sequential Circuit for Case Study 2

The sequence should be as follow:-

A+ B+ C+ A- C- B-

Starting with A+ .At this point the sequence will stop as the feedback goes from c- to B- and because air pressure is applied to both B+ and B- at the same time the valve will not move [11].

2.4 <u>Cascade Control:-</u>

When a sequence requires one or more cylinders to move twice within a cycle, the solution becomes more complicated and s systematic method is needed to produce it.

As for the example in sequential control if we consider the cycle

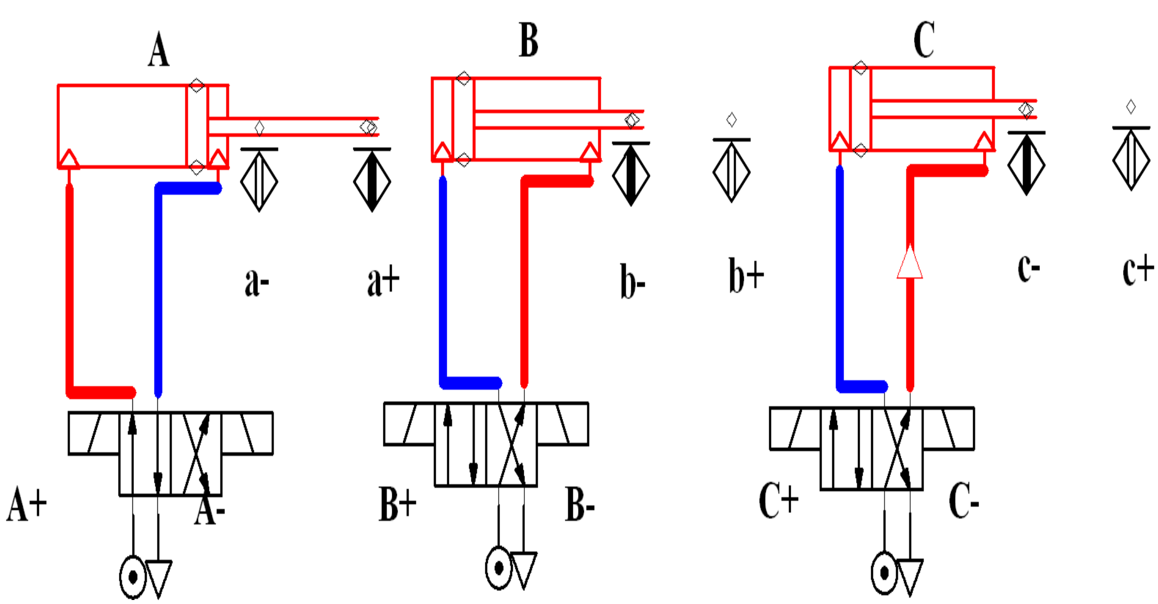
A+, C+, B+, B-, B+, B-, C-, A-

Cylinders B make two complete motions but cylinders A and C only makes one. Electro-pneumatic systems could overcome this with a programmable logic controller (PLC) but to do the job completely with pneumatics or hydraulics requires a more complex circuit using logic valves. One systematic way to produce such a circuit is called cascade control [11].

2.4.1 Case Study 1

For an economical solution the sequence is:

A+, C+, B+, B-, B+, B-, C-, A-



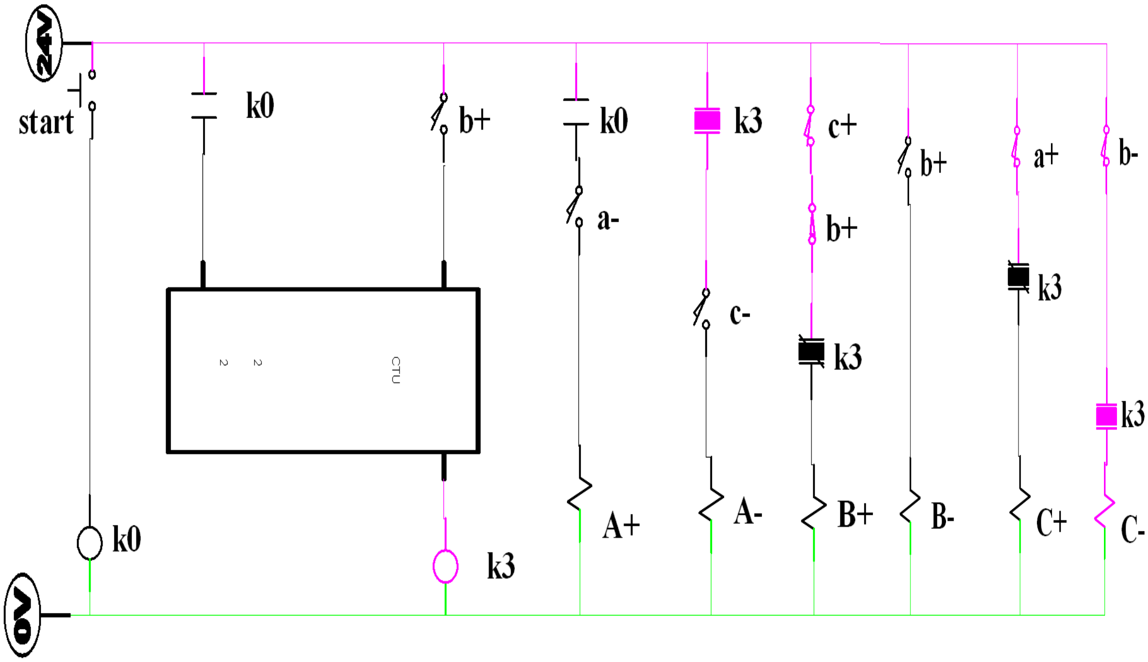


Figure (5): Cascade Circuit for Case Study 2

When using cylinder actuating valves with double pilot lines, it is important to avoid contradictory (i.e., concurrent) control signals in the two side of any valve, since this is almost certain to result in circuit malfunction. In the cascade method this can be avoided

It is assumed that at the beginning of the sequence, each valve is in the initial positions. When the START button is pressed, this will reset the counter to count the strokes for cylinder B, the a- sensor is on this will set the solenoid A+ which will extend cylinder A, sensor a+ is now on and will set solenoid C+ means cylinder C will extend, now sensor c+ is on this will set solenoid B+ (cylinder B will extend) now b+ is on(at this point the counter will count 1 stroke of its 2 preset value), this will reset solenoid B+(since it's normally closed with solenoid B+ then when it sets it will reset solenoid B+ to avoid contradictory)and will set solenoid B- to retract cylinder B, again solenoid B+ will be set and cylinder B will extend at this time the counter will reach its preset value 2 and will set its output contact K3 which(like b+) will reset solenoid B+ since K3 is normally closed with it , sensor b+ will set solenoid B- to retract cylinder B, now sensor b- with contact K3 on will set solenoid C+(cylinder C retracts)then sensor c- well be on with K3 together will set solenoid A- to retract cylinder A

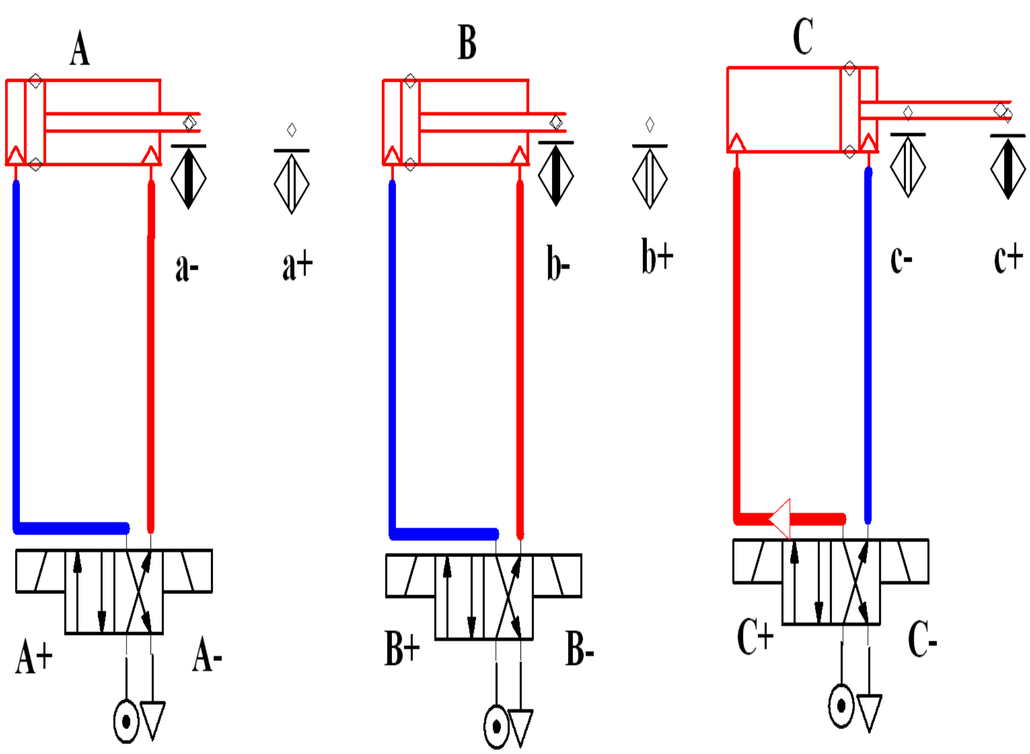
2.4.2 Case Study 2:

If we consider tree cylinders A, B and C must perform the following sequence: start, A+, B+, B-, A-, C+, C-

This sequence might represent a system in which cylinder *A* is used to clamp a work piece; cylinder *B* produces some operation, such as cutting, drilling, or punching; and cylinder *C* removes the work piece from the station.

If we tried solving this with direct operation we would end up with opposing feedback signals. This sequence could be solved as below

Let's consider the feed back signals are obtained for each cylinder.



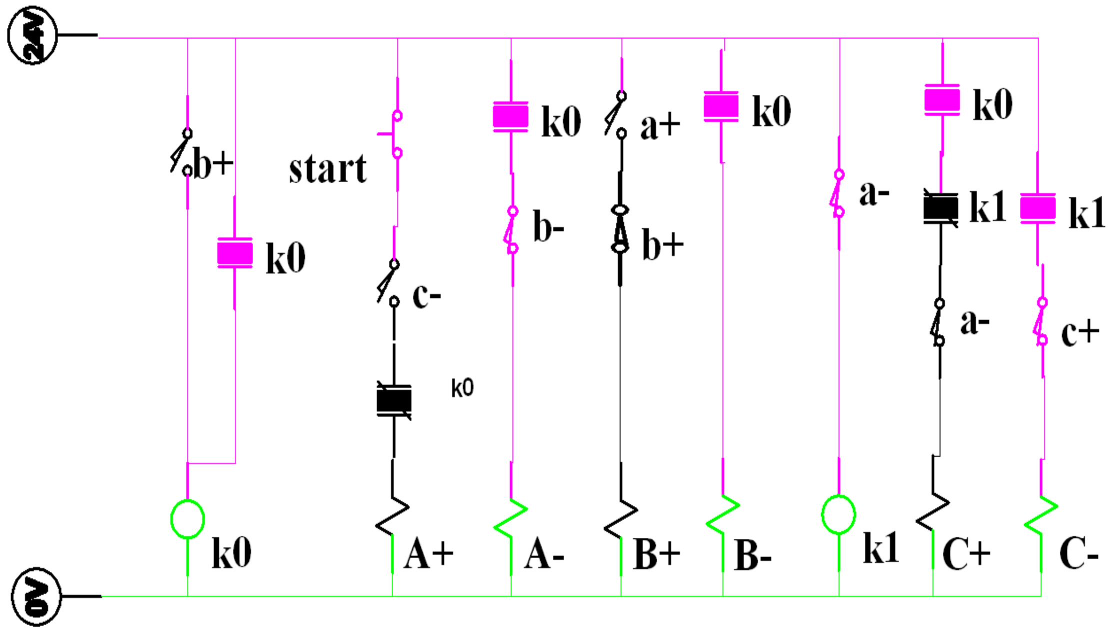


Figure (6): Cascade Circuit for Case Study 2

In order to tell the difference between input signals and feed back signals we use capital letters for the inputs and lower case letter for the feed back. Each cylinder is control by a 4/2 way valve. 5/2 valves are more common for pneumatic and do the same thing. The feed back signals are derived from proximity sensors [12].Now the first step depends on the last step so we put the sensor responsible of retracted state of cylinder C (c-) with the start push buttons ,when pressing start and sensor c- is on this will set solenoid A+ to extend cylinder A, at this point senor (a+) and sensor (b+) is normally closed with solenoid B+ then solenoid B+ will be set and this extends cylinder B at this point there will be latch to latch the state of sensor (b+) and the contact (K0) will be on setting solenoid B- ,at the before that solenoid B+ will be reset because sensor (b+) is normally closed with solenoid B+ as mentioned. So cylinder B retracts, now sensor (b-) is on, the contact (K0) with sensor (b-) will set solenoid A- this retracts cylinder A, now sensor (a-) is on, contact (K0) is on and contact (K1) is normally closed with solenoid C+ this sets solenoid C+ and cylinder C extends, after that cylinder C retracts because contact (K1) is on since it depends on sensor (a-) which will reset solenoid C+ and sensor (c+) is on this sets solenoid C- so cylinder C retracts.

2.5 Cycle Diagram:-

The cycle diagram is a useful tool and shows the status of the cylinders, the input signals and the feed back signals at each point in the cycle. The time intervals are shown as equal but although this may not be the real case, it is irrelevant. It takes one interval for the cylinder to move. Following the application of the input signals, the corresponding feed back signal occurs one interval later. Only show the changes to the input and if there is more than one way to arrange the groups then the one with the least number of groups should be used [11].

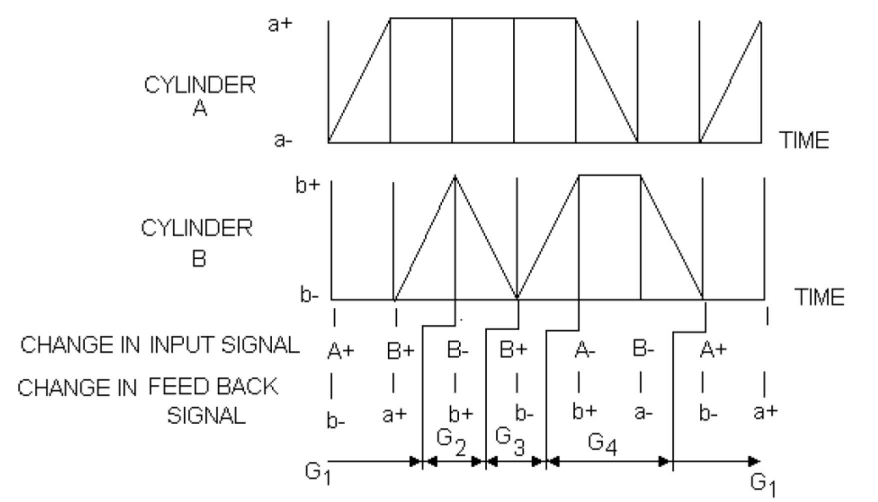


Figure (7): Cycle Diagram for the Above Application

CHAPTER-THREE

Design & Simulation for Electro-Pneumatic System with PLC

3.1 Introduction:-

The relay control represented for a long time the main solution used in industrial process automation.

The main advantages of relay actuation systems are represented by:

1. Small price of the system, compared with automation systems controlled by industrial microprocessors;

2. Maintenance and repair requiring staff with general technical training, less specialized.

3. Low maintenance costs.

These arguments recommend relay actuation systems for reduced complexity automation systems. The design of such system starts with the functional diagram and is followed by the functional scheme and by the electrical scheme [15].

The main disadvantage of using relay schemes consists in the difficulty of designing the electrical scheme [15].

The designer of such systems has to manage a series of designing techniques, especially in the case of high complexity actuation systems or in the case of systems that cross over successively the same state during a cycle, each time having to execute different actions [15].

The movement-phase diagram presented in Figure 1 constitutes an example of this type [15].

The diagram shows that the system crosses over the same state at the beginning of phases 1 and 3: the assemblies of the three cylinders A, B and

C are retracted. A similar situation is noticed at the beginning of phases 4 and 6: the assemblies of the cylinders *A* and *C* are retracted and the cylinder assembly *B* is advanced. In such cases, the automation is not depending Only of the state of the sensors mounted in the system [15].

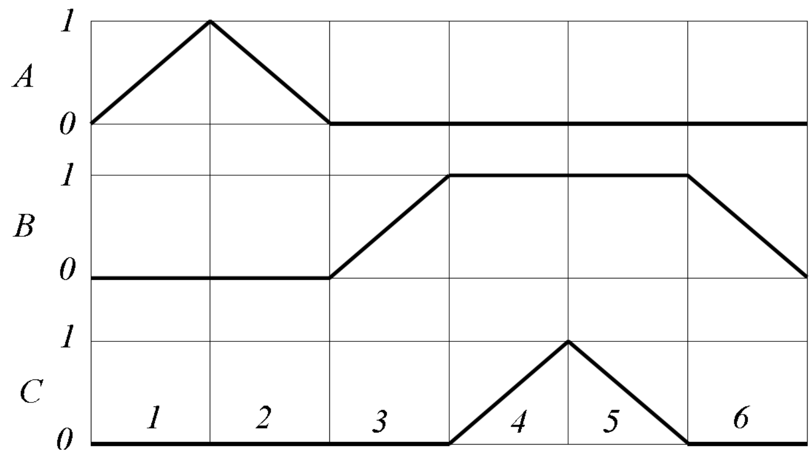


Figure (1): Movement-Phase Diagram

The diagram proves the impossibility of finding the sensor that determines the advance of the cylinder *A* at step 1 and the advance of the cylinder B at step 3 [15].

There are a series of methods for the design of relay automation schemes. Two of them are the best known:

1. Cascade switching method;

2. Sequential switching method.

These methods use relays with at least three auxiliary contacts:

1. An auto-maintaining contact;

2. A contact for reaching a requirement referring to the interlocking or cutting of auto-maintaining for another relay.

3. A contact for the force circuit (current line feeding an electromagnet).

S1	S2	S3	S4	S5	S6	S7
a0	a1	a0	b1	c1	c0	b0

Table 1 – Order of sensors

3.2 <u>Sequential Switching Method:-</u>

The method requires the successive activation of a number of relays. Only a relay can be activated at a certain moment. The method is recommended when 5/2 memory valves are used for the supplying of motors in the system. Once interlocked, a relay must auto-maintain.the relay Ki is activated only if two requirements are simultaneously reached:

1. A process event: activation of a sensor, end of a temporization etc.
2. Activation of the previous relay (Kn-1).

After its activation, the relay *Ki* must inactivate the relay *Ki-1* (by cutting its auto-maintaining). Activation of the last relay Kn will represent an initial condition for the activation of the first relay *K1* and the relay *K1* will inactivate the previous relay Kn [15].

This method does not require the existence of various serial relay contacts for the control of memory distributors. A number of contacts mounted in parallel may however exist if the controlled motor has to perform identical movements during a cycle [15].

Figure 10 presents the electrical scheme obtained by applying sequential switching method for the considered example. one can notice the three circuit structures (start structure, basic structure and final structure) [15].

The following notations are used:

Si – the sensor which initiates the “i”th phase.

Ki – the relay that commands the “i”th phase.

Start – The button that initiates the working cycle.

3.3 The Application Being Used:-

In this project the application of Electro-Pneumatic system will be as fellow:

There will be three cylinders A,B & C. cylinder A will extend and retract then cylinder B will extend then cylinder C will extend after it retracts cylinder B will retract the sequence could be written as below:

A+ A- B+ C+ C- B-

And the above sequence is represented in figure (1)

This application could be used in a factory where cylinder A represent the uploading to the work piece and cylinder B represents the clamping for the work piece and cylinder C represents the drilling operation.

3.4 The Design of the Electro-Pneumatic Application:-

The design will include pneumatic parts and electric parts

As for the pneumatic parts they are

1. Three double acting cylinder cylinders A, B and C which we will work in

2. 5/2 way NC (normally closed) directional valve solenoid operated for each cylinder to Control the piston movement.

3. Pressure source to move the piston.

4. Exhaust to get rid of the pressure.

5. Proximity sensors two for each cylinder to sense the retracting and Extending positions of the cylinders.

6. Non Return throttle valve two for each cylinder to control the speed regulation of the cylinders.

7. Compressor to compress the air to the desired working pressure

While the electric parts are:

1. Push button to control the start of the system

2. Push button to control the stop of the system

3. Normally open contacts

4. Normally close contacts.

5. Coils

The symbols of every pneumatic and electric component used will be shown in the appendix

3.5 The Connecting of the Pneumatic Circuit

1. Connect each output port of each directional valve to the Throttle valve.

2. Connect each throttle valve to each cylinder so that the port of the directional valve that is connected to the pressure source is connected to part that is responsible of retracting the piston through throttle valve while the other port of the directional valve connected to the exhausted for moving the pressure out is connected to the cylinder through another throttle valve.

3. The input port of each directional valve which is responsible of retracting the piston is connected to the compressor.

4. The port of the directional valve which is responsible of moving out the pressure from the other side of the piston is connected to the exhaust

5. The compressor is connected to the pressure source.

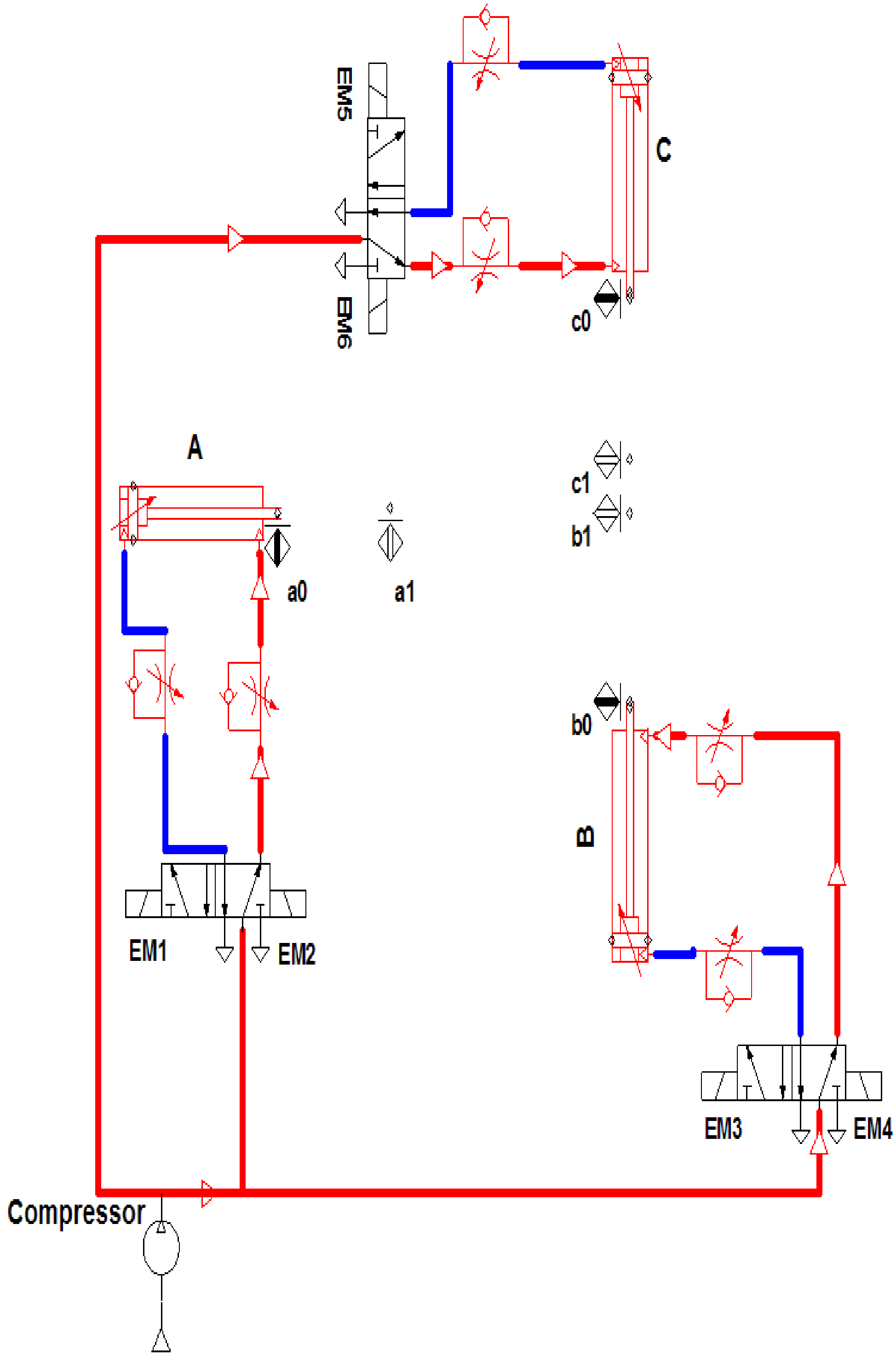


Figure (2): The Pneumatic Circuit

3.6 The Connecting of the PLC Electric Circuit:-

1. Connect a contact named start assigned by a push button to start the operation.

2. Connect the normally open contact related to sensor b0 and normally close K2(so that when coil K2 activates it turns off K1 to avoid signal opposing) to the coil K1 to be the input for the solenoid EM1 responsible for extending cylinder A.

3. Connect the normally open contact a1 with the normally open contact K1 (because present step depends on the previous one) to the coil K2 to activate the solenoid EM2 to cause cylinder A to retract.

4. Connect the normally open contact a0 with the normally open contact K2 (as before since the present step depends on the previous one) to the coil K3 to activate the solenoid EM3 to cause cylinder B to extend.

5. Connect the normally open contact b1 with the normally open contact K3 (as before since the present step depends on the previous one) with normally closed contact K5 (to avoid signal opposing) to the coil K4 to activate the solenoid EM5 to cause cylinder C to extend.

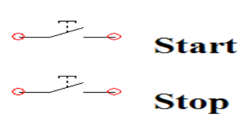
6. Connect the normally open contact c1 with the normally open contact K4 to the coil K5 to activate the solenoid EM6 to cause cylinder C to retract.

7. Connect the normally open contact c0 with the normally open contact K5 to the coil K6 to activate the solenoid EM4 to cause cylinder B to retract ,contact K6 will be connect as normally closed with EM3 to turn it off to avoid signal opposing.

8. A normally closed contact used to latch the signal will be connect as OR case with each coil named as the name of that coil

9. There will be coil K7 connect to it the last case which is b retracting (normally close contact b0 with normally close contact k6) where coil K7 will be connect as normally close contact with every coil to make sure that the work continues until the stop button of the simulation is pressed. The coil will be connected after the latch of each coil.

10. A contact named Stop assigned by a push button will be connected in OR way to the coil K7 that's if the push button is pressed the contact Stop will be on turning on coil K7 lead to turn off all the system even if the start button still pressed



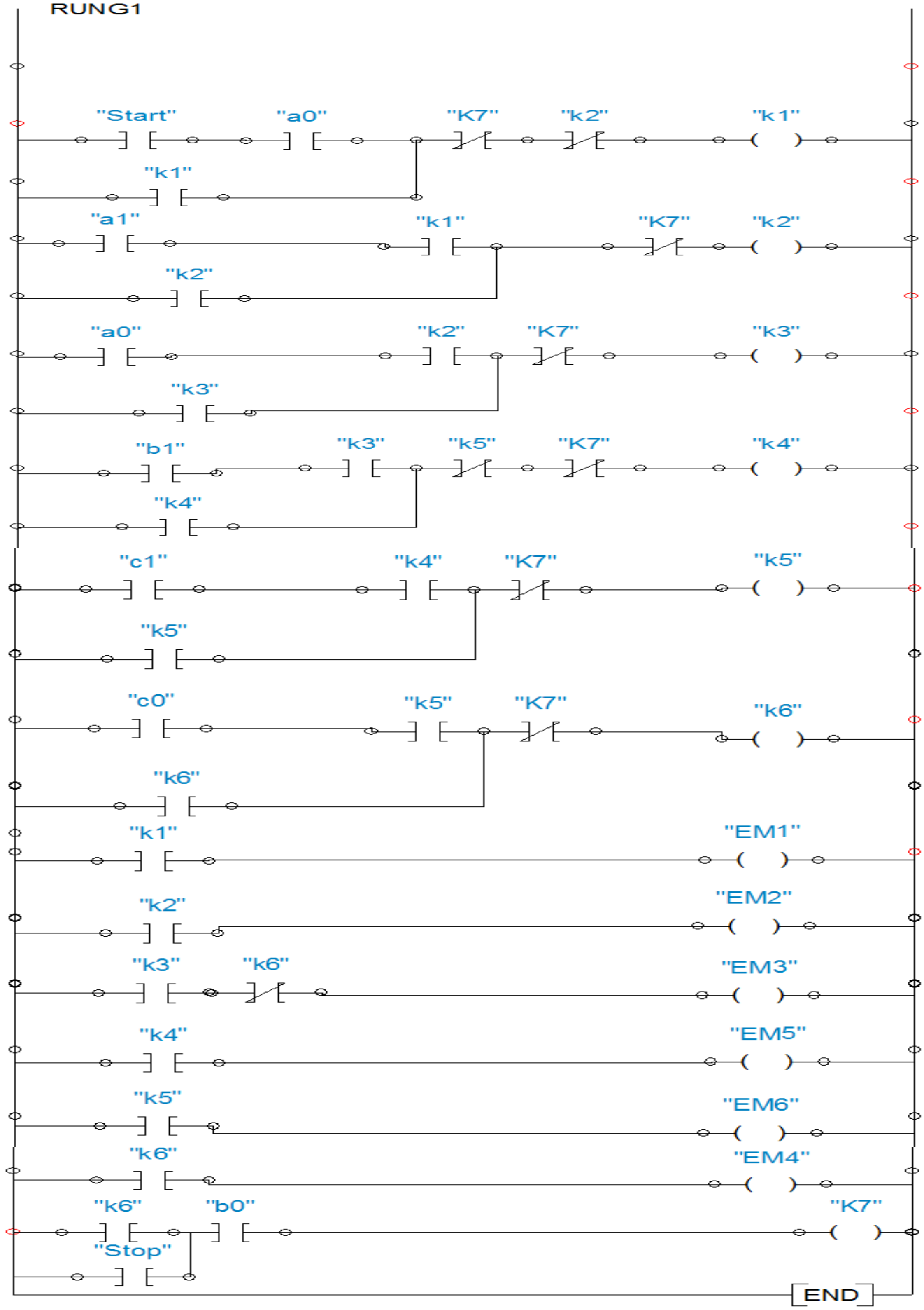


Figure (3): PLC Electric Circuit

3.7 Simulation:-

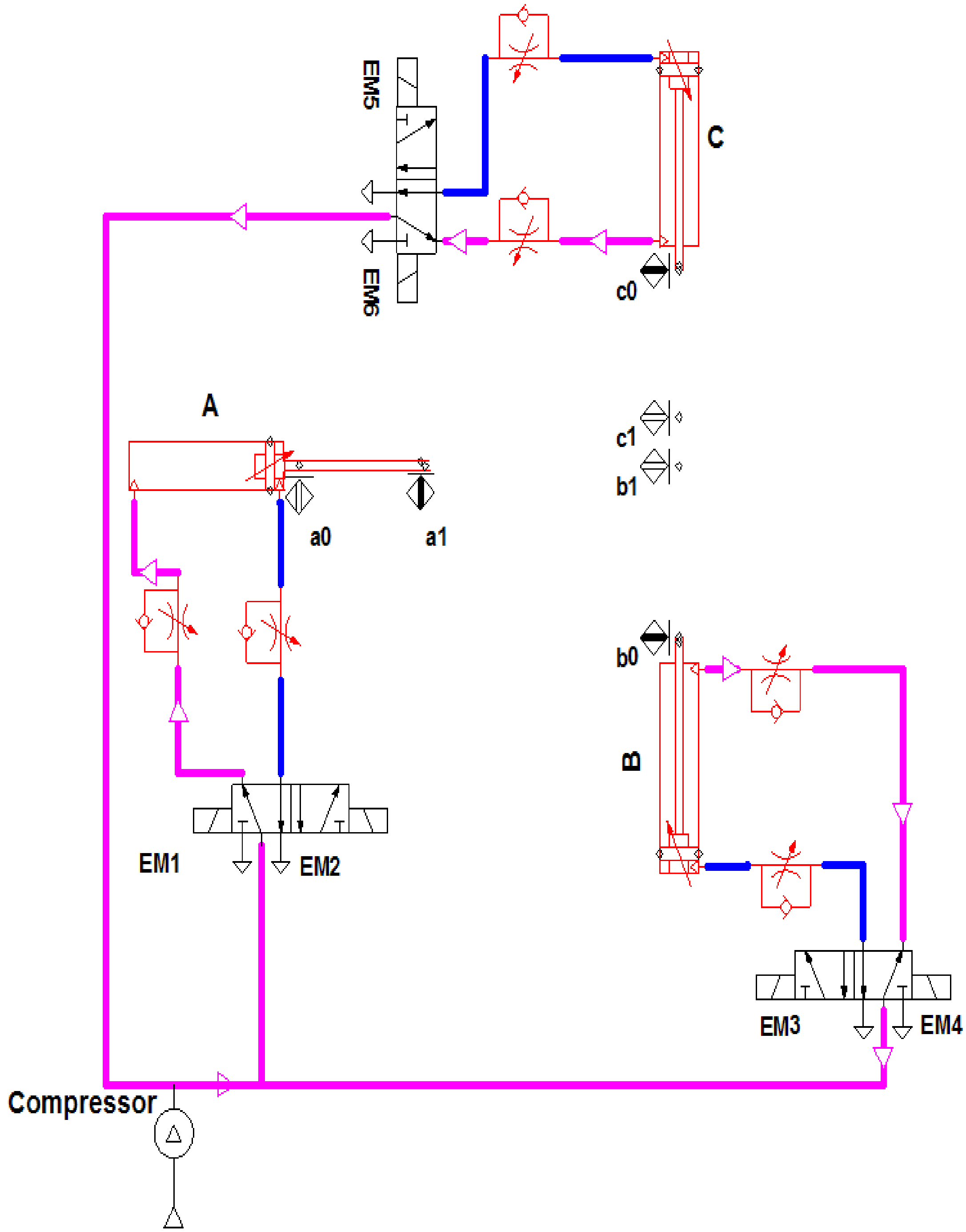


Figure (4): Pnuematic Circuit

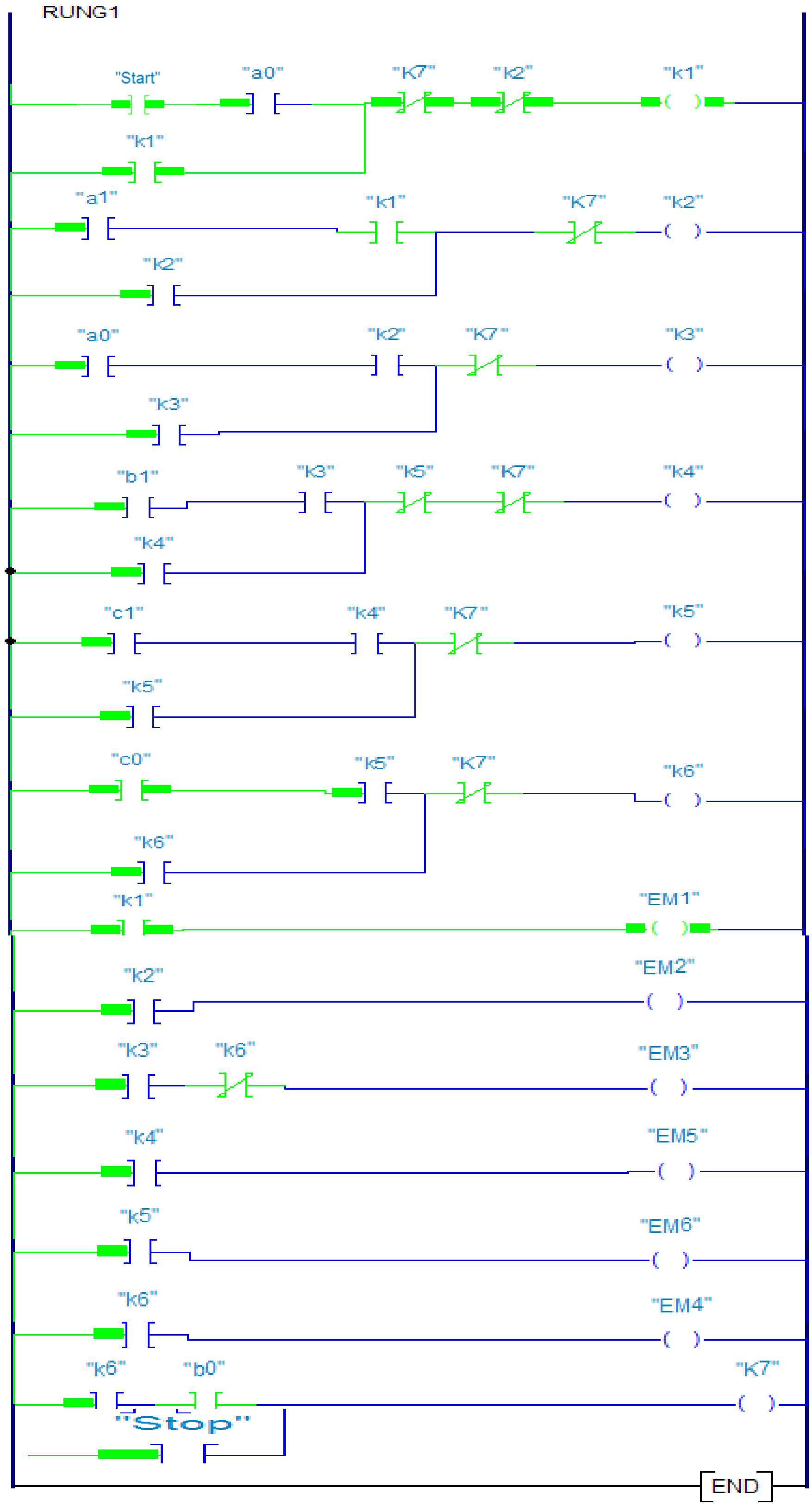


Figure (5): PLC Electric Circuit

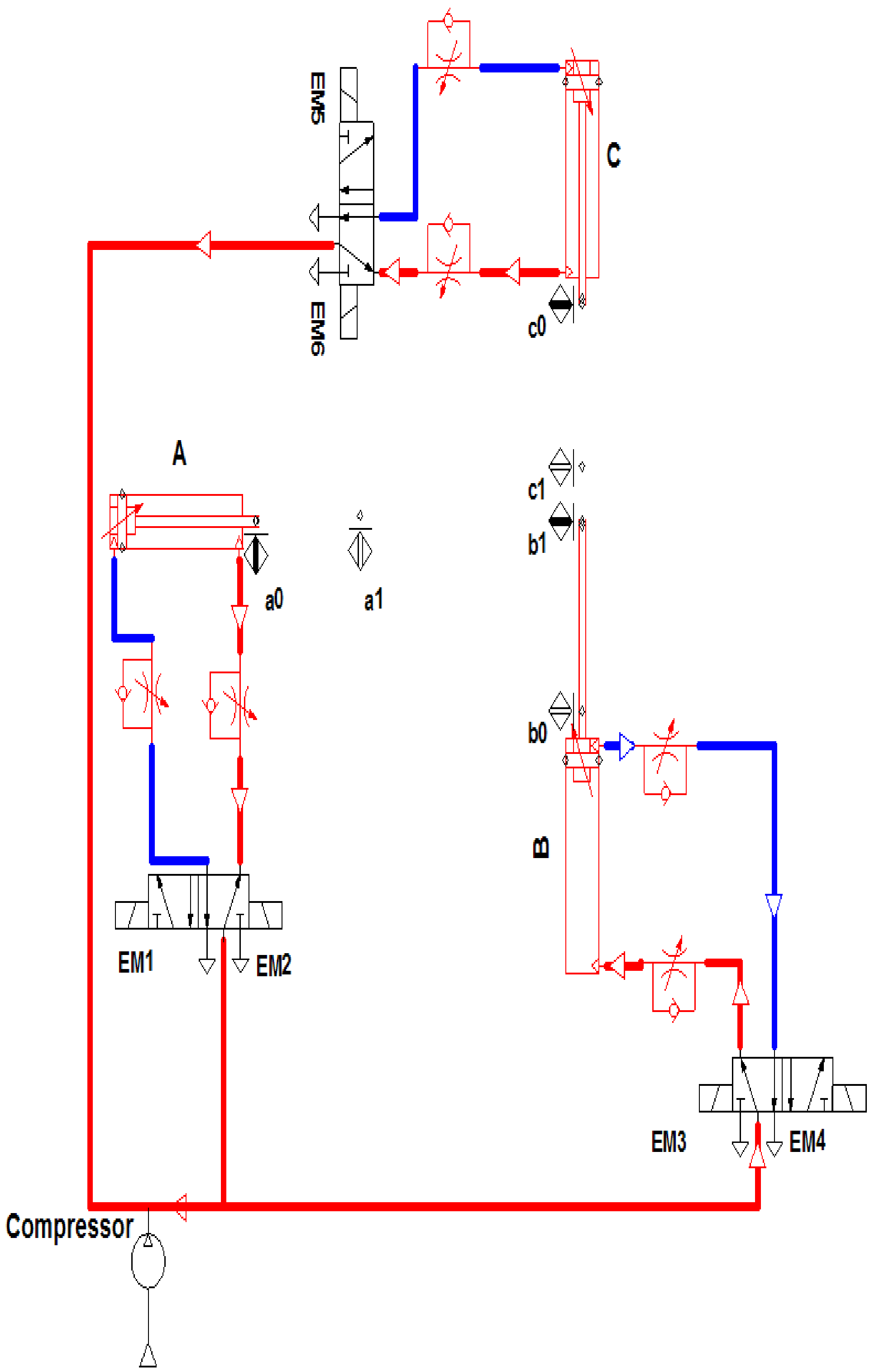


Figure (6): Pneumatic Circuit

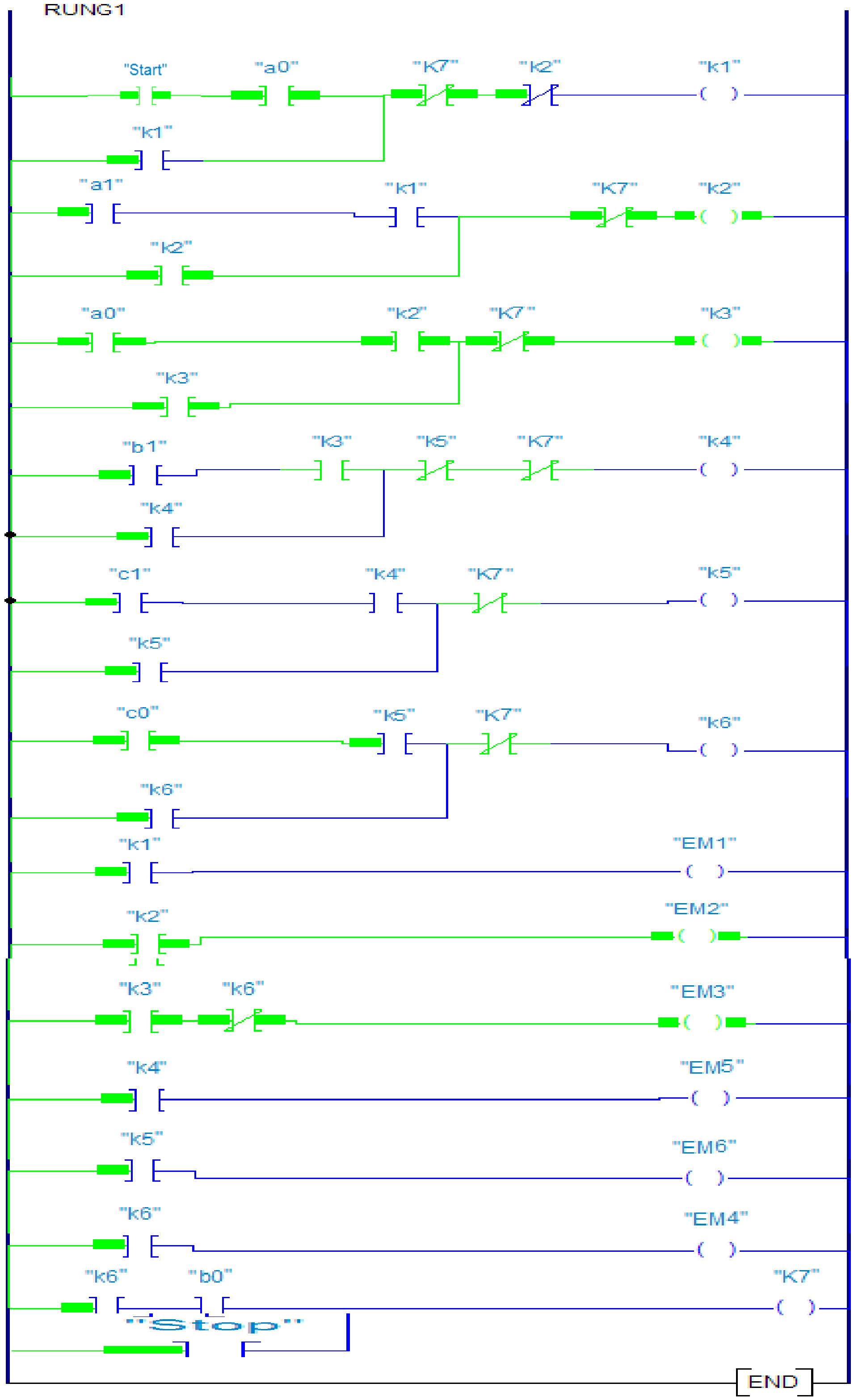


Figure (7): PLC Electric Circuit

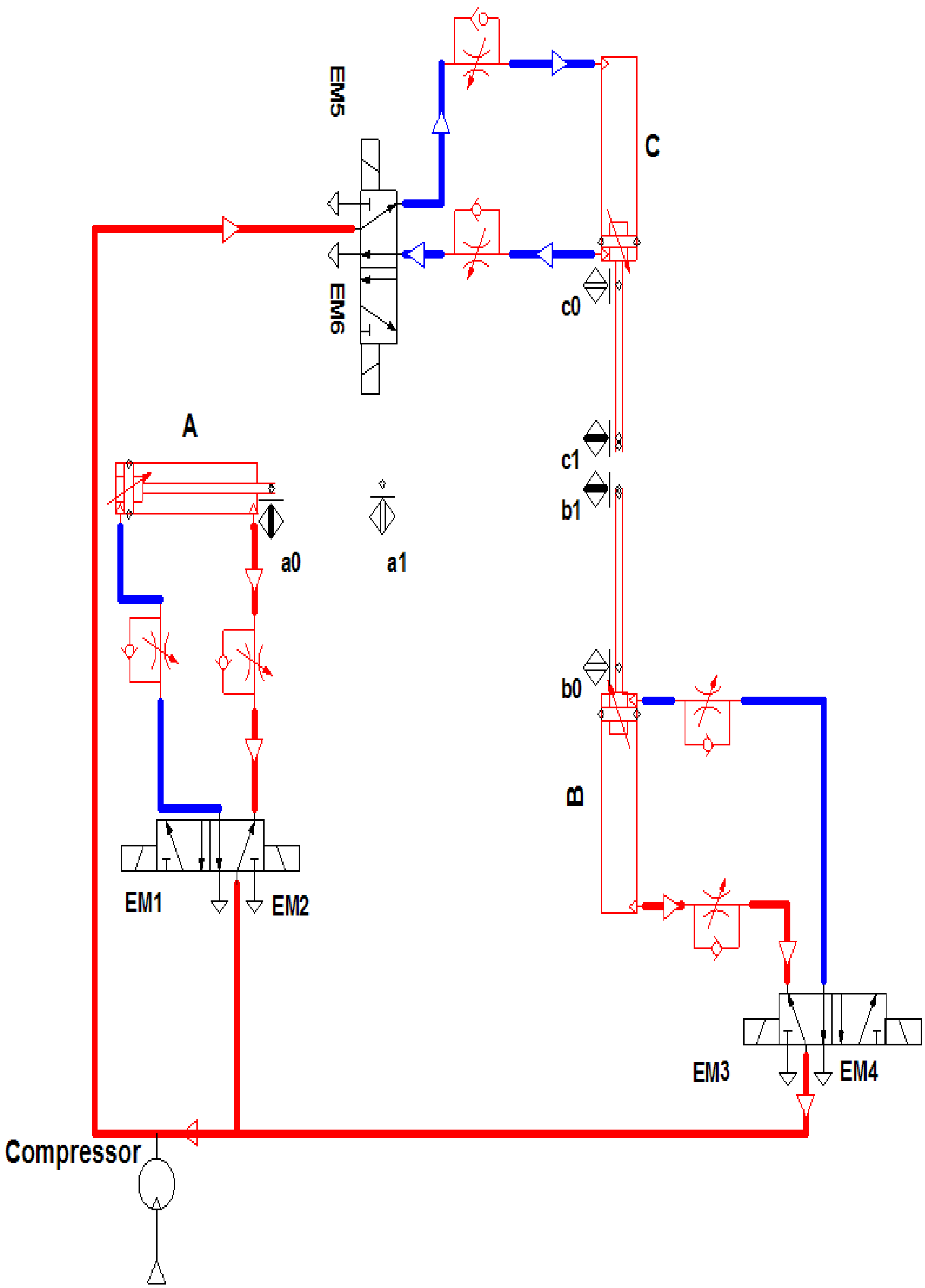


Figure (8): Pneumatic Circuit

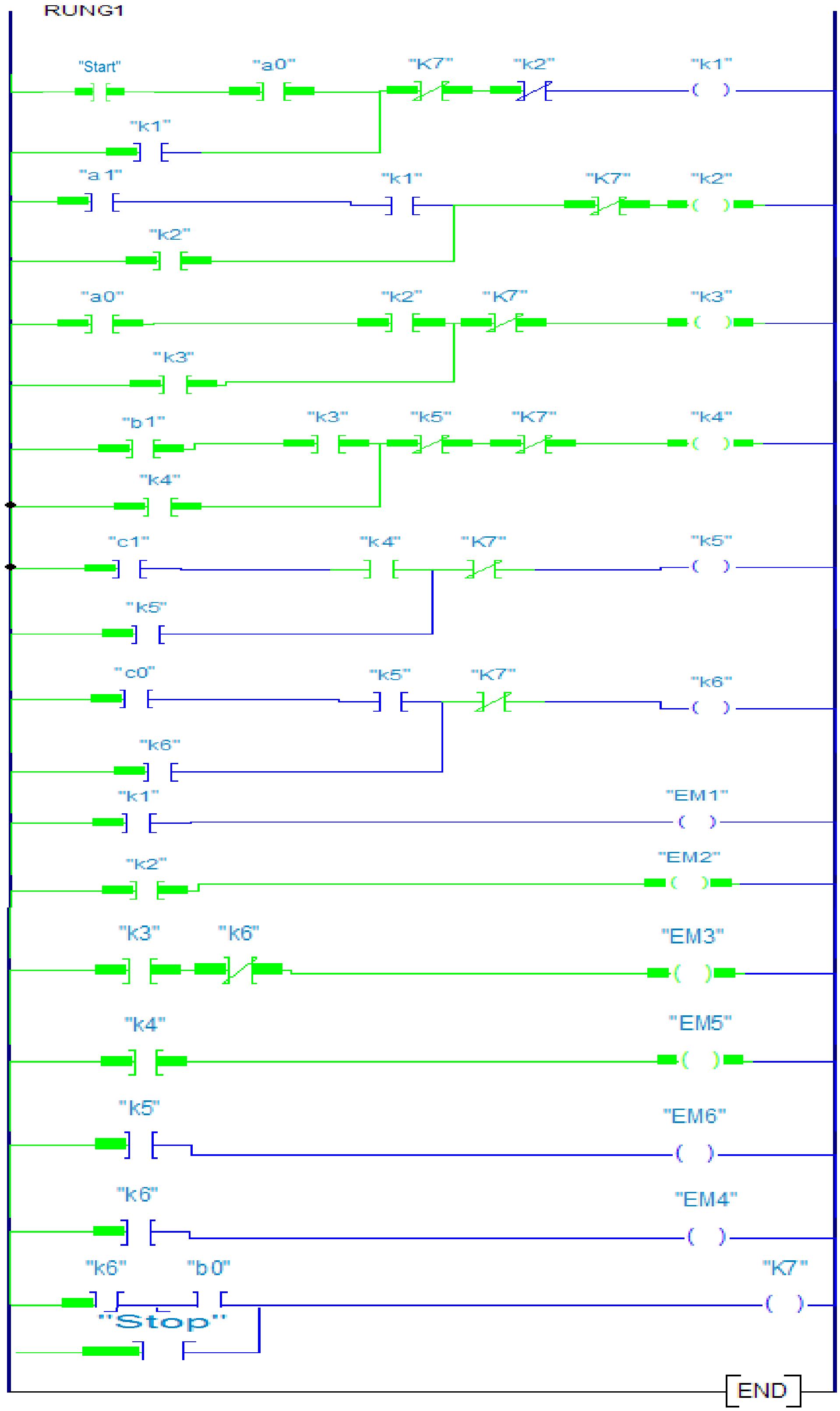


Figure (9): PLC Circuit

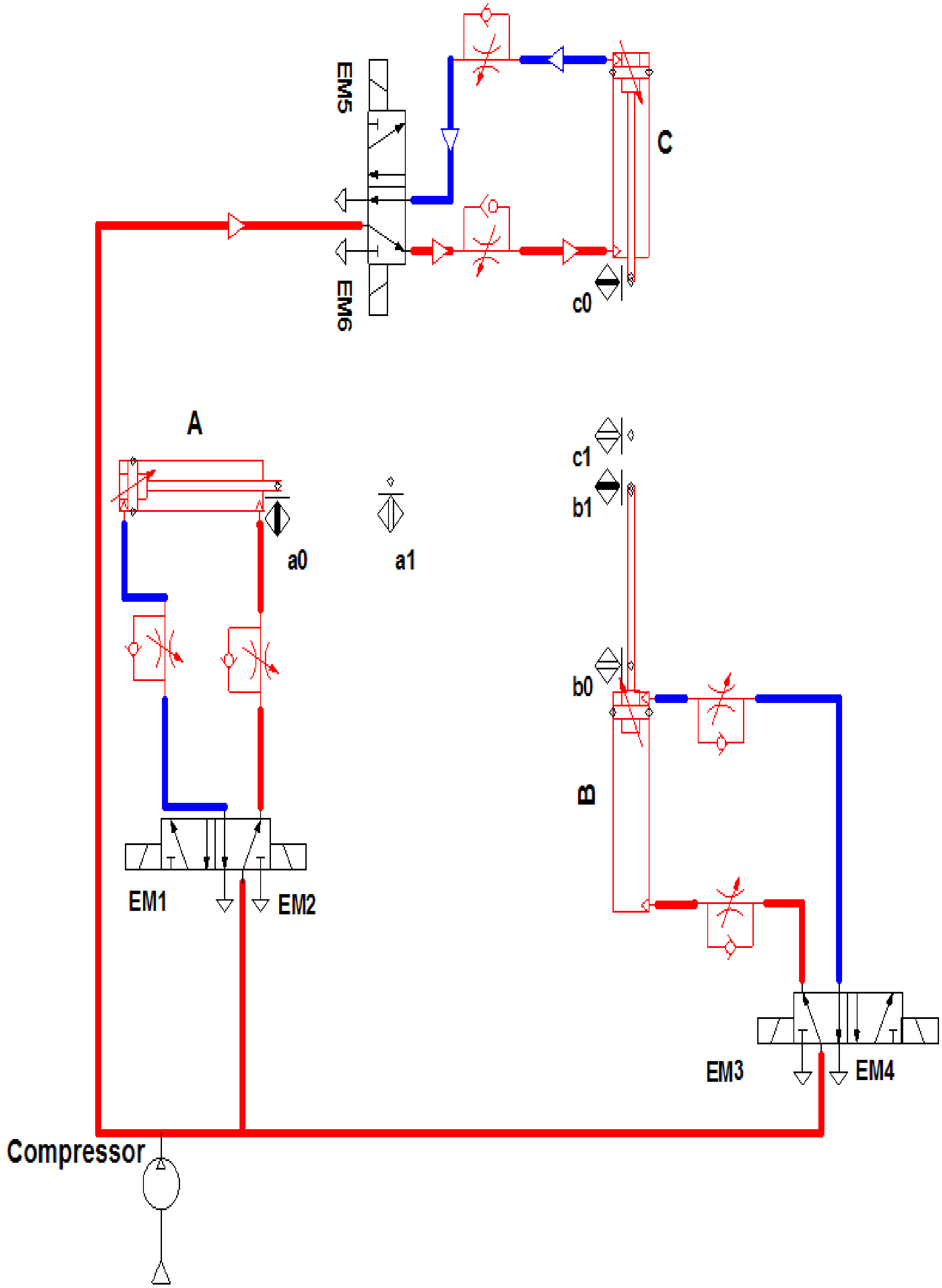


Figure (10): Pneumatic Circuit

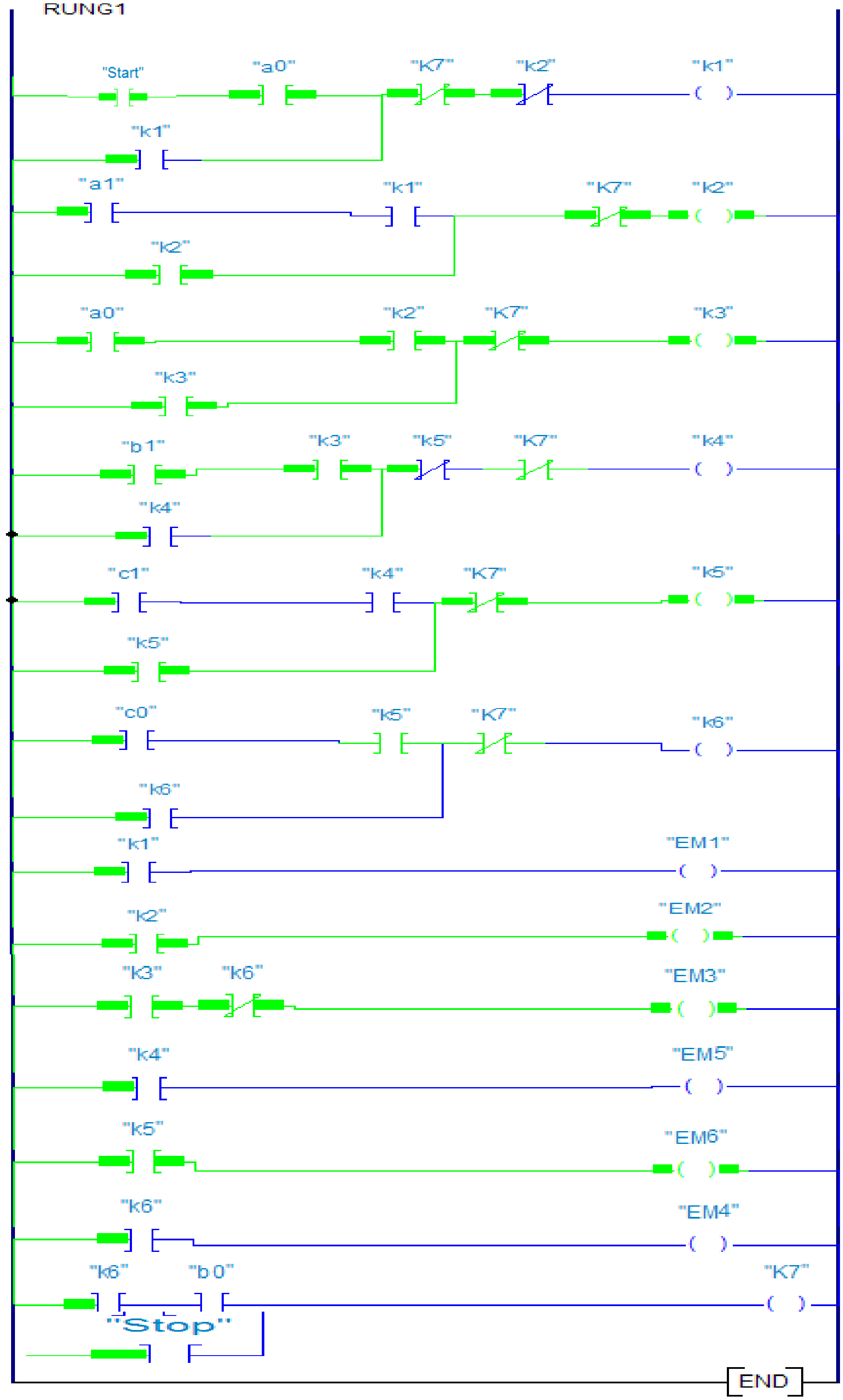


Figure (11): PLC Circuit

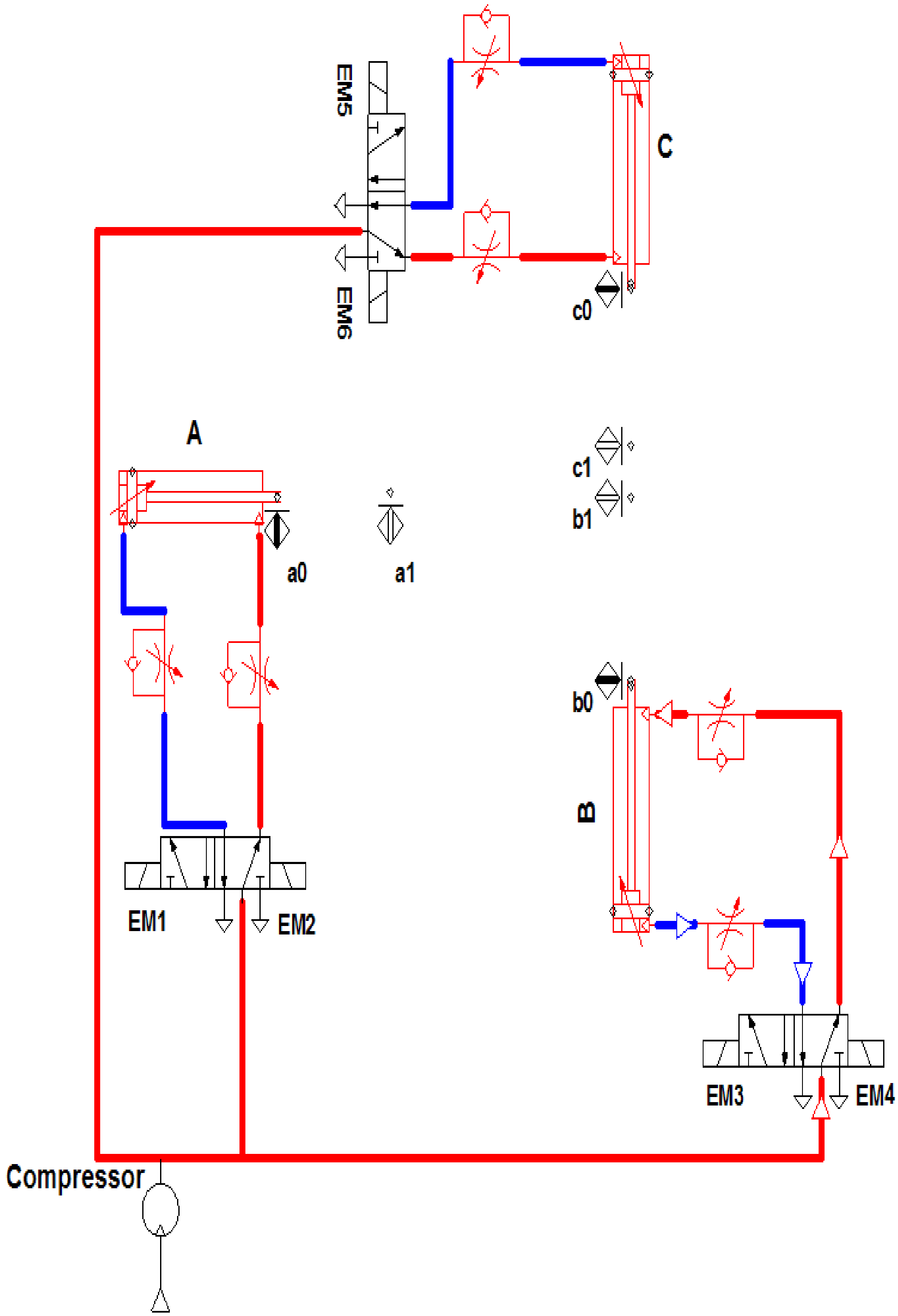


Figure (12): Pneumatic Circuit

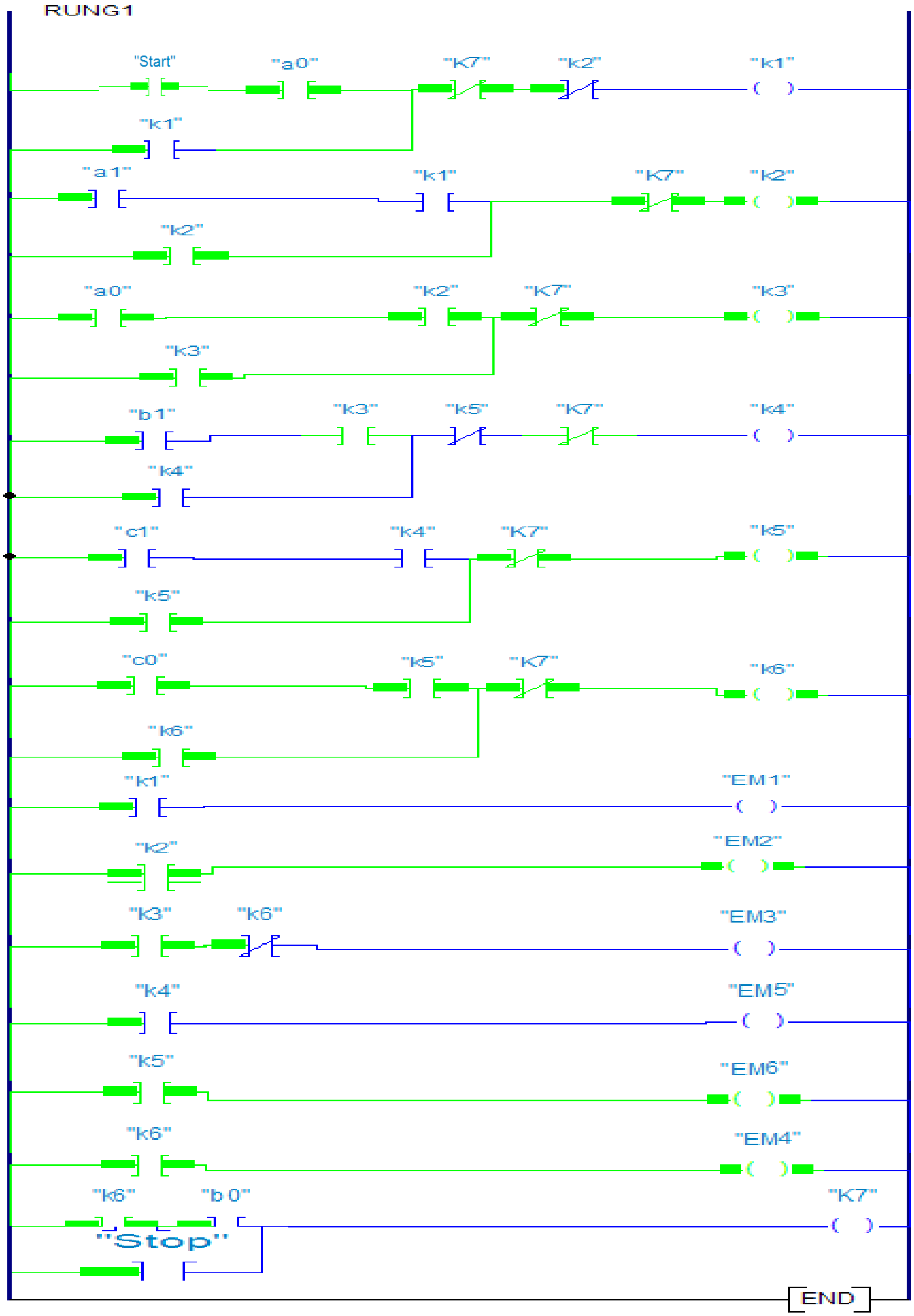


Figure (13): PLC Circuit

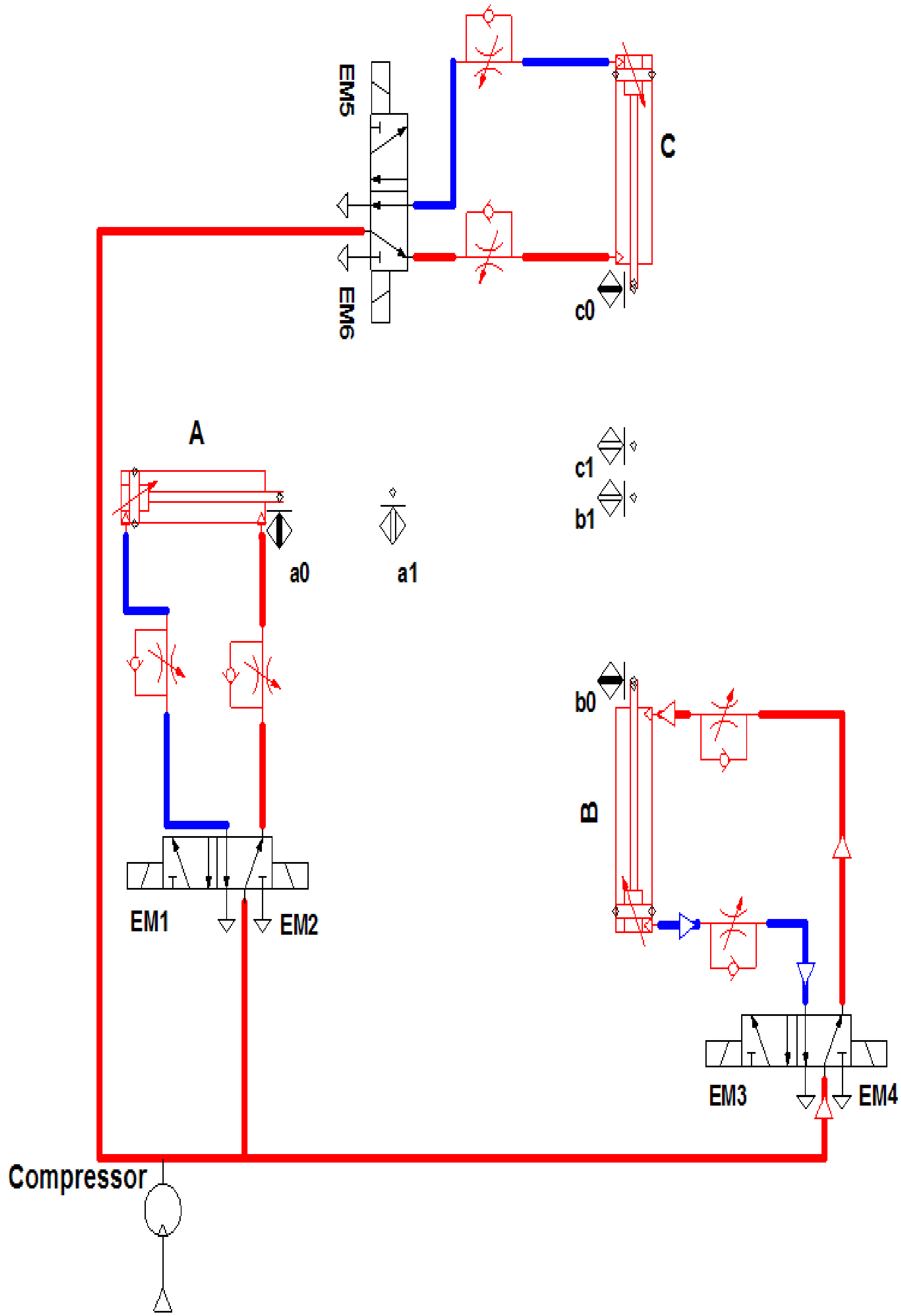


Figure (14): Pneumatic Circuit

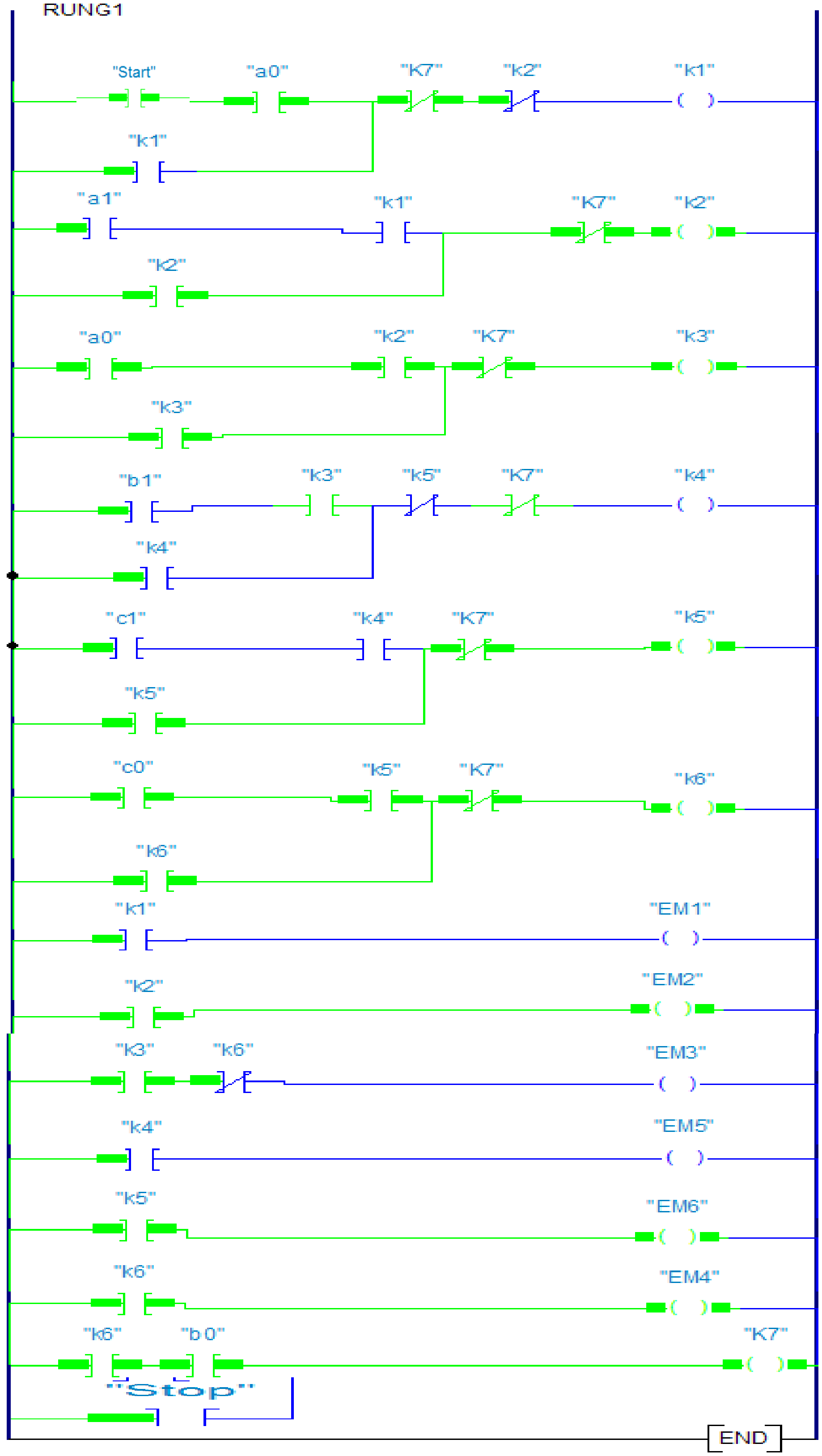


Figure (15): PLC Circuit

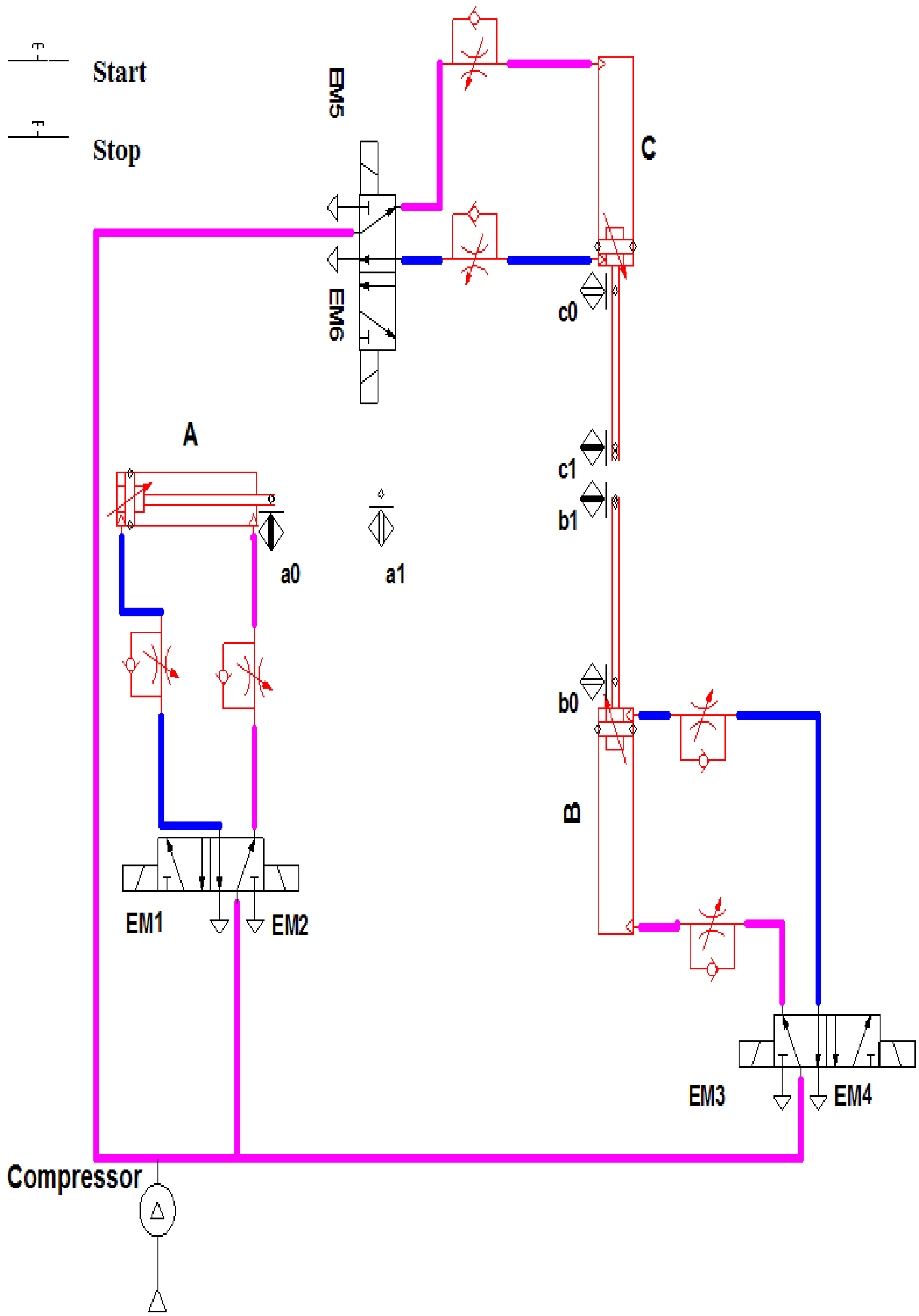


Figure (16): Pneumatic Circuit

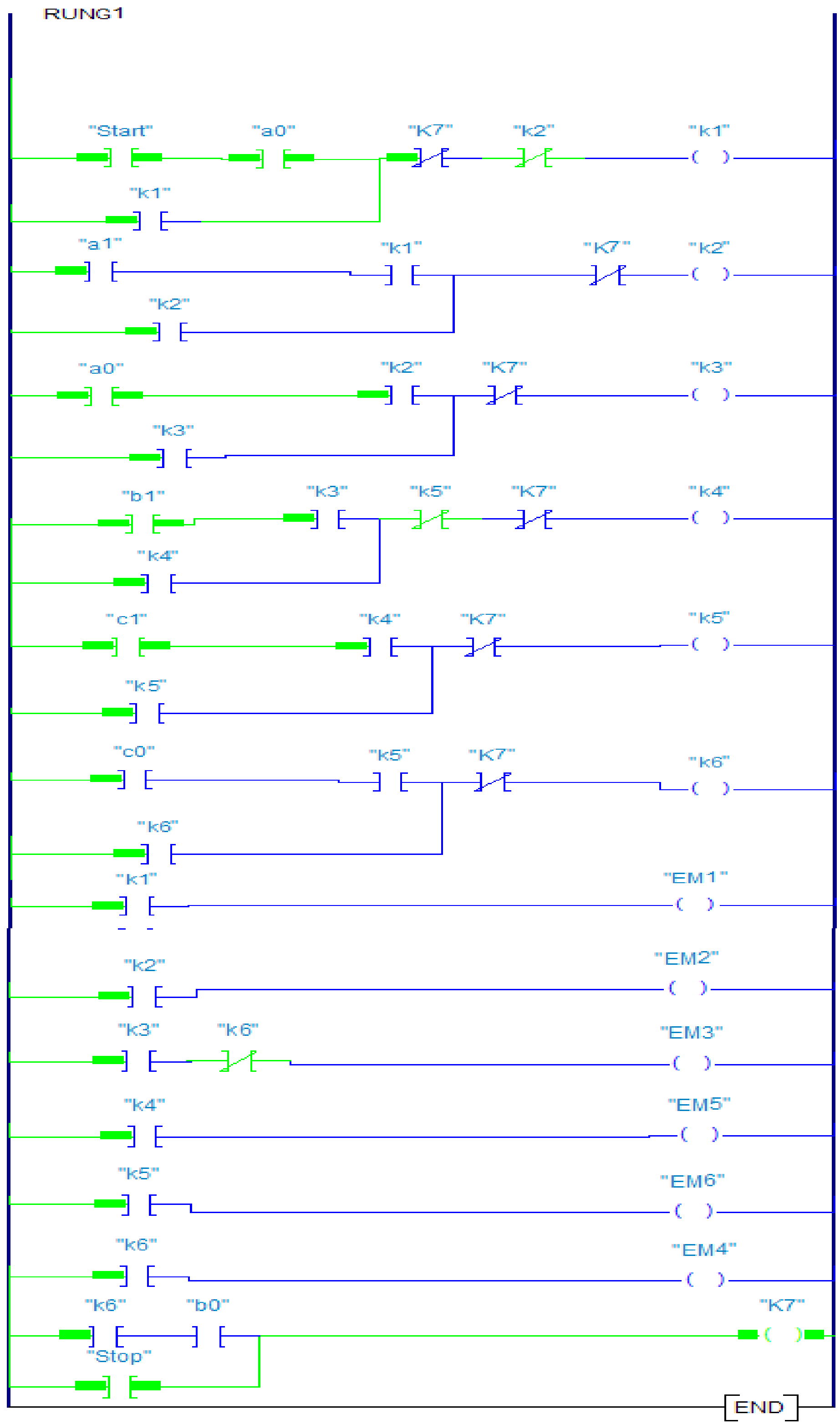


Figure (17): PLC Circuit

Chapter Four

Conclusion & Suggestion for the Future

4.1 Conclusion:-

In this project one can notice that electro-pneumatic control system though Its using is restricted in flammable environments as mentioned but it is used in many applications for its specifications which this system provides like automation can be easy even with complex processes, increasing the productivity which leads to a decrease in production time, mistakes can be discovered and corrected with help of PLC (programmable logic controller) also design and simulation of an electro-pneumatic control system with PLC is much easier even if the complexity of the system increased besides this system is help to control processes from remote distances.

4.2 Suggestion for the Future:-

According to what one can see from the specifications of using electro-pneumatic control system with PLC, so the suggestion is to use PLC which would be much easier in controlling and simulation any control system rather than using other controllers because PLC is computer designed for industrial operations, in our case Pneumatic system since its wild in use. Also the another suggestion is to use Ladder diagram language with PLC since it's easy to understand by any designer while other languages like structured text(ST) high level language of PASCAL type where one must study and learn this language carefully to know how to design in PLC.

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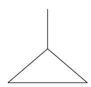
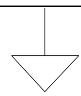
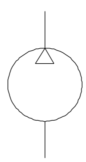
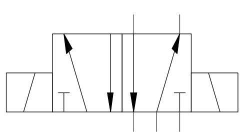
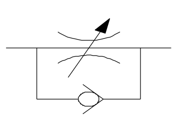
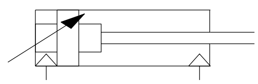
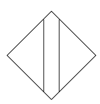
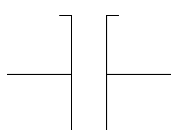
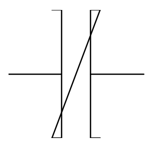
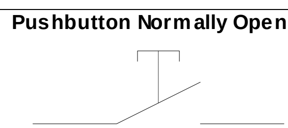
Appendix

symbol	description
	**Compressed air supply** The compressed air supply provides the needed air. It contains a pressure control valve that can be adjusted to output the desired operating pressure
	**Exhaust** For the pressure to move out
	**Compressor** To increase the pressure of air by increasing its density and delivered the the fluid against the connected system resistance on the discharge side
	**5/2 way normally closed Directional control valve operated by solenoid** The solenoid valve is controlled by applying a voltage signal at the solenoid coil.
	**One-way flow control valve** The one-way flow control valve is made up of throttle valve and a check valve. The check valve stops the flow from passing in a certain direction. The flow then passes through the throttle valve. The cross-section of the throttle is adjustable via a regular screw. In the opposite direction the flow

	can pass through the check valve. Adjustable parameters: Opening level: 0>opening<=100%
	**Double acting cylinder** The piston rod of a double acting cylinder is operated by the reciprocal input of compressed air at the front and back of the cylinder. The end position damping is adjustable via two regular screws.
	**Proximity sensor** The proximity sensor reacts to the presence of objects disturbing the magnetic field emitted by the sensor. Placed against an aluminum cylinder, it reacts to the passage of the steel rod. The switch is then closed and an electrical signal activates the component from the electrical diagram associated with this sensor
	**Normally open contact** Used in association with coils in contact relays. Can be normally opened or closed. It characterize the electrical behavior of contacts when they are not activated, i.e. when the coil to which they are associated is not activated. As soon as the coil has a current going through it, contacts to which it is associated change their status. Normally open(NO) contacts close and vise

	versa. It blocks the passage of current in a circuit when not activated. Once activated, the contacts allow the passage of electrical current.
	**Normally closed contact** Same as the normally open contact it characterize the electrical behavior of contacts when they are not activated. As soon as the coil has a current going through it, contacts to which it is associated change their status.noramlly close (NC) contact allows the passage of electrical current when not activated and blocks it when activated.
	**Push button normally open** This component does the same thing as switch activated by finger pressure. It constitutes the link between the user and the circuit. It has a return spring i.e. a spring that brings back the push button to its initial position as soon as the button released. In simulation diagrams, push buttons can be associated with switches that have the same tag name