

Design, Simulation and Prototype Development of a Multi-Cylinder Pneumatic Circuit for Stamping Application

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Abstract – The term *pneumatic* is derived from a Greek word meaning ‘wind,’ and it relates to the study and application of air movement. In today’s fast-paced industrial environment, sheet metal operations play a vital role in manufacturing. These operations may be performed manually or with the assistance of hydraulic or pneumatic actuators. Among these, pneumatic systems are highly preferred in industries due to their reliability and the low cost and easy availability of compressed air. This paper focuses on the design, simulation, and development of a pneumatic sequence circuit for engineering applications.

Key Words: *Pneumatics, Pneumatic, Hydraulic, Sheet metal.*

1. INTRODUCTION

In this era industries should deliver high quality and precise products with reasonable prices. Industries developing new technologies, automation save material, money and labour. Sheet metal industry contributes significantly to national infrastructure development. Sheet metal is widely used in sectors such as automobiles, aerospace and shipbuilding. In industries Sheetmetal operations are usually carried out either manually or with the help of hydraulic or pneumatic systems. In small and medium industry hydraulic systems are not economical. Pneumatic systems have a wide application in automation. Pneumatic system uses compressed gas or air to control or regulate movement.

This project aims to design, analyze, and develop a pneumatic sequence system A+ A- B+ B- C+ C- used extensively in sheet metal punching processes.

2 LITERATURE REVIEW

1. Development and Fabrication of Electro Pneumatic Automatic Stamping Machine

Author: Pawan Koppa, Dr.N.Nagaraja, Amith.V,Sushilendra Mutalikdesai,Vyasaraj.T,Gururaj Hatti

This work applies electro-pneumatics for stamping operations using pneumatic cylinders, with a PLC controlling the sequential movement of three cylinders. A motion diagram is developed from the required sequence and converted into an electrical control circuit, which is then programmed in ladder logic for PLC implementation. The clamping cylinder holds the workpiece, the stamping cylinder

performs the stamping operation, and the ejection cylinder removes the finished part. Two single-solenoid DC valves control the clamping and ejection cylinders, while a double-solenoid valve operates the stamping cylinder. Inductive sensors monitor cylinder end positions to ensure accurate and reliable sequence control.

2. Design and Simulation of Electro-Pneumatic Sequential System Using Fluid Sim Software

Author: Muhammed Ishack V, Ahammed Adil P, Amal P K, Rohith V T, Jibi R

This work involves the design and simulation of a pneumatic cascade A+ B+ B- A- sequential circuit using Fluid SIM-P software. Fluid SIM is a powerful simulation tool used for creating and analyzing hydraulic, pneumatic, electro-pneumatic, and electro-hydraulic systems. In this work, the FESTO Fluid Sim software is utilized to simulate the pneumatic power system effectively. An electro-pneumatic system includes both an electrical signal control section and a pneumatic power section to achieve precise and automated operation. The circuit is composed of solenoid-operated 5/2 direction control valves, relays for group changing, a start push button, and sensors, all integrated to ensure accurate sequential movement of the actuators.

3. Design and Fabrication of Two Step Speed Control of a Cylinder Circuit using Pneumatics

Author: V. Priya, Dhanasekar. J M. Chandra Mohan

The main objective of this work is to design and fabricate a pneumatic two-step control system for a double-acting cylinder. The work involves developing an automatic cylinder reciprocation circuit using pneumatic components to achieve continuous operation for various industrial applications, particularly in material handling. The circuit consists of a push-button-operated 5/2 pilot-actuated DC valve, flow control valves, a shuttle valve, a cam-operated push button, a double-acting cylinder, an FRL unit, and a compressor. This automated reciprocating system is especially useful in industries where materials need to be moved or repositioned continuously, offering a reliable solution for handling loads that cannot be managed manually by workers.

4. Design Simulation and Development of Sequential Pneumatic Circuit for Industrial Applications

Author: Muhammed Ishack V, Ahammed Adil P, Amal P K, Rohith V T, Jibi R

This project work consists design simulation and development of cascade pneumatic sequential circuit. Main aim of work is design simulate and development of pneumatic cascade sequential circuit A+B+B-A-configuration. Pneumatic diagram describes the relation between each pneumatic components as per equipment of pneumatic system. Most of the practical pneumatic systems involve the use of multiple actuators (cylinders, semi-rotary actuators, etc.) which when operating in specified sequences carry out the desired control tasks. In multicylinder applications A+B+B-A- has wide applications. Sheet metal operation in a press shop, a stamping operation is to be performed using a stamping machine. The work piece has to be first clamped under the stamping station. Then the stamping tool gets in to position and performs the stamping operation. The work piece must be unclamped only after the operation is completed. The cascade system provides a straightforward method of designing sequential circuits. It will always give a workable circuit.

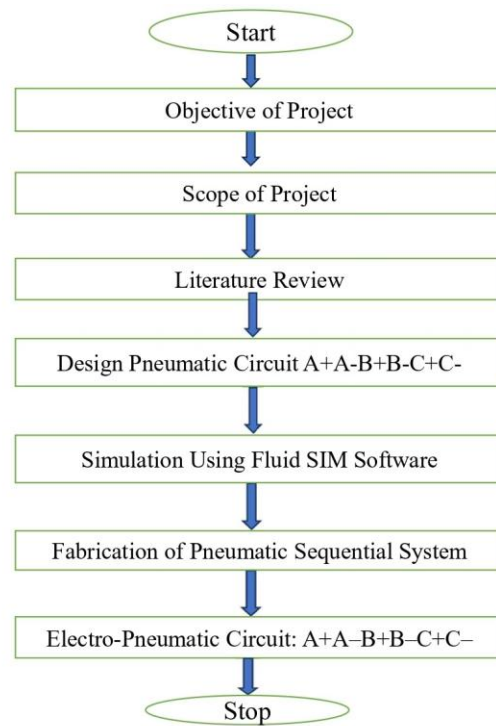


Fig 1: Project Methodology

5. Multi Operational Pneumatic Machine for Sheet Metal

Author: Chetan Baseganni, Syed Suhel, Mallikarjun Gundur

Sheet metal operations are traditionally carried out either manually or using hydraulic actuators. The main objective of this work is to perform shearing, bending, piercing, and embossing operations on sheet metal using a single pneumatic cylinder. In this project, a die model has been developed that integrates the capabilities for punching, piercing, embossing, and bending within a single unit. All these operations can be executed on one machine, controlled efficiently through a pneumatic system, making the process simpler, faster, and more cost-effective.

3 METHODOLOGIES

Methodology is one of the most critical elements to be considered to make sure the fluent of the project and get expected result. In other words, the methodology can be described as framework where it contains the elements of the work based on the objectives and a scope of the project. A good framework can get the overall view of the project and get the data easily. This included literature study, Design of pneumatic circuit A+A-B+B-C+C- simulation using Fluid SIM software, fabrication of pneumatic sequential system and simulation of electro pneumatic system.

4. WORK DONE

The objective is to design, simulate, and develop a pneumatic circuit for a multiple-actuator sequential system. Manual stamping processes are time-consuming, inconsistent, and prone to human error. Need to develop an automated stamping system that ensures precise, repeatable, and sequential operation of multiple actuators. The proposed system should allow a workpiece to be manually positioned in a fixture and, upon activation, enable multiple pneumatic cylinders to operate in a predefined sequence to perform stamping operations.

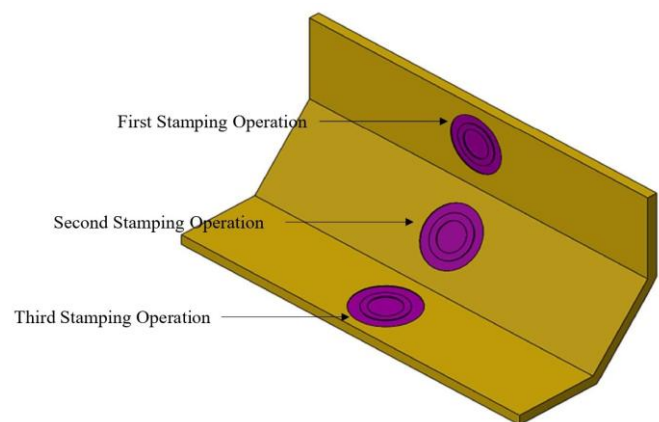


Fig 2: Sheet Metal Component

Conceptual Design of Stamping Fixture

The conceptual design of the stamping fixture shown below consists of a fixture base and fixture plates for holding and locating the workpiece, along with three pneumatic cylinders. The sheet metal is manually placed in the fixture for operation.

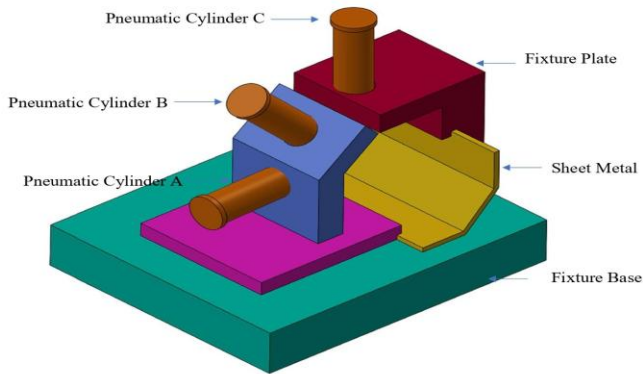


Fig 3: Stamping Fixture

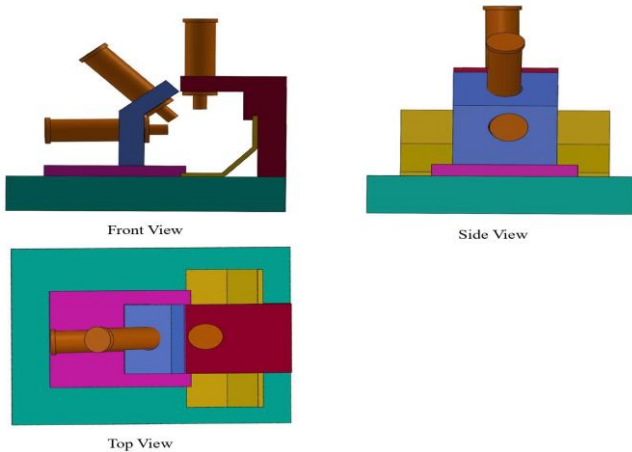


Fig. 4: Orthographic View of Stamping Fixture

Positional Diagram

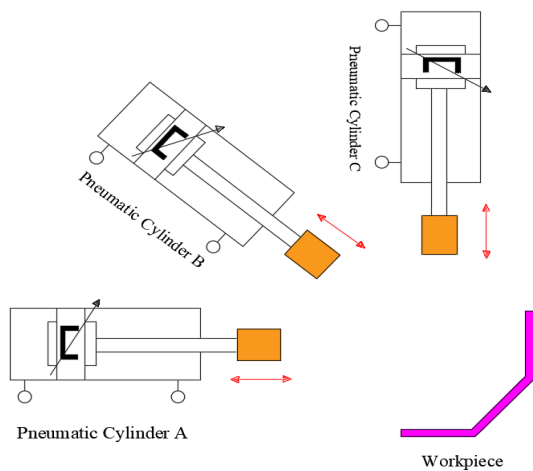


Fig. 5: Positional Diagram

First Stamping Operation

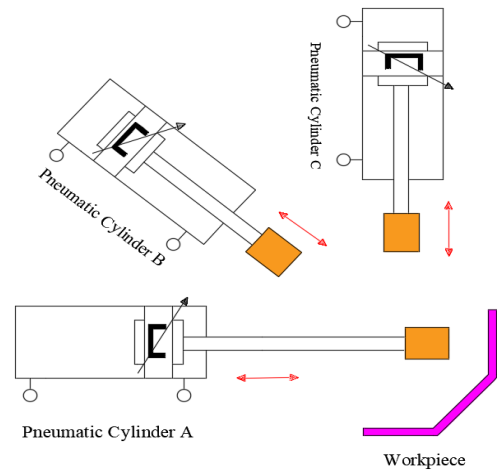


Fig 6: First Stamping Operation

Second Stamping Operation

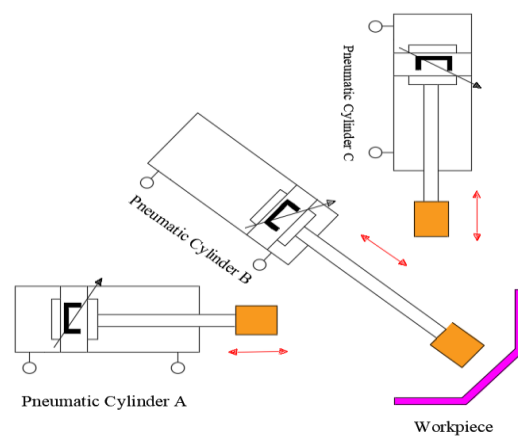


Fig. 7 Second Stamping Operation

Third Stamping Operation

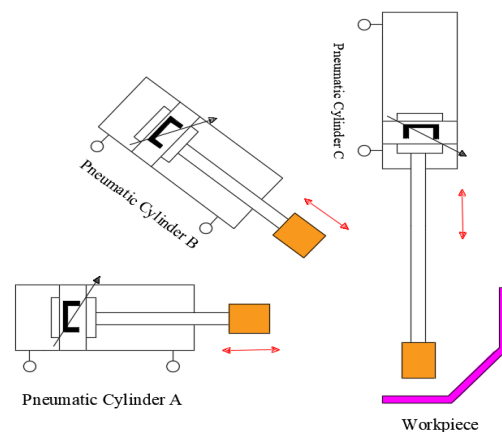


Fig. 8 Third Stamping Operation

Flow Chart for Pneumatic Circuit Design

The block diagram illustrates the systematic procedure for designing and analyzing a pneumatic circuit. The process begins with drawing the positional layout and representing the control task using appropriate notations. A displacement or step/time diagram is then prepared to define the sequence of operations. Based on this, the pneumatic circuit is analyzed and drawn, followed by the development of the power and control circuits. The input and output signals are analyzed and linked to ensure proper coordination. Finally, the overall pneumatic circuit is analyzed to verify correct operation before completion.

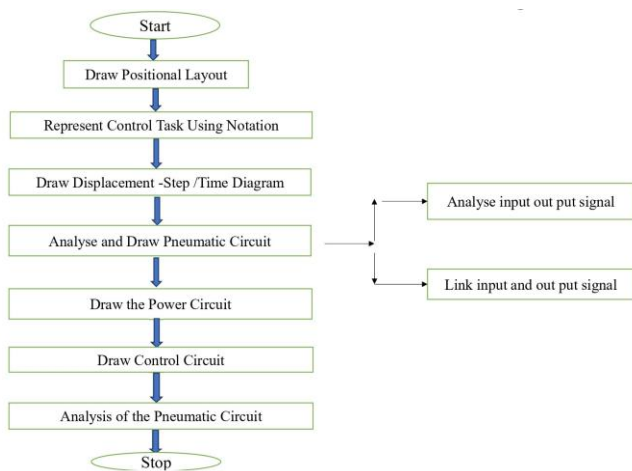


Fig. 9 Pneumatic Circuit Design

Step 1: Positional Layout

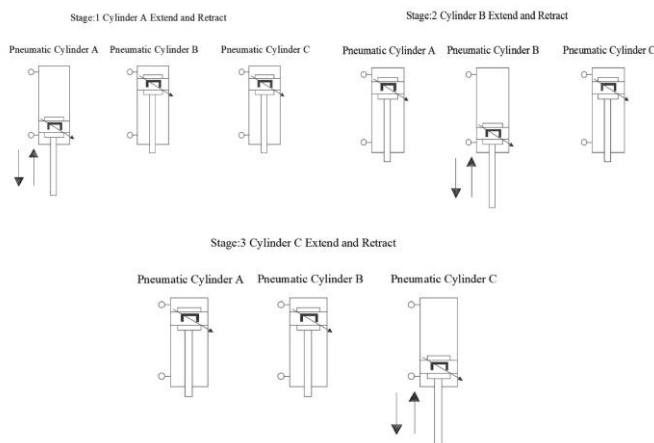


Fig 10: Positional Layout

Step 2: Represent Control Task Using Notation

Cylinder A advancing is designated as A+
 Cylinder A retracting is designated as A-
 Cylinder B advancing is designated as B+
 Cylinder B retracting is designated as B-
 Cylinder C advancing is designated as C+
 Cylinder C retracting is designated as C-

The sequencing of pneumatic cylinder is A+A-B+B-C+C-

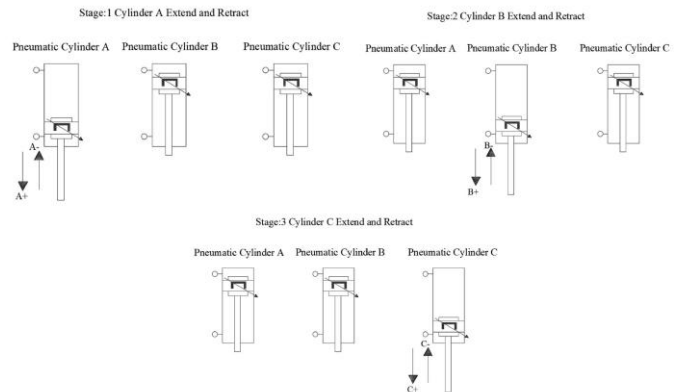


Fig 11: Positional Layout with Notation

Step 3: Displacement -Step Diagram

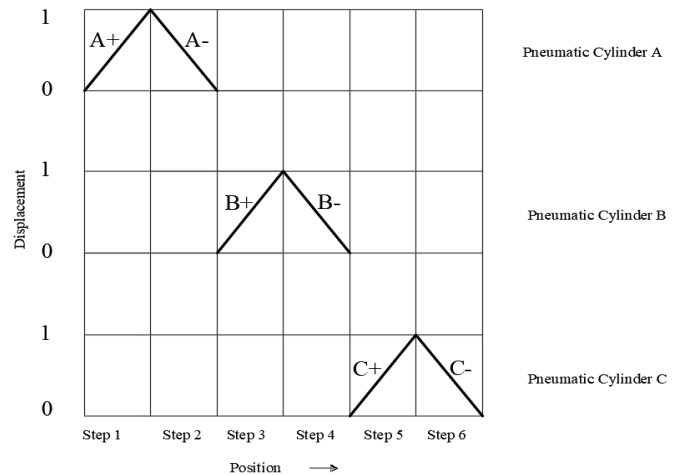


Fig 12: Displacement -Step Diagram

Step 4: Displacement -Time Diagram

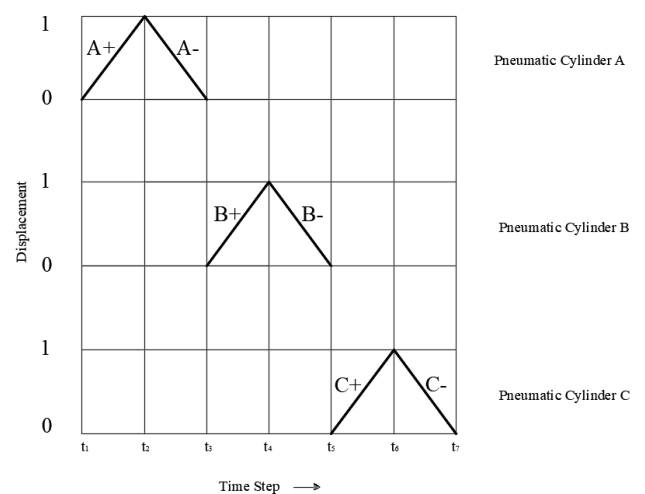


Fig 13: Displacement -Time Diagram

Step 5: Analyse and Draw the Pneumatic Circuit

Step 5.1 Analyse input and Output Signal

Input Signals

- Cylinder A: Limit switch at home position a0
Limit switch at home position a1
- Cylinder B: Limit switch at home position b0
Limit switch at home position b1
- Cylinder C: Limit switch at home position c0
Limit switch at home position c1

Output Signal

- Forward motion of cylinder A(A+)
- Return motion of cylinder A(A-)
- Forward motion of cylinder B(B+)
- Return motion of cylinder B(B-)
- Forward motion of cylinder B(C+)
- Return motion of cylinder B(C-)

Step 5.2 Displacement Step diagram linked to input output signal

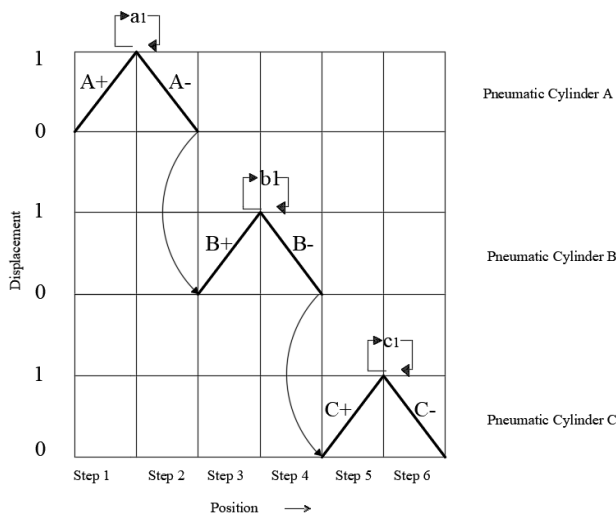


Fig 14: Displacement Step diagram linked to input output signal

The start signal is required along with a0 signal for movement A+
 A+ generate sensor signal a1, which is used for group changing
 A- generate sensor signal a0, which is used for the B+ operation
 B+ generate sensor signal b1, which is used for group changing
 B- generate sensor signal b0, which is used for the C+ operation
 C+ generate sensor signal c1, which is used for group changing
 C- generate sensor signal c0, which is used for the C+ operation and the push button signal.

Step 6: Pneumatic Cascade Circuit A+A-B+B-C+C-

Operating Sequence =A+A-B+B-C+C-

No of groups =4

- Group 1: A+
- Group 2: A-B+
- Group 3: B-C+
- Group 4: C-

No of pressure line=No of group =4

Selection of valve

No of pioret operated 5/2 valve=No of cylinders =3

No of limit valve=No of cylinderx2=3x2=6

No of group changing valve = No of group -1=4-1=3

Components of Pneumatic Sequential System

Table 1: Components of Pneumatic Sequential System

SI No	Components	Nos
1	3/2 Push Button Spring Valve	1
3	5/2 Double Piolet Valve	6
4	3/2 Roller Spring Valve	6
5	Pneumatic Double Acting Cylinder	3
6	Flow Control Valve	6

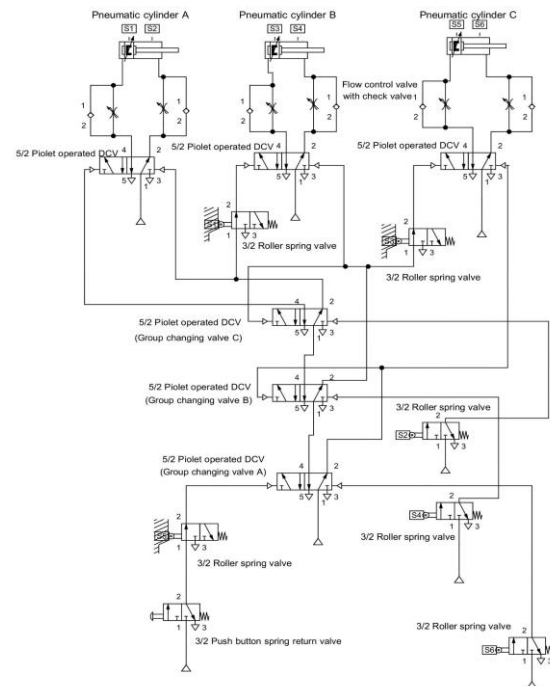


Fig 15: Pneumatic Circuit A+A-B+B-C+C-

First Cycle A+ Group 1 Selected

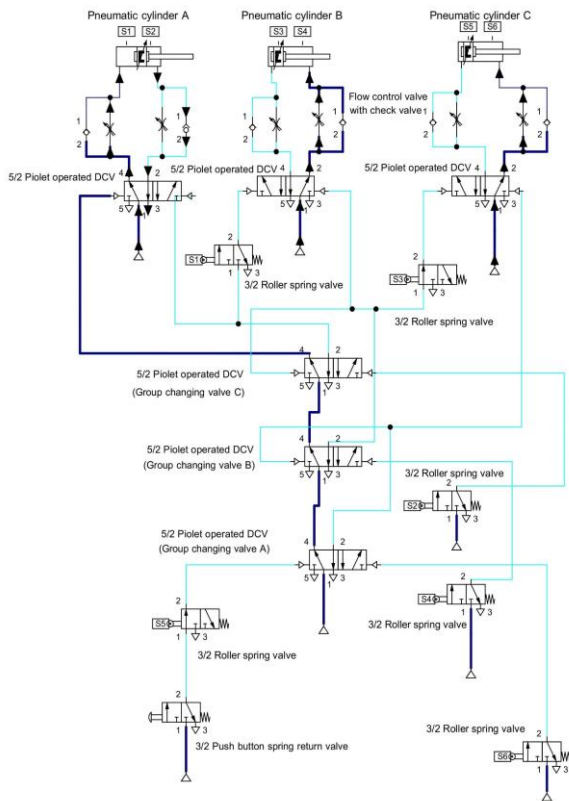


Fig 16: Pneumatic Circuit A+

Second Cycle A-B+ Group 2 Selected

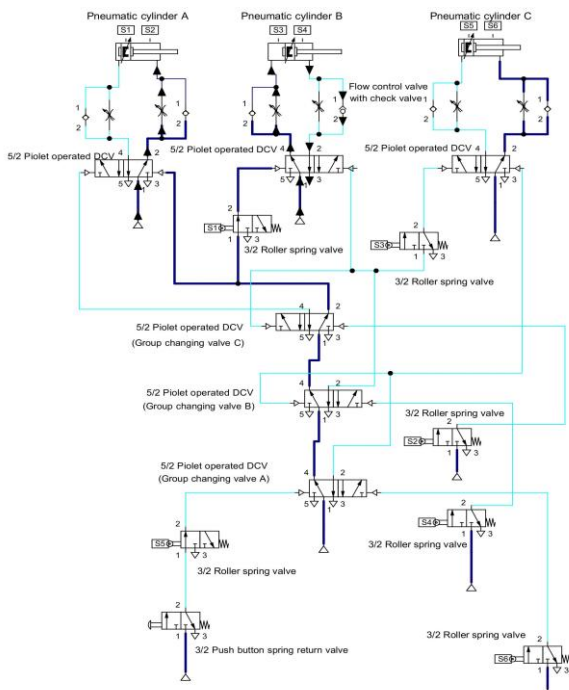


Fig 17: Pneumatic Circuit A-B+

Third Cycle B-C+ Group 3 Selected

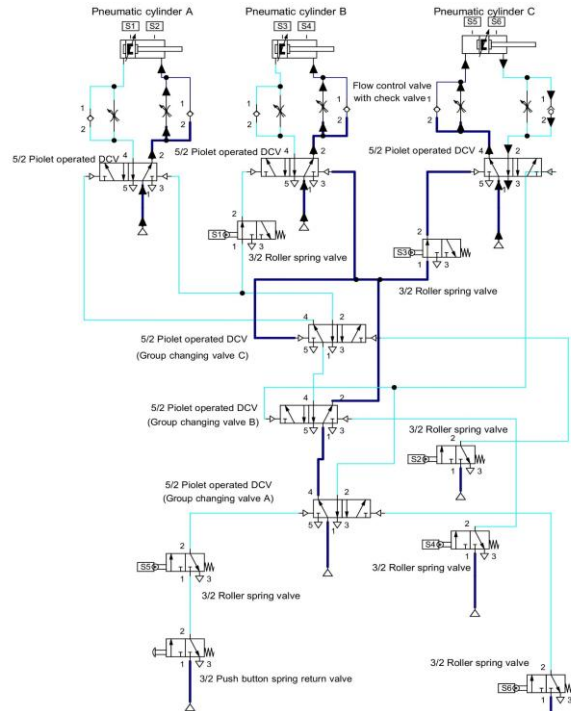


Fig 18: Pneumatic Circuit B-C+

Fourth Cycle C- Group 4 Selected

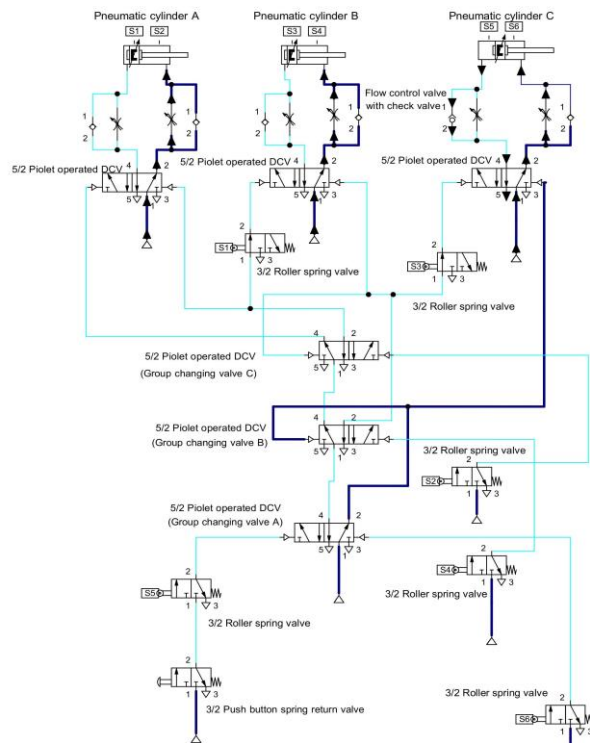


Fig 19: Pneumatic Circuit C-

Group Changing Valve

For group changing in pneumatic circuit, 5/2 double pilot valve is used.

Group changing valve (Selecting group 1)

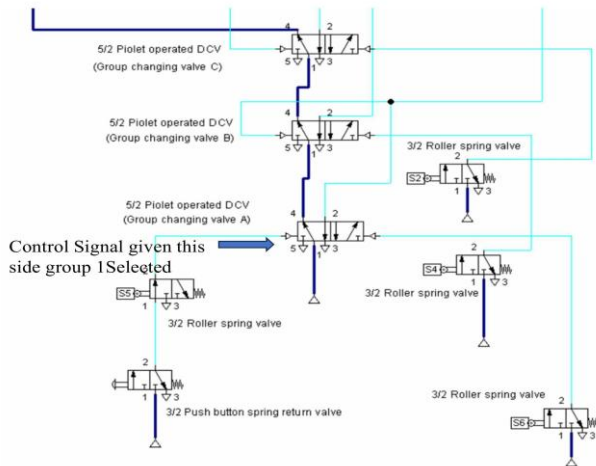


Fig. 20: Group 1 – Changing Valve

When the 3/2 Push Button Spring Return Valve is pressed, it generates a pilot signal that acts on the left side of the 5/2 Pilot operated directional control valve (Group Changing Valve A). This causes the valve to shift position, thereby activating Group 1. The valve directs pressure to produce the required control signal for extending Pneumatic Cylinder A.

Group changing valve (Selecting group 2)

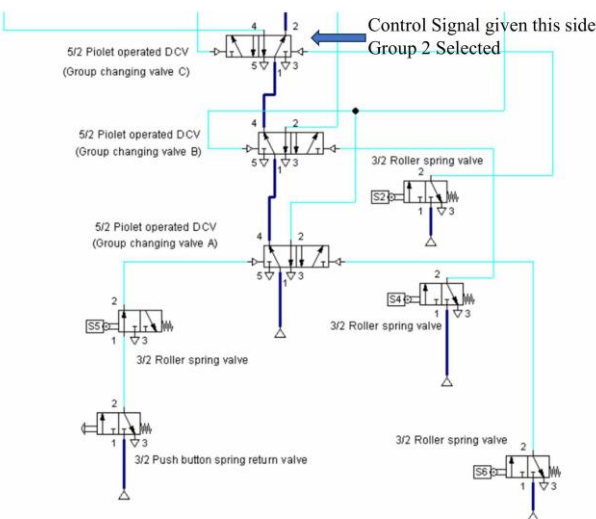


Fig. 21: Group 2 – Changing Valve

When Cylinder A extends, it actuates the limit switch S2, which sends a pilot signal to the right side of Group Changing Valve C, shifting it to activate Group 2. As Cylinder A retracts, Sensor S1 is actuated during the A- movement, allowing air to pass through S1 and causing Cylinder B to extend.

Group changing valve (Selecting group 3)

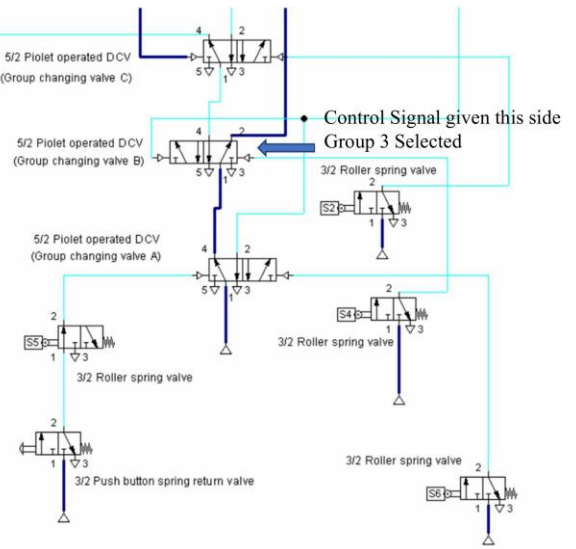


Fig. 22: Group 3 – Changing Valve

As Sensor S4 is actuated during the extension of Cylinder B, it sends a pilot signal to the right side of Group Changing Valve B, shifting it to activate Group 3 and initiating the automatic retraction of Cylinder B. Subsequently, when Sensor S3 is actuated due to the retraction of Cylinder B, it produces a control signal that triggers the extension of Cylinder C automatically.

Group changing valve (Selecting group 4)

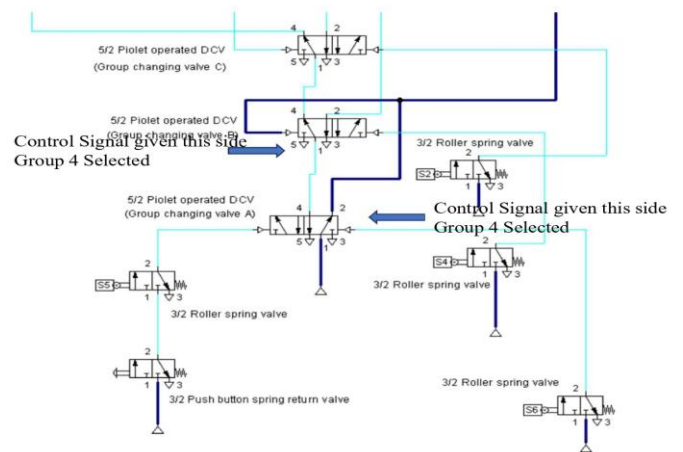


Fig. 23: Group 4 – Changing Valve

As Sensor S6 is actuated during the extension of Cylinder C, it sends a pilot signal to the right side of Group Changing Valve 1, activating Group 4 and initiating the retraction of Cylinder C. Subsequently, Sensor S5 is actuated as a result of the retraction of Cylinder C.

Power Circuit –Pneumatic Cylinder

5/2 Double Piolet valve used for actuating double acting cylinder. Flow control valve used to control flow of compressed air in to cylinder.

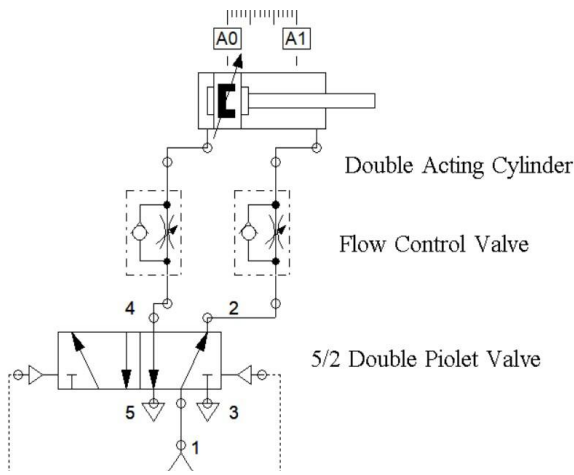


Fig 24: Power circuit 5/2 Double Piolet operated DCV

Operating Modes of Pneumatic Circuit

Manual operating mode: In the manual operating mode, pressing the push button initiates one complete cycle during which all three pneumatic cylinders extend and retract. To start the next cycle, the push button must be pressed again.

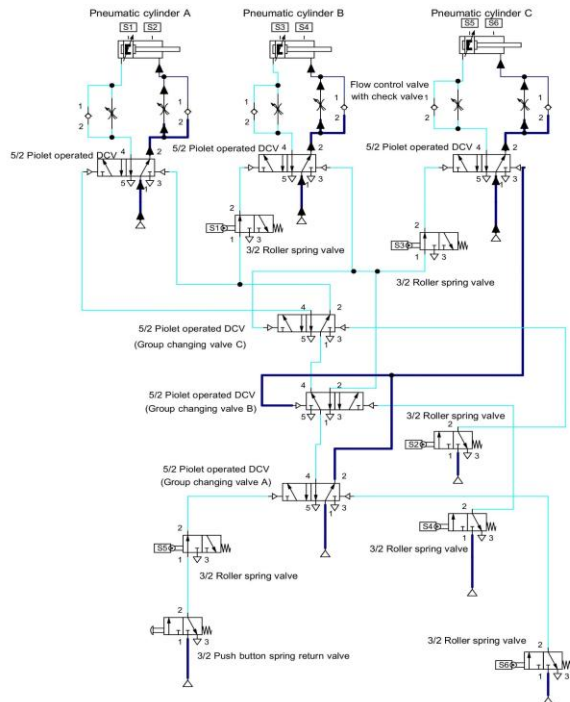


Fig 25: Manual Operating Mode

Continuous operating mode: In the continuous operating mode, once the pneumatic circuit is activated, the cycle repeats continuously without any interruption or delay.

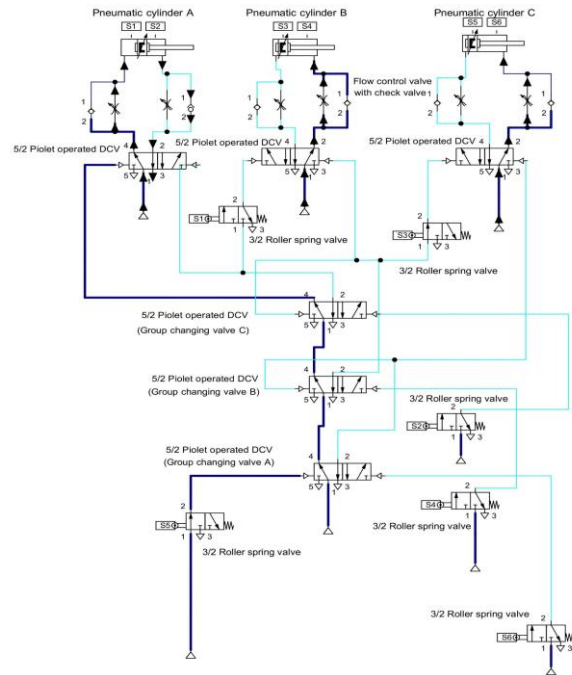


Fig 26: Continuous Operating Mode

Time-delay operating mode: In the time-delay operating mode, the pneumatic circuit operates with a delay between each cycle, allowing the next sequence to start automatically after the interval.

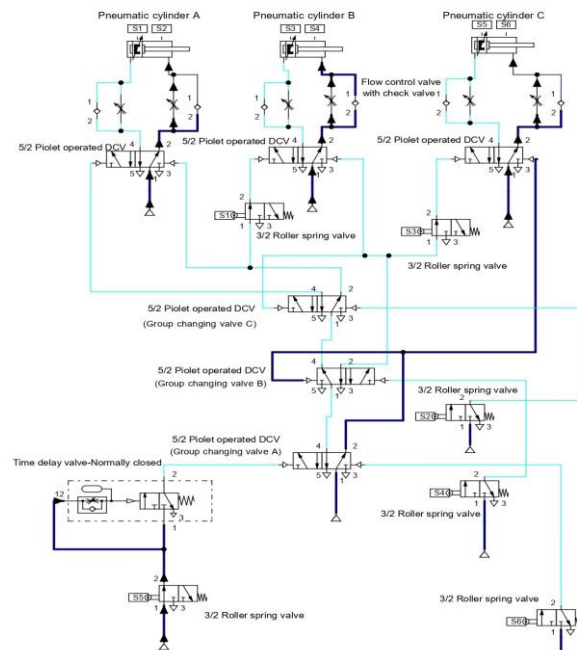


Fig 27: Time delay Operating Mode

Development of A+A-B+B-C+C- Circuit



Fig 28: Assembly of Model

Cost Analysis

Table 2: Components Cost

Sl No	Item	Unit/Cost	Total No	Cost/RS
1	Techno -DA Pneumatic Cylinder SC 50X100	1020	3	3060
2	Techno-Flow control valve 1/4x6	70	6	420
3	Techno-Dou. Piolet valve 4A-220-08	520	6	3120
4	Techno-3/2 Roller Spring Valve	430	6	2580
5	Techno-1/4 FRL Unit	1060	1	1060
6	3/2 way -1/8 pushbutton actuator	450	1	450
7	Silencer -1/8 inch	15	12	180
8	Silencer -1/4 inch	28	6	168
9	Straight connector 1/4x6	13	30	390
10	Straight connector 1/8x6	13	15	195

11	Straight connector 1/4x8	40	2	80
12	6mm Tee connector	27	10	270
13	6mm 4way distributor	62	1	62
14	8mm Od Tubing	18 per Meter	15 Meter	270
15	6mm Od Tubing	16.5 per Meter	20 Meter	330
16	Tee connector 8mm Od Tubing	26	2	52
17	Miscellaneous Expense			1250
Total Cost				13937

Electro-Pneumatic Circuit: A+A-B+B-C+C- Sequence

The electro-pneumatic circuit consists of two main parts the pneumatic part and the electrical part. The pneumatic section includes three double-acting cylinders, three 5/2 double solenoid valves, and a source of compressed air. The electro-pneumatic cascade circuit is divided into four groups, represented by relays K1, K2, K3, and K4, each assigned to a specific sequence of operations. Relay K1 controls the A+ movement, relay K2 controls the A-B+ movement, relay K3 controls the B-C+ movement, and relay K4 controls the C- movement. Group 1 is active when relay K1 is energized, group 2 is active when relay K2 is energized, group 3 is active when relay K3 is activated and group 4 is active when relay K4 is activated.

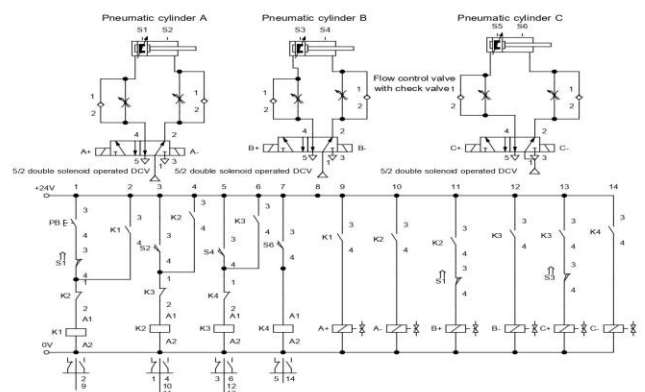


Fig 29: Electro Pneumatic Circuit

Electro-Pneumatic Circuit: A+ (Relay 1 ON)

The sequence begins when the push button PB is pressed, energizing relay K1 to activate solenoid A+ extending Cylinder A

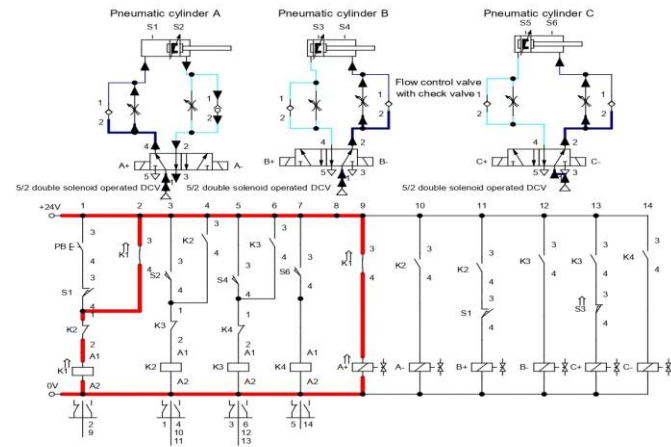


Fig 30: Electro Pneumatic Circuit A+

Electro-Pneumatic Circuit: A-B+ (Relay 2 ON)

When limit switch S2 is actuated, relay K2 is energized, causing Cylinder A to retract and Cylinder B to extend.

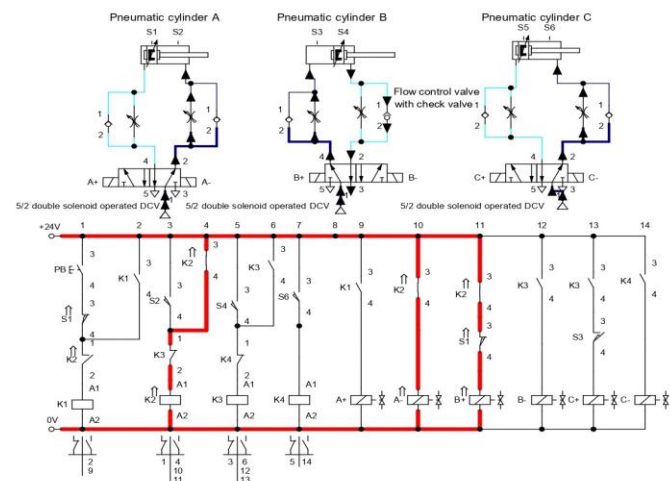


Fig 31: Electro Pneumatic Circuit A-B+

Electro-Pneumatic Circuit: B-C+ (Relay 3 ON)

The actuation of S4 energizes relay K3, resulting in the retraction of Cylinder B and the extension of Cylinder C.

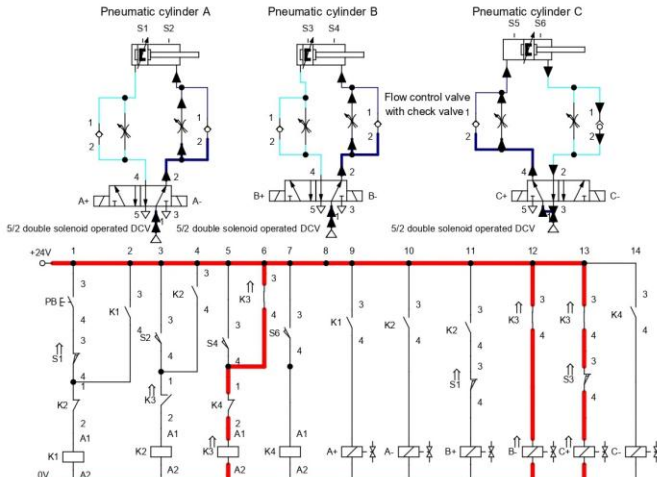
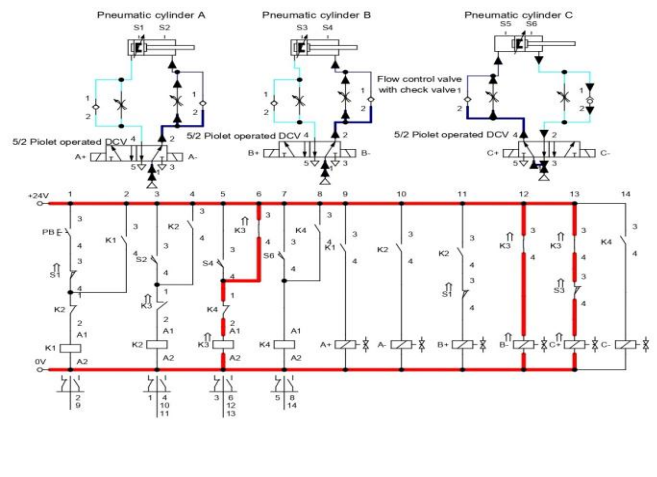
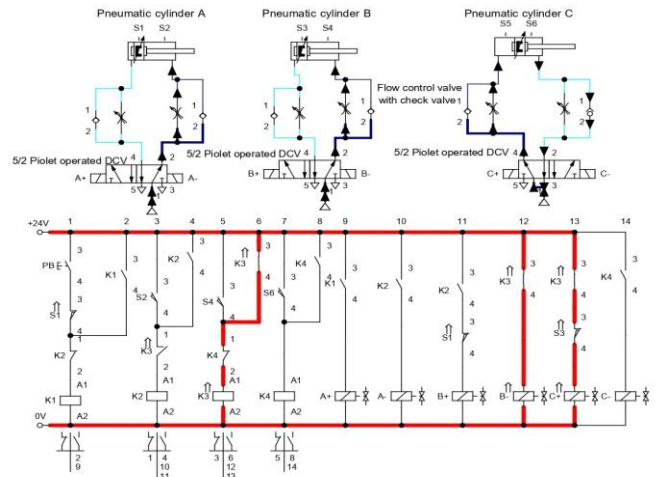


Fig 32: Electro Pneumatic Circuit B-C+

Electro-Pneumatic Circuit: C- (Relay 4 ON)

When S6 is actuated, relay K4 energizes to retract Cylinder C completing the sequence.

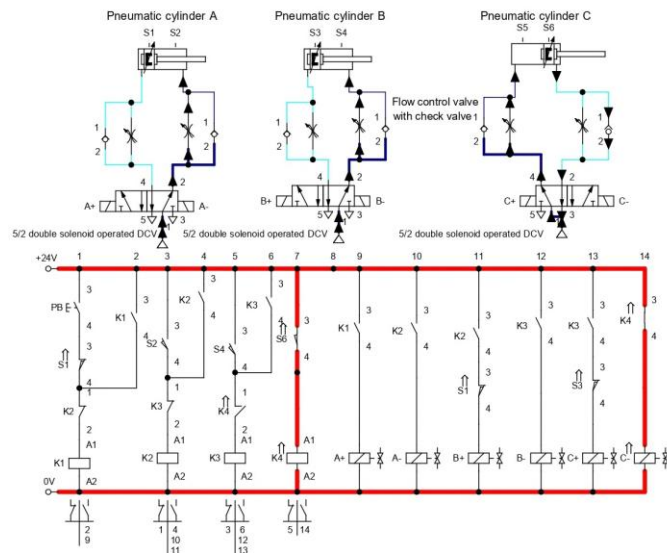


Fig 33: Electro Pneumatic Circuit C-

PLC Ladder Diagram-A+A-B+B-C+C-

When the push button PB1 is pressed, relay R1 is energized and latched. This initiates the automatic sequence. Relay R1 energizes the solenoid A+, causing Cylinder A to extend. When Cylinder A reaches its forward end, limit switch S2 is actuated. Actuation of S2 energizes relay R2, which in turn activates solenoid A-, retracting Cylinder A. On full retraction, limit switch S1 is actuated. Actuation of S1 energizes relay R3, switching solenoid B+ ON and extending Cylinder B. At full extension, limit switch S4 is actuated. Limit switch S4 energizes relay R4, which activates solenoid B-, retracting Cylinder B. On full retraction, limit switch S3 is actuated. Actuation of S3 energizes relay R5, switching ON solenoid C+, extending Cylinder C. When fully extended, limit switch S6 is actuated. Limit switch S6 energizes relay R6, which activates solenoid C-, retracting Cylinder C and completing the cycle.

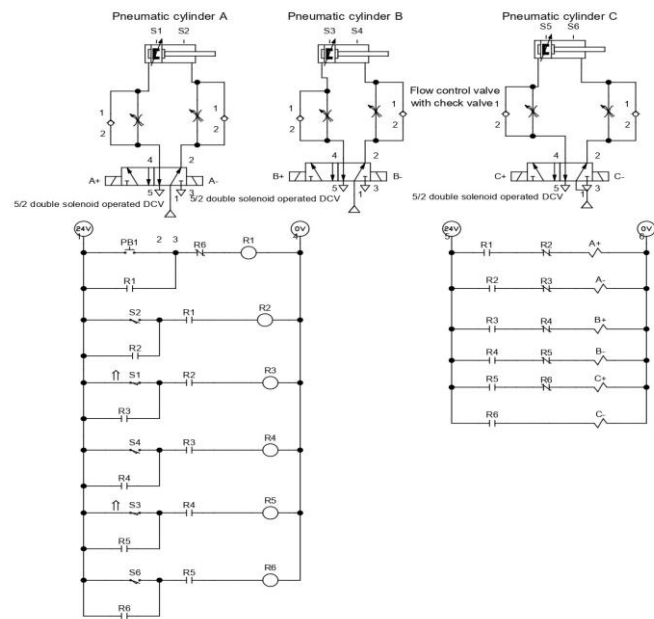


Fig 34: PLC Ladder Diagram-A+A-B+B-C+C-

6. CONCLUSION

Such systems are widely used in automated manufacturing, material handling, and sheet metal operations, where synchronization of multiple pneumatic actuators is essential for achieving consistent performance and productivity

7. FUTURE WORK

The development of an Electro-Pneumatic Circuit with the sequence A+ A- B+ B- C+ C- is proposed. This system aims to automate the sequential operation of multiple cylinders using electrical control through sensors, relays, and solenoid valves. The integration of electrical components will enhance the accuracy, reliability, and flexibility of the pneumatic system. By implementing this electro-pneumatic sequence, the process can achieve improved synchronization, faster cycle times, and better control over each actuator's motion.

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