

## Lecture 40

### MULTI ACTUATOR CIRCUITS

#### Learning Objectives

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Upon completion of this chapter, Student should be able to

- ✚ Differentiate between single actuator and multi actuator circuit
- ✚ List the various methods available for pneumatic circuit design
- ✚ Explain the signal conflict in double piloted memory valve
- ✚ Draw motion and displacement diagram for multi cylinders
- ✚ List and explain various signal elimination methods
- ✚ Explain the working of idle roller valves and its use
- ✚ Design multi cylinder circuits using cascade method and step counter method

#### 1.1 SINGLE ACTUATOR CIRCUIT VERSUS MULTI ACTUATOR CIRCUITS

In the previous chapter, we have learnt about the various means and ways to control a single actuator circuits, both for single acting and double acting cylinders. Implementation of logic gates along with use of pressure sequence valve and time delay was systematically presented.

Most of the practical pneumatic circuits use multi cylinders. They are operated in specific sequence to carry out the desired task. For example, to drill a wooden component first we need to clamp and then drill. We can only unclamp the cylinder, if and only if the drill is withdrawn away from the workpiece. Here sequencing of movement of clamp cylinders and cylinder which carries the drill is important. This sequencing is carried out by actuation of appropriate final control valves like directional control valves. The position of the cylinders is sensed by the sensors like limit switches, roller or cam operated valves.

Multi cylinder pneumatics circuits can be designed in various methods. There is no universal circuit design method that suits all types of circuits. Some methods are commonly used for compound circuits but would be too expensive for simple circuits. There are five common methods used by engineering and they are given below

- Classic method or Intuitive method
- Cascade method
- Step counter method
- Karnaugh–veitch method
- Combinational circuit design

In this chapter Classic method, cascade method and step counter methods are discussed. Chapter 8 deals with Boolean algebra, KV mapping method and combinational circuit methods. Double piloted 4/2 and 5/2 directional control valves are susceptible to signal conflicts. Cascading and Step counter method are more systematic methods than intuitive methods. Signal conflict can be eliminated by using cascade and stepper counter method.

## **1.2 CLASSIC METHOD OR INTUITIVE METHOD**

In intuitive method, circuit design is done by use of general knowledge of pneumatics following the sequence through intuitively. In general, steps involves

- Write down sequence and draw motion diagrams
- Draw in cylinders and control valves
- Complete circuits intuitively.

### **1.2.1 Coordinated and sequential motion control.**

In majority of the pneumatic applications more than one cylinder is used. The movement of these cylinders are coordinated as per the required sequence. Sensors are used for confirming the cylinder position and the resultant actuation of the final control element. Normally limit switches are used. The activation of limit switches of different cylinders will provide set or reset signal to the final control valves for further controlling the movement of various cylinders. The limit switches have to be arranged in the proper location with the help of motion diagram

### **1.2.2 Demonstration of Classic method**

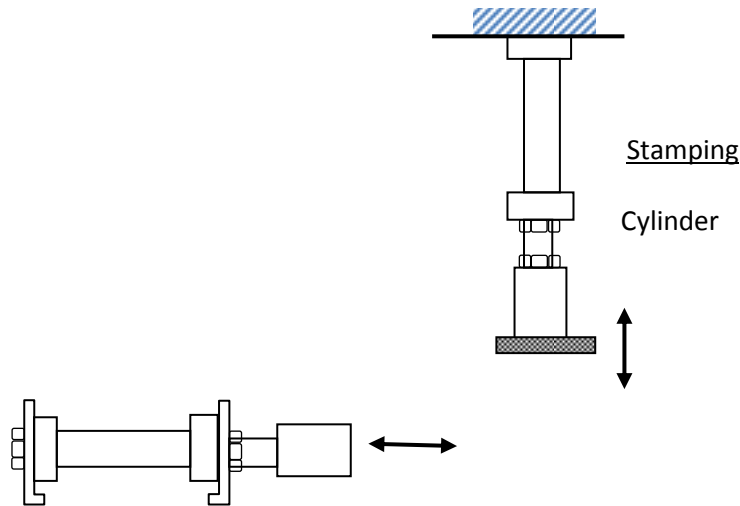
In order to develop control circuitry for multi cylinder applications, it is necessary to draw the motion diagram to understand the sequence of actuation of various signal input switches-limit switches and sensors. Motion diagram represents status of cylinder position -whether extended or retracted in a particular step

**Example 1 :** In a press shop, stamping operation to be performed using a stamping machine. Before stamping, workpiece has to be clamped under stamping station. Then stamping tool comes and performs stamping operation. Work piece must be unclamped only after stamping operation.

**Step 1: Write the statement of the problem:**

Let A be the clamping cylinder and B be the stamping cylinder as shown in the Figure xxx. First cylinder A extends and brings under stamping station where cylinder B is located. Cylinder B then extends and stamps the job. Cylinder A can return back only cylinder B has retracted fully.

**Step 2: Draw the positional layout. (Figure 1.1)**



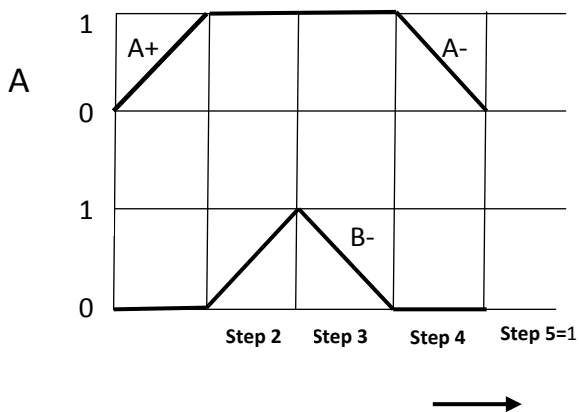
**Figure 1.1 Positional layout**

**Step3: Represent the control task using notational form**

- Cylinder A advancing step is designated as **A+**
- Cylinder A retracting step is designated as **A-**
- Cylinder B advancing step is designated as **B+**
- Cylinder B retracting step is designated as **B-**

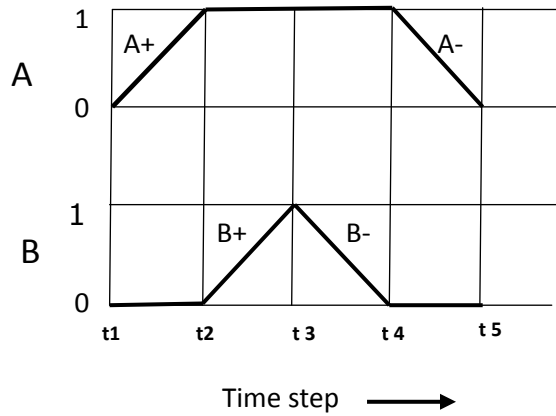
Therefore, given sequence for clamping and stamping is **A+B+B-A-**

**Step 4 Draw the Displacement –step diagram (Figure 1.2)**



**Figure 1.2 Displacement step diagram**

**Step 5 Draw the Displacement –time diagram (Figure 1.3)**



**Figure 1.3 Displacement time diagram**

**Step 6: Analyse and Draw Pneumatic circuit.**

**Step 6.1 Analyse input and output signals.**

### **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

### **Output Signal**

Forward motion of cylinder A ( A+)

Return motion of cylinder A (A-)

Forward motion of cylinder B( B+)

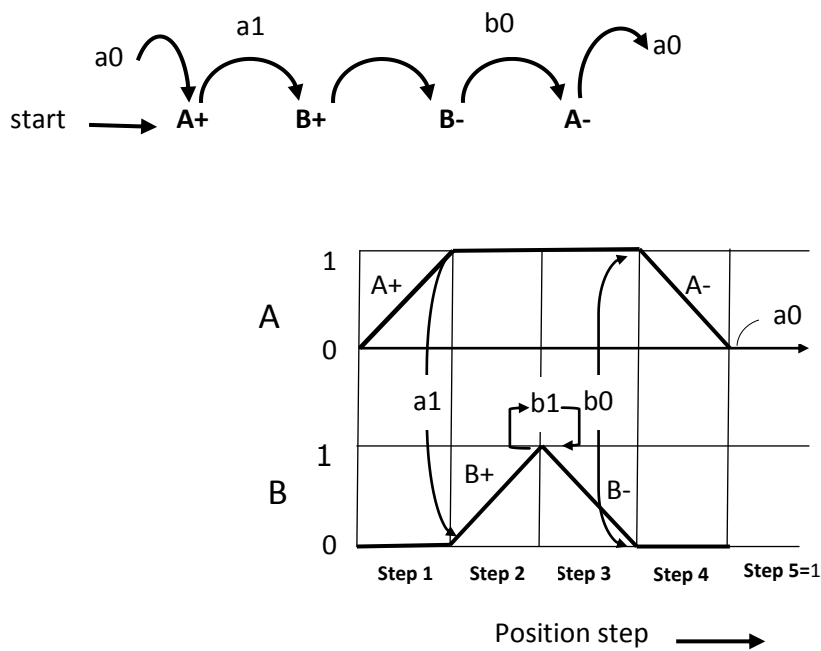
Return motion of cylinder B( B-)

**Step 6.2 Using the displacement time/step diagram link input signal and output signal.(Figure 1.4)**

Usually start signal is also required along with a0 signal for obtaining A+ motion.

1. A+ action generates sensor signal a1, which is used for B+ motion
2. B+ action generates sensor signal b1, which is used for B- motion
3. B- action generates sensor signal b0, which is used for A- motion
4. A- action generates sensor signal a0, which is used for A+ motion

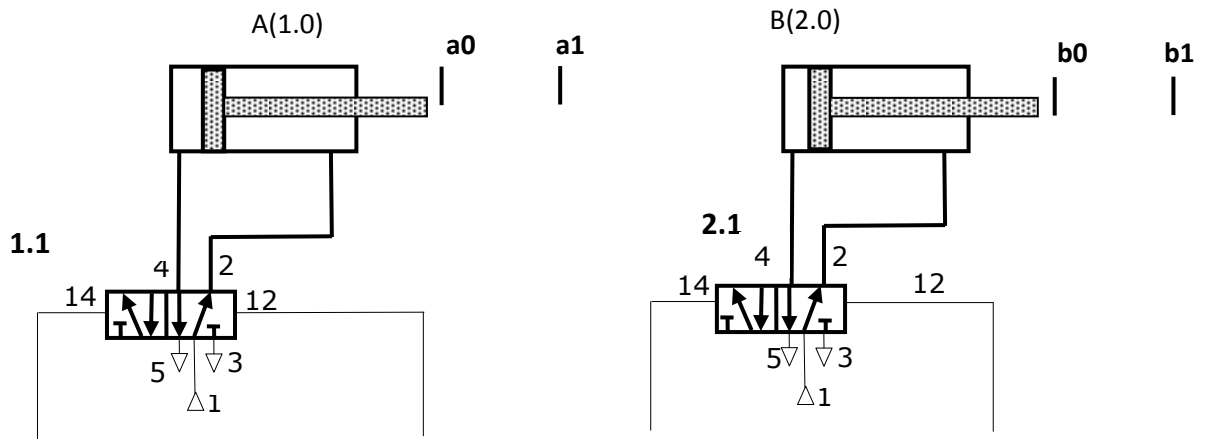
Above information (given in 6.2) is shown below graphically



**Figure 1.4 Input/output signal flow**

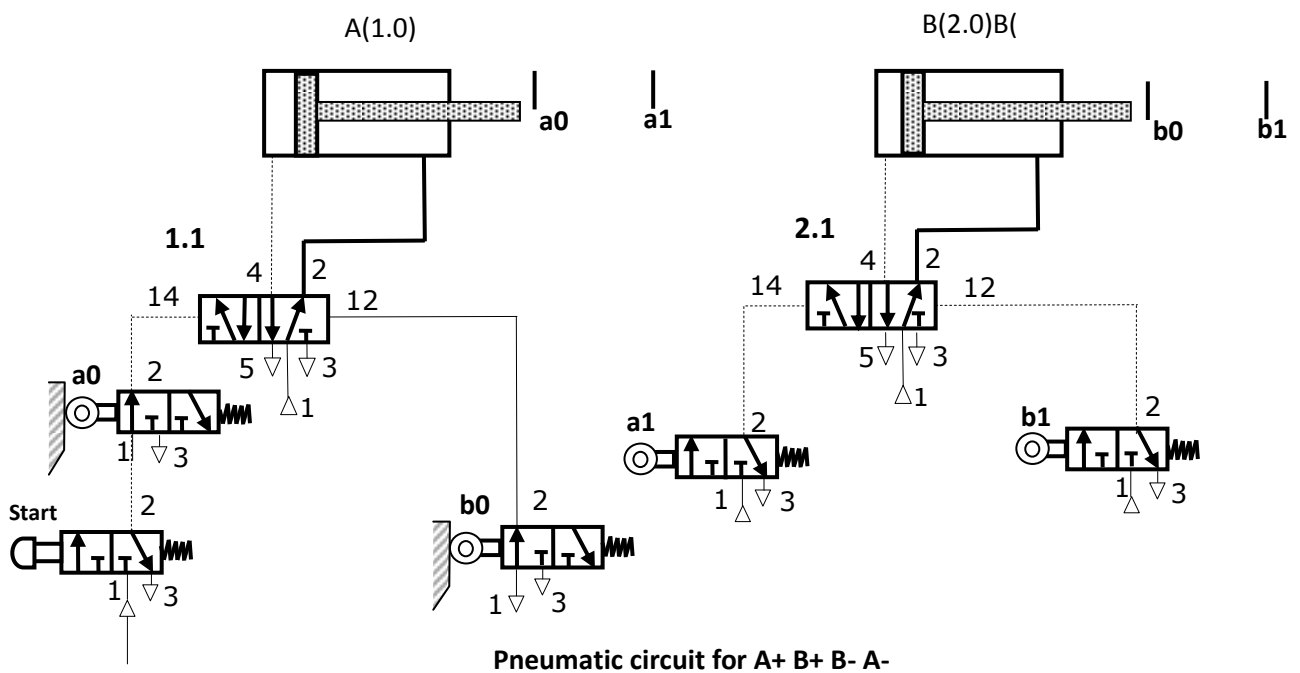
**Step 7 Draw the power circuit (Figure 1.5)**

- i) Draw the cylinders A(1.0) and B(2.0).
- ii) Draw the DCVs 1.1 and 2.1 in unactuated conditions
- iii) Mark the limit switch positions for cylinders A(1.0) and B(2.0).



**Figure 1.5 Power circuit diagram**

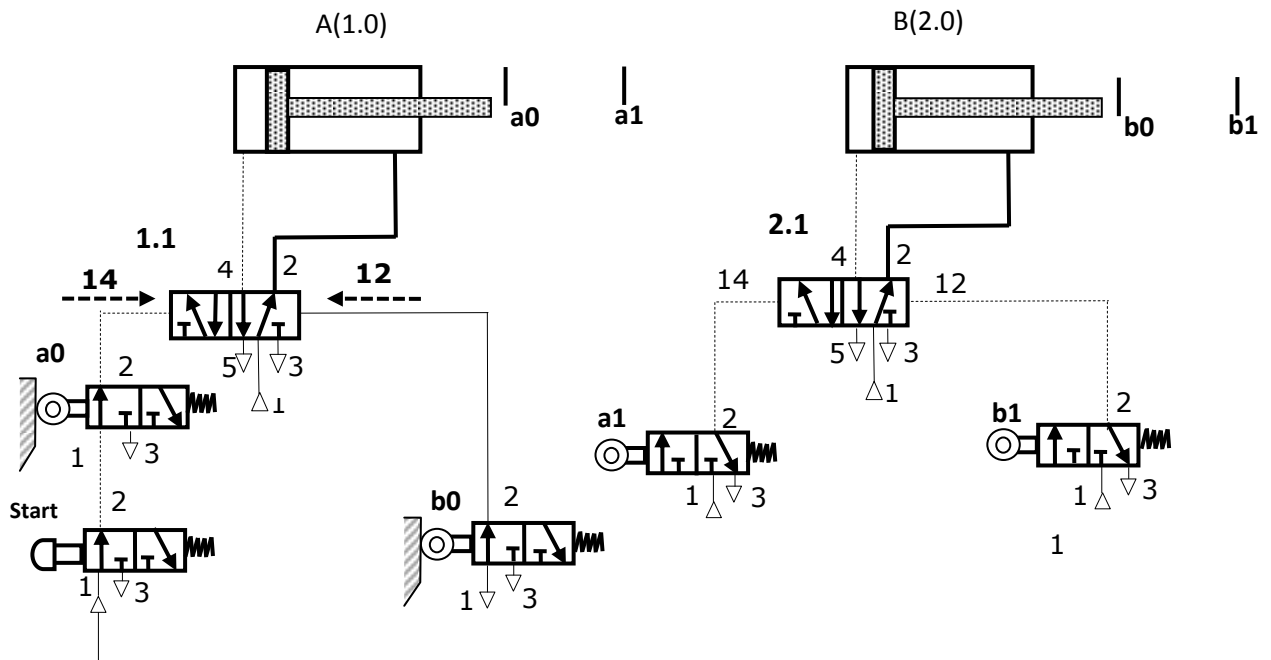
**Step 8 Draw the control circuit (Figure 1.6)**



**Figure 1.6 Control circuit diagram**

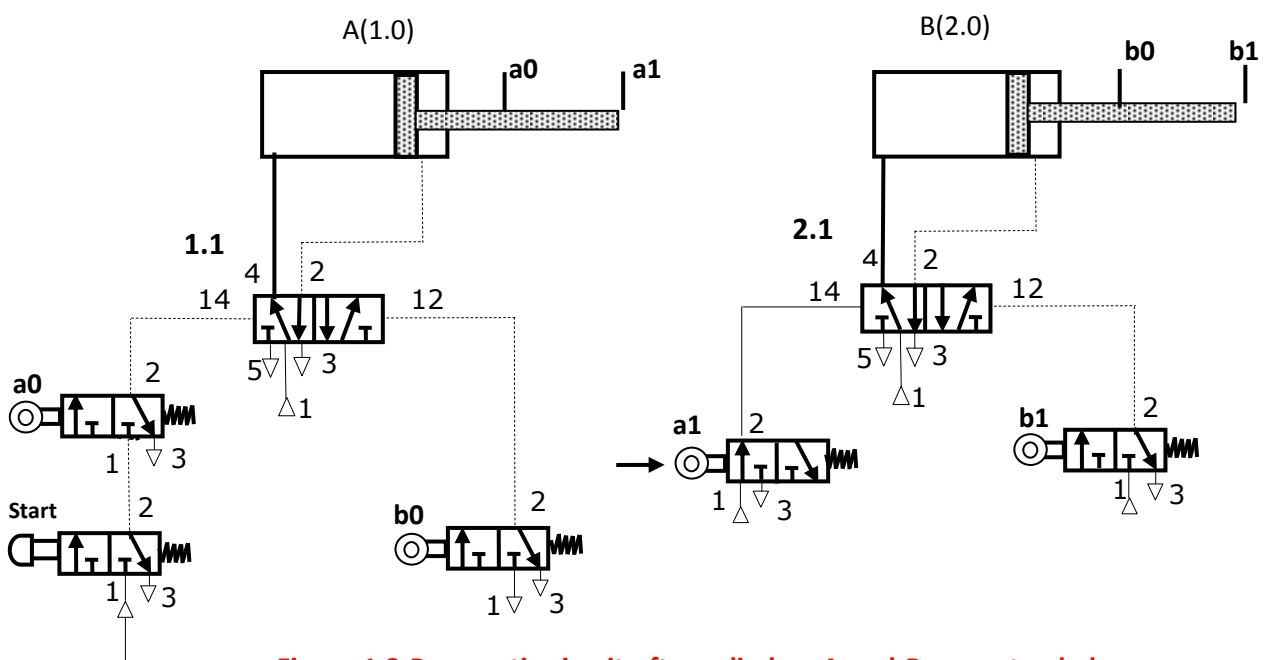
**Step 9 Analysis of pneumatic circuit**

1. When the start button is pressed, the signal appears at port 14 of valve 1.1 through limit switch signal a0.
2. Check for the presence of the signal at the other end (12) of valve 1.1. Notice that the signal is also present at port 12 of valve 1.1. (because b0 is also pressed). This results in signal conflict and valve 1.1 is unable to move.(Figure 1.7)



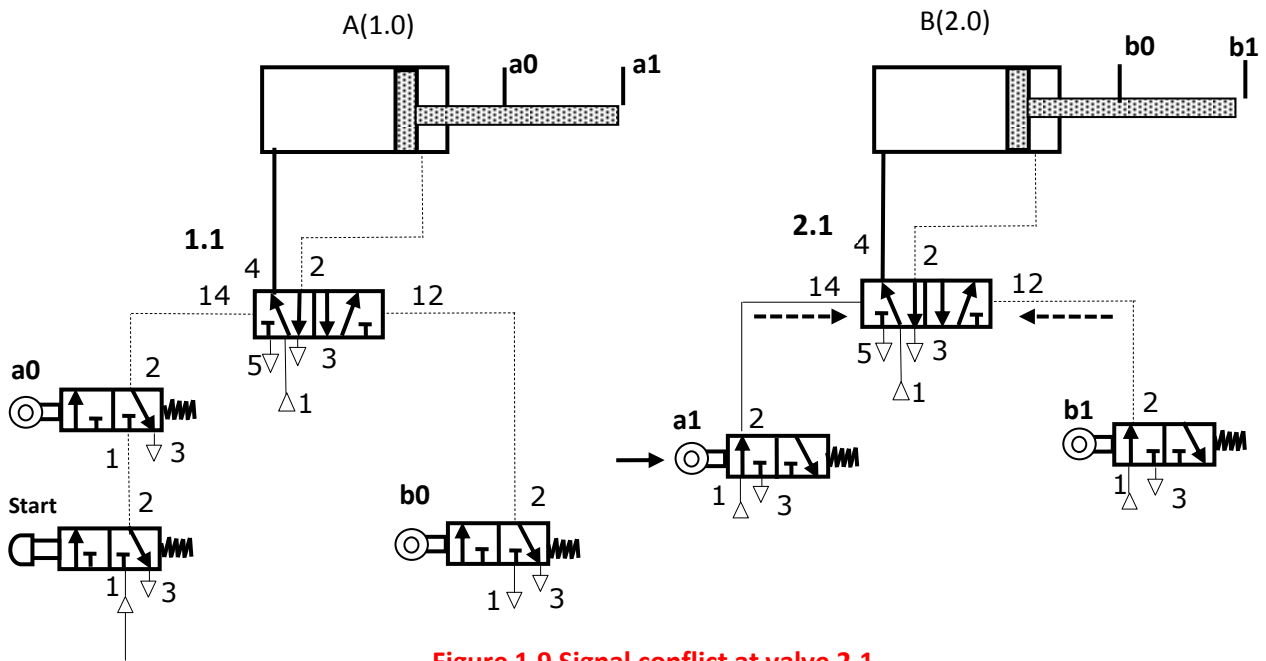
**Figure 1.7 Signal conflict at valve 1.1**

3. Let us assume for time being,  $b_0$  is somehow disengaged so that valve 1.1 can switch over and consequently cylinder A can extend. When the start button is pressed. (Figure 1.8)



**Figure 1.8 Pneumatic circuit after cylinders A and B are extended**

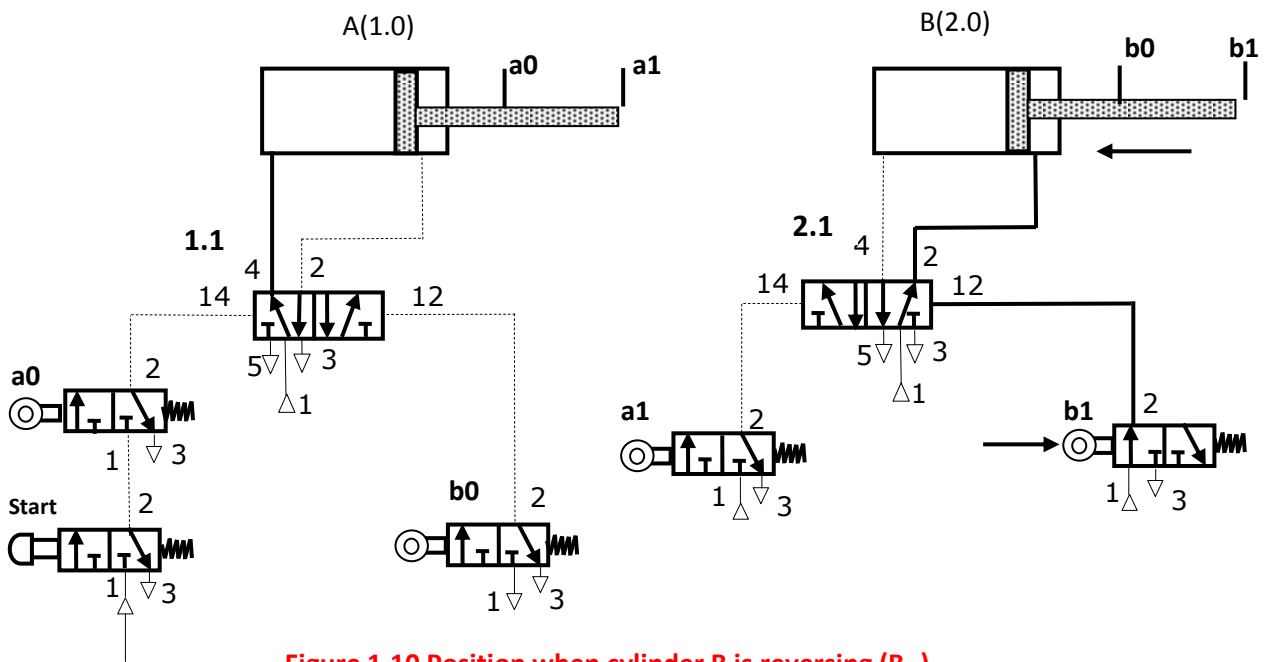
4. When cylinder A fully extends, it generates a limit switch signal a1, which is applied to port 14 of the valve 2.1.
5. Check for the presence of the signal at the other end (12) of valve 2.1. Signal is not present at port 12 of valve 2.1 and hence there is no signal conflict
6. Signal applied to port 14 of the valve 2.1 causes the shifting of DCV 2.1 and cylinder B extends.
7. When cylinder B fully extends, it generates a limit switch signal b1, which is applied to port 12 of valve 2.1
1. Check for the presence of the signal at the other end of 14 of valve 2.1. It can be seen that signal is also present at the port 14 of valve 2.1(because a1 is also pressed). This results in signal conflict and valve 2.1 is unable to move (Figure 1.9)



**Figure 1.9 Signal conflict at valve 2.1**

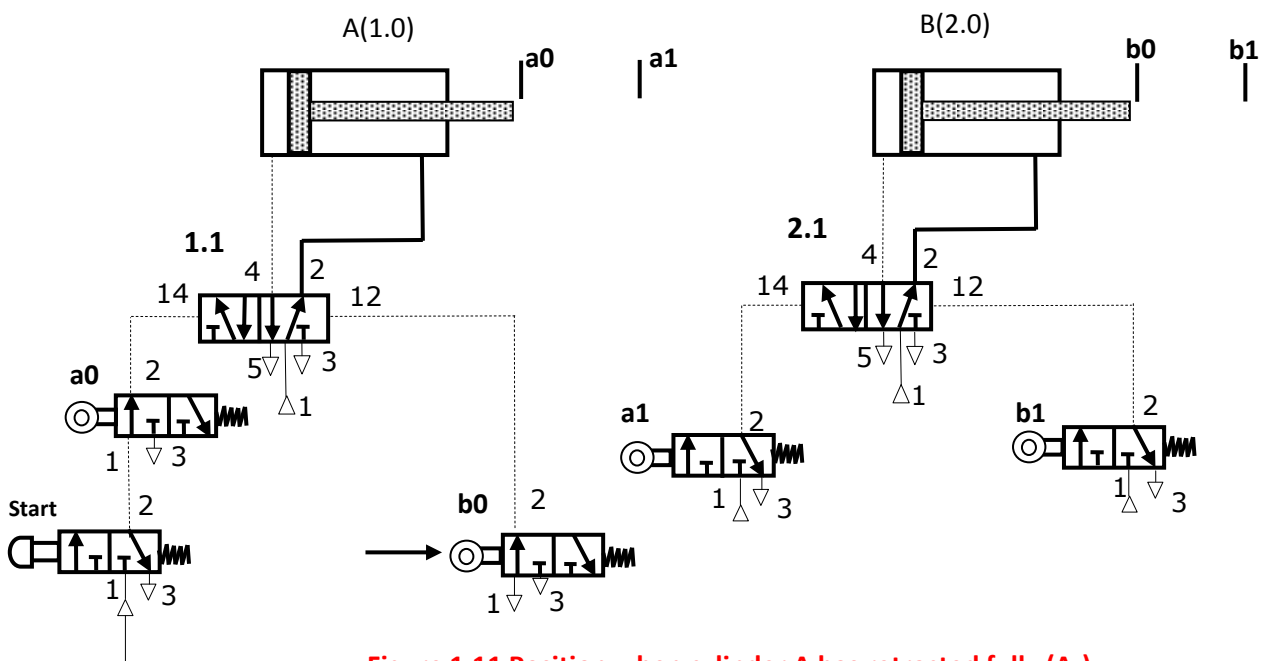
9. Let us assume for time being, b1 is somehow disengaged so that valve 2.1 can switch over and consequently cylinder B can retract.(Figure 1.10)





**Figure 1.10** Position when cylinder B is reversing (B -)

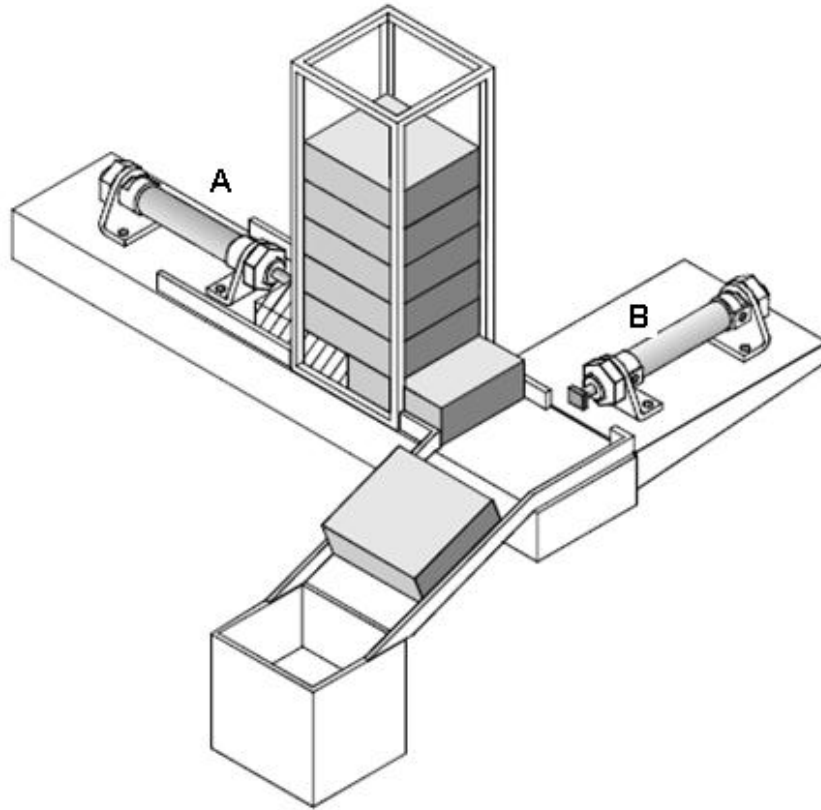
10. When the cylinder B is fully retracted, it generates a limit switch signal b0, which is applied to port 12 of the valve 1.1. (Figure 1.11)



**Figure 1.11** Position when cylinder A has retracted fully (A-)

11. Check for the signal at the other end 14 of the valve 1.1 Notice that signal is not present at port 14 of the valve 1.1 and hence there is no signal conflict. So valve 1.1 can switch over and Cylinder A can retract.

**Example 2 :** Two cylinders are used to transfer parts from a magazine onto a chute (Figure 1.12). When a push button is pressed, the first cylinder extends. Pushing the part from the magazine and positions it in preparation for transfer by the second cylinder onto the out feed chute. Once the part is transferred, the first cylinder retracts, followed by the second. Confirmation of all extended and retracted positions are required.

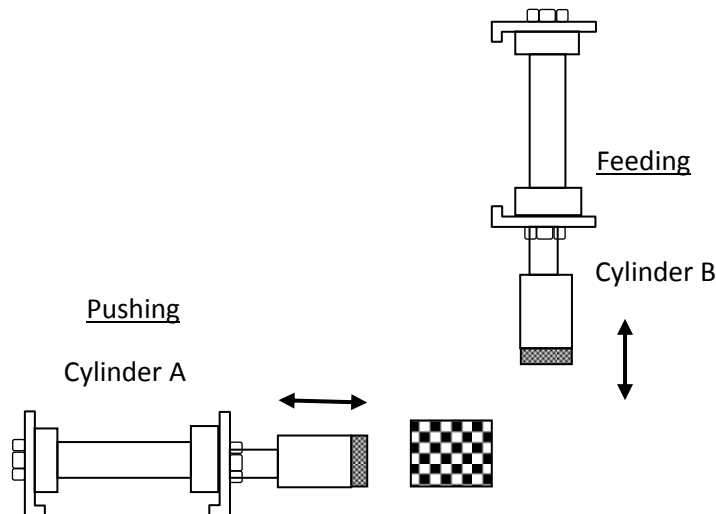


**Figure 1.12 Positional diagram**

**Step 1: Write the statement of the problem:**

Let A be the first cylinder (Pushing) and B be second cylinder (feeding) as shown in the Figure xxx. First cylinder A extends and brings under stamping station where cylinder B is located. Cylinder B then extends and stamps the job. Cylinder A can return back only cylinder B has retracted fully.

**Step 2: Draw the positional layout. (Figure 1.13)**



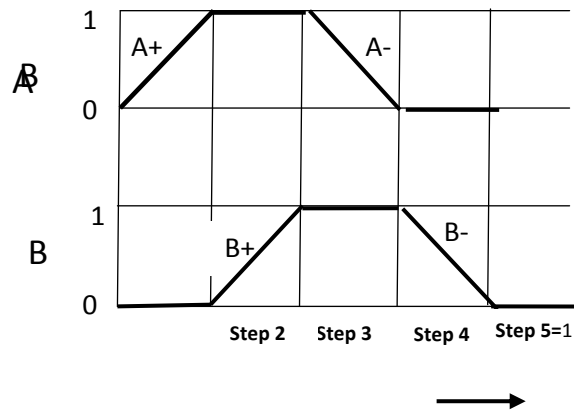
**Figure 1.13 Positional diagram**

**Step3: Represent the control task using notational form**

- Cylinder A advancing step is designated as **A+**
- Cylinder A retracting step is designated as **A-**
- Cylinder B advancing step is designated as **B+**
- Cylinder B retracting step is designated as **B-**

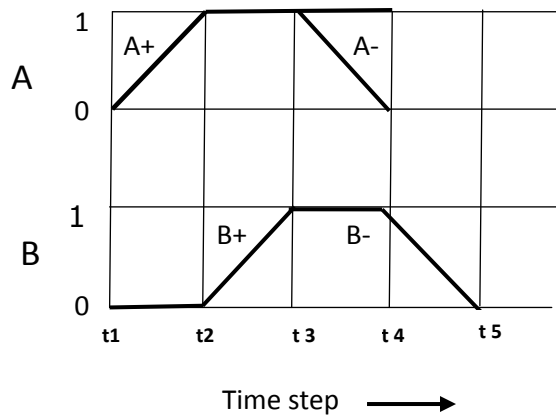
Therefore, given sequence for clamping and stamping is **A+B+A-B-**

**Step 4 Draw the Displacement –step diagram (Figure 1.14)**



**Figure 1.14 Displacement step diagram**

**Step 5 Draw the Displacement –time diagram (Figure 1.15)**



**Figure 1.15 Displacement time diagram**

**Step 6: Analyse and Draw Pneumatic circuit.**

**Step 6.1 Analyse input and output signals.**

### **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

### **Output Signal**

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

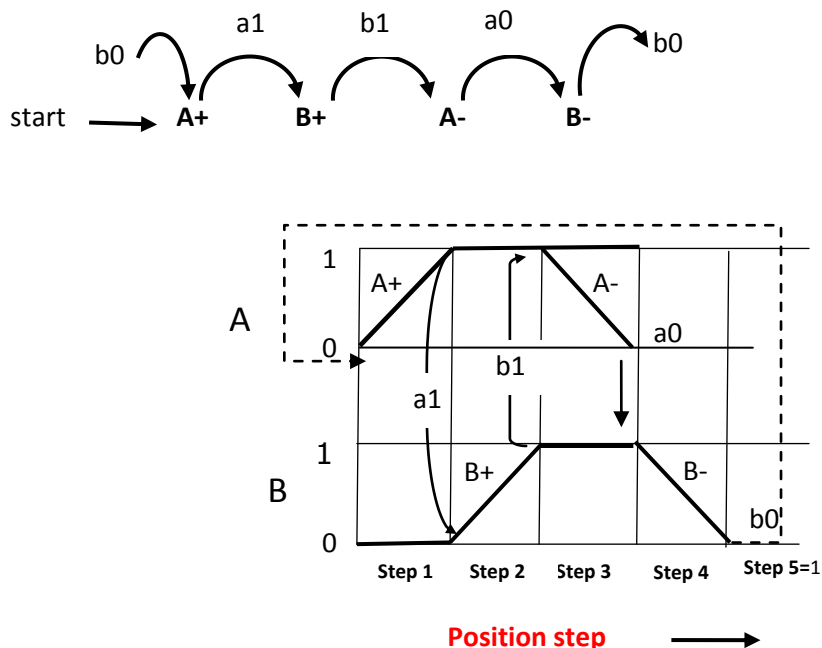
Return motion of cylinder B( B+)

**Step 6.2 Using the displacement time/step diagram link input signal and output signal. (Figure 1.16)**

Usually start signal is also required along with b0 signal for obtaining A+ motion.

1. A+ action generates sensor signal a1, which is used for B+ motion
2. B+ action generates sensor signal b1, which is used for A- motion
3. A- action generates sensor signal a0, which is used for B- motion
4. B- action generates sensor signal b0, which is used for B- motion

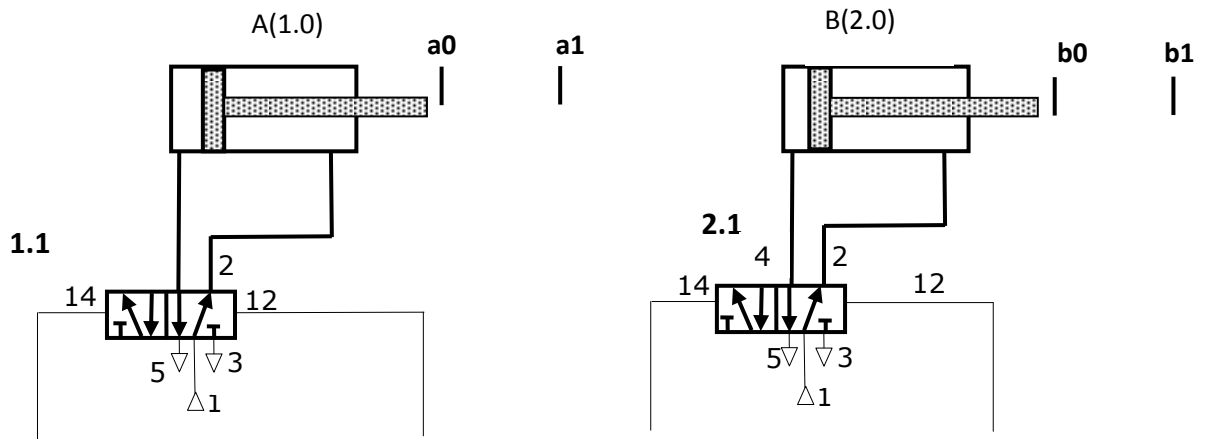
Above information (given in 6.2) is shown below graphically



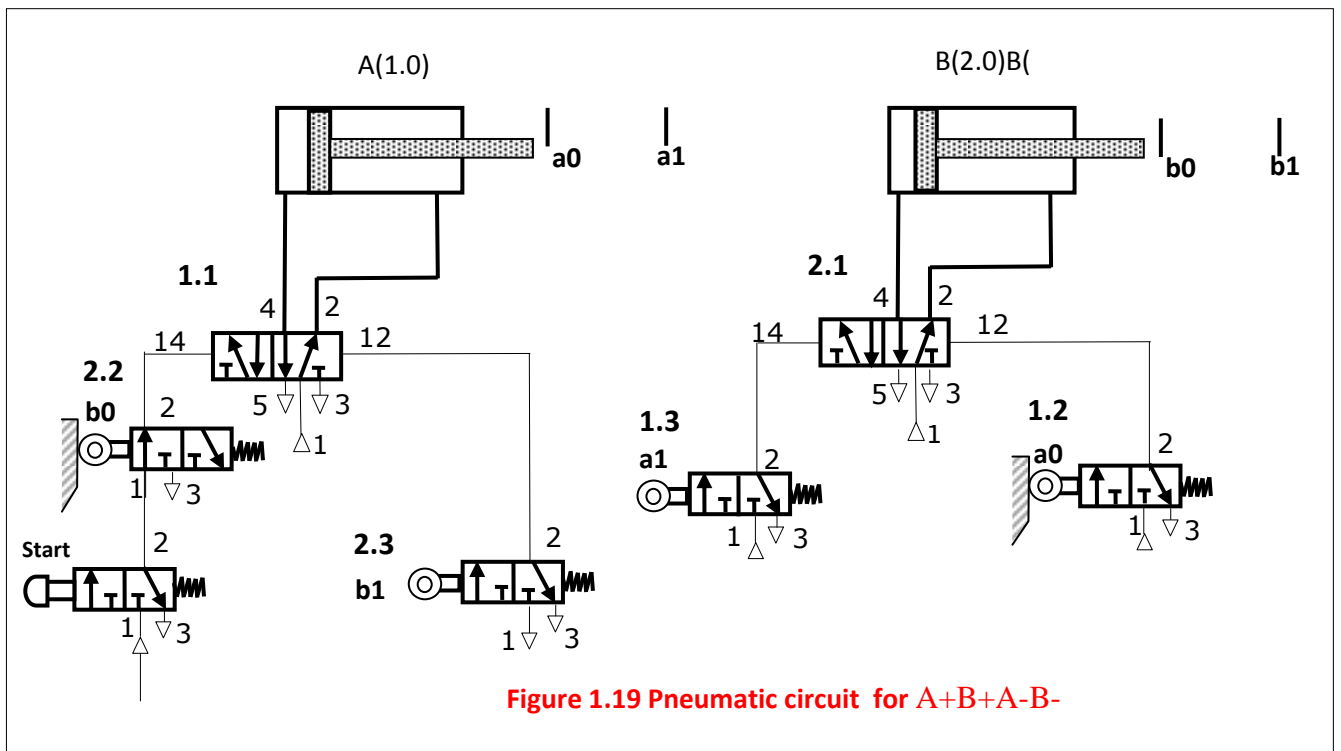
**1.16 Input output signal flow**

**Step 7 Draw the power circuit (Figure 1.18)**

- i) Draw the cylinders A(1.0) and B(2.0).
- ii) Draw the DCVs 1.1 and 2.1 in unactuated conditions
- iii) Mark the limit switch positions for cylinders A(1.0) and B(2.0).



**Step 8 Draw the control circuit (Figure 1.19)**



**Figure 1.19 Pneumatic circuit for A+B+A-B-**

**Step 9 Analysis of pneumatic circuit**

1. When the start button is pressed, the signal appears at port 14 of valve 1.1 through limit switch signal b0.
2. Check for the presence of the signal at the other end (12) of valve 1.1. Notice that the signal is not present at port 12 of valve 1.1. (Because b1 is not pressed). There is no signal conflict and valve 1.1 is able to move. So A advances to forward position.
3. When cylinder A fully extends, it generates a limit switch signal a1, which is applied to port 14 of the valve 2.1. Cylinder B advances to forward position.

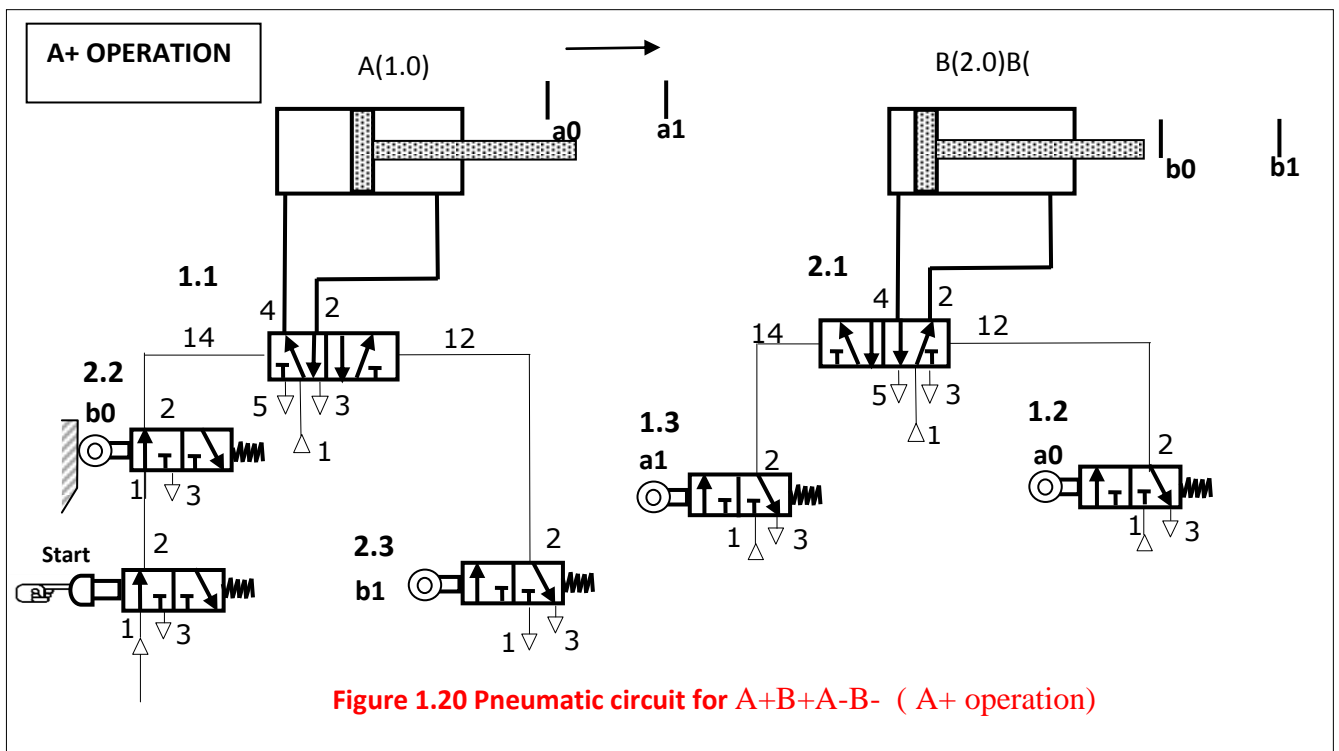
5. Check for the presence of the signal at the other end (12) of valve 2.1. Signal is not present at port 12 of valve 2.1 (because a0 is not pressed, A is already in extended position now) and hence there is no signal conflict

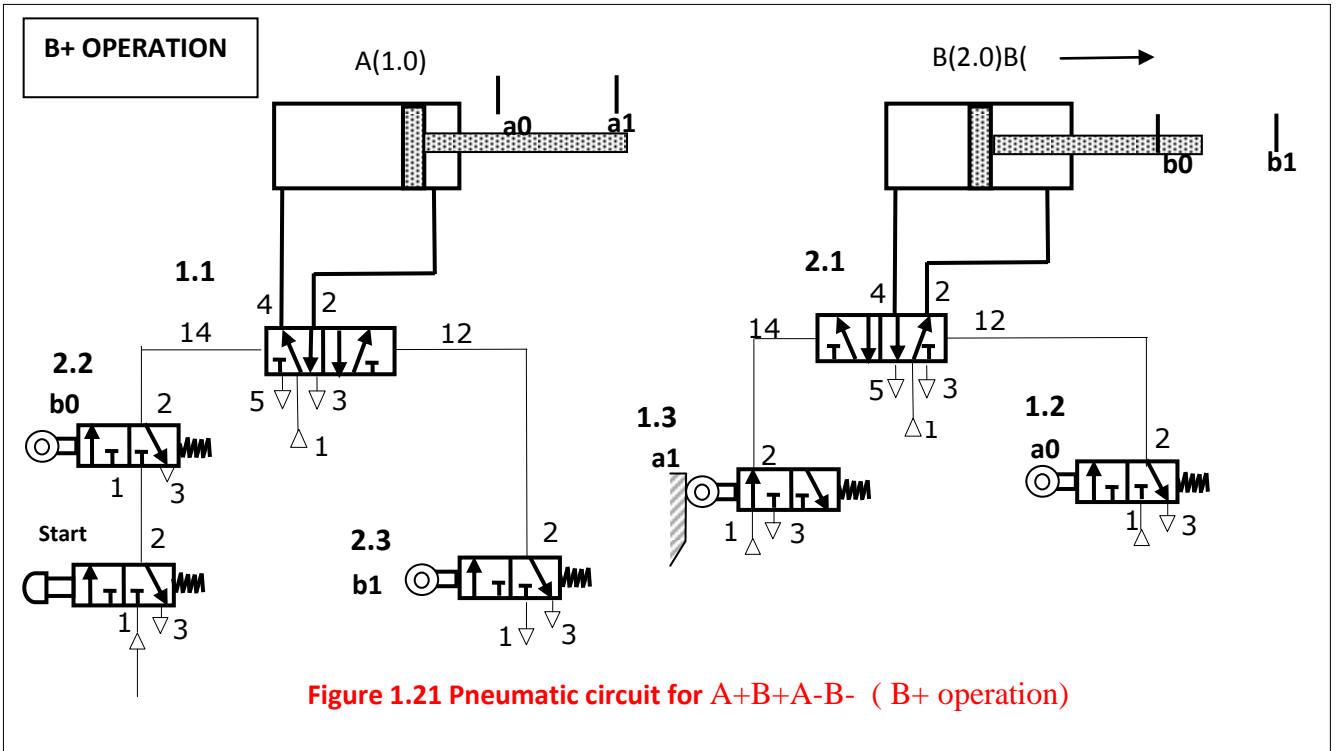
6. Signal applied to port 14 of the valve 2.1 causes the shifting of DCV 2.1 and cylinder B extends.

7. When cylinder B fully extends, it generates a limit switch signal b1, which is applied to port 12 of valve 1.1 . Cylinder A returns and a0 is pressed. There is no signal conflict, as a0 and a1 are mutually exclusive signals.

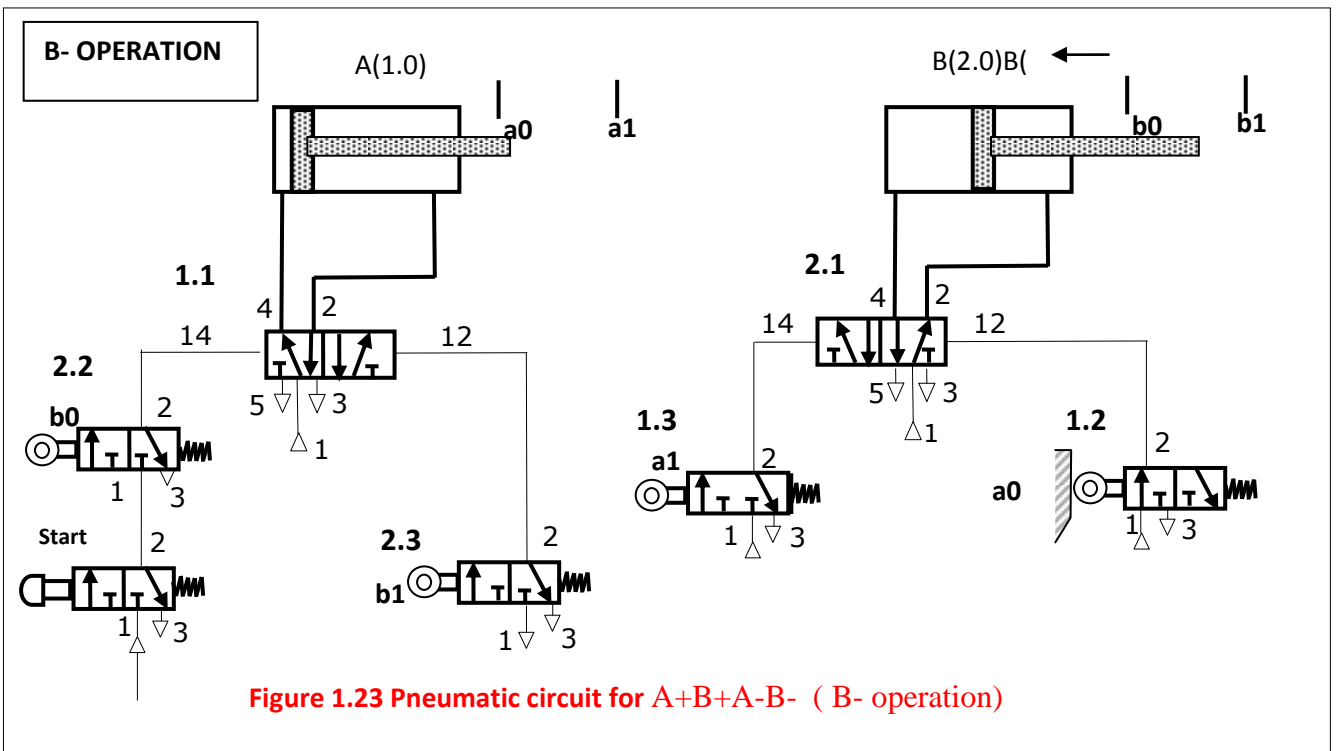
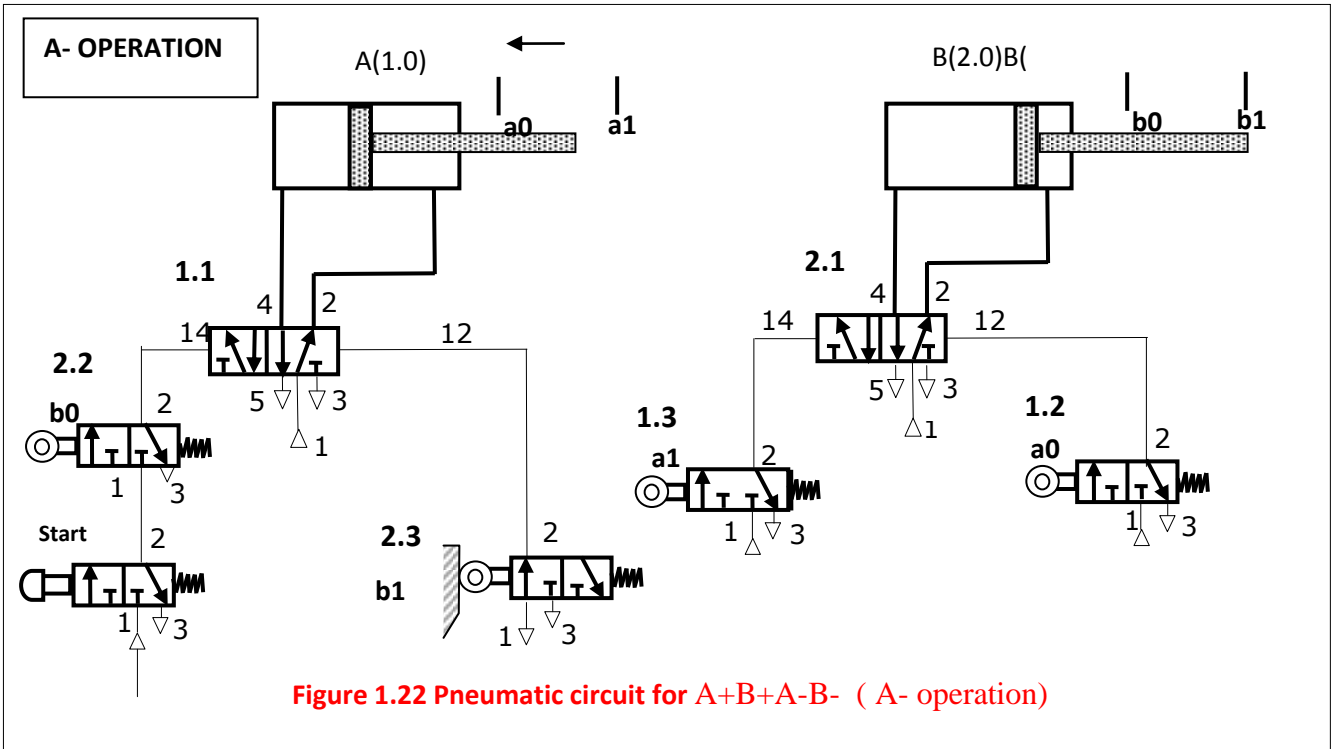
10. When the cylinder A is fully retracted, it generates a limit switch signal a0, which is applied to port 12 of the valve 2.1. Cylinder B retracts.

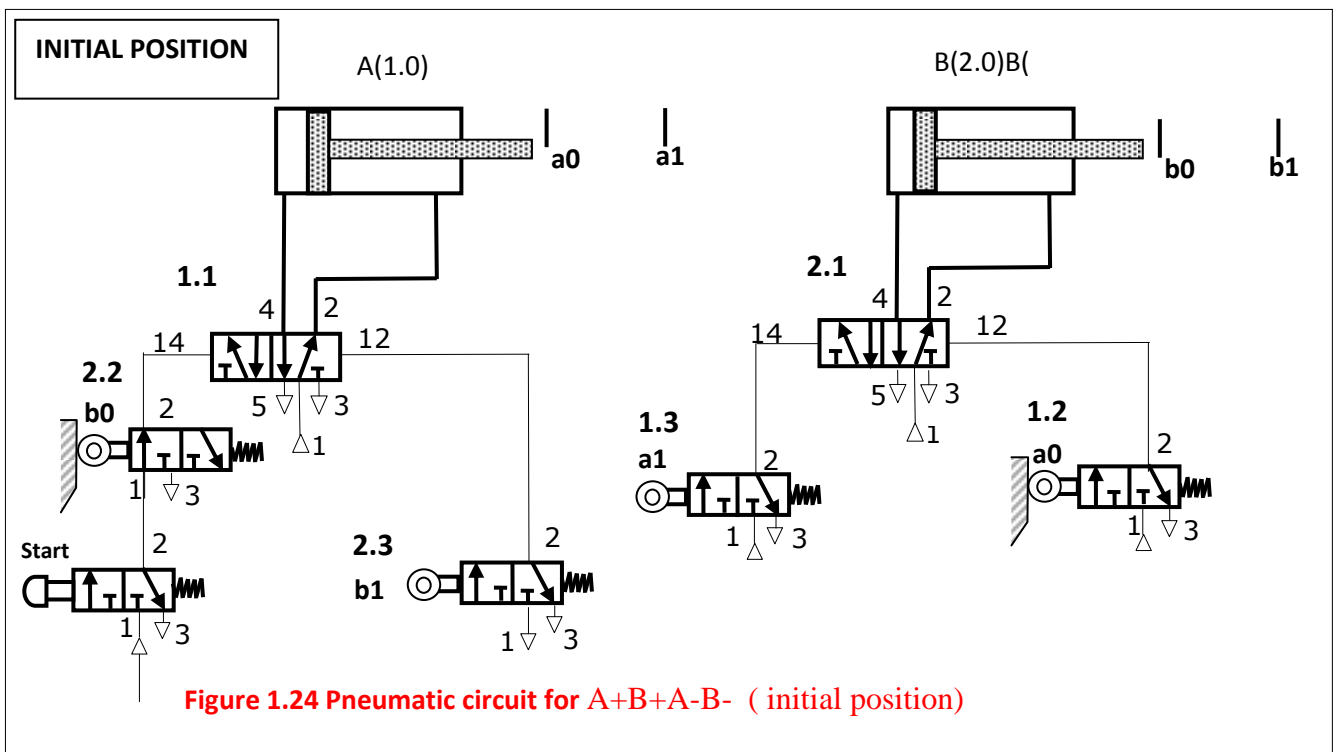
All five sequence of operations are shown in Figure 1.20 to Figure 1.24











### 1.2.3 Elimination of Signal Conflict

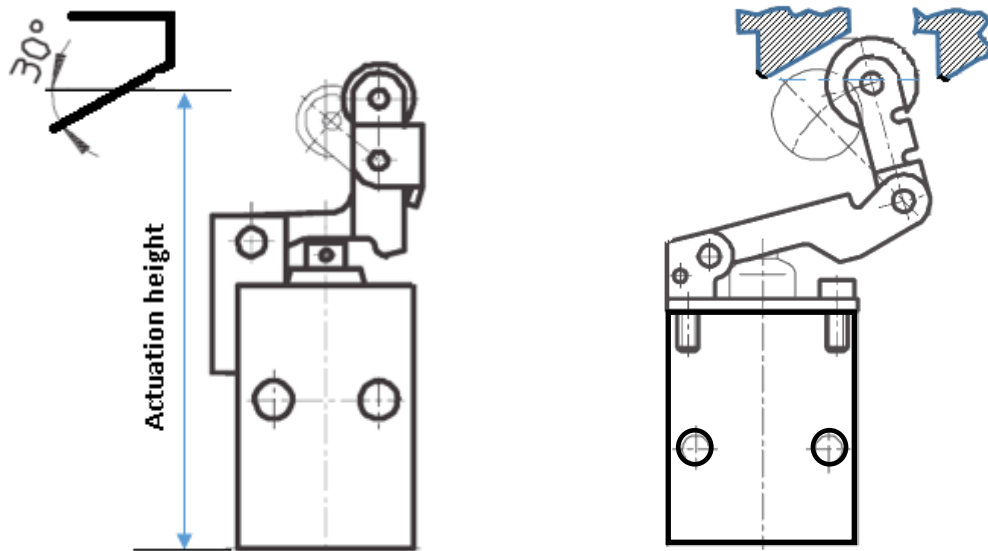
Various methods are used to solve problem of signal conflicts in multi cylinder circuits.

- Idle return roller
- Reversing valves ( memory valves)
- Modules as combination of valves

Cascading method uses the reversing valves ( also known group changing valves) and Step counter method uses modular valves. Both methods are discussed in subsequent section in this chapter.

#### 1.2.3.1 Use of Idle Return Rollers.

An idle-return roller valve consists of a 3/2 DCV fitted with an idle return roller mechanism. The two designs of the idle roller is shown in [Figure 1.25](#)



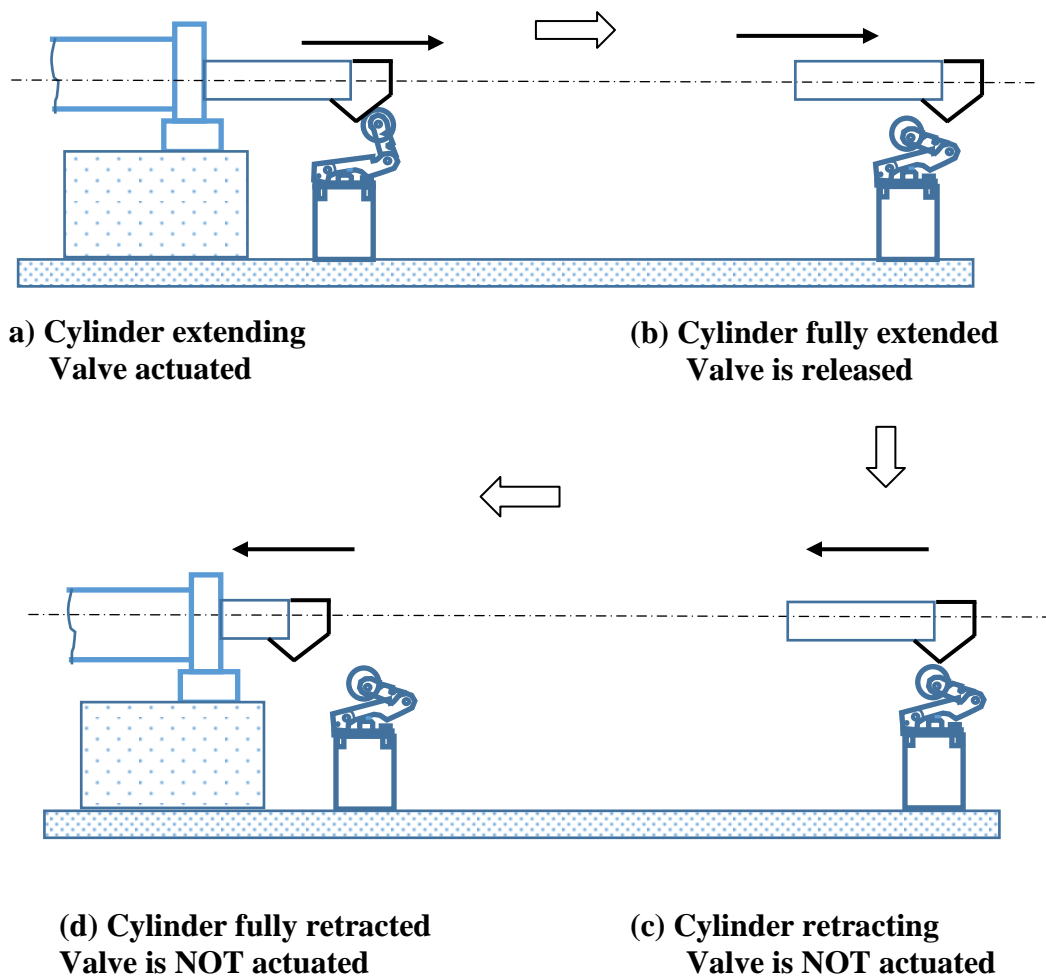
**Figure 1.25 Two designs of Idle return rollers**

The action of the idle return roller valve can be understood using the [Figure 1.26](#). The idle return roller may be positioned in the control system so that when the cylinder extends, the piston passes over the idle – roller mechanism of the valve, thus activating the valve. ([Figure 1.26a](#)), but also permitting the valve to be deactivated immediately when the piston moves to the extreme end position ([Figure 1.26b](#)). As a result, the valve generates a short output pulse during the forward motion of the cylinder. The idle return mechanism also allows the cylinder to retract without re-activating the valve ([Figure 1.26c](#) and [Figure 1.26d](#)). Hence, in the end position or during the return motion of the piston, the valve does not get actuated, and no output signal is produced. For the generation of short output pulse by the idle-return roller valve during the return motion of the cylinder, this valve may be positioned in the opposite direction as compared to the case during the forward motion of the cylinder.

In the previous sequence problem, we have identified that roller valves b1 and a1 are responsible for signal conflicts. To eliminate the problem of signal conflicts the roller valve b1 and a1 to be replaced by idle return rollers.

Drawbacks of idle –return rollers.

1. This method is not reliable
2. End position cannot be sensed accurately
3. Fast control system cannot be set up.



**Figure 1.26 Actions of Idle return rollers**

**Example 3 :** Develop Pneumatic circuit for A+ B+ B- A- sequence. Avoid signal conflict using idle – return roller.

**Figure 1.27** shows the circuit for getting the control sequence A+ B+ B- A- using the idle –return rollers at the position b0 and a1. The roller valves at position a0 and b1 need be replaced with the idle return rollers as these valves do not cause signal conflicts for the given sequence circuit.

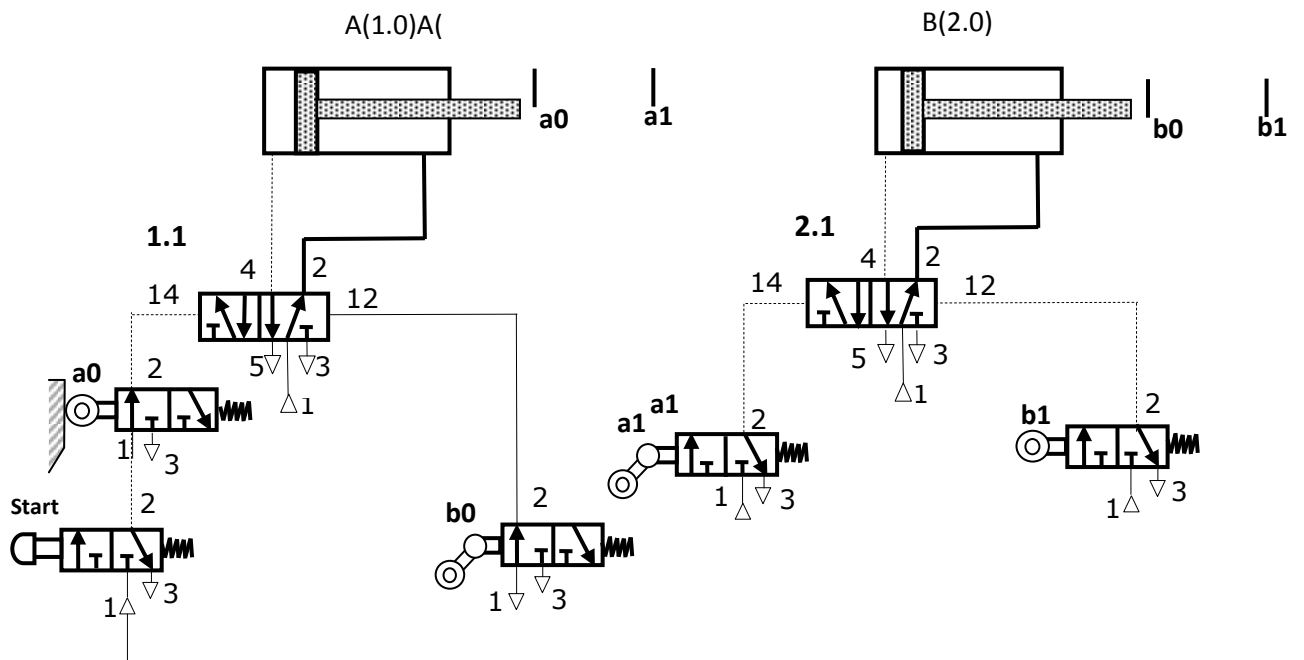


Figure 1.27 Pneumatic circuits for A+ B+ B- A- (with idle return roller)

### 1.3 CASCADE METHOD

A Bi-stable memory valve or reversing valve can be used to eliminate signal conflicts. Signal conflict is avoided by allowing the signal to be effective only at times when they are needed. Two of the possible designs are possible.

- i) Cascade method
- ii) Shift register method

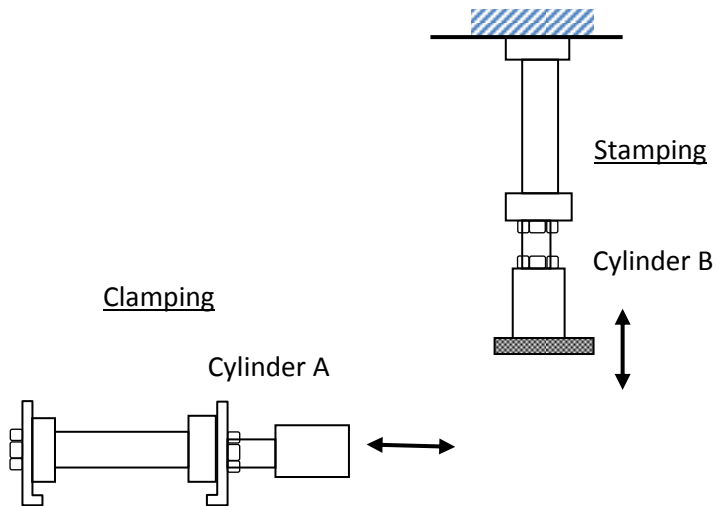
#### 1.3.1 Demonstration of Cascade method

In order to develop control circuitry for multi cylinder applications, as done before in classic method, it is necessary to draw the motion diagram to understand the sequence of actuation of various signal input switches-limit switches and sensors. Motion diagram represents status of cylinder position - whether extended or retracted in a particular step

**Step 1: Write the statement of the problem:**

First cylinder A extends and brings under stamping station where cylinder B is located. Cylinder B then extends and stamps the job. Cylinder A can return back only cylinder B has retracted fully.

**Step 2: Draw the positional layout. (Figure 1.28)**



**Figure 1.28 Positional diagram**

**Step3: Represent the control task using notational form**

Cylinder A advancing step is designated as **A+**

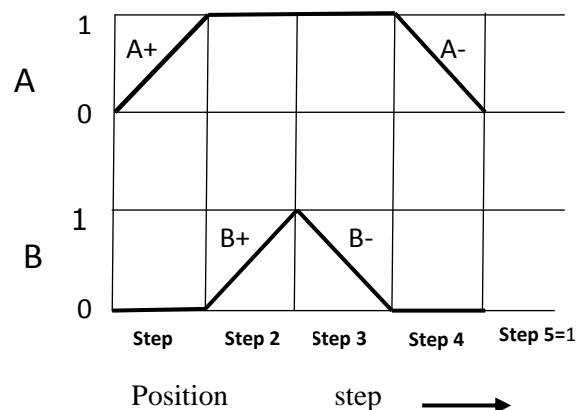
Cylinder A retracting step is designated as **A-**

Cylinder B advancing step is designated as **B+**

Cylinder B retracting step is designated as **B-**

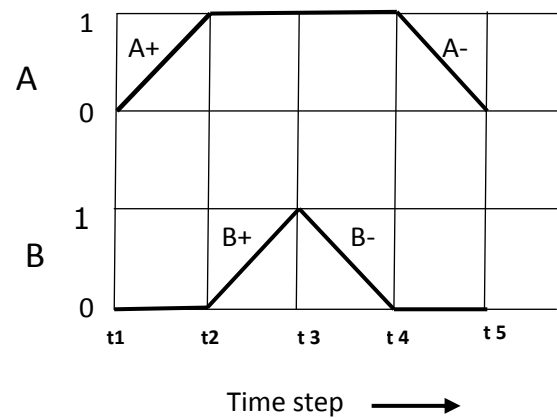
Given sequence for clamping and stamping is **A+B+B-A-**

**Step 4 Draw the Displacement –step diagram (Figure 1.29)**



**Figure 1.29 Displacement step diagram**

**Step 5 Draw the Displacement –time diagram (Figure 1.30)**



**Figure 1.30 Displacement time diagram**

**Step 6: Analyse and Draw Pneumatic circuit.**

**Step 6.1 Analyse input and output signals.**

**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

**Output Signal**

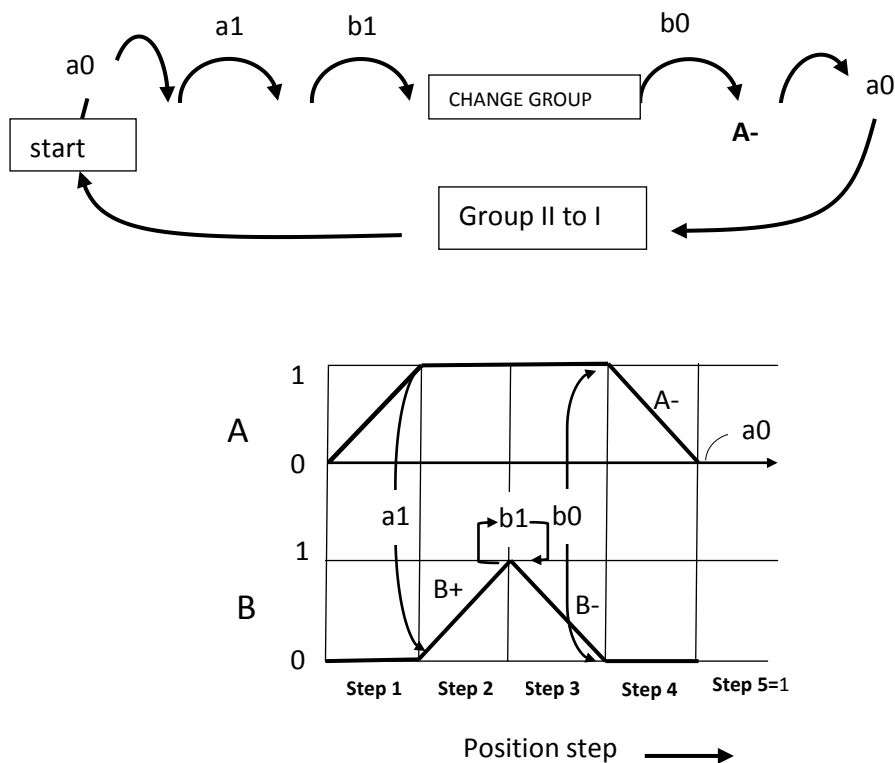
- Forward motion of cylinder A ( A+)
- Return motion of cylinder A ( A-)
- Forward motion of cylinder B ( B+)
- Return motion of cylinder B( B-)

**Step 6.2 Using the displacement time/step diagram link input signal and output signal. (Figure 1.31)**

Usually start signal is also required along with a0 signal for obtaining A+ motion.

1. A+ action generates sensor signal a1, which is used for B+ motion
2. B+ action generates sensor signal b1, which is used group changing.
3. B- action generates sensor signal b0, which is used for A- motion
4. A- action generates sensor signal a0, which is used for group changing

Above information (given in 6.2) is shown below graphically



**Figure 1.31 Displacement time diagram**

**Step 7 Draw the power circuit (Figure 1.32)**

- i) Divide the given circuits into groups. Grouping should be done such that there is no signal conflict. Do not put A+ and A- in the same group. Similarly B+ and B- should not be put in the same group. In other word A+ and A- should belong to different group to avoid signal conflict.

In our example of A+ B+ B- A- we can group as

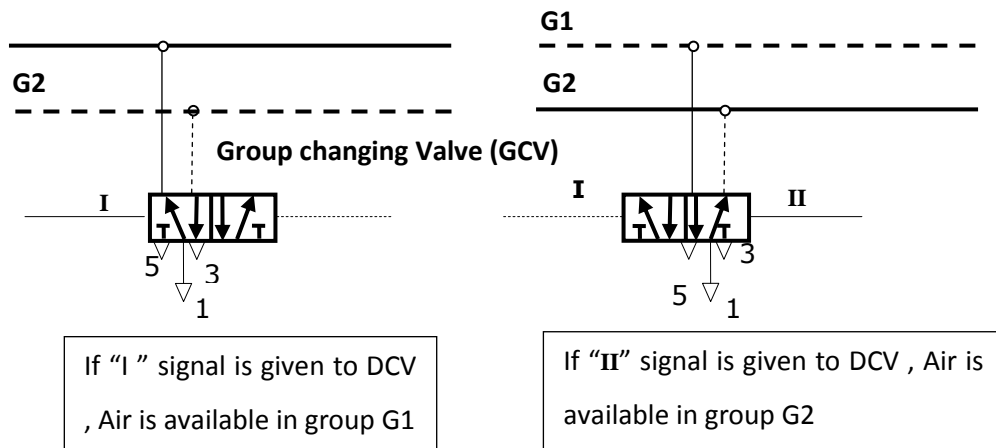
A+ B+	B- A-
Group 1	Group 2



ii) Choose the number of **group changing valve** = no of groups -1

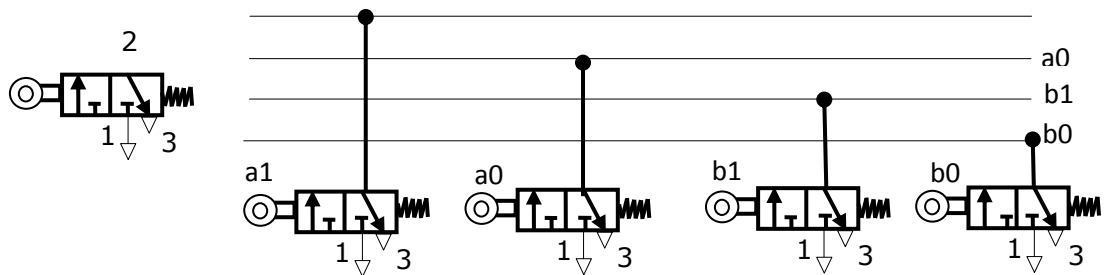
In our example, we have 2 groups so we need one group changing valve

Connect the group changing valve as follows. From the figure it is clear that when the control signals I and II are applied to group changing valve, the air (power) supply changes from Group 1(G1) to Group 2 (G2)



**Figure 1.32**

iii) Arrange the limit switch and start button as given below (**Figure 1.33**)



**Figure 1.33**

iv) Draw the power circuit (**Figure 1.34**)



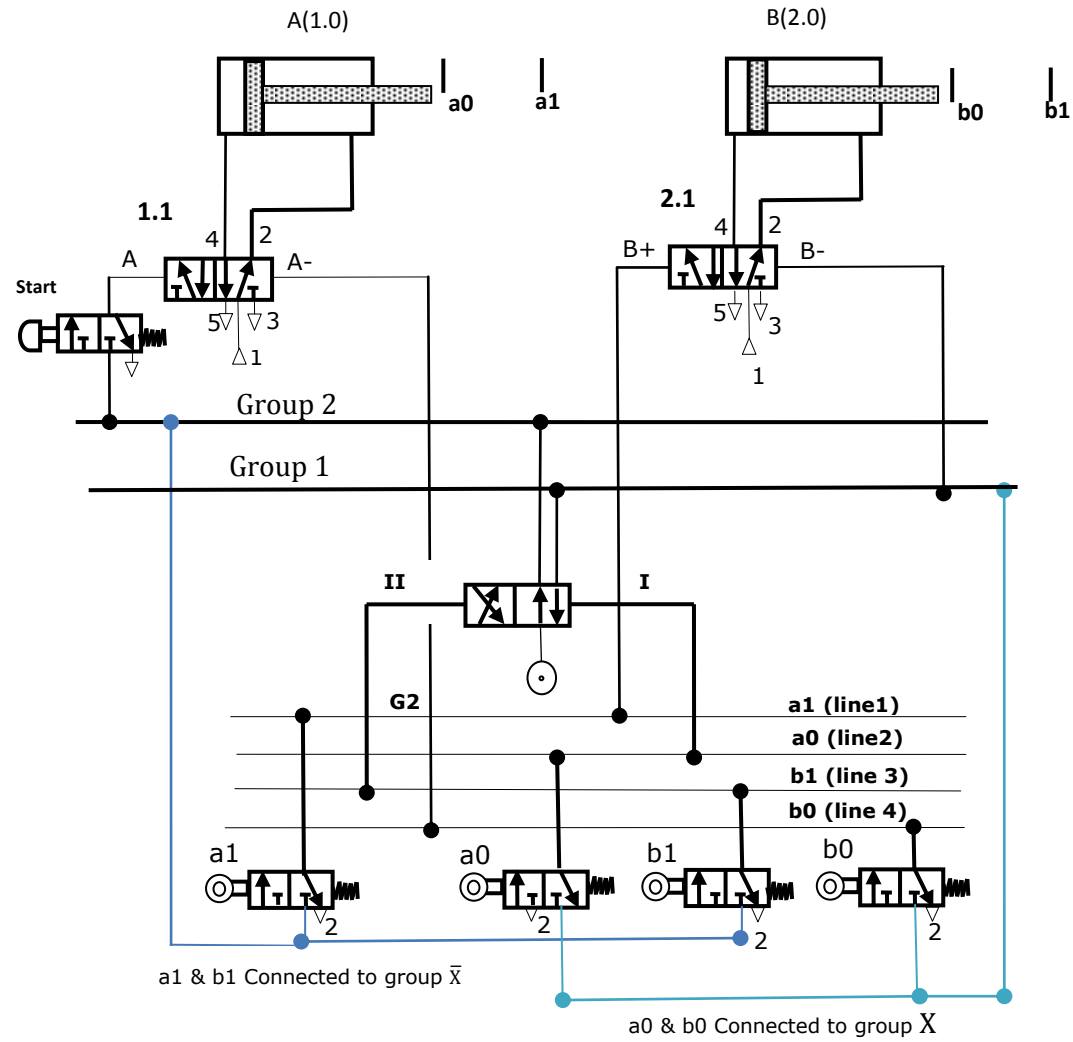


Figure 1.35 Pneumatic circuits for  $A + B + B - A -$

### Step 9 Analysis of pneumatic circuit

1. Assume that air is available in the line G2 to start with. (Say from last operation)
2. When the start button is pressed, Air supply from Group G2 is directed to line 2 through actuated limit switch a0. Now the air available in line 2, actuates the Group changing valve (GCV) to switch over to position I. This switching of the GCV causes air supply to change from G2 to G1.
3. Now the air is available in line G1. The air supply from group G1 is directed to port 14 of the valve 1.1. As there is no possibility of signal conflict here, valve 1.1 switches over causing the A+ action.
4. Sensor a1 is actuated as the result of A+ action, allowing the air supply from the Group G1 to reach to line 1 through a1. Now the air available reaches port 14 of valve 2.1. As there is no possibility of signal conflict here, valve 2.1 switches over, causing B+ action automatically.
5. Sensor b1 is actuated as result of B+ action, allowing the air supply in line 3. Air from line 3 allows the air to reach port 12 of Group changing valve (also called reversing valve). As a result, the Group changing valve switches over, causing the group supply to change from G1 to G2.
6. Now the air is available in G2. Air from G2 acts on port 12 of the Valve 2.1. As there is no possibility of signal conflict here, valve 2.1 switches over, causing B- action automatically.
7. Sensor is actuated as the result of B- action. Now the air is available in line 4. Air from line 4 reach port 12 of the valve 1.1 , As there is no possibility of signal conflict here, valve 2.1 switches over , causing A- action automatically.

The cascade system provides a straightforward method of designing any sequential circuit. Following are the important points to note:

- a) **Present** – the system must be set to the last group for start-up
- b) **Pressure drop**- Because the air supply is cascaded, a large circuit can suffer from more pressure drop.
- c) **Cost** – Costly due to additional reversing valves and other hardware.

## Objective Type Questions

1. Design of circuits using intuitive method is ----- time consuming compared to step counter method.
2. When hard ware costs are not important but circuit design time must be minimal, then ..... method of the circuit design is used.
3. Where the hardware costs are paramount, then ----- circuit methods are used.
4. When absolute fool proofing of circuits is required, ----- circuit methods are used.
5. ----- are used to sense the end position of cylinder movements

## State True or False

1. We have to draw all valves in their de-actuated , unpressurised rest position as in electrical switching components
2. In order to gain fully controlled sequence of all cylinders in a program , it is essential to install end position sensors at all movements end position.
- 3 4/2 or 5/2 double piloted valves are free from signal overlaps.
4. Step counter method is absolutely free from signal conflicts
5. Time delay and pressure delay functions cannot be used in multicylinder circuit design

## Review Questions

1. Explain how signal conflict occurs using an example
2. What is the effect of signal conflict in multi actuator circuit design
3. What are the different ways to eliminate signal conflict in multi actuator circuit design
4. Explain the step displacement diagram for A+B+B-A- sequence.
5. List few disadvantages of using idle return rollers for overcoming signal conflicts
6. Explain the principle of cascade method with a suitable sequence example
7. Briefly explain the principles of step counter method with a suitable example
1. Draw a group changing cascade circuit for two groups, three groups, four groups and five groups.
9. Explain with the help of neat sketch the construction and working of pressure sequence valve
10. What are the different ways to sense the end position and movement of cylinders

## Answers

### Fill in the Blanks

1. More
2. Step counter
3. logic
4. step counter
5. limit switches

### State True or False

1. True
2. True
3. False
4. True
5. False