6

Circuit Design

Contents

6.1 Introduction of Hydraulic Circuit

A hydraulic circuit is a group of components such as pumps, actuators, control valves, conductors and fittings arranged to perform useful work. There are three important considerations in designing a hydraulic circuit:

- Safety of machine and personnel in the event of power failures.
- Performance of given operation with minimum losses.
- Cost of the component used in the circuit.

6.2 Control of A Single-Acting Hydraulic Cylinder

- *Fig.6.1* shows that the control of a single-acting, spring return cylinder using a three-way two-position manually actuated, spring offset direction-control valve (DCV). In the spring offset mode, full pump flow goes to the tank through the pressure-relief valve (PRV).

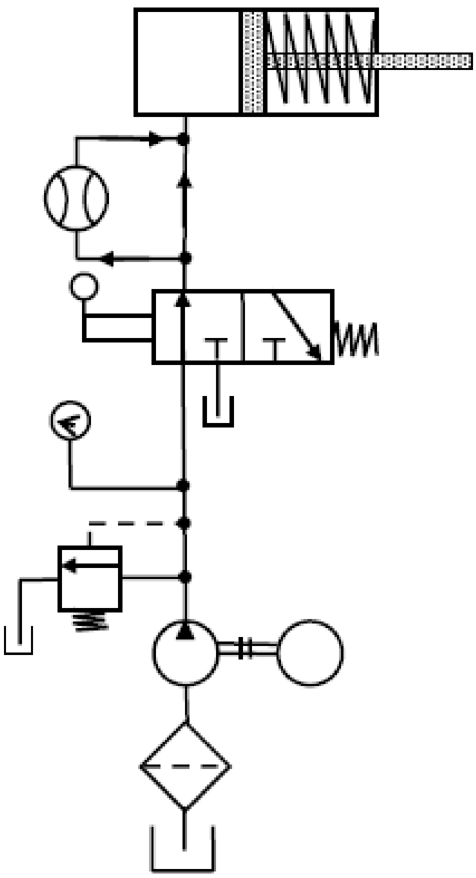


Fig.6.1 Control of a single-acting cylinder

- The spring in the rod end of the cylinder retracts the piston as the oil from the blank end drains back into the tank. When the valve is manually actuated into its next position, pump flow extends the cylinder.
- After full extension, pump flow goes through the relief valve. Deactivation of the DCV allows the cylinder to retract as the DCV shifts into its spring offset mode.

6.3 Control of A Double-Acting Hydraulic Cylinder

- The circuit diagram to control double-acting cylinder is shown in *Fig.6.2*. The control of a double-acting hydraulic cylinder is described as follows.

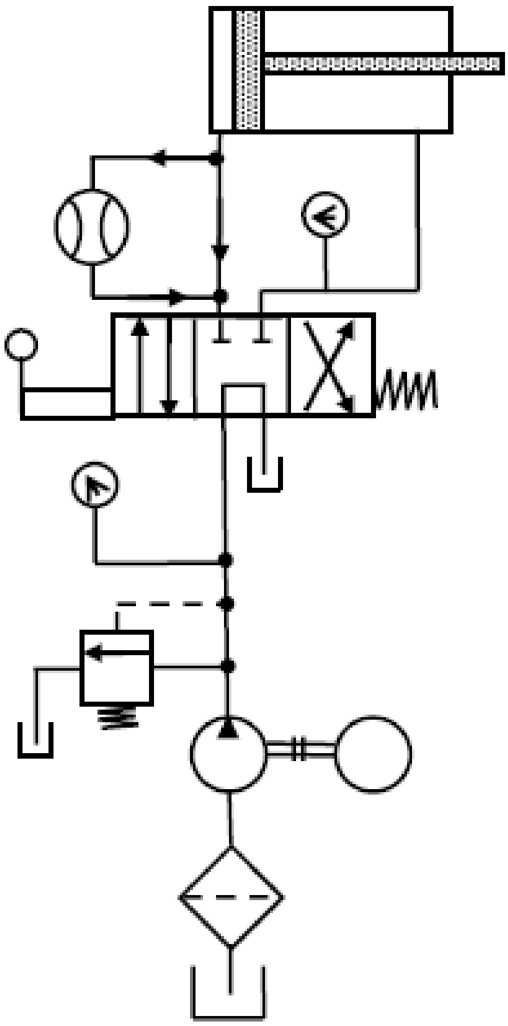


Fig.6.2 Control of a double-acting cylinder

- When the 4/3 valve is in its neutral position (tandem design), the cylinder is hydraulically locked and the pump is unloaded back to the tank.
- When the 4/3 valve is actuated into the flow path, the cylinder is extended against its load as oil flows from port P through port A. Oil in the rod end of the cylinder is free to flow back to the tank through the four-way valve from port B through port T.
- When the 4/3 valve is actuated into the right-envelope configuration, the cylinder retracts as oil flows from port P through port B. Oil in the blank end is returned to the tank via the flow path from port A to port T.
- At the ends of the stroke, there is no system demand for oil. Thus, the pump flow goes through the relief valve at its pressure level setting unless the four-way valve is deactivated.

6.4 Regenerative Cylinder Circuit

- *Fig.6.3* shows a regenerative circuit that is used to speed up the extending speed of a double-acting cylinder. The pipelines to both ends of the hydraulic cylinder are connected in parallel and one of the ports of the 4/3 valve is blocked by simply screwing a thread plug into the port opening.

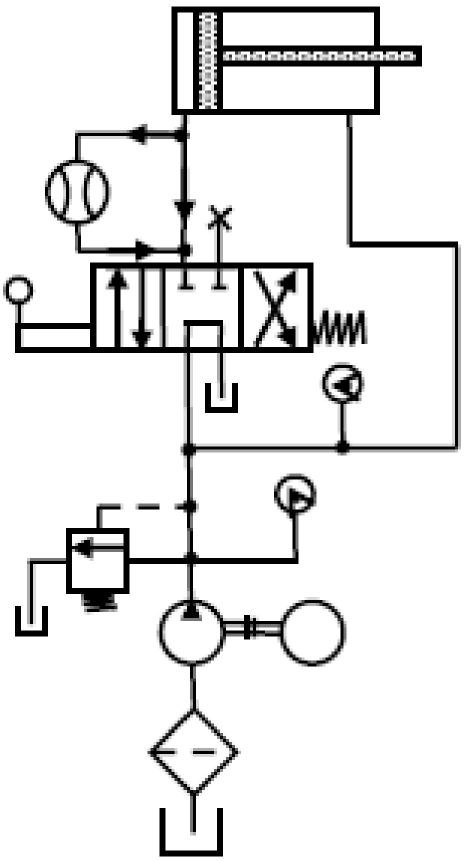


Fig.6.3 Regenerative Cylinder Circuit

- During retraction stroke, the 4/3 valve is configured to the right envelope. During this stroke, the pump flow bypasses the DCV and enters the rod end of the cylinder. Oil from the blank end then drains back to the tank through the DCV.
- When the DCV is shifted in to its left-envelope configuration, the cylinder extends as shown in *Fig.6.3*. The speed of extension is greater than that for a regular double-acting cylinder because the flow from the rod end regenerates with the pump flow Q_P to provide a total flow rate Q_T.

6.5 Double-Pump Hydraulic System (Unloading Circuit)

- *Fig.6.4* shows an application for an unloading valve. It is a circuit that uses a high-pressure, low-flow pump in conjunction with a low-pressure, high-flow pump.
- A typical application is a sheet metal punch press in which the hydraulic cylinder must extend rapidly over a great distance with low-pressure but high-flow requirements. This occurs under no load.
- However during the punching operation for short motion, the pressure requirements are high, but the cylinder travel is small and thus the flow requirements are low. The circuit in *Fig.6.4* eliminates the necessity of having a very expensive high-pressure, high-flow pump.
- When the punching operation begins, the increased pressure opens the unloading valve to unload the low-pressure pump. The purpose of relief valve is to protect the high-pressure pump from over pressure at the end of cylinder stroke and when the DCV is in its spring-centered mode.

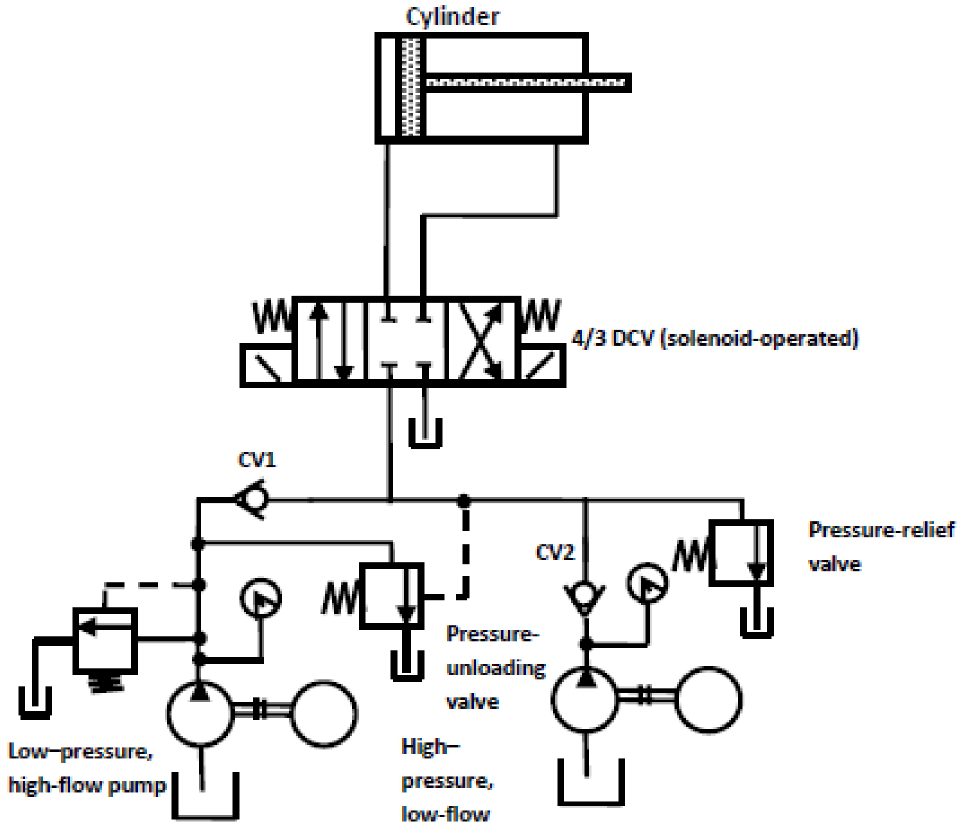


Fig.6.4 Unloading Circuit

- The check valve protects the low-pressure pump from high pressure, which occurs during punching operation, at the ends of the cylinder stroke and when the DCV is in its spring-centered mode.

6.6 Counterbalance Valve Application

- A counterbalance valve is applied to create a back pressure or cushioning pressure on the underside of a vertically moving piston to prevent the suspended load from free falling because of gravity while it is still being lowered.

6.6.1 Valve Operation (Lowering)

- The pressure setting on the counterbalance valve is set slightly higher than the pressure required to prevent the load from free falling. Due to this back pressure in line A, the actuator piston must force down when the load is being lowered.
- This causes the pressure in line A to increase, which raises the spring-opposed spool, thus providing a flow path to discharge the exhaust flow from line A to the DCV and then to the tank.
- The spring-controlled discharge orifice maintains back pressure in line A during the entire downward piston stroke.

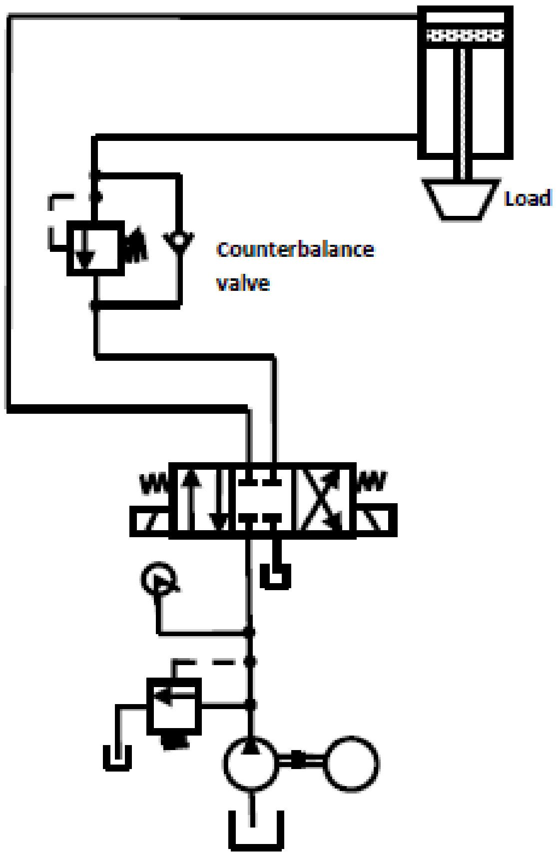


Fig.6.5 Counterbalance valve in circuit

6.6.2 Valve Operation (Suspension)

- When the valve is held in suspension, the valve remains closed. Therefore, its pressure setting must be slightly higher than the pressure caused by the load. Spool valves tend to leak internally under pressure. This makes it advisable to use a pilot-operated check valve in addition to the counterbalance valve if a load must be held in suspension for a prolonged time.

6.7 Hydraulic Cylinder Sequencing Circuit

- Hydraulic cylinders can be operated sequentially using a sequence valve. *Fig.6.6* shows that two sequence valves are used to sequence the operation of two double-acting cylinders.
- When the DCV is actuated to its right-envelope mode, the bending cylinder (B) retracts fully and then the clamp cylinder (A) retracts.
- This sequence of cylinder operation is controlled by sequence valves. This hydraulic circuit can be used in a production operation such as drilling.
- Cylinder A is used as a clamp cylinder and cylinder B as a drill cylinder.
- Cylinder A extends and clamps a work piece. Then cylinder B extends to drive a spindle to drill a hole. Cylinder B retracts the drill spindle and then cylinder A retracts to release the work piece for removal.

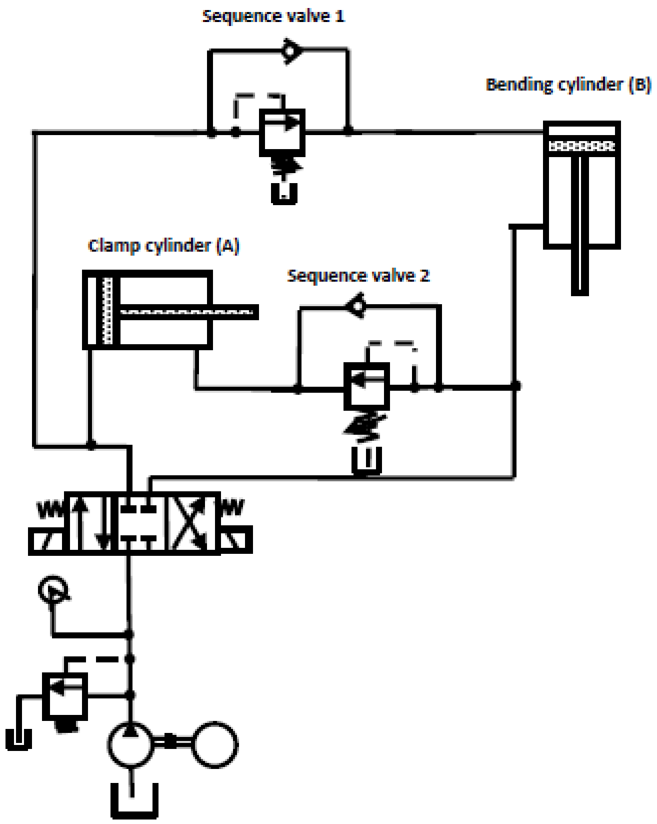


Fig.6.6 Sequencing Circuit

6.8 Automatic Cylinder Reciprocating System

- The hydraulic circuit shown in *Fig.6.7* produces continuous reciprocation of a double-acting cylinder using two sequence valves.
- Each sequence valve senses the completion of stroke by the corresponding build-up pressure. Each check valve and the corresponding pilot line prevent the shifting of the four-way valve until the particular stroke of the cylinder is completed.

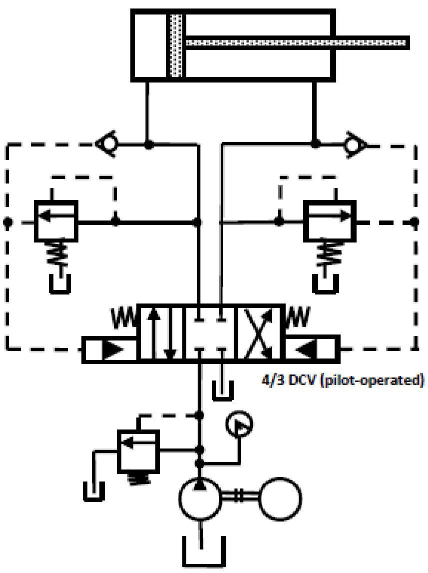


Fig.6.7 Automatic Cylinder Reciprocating System

- The check valves are needed to allow pilot oil to leave either end of the DCV while the pilot pressure is applied to the opposite end. This permits the spool of the DCV to shift as required.

6.9 Cylinder Synchronizing Circuits

- In industry, there are instances when a large mass must be moved, and it is not feasible to move it with just one cylinder. In such cases we use two or more cylinders to prevent a moment or moments that might distort and damage the load.
- For example, in press used for moulding and shearing parts, the platen used is very heavy. If the platen is several meters wide, it has to be of very heavy construction to prevent the damage when it is pressed down by a single cylinder in the middle.
- It can be designed with less material if it is pressed down with two or more cylinders. These cylinders must be synchronized. There are two ways that can be used to synchronize cylinders: Parallel and series.

6.9.1 Cylinders in Parallel

- *Fig.6.8* shows a hydraulic circuit in which two cylinders are arranged in parallel. When the two cylinders are identical, the loads on the cylinders are identical, and then extension and retraction are synchronized. If the loads are not identical, the cylinder with smaller load extends first.
- Thus, the two cylinders are not synchronized. Practically, no two cylinders are identical, because of packing (seals) friction differences. This prevents cylinder synchronization for this circuit.

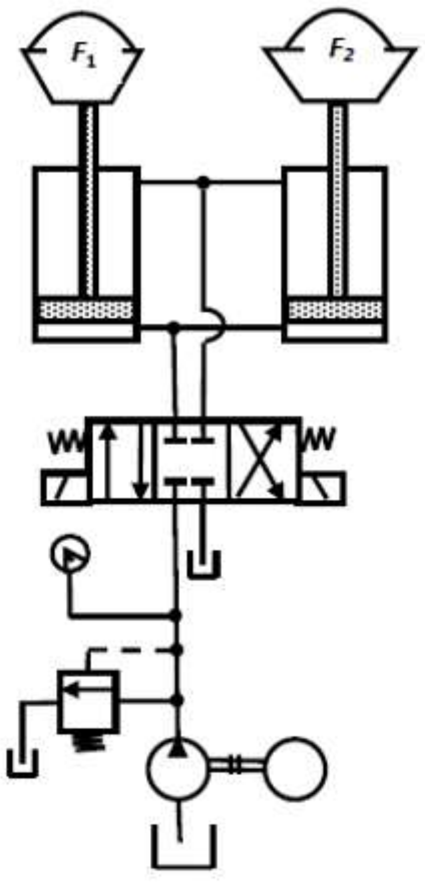


Fig.6.8 Cylinders in Parallel

6.9.2 Cylinders in Series

- During the extending stroke of cylinders, fluid from the pump is delivered to the blank end of cylinder 1. As cylinder 1 extends, fluid from its rod end is delivered to the blank end of cylinder 2 causing the extension of cylinder 2. As cylinder 2 extends, fluid from its rod end reaches the tank.

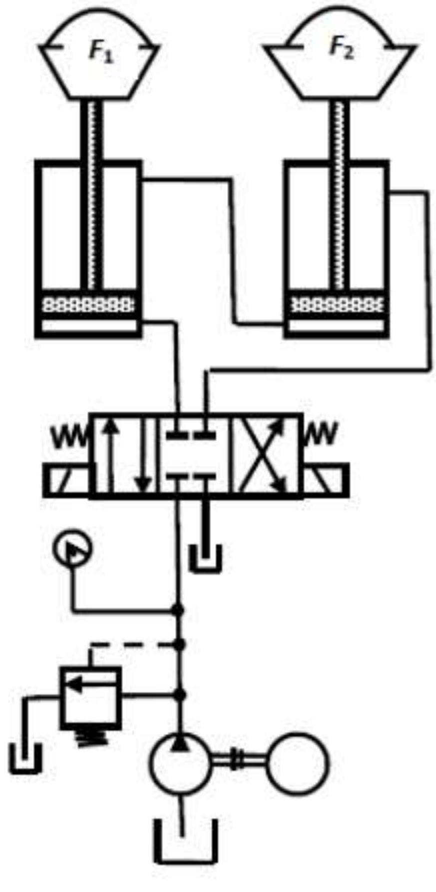


Fig.6.9 Cylinders in Series

6.10 Speed Control of A Hydraulic Cylinder

- The speed control of a hydraulic cylinder circuit can be done during the extension stroke using a flow-control valve (FCV). This is done on a meter-in circuit and meter-out circuit as shown in below section.

6.10.1 Meter-In Circuit

- When the DCV is actuated, oil flows through the FCV to extend the cylinder. The extending speed of the cylinder depends on the FCV setting. When the DCV is deactivated, the cylinder retracts as oil from the cylinder passes through the check valve. Thus, the retraction speed of a cylinder is not controlled.
- The FCV is placed in the line leading to the inlet port of the cylinder. Thus, it is called the meter-in control of speed. Meter-in flow controls the oil flow rate into the cylinder.
- Meter-in systems are used primarily when the external load opposes the direction of motion of the hydraulic cylinder. When a load is pulled downward due to gravity, a meter-out system is preferred. If a meter-in system is used in this case, the load would drop by pulling the piston rod, even if the FCV is completely closed.

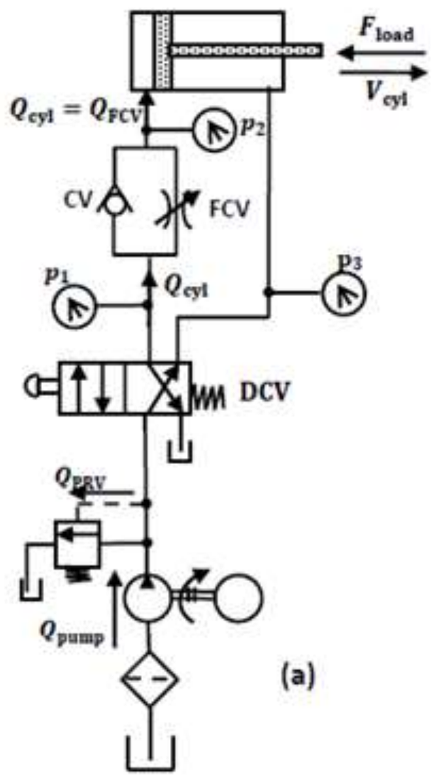


Fig.6.10 Meter-In Circuit

6.10.2 Meter-Out Circuit

- *Fig.6.1*shows meter-out circuit; when DCV is actuated, oil flows through the rod end to retract the cylinder.
- A meter-out flow control system is one in which the FCV is placed in the outlet line of the hydraulic cylinder. Thus, a meter-out flow control system controls the oil flow rate out of the cylinder.
- One drawback of a meter-out system is the excessive pressure build-up in the rod end of the cylinder while it is extending. In addition, an excessive pressure in the rod end results in a large pressure drop across the FCV. This produces an undesirable effect of a high heat generation rate with a resulting increase in oil temperature.

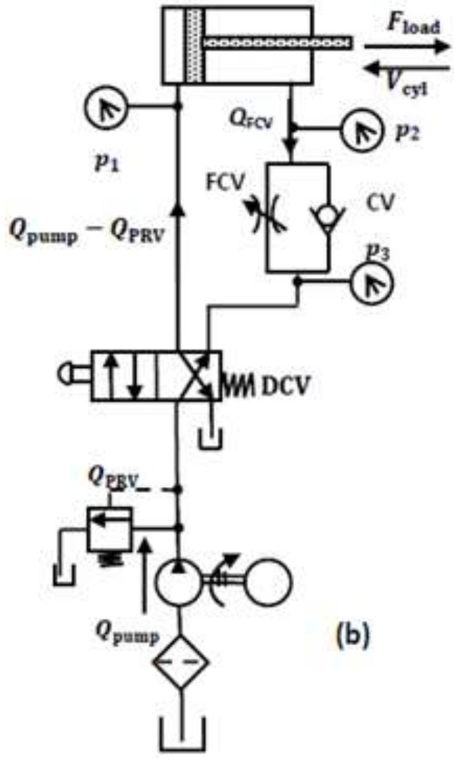


Fig.6.11 Meter-Out Circuit

6.11 Fail-Safe Circuits

- Fail-safe circuits are those designed to prevent injury to the operator or damage to the equipment. In general, they prevent the system from accidentally falling on an operator and also prevent overloading of the system.
- In following sections, we shall discuss two fail-safe circuits:
    1. Protection from inadvertent cylinder extension
    2. fail-safe overload protection

6.11.1 Protection from Inadvertent Cylinder Extension

- *Fig.6.12* shows a fail-safe circuit that is designed to prevent the cylinder from accidentally falling in the event when a hydraulic line ruptures or a person inadvertently operates the manual override on the pilot-actuated DCV when the pump is not working.
- To lower the cylinder, pilot pressure from the blank end of piston must pilot open the check valve to allow oil to return through the DCV to the tank.
- This happens when the push button is actuated to permit the pilot pressure actuation of DCV or when the DCV is directly manually actuated when the pump operates.
- The pilot-operated DCV allows free flow in the opposite direction to retract the cylinder when this DCV returns to its offset mode.

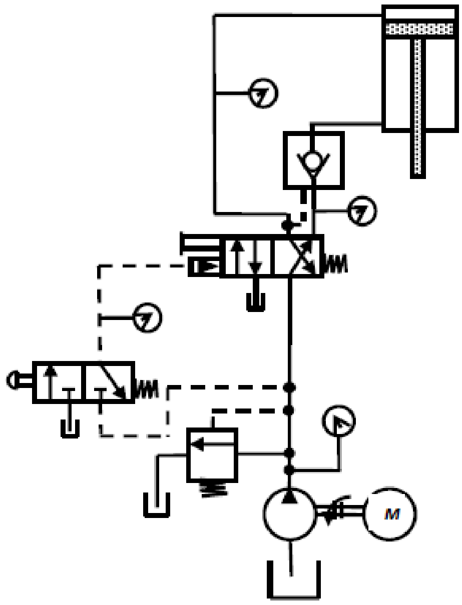


Fig.6.12 Protection from Inadvertent Cylinder Extension

6.11.2 Fail-Safe System with Overload Protection

- Figure 5.11 shows a fail-safe system that provides overload protection for system components. The DCV V1 is controlled by the push-button three-way valve V2.

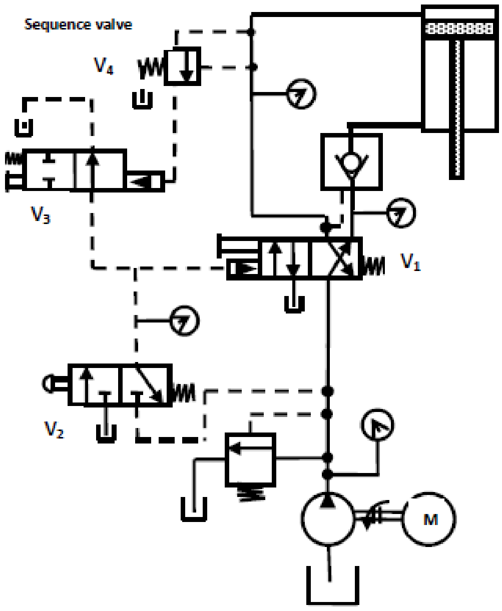


Fig.6.13 Fail-Safe System with Overload Protection

- When the overload valve V3 is in its spring offset mode, it drains the pilot line of valve V1. If the cylinder experiences excessive resistance during the extension stroke, sequence valve V4 pilot-actuates overload valve V3.
- This drains the pilot line of valve V1 causing it to return to its spring offset mode. If a person then operates the push-button valve V2 nothing happens unless overload valve V3 is manually shifted into its blocked-port configuration.
- Thus, the system components are protected against excessive pressure due to an excessive cylinder load during its extension stroke.

Prof. Sagar S. Kanjiya, Department of Mechanical Engineering

6.12 Introduction of Pneumatic Circuit

- Pneumatic control systems can be designed in the form of pneumatic circuits. A pneumatic circuit is formed by various pneumatic components, such as cylinders, directional control valves, flow control valves, pressure regulator, signal processing elements such as shuttle valve, two pressure valve etc. Pneumatic circuits have the following functions
    - To control the entry and exit of compressed air in the cylinders.
    - To use one valve to control another valve
    - To control actuators or any other pneumatic devices
- A pneumatic circuit diagram uses pneumatic symbols to describe its design. Some basic rules must be followed when drawing pneumatic diagrams.
- To be able to design pneumatic circuits, it is better for one to have basic knowledge on the designing simple pneumatic circuits. With this foundation, one would be able to move on to the designing more complicated circuits involving many more cylinders.

6.13 Control of Single Acting Cylinder

6.13.1 Direct Control of Single Acting Cylinder

- Pneumatic cylinders can be directly controlled by actuation of final directional control valve (Figure 6.14). These valves can be controlled manually or electrically. This circuit can be used for small cylinders as well as cylinders which operates at low speeds where the flow rate requirements are less.

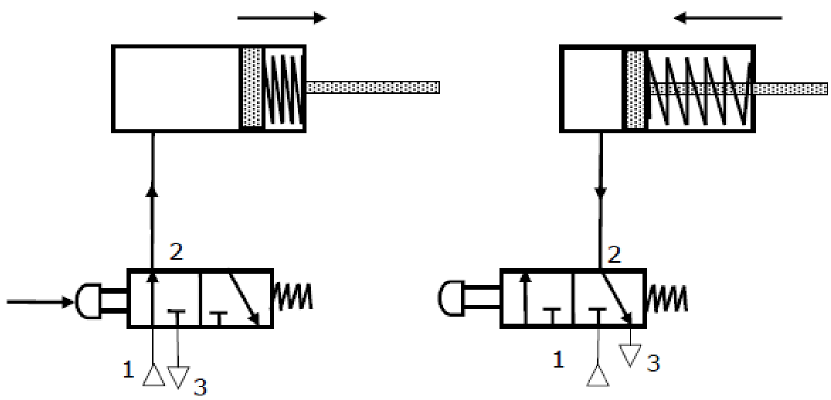


Fig.6.14 Direct control of a single acting cylinder

- When the directional control valve is actuated by push button, the valve switches over to the open position, communicating working source to the cylinder volume. This results in the forward motion of the piston. When the push button is released, the reset spring of the valve restores the valve to the initial position [closed].
- The cylinder space is connected to exhaust port there by piston retracts either due to spring or supply pressure applied from the other port.

6.13.2 Example-1

A small single acting cylinder is to extend and clamp a work piece when a push button is pressed. As long as the push button is activated, the cylinder should remain in the clamped position. If the push button is released, the clamp is to retract. Use additional start button. Schematic diagram of the setup is shown in *Fig.6.15*.

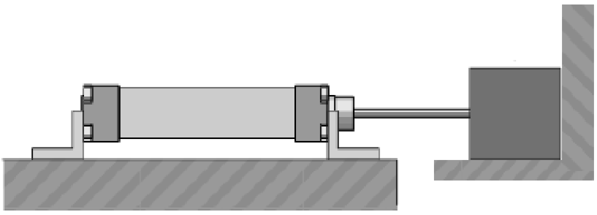


Fig.6.15

Solution

- The control valve used for the single acting cylinder is the 3/2 way valve. In this case, since the cylinder is of small capacity, the operation can be directly controlled by a push button 3/2 way directional control valve with spring return.

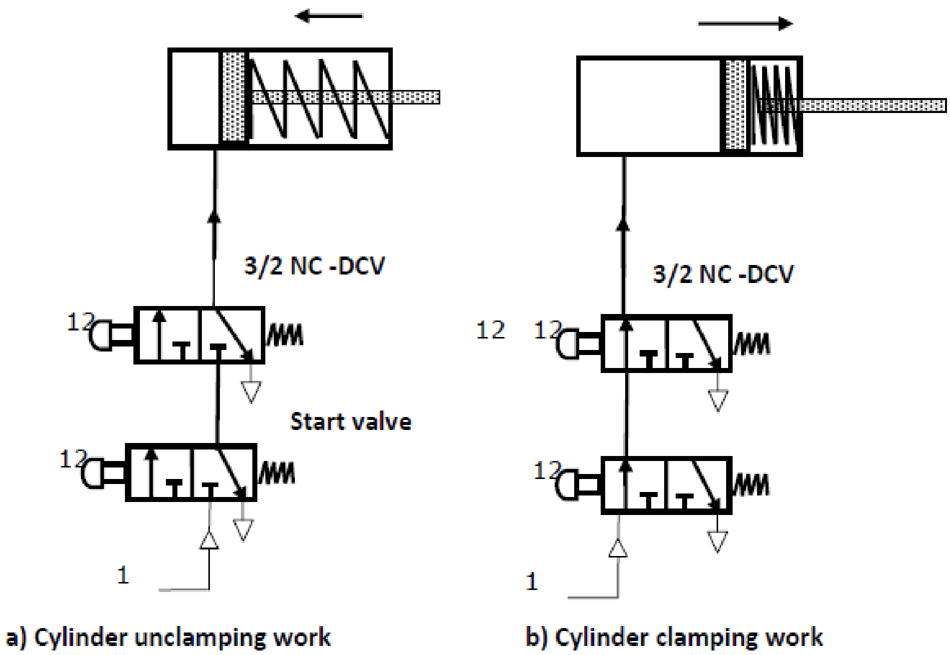


Fig.6.16

- When start button and 3/2 NC valve is operated, cylinder moves forward to clamp the work piece. When start button and 3/2 way valve is released cylinder comes back to the retracted position as shown in *Fig.6.16*.

6.13.3 Indirect Control of Single Acting Cylinder

- This type of circuit (Figure 6.17) is suitable for large single cylinders as well as cylinders operating at high speeds. The final pilot control valve is actuated by normally closed 3/2 push button operated valve. The final control valves handle large quantity of air.
- When the push button is pressed, 3/2 normally closed valve generate a pilot signal 12 which controls the final valve thereby connecting the working medium to piston side of the cylinder so as to advance the cylinder.
- When the push button is released, pilot air from final valve is vented to atmosphere through 3/2 NC – DCV.

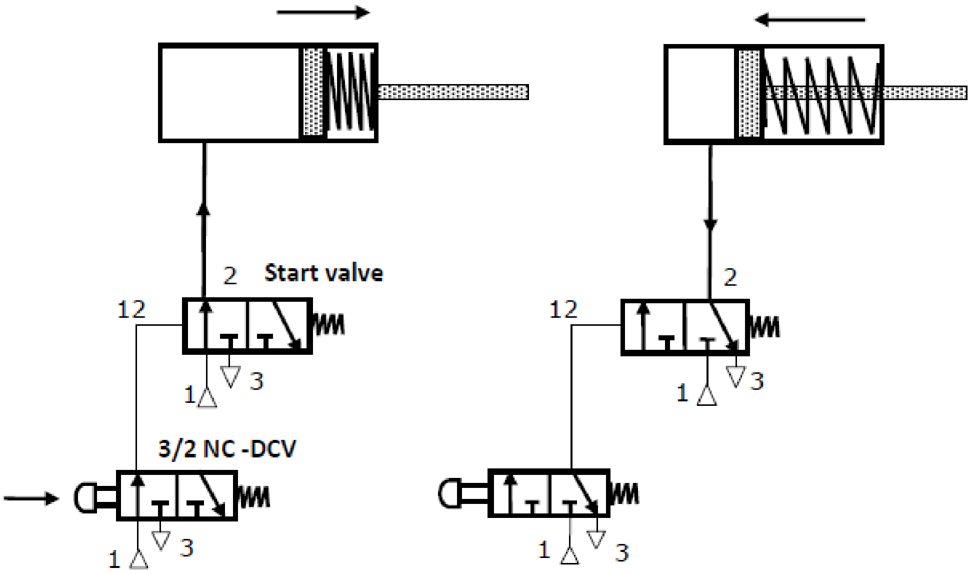


Fig.6.17 Indirect Control of Single Acting Cylinder

- The signal pressure required can be around 1-1.5 bar. The working pressure passing through the final control valve depends on the force requirement which will be around 4-6 bar.
- Indirect control as permits processing of input signals. Single piloted valves are rarely used in applications where the piston has to retract immediately on taking out the set pilot signal.

6.13.4 Example-2

A large single acting cylinder is to extend and clamp a work piece when a push button is pressed. As long as the push button is activated, the cylinder should remain in the clamped position. If the push button is released, the clamp is to retract. Use additional start button.

Solution

- The control valve used for the single acting cylinder is the 3/2 way valve. In this case, since the cylinder is of large capacity, the operation cannot be directly controlled by a push button 3/2 way directional control valve with spring return. Indirect control is to be used as shown in the *Fig.6.18*.
- Valve 2 is a small capacity valve which controls the large capacity valve 3. When the valve 2 is unactuated the cylinder is in the retracted condition. When the valve 2 is actuated the cylinder is in the extended position to clamp the work piece.

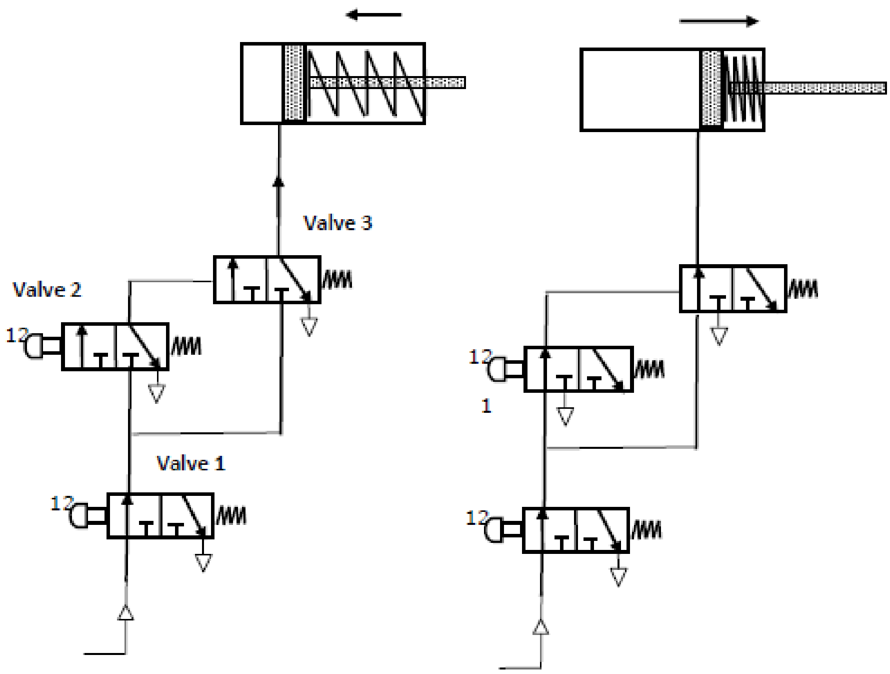


Fig.6.18

6.13.5 Control of Single Acting Cylinder Using "OR" Valve (Shuttle Valve)

- Shuttle valve is also known as double control valve or double check valve. A shuttle valve has two inlets and one outlet (Figure 6.19). At any one time, flow is shut off in the direction of whichever inlet is unloaded and is open from the loaded inlet to the outlet. This valve is also called an OR valve.
- A shuttle valve may be installed for example, when the cylinder or valve is to be actuated from two points, which may be remote from one another.

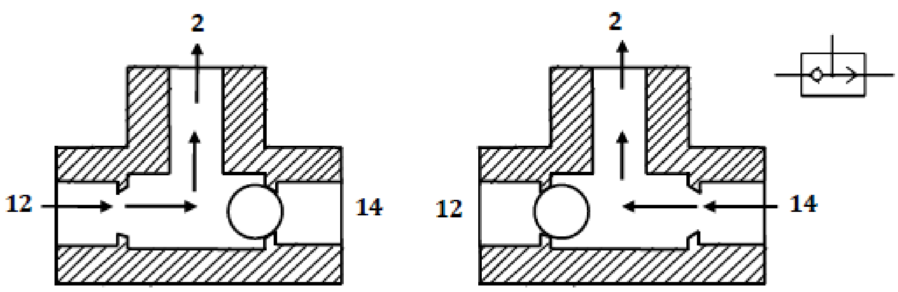


Fig.6.19 Shuttle Valve

- The single acting cylinder in Fig.6.20 can be operated by two different circuits. Examples include manual operation and relying on automatic circuit signals, that is, when either control valve 1 or control valve 2 is operated, the cylinder will work. Therefore, the circuit in Fig.6.20 possesses the OR function.

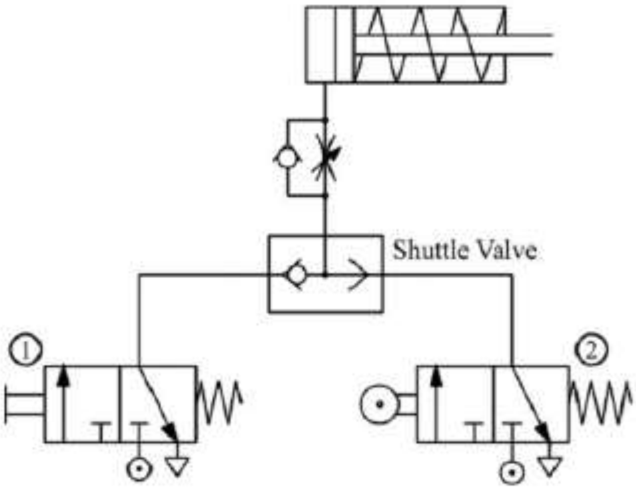


Fig.6.20 Control of a single acting cylinder using OR valve

6.13.6 Control of Single Acting Cylinder Using "AND" Valve (Non Return Valve)

- This valve is the pneumatic AND valve. It is also derivate of Non Return Valve. A two pressure valve requires two pressurised inputs to allow an output from itself. The cross sectional views of two pressure valve in two positions are given in *Fig.6.21*.

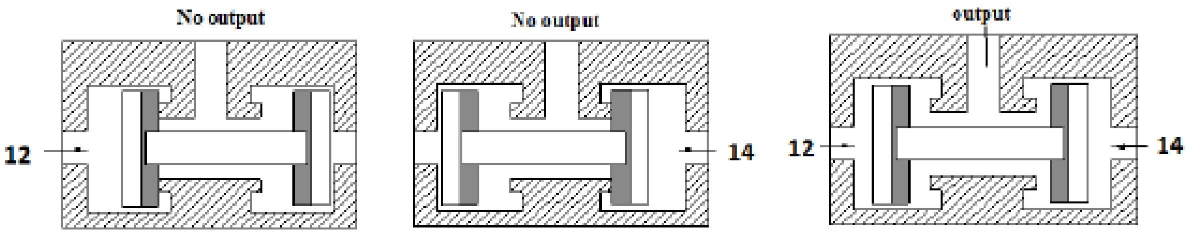


Fig.6.21 AND Valve

- As shown in the *Fig.6.21*, this valve has two inputs 12 and 14 and one output 2. If the compressed air is applied to either 12 or input 14, the spool moves to block the flow, and no signal appears at output 2. If signals are applied to both the inputs 12 and 14, the compressed air flows through the valve, and the signal appears at output 2.

6.14 Control of Double Acting Cylinder

6.14.1 Direct Control of Double Acting Cylinder

- The only difference between a single acting cylinder and a double acting cylinder is that a double acting cylinder uses a 5/2 directional control valve instead of a 3/2 directional control valve (Figure 6.22).
- Usually, when a double acting cylinder is not operated, outlet 'B' and inlet 'P' will be connected. In this circuit, whenever the operation button is pushed manually, the double acting cylinder will move back and forth once.

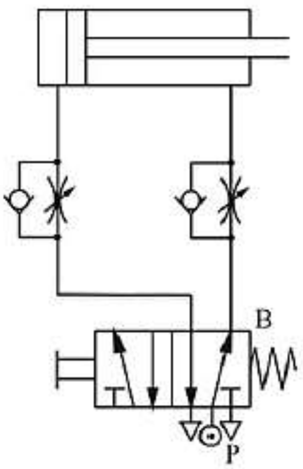


Fig.6.22 Direct Control of Double Acting Cylinder

- In order to control the speed in both directions, flow control valves are connected to the inlets on both sides of the cylinder. The direction of the flow control valve is opposite to that of the release of air by the flow control valve of the single acting cylinder.
- Compared to the throttle inlet, the flow control valve is tougher and more stable. Connecting the circuit in this way allows the input of sufficient air pressure and energy to drive the piston.

6.14.2 Example-3

Pneumatic system is to be designed to operate a door of public transport vehicles. (Figure 6.23). Assuming that the opening and closing of the doors are controlled by two button switches ON and OFF. When the button switch ON is pressed, the door will open. When the button switch OFF is pushed, the doors will close.

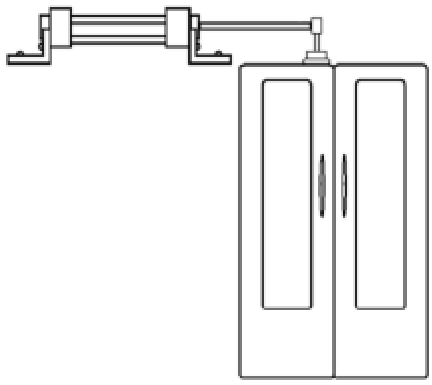


Fig.6.23 Operation of pneumatic system that controls the door of vehicle

Solution

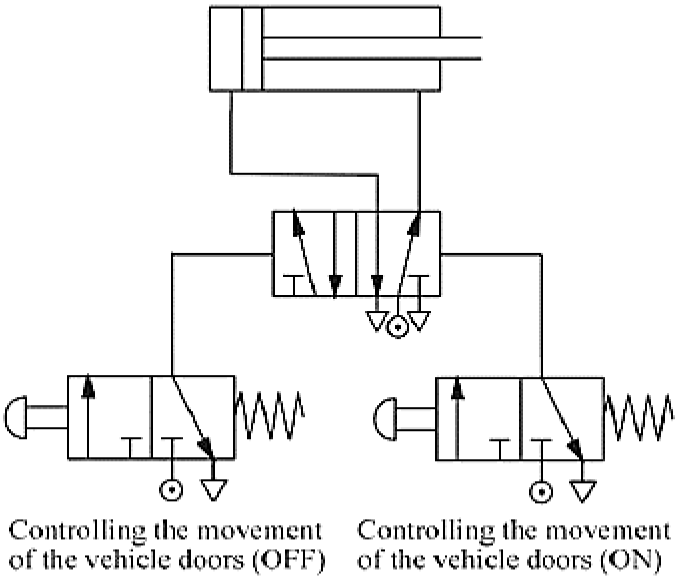


Fig.6.24 Pneumatic circuit to control the door of vehicle

6.14.3 Indirect Control of Double Acting Cylinder Using Memory Valve

- When the 3/2 way valve meant for Forward motion (Figure 6.25 b) is pressed, the 5/2 memory valve switches over through the signal applied to its pilot port 14. The piston travels out and remains in the forward end position.
- Double piloted valve is also called as the Memory valve because now even if this push button meant Forward is released the final 5/2 control valve remains in the actuated status as the both the pilot ports of 5/2 valves are exposed to the atmosphere pressure and the piston remains in the forward end position.

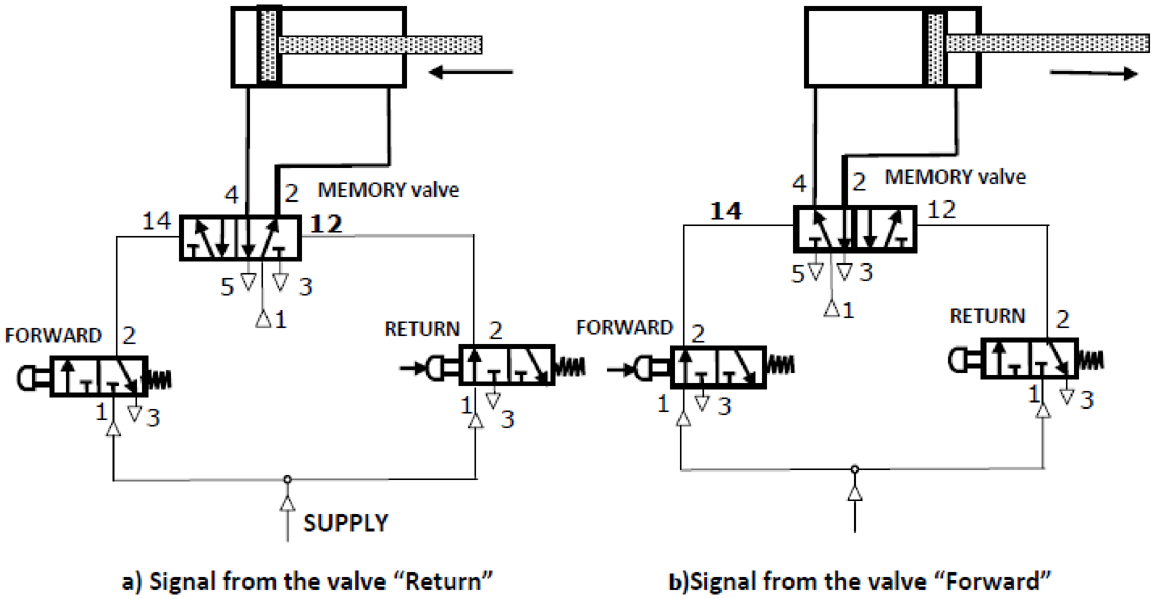


Fig.6.25 Indirect control of double acting cylinder using memory valve

- When the 3/2 way valve meant for return motion (Figure 6.25 a) is pressed, the 5/2 way valve switches back to initial position through the signal applied to its pilot port 12. The piston then returns to its initial position and remains in the rear end position. Now even if the Return push button is released the status of the cylinder will not change.

- The circuit is called a memory circuit because it uses a 5/2 way double pilot memory valve. 5/2 way valve can remember the last signal applied in terms of the position of the spool in the absence of reset springs, thus memorizing or storing the pneumatic signal. Double piloted 4/2 way valve also can be used as memory valve.

6.15 Supply Air Throttling and Exhaust Air Throttling

- It is always necessary to reduce the speed of cylinder from maximum speed based on selected size of final control valve to the nominal speed depending on the application.
- Speed control of Pneumatic Cylinders can be conveniently achieved by regulating the flow rate supply or exhaust air.
- The volume flow rate of air can be controlled by using flow control valves which can be either two way flow control valve or one way flow control valve
- There are two types of throttling circuits for double acting cylinders:
    1. Supply air throttling
    2. Exhaust air throttling

6.15.1 Supply Air Throttling

- This method of speed control of double acting cylinders is also called meter-in circuit (Figure 6.26). For supply air throttling, one way flow control valves are installed so that air entering the cylinder is throttled.

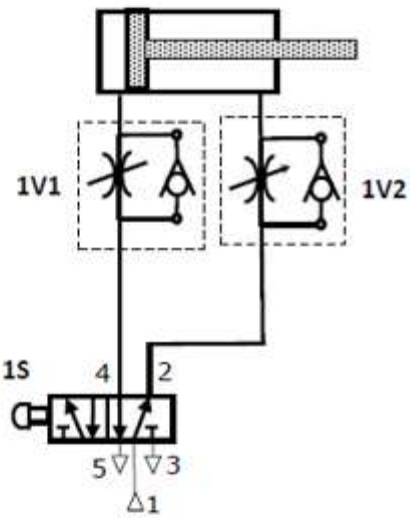


Fig.6.26 Supply air throttling circuit

- The exhaust air can escape freely through the check valve of the throttle valve on the outlet side of the cylinder. There is no air cushion on the exhaust side of the cylinder piston with this throttling arrangement. As a result, considerable differences in stroking velocity may be obtained even with very small variations of load on the piston rod.
- Any load in the direction of operating motion will accelerate the piston above the set velocity. Therefore supply air throttling can be used for single acting and small volume cylinders.

6.15.2 Exhaust Air Throttling

- This method of speed control of double acting cylinders is also called meter-out (Figure 6.27). In exhaust air throttling throttle relief valves are installed between the cylinder and the main valve in such a way that the exhaust air leaving the cylinder is throttled in both directions of the motion of the cylinder.

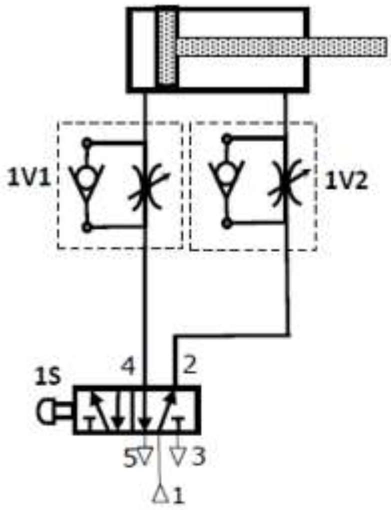


Fig.6.27 Exhaust air throttling circuit

- The supply air can pass freely through the corresponding check valves in each case. In this case, the piston is loaded between two cushions of air while the cylinder is in motion and hence a smooth motion of the cylinder can be obtained.
- The first cushion effect is due to supply air entering the cylinder through check valve, and second cushion effect is due to the exhaust air leaving the cylinder through the throttle valve at a slower rate. Therefore, exhaust air throttling is practically used for the speed control of double acting cylinders.
- Arranging throttle valves in this way contributes substantially to the improvement of feed behaviour.

6.16 Time Dependent Controls

- Pneumatic timers are used to create time delay of signals in pilot operated circuits. Available as normally closed timers and normally open timers. Usually pneumatic timers are on delay timers.
- Delay of signals is very commonly experienced in applications such as bonding of two pieces. Normally open pneumatic timers are also used in signal elimination. Normally open pneumatic timers are used as safety device in two hand blocks
- Time delay valve is a combination of a pneumatically actuated 3/2 direction control valve, an air reservoir and a throttle relief valve.
- The time delay function is obtained by controlling the air flow rate to or from the reservoir by using the throttle valve. Adjustment of throttle valve permits fine control of time delay between minimum and maximum times.
- In pneumatic time delay valves, typical time delays in the range 5-30 seconds are possible. The time delay can be extended with the addition of external reservoir.

- Pneumatic timer can be classified as
    1. On –delay timer
    2. Off – delay timer
- In on-delay timer, the 3/2 DCV is actuated after a delay with reference to the application of pilot

signal and is rest immediately on the application of the pilot signal. In off delay timer, the 3/2 DCV is actuated immediately on the application of the pilot signal and is reset only after a delay with reference to the release of the pilot signal.

- Pneumatic timers can also be classified according to type of pneumatically actuated 3/2 DCV as:
  1. Time delay valve, NC type
  2. Time delay valve, NO type.

6.16.1 Time Delay Valve, NC type

- The constructions of an on-delay timer (NC) type in the normal and actuated are shown in *Fig.6.28*. It can be seen that 3/2 DCV operates in the on delay mode permanently. But, in some designs, the valve can be operated in the off-delay mode by connecting the check valve in reverse direction. For this purpose, the ports of the throttle check valve should be brought out.

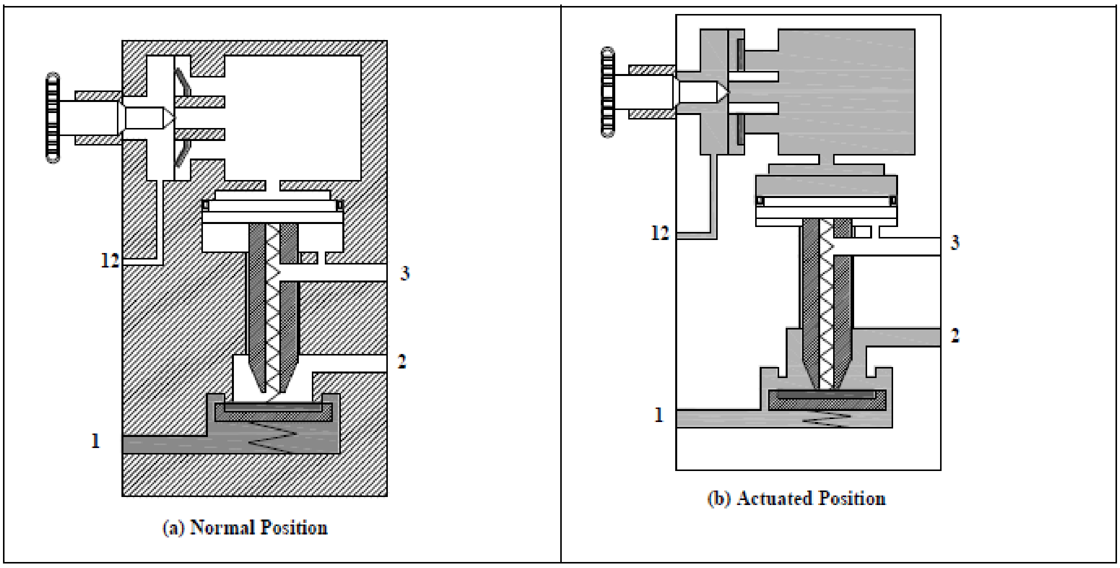


Fig.6.28

6.16.2 Time Delay Valve, NO type

- The construction and function of an on-delay timer (NO) type is similar to that of an on-delay timer (NC) type except for the type of 3/2 DCV valve. In the on-delay valve (NO) type, a 3/2 DCV (NO) type is used whereas in the on-delay timer (NC) type, a 3/2 DCV (NC) type is used.

6.17 Single Actuator Circuit Versus Multi Actuator Circuit

- 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 work piece. 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

1. Classic method or Intuitive method
2. Cascade method
3. Step counter method
4. Karnaugh–veitch method
5. Combinational circuit design

6.17.1 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

6.17.2 Example-4

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

Solution:

- 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

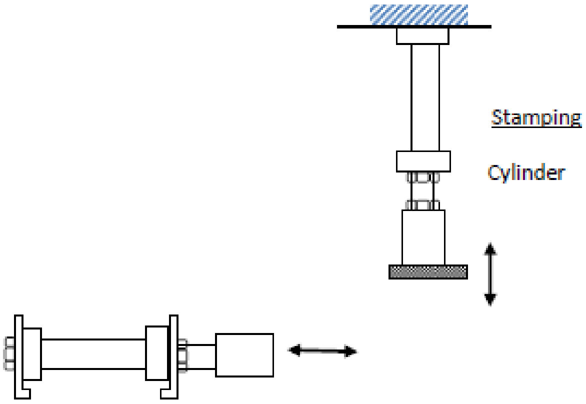


Fig.6.29 Positional layout

- 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

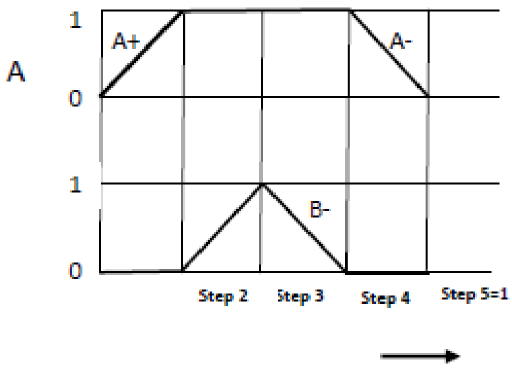


Fig.6.30 Displacement step diagram

- Step 5: Draw the Displacement –time diagram

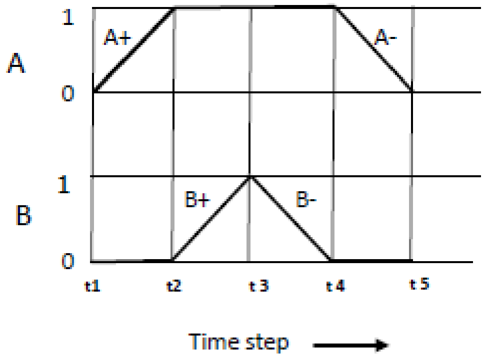


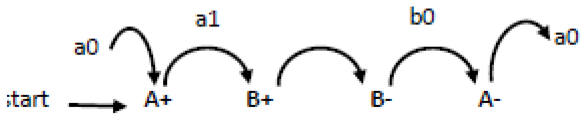
Fig.6.31 Displacement time diagram

- Step 6: Analyse and Draw Pneumatic circuit.
- Step 6.1 Analyse input and output signals.

Input Signals:
  - *Cylinder A – Limit switch at home position ao*
  - *Limit switch at home position a1*
  - *Cylinder B - Limit switch at home position bo*
  - *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.
- Usually start signal is also required along with a0 signal for obtaining A+ motion.
  - A+ action generates sensor signal a1, which is used for B+ motion
  - B+ action generates sensor signal b1, which is used for B- motion
  - B- action generates sensor signal b0, which is used for A- motion
  - A- action generates sensor signal a0, which is used for A+ motion



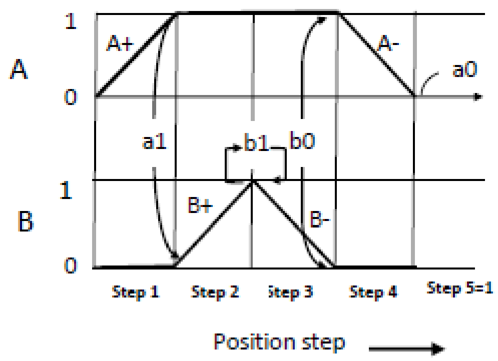


Fig.6.32 Input/output signal flow

- Step 7: Draw the power circuit
  - Draw the cylinders A(1.0) and B(2.0).
  - Draw the DCVs 1.1 and 2.1 in unactuated conditions
  - Mark the limit switch positions for cylinders A (1.0) and B (2.0).

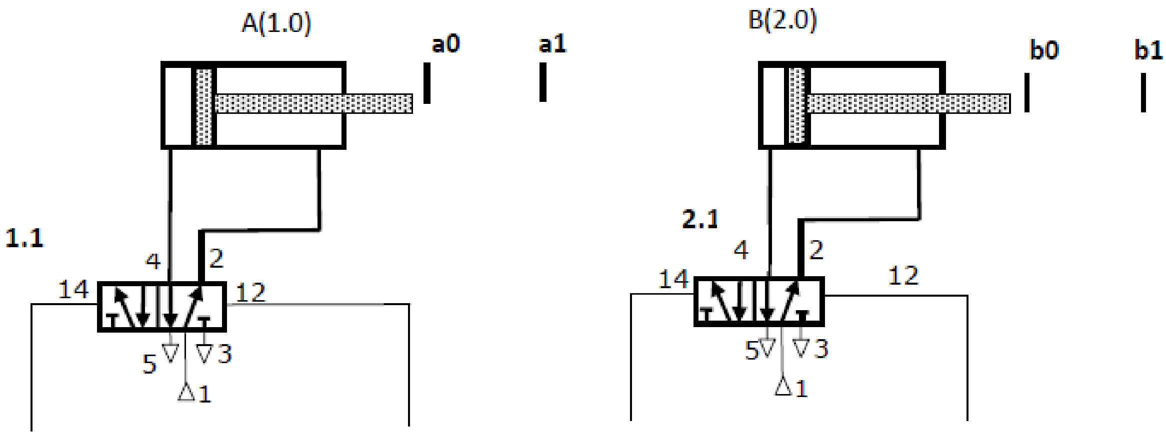


Fig.6.33 Power circuit diagram

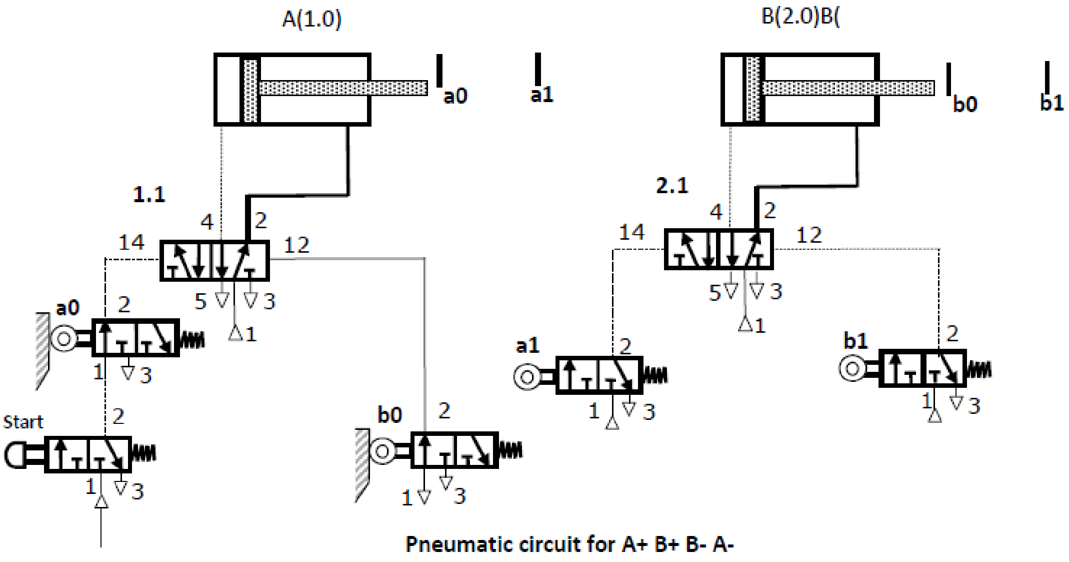


Fig.6.34 Control circuit diagram

- Step 8: Analysis of pneumatic circuit
  - When the start button is pressed, the signal appears at port 14 of valve 1.1 through limit switch signal a0.
  - 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 bo is also pressed). This results in signal conflict and valve 1.1 is unable to move. (Figure 6.36).
  - Let us assume for time being, bo is somehow disengaged so that valve 1.1 can switch over and consequently cylinder A can extend. When the start button is pressed. (Figure 7.24)
  - When cylinder A fully extends, it generates a limit switch signal a1, which is applied to port 14 of the valve 2.1.
  - 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.

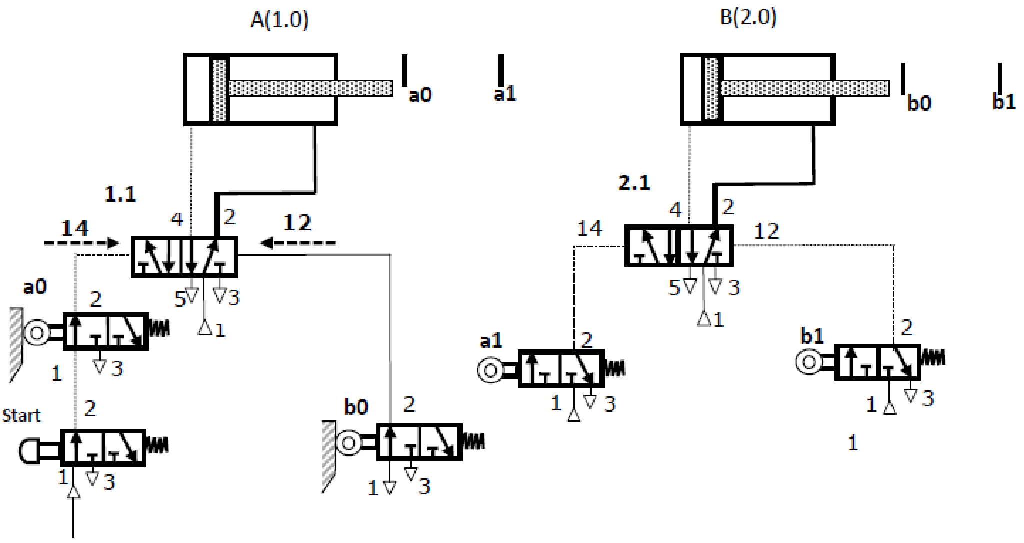


Fig.6.35 Signal conflict at valve 1.1

Prof. Sagar S. Kanjiya, Department of Mechanical Engineering

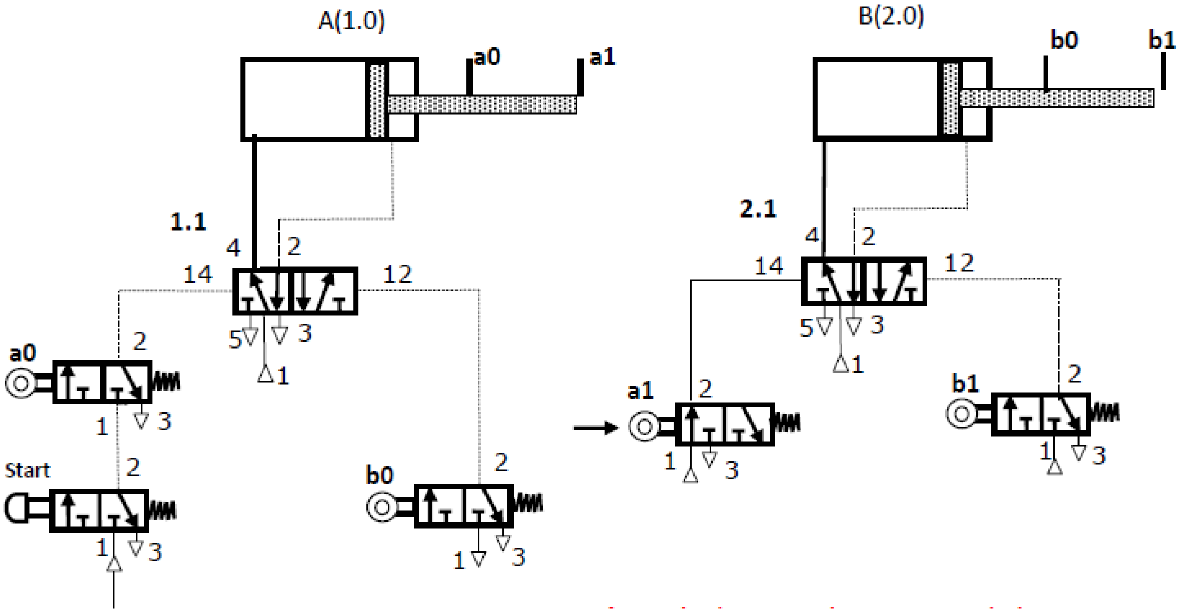


Fig.6.36 Pneumatic circuit after cylinders A and B are extended

- Signal applied to port 14 of the valve 2.1 causes the shifting of DCV 2.1 and cylinder B extends.
- When cylinder B fully extends, it generates a limit switch signal b1, which is applied to port 12 of valve 2.1
- 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 6.38)

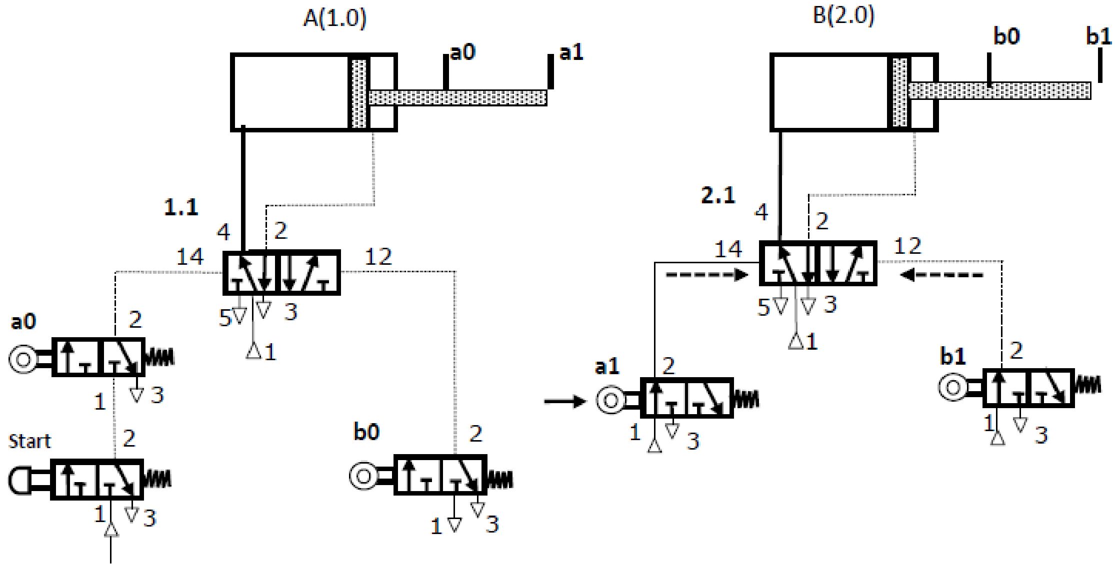


Fig.6.37 Signal conflict at valve 2.1

- 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 6.39)

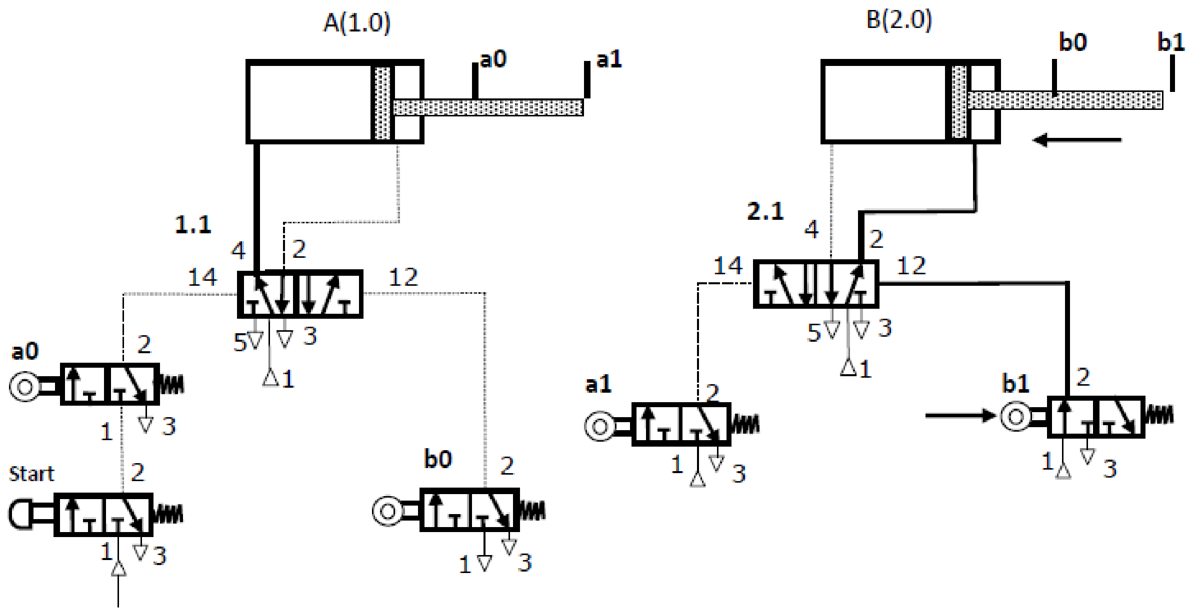


Fig.6.38 Position when cylinder B is reversing (B -)

- 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 6.40)
- 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.

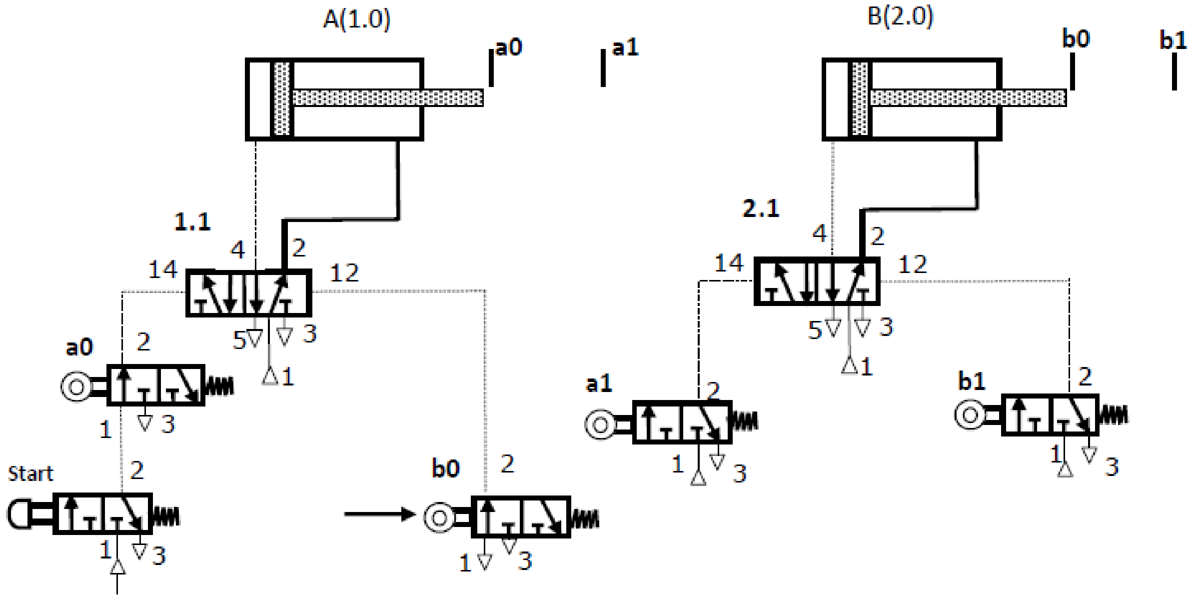


Fig.6.39 Position when cylinder A has retracted fully (A-)

6.18 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.

6.18.1 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.

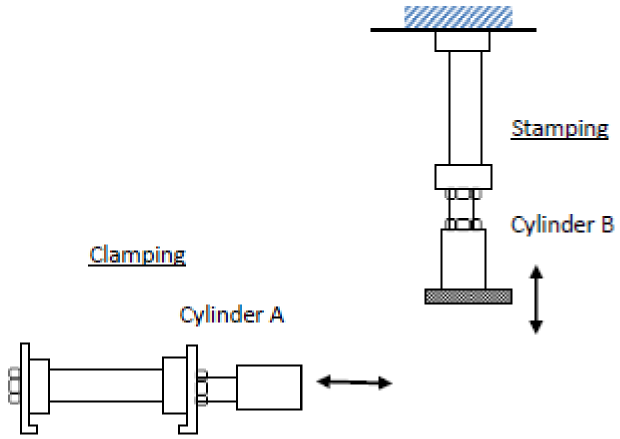


Fig.6.40 Positional diagram

- 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

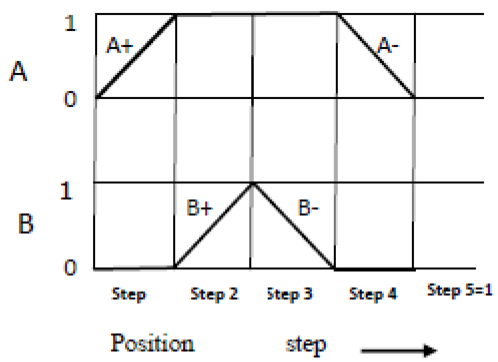


Fig.6.41 Displacement step diagram

- Step 5: Draw the Displacement –time diagram

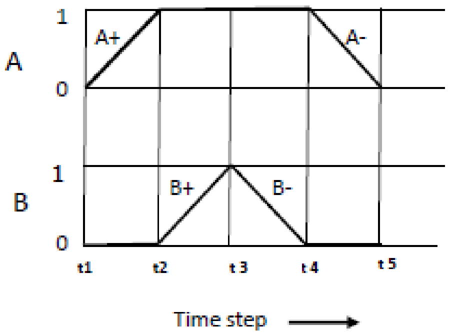
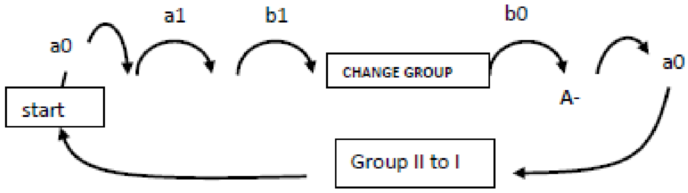


Fig.6.42 Displacement time diagram

- Step 6: Analyse and Draw Pneumatic circuit.
  Step 6.1 Analyse input and output signals.
  Input Signals
  - *Cylinder A – Limit switch at home position ao*
  - *Limit switch at home position a1*
  - *Cylinder B - Limit switch at home position bo*
  - *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 6.44)
- Usually start signal is also required along with a0 signal for obtaining A+ motion.
  - A+ action generates sensor signal a1, which is used for B+ motion
  - B+ action generates sensor signal b1, which is used group changing.
  - B- action generates sensor signal b0, which is used for A- motion
  - A- action generates sensor signal a0, which is used for group changing
- Above information is shown below graphically.



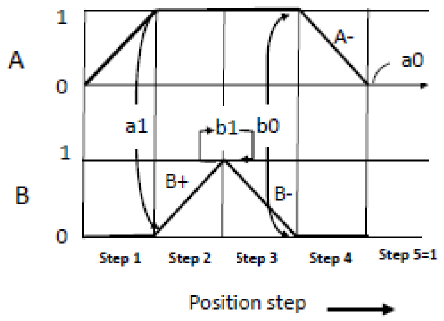


Fig.6.43

- Step 7: Draw the power circuit (Figure 6.45)
  - 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-
  - Group 1 A+ B+ and Group 2 B- A-
  - 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).

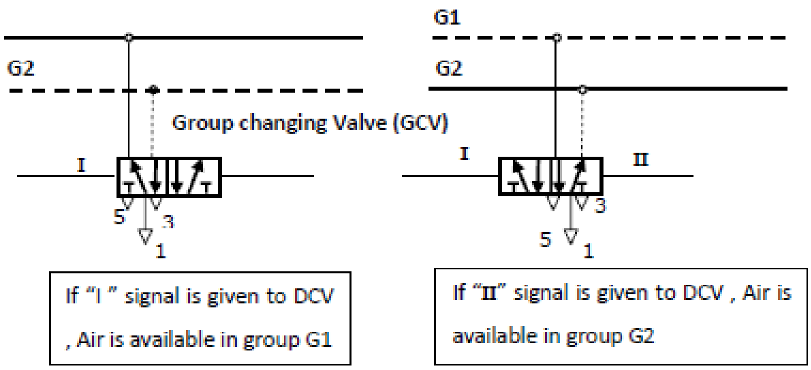


Fig.6.44 Power circuit

- Arrange the limit switch and start button as given below (Figure 6.46)

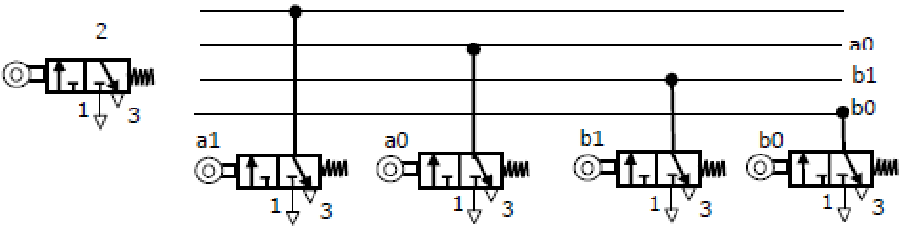


Fig.6.45 Arrangement of limit switches

- Draw the power circuit

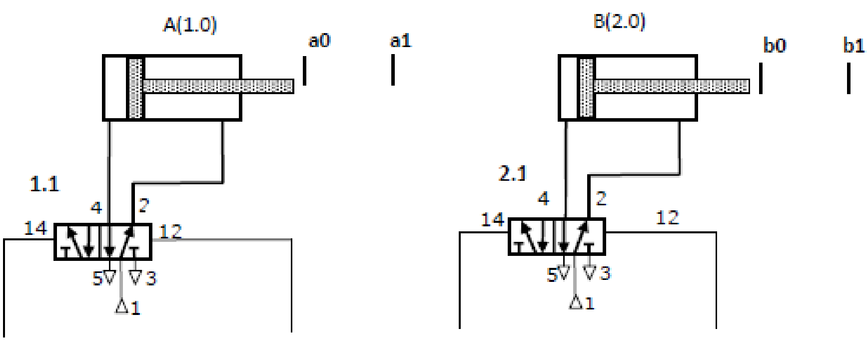


Fig.6.46 Power circuit

- Step 8: Draw the control circuit

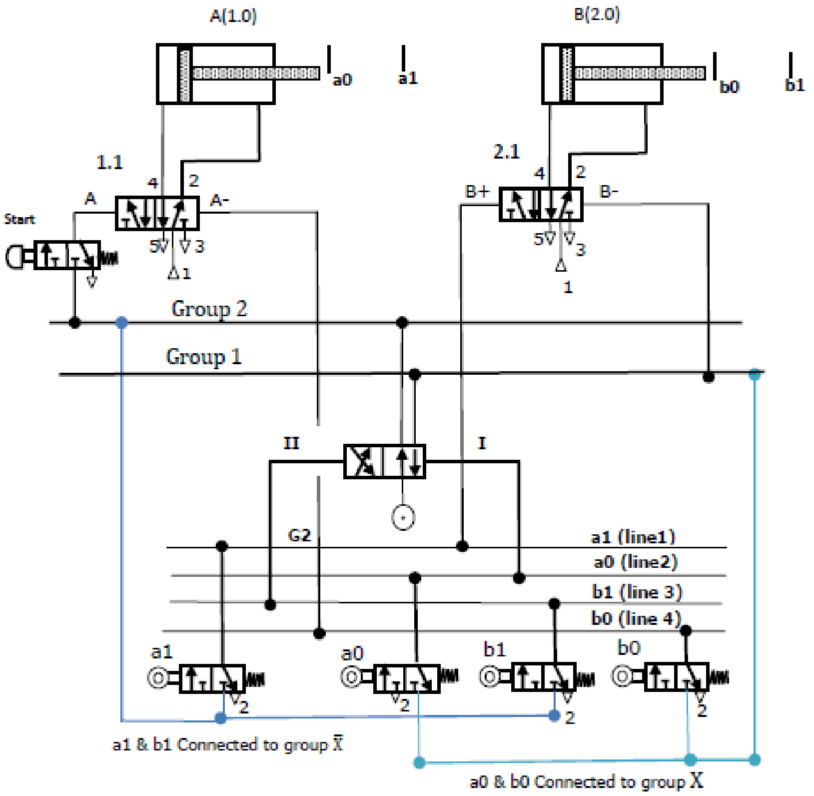


Fig.6.47 Pneumatic circuits for A+ B+ B- A-

- Step 9: Analysis of pneumatic circuit
  - Assume that air is available in the line G2 to start with. (Say from last operation)
  - 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.
  - 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.
  - 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.
  - 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.
  - 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.
  - 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.

Reference Books

1. Basic Pneumatic Systems, Principle and Maintenance by S R Majumdar, McGraw-Hill
2. Pneumatics Concepts, Design and Applications by Jagadeesha T
3. Fluid Power with Applications by Anthony Esposito, Pearson