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Pneumatics and Electro-pneumatics

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1.0 Safety Measures and Procedures when Working with Pneumatic and Electro-Pneumatic Systems

1.1 Introduction

When working with pneumatic and electro-pneumatic systems, we must ensure that we follow the safety rule and practices. Do not be deceived that it is quite safe as we are only working with air. The dangers of working with compressed air are numerous and we must be careful.

1.2 Safe Working Practices

The following maintenance work must be carried out frequently and at short intervals:

- Service unit
  – Check the filter
  – Drain water regularly
  – Refill and set lubricator, if a lubricator is used.
- Check signal generators for possible deposits of dirt or swarf

The following maintenance work can be undertaken at greater time intervals:

- Check the seals of the connectors for leaks
- Replace lines connected to moving parts
- Check the rod bearings in the cylinders for wear and replace if necessary
- Clean or replace filter elements
- Check function of safety valves
- Check mountings

1.3 Maintenance Requirements for Pneumatic Systems

Systematic maintenance helps to prolong service life and improve the functional reliability of pneumatic control systems.

A detailed maintenance plan should be drawn up for every pneumatic system. A maintenance plan lists the maintenance tasks and time intervals. In the case of complex control systems, the maintenance documentation must include a function diagram and circuit diagram.

The time intervals between individual maintenance works to be carried out are dependent on the period of use, the wear characteristics of the individual components and the ambient medium.

As with all systems, preventive maintenance is also applicable to pneumatic systems.

Premature wear or failure of components can be the result of design or planning errors. If the following points are taken into consideration during the planning phase, this minimises the risk of premature machine failure.

- Selection of the appropriate components and signal generators. They should be adjusted to suit the environmental and operational conditions of the system (e.g. switching frequency, heavy loads)

- Protection of components against contamination
- Mechanical absorption of the actuating forces through additional shock absorbers
- Short line lengths, fitted with amplifiers where necessary

1.4 Compressed Air Safety

Compressed air is piped around many workplaces in order to drive tools and to provide the air for certain types of equipment. Compressed air is very dangerous when used for anything but the correct purpose.

- Before opening the valve from the air supply line, check that the hose and connections are not damaged and hold the end of the hose to stop it whipping about when you turn on the air.
- Never use compressed air to clean your clothes or hair. Eye damage or ruptured ear drums result from this. Also, air could enter the blood stream through cuts or scratches on the skin.
- Use rubber gloves if components have to be cleaned with compressed air.
- Never blow down a bench or a machine tool with compressed air. It may blow metal filings and chips for 6 to 10 metres or more.
- Before changing an air tool, close the valve at the supply line and release the pressure in the hose.
- Do not use any pneumatic tool which has a faulty operating valve or governor.

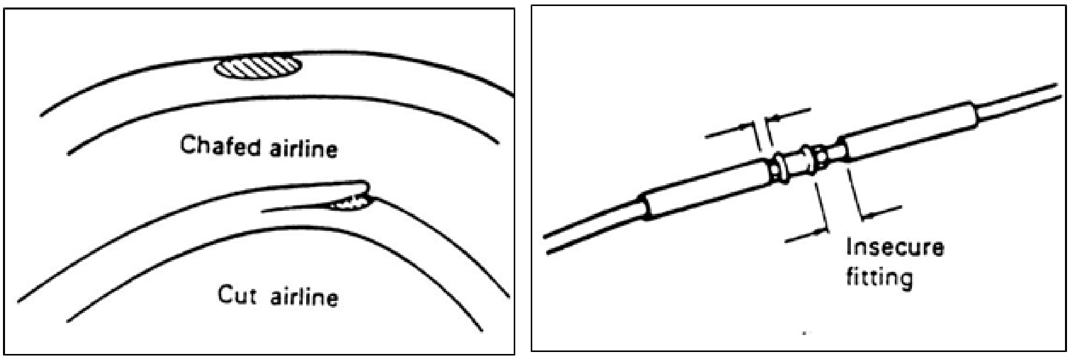


Figure 1.1 - Compressed Air Safety

2.0 Features and Applications of a Pneumatic System

2.1 Introduction

Pneumatics has for some considerable time been used for carrying out the simplest mechanical tasks, but in more recent times has played a more important role in the development of pneumatic technology for automation.

In most of applications compressed air is used for one or more of the following functions:

- To determine the status of processors (sensors)
- Information processing (processors)
- Switching of actuators by means of final control elements
- Carrying out work (actuators)

To be able to control machinery and installations necessitates the construction of a generally complex logic interconnection of statuses and switching conditions. This occurs because of the interaction of sensors, processors, control elements and actuators in pneumatic or partly pneumatic systems.

2.2 Features of a Pneumatic System

The technological progress made in material, design and production processes has further improved the quality and diversity of pneumatic components and thereby contributed to their widely spread use in automation.

Pneumatic components can perform the following types of motion:

- Linear
- Swivel
- Rotary

2.3 Applications of Pneumatic Systems

Some industrial applications employing pneumatics are listed below:

General methods of material handling:

- Clamping
- Shifting
- Positioning
- Orienting

General applications:

- Packaging
- Filling
- Metering
- Driving of axes
- Transfer of materials
- Turning and inverting of parts

- Sorting of parts
- Stacking of components
- Stamping and embossing of components

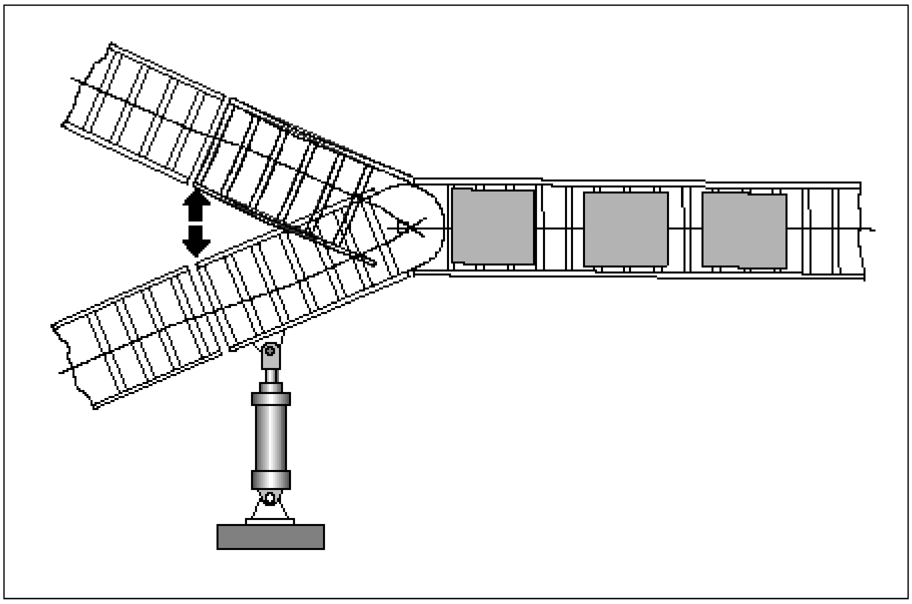


Figure 2.1 – Points Switch for Two Conveyor Belts

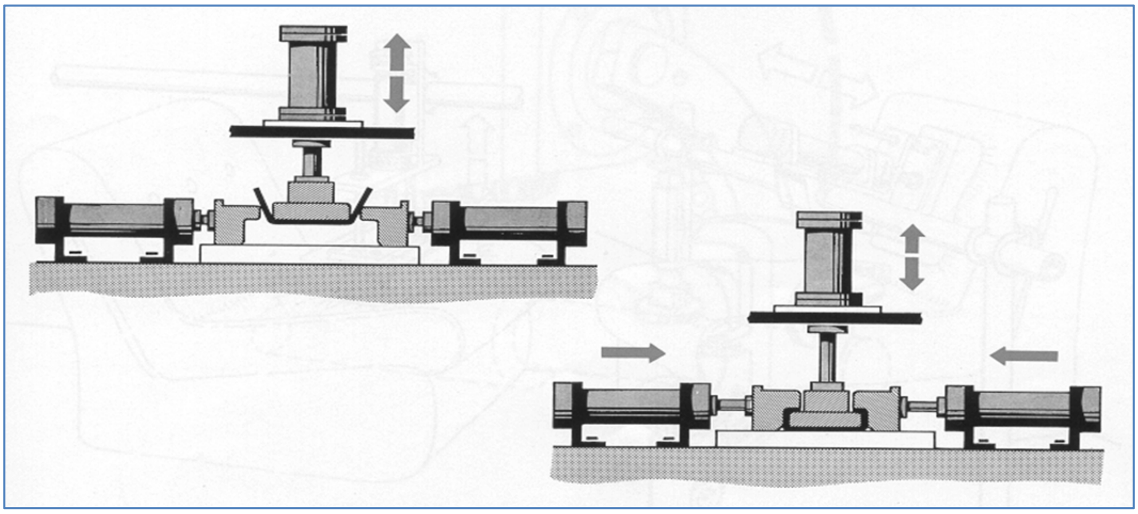


Figure 2.2 – Pneumatics Used in Forming

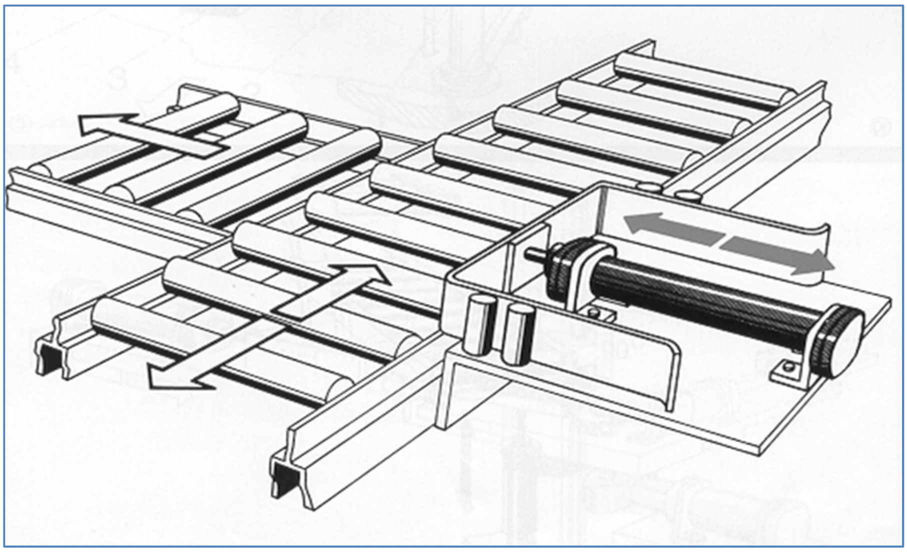


Figure 2.3 – Pneumatics Used in Pushing

Pneumatics is used in carrying out machining and working operations.

For example:

- Drilling
- Turning
- Finishing
- Forming
- Quality control

3.0 Features and Applications of the Compressed Air System

3.1 Introduction

Compressed air is one of the oldest forms of energy known to man and applied to enhance his capability. The deliberate utilization of air as a medium, as well as a more or less deliberate working with this "medium" can be traced back thousands of years. But real practical industrial application of pneumatics in production dates back only to about 1950 where the need for automation and rationalisation of operational sequences continued to increase.

Today, it is not possible to imagine modern factories being without compressed air. For this reason, compressed air devices are installed in the most diverse branches of industry

3.2 Pressure

Pressure is defined as force per unit area.

In mathematical expression:

$$\text{Pressure (P)} = \frac{\text{Force (F)}}{\text{Area (A)}}$$

The unit for pressure is N/m² and is designated Pascal (Pa). Since Pascal denotes such a small pressure, a unit representing KPa or Bar is used.

1 bar = 100000 Pa
= 100 KPa

3.2.1 Atmospheric Pressure

Atmospheric pressure is due to the weight of the mass of air per m^2 on the earth's surface. Atmospheric pressure at sea level is 1.013 bar.

3.2.2 Gauge Pressure

Pressure gauge measures pressure in a pipeline (or in a container) above or below atmospheric pressure. If the gauge shows a zero reading, then the pressure is atmospheric. If the pressure reading is below atmospheric pressure, it is referred to as vacuum and is negative relative to atmospheric pressure.

3.2.3 Absolute Pressure

Absolute pressure is

- Atmospheric Pressure + Gauge Pressure (Pressure above atmospheric pressure)
- Atmospheric Pressure - Vacuum Pressure (Pressure below atmospheric pressure)

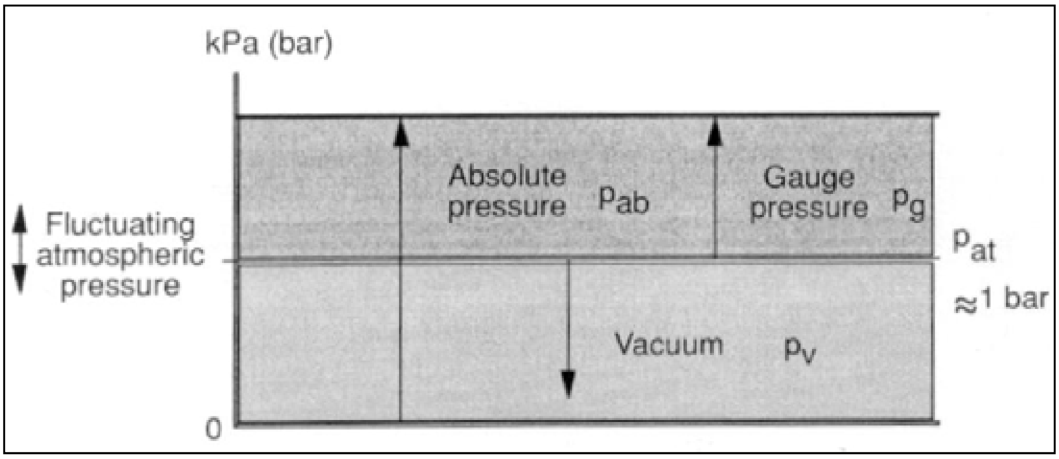


Figure 3.1 - Pressure Differences

3.3 Generation of Compressed Air

The compressed air supply for a pneumatic system should be adequately calculated and made available in the appropriate quality. Air is compressed by the air compressor and delivered to an air distribution system in the factory. To ensure the quality of the air is acceptable, air service equipment is utilised to prepare the air before being applied to the control system.

As a rule, pneumatic components are designed for a maximum operating pressure of 800-1000 kPa (8 - 10 bar) but in practice it is recommended to operate at between 500-600 kPa (5 and 6 bar) for economic use. Due to the pressure losses in the distribution system the compressor should deliver between 650-700 kPa (6.5 and 7) bar to attain these figures.

To understand the need for good air preparation, we will go through the compressed air distribution flow chart.

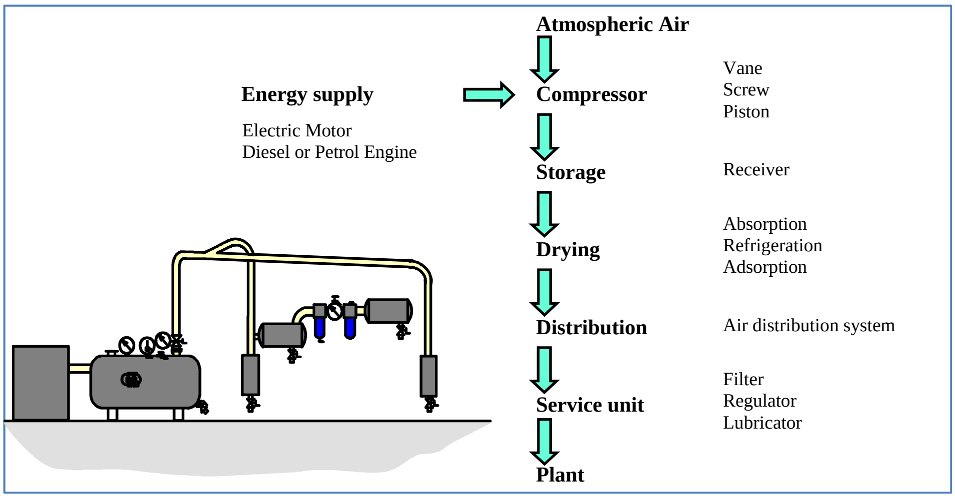


Figure 3.2 – Compressed Air Supply

3.3.1 Air Compressors

The compressor is the first part of the flow chain, it is used to compress the air at atmospheric pressure of about 1 bar to working pressure of 6 to 10 bar. There are a variety of compressors available in the market.

- Reciprocating piston compressor
- Rotary piston compressor
- Flow compressor
- Piston compressor
- Diaphragm compressor
- Radial-flow compressor
- Axial flow compressor
- Sliding vane rotary compressor
- Two-axle screw compressor
- Roots blower

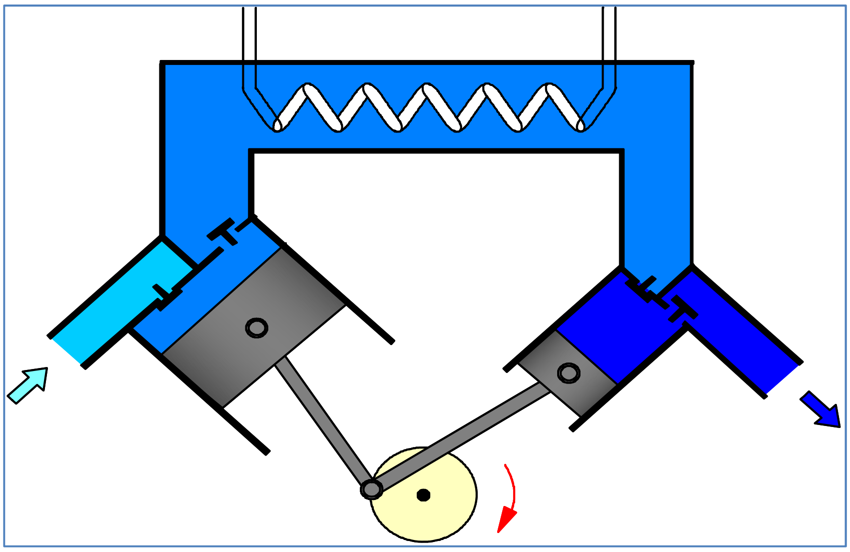


Figure 3.3 – Piston Compressor

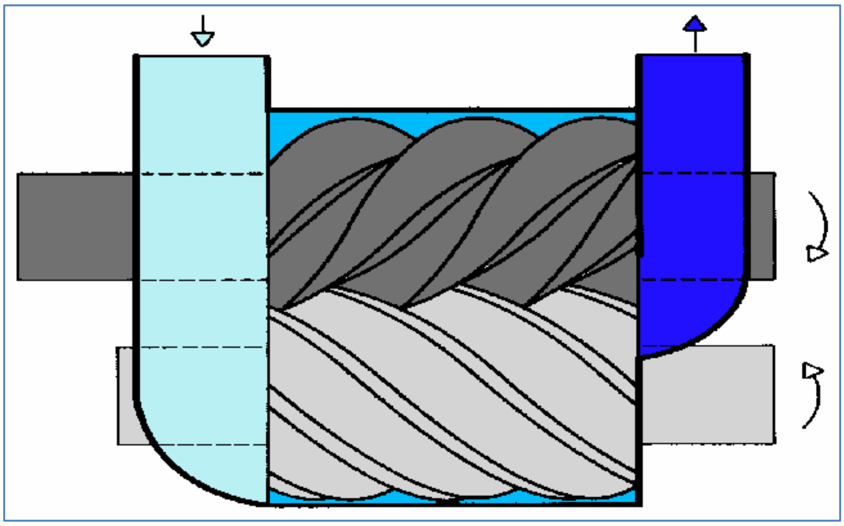


Figure 3.4 – Screw Compressor

3.3.2 Air Receivers

After the compressor has compressed the air to working pressure it is directed to the air receiver. The receiver has several functions:

- Providing constant air pressure in a pneumatic system regardless of fluctuating consumption
- Emergency supply to the system in cases of emergency
- The large surface area cools the air
- Moisture can be separated from the air

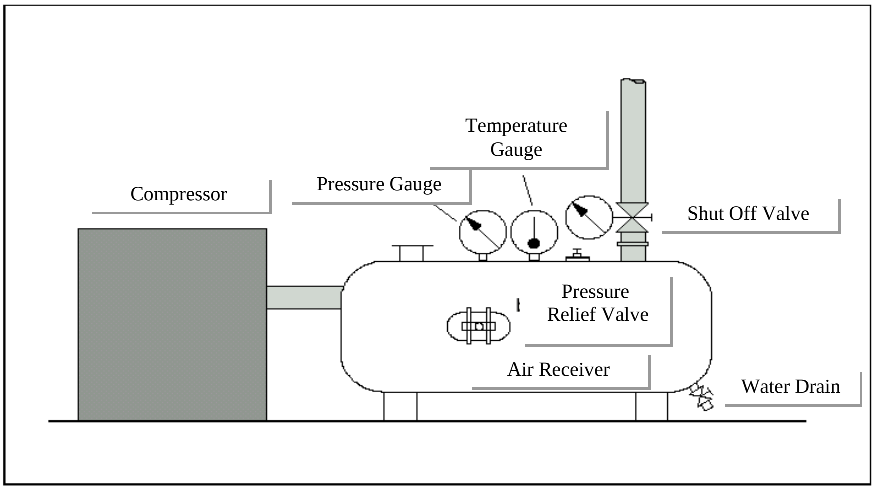


Figure 3.5 – Air Receiver

3.3.3 Air Dryers

Moisture in the system causes considerable damage. If the intercooler and aftercooler do not have the capacity to produce absolute dry compressed air, the air must be put through a further drying process. The three commonly used drying methods are:

- Absorption Drying
- Adsorption Drying
- Low Temperature Drying

a. Low Temperature Drying

If compressed air is cooled down below dew point, condensation occurs and water is precipitated. The compressed air to be cooled flows into the low temperature dryer via the air to air heat exchanger in the first part of the equipment. Here the warm compressed air to be dried is precooled by the cold and dry air flowing out. This causes water and oil to be separated, and thus the refrigerating machinery is required to operate at a capacity of only about 40%. The precooled compressed air enters the refrigerating unit only in the second station. Compressed air is then cooled to a temperature of 1.7°C.

To ensure that the function of the air to air heat exchanger and the refrigerating unit is not affected by oil, a prefilter is provided to ensure that the oil and dirt particles are separated prior to their entry into the drying unit.

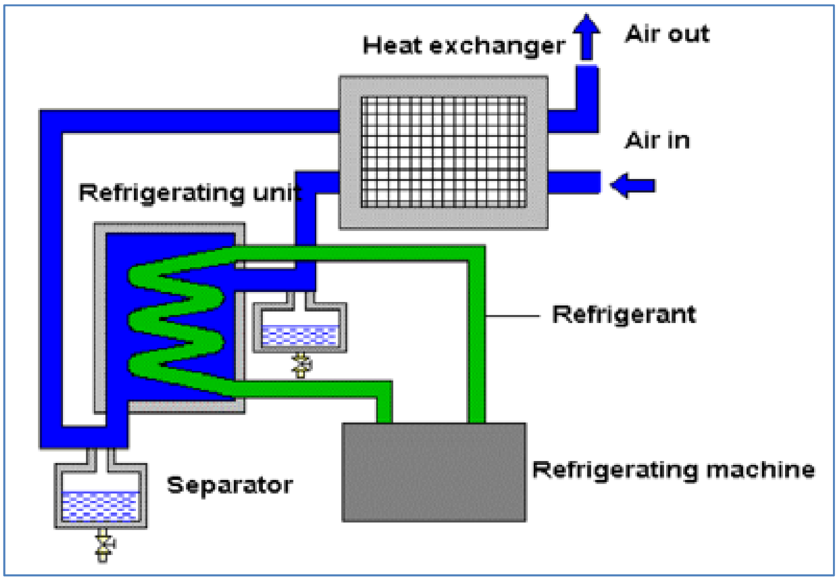


Figure 3.6 – Low Temperature Drying

b. Adsorption Drying

Adsorption drying is based on a physical process. The moisture is deposited onto the surface of a solid body which can be silica gel, activated illumina, or molecular sieves. As the warm moist air passes over the granules, the moisture is removed from the air. The saturated gel bed is generated by a simple method of lowing warm air through the bed and the warm dry air becomes moist as it takes the moisture out of the gel.

The capacity of the gel bed is limited under normal conditions, it will be necessary to replace the drying agent every two to three years.

Once again, a prefilter and a refilter must be used with this system to remove oil at the input and to remove any possible solid material taken from the bed.

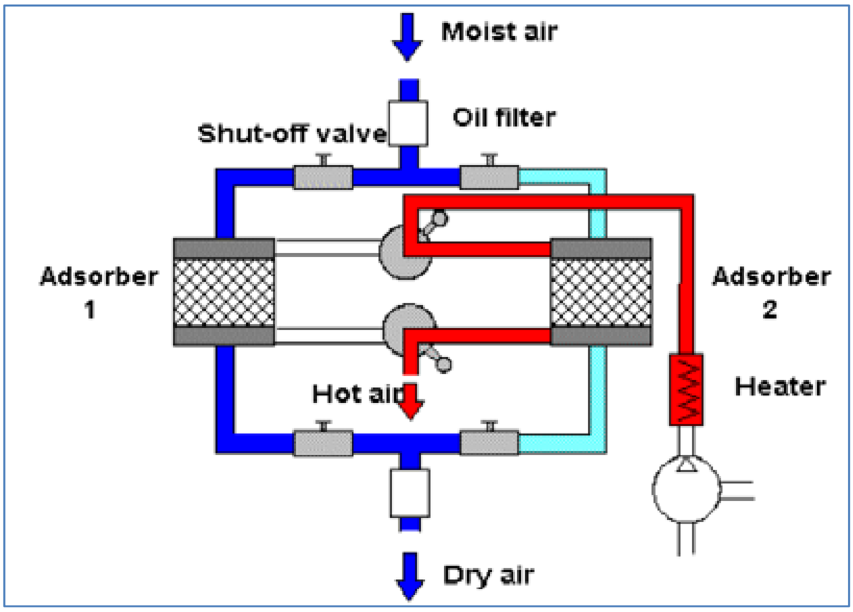


Figure 3.7 – Adsorption Drying

c. *Absorption Drying*

It is a purely chemical process. The air is guided over a bed containing salt tablets, the tablets will absorb the water vapour from the air and become a liquid which will drop to the bottom of the drying tank.

Unfortunately, most of the drying agents used are strongly corrosive and filtering is necessary to ensure that the drying agent is not carried along with the dried air. Prefiltering is also necessary to prevent the oil from damaging the drying agent. A further problem with this type of drying agent is that at temperatures exceeding 30°C the drying agent will soften and bake, which will lead to increased pressure drop through the dryer.

The special features of the absorption process are:

- Simple installation of the equipment.
- Low mechanical wear as there are no moving parts.
- No external energy requirements.

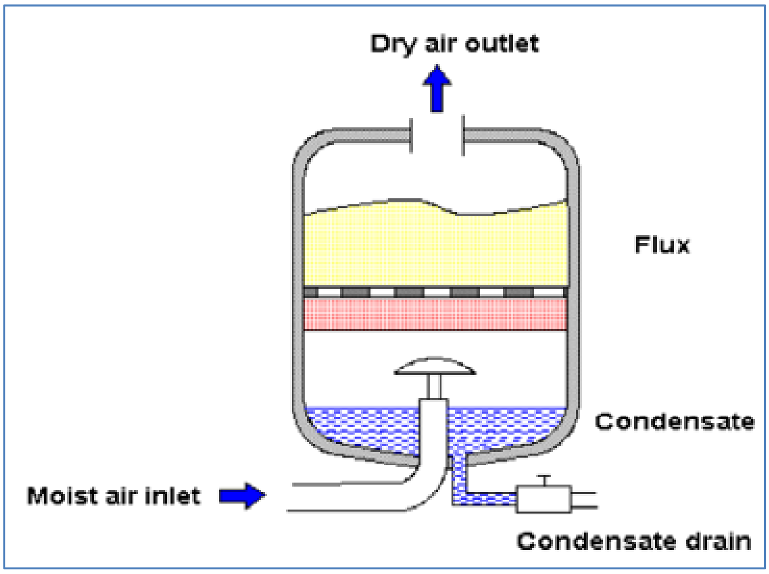


Figure 3.8 – Absorption Drying

The effect of the incorrect preparation of air in the pneumatic system is that we have a loss of repeatability and accuracy of working elements, a loss in the reliability of the operation of valves due to their sticking and the corrosion of metal parts and the inside diameter of cylinder barrels. Thus, it is very important that the preparation of air as outlined is carried out properly and that proper maintenance is conducted on these items to ensure their satisfactory operation.

3.4 Air Service Units

At the plant level, the service unit is the last protection before the air is used in the system.

The Service Unit consists of

- Air Filter
- Pressure Regulator
- Air Lubricator
- Pressure Gauge

3.4.1 Compressed Air Filter

The Air Filter is used for

- Preventing dirt particles from entering into the system
- Separate condensate out of the compressed air.

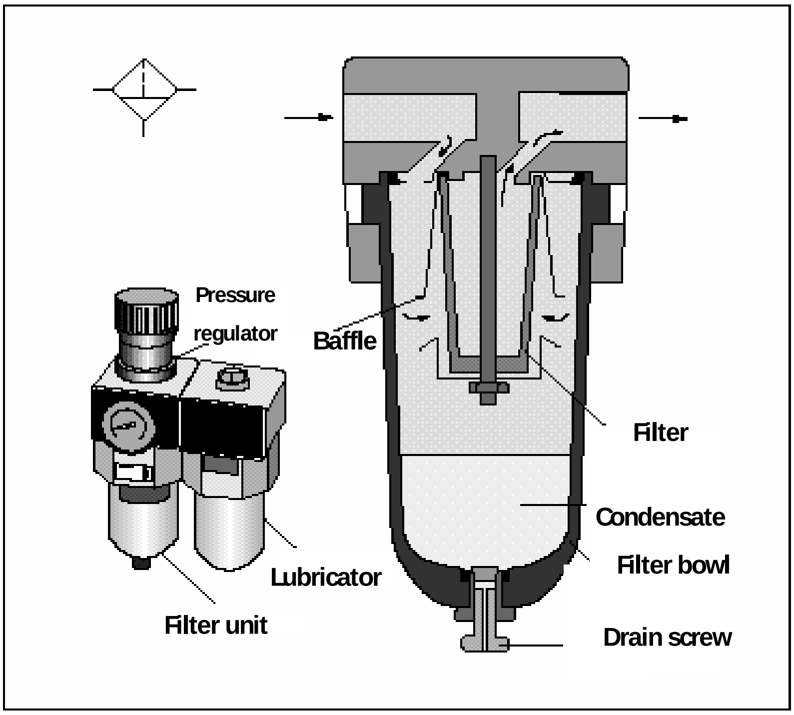


Figure 3.9 – Air Filter

3.4.2 Pressure Regulator

The pressure regulator is used for providing a constant supply pressure irrespective of the pressure fluctuations in the main line

All pneumatic systems have an optimum pressure (6 bar) and is lower than working pressure in the pipeline (10 – 15 bar). Pressure is always fluctuating due to the air being compressible.

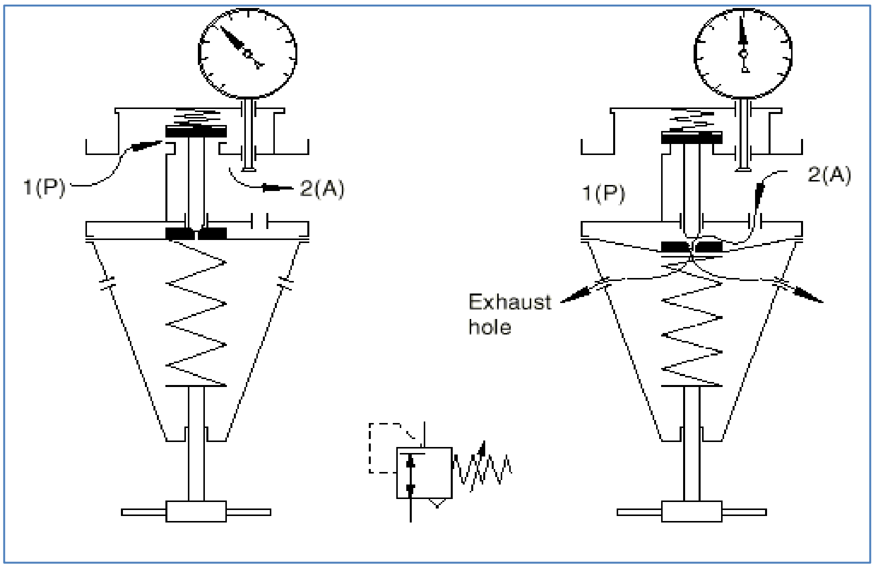


Figure 3.10 – Air Regulator

3.4.3 Compressed Air Lubricator

Lubrication of the compressed air by means of mist lubricators may be necessary in certain cases:

- In cases where extremely rapid oscillating motions are required.
- With cylinders of large diameter, from approximately 125 mm upwards.

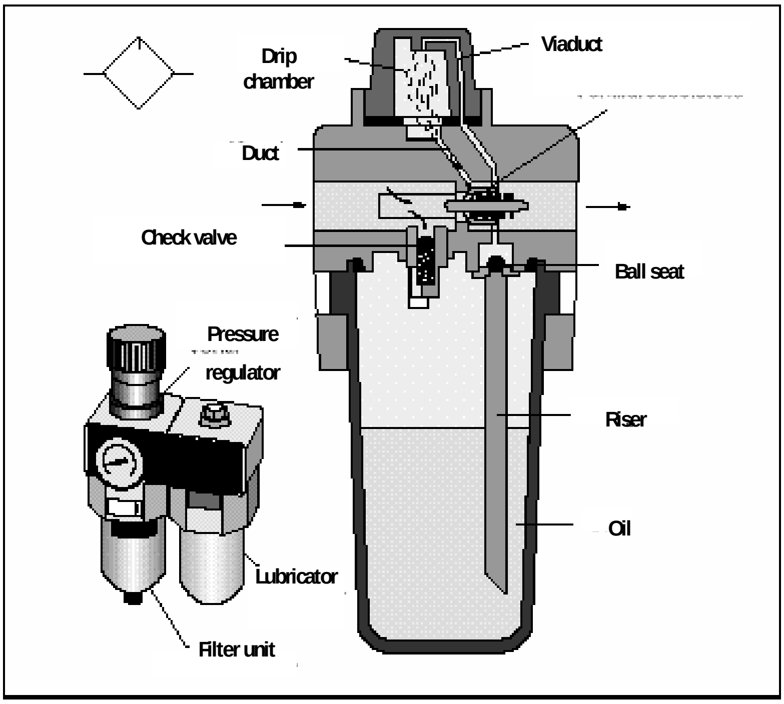


Figure 3.11 – Air Lubricator

3.5 Air Distribution

Owing to the increased rationalization and automation of manufacturing equipment, the air requirement in factories continues to rise. Each machine and each appliance needs a certain volume of air, and is provided with air from the compressor via a pipe system. The pipe diameter should therefore be selected such that the pressure drop between the receiver and user does not exceed 10kPa (0.1 bar). A higher pressure drop endangers the economics of the system and considerably reduces the performance.

When planning a new installation, allowance should be made for a possible later enlargement to the compressor plant, ie. higher air consumption, and the pipelines should therefore be generously dimensioned. Later installation of a larger pipe system is often very expensive.

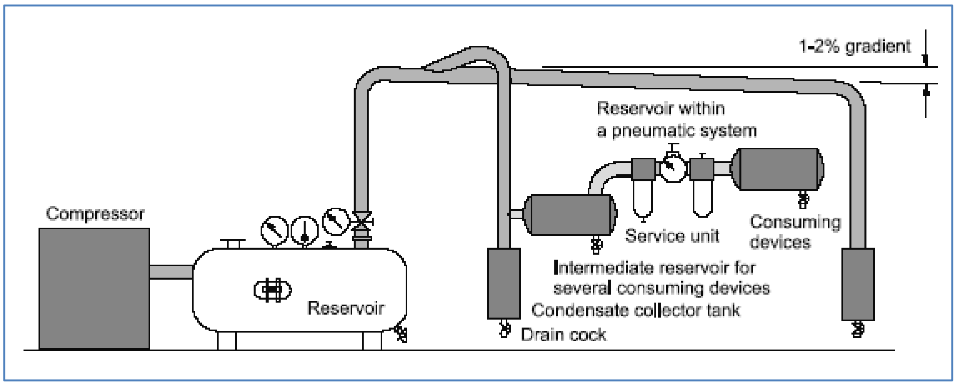


Figure 3.12 – Air Distribution System

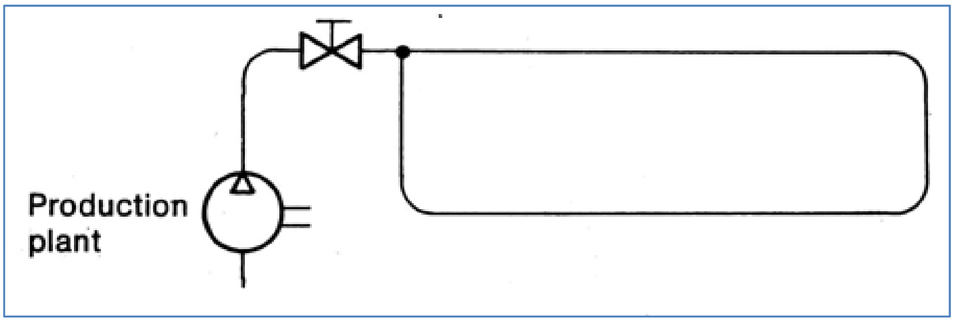


Figure 3.13 – Ring Circuit

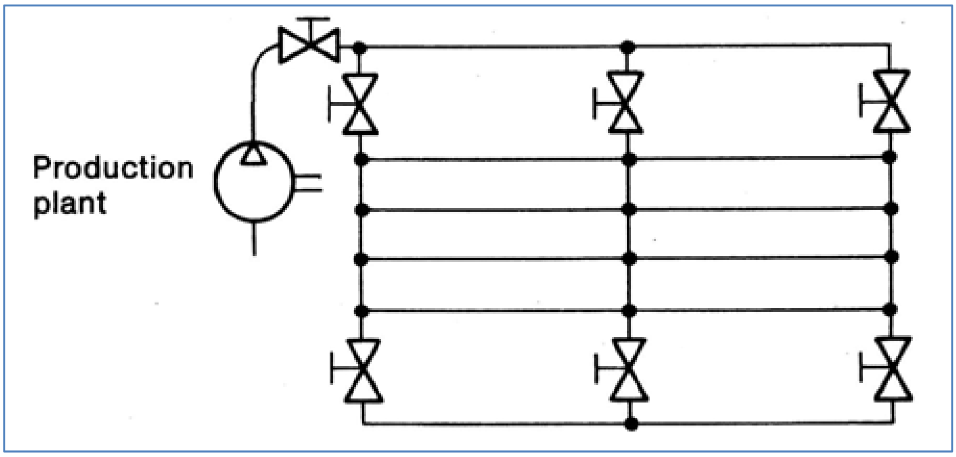


Figure 3.14 – Interconnected Circuit

4.0 Advantages and Disadvantages of Using Compressed Air

4.1 Introduction

Compressed air is essential for pneumatic systems. There are advantages and disadvantages in using compressed air.

4.2 Advantages of Using Compressed Air

4.2.1 Amount

Air is available practically everywhere for compression in unlimited quantities.

4.2.2 Transport

Air can be easily transported in pipelines, even over larger distances. It is not necessary to return the compressed air.

4.2.3 Storage

A compressor need not be in continuous operation. Compressed air can be stored in and removed from a reservoir (eg. Cylinder).

4.2.4 Temperature

Compressed air is insensitive to temperature fluctuations. This ensures reliable operation, even under extreme conditions of temperature.

4.2.5 Explosion Proof

Compressed air offers no risk of explosion or fire, hence no expensive protection against explosion is required.

4.2.6 Cleanliness

Compressed air is clean since any air which escapes through leaking pipes or elements does not cause contamination. This cleanness is necessary, for example, in food, wood, textile and leather industries.

4.2.7 Construction

The operating components are of simple construction and are therefore inexpensive.

4.2.8 Speed

Compressed air is a very fast working medium. This enables high working speeds to be attained. (Pneumatic cylinders have a working speed of 1~2 m/sec)

4.2.9 Overload Safe

Pneumatic tools and operating components can be loaded to the point of stopping and are therefore overload safe.

4.3 Disadvantages

4.3.1 Preparation

The compressed air needs good preparation. Dirt and humidity may not be present. (Wear of pneumatic components).

4.3.2 Compressible

It is not possible to achieve uniform and constant piston speeds with compressed air.

4.3.3 Force Requirement

Compressed air is economical only up to a certain force requirement. Under the normally prevailing working pressure of 700 KPa (7 bar) and dependent on the travel and speed, the limit is between 20,000 N and 30,000 N.

4.3.4 Exhaust Air

The exhaust air is loud. This problem has now, however, been largely solved due to the development of sound absorption material.

5.0 Pneumatic Directional Control Valves

5.1 Introduction

Pneumatic valves provide the interface between compressed air, the control signal and the working elements. Directional control valves are used to direct the flow of compressed air from one place to another in the pneumatic system, to permit the actuating parts to perform the work.

Control valves used in pneumatic systems are identified by four different methods:

- No. of Connecting Ports - 2, 3, 4, or 5-way valves
- No. of Control Positions - 2 or 3
- Type of Control Element - Poppet, Spool and Disc
- Method of Operation - Manual or Automatic

5.2 Types of Directional Control Valves

The design of the directional control valves is categorised as follows:

5.2.1 Poppet Valves

In poppet valves, the connections are opened and closed by means of balls, discs, plates, or cones. The valve seats are usually sealed simply using elastic seals. Seat valves have few parts which are subject to wear, and hence they have a long service life. They are insensitive to dirt and they are robust. The actuating force is relatively high as it is necessary to overcome the force of the built-in reset spring and the air pressure.

- Poppet Valves - Ball seat valve
  - Disc seat valve

5.2.2 Slide Valves

In slide valves, the individual connections are linked together or closed to one another by means of spool slides, spool flat slides or rotary slides.

- Slide Valves - Longitudinal slide valve
  - Longitudinal flat slide valve
  - Plate slide valve (Rotary slide valve)

5.3 Number of Flow Paths and Shifting Conditions

Directional control valves are designated by their flow paths and shifting conditions.

5.3.1 Flow Paths

As directional control valves direct the fluid flow, there are a number of flow paths or ports. These flow paths designate the first number of the valve.

5.3.2 Shifting Conditions

The shifting conditions or positions signify the number of positions the valve can have.
From the flow paths and shifting positions, the directional control valve is identified. For example, a 3/2-way directional control valve has 3 ports and 2 switching positions. At any one time, the valve is in one position, usually the right position

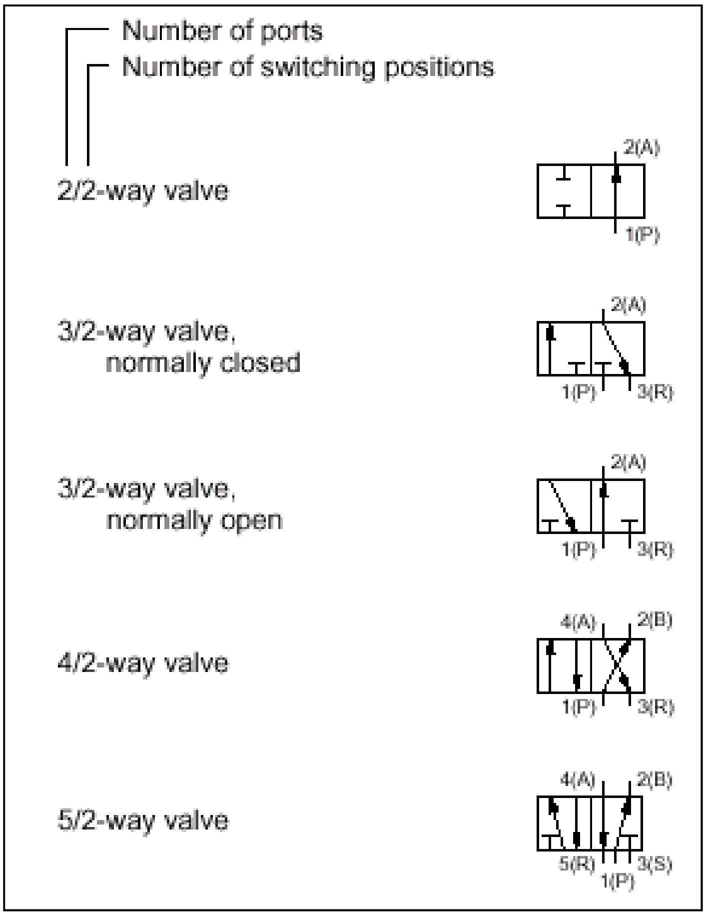


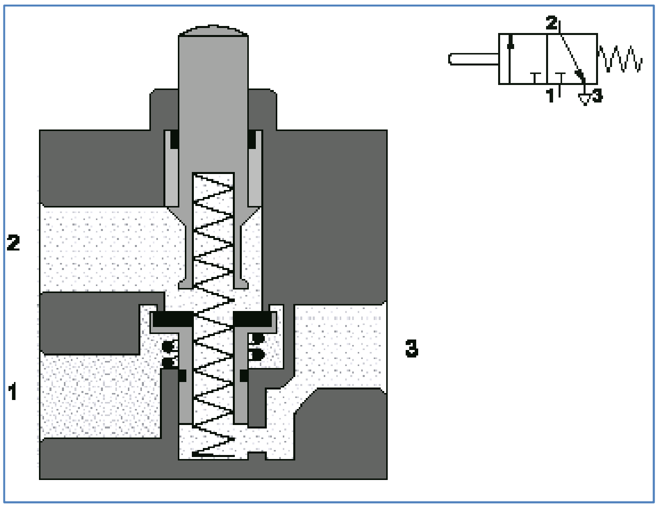
Figure 5.1 – Ports and Positions

5.4 2 Ports, 2 Positions Way Valves (2/2-way DCV)

The 2/2-way valve has two ports and two positions (open, closed). It is rarely used except as an on-off valve, since its only function is to enable signal flow through and cannot release the air to atmosphere once in the closed position in contrast to the 3/2-way valve. The 2/2-way valve is normally of the ball seat construction.

5.5 3 Ports, 2 Positions Way Valves (3/2-way DCV)

It consists of three ports inside the valve. Most 3/2-way valves are shifted backward and forward when they are actuated. This valve may be used as diverter or selector valve, holding valve and directional control valve. Some 3/2-way valve can also be classified as normally open or normally closed. This depends on the position of the valve when it is in the non-actuated position.



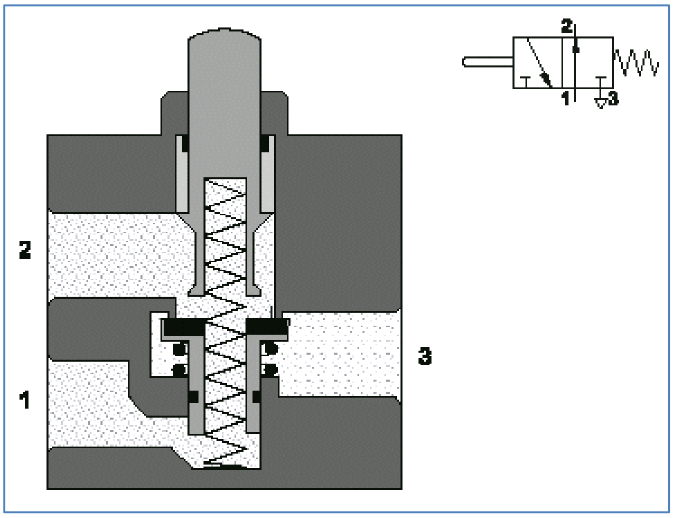


Figure 5.2 - 3/2-way Valves

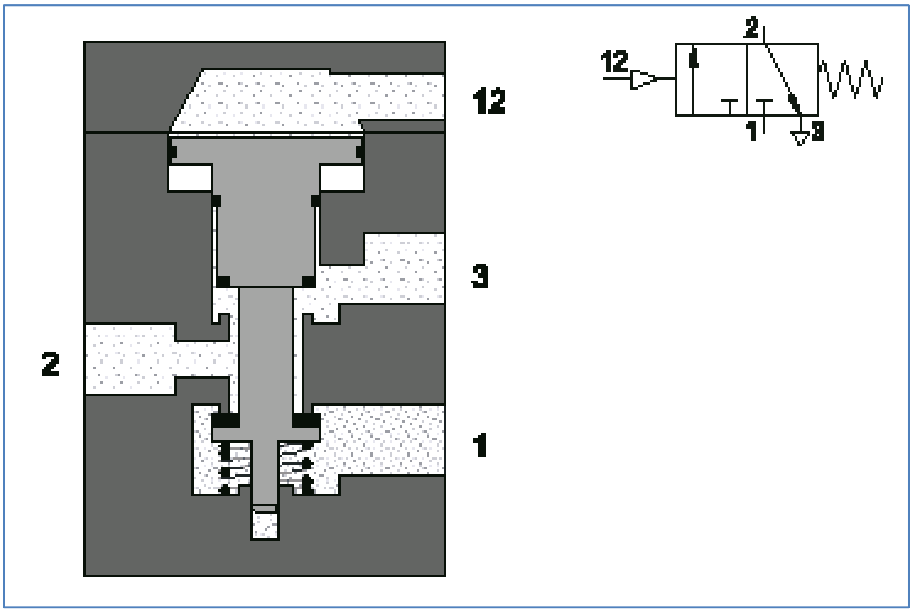


Figure 5.3 - 3/2-way Valve

5.6 4 Ports, 2 Positions Way Valves (4/2-way DCV)

4/2-way valves are used to simplify pneumatic circuits. This 4/2-way valve consists of four primary connections. These include a pressure line, an exhaust line and two actuator connections. A 4/2-way valve supplies compressed air to one chamber while bleeding off air from the other side of the cylinder. When the valve position is reversed, the air flow is also reversed.

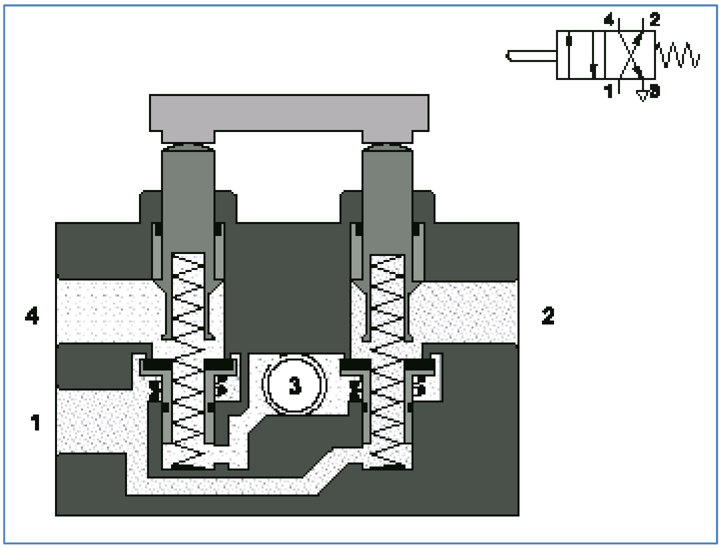


Figure 5.4 - 4/2-way Valves

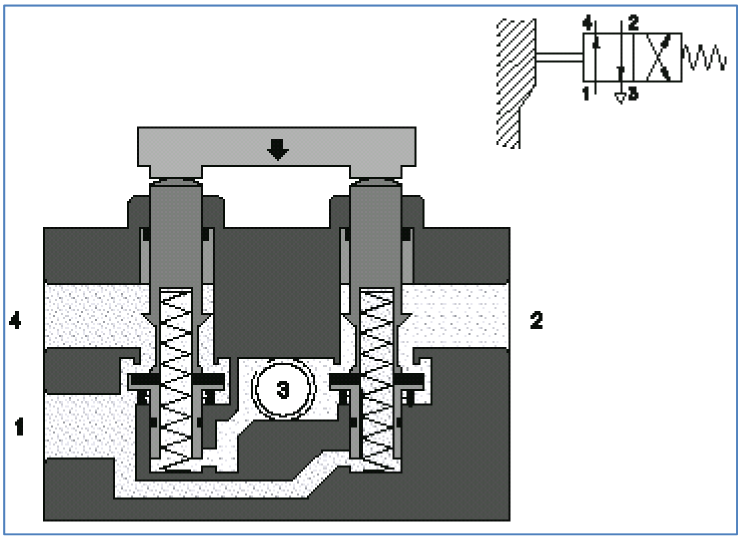


Figure 5.5 - 4/2-way Valves

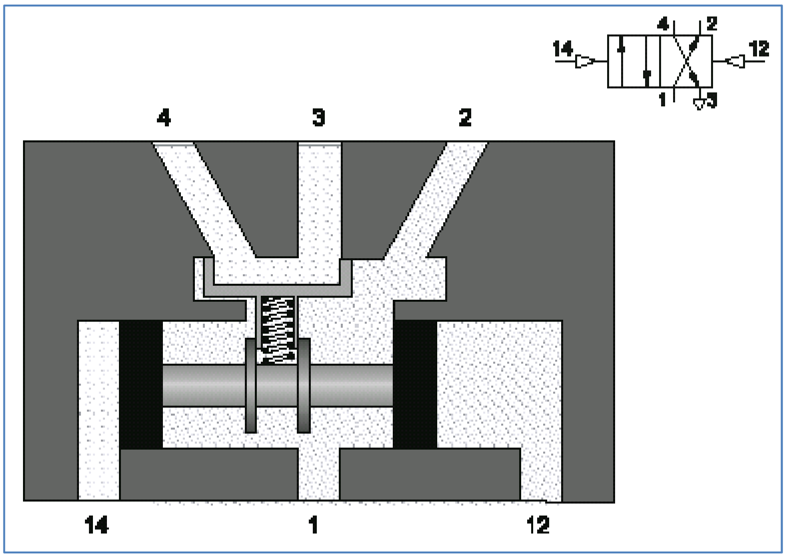


Figure 5.6 - 4/2-way Valves

5.7 4 Ports, 3 Positions Way Valves (4/3-way DCV)

4/3-way valves have 4 ports and 3 positions. The centre position is in its initial position. The valve is either switched to the left or the right when in use.

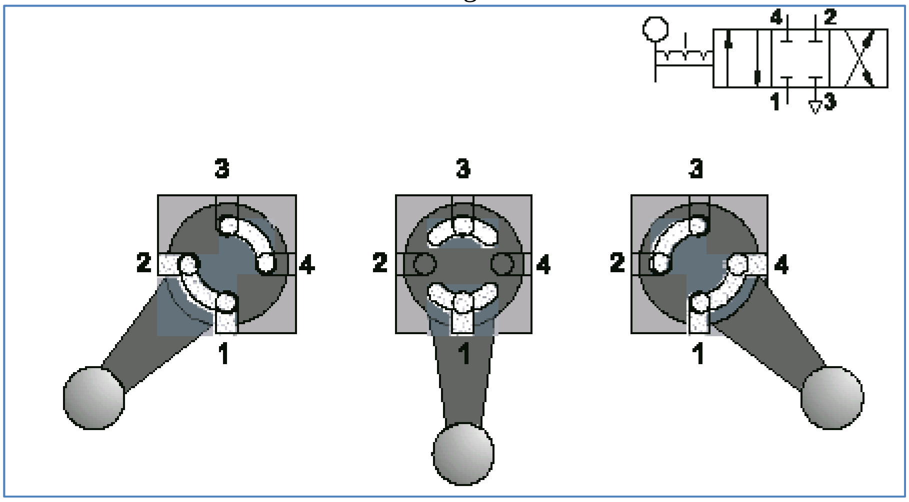


Figure 5.7 – 4/3-way Valve

5.8 5 Ports, 2 Positions Way Valves (5/2-way DCV)

A 5/2-way valve is a special four-way valve with five external connections. It has one power connection, two exhaust connections and two actuator connections.

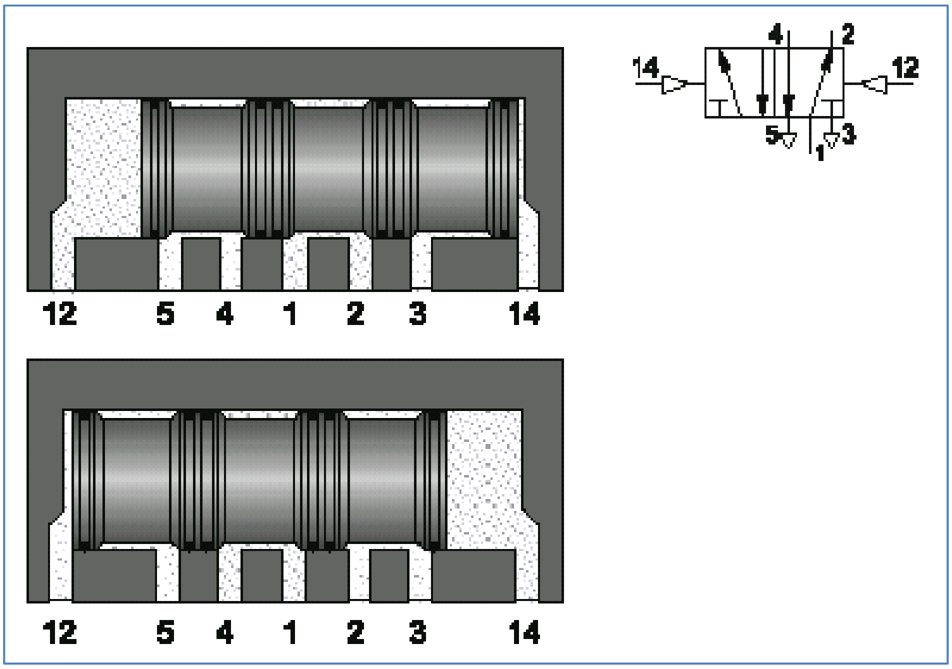


Figure 5.8 - 5/2 Way Valves

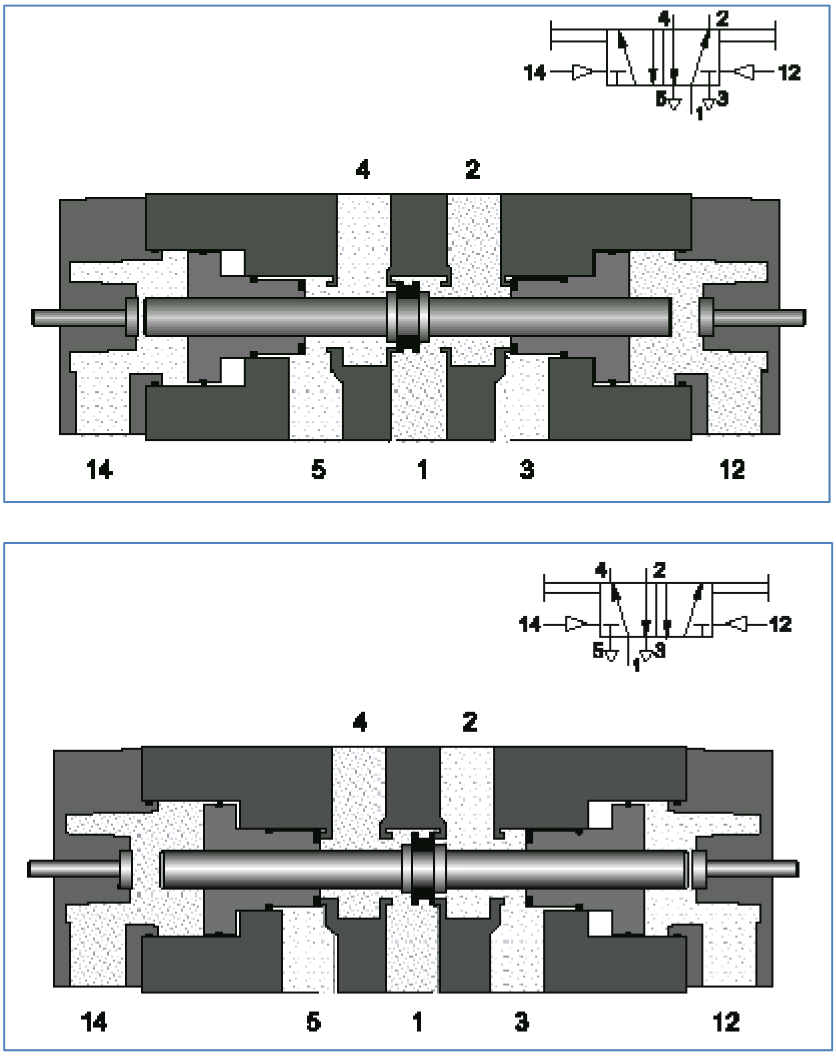


Figure 5.9 - 5/2-way Valves

5.9 5 Ports, 3 Positions Way Valves (5/3-way DCV)

A 5/3-way valve has 5 ports and 3 positions. It can be used to stop cylinders within its stroke length.

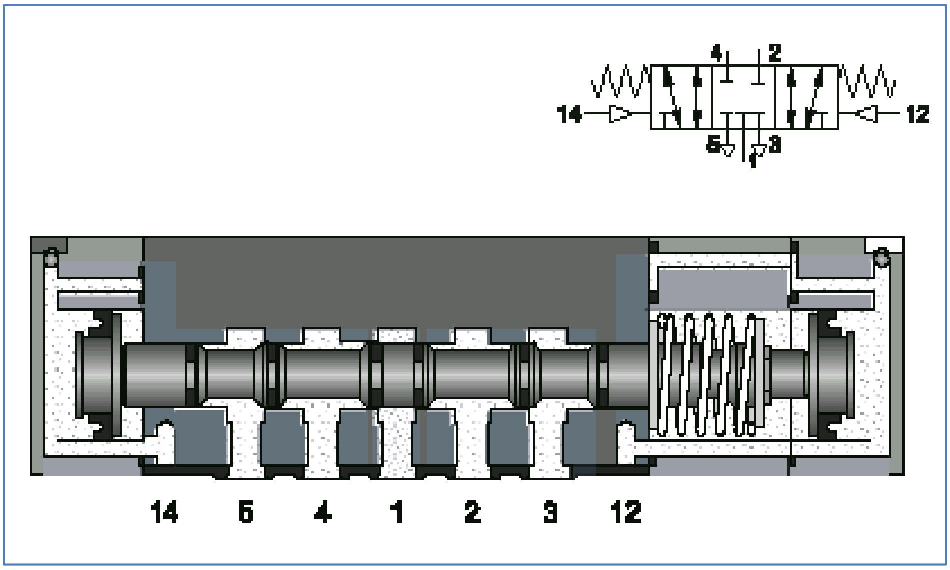


Figure 5.10 – 5/3-way Valve

5.10 Actuation Methods

Having identified the directional control valve, the last item would be the actuation method. The directional control valve can be actuated by:

- Manual
- Mechanical
- Pneumatic
- Electrical

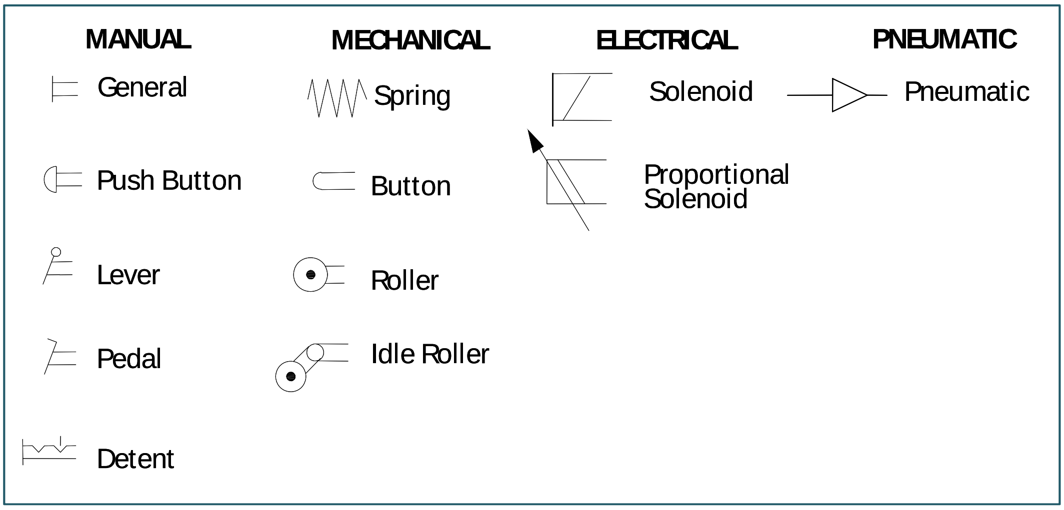


Figure 5.11 – Actuation Methods

6.0 Pneumatic Auxiliary Valves

6.1 Introduction

Besides the directional control valves, there are other pneumatic valves which are used in control applications.

6.2 Shuttle Valve ("OR" element)

This valve is also called double control valve or double check valve. This non-return valve has two inlets P_1 and P_2 and one outlet A. If compressed air is applied to inlet P_1, the ball seals off inlet P_2 and the air flows from P_1 to A. Alternatively, the air flows from P_2 to A when P_1 is closed. When the air flow is reversed, ie. a cylinder or valve is exhausted, the ball remains in its previously assumed position because of the pressure conditions.

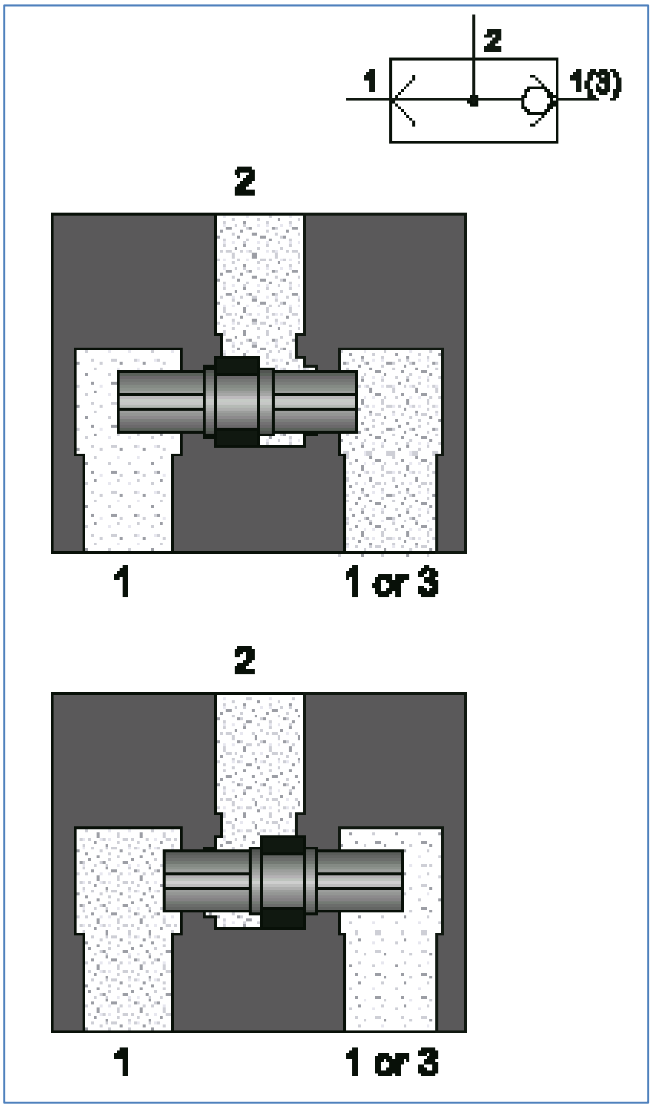


Figure 6.1 - Shuttle Valve

This valve is also called an “OR” component. It separates signal emitted from signal valves in various positions and prevents air from being diverted through a second signal valve. If a cylinder or control valve is to be actuated from two or several positions, a shuttle valve must be used.

6.3 Two-Pressure Valve (“AND” element)

The two-pressure valve has two inlets P_1 and P_2 and one outlet A. Compressed air flows through only if signals are applied to both inlets. One input signal to P_1 and P_2 blocks the flow because of the force differential across the spool. If input signals are applied simultaneously to both sides, the signal which is last applied passes to the outlet. If the input signals are of different pressures, the larger of the two pressures closes the valve and the smaller air pressure is transferred to the outlet. It is used mainly for interlocking controls, safety controls, check functions or logic operations.

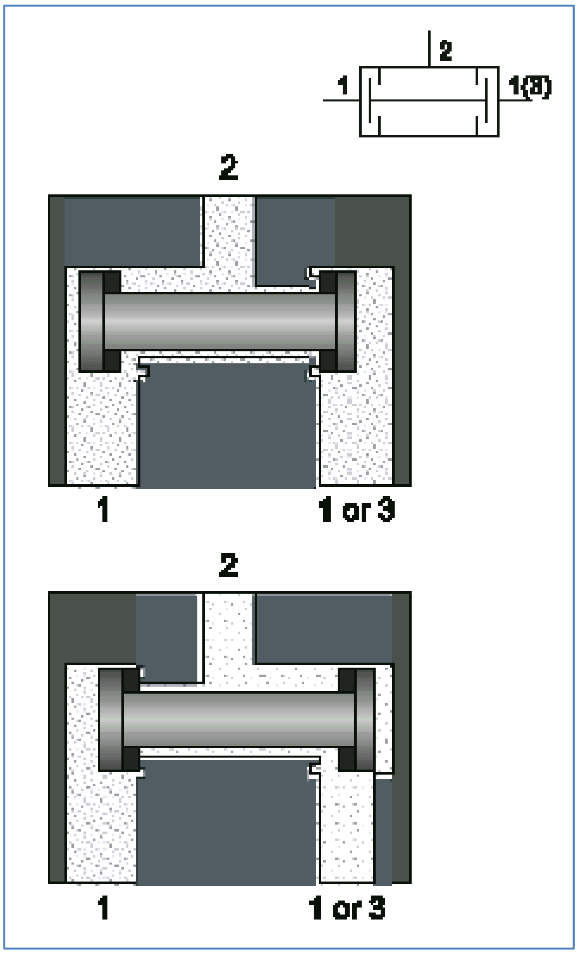


Figure 6.2 – Two-Pressure Valve.

6.4 Flow Control Valves

Flow control valves influence the volumetric flow of the compressed air in both directions. The throttle valve is a flow control valve.

6.4.1 Throttle Valve

Throttle valves are normally adjustable and the setting can be locked in position. Throttle valves are used for speed control of cylinders. Care must be taken that the throttle valve does not close fully, cutting off air from the system.

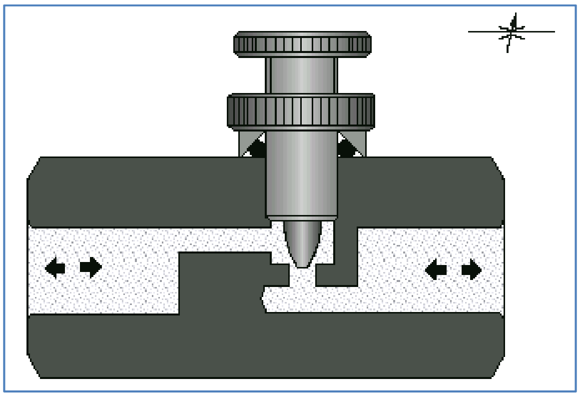


Figure 6.3 – Throttle Valve

6.4.2 One-Way Flow Control Valve

In the case of the one-way flow control valve, the air flow is throttled in one direction only. A check valve blocks the flow of air in the bypass leg and the air can flow only through the regulated cross-section. In the opposite direction, the air can flow freely through the opened check valve. These valves are used for speed regulation of actuators and if possible, should be mounted directly on the cylinder.

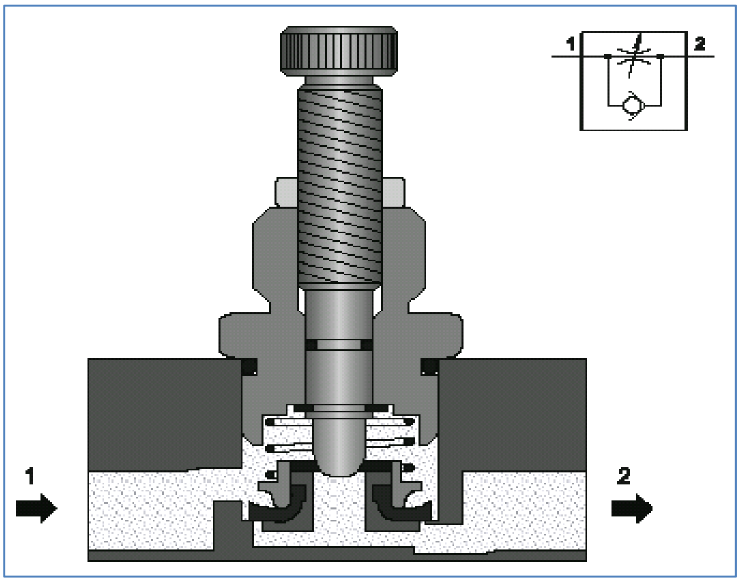


Figure 6.4 – One-way Flow Control Valve

6.5 Quick Exhaust Valve

Quick exhaust valves are used to increase the piston speeds in cylinders. This enables lengthy return times to be avoided, particularly with single-acting cylinders. The valve has a blockable pressure connection P, a blockable exhaust R, and an outlet A.

If pressure is applied at the connection P, the sealing disc completely covers the exhaust orifice R. The compressed air thus flows to A. If the pressure is removed from P, the air coming from A moves the sealing disc against connection P and closes it. The exhaust air can flow directly to atmosphere, without having to follow a long and possibly narrow path through the control lines to the pilot valve. It is best to mount the quick-exhaust valve directly on the cylinder, or as near to it as possible.

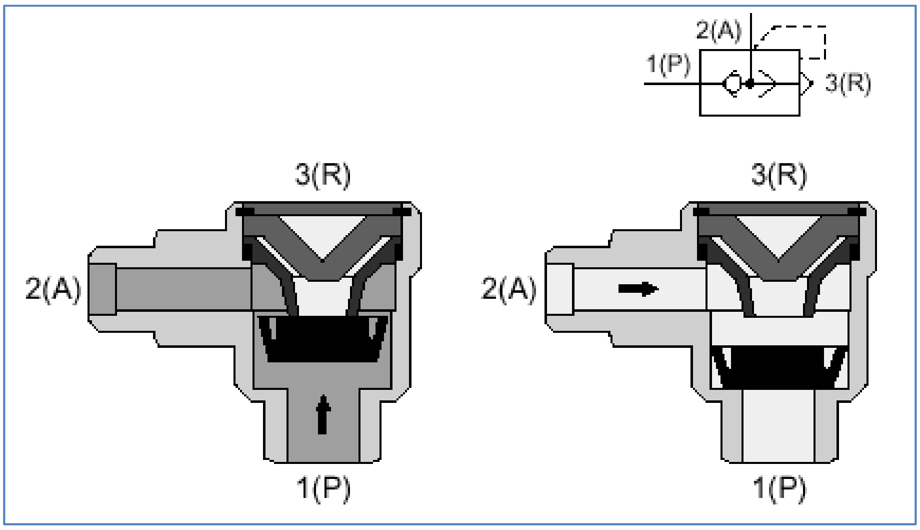


Figure 6.5 - Quick Exhaust Valve

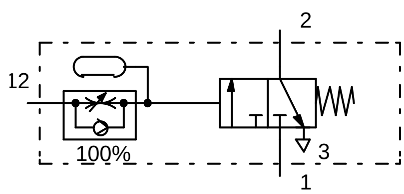
6.6 Time Delay Valve

The time delay valve is a combined 3/2-way valve, one way flow control valve and air reservoir. The 3/2-way valve can be a valve with normal position open or closed. The delay time is generally 0-30 seconds for both types of valves.

The following operational principle applies for a time delay valve with a 3/2-way valve in normally closed position: The compressed air is supplied to the valve at connection 1. The control air flows into the valve at 12 through a one-way flow control valve and depending on the setting of the throttling screw, a greater or lesser amount of air flows per unit of time into the air reservoir. When the necessary control pressure has built up in the air reservoir, the pilot spool of the 3/2-way valve is moved downwards. This blocks the passage from 2 to 3. The valve disc is lifted from its seat and thus air can flow from 1 to 2. The time required for pressure to build up in the air reservoir is equal to the control time delay of the valve.

If the time delay valve is to switch to its initial position, the pilot line 12 must be exhausted. The air flows from the air reservoir to atmosphere through the bypass of the one-way flow control valve and then to the exhaust line. The valve spring returns the pilot spool and the valve disc seat to their initial positions. Working line 2 exhausts to 3 and 1 is blocked.

Besides the normally closed position, there is the normally opened position, the only difference is that it will close when actuated.



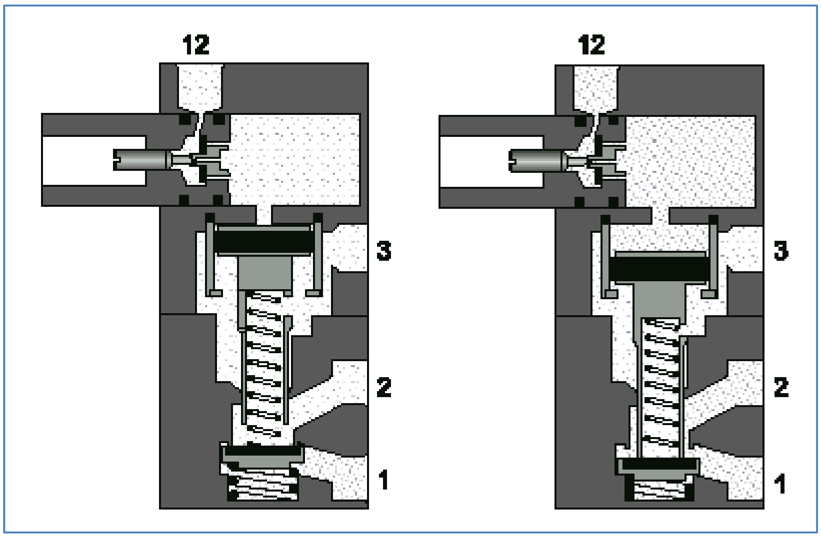


Figure 6.6 – Normally Closed Time Delay Valve

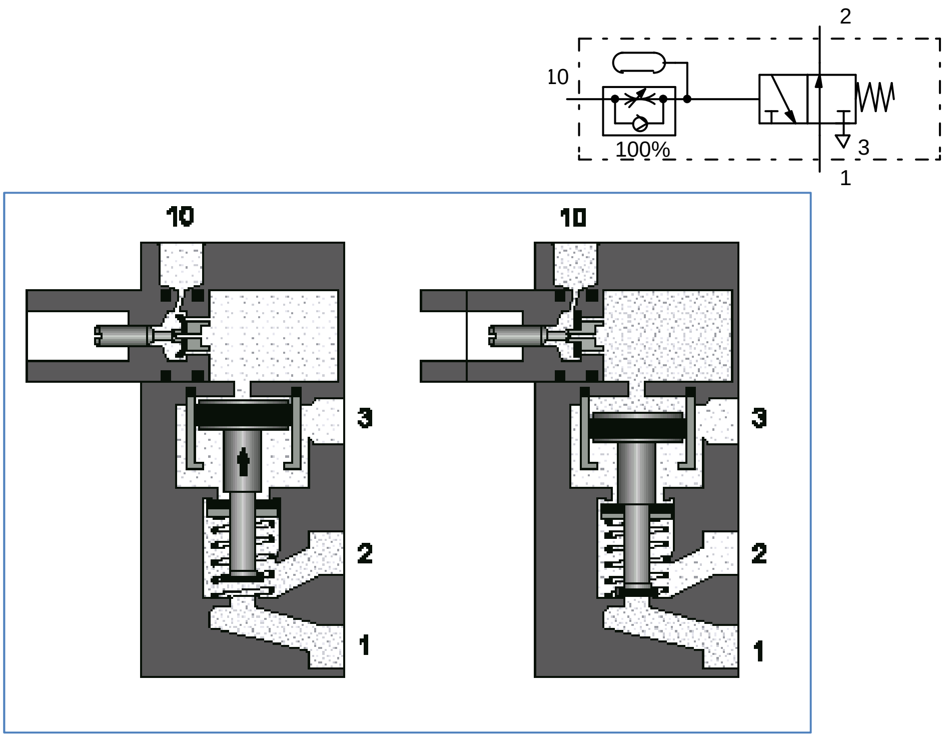


Figure 6.7 – Normally Opened Time Delay Valve

7.0 Pneumatic Actuators

7.1 Introduction

Actuators are the powering elements in a control system. They do the work in terms of generating movements (cylinders, motors) or other types of output/power (electrical, mechanical, thermal or hydraulic). Actuators are the devices at the end of the control chain. They convert the control signal into work (execution of instruction).

Below are some examples of actuators:

Cylinders, motors, lighting devices, heating devices, visual and acoustic alarm devices, etc.

Final control elements are also sometimes called actuators. Examples of final control elements are valves, contactors, power transistors, power thyristor etc.

Conversion of pneumatic, hydraulic & electrical energy into mechanical work is accomplished by actuators.

There are 3 ways to control/power an actuator. They are by:

- Pneumatics
- Hydraulics
- Electrics

Actuators can be categorised into three main areas. They are:

- Linear Motion
- Rotary Motion
- End Effectors

Linear motion can be achieved by pneumatic & hydraulic cylinders and electric actuators. Similarly, rotary motion can be achieved by pneumatic & hydraulic motors and electric motors.

7.2 Features of Pneumatic Cylinders

Pneumatic cylinders are the most widely used devices to produce linear force, work or power. The pressure of the air multiplied by the diameter of the cylinder gives the force and the volume of flow gives the cylinder its speed. The combination of force and motion produces work.

Creating a linear movement with electrically driven mechanical elements is often a complicated matter and requires a lot of power. This means that high current devices are required for such operations.

Pneumatically operated cylinders simplify these kinds of operations and also require less energy. Apart from this, pneumatic devices are safe from electrical hazards that are present in high current electrical devices.

7.2.1 Single-Acting Cylinder

In single acting cylinders compressed air is applied on only at one end. These cylinders can produce work in only one direction. Therefore, air is required for only one direction of movement. Either a built-in spring or an external force moves the piston in the opposite direction.

The spring force of the built-in spring is designed to return the piston to its starting position with a reasonably high speed under no load conditions. In single acting cylinders with built-in spring the stroke is limited by the natural length of the spring. Single acting cylinders are therefore normally only available with stroke lengths of up to approx. 80 -100mm.

The construction and simplicity of operation of the single acting cylinder makes it particularly suitable for compact, short stroke length cylinders for the following types of applications:

- clamping of workpieces
- cutting operations
- ejecting &/or injecting parts
- pressing operations
- feeding & lifting

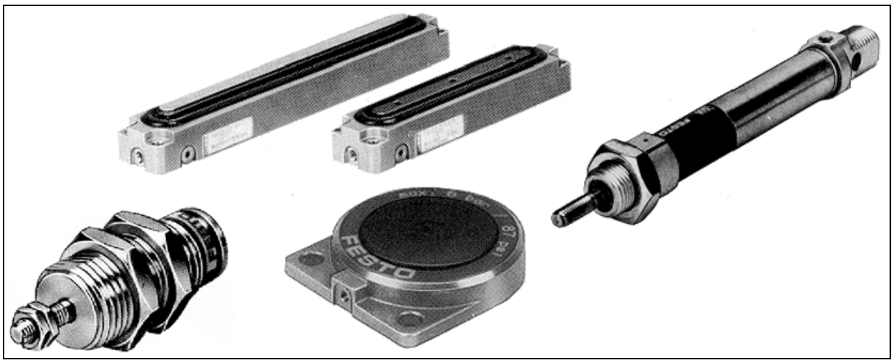


Figure 7.1 – Example of Single Acting Cylinders

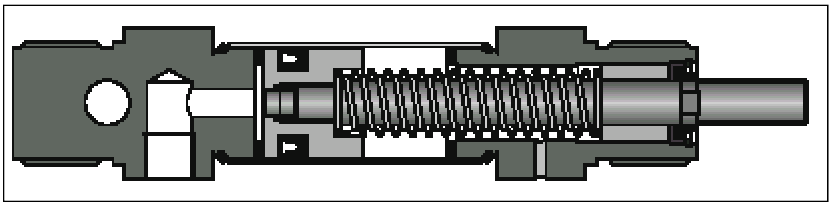


Figure 7.2 – Single Acting Cylinder

Construction of Single Acting Cylinders

The component parts of single acting cylinders are:

Tube, rear cap, bearing cap, piston with packing, piston rod, return spring and bearing bush with scraping ring. If compressed air hits the piston surface the piston rod moves out. When pressure is released the return spring moves the piston to its initial position. Due to the laid length of the return spring the stroke of single acting cylinders is restricted to approximately 100mm.

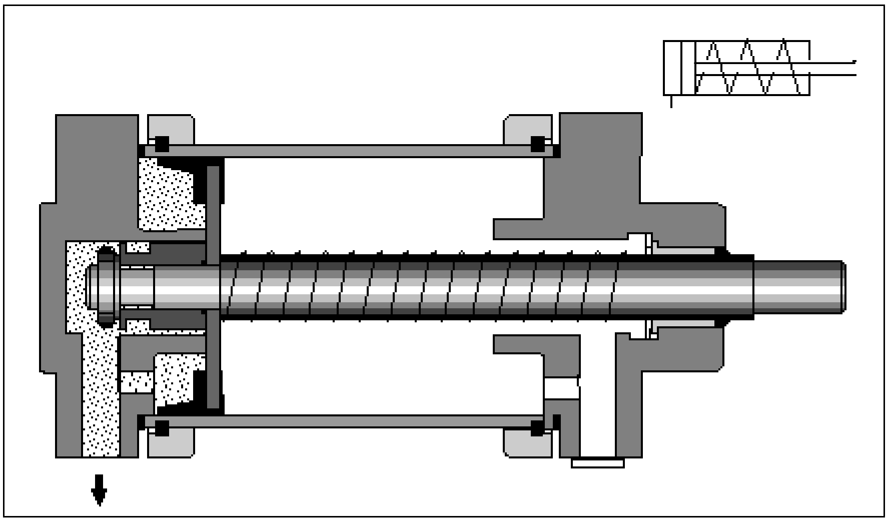


Figure 7.3 – Construction of Single Acting Cylinder

Short stroke clamping cylinders are ideal where there is little space and the cylinder won't fully extend before stopping, because of their compact size and inexpensive design.

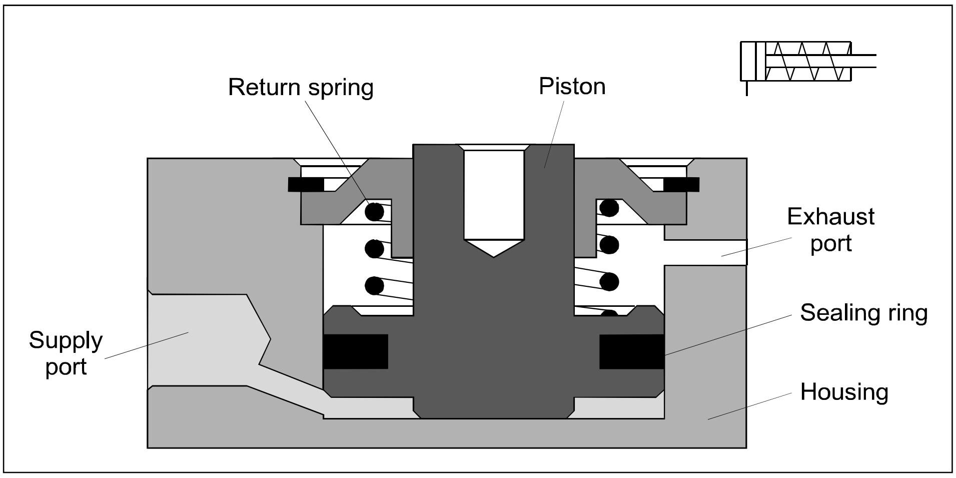


Figure 7.4 – Construction of a Single Acting Short Stroke Cylinder

There is a variety of other designs of single acting cylinders ideally suited to certain applications. These include:

- Compact short stroke cylinders
- Diaphragm cylinders

- Rolling diaphragm cylinders
- Clamping modules
- Cartridge cylinders
- Bellow cylinders
- Rectangular cylinders

Application

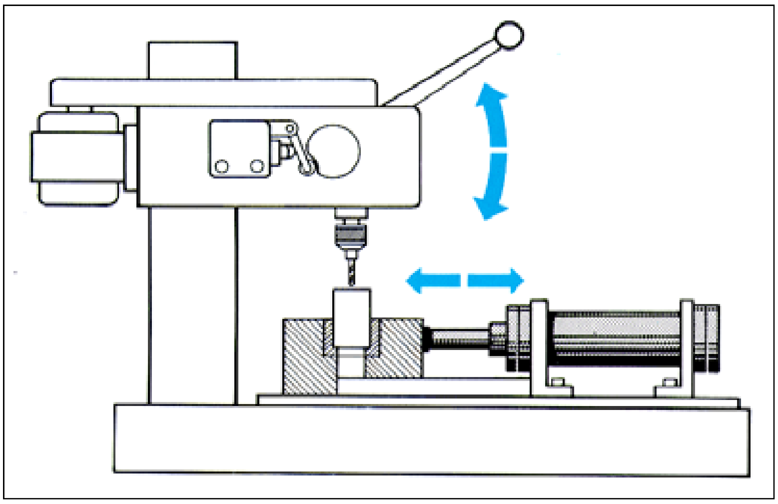


Figure 7.5 – Clamping Device using Single Acting Cylinder

7.2.2 Double-Acting Cylinder

The force exerted by the compressed air moves the piston in a double acting cylinder in two directions. A definite force is applied on both advance and return movements.

Double acting cylinders are used particularly when the piston is required to perform a work function not only on the advance movements but also on the return movement. In principle, the stroke length of the cylinder is unlimited although buckling and bending of the extended piston rod must be allowed for. Here too sealing is by means of sealing rings and pistons or diaphragms/double cup packing.

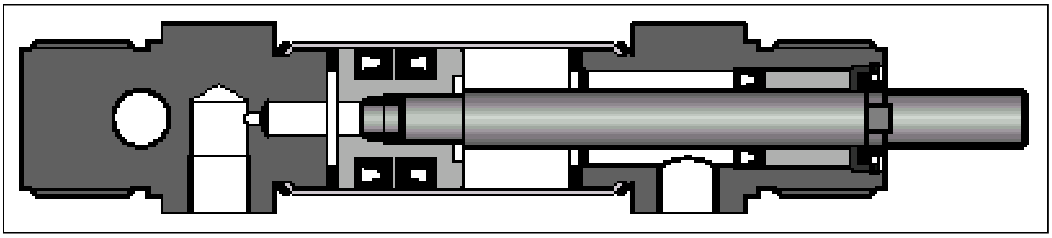


Figure 7.6 – Double Acting Cylinder

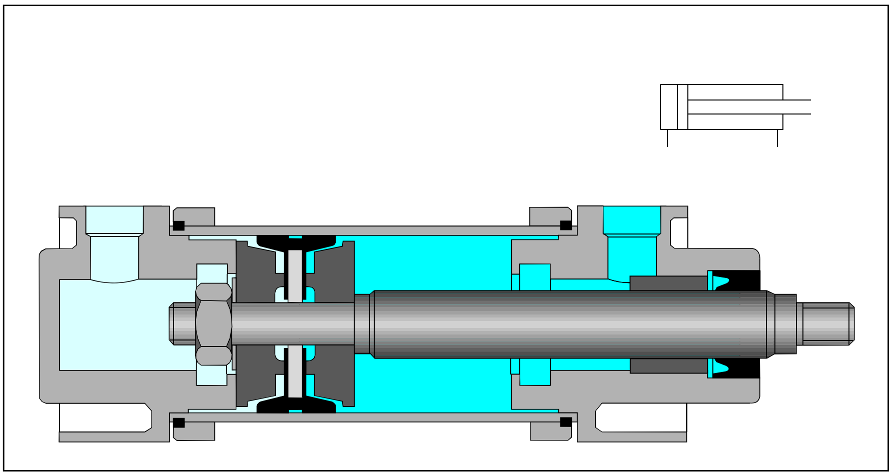


Figure 7.7 – Double Acting Cylinder

Construction of Double Acting Cylinders

Double acting cylinders are used particularly when the piston is required to perform a work function in both directions of motion. The construction principle is similar to that of the single acting cylinder. However, there is no return spring.

In front of the bearing bush is a scraper ring. This ring prevents dust and dirt particles from entering the cylinder space. Bellows are therefore not normally required. A sealing ring is fitted in the bearing cap to seal the piston rod. The bearing bush guides the piston rod and may be made of sintered bronze or plastic-coated metal.

The piston cylinder consists of a cylinder barrel, base and bearing cap, piston with seal (double-cup packing), piston rod, bearing push, scraping ring, in addition there are the connection parts and seals. Steel cylinder barrels are usually made of seamless drawn steel tube. Due to modern production techniques, most new cylinders are having extruded aluminium (anodised) barrels. This reduces cost, increases strength due to profile design and allow corporation of proximity switch mountings into the barrel.

For applications where the operation is infrequent or there are corrosive influences, then the barrel is made of brass or steel with hard chromed or nickel-plated surfaces

The base cap and the bearing cap are for the most part made of cast material (aluminium or malleable cast iron). The two caps can be fastened to the cylinder barrel by tie rods, threads, or flanges.

The piston rod is preferably made from heat-treated steel. A certain percentage of chromium is alloyed with the steel to provide rust protection. The piston rod can be hardened if desired.

Tumbling compacts, the surface and yields a piston rod peak-to-valley height of 0.1 mm. The threads are generally rolled to reduce the danger of fracture.

A sealing ring is fitted in the bearing cap to seal the piston rod. The bearing bush guides the piston rod and may be made of sintered bronze or plastic-coated metal. In front of this bearing bush is a scraping ring. It prevents dust and dirt particles from entering the cylinder space. Bellows are therefore not required.

The double-cup packing seals off the cylinder space. Round-cord rings or 0-rings are used for static sealing because the round-cord ring must be pre-tensioned. This would lead to high frictional losses in dynamic use.

Applications

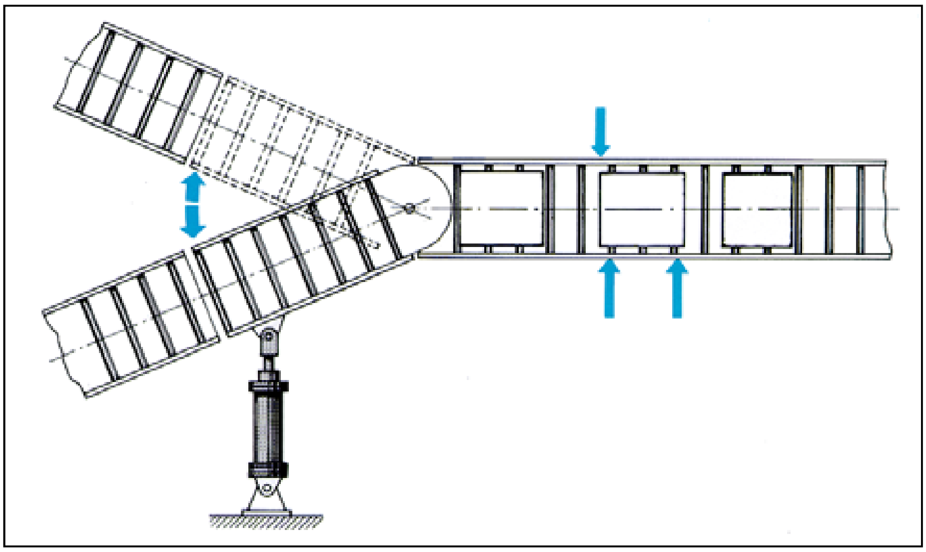


Figure 7.8 – Line Diverter for 2 Tracks

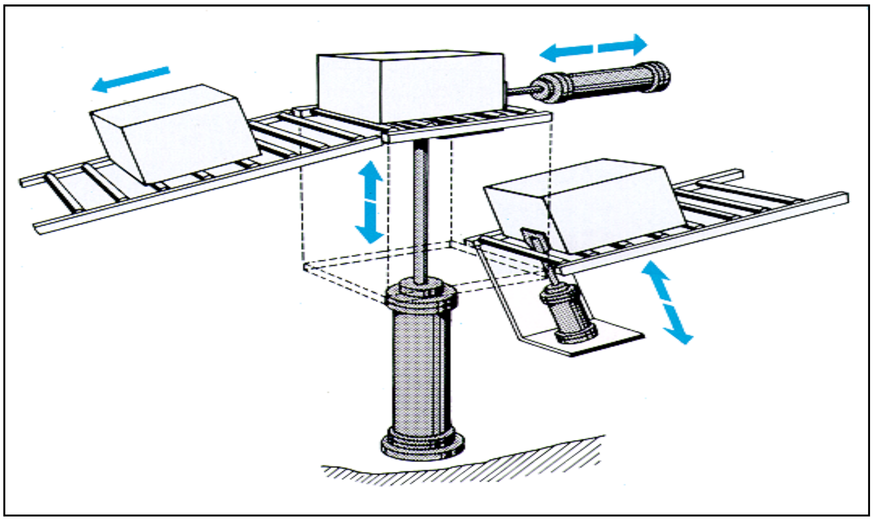


Figure 7.9 – System for Changing or Diverting Conveyors

7.2.3 Cylinder Cushioning

Double Acting Cylinders with End Position Cushioning

If large masses are moved by a cylinder, cushioning is used in the end positions to prevent sudden damaging impacts. Before reaching the end position, a cushioning piston interrupts the direct flow path of the air to the outside. Instead a very small and often adjustable exhaust aperture is open. For the last part of the stroke the cylinder speed is progressively reduced. If the exhaust passage adjustment is too

small or closed off, the cylinder may not reach the end position due to the blockage of air.
When the piston reverses, air flows without resistance through the return valve into the cylinder space. With very large forces and high accelerations extra measure must be taken such as external shock absorbers to assist the load deceleration. When cushioning adjustment is being carried out, it is recommended that to avoid damage, the regulating screw should first be screwed in fully and then backed off to allow the adjustment to be increased slowly to the optimum value.

It is important to consider fitting a magnet to the cylinder piston. Once manufactured the cylinder cannot normally be fitted with sensors magnets due to the difference in construction.

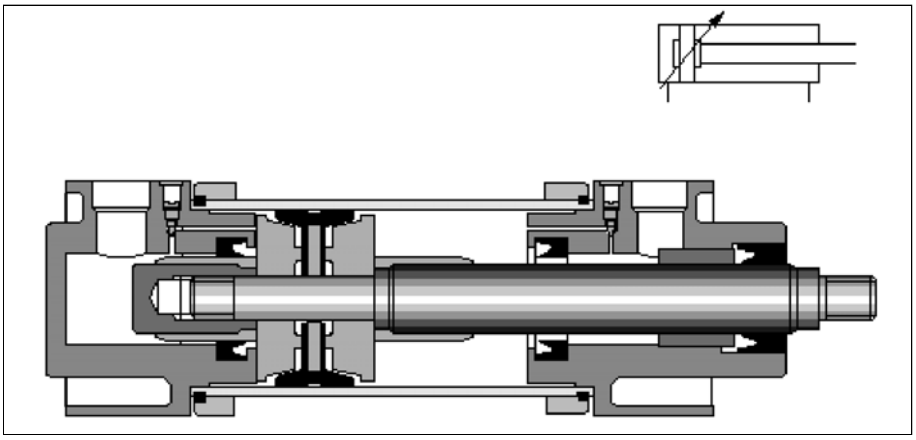


Figure 7.10 – Double Acting Cylinder with End Position Cushioning

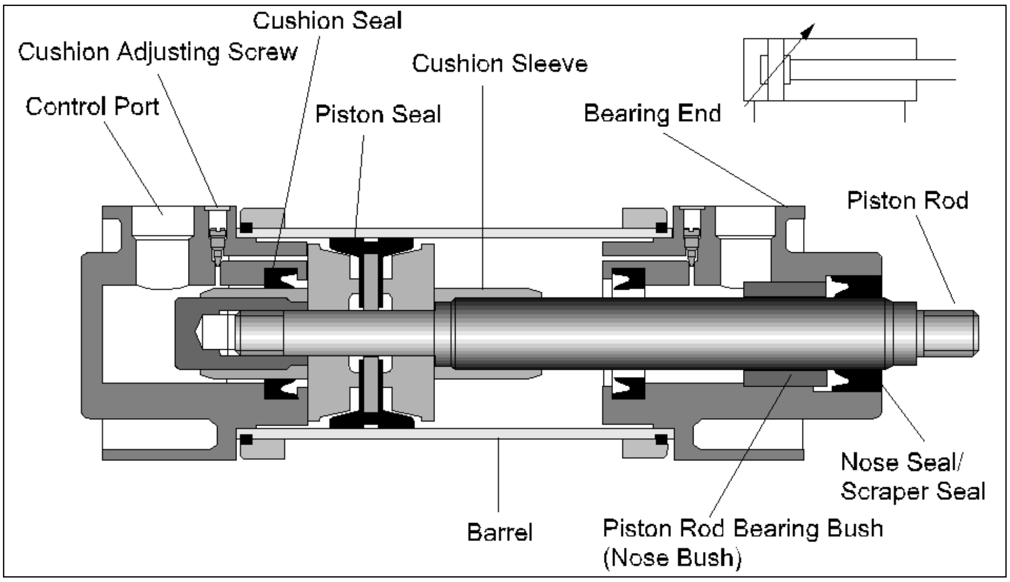


Figure 7.11 – Cylinder Construction for End Position Cushioning

7.3 Types of Pneumatic Cylinders

7.3.1 Cylinder with Double-Sided Piston Rod

This cylinder has a piston rod protruding form both ends. The piston rod passes right through the cylinder. Guidance of the piston rod is better because there are two bearing positions. With this design small lateral loads can also be applied.

Applications: A signal sending unit can be attached to the free side of the piston rod. The force is the same in both directions of motion because the piston area is the same.

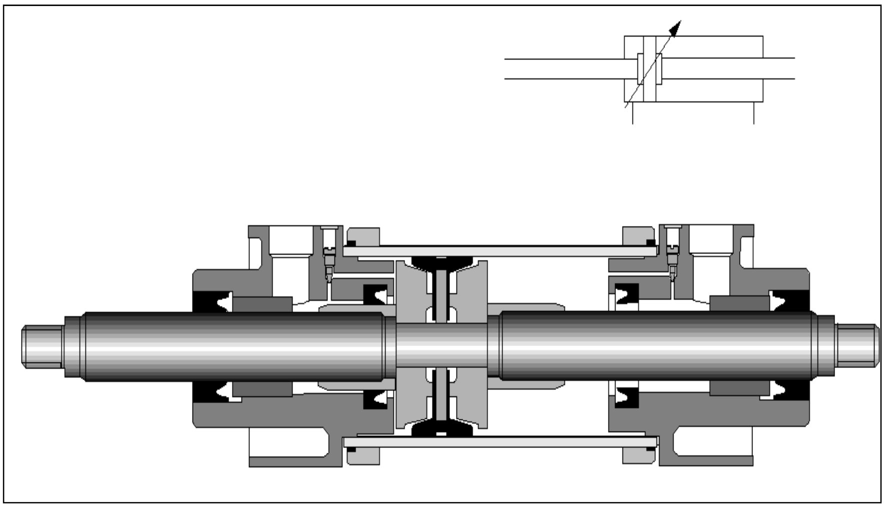


Figure 7.12 – Cylinder with Double Ended Piston Rod

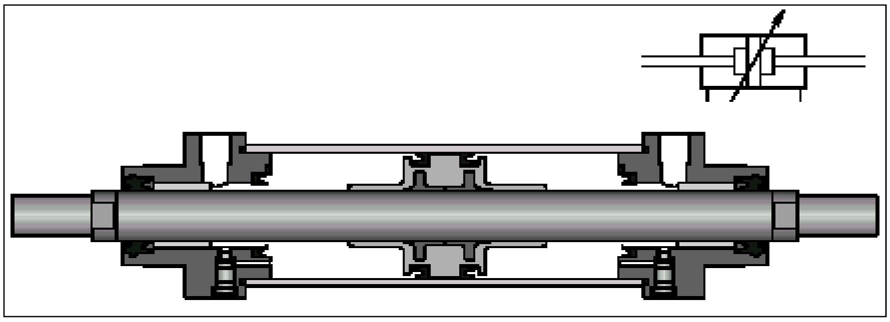


Figure 7.13 – Cylinder with Double Ended Piston Rod

7.3.2 Tandem Cylinder

This design features the characteristics of two double acting cylinders forming a single unit. This increases the effective piston area of the unit for high force applications. The force on the piston rod is almost doubled. It is suitable for applications where a large force is required but the cylinder diameter is restricted.

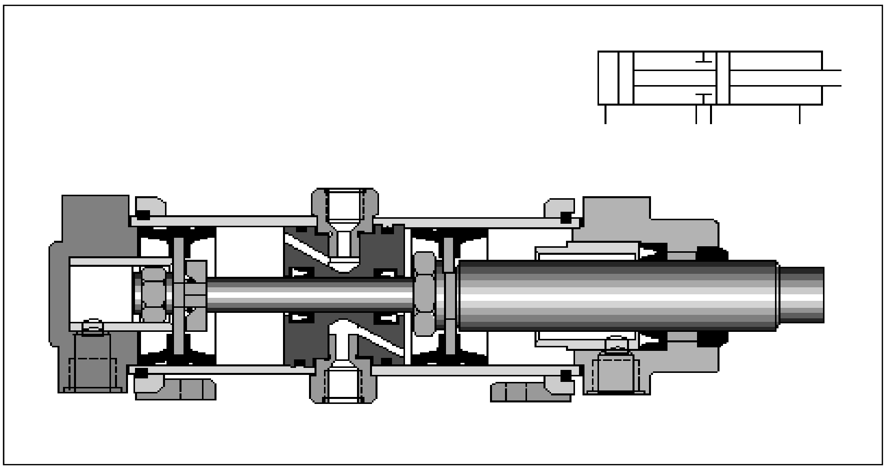


Figure 7.14 – Tandem Double Acting Cylinder

7.3.3 Multi-Position Cylinder

A 3-position or 4-position cylinder consists of two separate cylinders whose piston rods extend in opposite directions. Depending on the triggering and stroke pattern, this cylinder type can assume up to 4 positions. In each case, the cylinder is driven precisely against a stop. It should be noted that, if one end of the piston rod is fixed, the cylinder barrel executes the movement. The cylinder must be connected with flexible line connections.

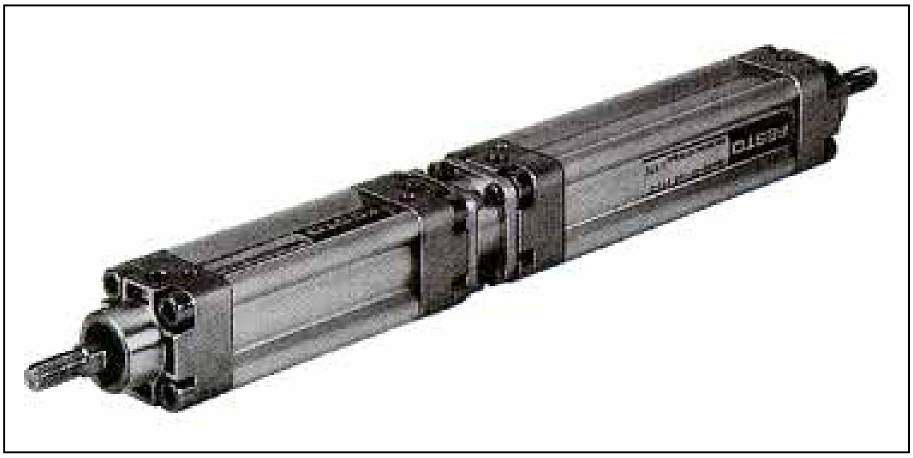


Figure 7.15 – Multi-Position Cylinder (Back to Back Cylinder)

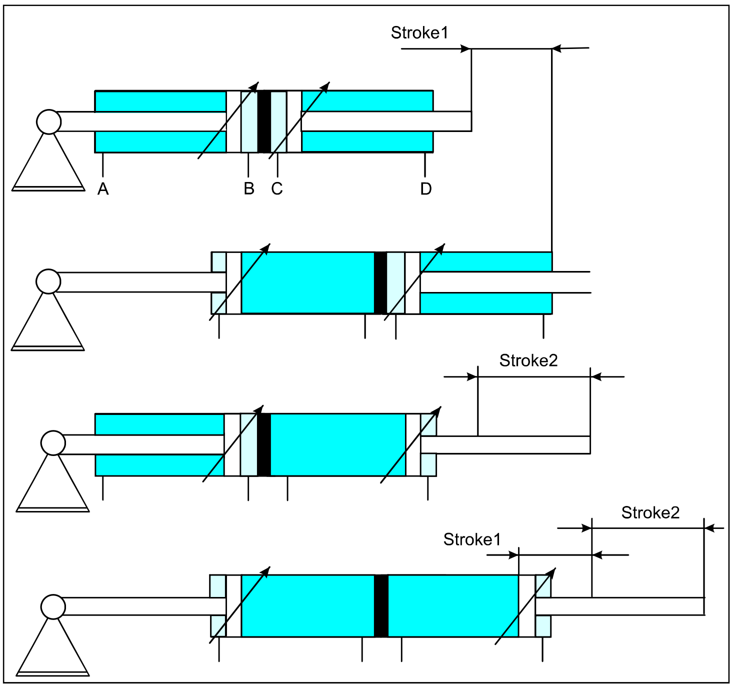


Figure 7.16 – 3-4 Positions are Achieved by Using the Same Stroke or Different Strokes

The multi-position cylinders are ideal for fast positioning with positive end stopping.

7.3.4 Impact Cylinder

If normal cylinders are used for forming operations, the thrust forces of the compressed air are limited. A cylinder producing high kinetic energy is the impact cylinder.

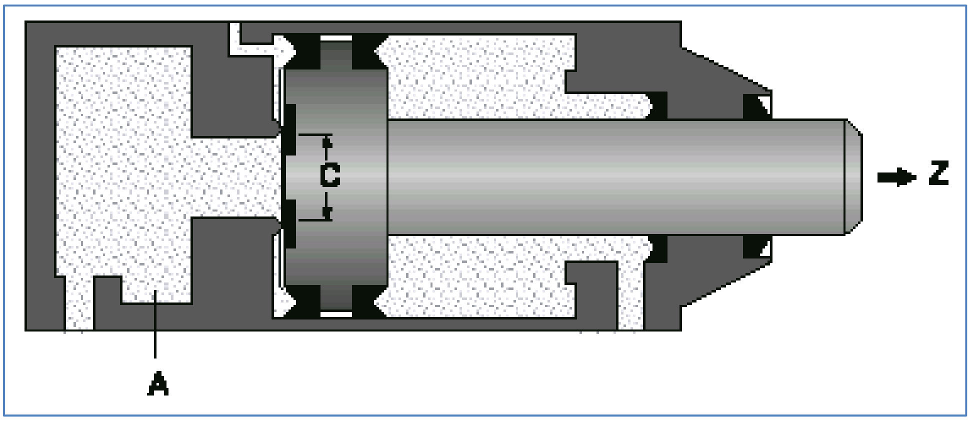


Figure 7.17 - Impact Cylinder

7.4 Cylinder Mountings

The way cylinders are mounted influences the service life, maintenance frequency and the success of the entire installation.

There are three main categories of cylinder mountings:

- Centreline Mounting
- Foot Mounting
- Pivot Mounting

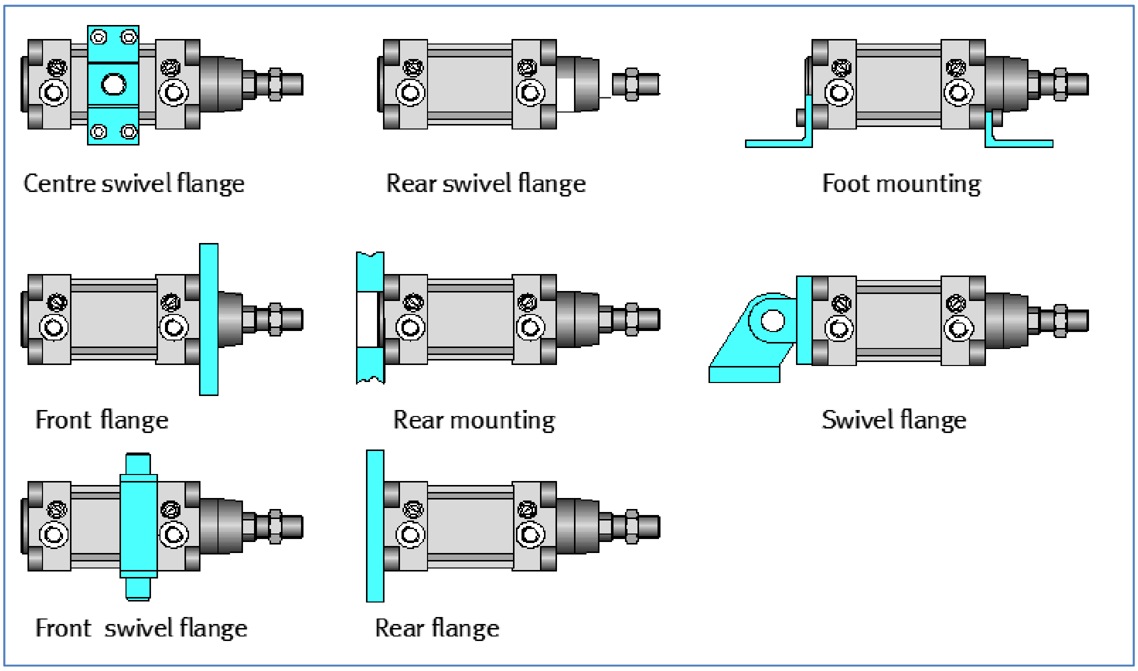


Figure 7.18 - Cylinder Mountings

8.0 Pneumatic Symbols

8.1 Introduction

The development of control systems is assisted by a uniform approach to the representation of the elements and the circuits. The symbols used for the individual elements must display the following characteristics:

- Function
- Actuation and return actuation methods
- Number of connections (all labelled for identification)
- Number of switching positions
- General operating principle
- Simplified representation of the flow path

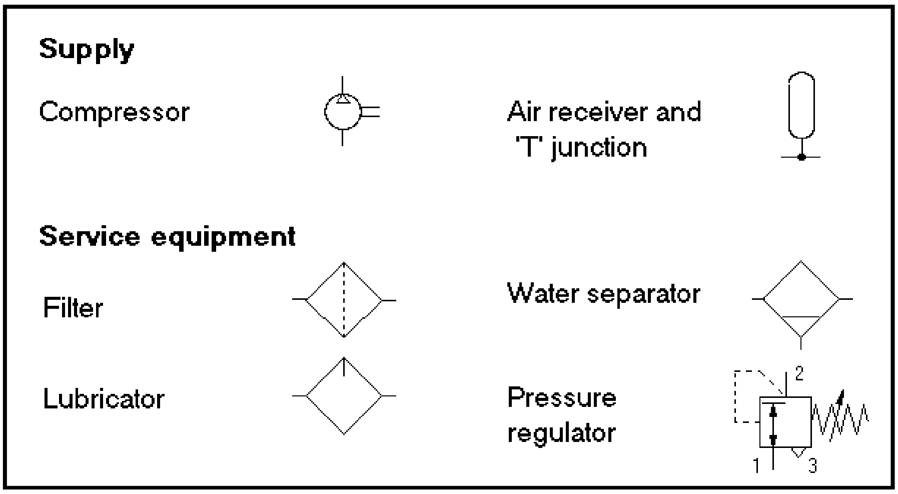
A symbol does not represent the following characteristics:

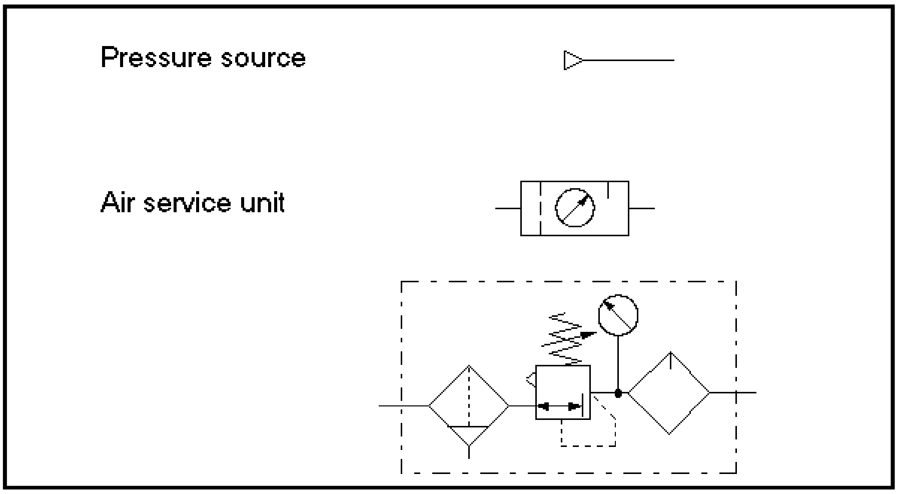
- Size or dimensions of the component
- Manufacturer, methods of construction or costs
- Orientation of the ports
- Any physical details of the element
- Any unions or connections other than junctions

The symbols used in pneumatics are detailed in the standard DIN ISO 1219.

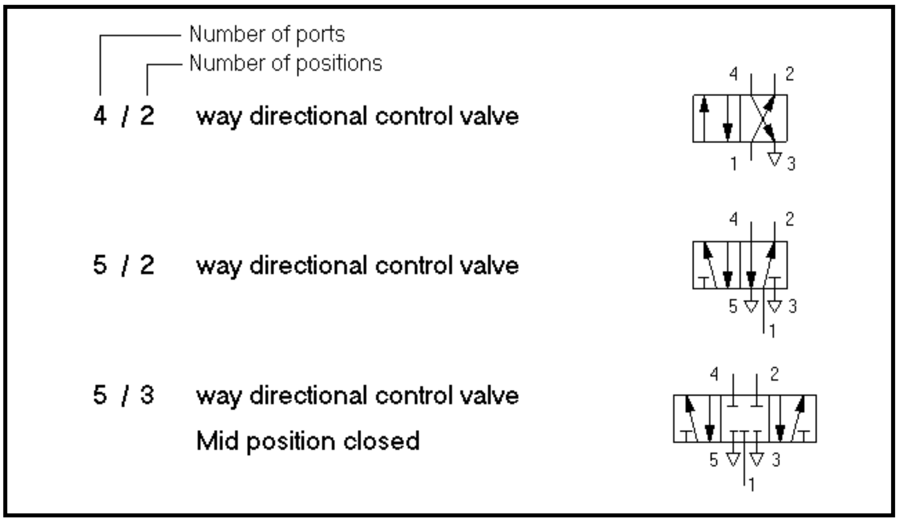
8.2 Symbols and Descriptions of Components

8.2.1 Symbols Used in Energy Conversion and Preparation

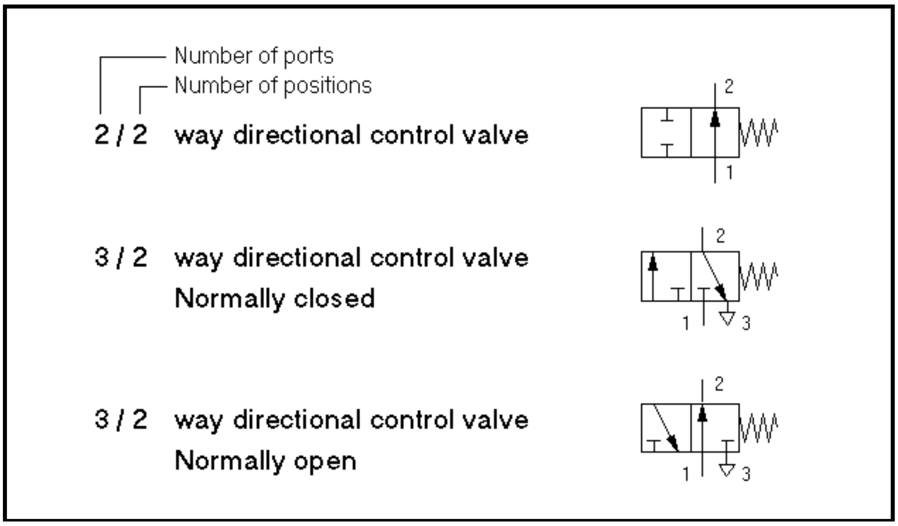




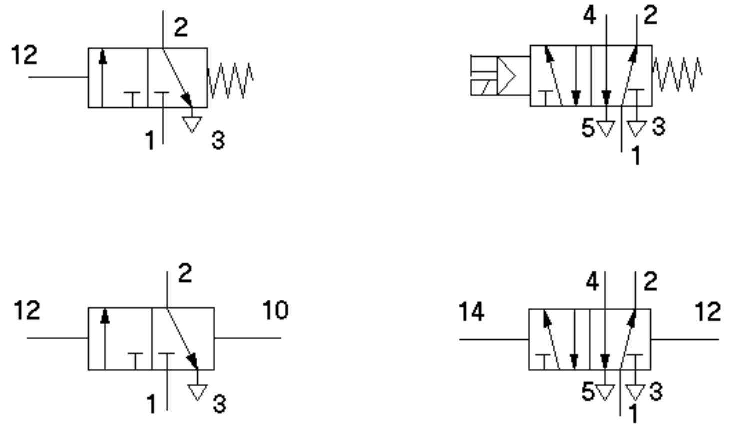
8.2.2 Directional Control Valves – Symbol Development



8.2.3 Directional Control Valves – Ports and Positions

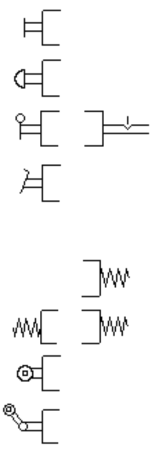


8.2.4 Directional Control Valves – Examples of Designation

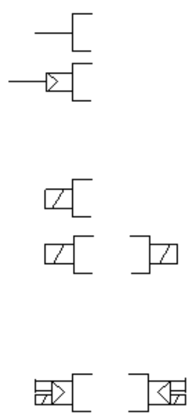


8.2.5 Directional Control Valves – Methods of Actuation

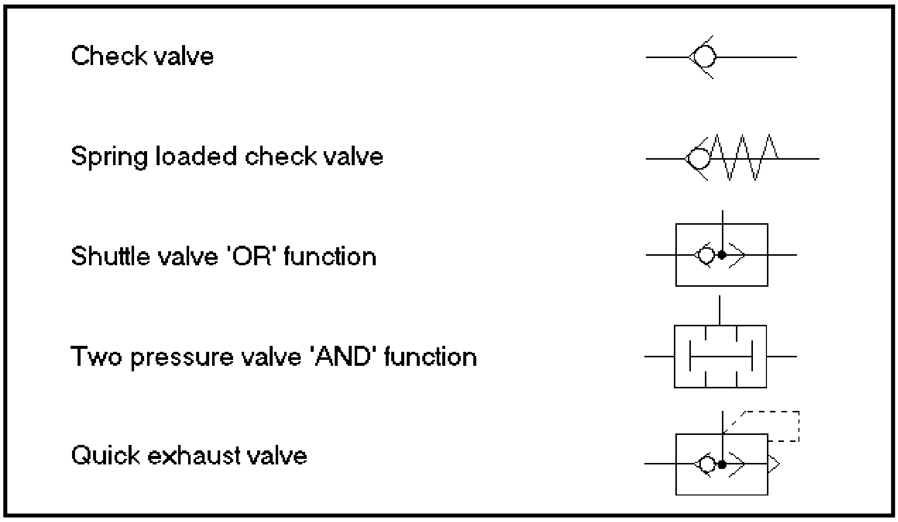
- **Manual**
  - General manual operation
  - Pushbutton
  - Detent lever operation
  - Foot pedal operation
- **Mechanical**
  - Spring return
  - Spring centred
  - Roller operated
  - Idle return roller



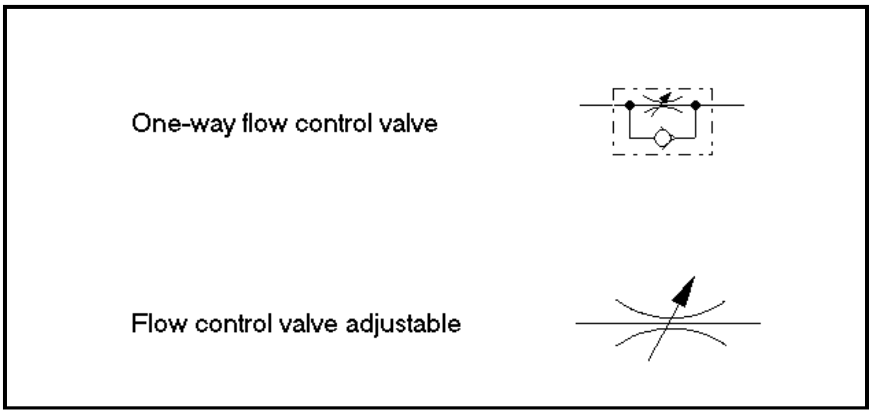
- **Pneumatic**
  - Direct pneumatic actuation
  - Indirect pneumatic actuation (piloted)
- **Electrical**
  - Single solenoid operation
  - Double solenoid operation
- **Combined**
  - Double solenoid and pilot operation with manual override



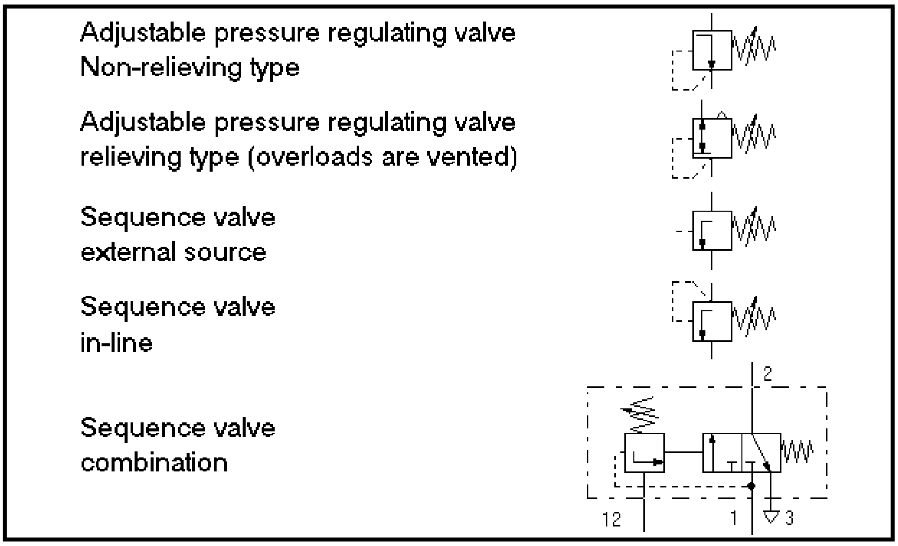
8.2.6 Non-Return Valves and Derivatives



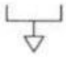
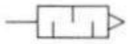
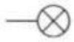
8.2.7 Flow Control Valves



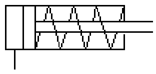
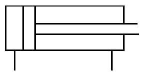
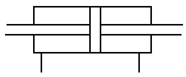
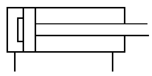
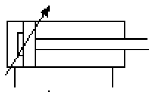
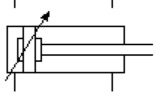
8.2.8 Pressure Valves



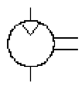
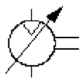
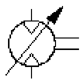
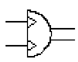
8.2.9 Auxiliary Symbols

Exhaust port	
Exhaust port with threaded connection	
Silencer	
Line connection (fixed)	
Crossing lines (not connected)	
Pressure gauge	
Visual indicator	

8.2.10 Linear Actuators

Single acting cylinder	
Double acting cylinder	
Double acting cylinder with double ended piston rod	
Double acting cylinder with non-adjustable cushioning in one direction	
Double acting cylinder with single adjustable cushioning	
Double acting cylinder with adjustable cushioning in both directions	

8.2.11 Rotary Motion

Air motor, rotation in one direction fixed capacity	
Air motor, rotation in one direction variable capacity	
Air motor, rotation in both directions variable capacity	
Rotary actuator limited travel rotation in both directions	

9.0 Developing Pneumatic Circuit Diagrams

9.1 Introduction

The solution to a control problem is worked out according to a system with documentation playing an important role in communicating the final result. The circuit diagram should be drawn using standard symbols and labelling. Comprehensive documentation is required including most of the following:

- Function diagram
- Circuit diagram
- Description of the operation of the system
- Technical data on the components

Supplementary documentation comprising

- Parts list of all components in the system
- Maintenance and fault-finding information
- Spare parts list

There are two primary methods for constructing circuit diagrams:

- The so-called intuitive methods
- The methodical design of a circuit diagram in accordance with prescribed rules and instructions

Whereas much experience and intuition is required in the first case and above all, a great deal of time where complicated circuits are concerned; designing circuit diagrams of the second category requires methodical working and a certain amount of basic theoretical knowledge.

Regardless of which method is used in developing the circuit diagram, the aim is to end up with a properly functioning and reliably operating control. Whereas previously emphasis was placed on the least expensive hardware solution, more importance is now attached to operational reliability and ease of maintenance by a clear layout and documentation.

This inevitably leads to increased usage of methodical design processes. In such cases, the control is always constructed in accordance with the given procedure and is less dependent upon personal influences from the designer. In many cases, however, more components will be required for the methodical solution than in a circuit devised by the intuitive method.

This additional material requirement will usually be rapidly compensated for by time-saving at the project stage and also later in terms of maintenance.

Generally, it must be ensured that the time spent in project design and particularly in simplifying the circuit, is in reasonable proportion to the overall effort.

9.2 Control Chain Flow Chart

The control chain is a categorised representation of a control system, from which amongst other things, the signal direction can be determined.

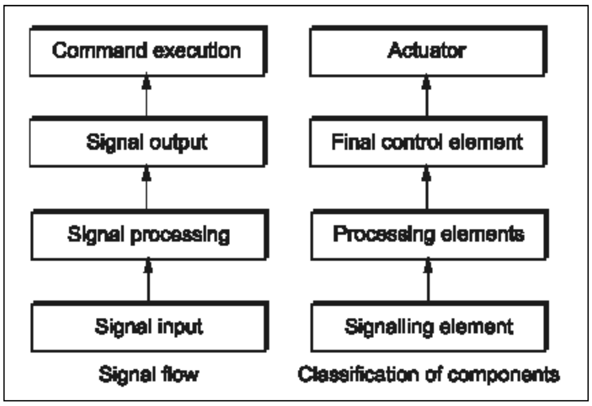


Figure 9.1- Control Chain Flow Chart

With the circuit design, the system breakdown produces a rough separation of signal input, signal processing, signal output and command execution. In practice, this separation can be easily seen. In the case of extensive installations, the control section is generally in a separate area to that of the power section.

The signal flow diagram indicates the path of a signal from signal input through to command execution. The following diagram illustrates a few examples for the allocation of devices to signal flow:

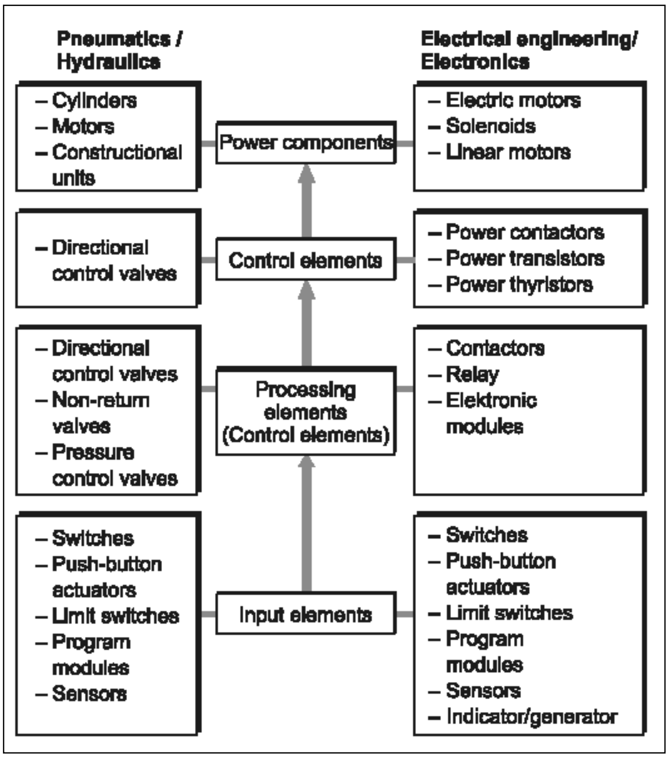


Figure 9.2 – Allocation of Devices to Signal Flow

The illustration below clearly shows the structure of the control chain.

- The input elements are the manually actuated valves 1S1, 1S2 (push-button valves) and the mechanically actuated valve 1S3 (roller lever valve).
- The processing element (processor) is the shuttle valve 1V1,
- The control element is the directional control valve 1V2.
- The power component is the cylinder 1A.

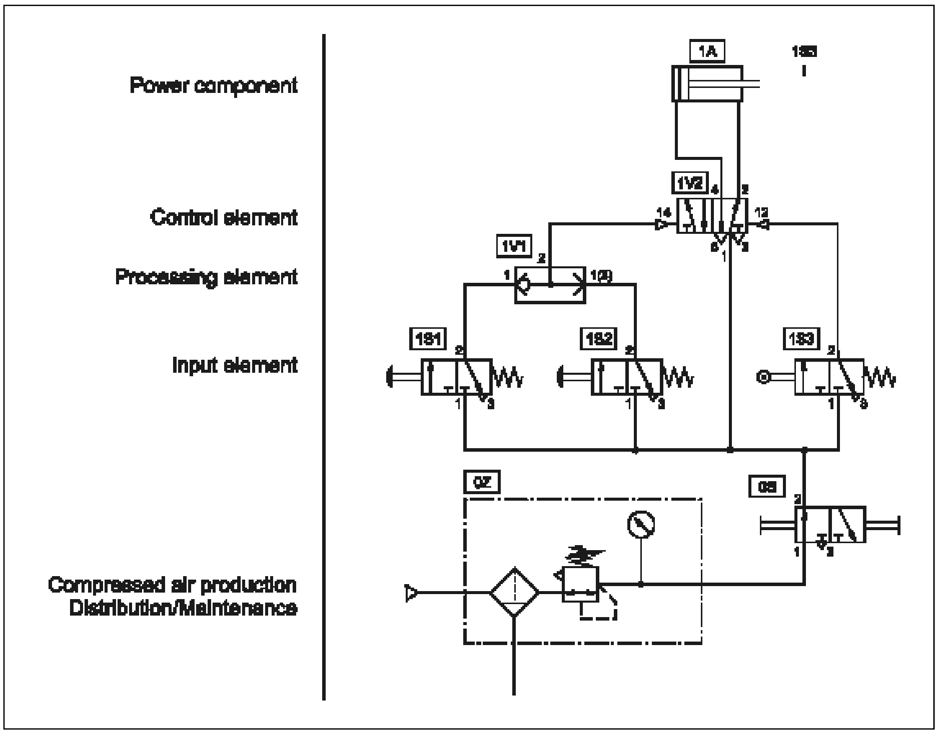


Figure 9.3 – Circuit Diagram

9.3 Circuit Layout

The piston rod of a double-acting pneumatic cylinder advances if either a manual push button or a foot pedal is operated. The cylinder returns to its starting position slowed down after fully extending. The piston rod will return provided the manual actuators have been released.

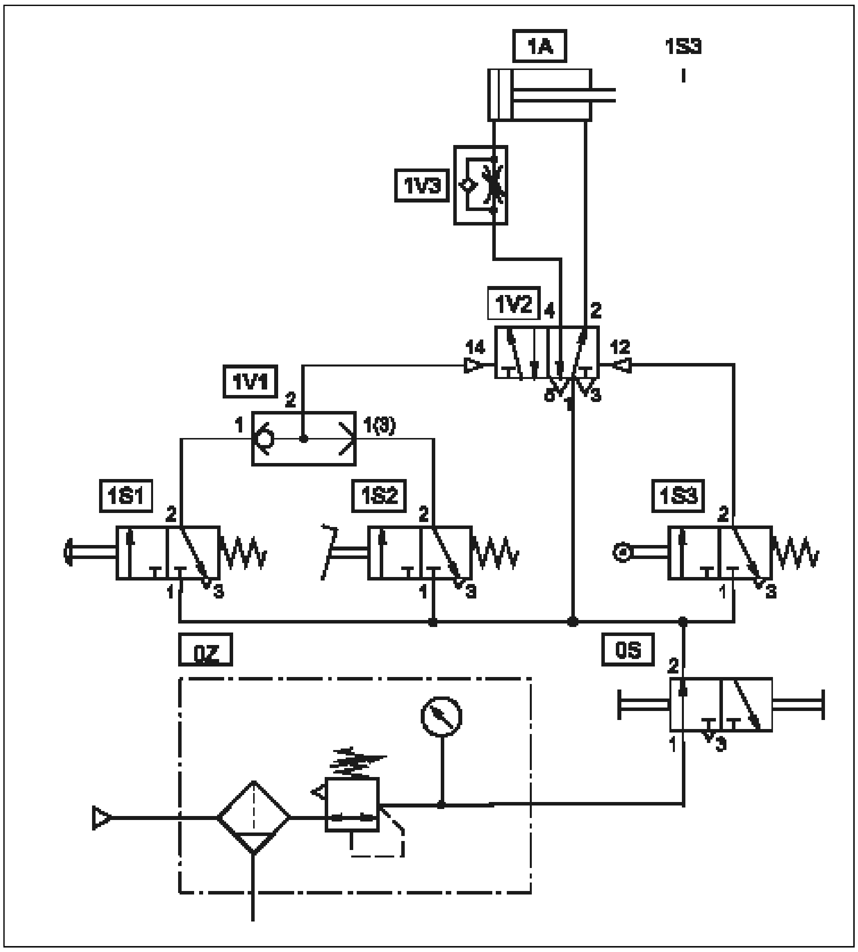


Figure 9.4 – Circuit Diagram

The roller lever valve 1S3 is positioned as a limit switch in the forward end position of the cylinder. The circuit diagram shows this element situated at the signal input level and does not directly reflect the orientation of the valve. The mark on the circuit at the extended cylinder position indicates the physical position of the limit switch 1S3 for circuit operation.

If the control is complex and contains several working elements, the control should be broken down into separate control chains, whereby a chain is formed for each cylinder. Wherever possible, these chains should be drawn next to each other in the same order as the operating sequence.

9.4 Designation of Individual Elements

Signal elements should be represented in the normal position in the circuit diagram. If valves are actuated in the initial position as a start precondition, this must be indicated by the representation of a trip cam. In this case, the actuated switching position must be connected.

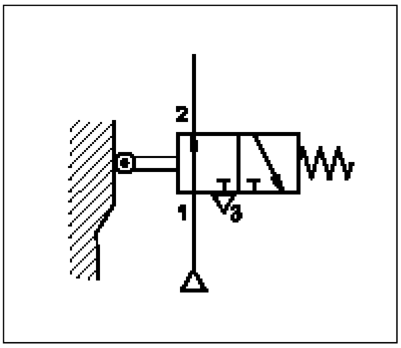


Figure 9.5 – Actuated Initial Position

With this type of designation, elements are divided into groups. Group 0 contains the elements for the power supply, groups 1,2,... designate the individual control chains. One group number is generally allocated for each cylinder.

1A, 2A, etc.	Power components
1S1, 2S1, etc	Limit switches, activated in the retracted end position of cylinders 1A, 2A
1S2, 2S2, etc	Limit switches, activated in the forward end position of cylinders 1A, 2A

Figure 9.6 – Designation by Letters

To summarise:

- Physical arrangement of the elements is ignored.
- Draw the cylinders and directional control valves horizontally wherever possible.
- The energy flow within the circuit moves from the bottom to the top.
- Energy source can be shown in simplified form.
- Show elements in the initial position of the control. Identify actuated elements by a cam.
- Draw pipelines straight without cross-over wherever possible.

9.5 Representing the Working Sequence of a Pneumatic Circuit

There are a number of methods representing the working sequence of a pneumatic circuitry. In order to understand the different methods of representing the working sequence of a pneumatic circuitry we will use the example of a bending and punching fixture.

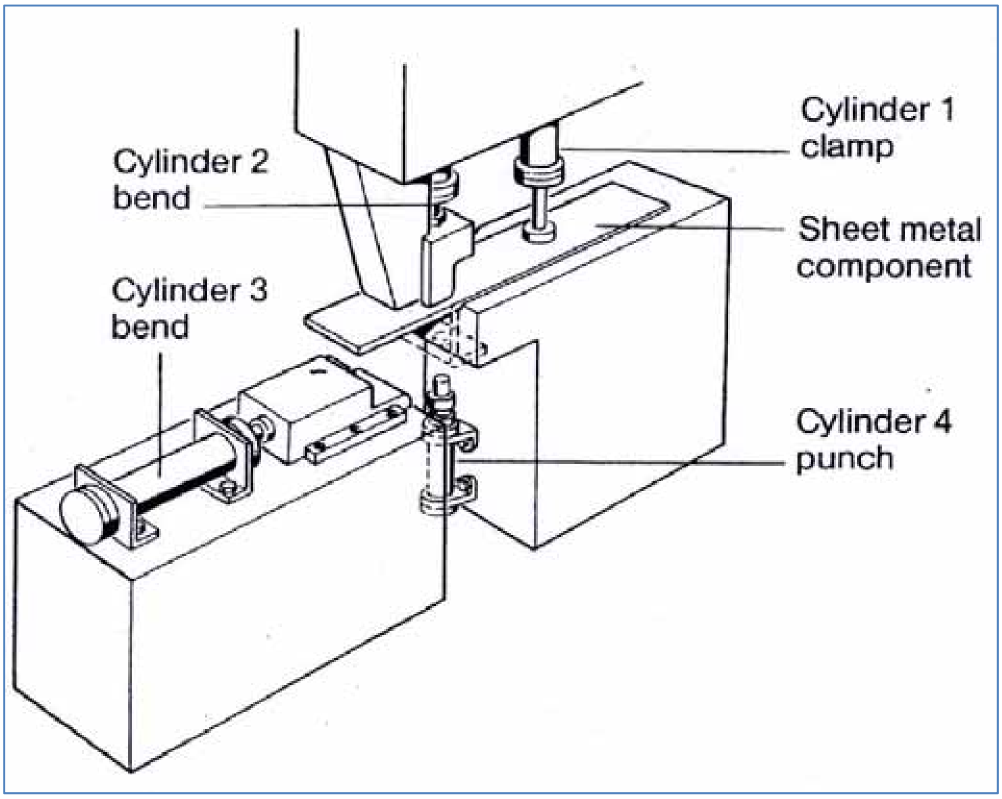
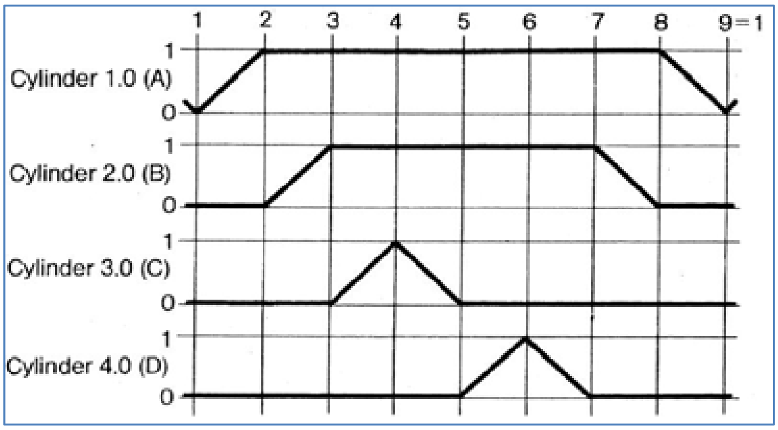


Figure 9.7 - Bending and Punching Fixture

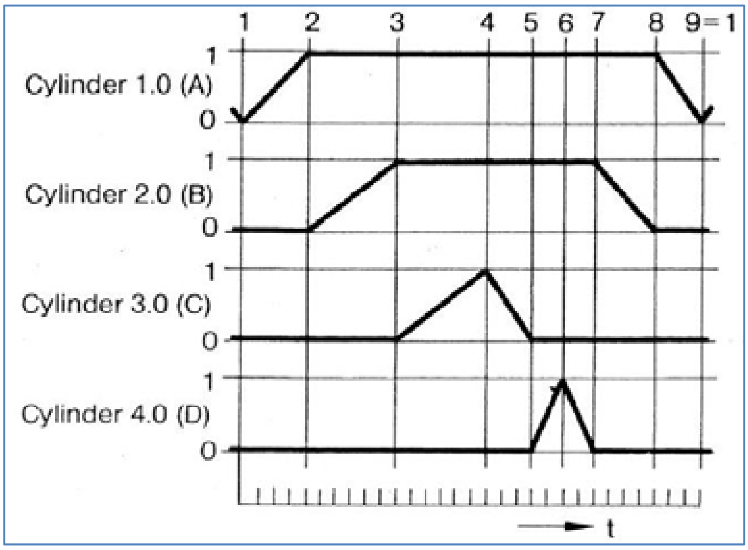
Sheet metal components are placed by hand in a holder. The sheet metal component is clamped by means of a pneumatic cylinder. Two other cylinders bend the component until another cylinder punches a hole.

9.5.1 Graphical Form of Representation

a. Displacement-Step Diagram



b. Displacement-Time Diagram



c. Designations in the Circuit Diagram

Designation	**Elements**	**Example**
1.0, 2.0, 3.0, ...	Working Elements	Cylinders, etc
1.1, 2.1, 3.1, ...	Actuating Elements	4/2-way, 5/2-way DCV, etc.
1.2, 1.4, 2.2, 2.4, ... 1.3, 1.5, 2.3, 2.5, ...	Signal Elements (Advance Movement) (Return Movement)	3/2-way DCV, shuttle valve, two-pressure valve, delay valve, etc.
0.1, 0.2, 0.3, ...	Supply Elements	Service Unit, Shut-off Valve and Reversing valve for cascade.
1.02, 1.03, 2.02, ...	Auxiliary Devices	Throttle valve, relief valve, check valve, quick exhaust valve, etc

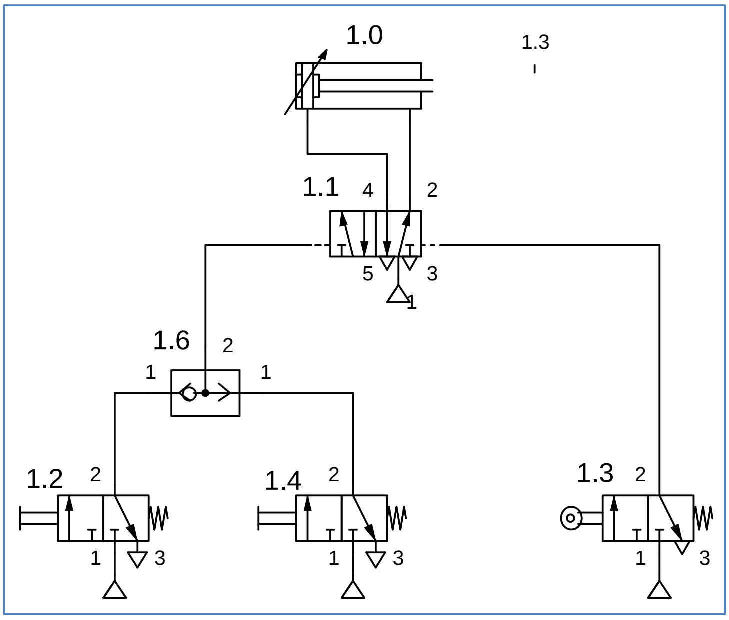


Figure 9.8 - Example 1

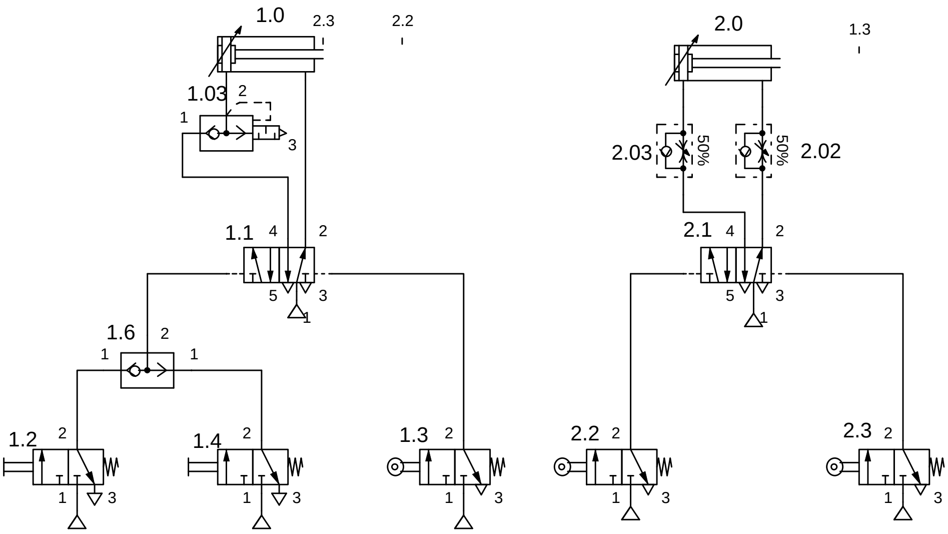
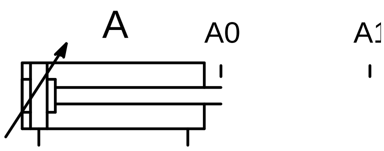


Figure 9.9 - Example 2

9.5.2 Designation Using Alphabetic Characteristics

This type of designation is often used for developing circuit diagrams, but it is also used frequently in the circuit diagram instead of numerical designation. With this method, the working elements are given capital elements and signal elements are given small letters.



A, B, C, ... Allocated to the working elements.

a_1, b_1, c_1, ... Allocated to the signal elements in the forward end position.

a_0, b_0, c_0, ... Allocated to the signal elements in the rear end position.

For the above sequence, it would be

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

10.0 Cascade Control Systems

10.1 Introduction

The cascade system is a method used for designing multiple cylinder circuits. This method is very useful when we encounter signal overlaps of opposing signals.

10.2 Basic Circuits with Single Cylinders

To be able to design pneumatic circuits, it is better for one to have basic knowledge on the designing simple single cylinder circuits. With this foundation, one would be able to move on to the designing more complicated circuits involving many more cylinders.

10.2.1 Control of a Single-Acting Cylinder

When the 3/2-way DCV is actuated, compressed air flows from P to A, and line R is blocked. Resetting by spring causes the cylinder chamber to exhaust from A to R, and the compressed air connection P is blocked.

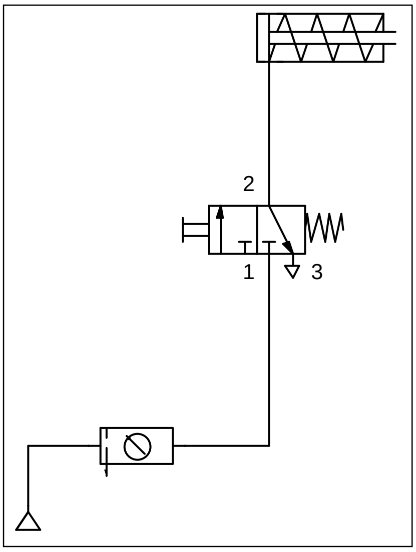


Figure 10.1 - Control of a Single-Acting Cylinder

10.2.2 Control of a Double-Acting Cylinder

Either a 4/2-way or a 5/2-way DCV is used to actuate the double-acting cylinder. When the valve is actuated, compressed air flows from P to A extending the cylinder rod, and the exhaust from B to R. When the valve is released, compressed air flows from P to B retracting the cylinder rod and the exhaust A to R.

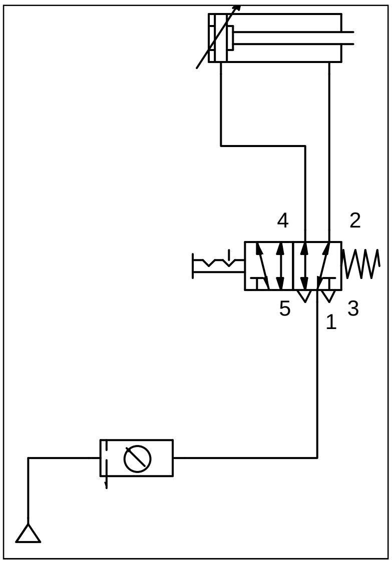


Figure 10.2 - Control of a Double-Acting Cylinder

10.2.3 Indirect Control of a Single-Acting Cylinder

Actuation of valve 1.2 opens the passage from P to A to the compressed air, and hence the signal at Z on the valve 1.1. Owing to valve 1.1 switching over, air flows from P to A and thus to the single-acting cylinder.

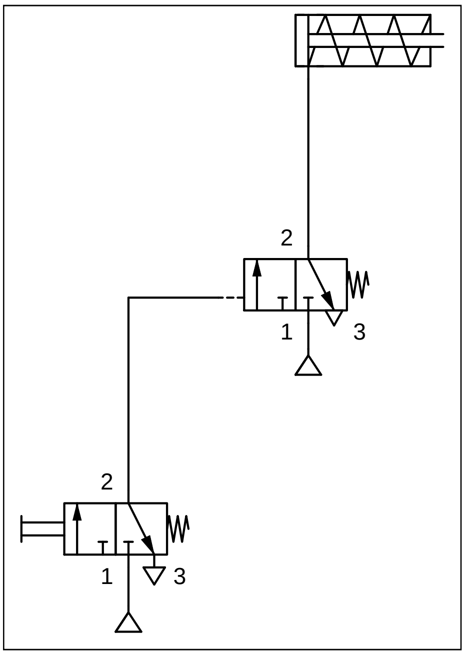


Figure 10.3 - Indirect Control of a Single-Acting Cylinder

10.2.4 Indirect Control of a Double-Acting Cylinder

When valve 1.2 is actuated, it sends a signal to the 5/2-way DCV 1.1 which switches over. The cylinder moves out. It remains in this position until a signal from valve 1.3 switches valve 1.1 back at Y.

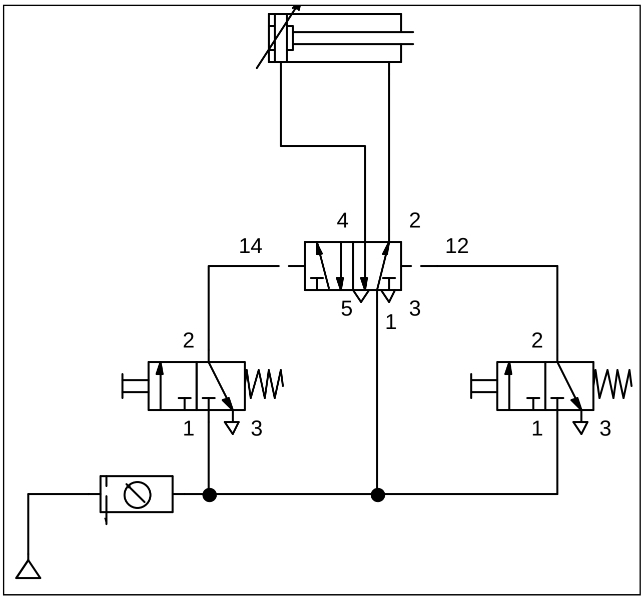


Figure 10.4 - Indirect Control of a Double-Acting Cylinder

10.2.5 Control with Shuttle Valve

On actuating valve 1.2, the compressed air flows from P to A and also from P_1 to A to the cylinder. The same occurs when switched over to valve 1.4. Without the shuttle valve, the air would escape through the exhaust of the other valve when 1.2 or 1.4 is operated.

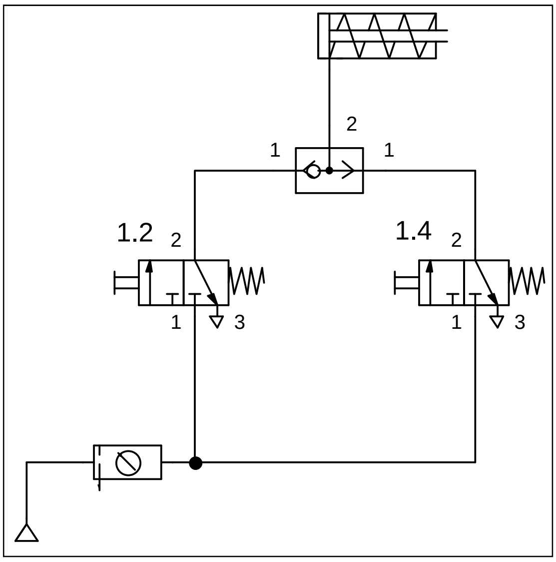


Figure 10.5 - Control with Shuttle Valve

10.2.6 Speed Regulation with Single-Acting Cylinders

By placing the flow control valve in various positions, you can regulate the speed of the cylinder either for the advance stroke or the return stroke. Figure 10.6 shows the speed control for the advance movement and Figure 10.7 for the return movement. By placing two flow control valves, you can control both the advance and return stroke. This is shown in Figure 10.8.

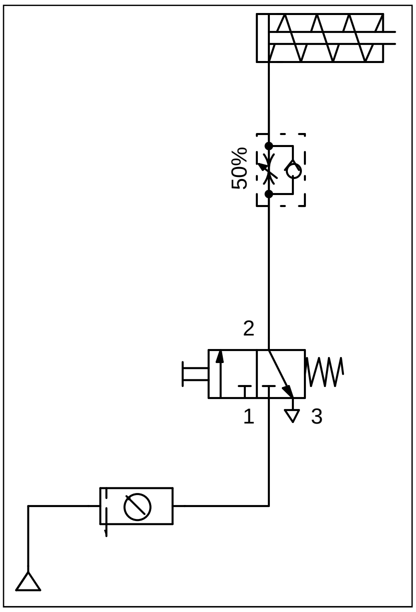


Figure 10.6 - Speed Regulation on Single-Acting Cylinders for Advance Stroke

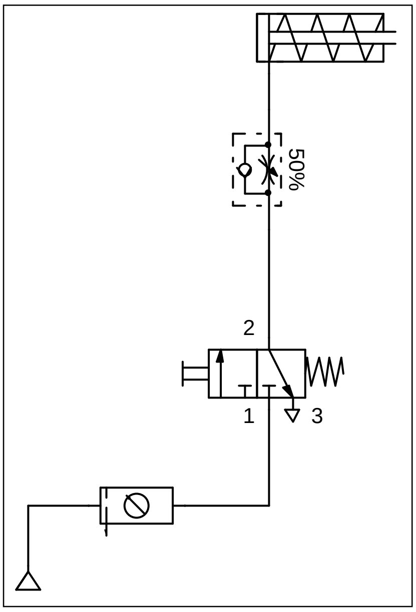


Figure 10.7 - Speed Regulation on Single-Acting Cylinders for Return Stroke

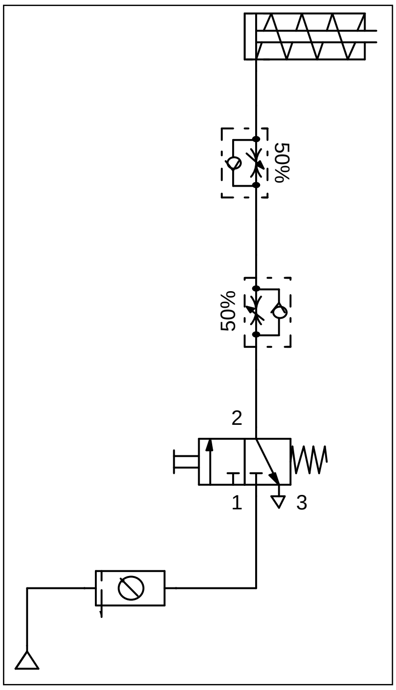


Figure 10.8 - Speed Regulation on Single-Acting Cylinders for Both Strokes

10.2.7 Speed Regulation with Double-Acting Cylinders

There are two ways of regulating the speed for a double-acting cylinder, you can exhaust throttle (meter-out) or supply air throttle (meter-in). For exhaust throttling, there is an initial jolt and then the forces are equalised but it has a better possibility for regulating. For supply air throttling, it has a steady initial motion but poor possibility of regulation. It is used mainly for small cylinders against the load.

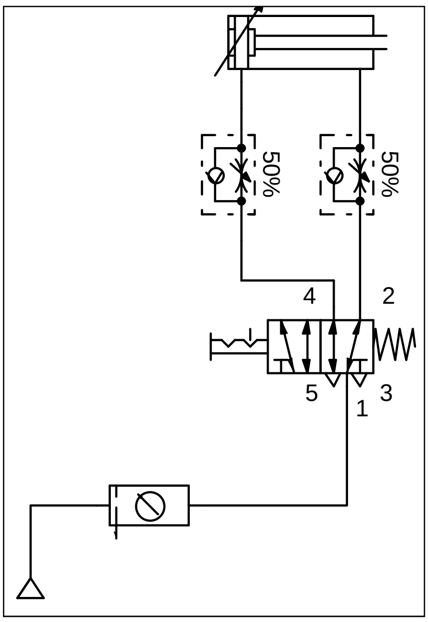


Figure 10.9 - Exhaust Throttling

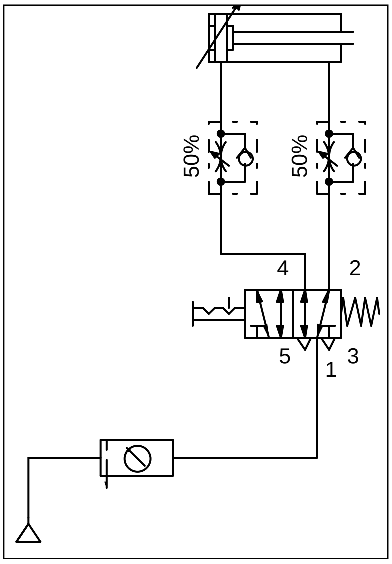


Figure 10.10 - Supply Air Throttling

10.2.8 Raising the Speed on Single-Acting and Double-Acting Cylinders

The speed of either the advance or the return stroke of the cylinder is increased by the use of the quick exhaust valve.

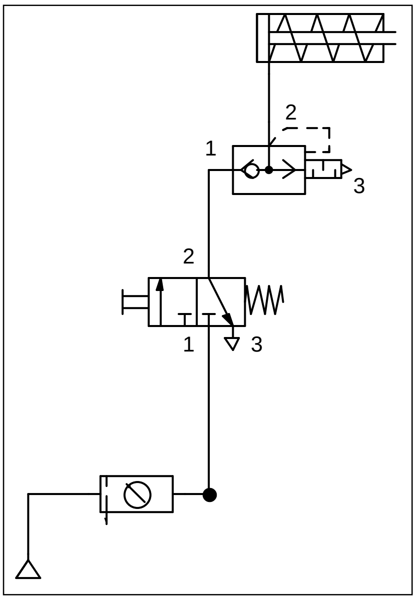


Figure 10.11 - Increasing the Return Speed of a Single-Acting Cylinder

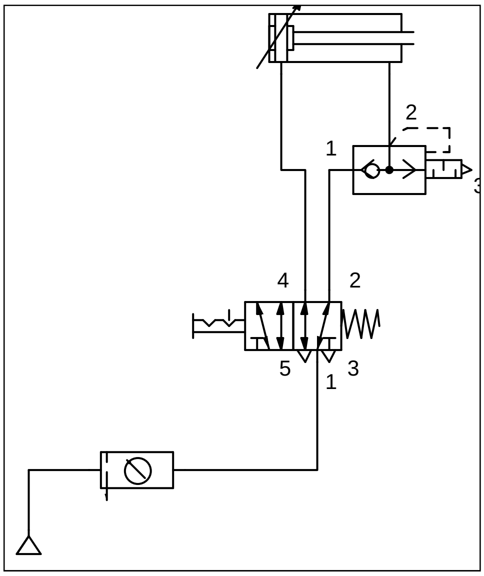


Figure 10.12 - Increasing the Advance Movement of a Double-Acting Cylinder

10.2.9 Control with Two-Pressure Valve

Actuation of valves 1.2 and 1.4 produces the signal at P_1 and P_2, thus permitting compressed air to be applied to the cylinder.

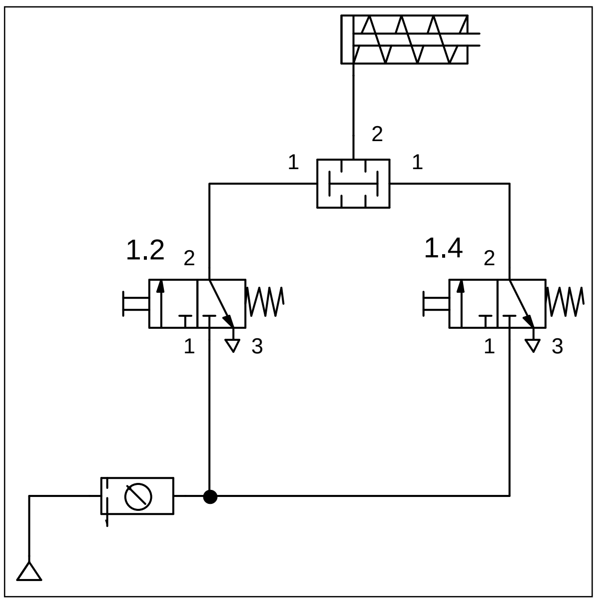


Figure 10.13 - Control with Two-Pressure Valve

10.2.10 Automatic Return Control of a Double-Acting Cylinder Using a Limit Switch

When the piston rod touches the valve 1.3, a signal is provided for the piston to return to its original state.

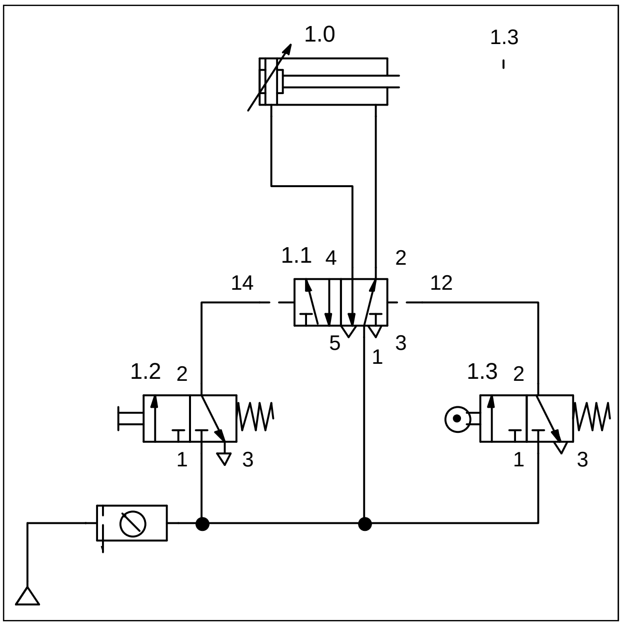


Figure 10.14 - Automatic Return Control of a Double-Acting Cylinder

10.2.11 Automatic Return Control of a Double-Acting Cylinder Using a Limit Switch and a Timer

When the piston rod touches the valve 1.3, a signal is sent to the timer which will return the piston to its original state are a preset time.

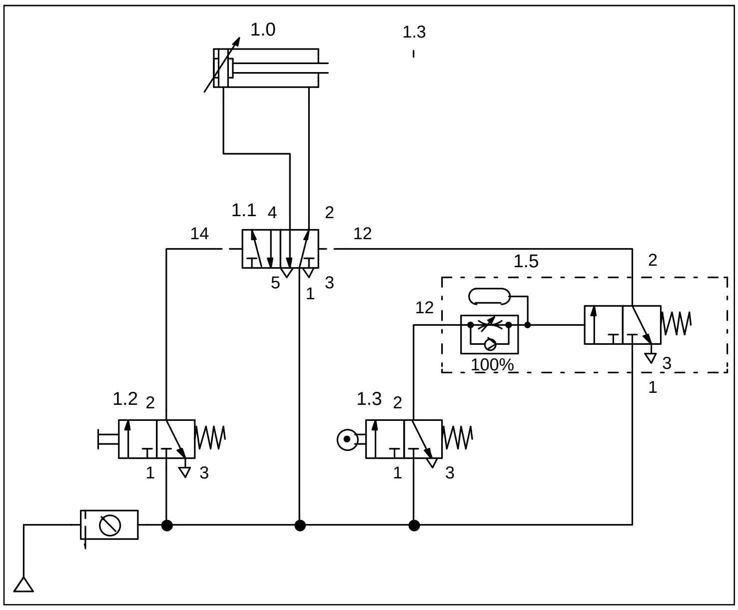


Figure 10.15 - Automatic Return Control of a Double-Acting Cylinder with Timer

10.3 Pneumatic Circuit with Multi-Cylinders

10.3.1 A+ B+ A- B-

In this basic two-cylinder circuit, cylinder A moves out followed by cylinder B. After cylinder B has extended, cylinder A retracts followed by cylinder B. The following circuit shows this.

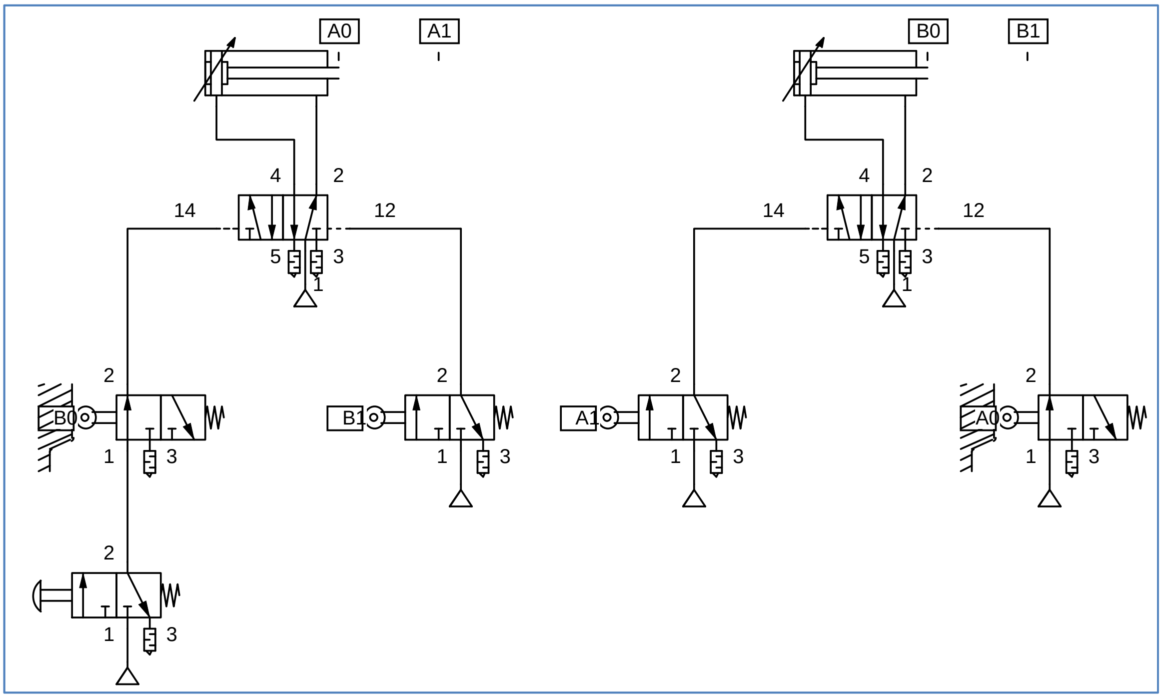


Figure 10.16 - Circuit Diagram for A+ B+ A- B-

10.4 Introduction to Cascade Systems

The cascade system uses signal cut-out by means of reversing valves. Air supply to the various limit switches are no longer derived from the main air supply, but from a reversing valve. These valves are controlled by limit switches.

10.5 Design of a Cascade System

In the design of cascades, they work on the principle that at any one time, only one output line is pressurised. The following arrangements ensure that at any one time, only one output line is pressurised and all others are vented to atmosphere.

10.5.1 Arrangement for 1 Reversing Valve

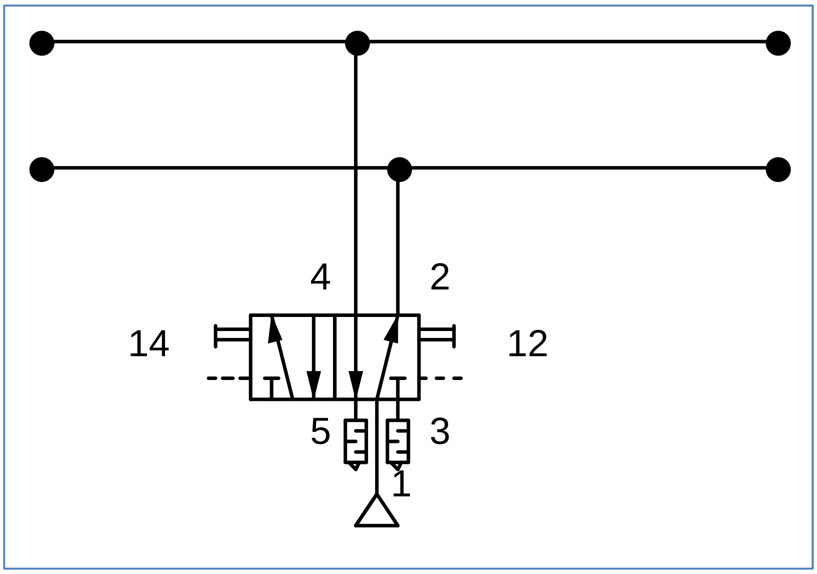


Figure 10.17 - Arrangement for 1 Reversing Valve

10.5.2 Arrangement for 2 Reversing Valves

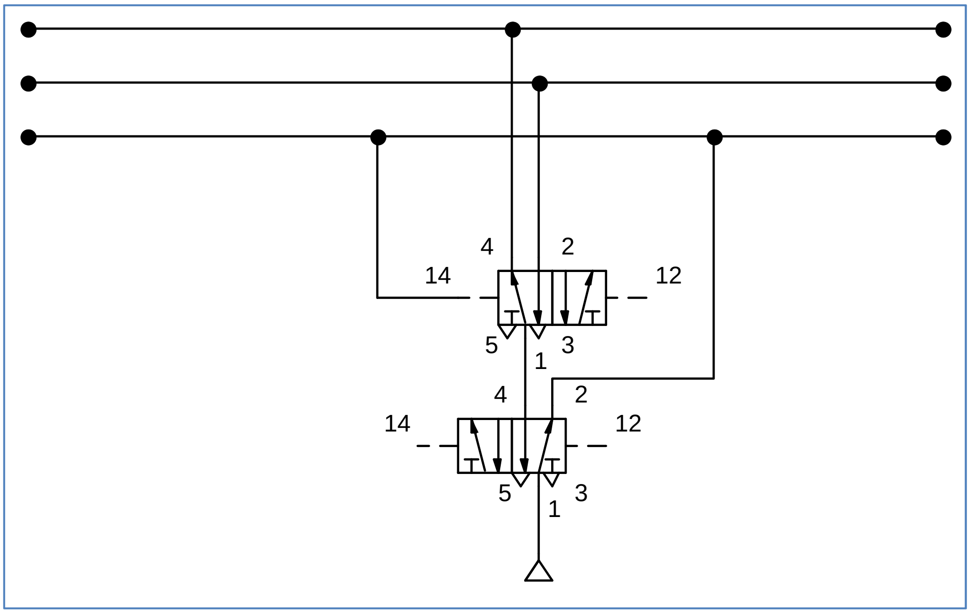


Figure 10.18 - Arrangement for 2 Reversing Valves

10.5.3 Arrangement for 3 Reversing Valves

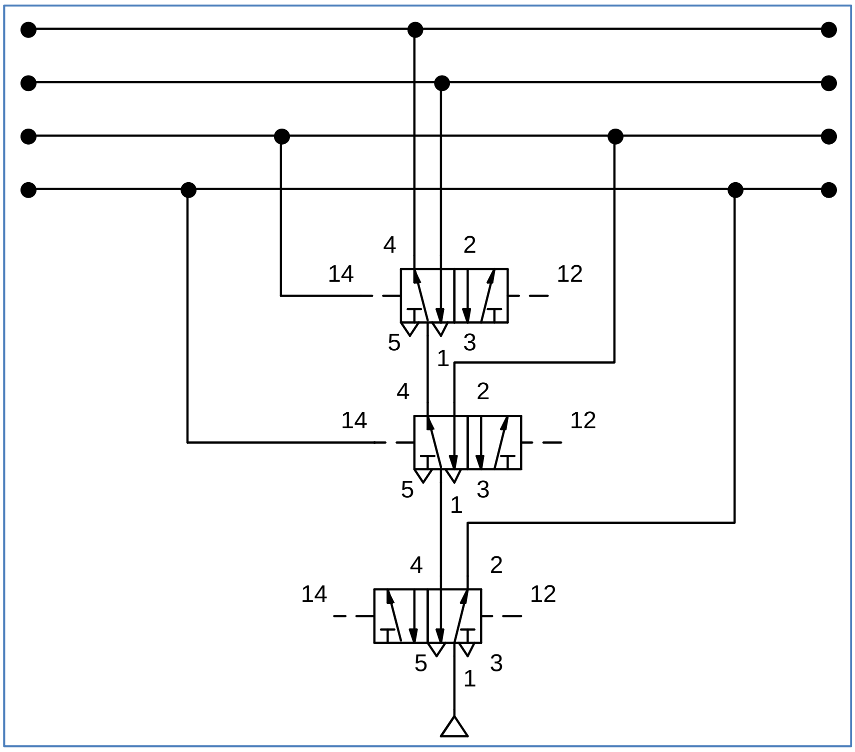


Figure 10.19 - Arrangement for 3 Reversing Valves

10.5.4 Controlling the Reversing Valves with Limit Switches

The switching of groups is done through limit switches.

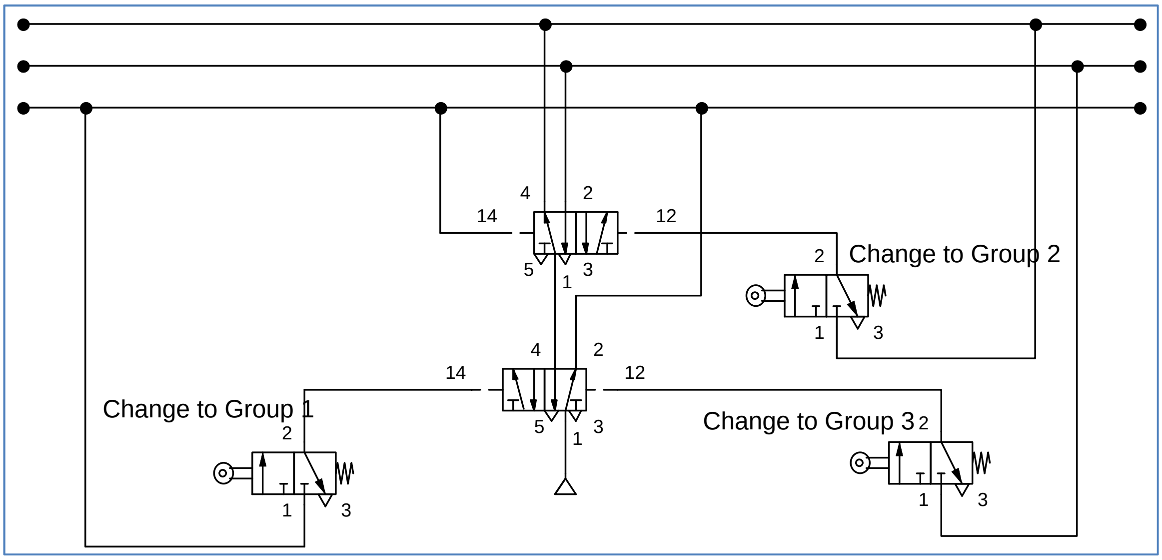


Figure 10.20 - Controlling the Reversing Valves with Limit Switches

10.5.5 Various Stages when Switching through the Cascade

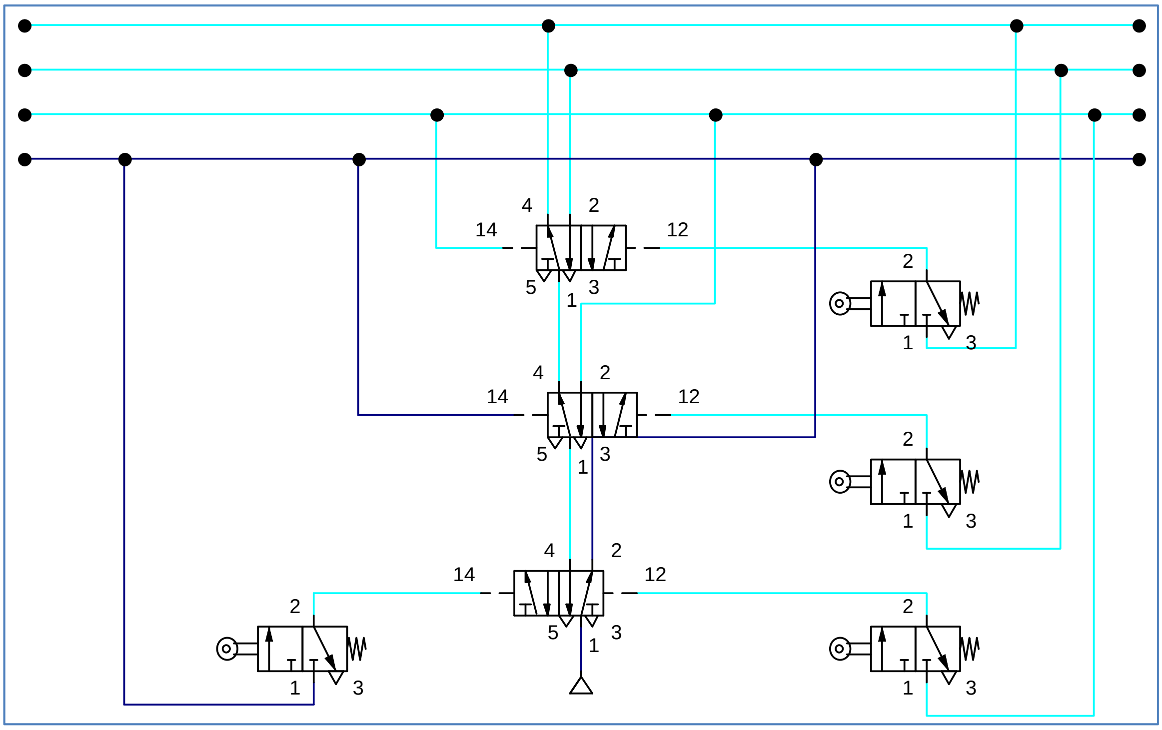


Figure 10.21 – Initial Stage Line 4 is Live

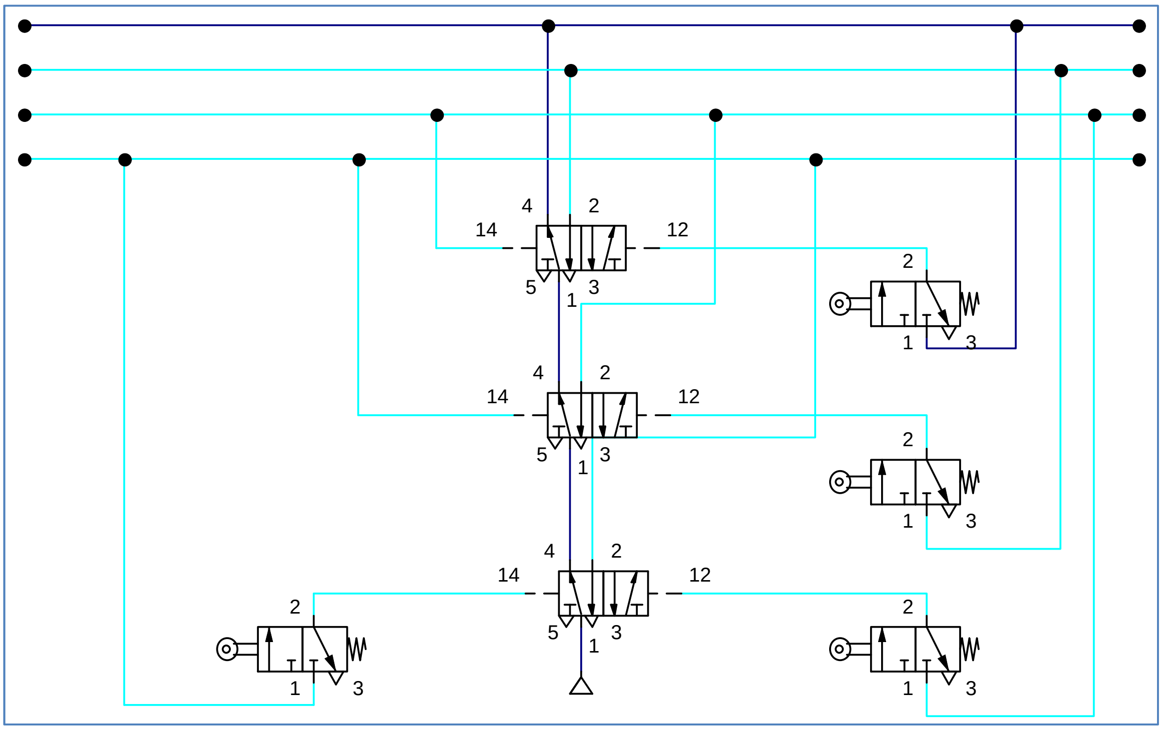


Figure 10.22 – Line 1 is Live

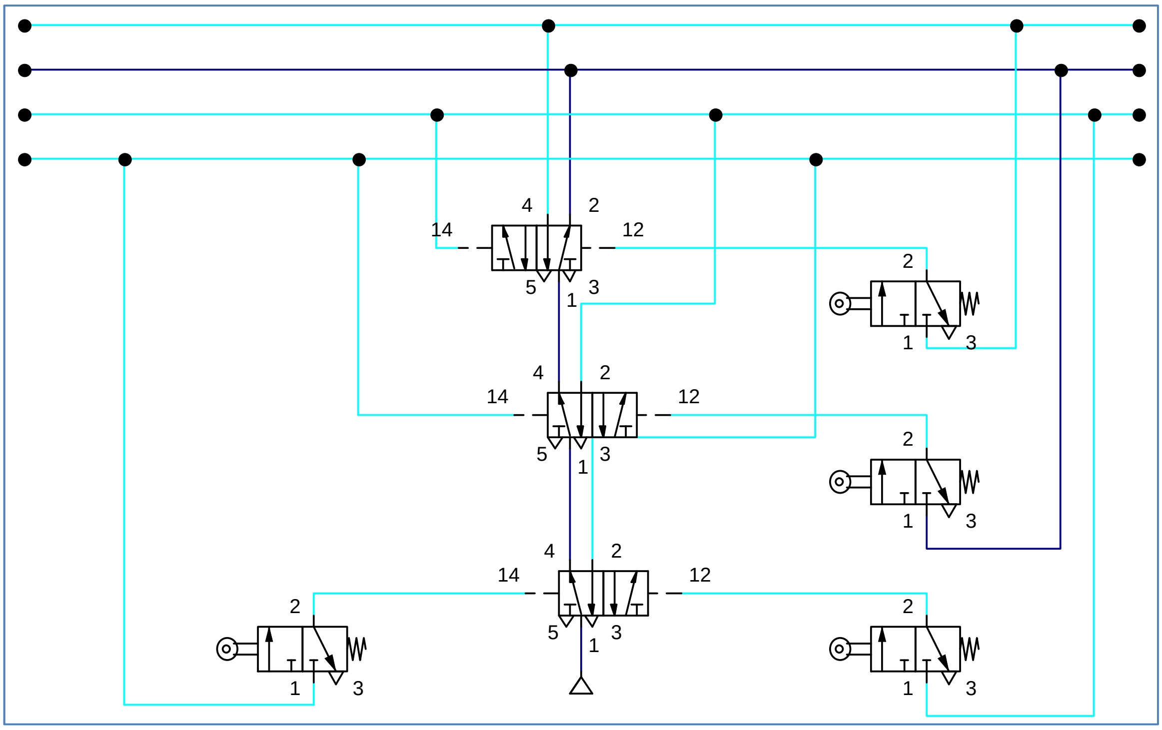


Figure 10.23 – Line 2 is Live

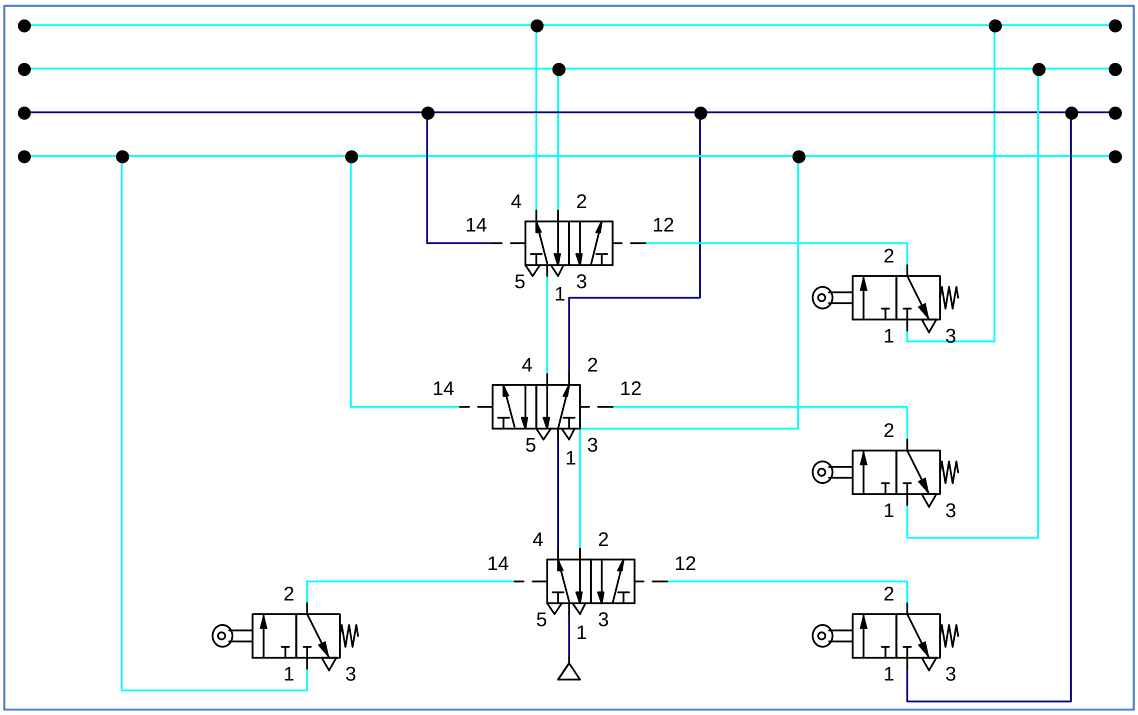


Figure 10.24 – Line 3 is Live

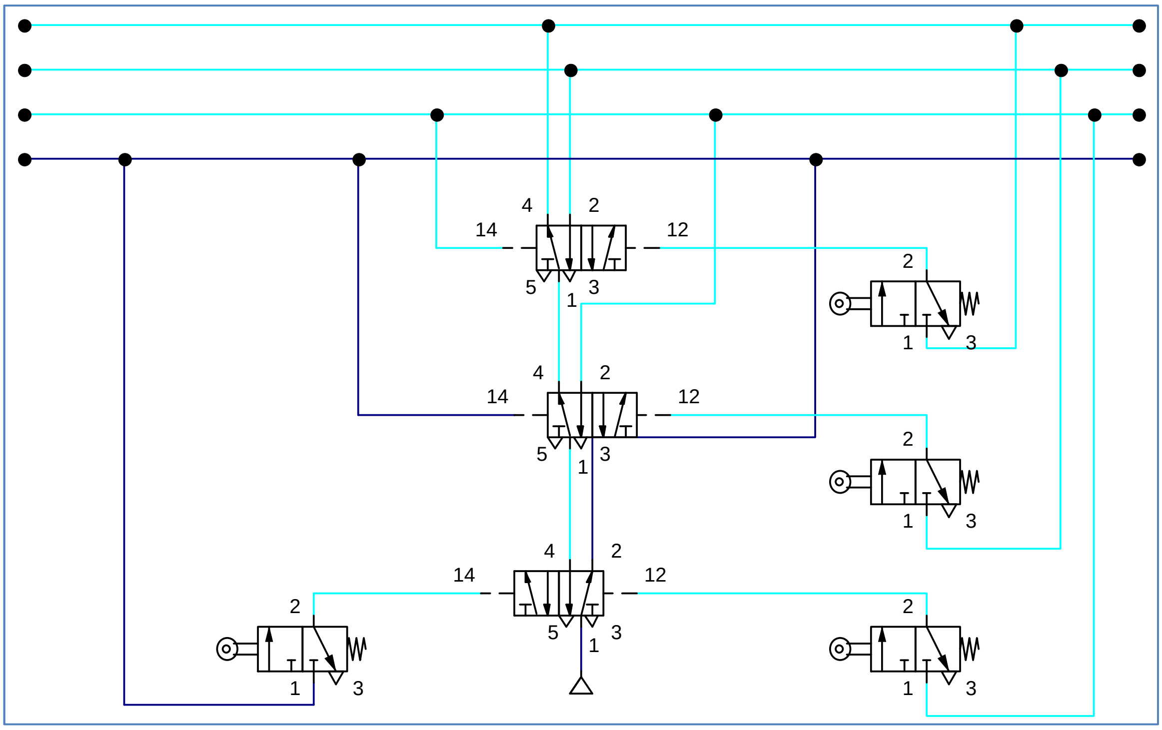


Figure 10.25 – Cycle End

The resultant pressure drop becomes significant if a large number of valves are connected in series and hence the control becomes slower. Therefore, not more than 3 reversing valves or 4 groups should be used.

10.6 Procedure for Constructing a Cascade System

a. Define the Sequence of Motion by Abbreviated Notation.

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

b. Divide Them into Groups

Break into groups such that a cylinder operation occurs only once in a group, and the minimum number of groups is obtained. That is A+ and A- cannot be in the same group. Give each group a number; I, II, III, etc.

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

I II III

c. Supply Lines

For each group, a supply is required. For 3 groups, there must be 3 supply lines.

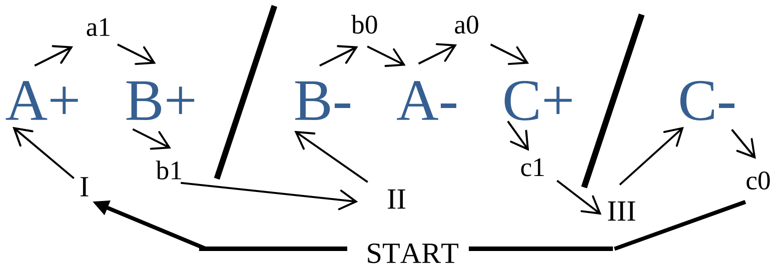
d. Reversing Valves

The number of reversing valves = Number of groups - 1

Therefore, the number of reversing valves = 3 - 1 = 2

e. Limit Switches

Write on the abbreviated notation, the number of limit switches.



Note:

- Limit switches/valves which cause changeover of groups are designated below the abbreviated notation.
- Limit switches within a group are designated above the abbreviated notation.
- Arrows designate signals which trigger cylinder operation.
- The last group must be "Live".

f. Transposition into the Circuit

When transposition into the circuit, the following points are important:

- Limit switches/valves which cause changeover of groups are drawn below the supply lines.
- If a cylinder extends two or more times during a cycle, limit switch signals must be interlocked by means of two-pressure valves.
- Limit switches within a group are drawn above the supply line.
- Auxiliary conditions and additional interlocks are incorporated only when the basic sequence of the motions has been completely designed.

10.7 Auto Start and Auto Stop Modes in Cascade Control

If you wish to include auto-start and auto-stop modes in the circuit, you have to add the following valves as shown.

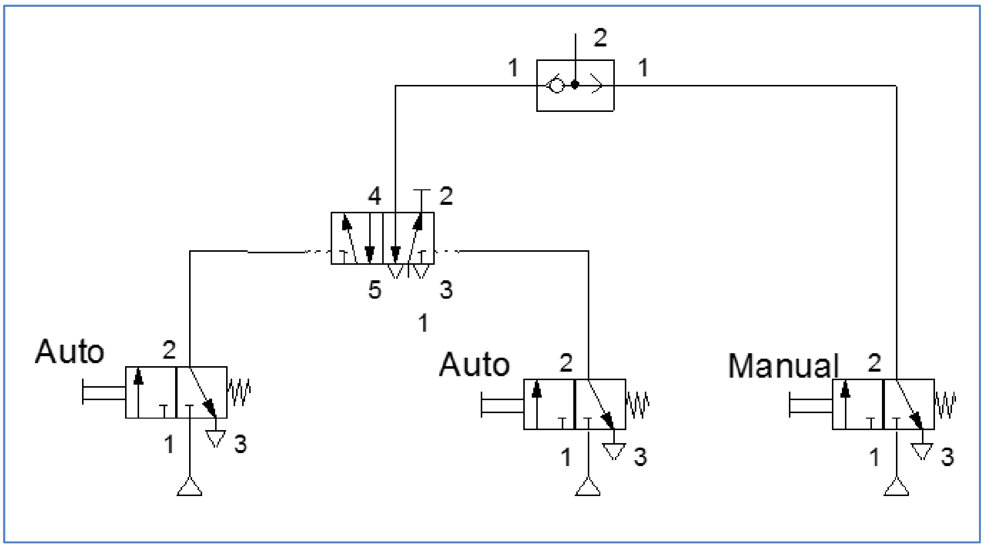


Figure 10.26 - Auto-Start and Auto-Stop Modes

10.8 Advantages and Disadvantages of Cascade Systems

10.8.1 Advantages

- Circuits can be designed and checked quickly.
- Fault tracing is simple. It is easy to determine which valve or group has failed.
- The system ensures that signals are inherently of sufficient duration to perform their required tasks.

10.8.2 Disadvantages

- For certain circuits, the cascade method may not yield the simplest solution to a control problem.
- The pressure drop becomes significant as the number of stages of the cascade increases.
- When a limit switch is depressed by some external source not dependent on the circuit itself, particularly if held down throughout the cycle, great care should be exercised.

10.9 Examples of Cascade Control Systems

10.9.1 Distributor

Figure 10.27 shows the pictorial view of the distributor and its displacement-step diagram.

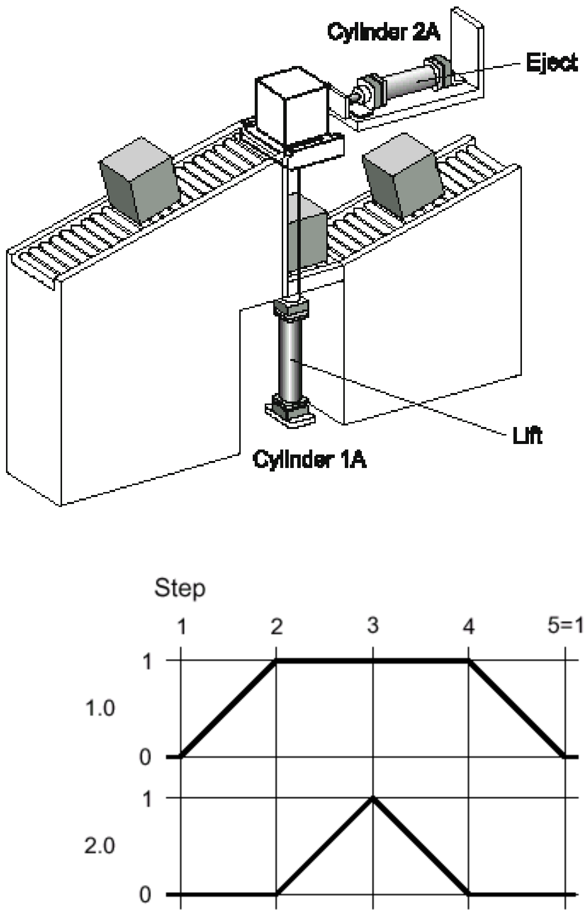
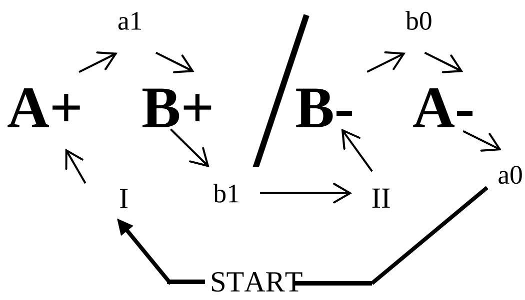


Figure 10.27 – Distributor

-



The design of the cascade with two groups.

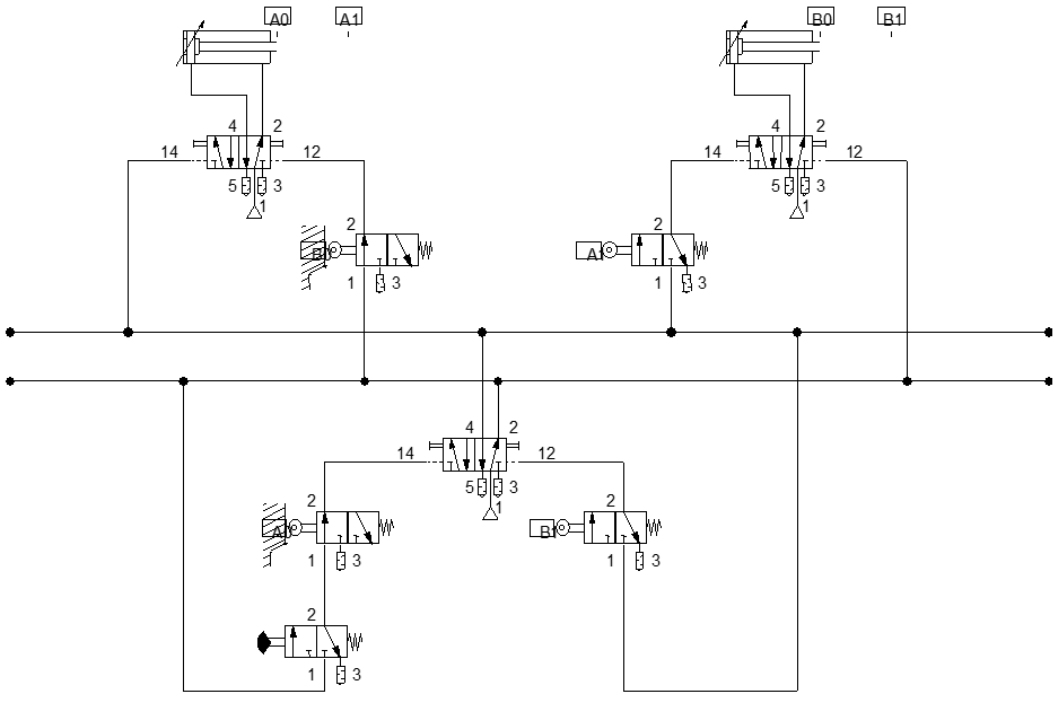
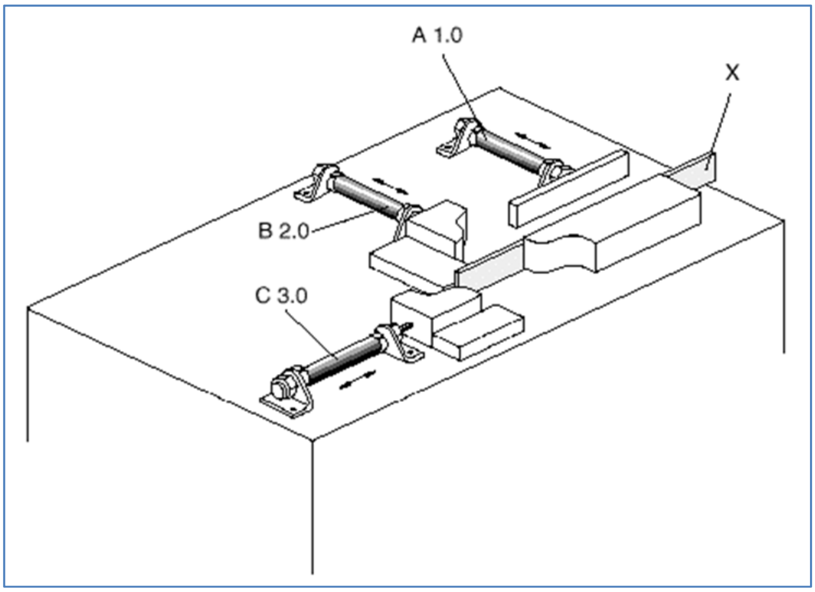


Figure 10.28 - Distributor Circuit Using Cascade System

10.9.2 Bending Device

Metal strips are placed manually in a fixture. Cylinder 1.0 clamps the metal strip when a push button is pressed. Cylinder 2.0 starts the bend and retracts. Cylinder 3.0 completes the bending operation. After Cylinder 3.0 has returned to its initial position, Cylinder 1.0 releases the part.



Displacement-Step Diagram

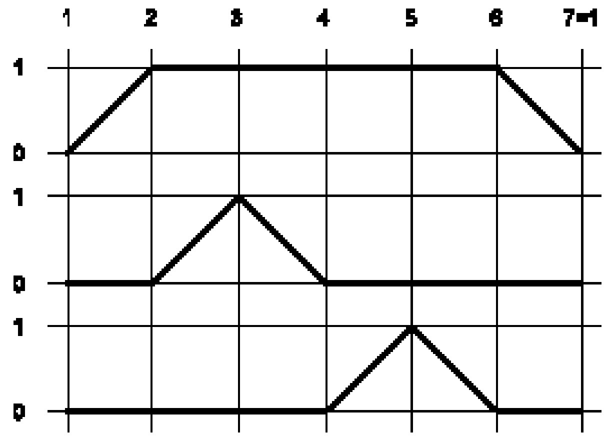
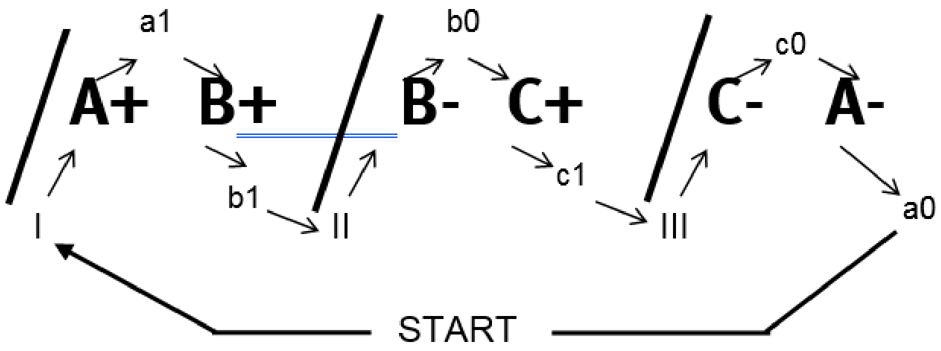


Figure 10.29 – Bending Device



The design of the cascade with three groups.

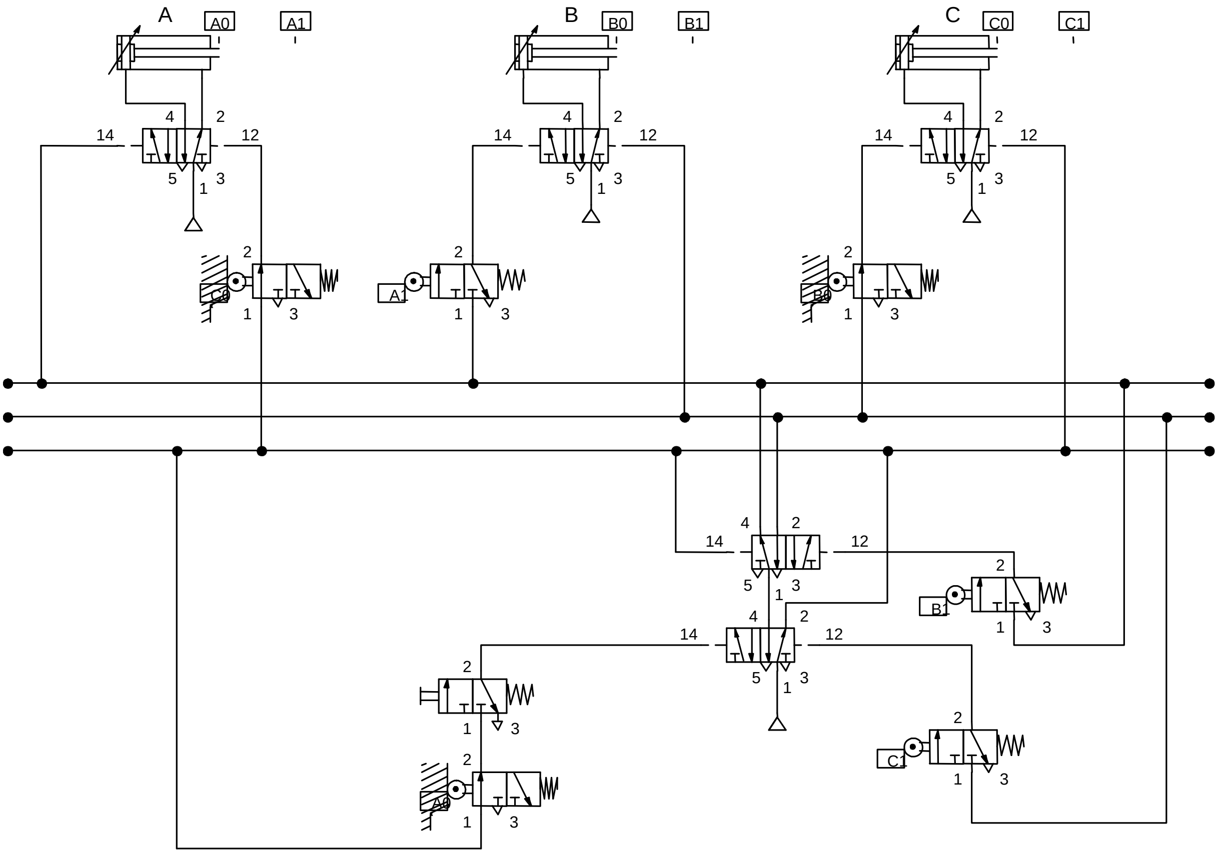


Figure 10.30 – Bending Device using Cascade System

11.0 Failures and Remedies in Pneumatic System Components

11.1 Troubleshooting a Pneumatic System

For all pneumatic systems, general preventive maintenance is essential to ensure that the systems work correctly without any faults and the control sequence is achieved. In the case of problems encountered, we need to troubleshoot the system.

11.2 What is Troubleshooting?

Troubleshooting is the art or skill of solving a problem using:

- An understanding of how the system works.
- Theory of operation of components and the system they are part of.
- Understand the history of the equipment (recurring problems).
- Gather symptoms.
- Using common sense with the first four items and decide where the problem is.

11.3 Seven Basic Steps of Troubleshooting

- Know the system
- Ask the operator questions
- Operate the machine
- Inspect the machine
- List possible causes of problems
- Reach a conclusion
- Test your conclusion

11.3.1 Know the System

The first step is that you need to know and understand the system, how it works and what it does. With this knowledge, it would be easy for you to troubleshoot the machine.

11.3.2 Ask the Operator Questions

As the operator is one using the machine, most of the time, he is the best person to give you information such as symptoms of the fault. Check with the operator on any occurrence which is out of the ordinary.

11.3.3 Operate the Machine

If it is safe, run the machine to locate the fault. This is the best method to identify the fault.

11.3.4 Inspect the Machine

Once you think you know where the problem is, do an inspection of the machine.

11.3.5 List Possible Causes of Problems

Make a list of all the possible causes of the fault.

11.3.6 Reach a Conclusion

From the list of the fault, try to eliminate the unlikely fault and decide on what you think the cause of the fault is. You need not try to identify all the faults but only the major ones as fixing one fault may also remedy other minor faults.

11.3.7 Test Your Conclusion

Having decided on the fault or faults, take remedy action and check if the problem has been resolved.

11.4 Terms Used in Troubleshooting

In troubleshooting, we usually hear three terms:

11.4.1 Symptom

It is an indication that there is a disturbance to normal operations which may be attributed to either a fault in the system of its devices.

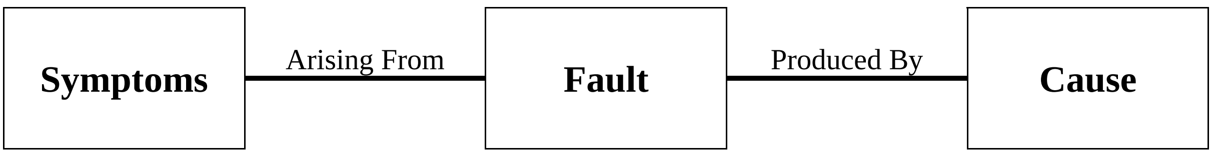
11.4.2 Fault

It is a defect in the system or devices which caused the symptom to appear.

11.4.3 Cause

It is the reason for the fault.

There is a logical approach to follow in order to recognise all the signs that indicate a fault and find its cause.



For example; a compressed air system

11.5 Maintaining a Pneumatic System

11.5.1 Daily Maintenance

Drain condensate from the filters if the air has a high-water content and if no automatic condensate drainage has been provided. With large reservoirs, a water separator with automatic drain should be fitted as a general principle. Check the oil level in the compressed-air lubricator, and check the setting of the oil metering.

11.5.2 Weekly Maintenance

Check signal generators for possible deposits of dirt and swarf. Check the pressure gauge of the pressure regulators. Check that the lubricator is functioning correctly.

11.5.3 Quarterly Maintenance

Check the seals of the connectors for leaks. If necessary, re-tighten the connectors. Replace lines connected to the moving parts.

Check the exhaust ports of the valves for leaks. Clean filter cartridges with soapy water (do not use solvents), and blow them out with compressed air in the reverse of the normal flow direction. Check the function of the automatic exhaust valves.

11.5.4 Half-Yearly Maintenance

Check the rod bearings in the cylinders for wear, and replace if necessary, also replace the scraper and sealing rings.

12.0 Diagnosing and Rectifying Faults in Pneumatic Systems

12.1 Introduction

When handling pneumatic systems, there might be cases where faults occur. In these cases, we need to diagnose and rectify the faults

12.2 Methods Used

There are several methods used, we will cover only two:

- Fault finding charts and guides
- Flow chart diagram

12.2.1 Fault Finding Charts

Many manufacturers' manuals include a section, which contains fault finding, or troubleshooting charts covering many known faults. The information contained in these charts is based on previous experience of the equipment in service. Predicted or possible faults may also be included based upon the knowledge and experience of the design engineer.

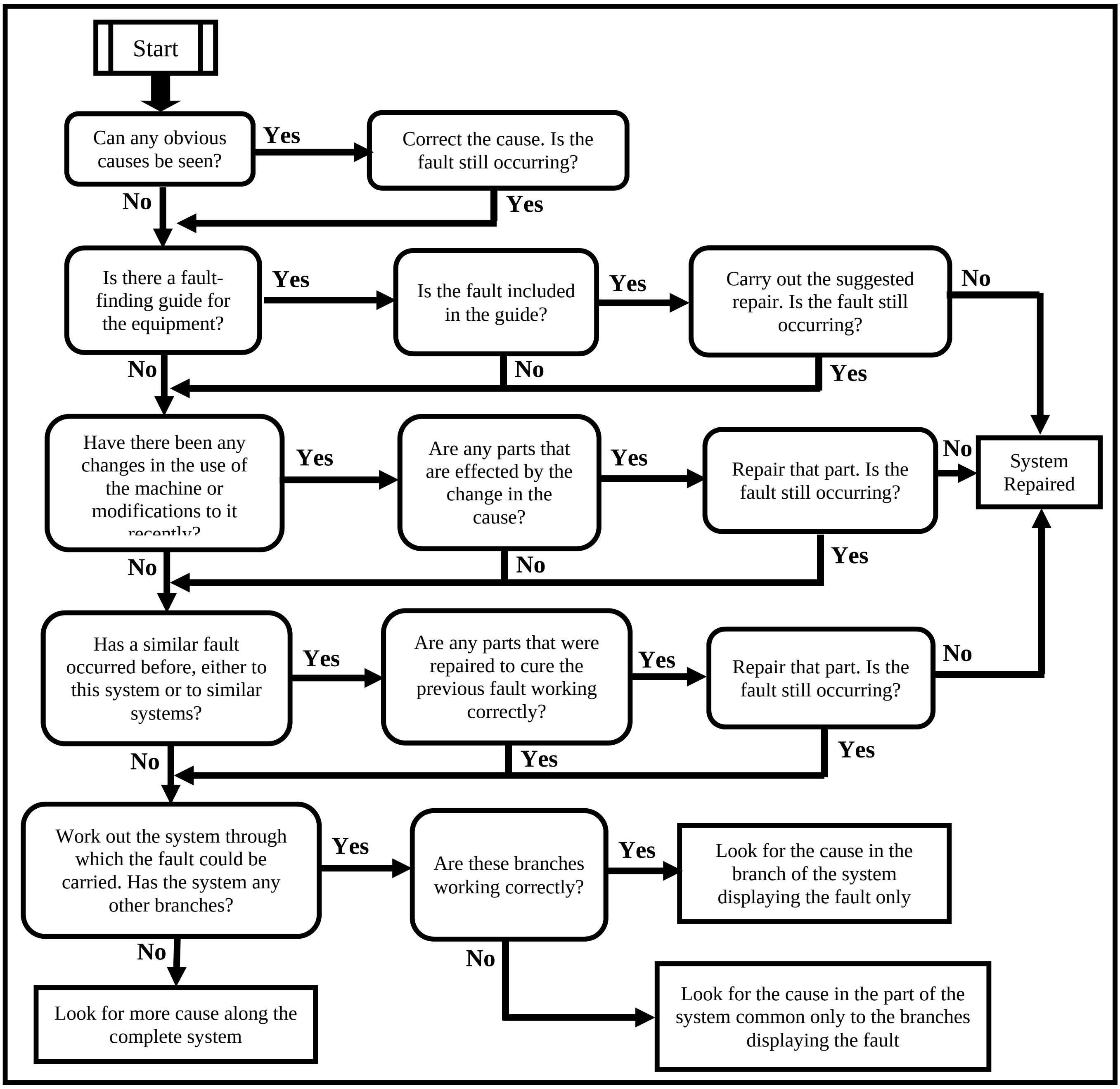


Figure 12.1 - Fault Finding Chart

These charts normally contain the fault, its possible causes and the remedy recommended. Despite the confusion caused by the different terminology used, these charts are a useful aid to fault diagnosis, particularly in relation to product or process faults. Where these chats are available, they should always be used.

12.2.2 Flow Chart Diagrams

A flow chart shows the flow path and progress through the chart is determined by the awareness to a series of questions. The questions are formed in such a way that the only possible answers are “yes” or “no”. The design of flow charts can be difficult as their usefulness depends upon the designer’s ability to anticipate and accommodate a wide range of possible thoughts. They can however, be effectively used by persons with a limited knowledge of the system or equipment.

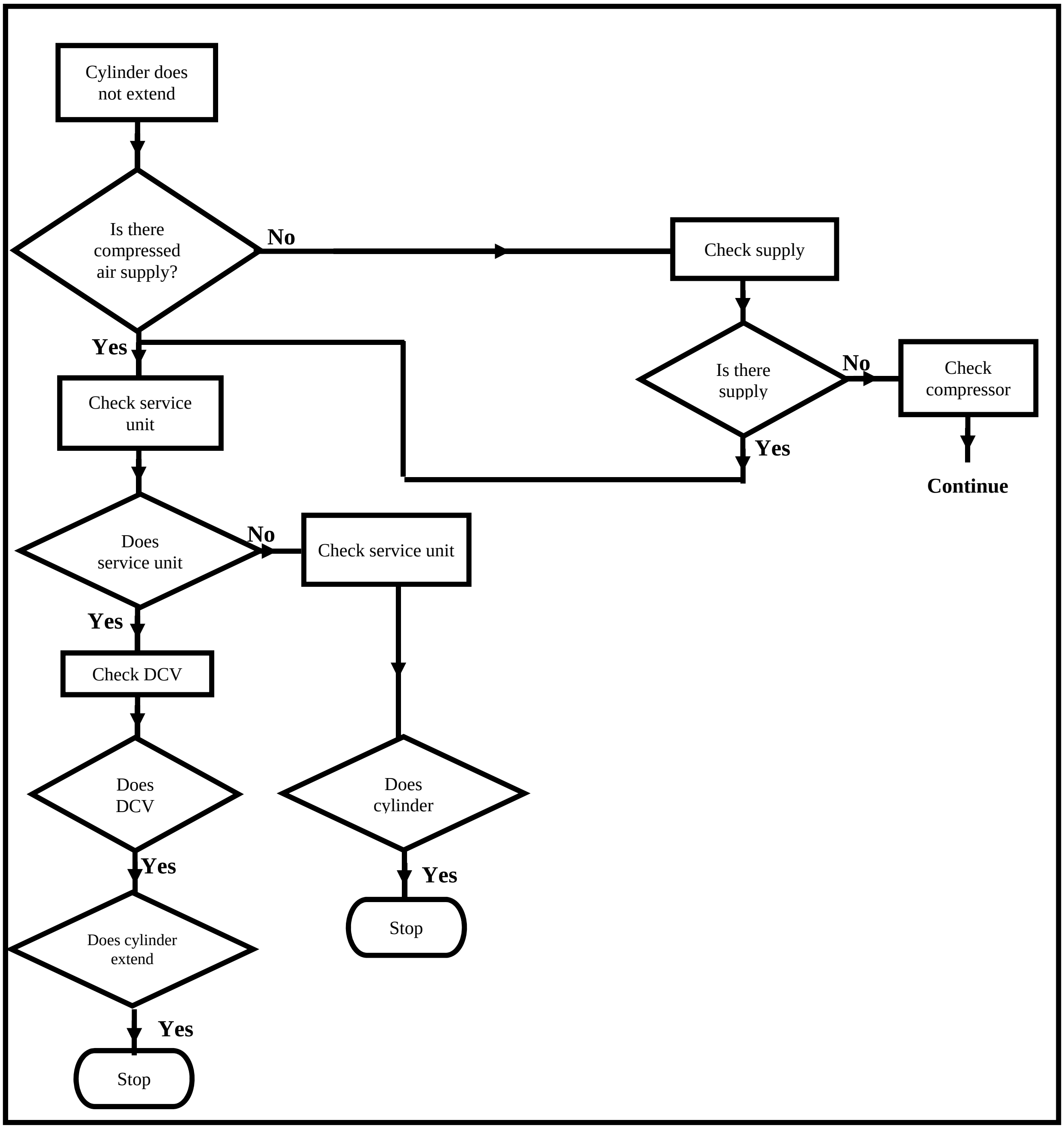


Figure 12.2 – Flow Chart

12.3 Malfunctions in Compressed Air Preparation

Malfunctions and failures may be caused by the following:

- Natural wear and tear of components and lines. The effects of external and internal environmental influences considerably accelerate natural wear and tear.
- Wear of units may lead to breakage, seizure of units, functional failures, leakage, etc.
- Contaminated air may lead to component failure caused by blockages.
- Lines may become blocked, split or bent, or may age prematurely due to external influences.
- Deposits may cause additional resistance in lines and components that may cause a marked pressure drop and possibly incorrect switching.

- Incorrect switching can also be expected in cases where a pressure drop is caused by leaks or by fluctuating supply pressure. Filter elements that have not been correctly serviced can be a further cause of pressure drop of this kind.
- Incorrect fitting of cylinders and incorrect loads lead to premature wear.
- Limit valves have not been mounted correctly, or signal lines are too long (sluggish signals).

Compressed Air Which is Poorly Prepared Will Lead to Malfunctions in Pneumatic Equipment

- Rapid wear of seals, O-rings and moving parts in the cylinders and valves.
- “Sticking effect” in control valves.
- Dirty and contaminated silencers.
- Elevated level of condensate in the air filter.
- Corrosion of metal parts.

12.3.1 Malfunctions Caused by Undersized Air Supply

It frequently occurs that sections of pneumatic systems are extended without enlarging the necessary air supply. Malfunctions that can be caused by under-sized air supply are:

- The piston rod speed is not always correct
- The force at the power cylinder drops for a short time during a pressure drop.
- Switching times are too long

The same symptoms may occur as the result of changes in orifice cross-sections caused by contamination or kinked lines or if leakage is causing a pressure drop.

12.3.2 Malfunctions Caused by Condensate

Apart from the corrosive damage caused to surfaces by condensate which is, in many cases extremely aggressive, there is the considerable danger of seizure of valve components if they need to be reset by spring force after being held in one switching position for a considerable time. Lubricants without additives have a tendency to emulsify and create resin or gumming. All close-tolerance sliding fits in valves are particularly susceptible to these resistances to movement.

12.3.3 Malfunctions Caused by Contamination

In a pneumatic system, a service unit should generally be connected upstream in the compressed air supply section. This filters the dirt particles from the compressed air supply.

During assembly or maintenance work, dirt particles (e.g. thread particles, sealing agents, etc.) may remain in the pressure lines and get into the valve during operation.

In the case of systems which have been in service for some time, may find their way into the lines. This contamination of the lines may produce the following effects:

- Sticking or seizure of slide-valve seats
- Leaks in poppet valves
- Blockage of flow control valve nozzles

12.4 Possible Faults in Air Service Units

Fault	Cause	Remedy
Air filter does not separate dirt and water.	Filter has been fitted incorrectly.	Fit and connect filter behind the direction of flow. (the sintered cartridge in the filter must be cleaned after a lengthy period of time)
	Condensate level is higher than the marking line.	Drain condensate by turning the screw clockwise, fit automatic water separator.
The air flows to atmosphere at the pressure regulating valve.	Pressure regulator is fitted incorrectly with respect to the direction of flow.	Refit the regulator.
Resinfication of the lubricator.	Wrong oil used.	Wash out lubricator. Select and replace with correct oil.
The lubricator does not function properly.	The lubricator is mounted incorrectly.	Remount the lubricator according to the arrow. The arrow specifies the direction of flow.
There is too much oil in the system.	Lubricator is set incorrectly.	Reset the lubricator.
	The oil is filled over the marked line.	Drain the oil. (Check oil level and the oil bowl should be kept clean in order to allow oil level to be checked at any time)
The oil is used up quickly in the lubricator.	The O-ring is not tight.	Exchange and fit new O-ring.
	Lubricator is set incorrectly.	Set lubricator properly.

12.5 Possible Faults in Pneumatic Cylinders

Before failure of pneumatic cylinder occurs, damage often becomes noticeable in a stage in which the cylinders still operate correctly. Here, regular inspections allow imminent failures to be recognise in appropriate time.

- Visual Inspection

If increasingly heavy longitudinal scoring is discovered on the piston rods of pneumatic cylinders, it can be expected that the rod seals will soon fail due to wear. The presence of black, dry stuck-on lubricant on large areas of the piston rods indicates an unstable condition, as the result of which the piston rod seals and bearings can quickly become unserviceable.

With low operating pressures, this factor will also increase the tendency to judder. Smooth running may also be impaired by wear of the piston seal, causing a dry mixture of grease and rubber particles to be deposited on the cylinder barrel.

- Acoustic Check

If the cylinders are already leaking to such an extent that the hiss of air can be heard clearly as it discharges, action must be taken immediately. Continuous blow-off of air at switching valves under idling conditions is also a warning signal that either the piston seals of cylinders or even the sealing elements in the valves have suffered damage.

- Measuring Response Times

If, under the same conditions, it is noticed that the response time of slide valves with elastic rubber seals has suddenly become noticeably longer, this is an indication that a malfunction is imminent.

Fault	Cause	Remedy
The air escapes to atmosphere at the bearing bushing.	Packing not tight, packing worn, packing mounted incorrectly	Replace bearing
Piston rod is not guided smoothly.	Bearing bushings worn	Replace bearing
With the valve connected, air blow out of the vent hole	Packing leaks or is loose	Replace packing
Piston travels out slowly.	Too much oil in the cylinder barrel, due to one way flow control valve	Adjust flow control valve
Air escapes at the piston rod.	Groove ring is defective	Replace groove ring
For single-acting cylinders, piston rod does not return to the end position	Compression spring damaged, air filter is blocked	Clean air filter and replace spring if damaged
For double-acting cylinder, end position cushioning in a cylinder does not respond.	Lip seal on the cushioning plunger leaks or has been fitted in the wrong way	Replace lip seals
Wear is increased.	Water in the cylinder	Check air supply

12.6 Possible Faults in Directional Control Valves

Fault	Cause	Remedy
Valve is sluggish (Slow moving)	Dirt in the valve especially in the groove ring.	Replace groove rings, clean valve. If there is a lot of dirt and oil, functioning of the pilot valve cannot be guaranteed.
Valve does not switch properly.	Control pressure too low.	Set control pressure properly (Regulator).
	Groove rings are defective.	Replace rings
Valve leaks	Groove ring has been damaged, valve discs worn.	Replace damaged parts.
Spool does not reverse.	Control pressure too low.	Check regulator and reset.
	Overlapping signals.	Check control signals to solenoids to eliminate overlapping signals.
	Spool jams in the upper part of the housing; mounting surface not quite level, valve distorts when installed.	Check the spool and the sealing rings; rework mounting surface.
Spool does not completely reverse.	Switching plunges has broken, blocking the travel of the spool.	Dismantle valve, remove defective switching plunger; fit new one.
Air escapes from the armature tube.	Sliding surface on housing damaged; sealing washer in armature damaged.	Replace part.
Noises (Humming) from the solenoid head.	Dirt between coil and armature tube; excessive play in the armature and armature tube.	Clean the solenoid head.
Air escapes at exhaust.	Ports (1) P and (4) A are interchanged.	Reconnect lines if connected improperly. Make sure the supply voltage is correct.

12.7 Replacing Pneumatic Components

When the damaged parts are found and dismantled, you may be required to order the part as replacement. When ordering parts, you need to refer to the manufacturer's catalogue. It is important to take note of the following when ordering:

- For pneumatic cylinders
  - Correct diameter
  - Correct length
  - Correct accessories, such as mountings
  - Special requirements, such as corrosion resistance

- For directional control valves
    - Correct function, such as 3/2-way, 5.2-way, etc.
    - Normally open or normally closed where appropriate
    - Correct size

The above are the basic requirements, depending on the usage, more information might be required.

13.0 Pneumatic Solenoid Valves

13.1 Introduction

Directional control valves used in electro-pneumatics are like those used in conventional pneumatics. The only difference being the mode of actuation. Directional control valves used in electro-pneumatics are usually actuated by solenoids.

They can be divided into two groups:

- Spring-return valves only remain in the actuated position as long as current flows through the solenoid.
- Double solenoid valves retain the last switched position even when no current flows through the solenoid.

In the initial position, all solenoids of an electrically actuated directional control valve are de-energised and the solenoids are inactive. A double solenoid valve has no clear initial position, as it does not have a return spring.

The following figures show the application of solenoid operated directional control valves.

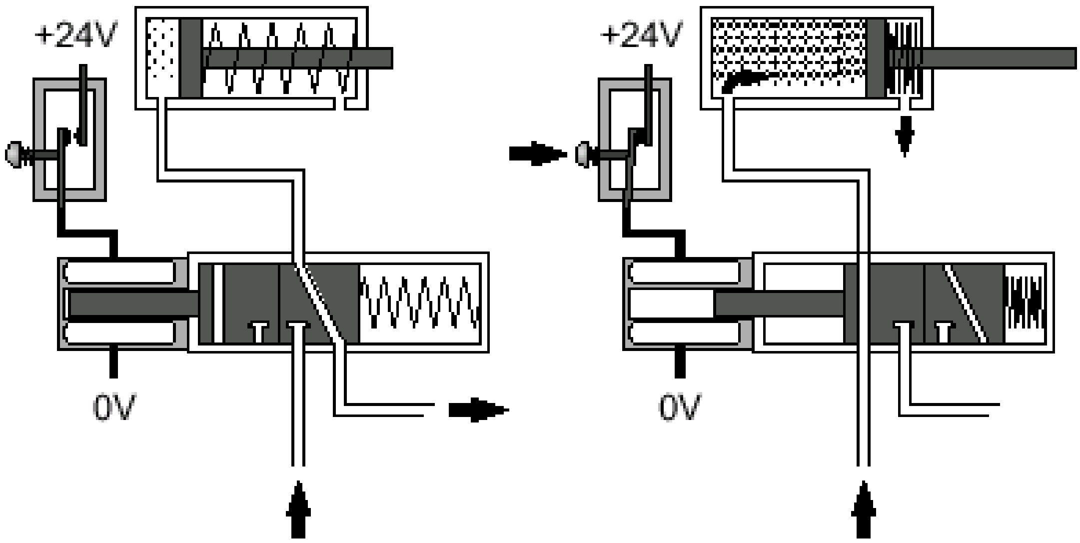


Figure 13.1 – Actuation of a Single-Acting Cylinder using a 3/2-way Solenoid Operated Directional Control Valve

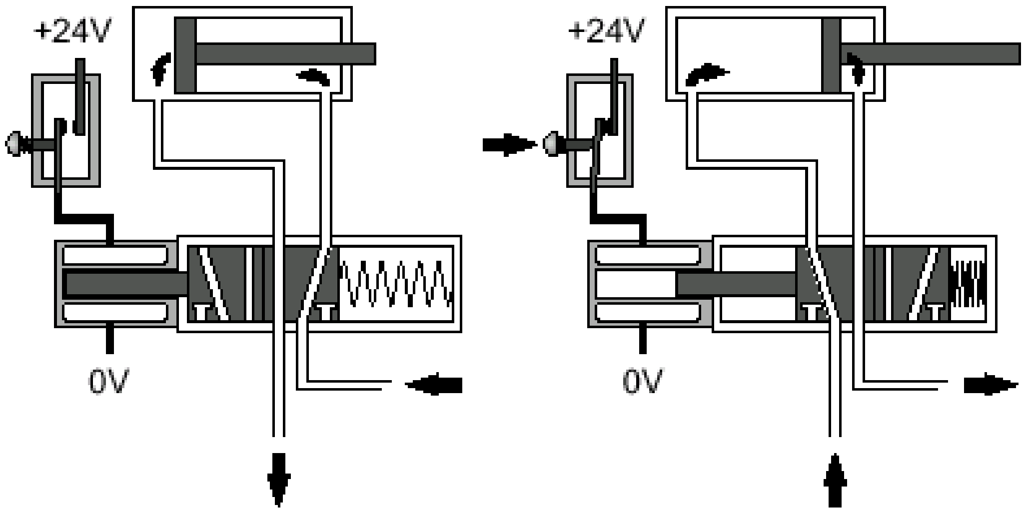


Figure 13.2 – Actuation of a Double-Acting Cylinder using a 5/2-way Solenoid Operated Directional Control Valve

13.2 Components Used in Electro-Pneumatics

In a basic electro-pneumatic system, there are certain additional components which are not used in conventional pneumatics.

The additional components are:

- 24V DC power supply
- Electrical switches
- Electrical contacts
- Electrical relays
- Solenoid operated valves
- Sensors

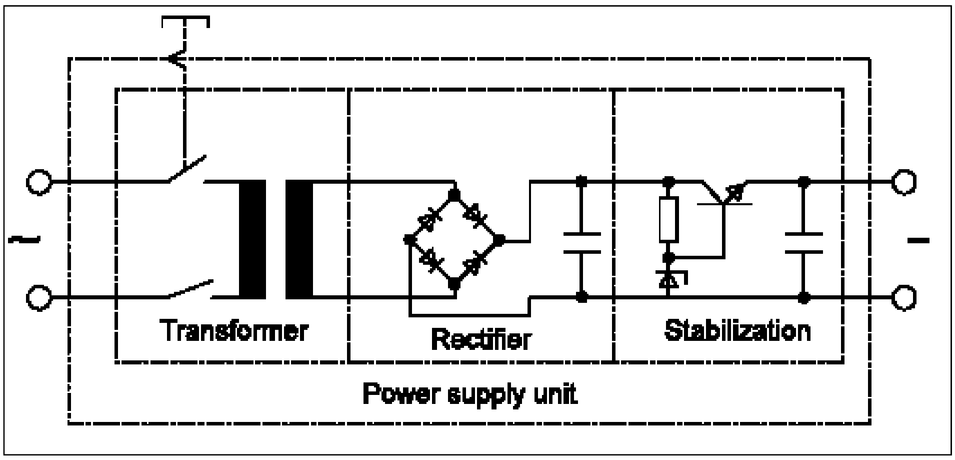


Figure 13.3 – Electrical 24V DC Power Supply

13.3 Solenoid Actuated Directional Control Valves

These solenoid coils are then attached to the valves to actuate them. It is basically the same as the valves used conventionally but now instead of a push button switch it is replaced by a solenoid.

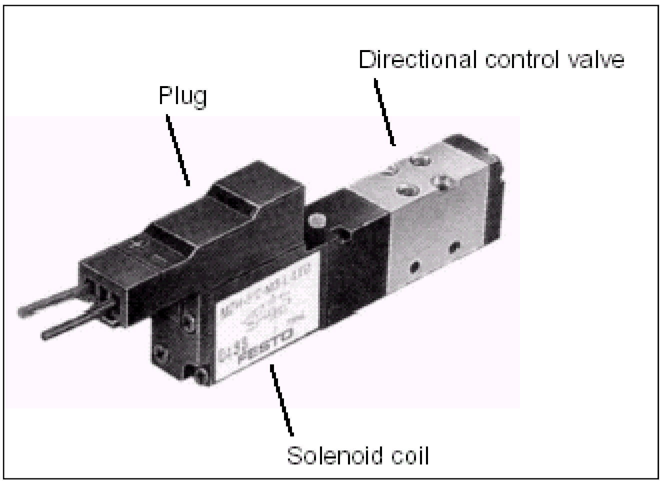


Figure 13.4 – Example of a Pneumatic Valve Activated by a Solenoid Coil

Solenoid actuated valves employ the advantages of pneumatic and electrical energy and can be described as electro-pneumatic converters. They consist of a pneumatic valve as the signal output medium and an electrical switching part called a solenoid.

An electric current applied to the solenoid generates an electromagnetic force (EMF) which moves an armature connected to the valve stem.

When current is removed from the solenoid coil, the EMF is dissipated allowing the internal spring to return the valve stem to the neutral position.

13.3.1 Operating Principle of a Solenoid

When a solenoid is energised, electro-magnetic forces are created and this will pull the soft iron core inwards. If this is attached to the spool, it will actuate the directional control valve.

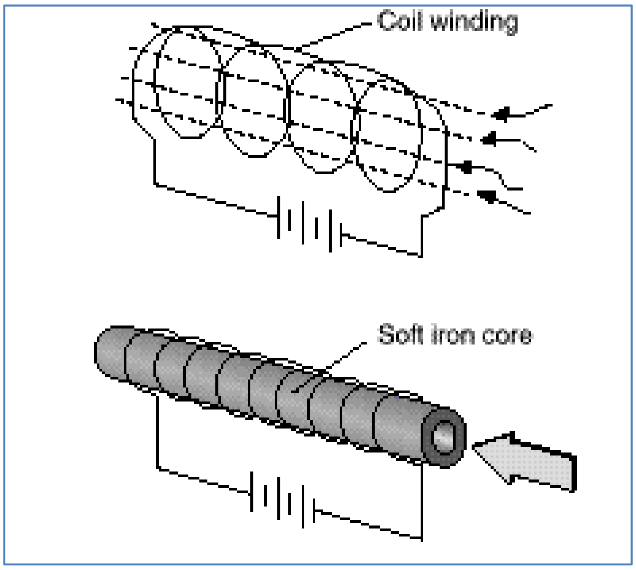


Figure 13.5 – Operational Principle of a Solenoid

13.4 Types of Solenoid Operated Directional Control Valves

13.4.1 2/2-Way Directional Control Valve

The 2/2-way valve illustrated has 2 ports. Input connection 1 and output connection 2. There are 2 switching positions, idle or neutral position and the actuated position. You will notice that when this valve is in the closed position, air cannot escape to atmosphere. Therefore, the application of this valve is somewhat limited and is primarily used as a shut off valve.

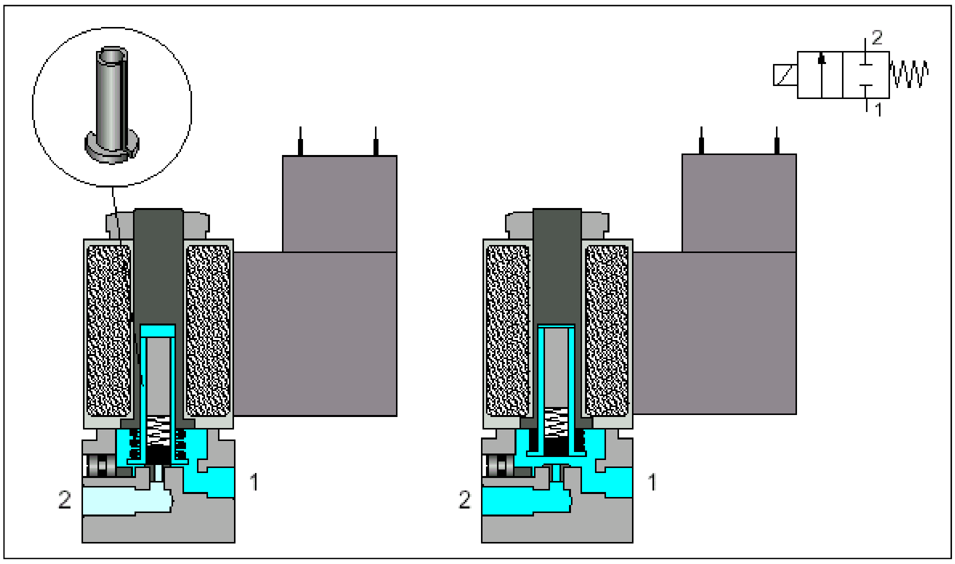


Figure 13.6 – 2/2-Way Single Solenoid Directional Control Valve

13.4.2 3/2-Way Directional Control Valve

This normally closed (NC) poppet valve is directly actuated by a solenoid and is returned to the idle position by spring return. Usually this valve incorporates the solenoid armature and valve stem as one unit and is therefore referred to as an armature or armature tube (the armature is hollow). The aperture of the armature is generally referred to as the bleed hole or exhaust aperture.

Operating Method

When an electric current (signal) is applied to the coil, an electromotive force (EMF) is generated which lifts the bottom sealing face of the armature from the valve sealing seat. Compressed air then flows from input 1 to output 2 and the exhaust aperture 3 is blocked by the top sealing faces of the armature. The armature is forced against the exhaust seal.

Rotation of the eccentric screw against the armature flange provides a manual override facility. Rotation of the screw from the zero (0) to the one (1) position places the valve in an override actuation position.

It is important to return the screw to the (0) position when normal solenoid operation is required.

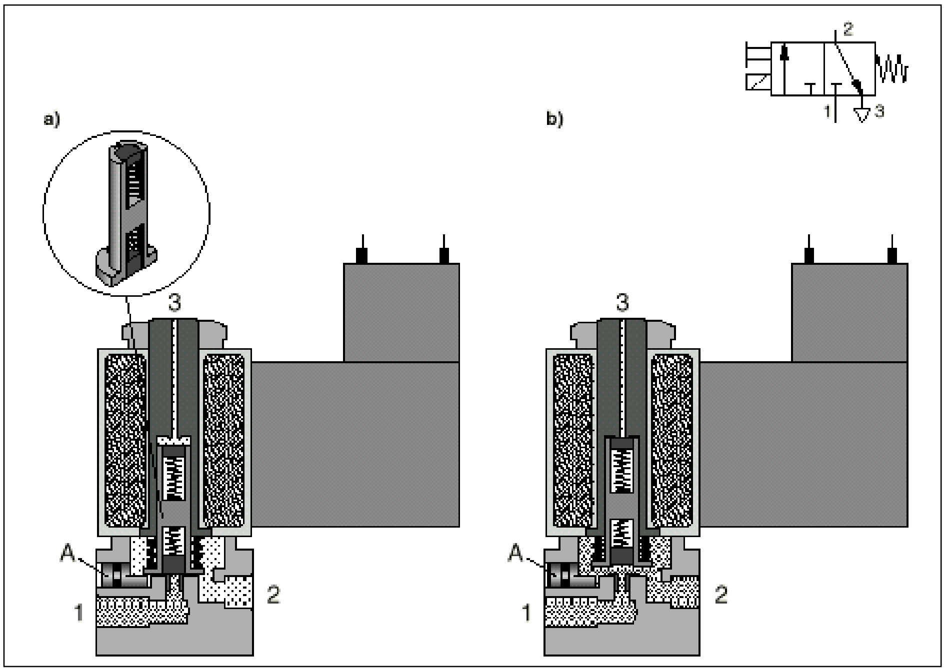


Figure 13.7 – 3/2-Way Single Solenoid Directional Control Valve, Normally Closed

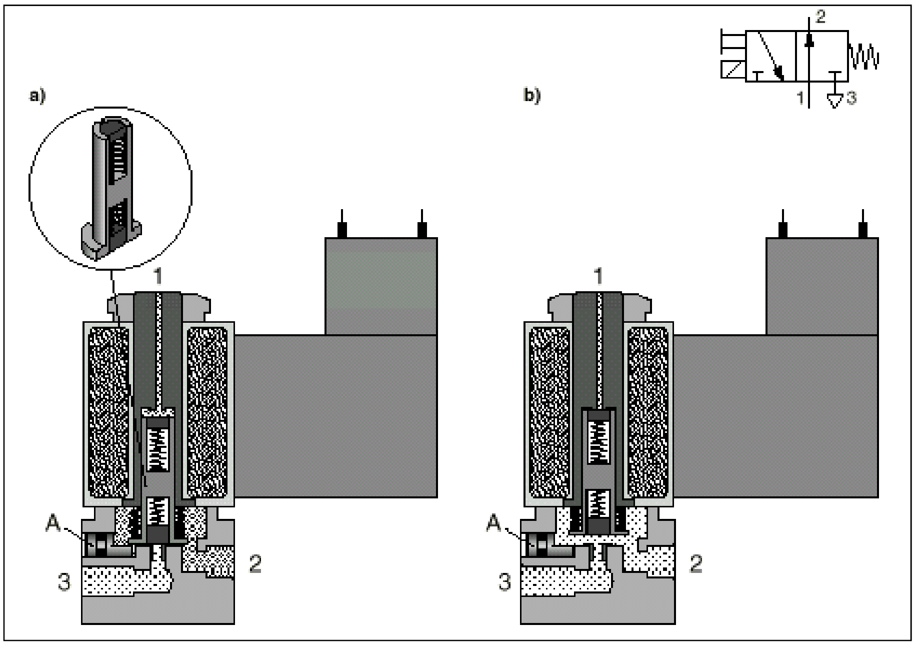


Figure 13.8 – 3/2-Way Single Solenoid Directional Control Valve, Normally Open

13.4.3 Pilot Operated Valve Solenoid Valves

By using pilot control, the size of the solenoid can be kept to a minimum. From an electrical point of view, this has two main advantages:

- Reduced power consumption
- Reduced heat generation

Pneumatically, the advantage is that the valve switching is positive. The electrical signal is applied to the solenoid which actuates the pilot valve armature. The pilot valve signal operates the main valve.

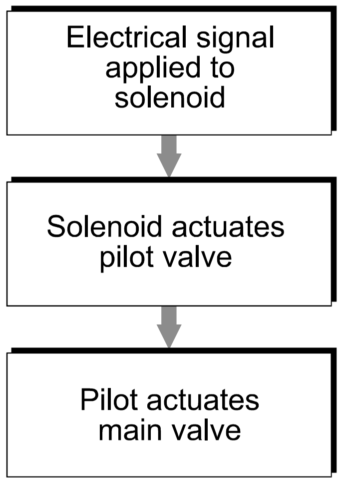


Figure 13.9 – Pilot Signal Flow

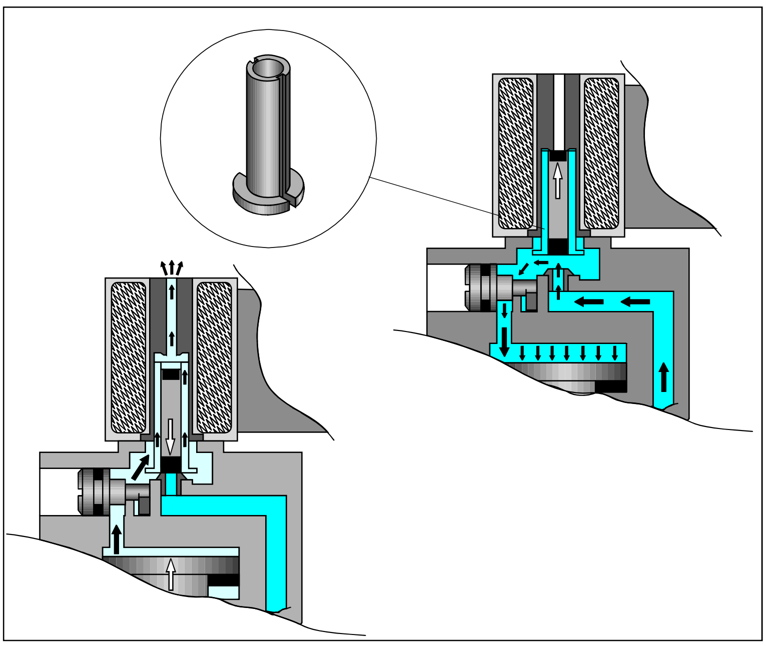


Figure 13.10 – Pilot Control

13.4.4 3/2-Way Pilot Controlled Directional Control Valve

The primary difference between this valve and the direct controlled design is the addition of an internal pilot. The pilot valve can be considered as an amplifier that is the force applied by the solenoid's EMF is amplified by the pilot valve providing a very positive switching characteristic. In the neutral position, the supply pressure at 1 act on the lower side of the piston forcing it against the sealing seat which blocks the flow of air from 1 to 2. The passage from the output 2 is open to atmosphere via the exhaust port 3.

Application of an electrical signal lifts the lower sealing face of the armature, opening the passage of air from 1 via the pilot air duct to the end face of the valve piston. As the piston surface area is greater than that of the lower seal, the resultant force acting against the supply pressure moves the piston. The lower seal lifts from its seat. The air flows from 1 to 2. At the same time, the piston stem is forced against the top face of the bottom seal blocking the escape of air atmosphere via 3.

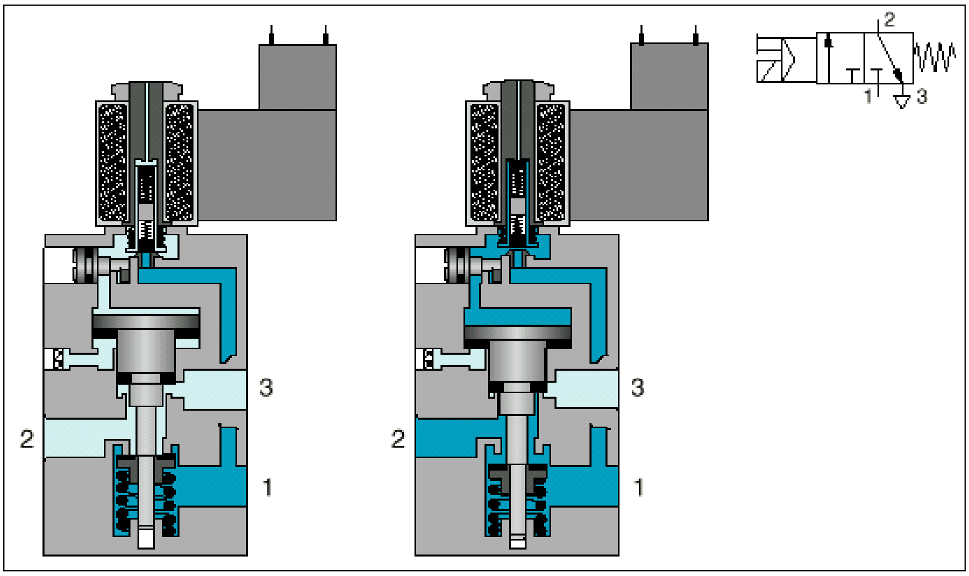


Figure 13.11 – 3/2-Way Single Solenoid Valve, Pilot Operated

When the solenoid is de-energised, the pilot signal is relieved through the stem of the solenoid allowing the piston to return. The supply pressure 1 is blocked and the passages 2 to 3 are interconnected. Note: It is important to ensure that the pilot exhaust path through the stem is not blocked to allow the valve to return to the neutral state.

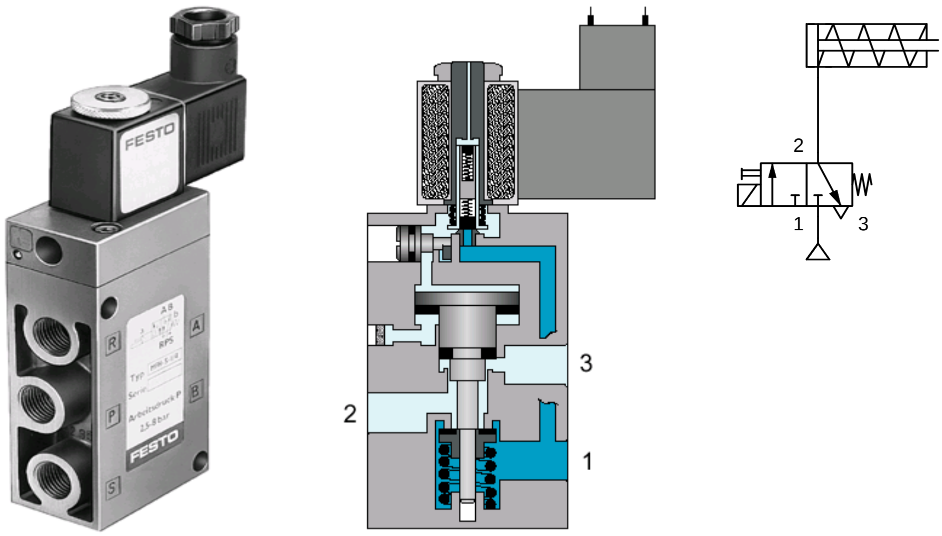


Figure 13.12 – Before Activation

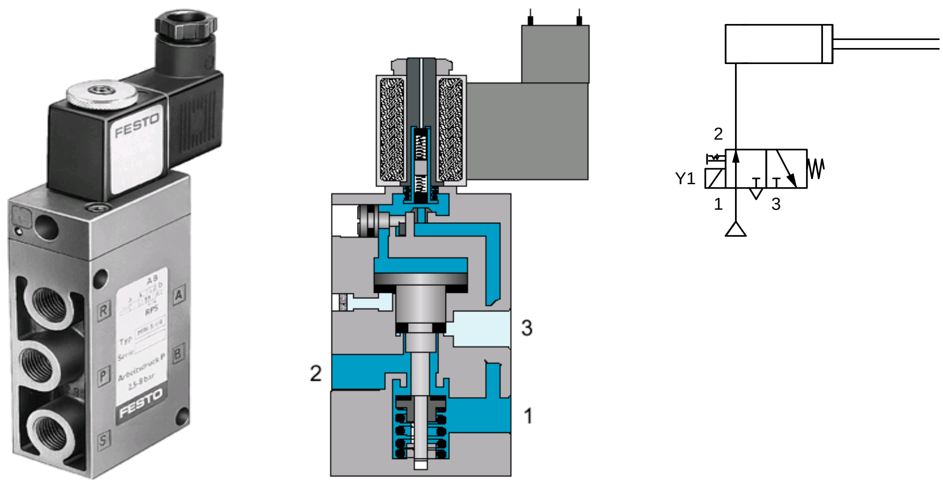


Figure 13.13 – After Actuation

13.4.5 5/2-Way Pilot Controlled Single Solenoid Directional Control Valve

The 5/2-way valve performs a similar function as the 4/2-way valve. The main difference is that this valve has two exhaust ports, whereas the 4/2-way valve has one exhaust port.

In the neutral state, the spring return forces the large diameter seal at the spring end against its seat, blocking airflow from 1 to 3. The spring force also loads the suspended disc against port 4 blocking the passage of air from 1 to 4. The opposite seal (solenoid end) lifts from its seat and exhausts air from 4 to 5. The suspended disc opens the air flow from 1 to 2.

Energising the solenoid moves the armature and opens the pilot air passage. The pilot air applies pressure to the right side of the valve piston, in turn forcing the suspended disc against the opposite sealing seat, resulting in:

- Air exhausts from 2 to 3
- Exhaust port 5 is blocked
- Air flows from 1 to 4

With the small switching movement, low frictional forces, and pilot actuation, this design can utilise the small solenoid as the means of actuation resulting in a fast-positive switching action.

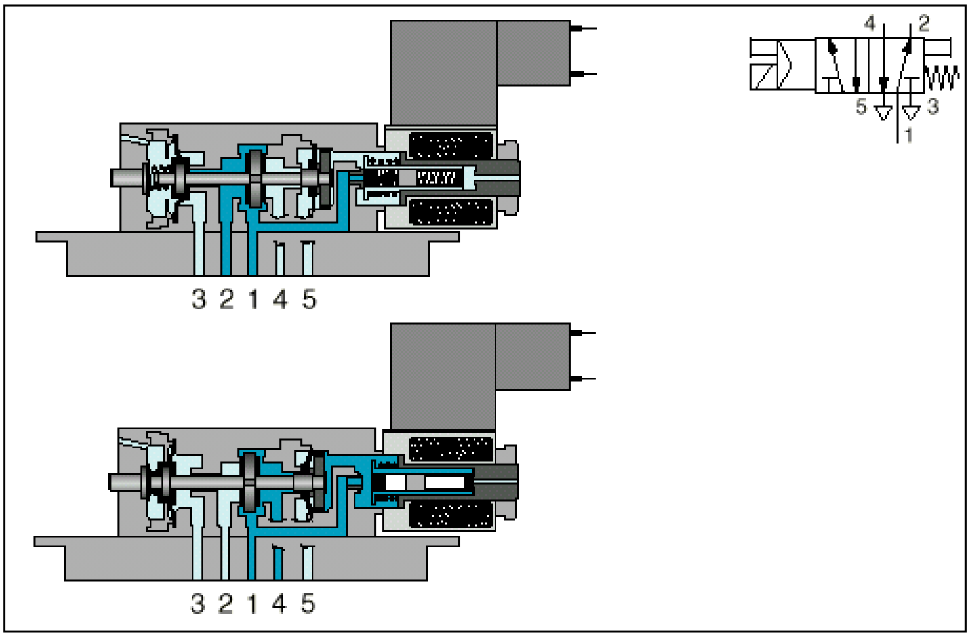


Figure 13.14 – 5/2-Way Single Solenoid Valve, Pilot Operated

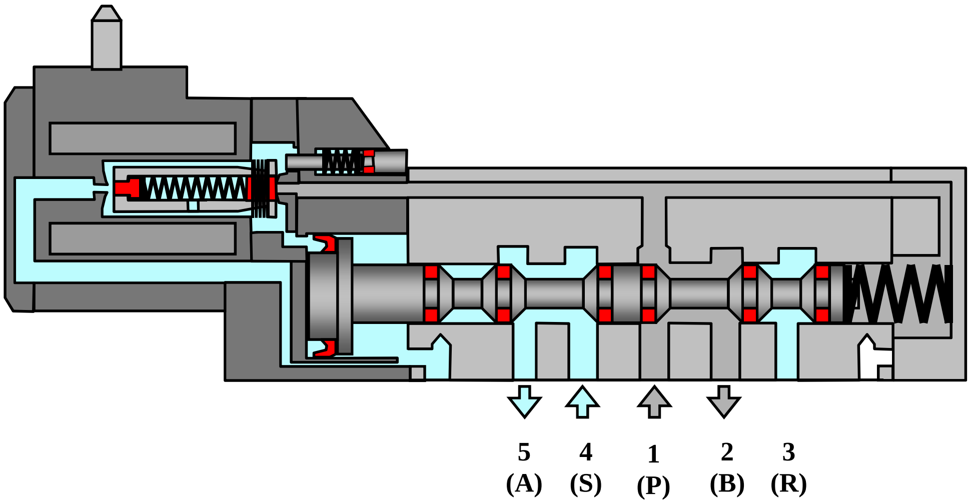


Figure 13.15 – Before Activation

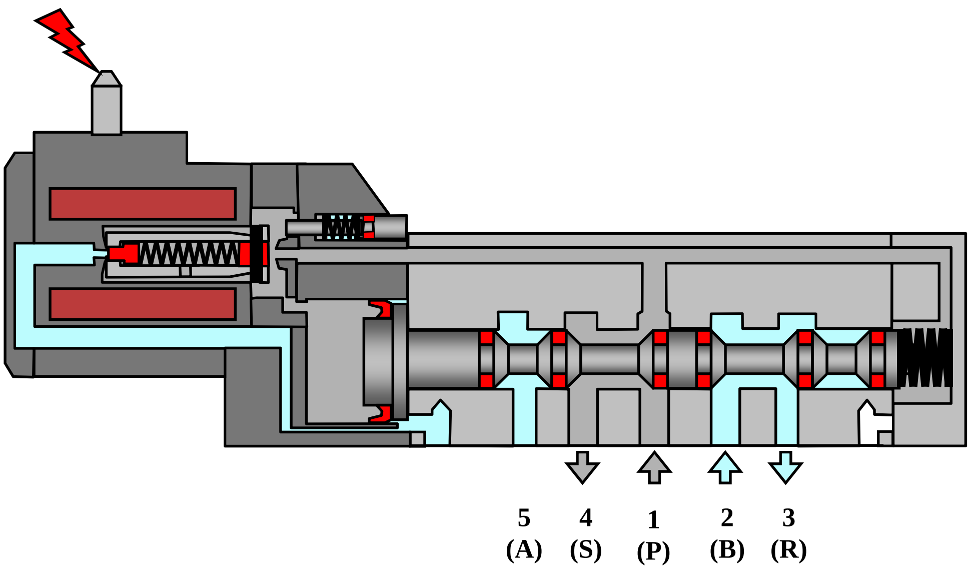


Figure 13.16 – After Actuation

13.4.6 5/2-Way Pilot Controlled Double Solenoid Directional Control Valve

The valves in the previous illustrations used a spring as the method of returning the valve to its neutral state, i.e. the solenoid actuated the valve in one direction and the spring provided actuation in the opposite direction. Of course, this means that whenever power is removed from the solenoid, the valve returns to its neutral state. This characteristic must be taken into consideration when designing a circuit.

In the case of a double solenoid valve, the spring return has been replaced by a second solenoid. If the last signal applied was at solenoid Y1, air flows from 1 to 2 and 4 is exhausted via 5. When the signal is removed from Y1 the suspended disc remains stationary and no change occurs in the switched state of the valve.

A signal applied at solenoid Y2 reverses the valve and air flows from 1 to 4 and 2 is exhausted via 3.

Unlike the valve with a spring return, this double solenoid valve remains in its last switched position, even with power removed from both solenoids, until an opposing signal is applied. Effectively this means that this valve has memory characteristics.

In electro-pneumatic circuits, this characteristic has many advantages, i.e. only a very short duration signal applied to the solenoid (10-25 ms) is necessary to switch the valve. Demand on the electric power supply can be minimised. In circuits with complex sequences of action, cylinder positions can be retained without the need for complicated switching arrangements, to latch the valves and cylinders in position.

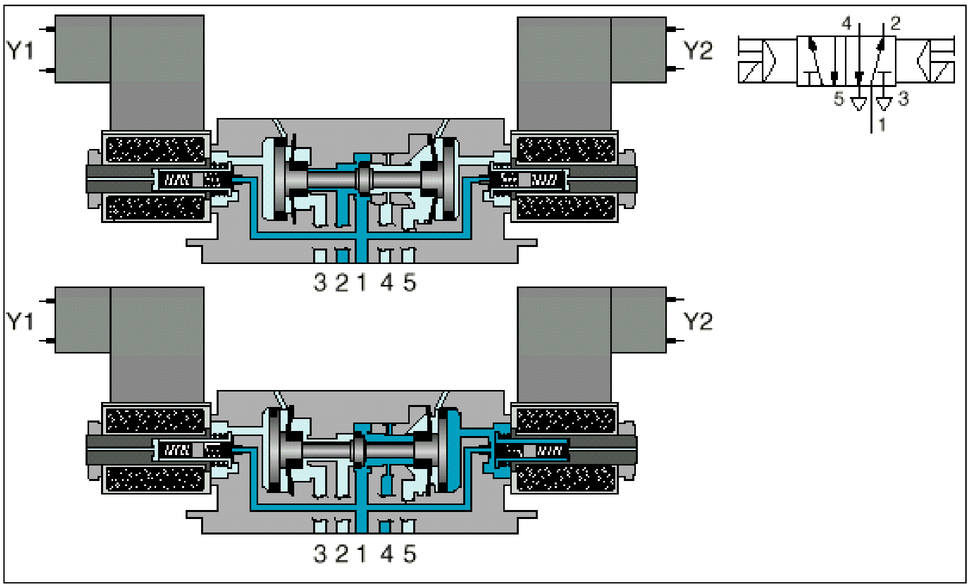


Figure 13.17 – 5/2-Way Double Solenoid Valve, Pilot Operated

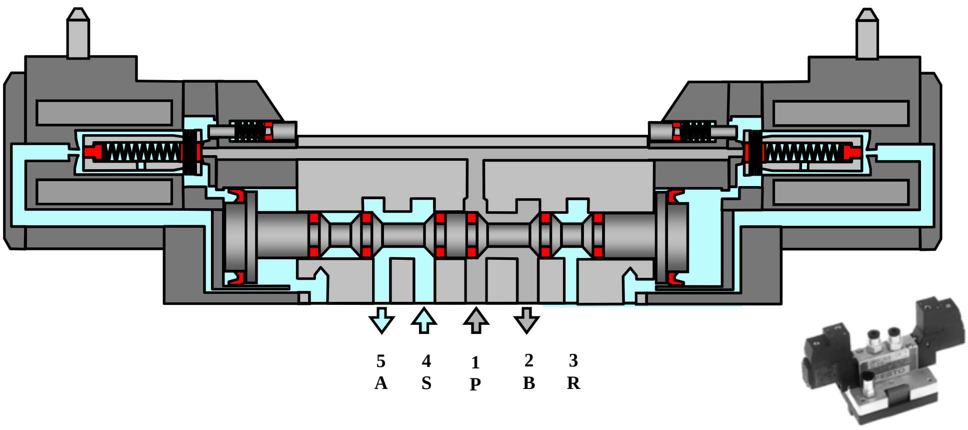


Figure 13.18 – 5/2-Way Double Solenoid Valve, Pilot Operated

13.4.7 5/3-Way Pilot Controlled Double Solenoid Directional Control Valve

Like the 5/2-way valve, with the only difference is the additional centre position. When the valve is in the neutral position, the centre position is active. To move to the left and right position, the respective solenoid is activated. The solenoid needs to be energised to remain in that position.

When purchasing 5/3-way valves, remember that there are different centre positions available and needs to be identified when ordering. There are different centre positions, namely:

- Closed
- Open
- Tandem
- Float

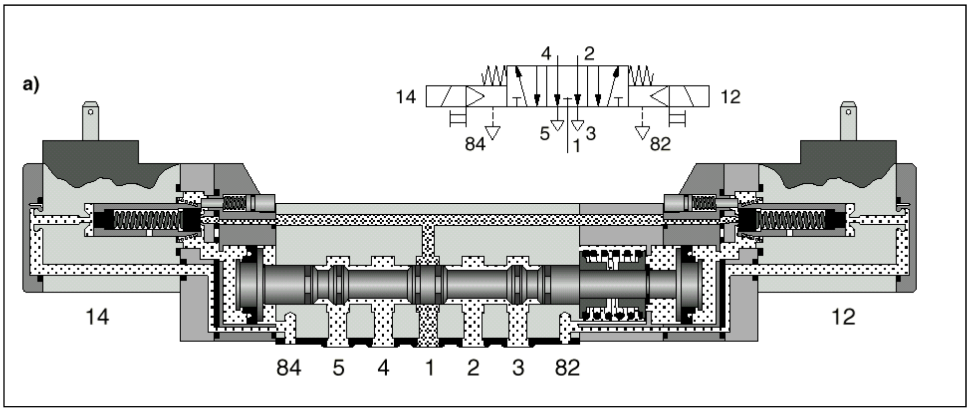


Figure 13.19 – Centre Position

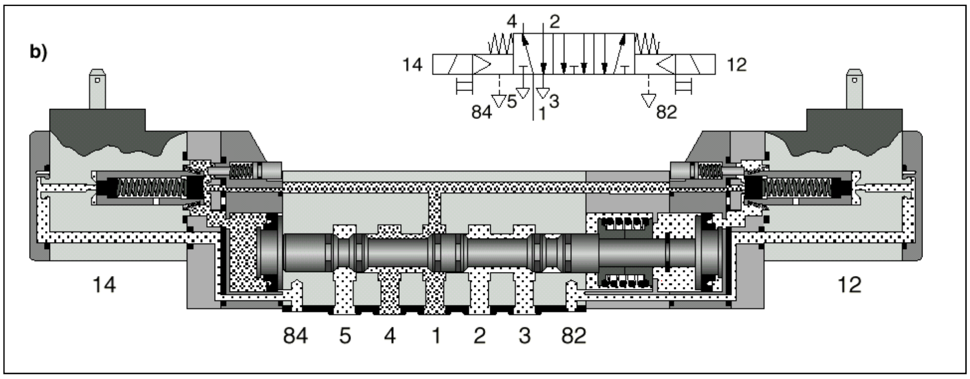


Figure 13.20 – Left Position

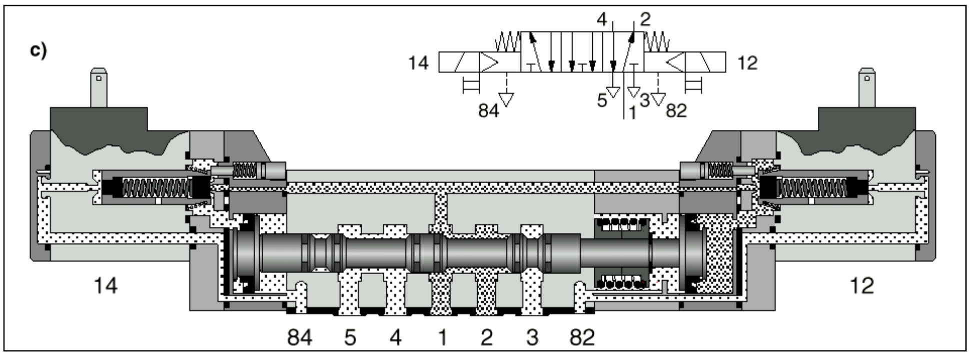


Figure 13.21 – Right Position

14.0 Switches, Relays and Electronic Sensors

14.1 Introduction

The main purpose of the signal input devices is to transfer electrical signals from various points of a control system to the area of signal processing. The input devices used are switches, relays and electronic sensors.

14.2 Electrical Switches

Switches are installed in a circuit to open or close the flow of current to the consuming device. There are two common types; one, which is momentarily activated, and the other mechanically interlocked (detented).

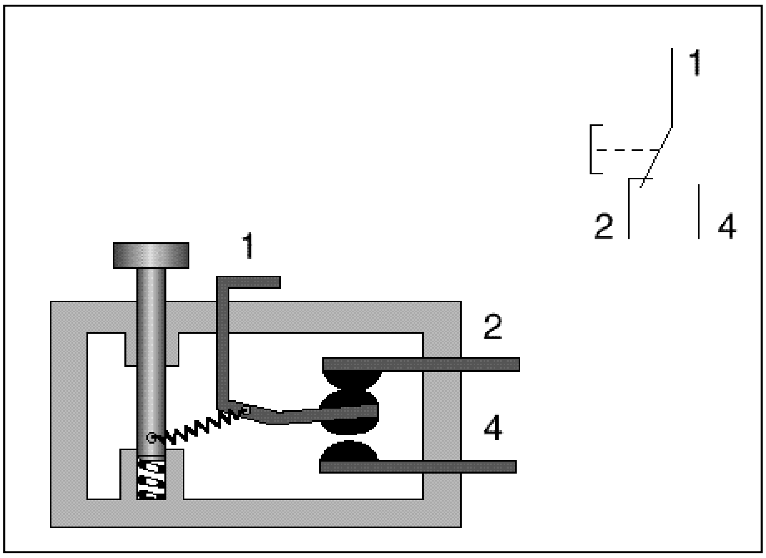


Figure 14.1 – Momentary Switch

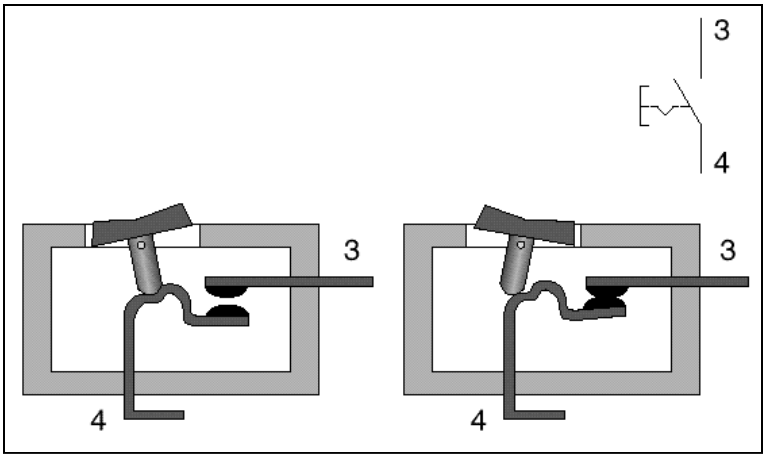


Figure 14.2 – Detented Switch

Both types are available for the operations with normally closed, normally open and changeover types.

14.2.1 Normally Open Switch

For this switch, the circuit is open when the push button is in the normal position; ie. not pressed. The circuit is closed when the control stem is actuated; the current then flows to the consuming device.

When the push button is released, the control stem is released and is returned to its original position, breaking the contact.

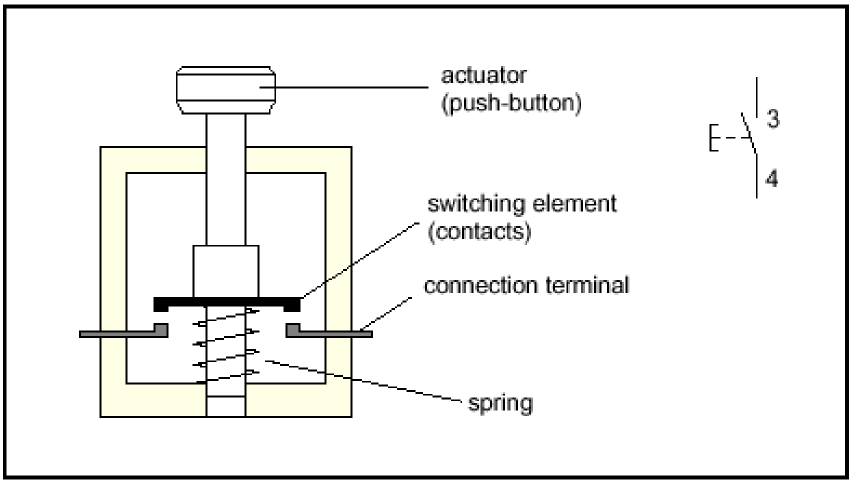


Figure 14.3 – Normally Open Switch

14.2.2 Normally Closed Switch

In the normally closed version, the circuit is closed when the push button is in the normal position. The spring action ensures that the contacts remain closed until the push button is pressed. The current flow is interrupted when the push button is pressed.

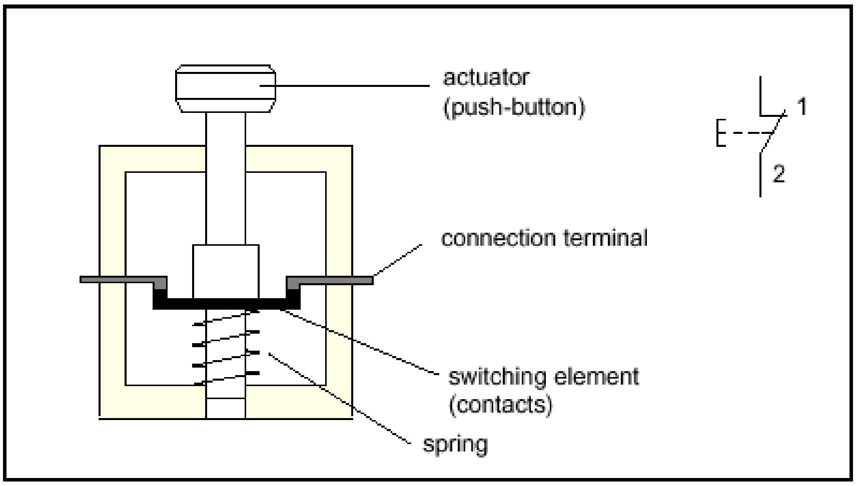


Figure 14.4 – Normally Closed Switch

14.2.3 Changeover Switch

The third version is the changeover switch. These switches combine the functions of both the open and closed switch in one unit. Changeover switches are used to close one circuit and open another at the same time.

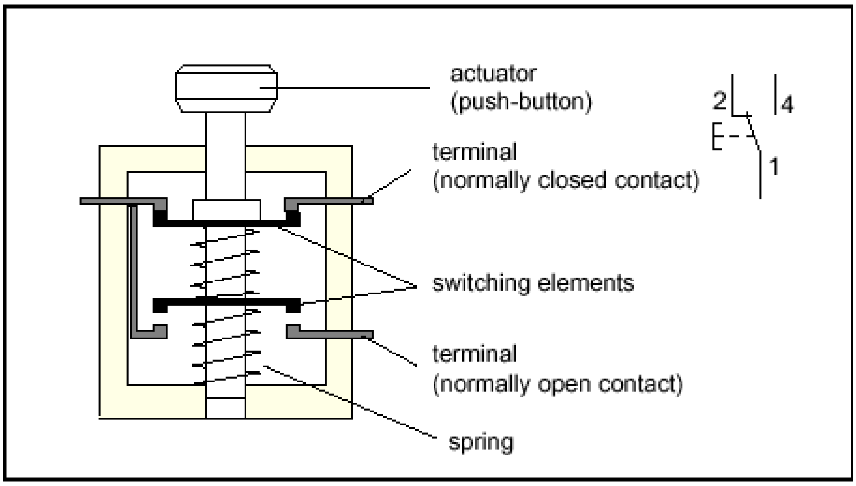


Figure 14.5 – Changeover Switch

14.3 Electrical Contacts

Contacts are basically made up of two elements; a terminal and a moving switch. They are also designed with normally open, normally closed and changeover contacts.

Contacts are different from switches in that they are activated by electrical means such as relays or contactors.

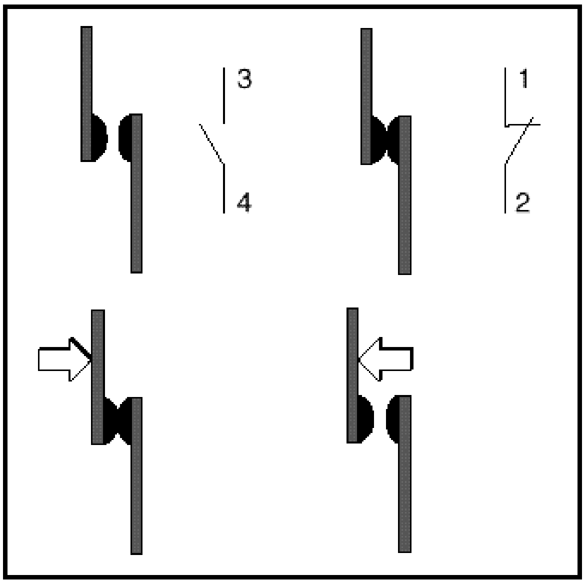


Figure 14.6 – Normally Open and Normally Closed Contacts

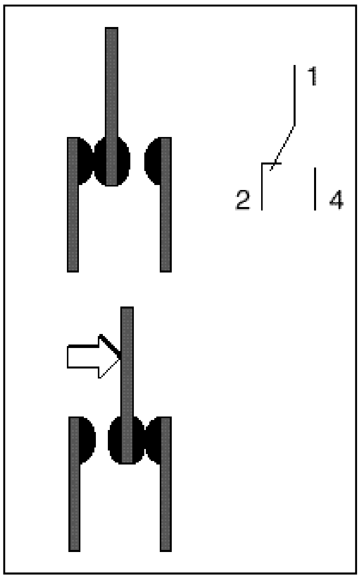


Figure 14.7 – Changeover Contact

14.4 Electrical Relays

Relays are used for switching and controlling electrical circuits requiring only a low amount of energy. They can be considered as an electro-magnetic switch. A small amount of energy applied to the coil can control a larger flow through the relay contacts.

Relays are generally used as signal processors in electro-pneumatic and circuits.

A relay has certain characteristics:

- Low maintenance.
- Able to switch a number or independent circuit paths.
- Easily adaptable to various operating voltages.
- Higher operating speed, ie. short switching time.

When voltage is applied to the coil (2), an electrical current flow through the winding; a magnetic field builds up and pulls the armature (1) against the core (4) of the coil. The armature is mechanically joined to contact 1 and is pulled against contact 4.

The switching position is maintained as long as the voltage is applied. When the voltage is removed, the armature is restored to its original position by spring (3). In the initial position, contact 2 is active.

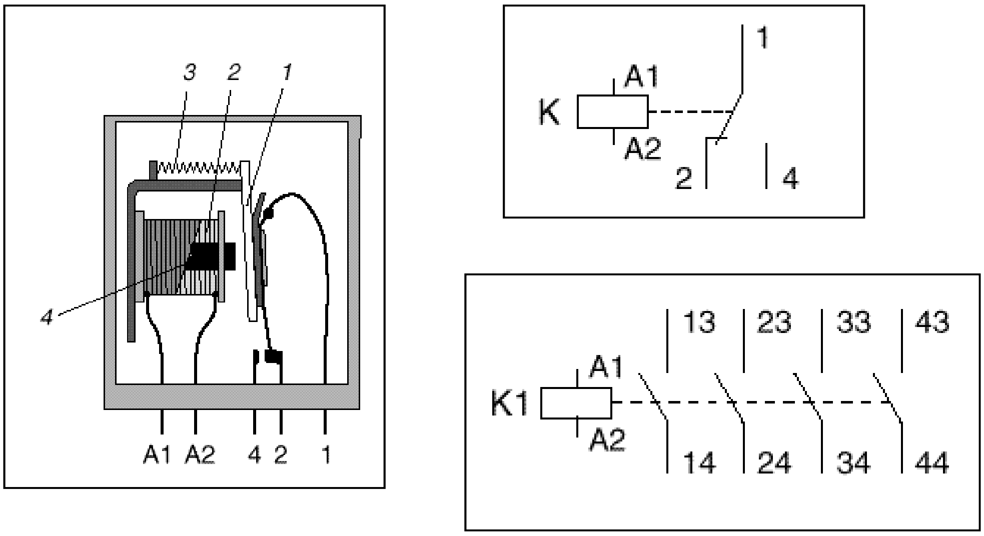


Figure 14.8 – Electrical Relays

14.5 Electrical Contactors

Contactors are similar to relays and work on the same principle but are used to switch higher loads. They are used for higher current usually above 20A.

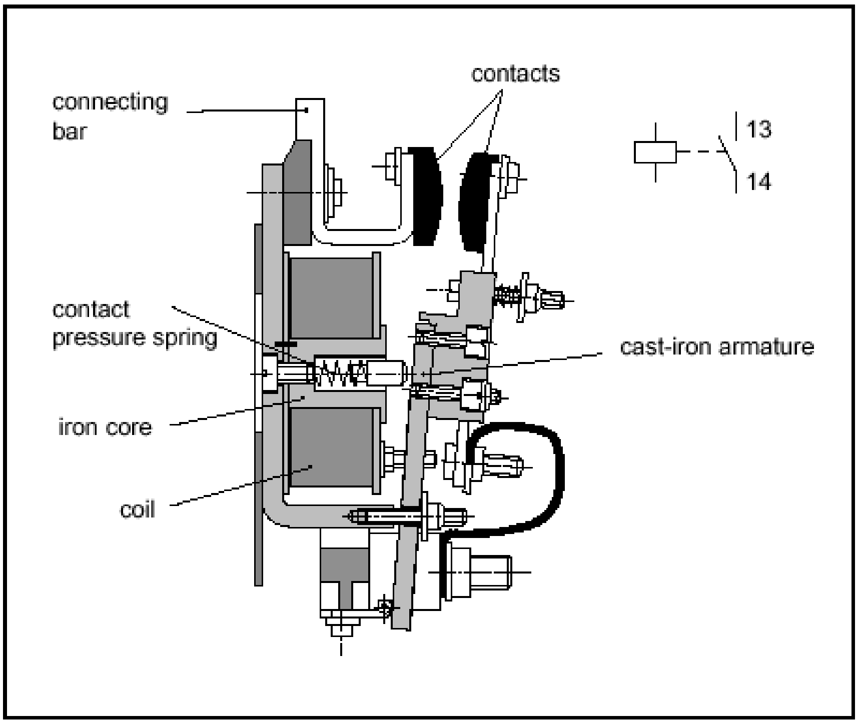


Figure 14.9 – Electrical Contactor

14.6 Electrical Sensors

Sensors are used to provide an input to the electrical system. They are used generally for detecting components or cylinder positioning.

14.6.1 Electrical Limit Switches

A limit switch is actuated when a machine part or workpiece is in a certain position. Normally, actuation is effected by a cam. Limit switches are normally changeover contacts.

They can then be connected

- as required
- as a normally open contact, normally closed contact or changeover contact.

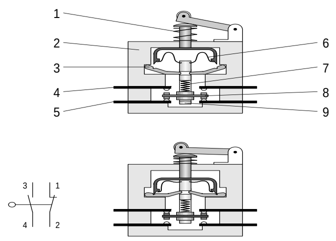


Figure 14.10 – Electrical Limit Switch

14.6.2 Reed Switches

Reed switches are also known as magnetically actuated proximity switches. In electro-pneumatic control circuits, reed switches are commonly used to sense the positions of cylinder piston rods and the angle of rotation of the shaft in rotary actuators. Reed switches are characterised by their small size and fast switching time. Since they are actuated by a magnetic field rather than by mechanical contact, the reed switch is reliable in operation providing the specified electrical connection and mounting requirements are adhered to.

In its basic form, the reed switch has a contact pair fused into an inert gas filled glass tube. In this configuration, the switch would be vulnerable to mechanical damage, therefore in industrial applications the switch is encapsulated in epoxy resin.

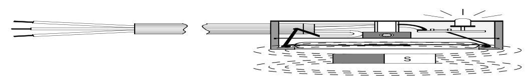


Figure 14.11 - Magnetic Reed Proximity Sensors

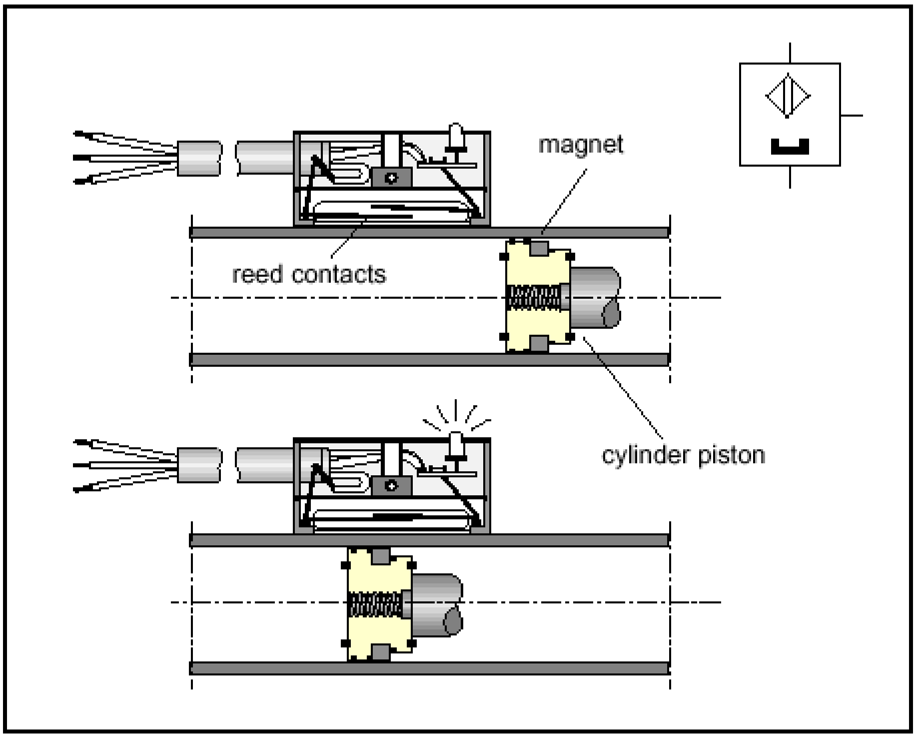


Figure 14.12 – Reed Switches

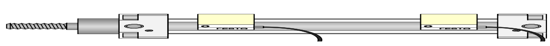


Figure 14.13 - Pneumatic Cylinder with Magnetic Proximity Sensors.

14.6.3 Pressure Switches

Pressure switches are used to convert pneumatic pressure to electrical signals. They can be used to open, close or change between circuits when a pre-set pressure is reached.

In general, the supply pressure acts on a piston surface. The resulting force acts against an adjustable spring pressure. If the pressure is greater than the force of the spring, the piston is moved and actuates contact assembly.

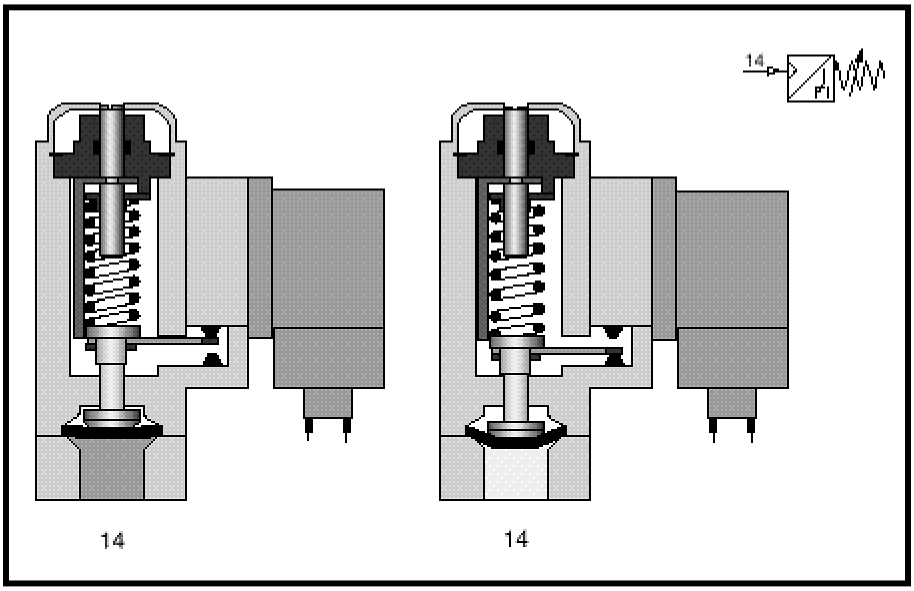


Figure 14.11 – Pressure Switches

14.6.4 Inductive Proximity Sensors

An inductive proximity sensor consists of an oscillating circuit (1), a triggering stage (2) and an amplifier (3). When a voltage is applied to the terminals, the oscillating circuit generates a high-frequency electro-magnetic field which is emitted from the end face of the proximity sensor. If a good electrical conductor is introduced into this oscillating magnetic field, the oscillating circuit is dampened. The downstream triggering stage evaluates the oscillating circuit signal and activates the switching output via the amplifier.

Inductive proximity sensors can only detect metals.

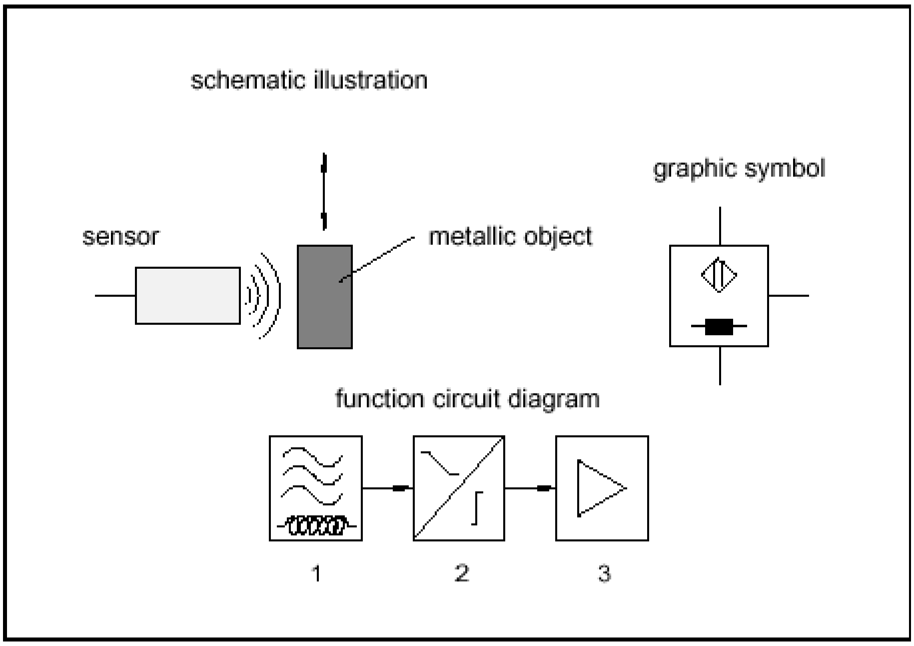


Figure 14.12 – Inductive Proximity Sensors

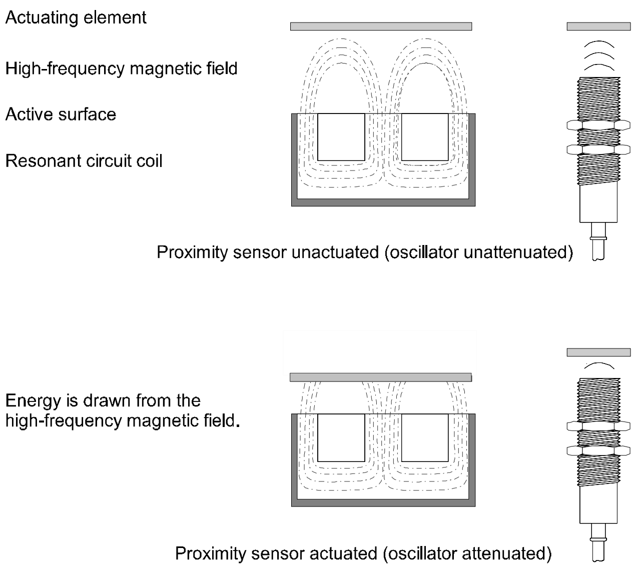


Figure 14.13 - Method of Operation of an Inductive Proximity Sensor

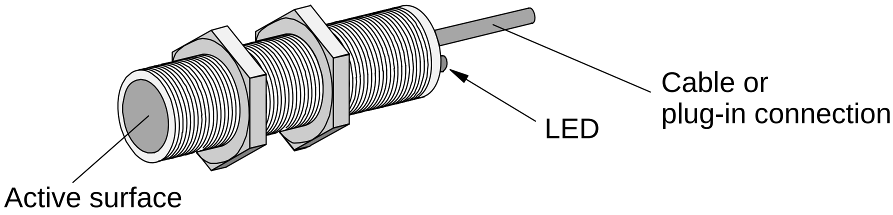


Figure 14.14 - Inductive Proximity Sensor in Threaded Design

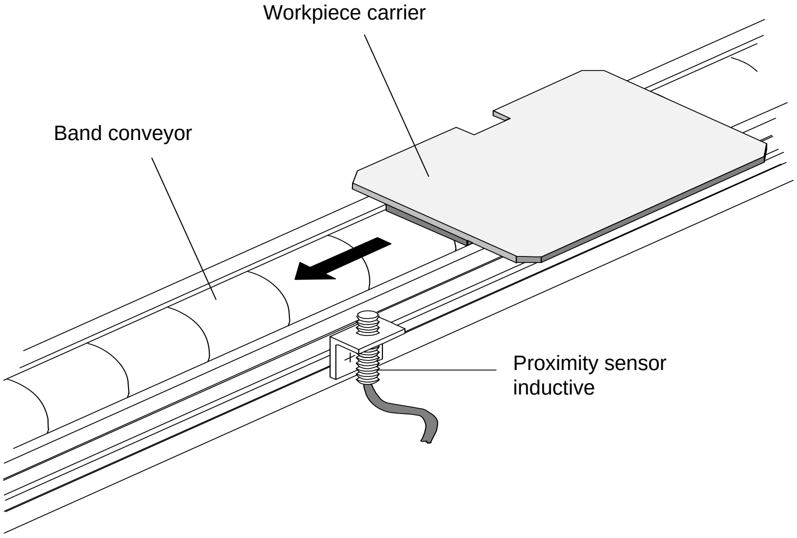


Figure 14.15 - Detection of Metallic Workpiece Carriers on a Band Conveyor

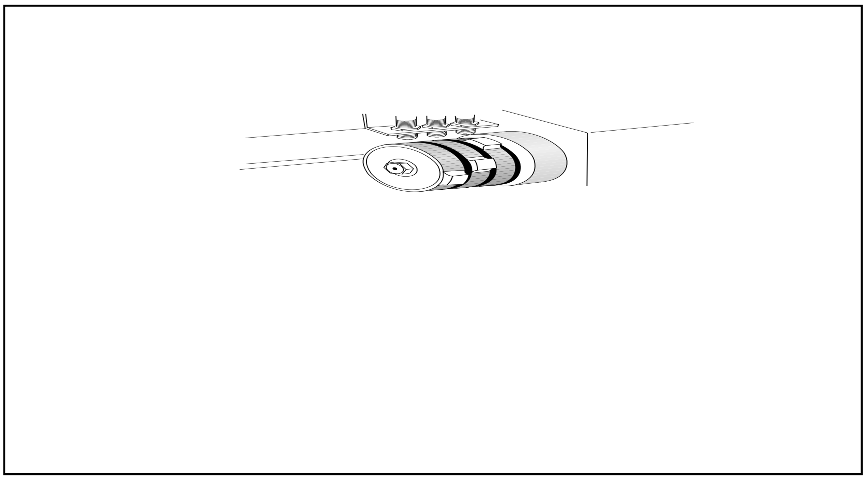


Figure 14.16 - Sensing a Cam Controller

14.6.5 Capacitive Proximity Sensors

Capacitive proximity sensors measure the change in capacitance in the electrical field of a capacitor caused by the approach of an object. The proximity sensor consists of an ohmic resistor, a capacitor (RC oscillating circuit) and an electronic circuit. An electrostatic field is built up in the space between active electrode and earth electrode.

If an object is then introduced into this stray field, the capacitance of the capacitor increases, thus detecting not only highly conductive materials, but also all insulators which possess a high dielectric constant, such as plastics, glass, ceramics, liquids and wood.

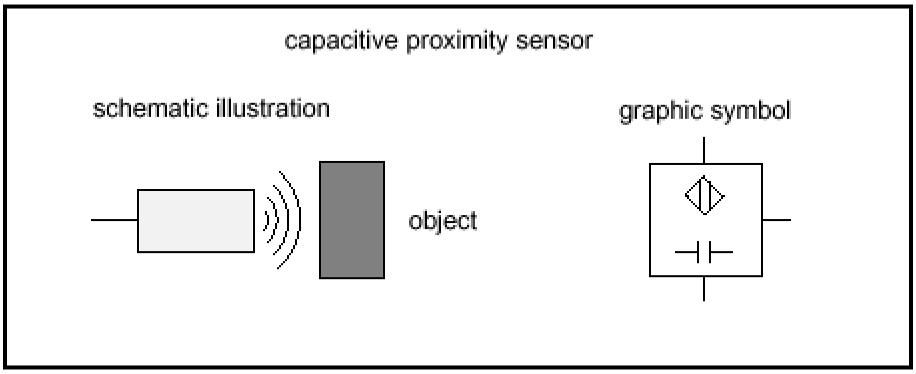


Figure 14.17 – Capacitive Proximity Sensor

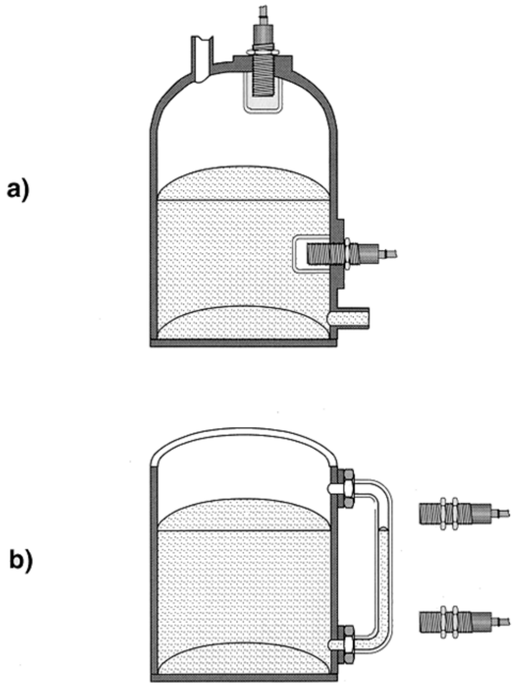


Figure 14.18 - Detection of Filling Level Inside a Steel Container

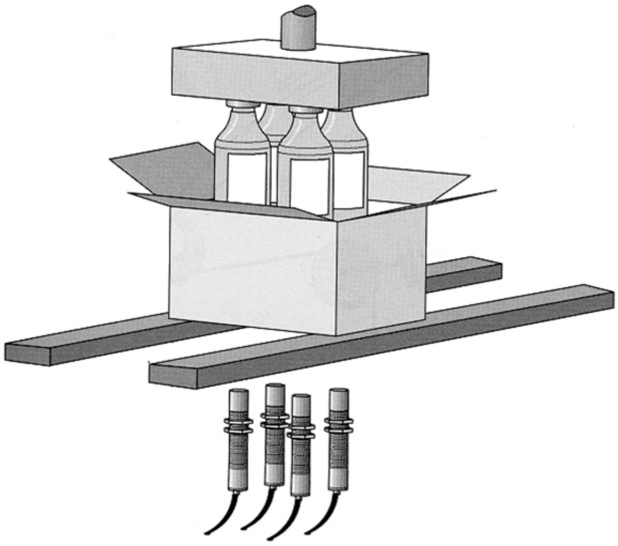
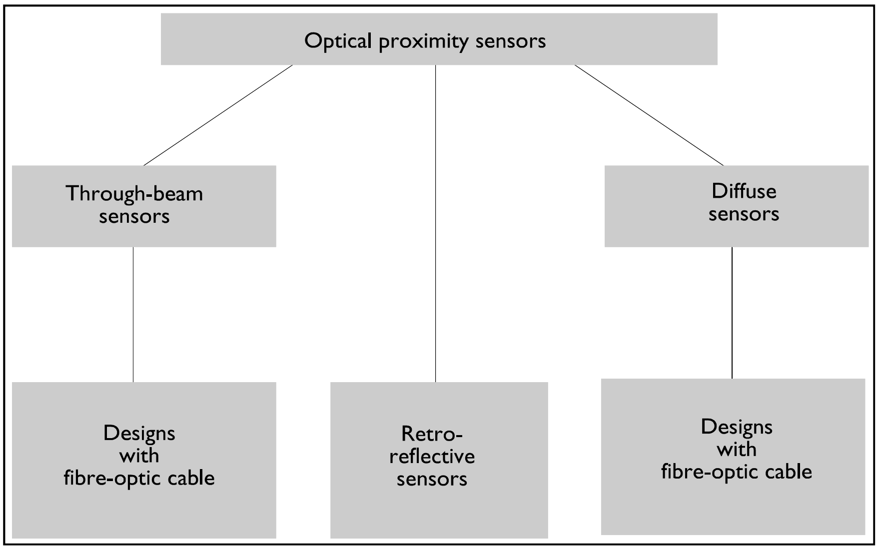


Figure 14.19 - Checking of Packaging Contents through Cardboard

14.6.6 Optical Proximity Sensors

Optical proximity sensors employ optical and electronic means for the detection of objects. Red or infrared light is used for this purpose. Semiconductor light emitting diodes (LED's) are a particularly reliable source of red and infrared light. They are small and robust, have a long service life and can be easily modulated.

There are three types of Optical proximity sensors:



a. Through Beam Sensors

The through-beam sensor consists of spatially separated transmitter and receiver units. The components are mounted in such a way that the transmitter is aimed directly at the receiver. If the light beam is interrupted, the contacts will either open or close.

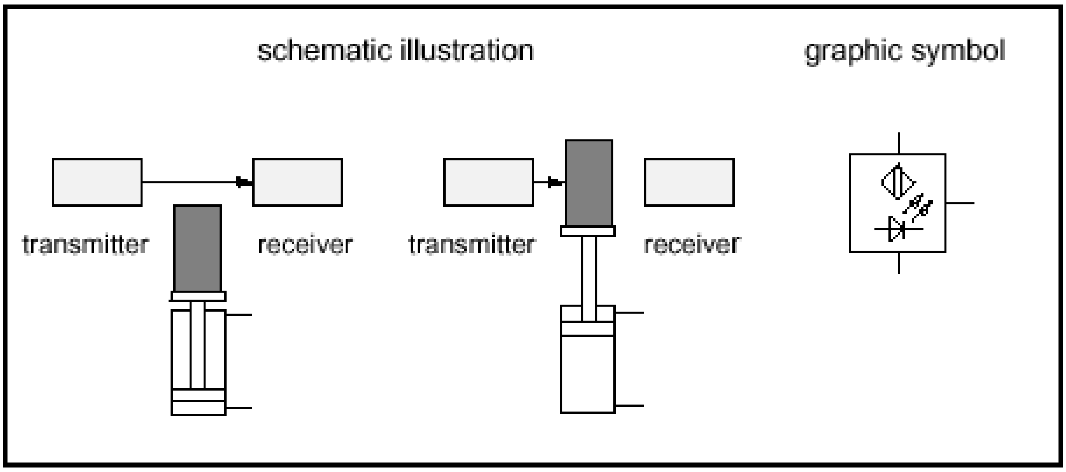


Figure 14.20 – Through Beam Sensor

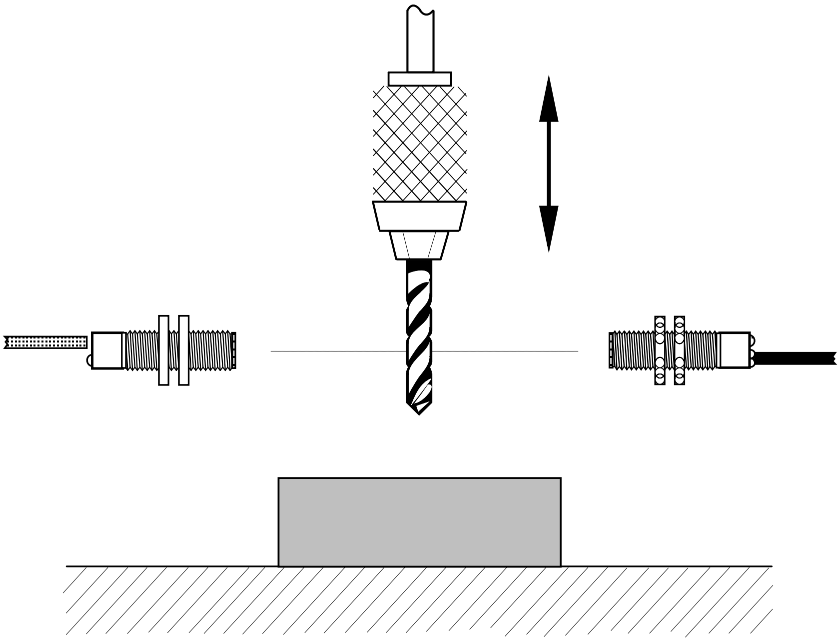


Figure 14.21 - Checking for Broken Drills with a Through-beam Sensor

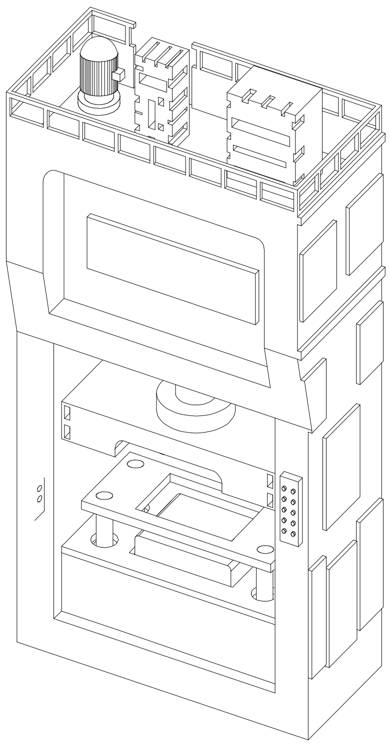


Figure 14.22 - Accident Prevention on a Press by Means of a Through-beam Sensor

b. Retro Reflective Sensors

In retro-reflective sensors, the transmitter and the receiver are mounted side by side in a common housing. For the correct function of these sensors, a reflector must be mounted in such a way that the light beam emitted by the transmitter is more or less totally reflected onto the receiver. Interruption of the light beam causes the sensor to switch.

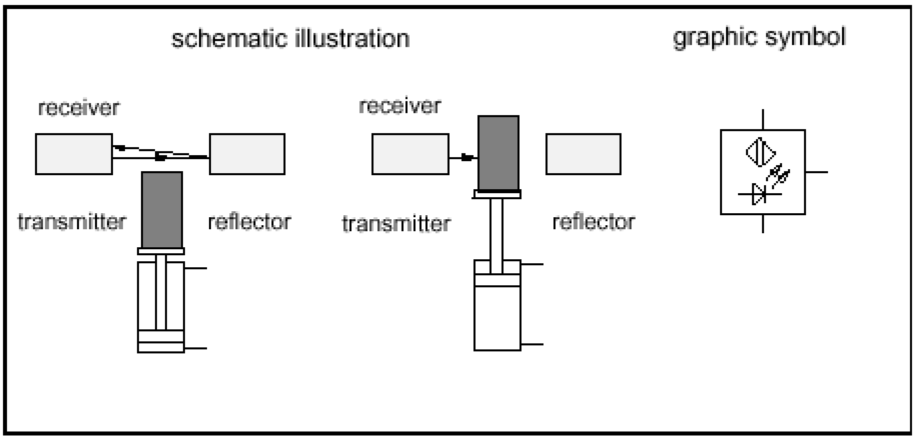


Figure 14.23 – Retro-Reflective Sensor

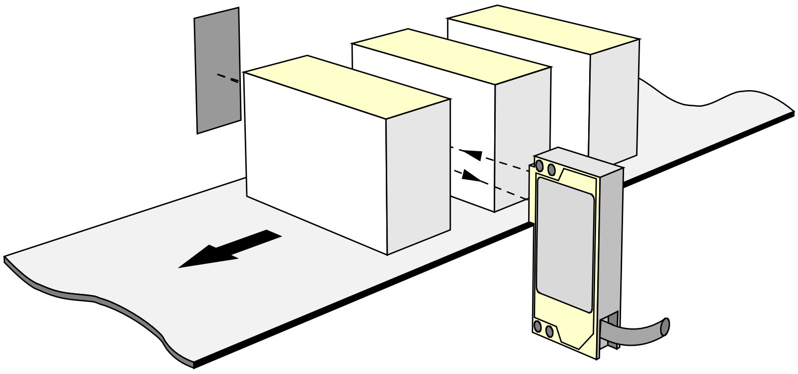


Figure 14.24 - Monitoring Build-up and Counting of Objects

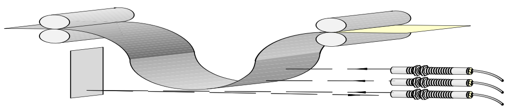


Figure 14.25 - Slack Control

c. Diffuse Sensors

The transmitter and receiver of the diffuse sensor are mounted in a similar way to that of the retro-reflective sensor. If the transmitter is aimed at a reflecting object, the reflected light is absorbed by the receiver and a switching signal is generated. The greater the reflection properties of the object in question, the more reliably the object can be detected.

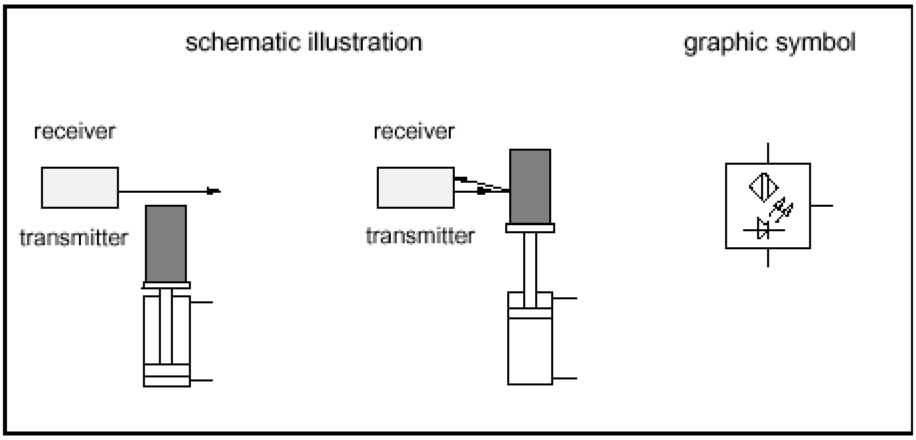


Figure 14.26 – Diffuse Sensor

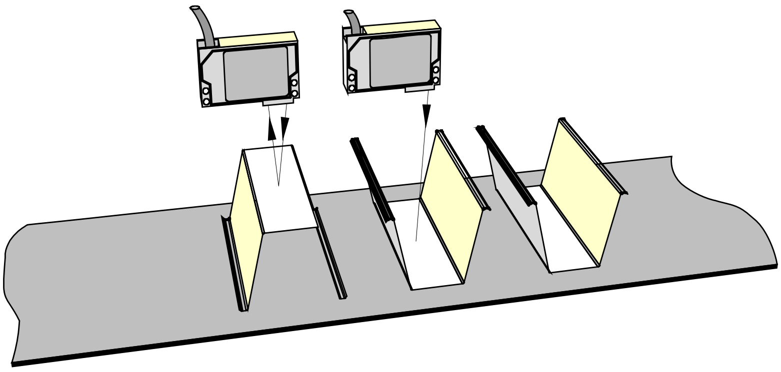


Figure 14.27 - Monitoring the Position of a Workpiece

15.0 Electro-Pneumatic Graphical Symbols

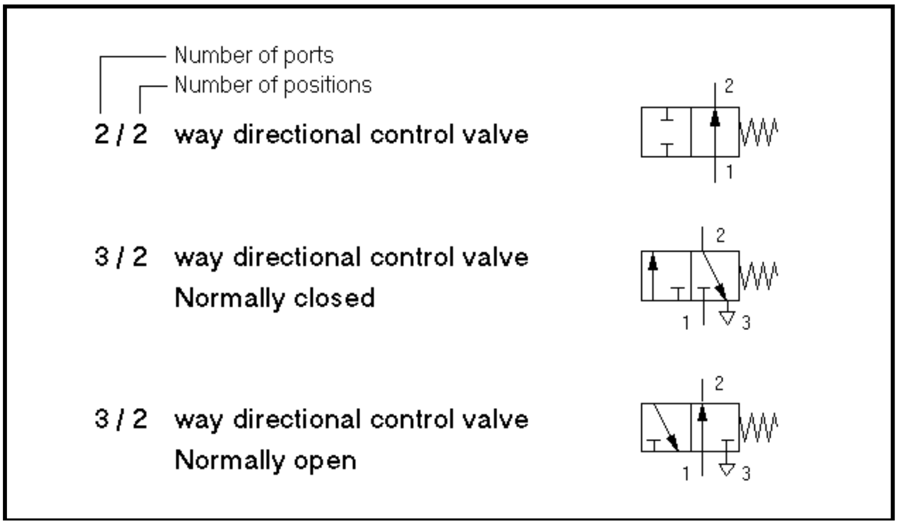
15.1 Introduction

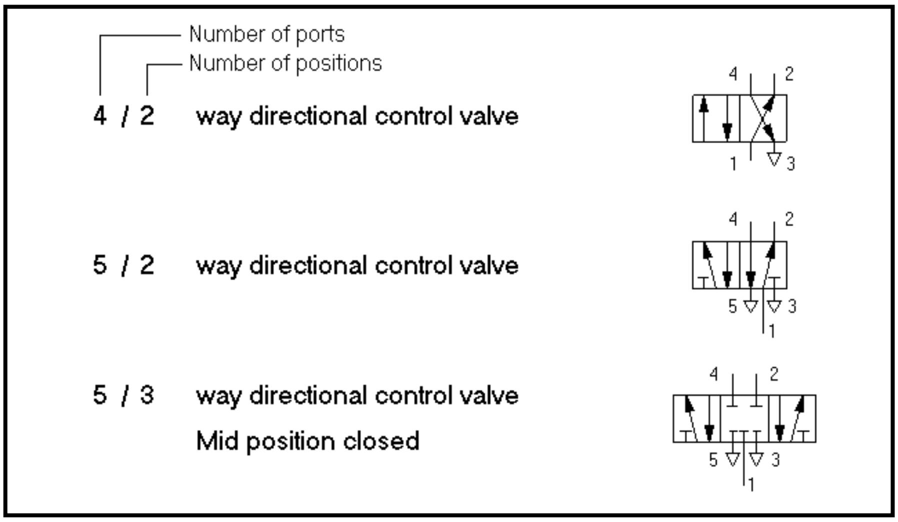
To simplify the presentation of electro-pneumatic systems in circuit diagrams, we use simple symbols (also called graphic and circuit symbols) for the various components.

A symbol is used to identify a component and its function, but tells us nothing about the design of the component. DIN ISO 1219 contains regulations on circuit symbols. The most important graphic symbols are explained below.

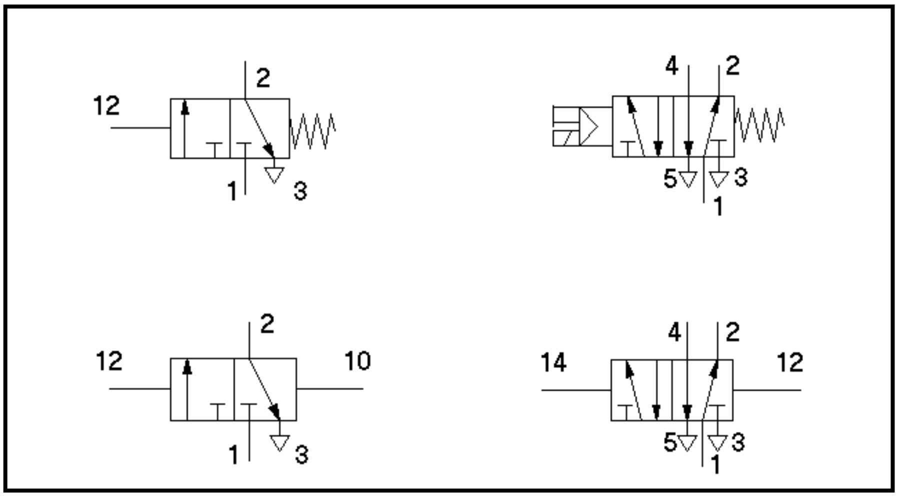
15.2 Directional Control Valves

15.2.1 Symbol Development

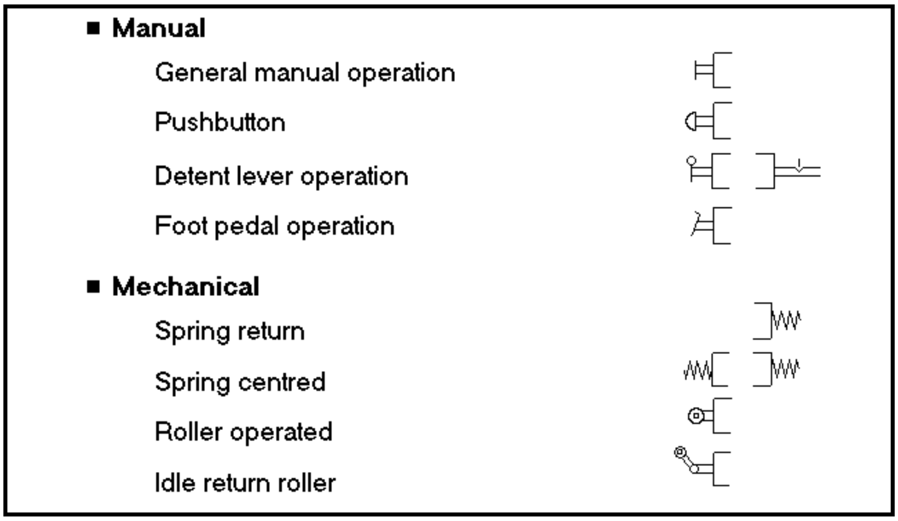


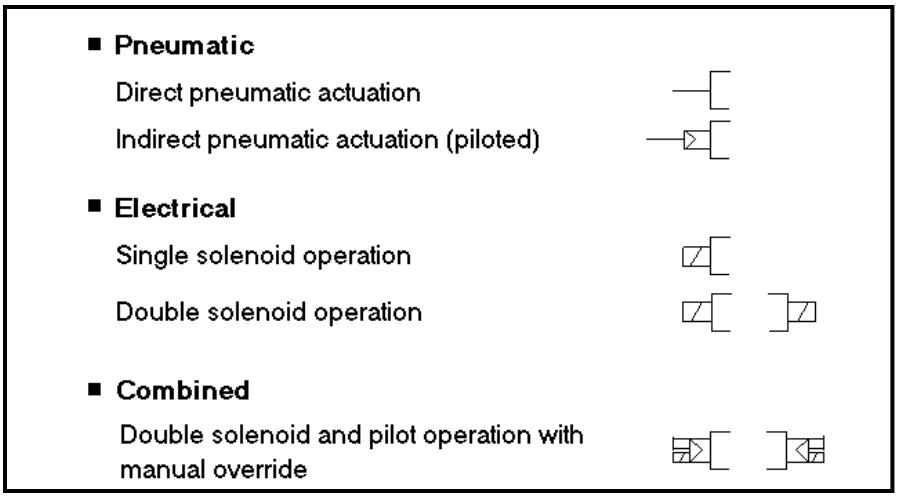


15.2.2 Examples of Designation

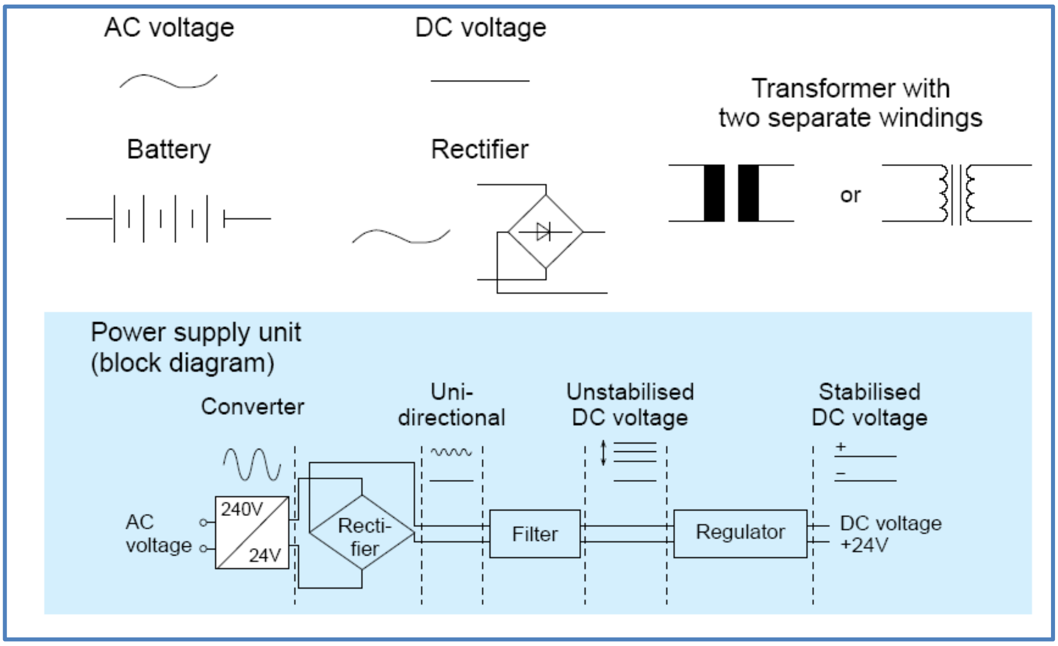


15.2.3 Method of Actuation

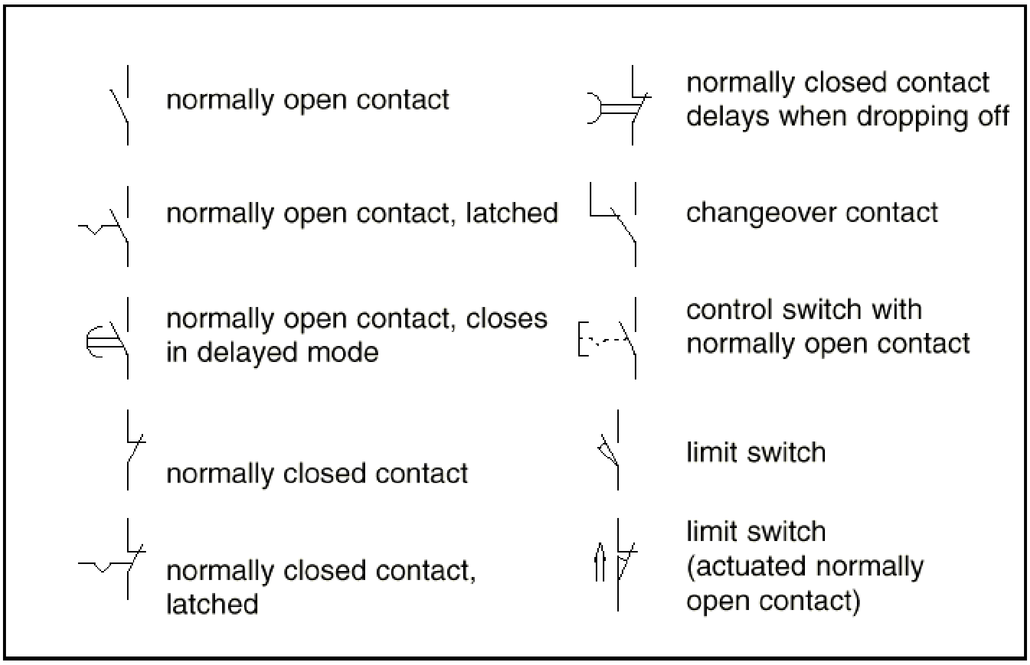


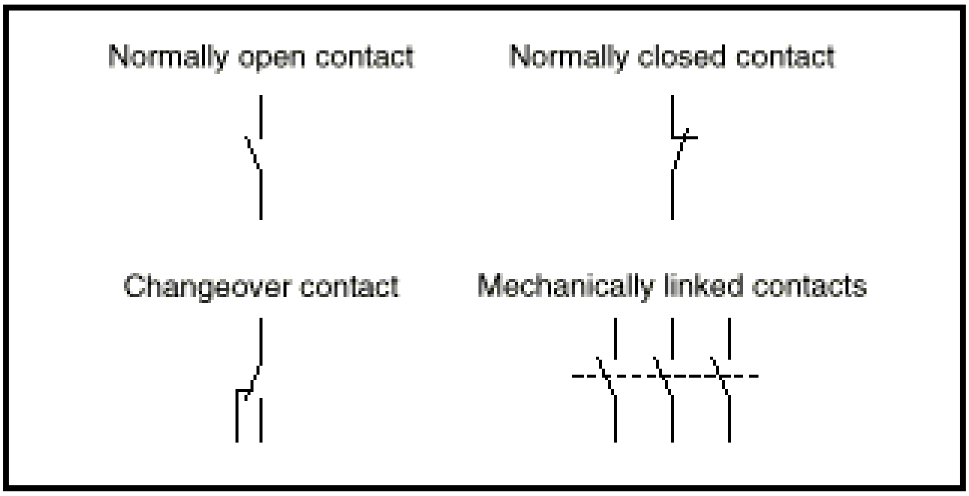


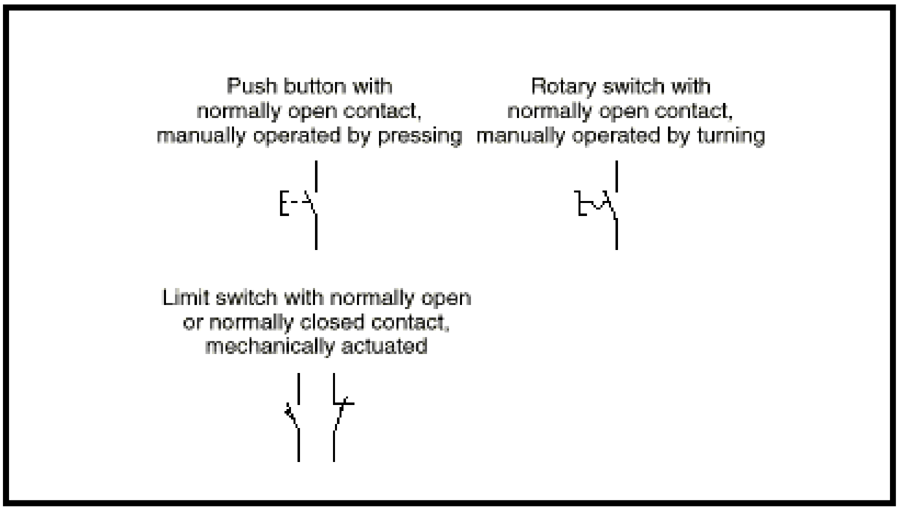
15.3 Power Supply Units



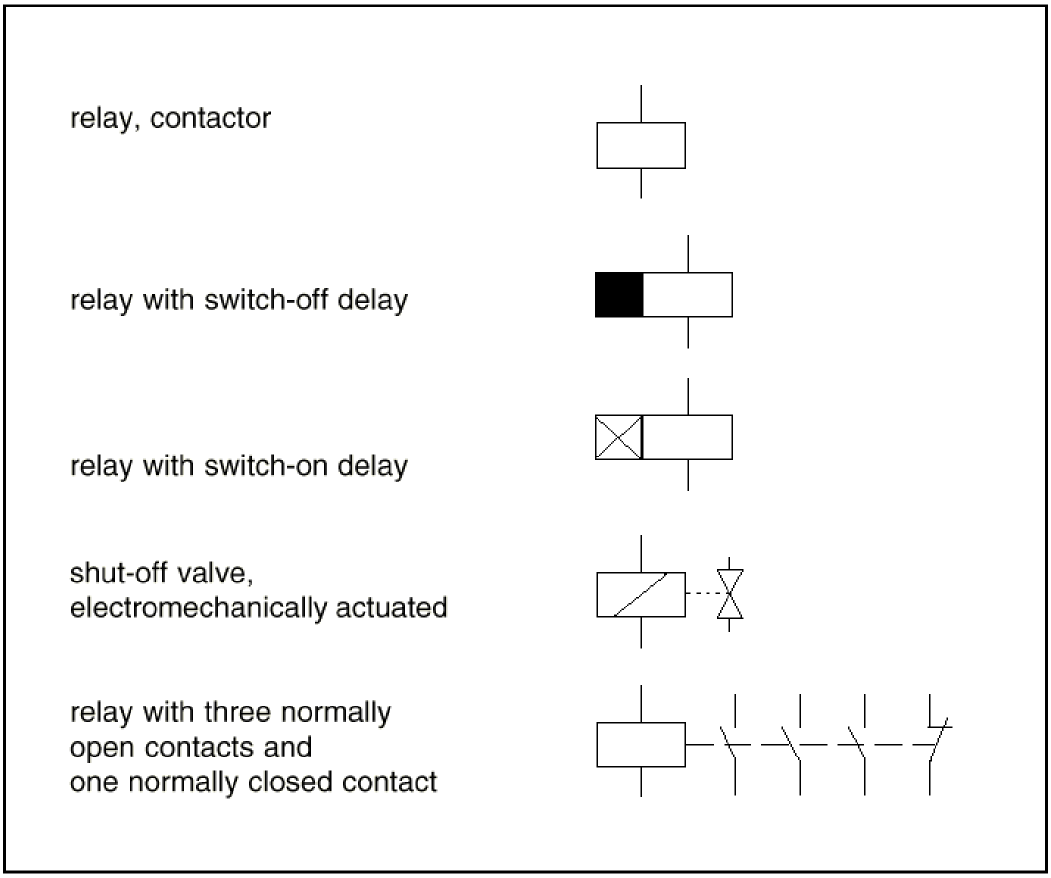
15.4 Switch, Contacts and Types of Actuation

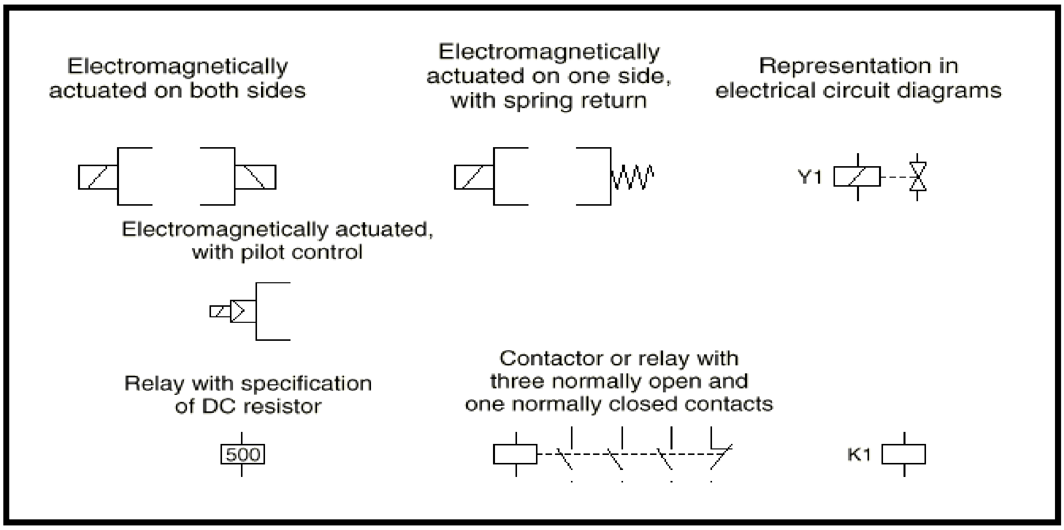



Normally open contact
Normally closed contact
Changeover contact
Mechanically linked contacts

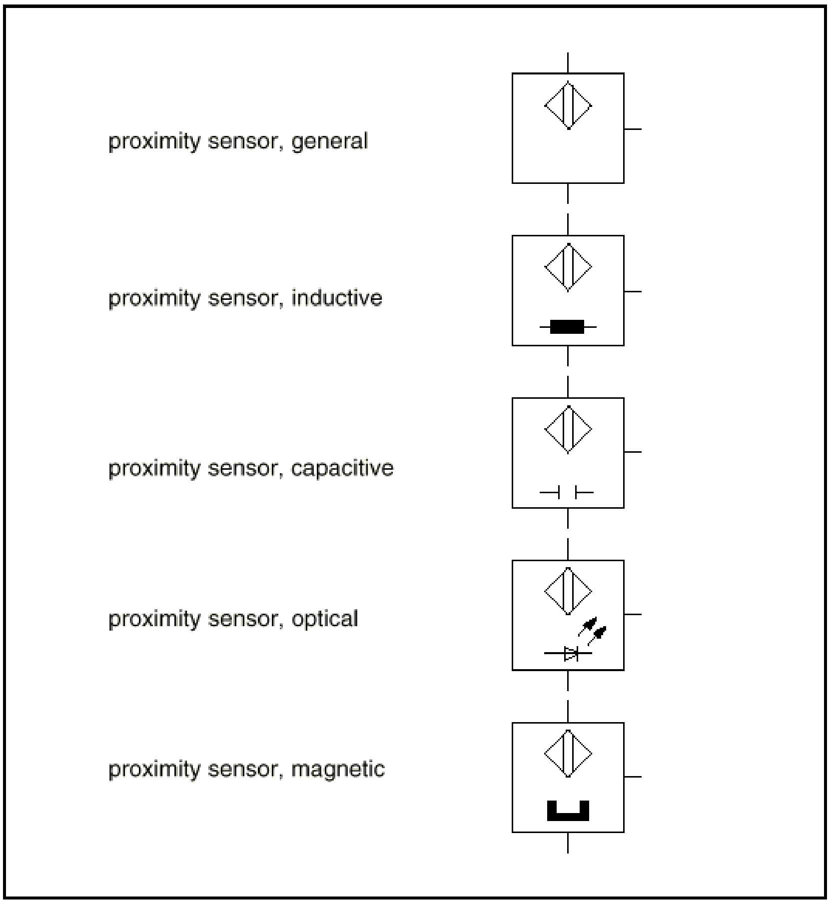

Push button with
normally open contact,
manually operated by pressing
Rotary switch with
normally open contact,
manually operated by turning
Limit switch with normally open
or normally closed contact,
mechanically actuated

15.5 Relays, Timers and Solenoids





15.6 Sensors


proximity sensor, general
proximity sensor, inductive
proximity sensor, capacitive
proximity sensor, optical
proximity sensor, magnetic

16.0 Logic Functions

16.1 Introduction

Electro-pneumatic circuits are developed depending on size and complexity, either on one drawing sheet or on separate sheets cross referenced to each other. The circuits can be divided into two groups:

- Pneumatic Circuit Diagram
- Electrical Circuit Diagram

There exists an interface between the pneumatic and electrical elements. These elements will appear on both the pneumatic and the electrical circuit diagrams with common identification markings.

16.2 Designing Electro-Pneumatic Circuits

16.2.1 Development Steps

The steps in development of basic circuits are:

- Describe the operation of the circuit.
- Develop a displacement-step diagram of the process.
- Draw the pneumatic components of the diagram.
- Draw the electrical portion of the diagram.
- Document maintenance information.
- Document component spares and technical data.

16.2.2 System Structure

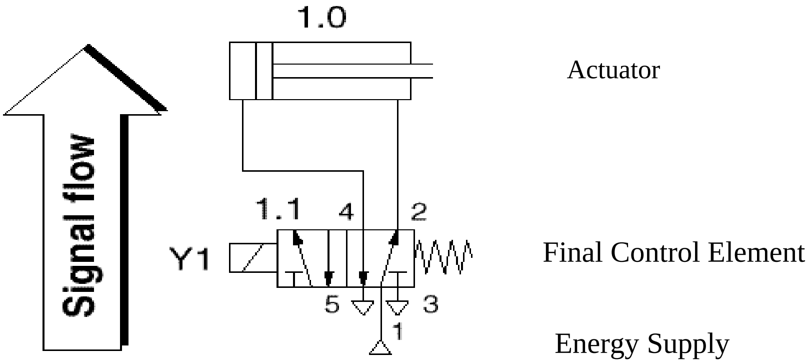
Components in a control system belongs to four basic groups:

- Energy Supply
- Input Elements
- Processing Elements
- Final Control Elements and Actuators

16.2.3 Development Guide

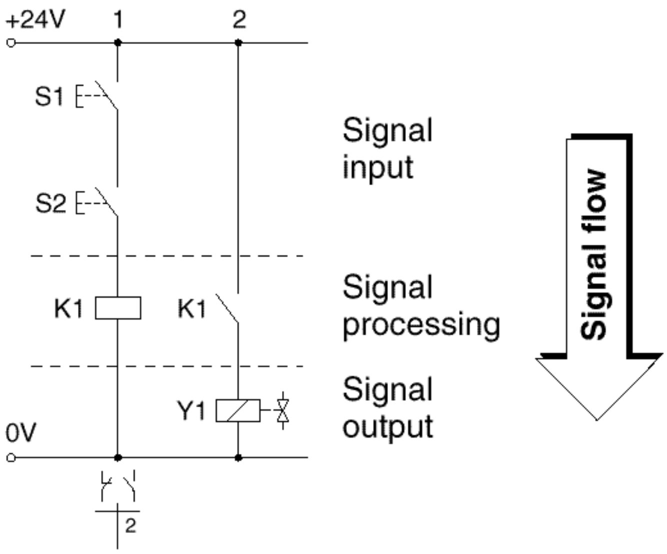
a. *Pneumatic*

- Circuit layout should follow the signal flow through the control chain from bottom to top.
- Cylinders and directional control valves are drawn horizontally with the cylinders operating from left to right.



b. *Electrical*

- Layout should where possible follow the signal flow through the control chain from top to bottom.
- Circuits with intermediate or relay control can be further divided into a control section and a power section and components placed in these sections from left to right according to the sequence of operations. These processes should be treated as a guide only, as a clear division of these functions is not always possible.



16.3 Logic Functions

There are seven commonly used logic functions in Electro-Pneumatics.

- YES Function
- NOT Function
- OR Function
- AND Function
- NOR Function
- NAND Function
- Memory Function

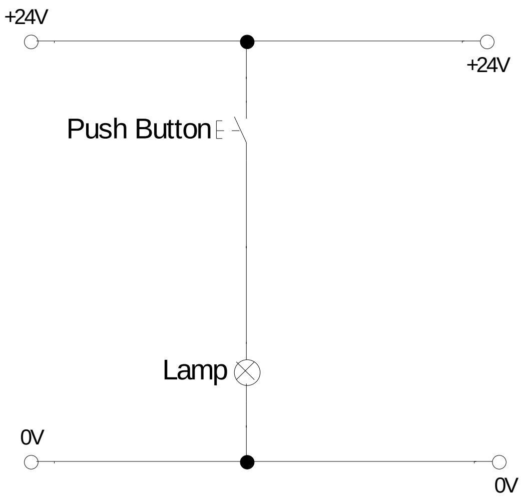
When designing circuits, you can do it directly or indirectly. When doing it indirectly, a relay is often used. The indirect method is commonly used in designing electro-pneumatic circuits.

16.3.1 YES Logic

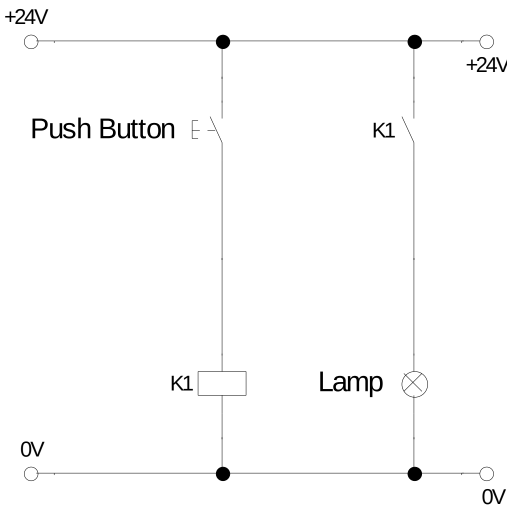
Truth Table

S1	Lamp
0	0
1	1

For the YES Logic, the Load (in this example we are using the Lamp) is not activated in the normal position. When Switch S1 is pressed, the Load will be "On".



Direct Method



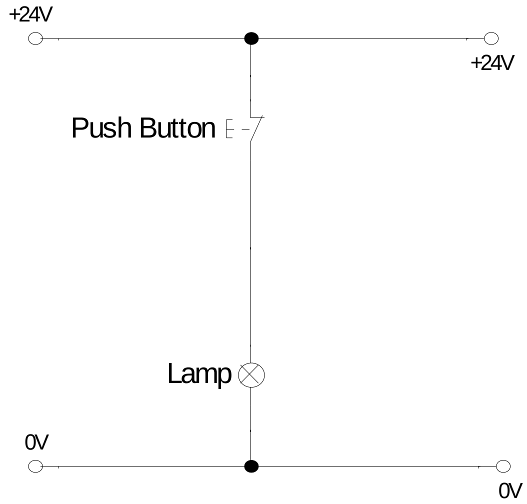
Indirect Method

16.3.2 NOT Logic

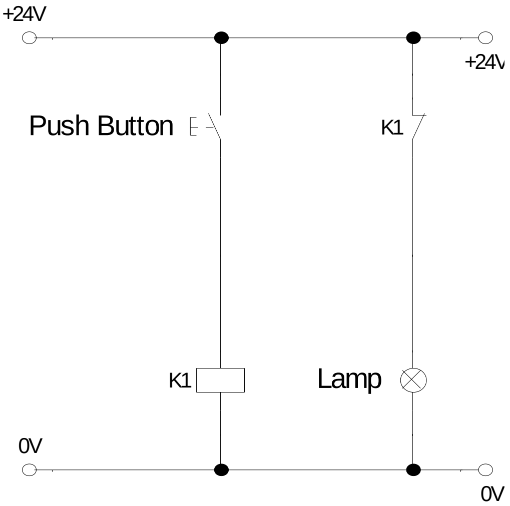
Truth Table

S1	Lamp
0	1
1	0

For the NOT Logic, the Load is activated in the normal position. When Switch S1 is pressed, the Load will be "Off". In the Indirect method, take note that the switch should not be normally closed but use a normally closed relay contact. This is to protect the relay from being energised always.



Direct Method



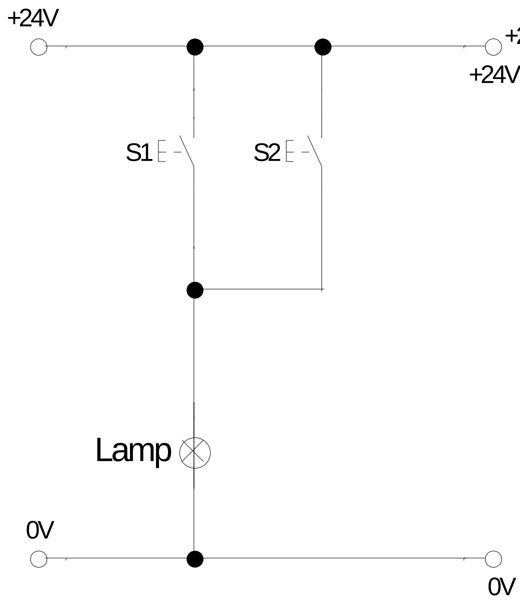
Indirect Method

16.3.3 OR Logic

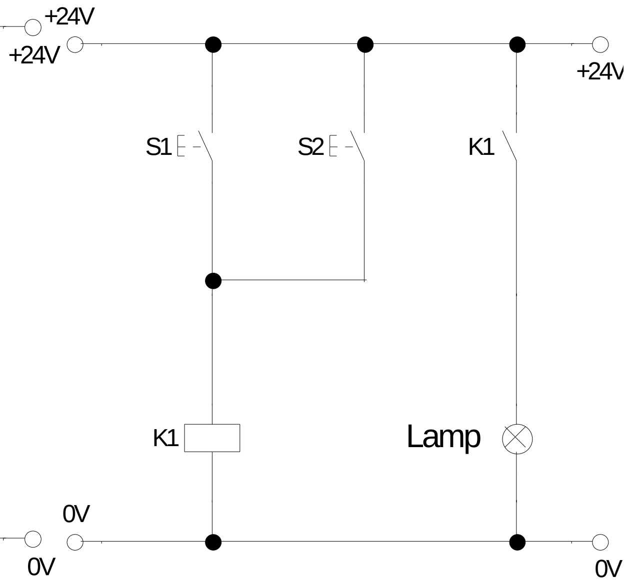
Truth Table

S1	S2	Lamp
0	0	0
1	0	1
0	1	1
1	1	1

For the OR Logic, the Load is "Off" in the normal position. When either Switch S1 or Switch S2 is pressed, the Load will be "On". The Load will also be "On" when both switches are pressed. The truth table above reflects this.



Direct Method



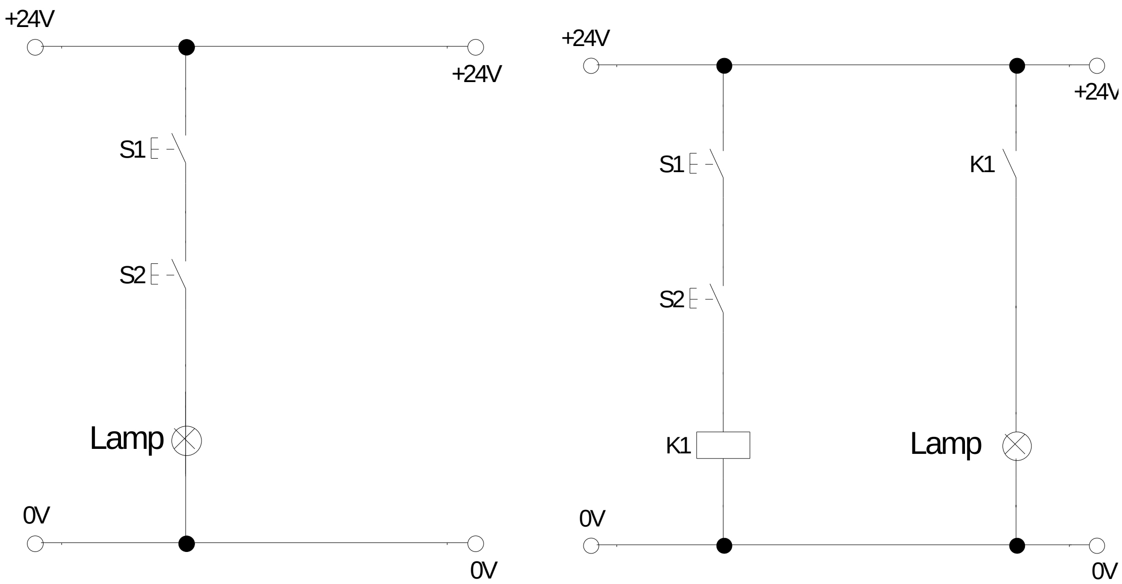
Indirect Method

16.3.4 AND Logic

Truth Table

S1	S2	Lamp
0	0	0
1	0	0
0	1	0
1	1	1

For the AND Logic, the Load is "Off" in the normal position. When both Switch S1 and Switch S2 are pressed, the Load will be "On".



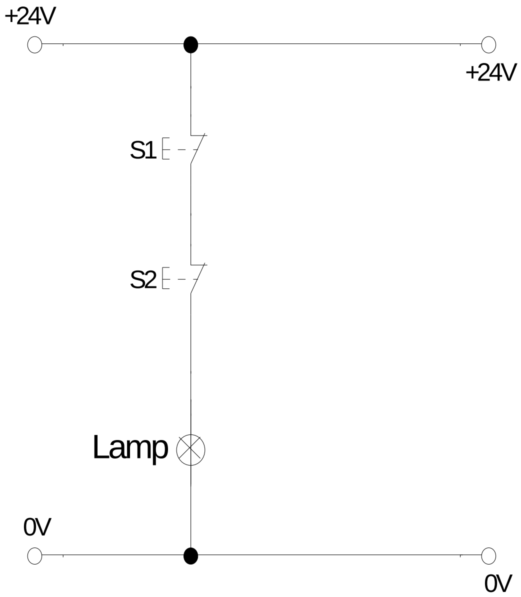
Direct Method Indirect Method

16.3.5 NOR Logic

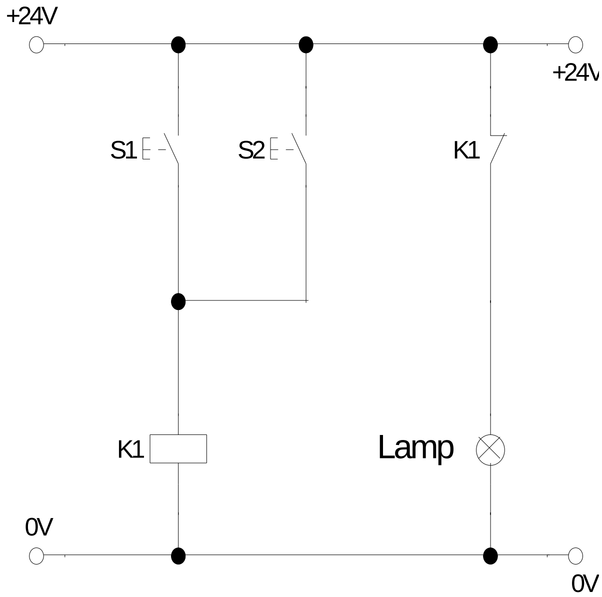
Truth Table

S1	S2	Lamp
0	0	1
1	0	0
0	1	0
1	1	0

The NOR Logic is a combination of NOT and OR, the Load is activated in the normal position. When either Switch S1 or Switch S2 are pressed, the Load will be "Off".



Direct Method



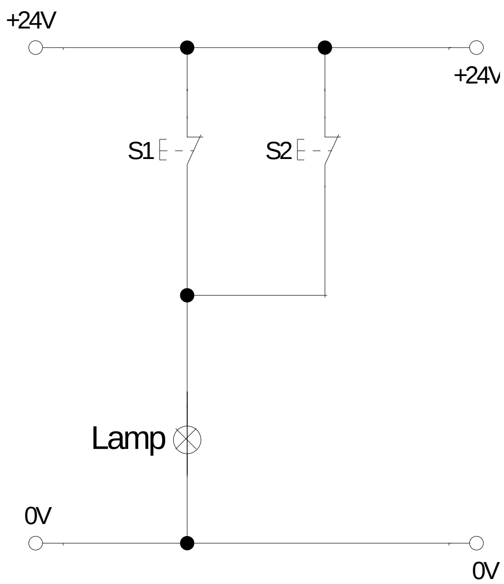
Indirect Method

16.3.6 NAND Logic

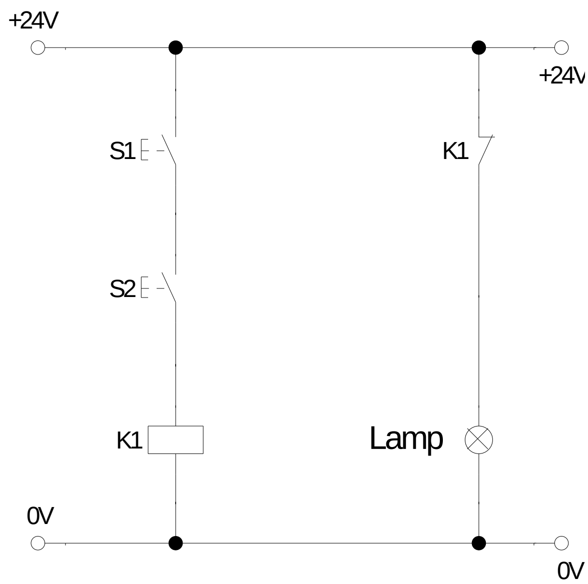
Truth Table

S1	S2	Lamp
0	0	1
1	0	1
0	1	1
1	1	0

The NAND Logic is a combination of NOT and AND, the Load is activated in the normal position. When both Switch S1 and Switch S2 are pressed, the Load will be "Off".



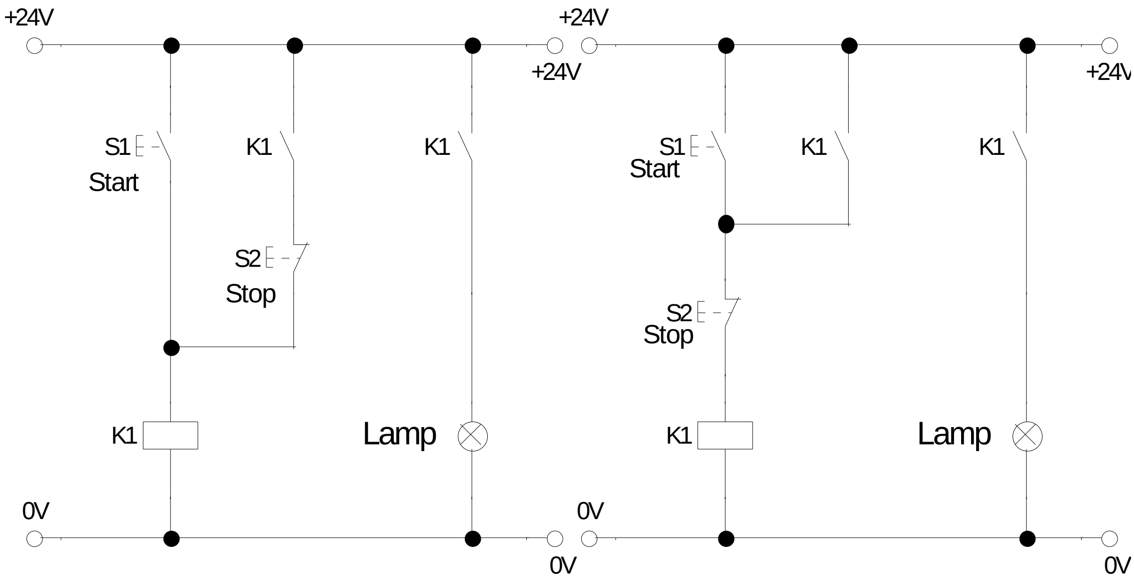
Direct Method



Indirect Method

16.3.7 Memory or Latching Function

So far, the following logic circuits needs the user to press the switches and hold on to it during usage. This is of course not practical in designing systems. It is usually the case where the switch is pressed once and the entire system runs without holding on to it. This latching system is very useful for sequencing circuits and is often used in electro-pneumatic circuit designs. There are two forms; Dominant On and Dominant Off. In dominant on, the "On" switch is dominant and the opposite for dominant off.



Dominant On Dominant Off

17.0 Basic Electro-Pneumatic Circuits

17.1 Controlling Circuits Remotely

Besides the logic functions, there are certain circuits which are controlled remotely. These enable the actuators to return automatically or to stop the actuators automatically.

These circuit designs can also be used to make or break certain parts of the electrical circuit.

It depends on:

- Position - Limit Switches
- Pressure - Pressure Switches (PE Switch)

17.1.1 Position

Actuators can use their position to activate either a limit switch or proximity sensor to make or break an electrical circuit. It is similar to the above logic circuits with the limit switches or proximity sensors replacing the push button switch.

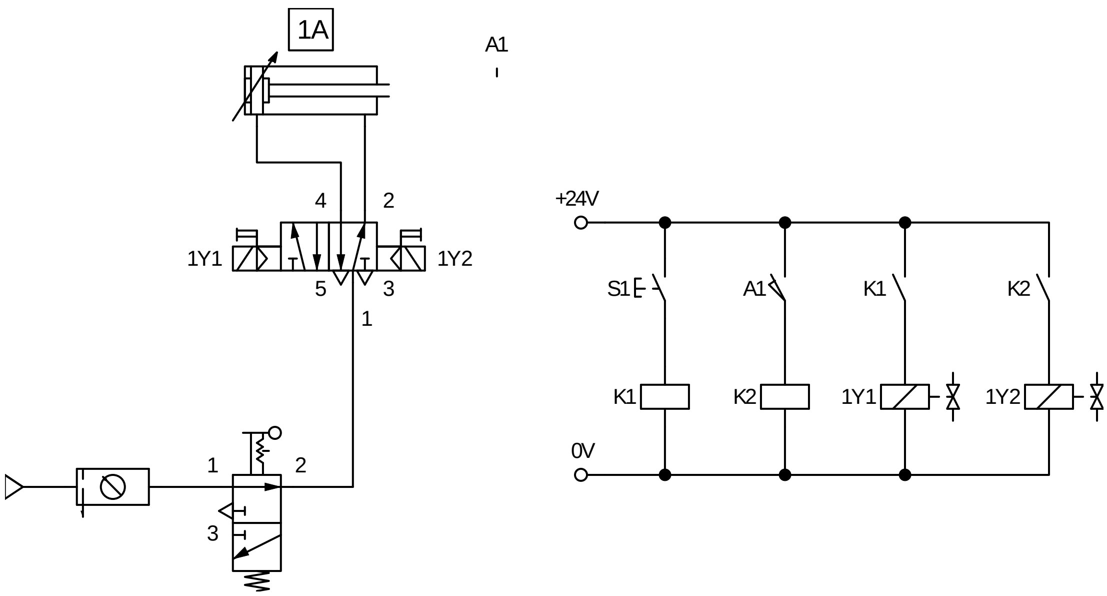


Figure 17.1 – Position

In this circuit, the limit switch A1 is activated once the cylinder extends. Once the limit switch A1 is activated, it will energise relay K2 and subsequently energise Y2 which will cause the cylinder to return automatically.

17.1.2 Pressure

Another method is the use of pressure to make or break the electrical circuit. Once, the pressure builds up to the required pressure setting of the pressure switch, it will be activated and works like the limit switch.

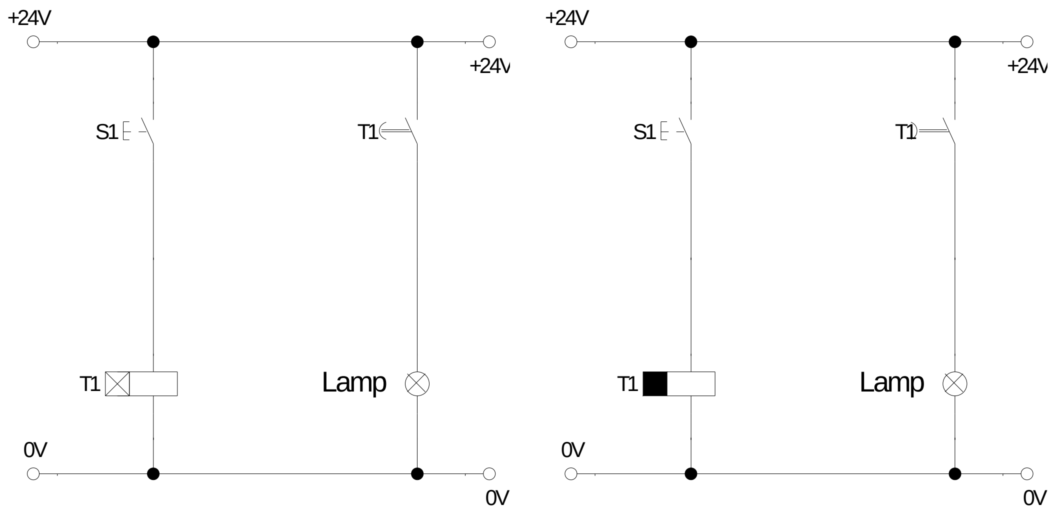
17.1.3 Time

Electrical timers are used to make or break electrical circuits once the preset time has expired. There are two different ways to set electrical timers; either "Delay On Timer" or "Delay Off Timer".

For "Delay On Timer", the signal must be present all the time and once the time has expired, the contact will switch over.

For "Delay Off Timer", once the signal is received, the contact will switch over immediately and will switch back once the preset time is up. For "Delay Off Timer", the signal must not be present all the time.

For the electrical timer, there are normally closed and normally open contacts available.



Delay On Timer Delay Off Timer

Figure 17.2 – Time

17.1.4 Count

Like the electrical timer, the electrical counter is used to make or break the electrical circuit. The electrical counter is pre-set with the desired number and once the counter reaches this pre-set number, the contact will switch over. There are normally closed and normally open contacts available.

Remember, that you need to give the electrical counter pulses for it to count; a long signal would just jump once. You would also have to design the circuit to reset the counter once it has completed its task, this can be done manually or automatically.

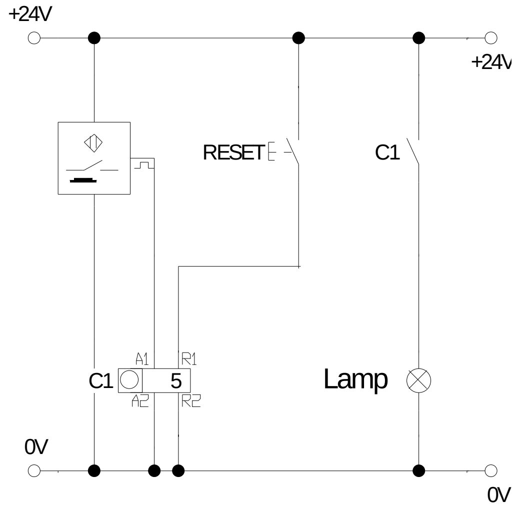


Figure 17.3 – Count

17.2 Basic Electro-Pneumatic Circuits

17.2.1 Control of a Single-Acting Cylinder

The piston of a single-acting cylinder is to travel out when a push button switch is pressed. When the button is released, the cylinder is to return to the final rear position.

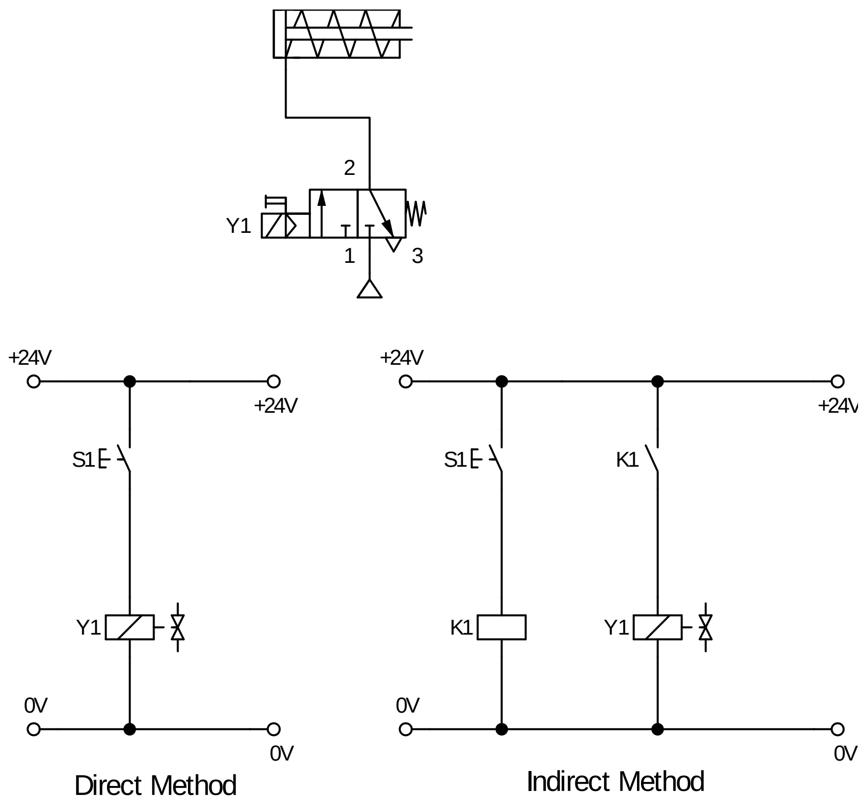


Figure 17.4 – Control of a Single-Acting Cylinder

a. Direct Method

The circuit is closed when push button switch S1 closes. A magnetic field is produced in coil Y1. The armature in the coil opens the passage for the compressed air. The compressed air flows from 1 to 2 to the cylinder, which travels to the final forward position.

When push button switch S1 is released, the circuit is interrupted. The magnetic field at coil Y1 collapses, the 3/2-way valve switches back to its original position and the cylinder travels to the final rear position.

b. Indirect Method

With the indirect method, the push button switch S1 energises a relay K1. The coil Y1 is energised via a normally open contact of K1 (indirect energising). Otherwise the sequence is the same as the direct method.

The indirect method must be applied when the switching capacity of signalling device (S1) is not sufficient to switch coil Y1, or if further processing is required with a different voltage (230V).

17.2.2 Control of a Double-Acting Cylinder

The piston of a double-acting cylinder is to travel out when a push button switch is pressed. It is to return when the push button switch is released.

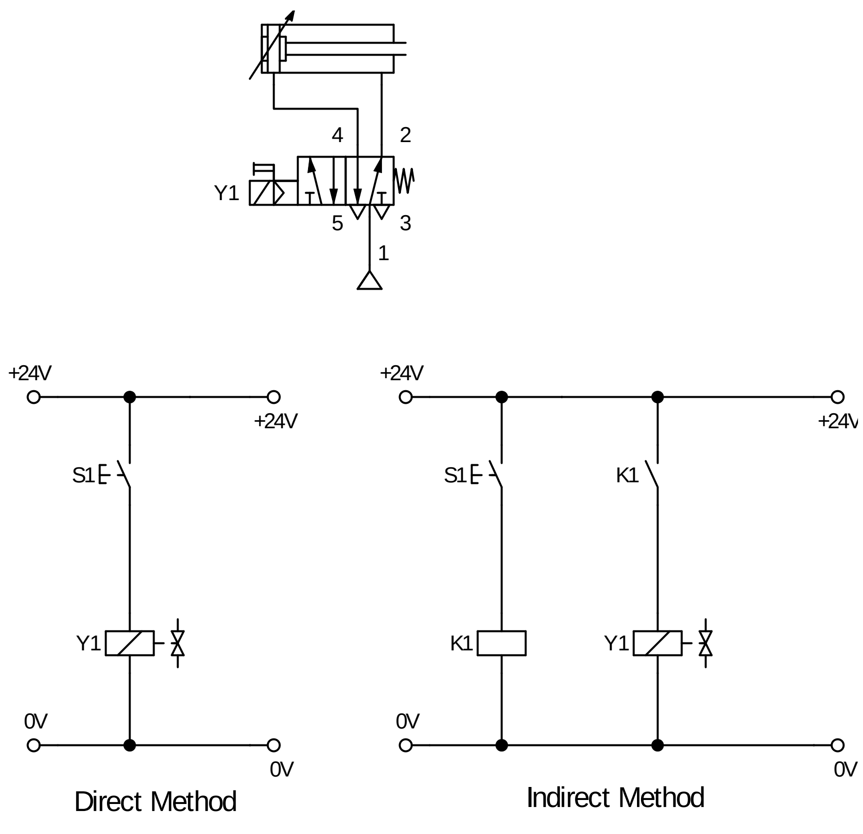


Figure 17.5 – Control of a Double-Acting Cylinder

The double-acting cylinder is controlled via a 5/2-way valve. When push button switch S1 is pressed, coil Y1 is energised and the directional control valve is activated by compressed air via pilot control. The piston travels to the final forward position. When S1 is released, the return spring at the directional control valve becomes active and the piston returns to its original position.

17.2.3 Parallel Circuit (OR Logic)

The piston of a double-acting cylinder is to travel out when either one of two push button switches is pressed. It is to return when the both push button switches are released.

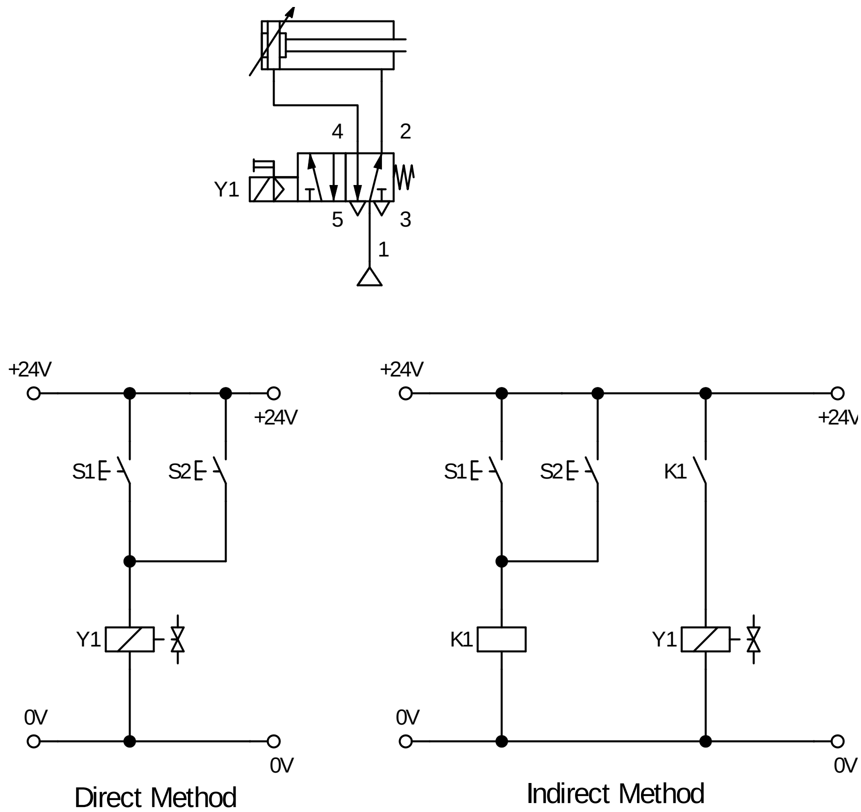


Figure 17.6 – Parallel Circuit (OR Logic)

When push button switches S1 or S2 are pressed, coil Y1 is energised. The directional control valve switches over and the piston travels to the final forward position. When both the push button switches are released, the signal is removed from Y1 and the cylinder travels back to its original position.

17.2.4 Series Circuit (AND Logic)

The piston of a double-acting cylinder is to travel out when both push button switches are pressed. It is to return when either one of the push button switch is released.

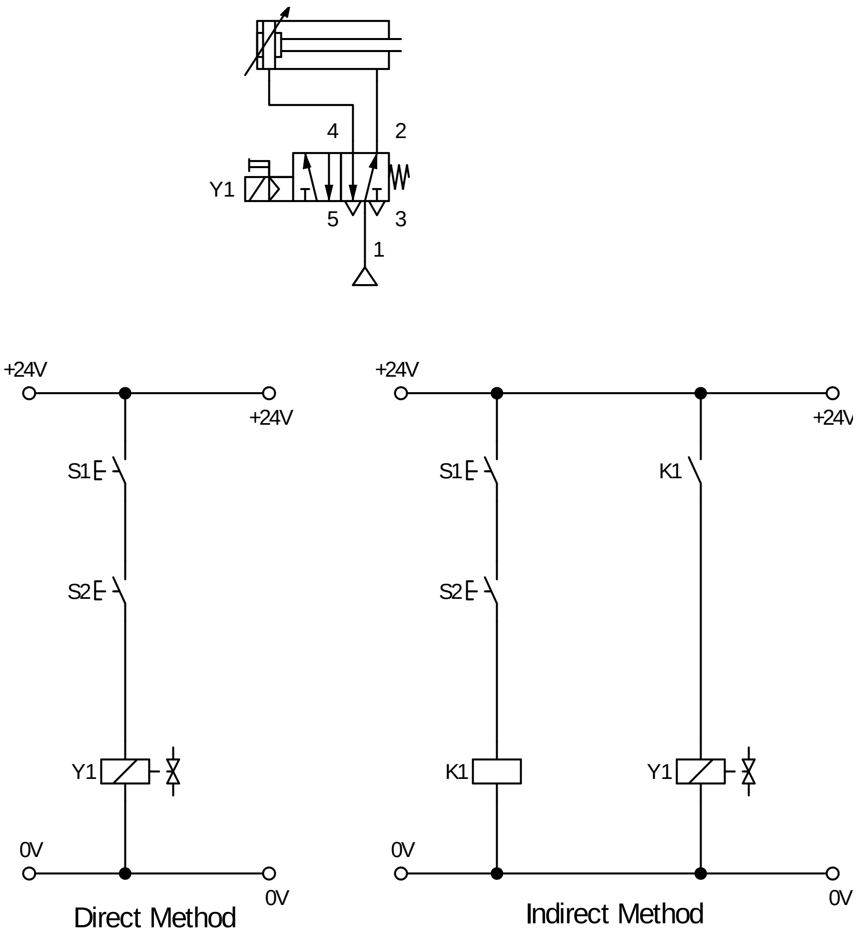


Figure 17.7 – Series Circuit (AND Logic)

If both push button switches S1 and S2 are pressed, the circuit closes. Coil Y1 is energised and the valve switches over. The piston travels to its final forward position. If either one of the push button switch is released, there is no longer a signal at Y1. The piston will return to its original position because the directional control valve has changed back.

17.2.5 Indirect Control of a Double-Acting Cylinder

The piston of a double-acting cylinder is to travel to the final forward position when push button switch S1 is pressed. It is to remain there until the return stroke is activated via push button switch S2.

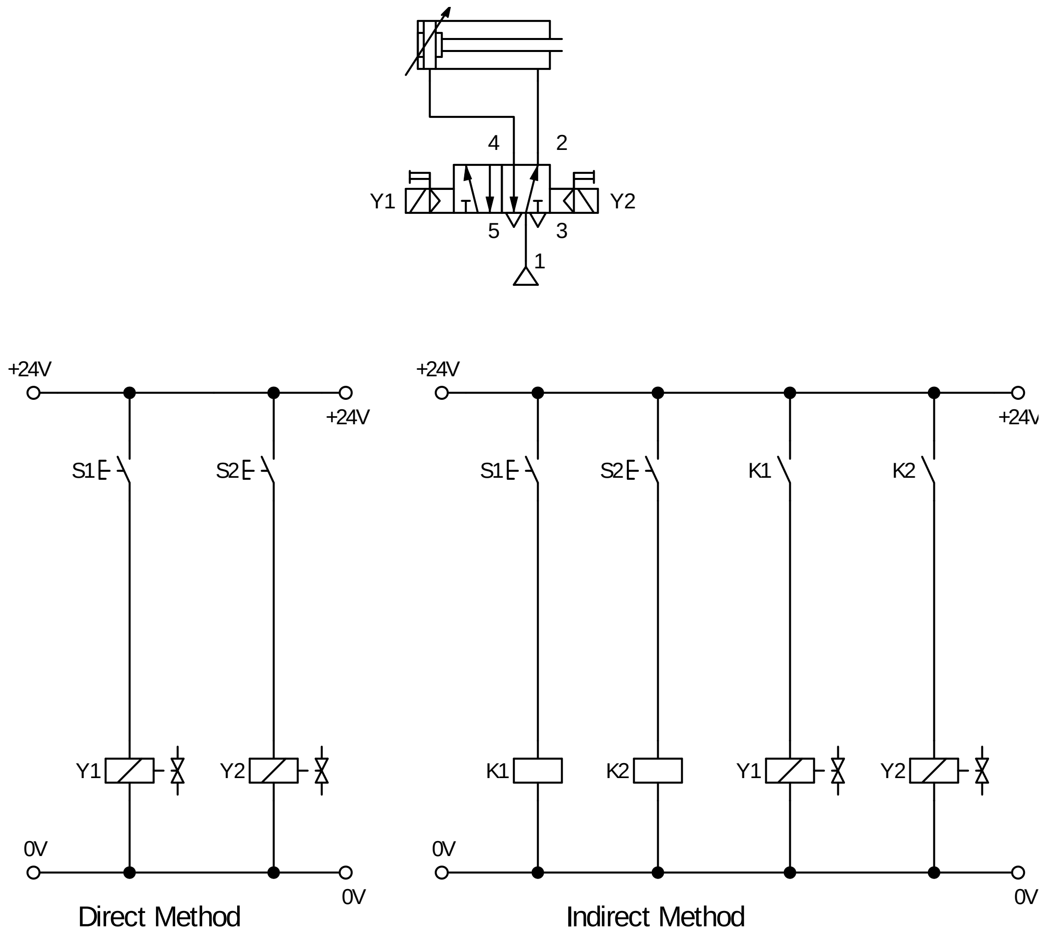


Figure 17.8 – Indirect Control of a Double-Acting Cylinder

When S1 is pressed, coil Y1 is energised and the 5/2-way directional control valve changes over. The piston travels out and remains in the final forward position until a signal is applied to coil Y2 via push button switch S2. Coil Y2 is energised and the piston returns to its original position because of the changeover of the 5/2-way valve.

Note:

- The 5/2-way directional control valve will remain in the last position until a new signal is given as it is a double solenoid valve and has no return spring.
- The 5/2-way directional control valve will not switch over if there is an active opposing signal. For example, if Y1 is switched on and a signal is given to switch Y2, there will be no reaction as there would be an opposing signal.

17.2.6 Automatic Return of a Double-Acting Cylinder

The piston of a double-acting cylinder is to travel to the final forward position when push button switch S1 is pressed. When it reaches this position, it is to return automatically to its original position.

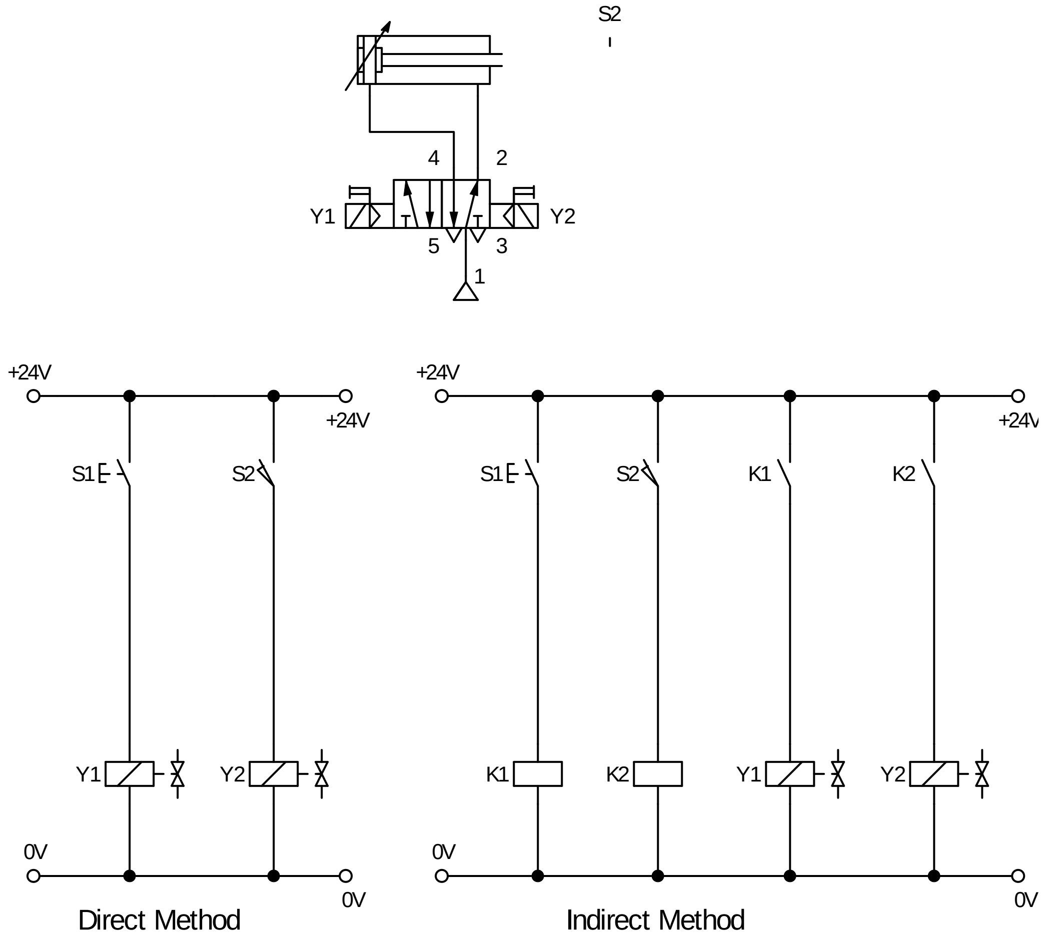


Figure 17.9 – Indirect Control of a Double-Acting Cylinder

When push button switch S1 is pressed, coil Y1 is energised and the piston travels to the final forward position. Once the piston reaches the final position, it actuates limit switch S2 which is installed there.

The limit switch S2 switches the 5/2-way directional control valve over and energises coil Y2. The piston returns to its original position. Remember that S1 must already be released.

17.2.7 Oscillating Motion of a Double-Acting Cylinder

When a sustained push button switch is closed, the piston is to travel back and forth until the switch is released. The piston must travel back to its original position (final rear position).

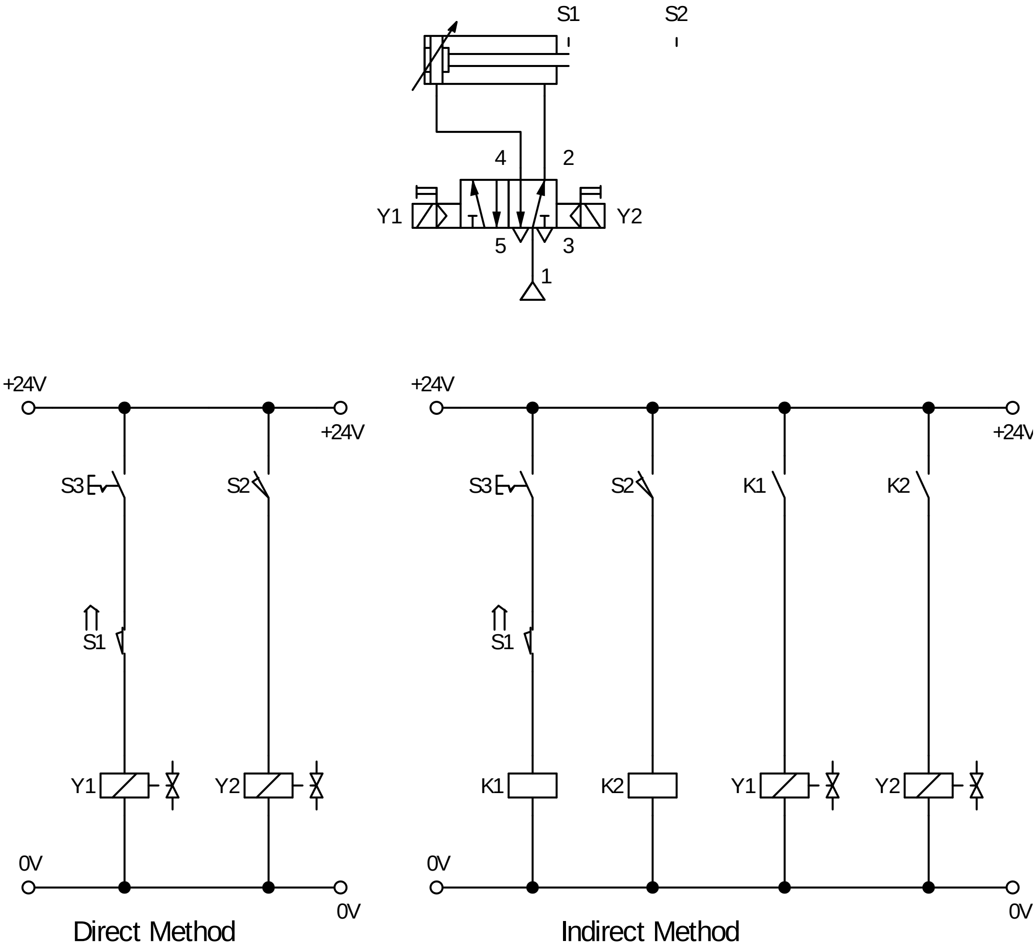


Figure 17.10 – Oscillating Motion of a Double-Acting Cylinder

Two mechanically-actuated limit switches S1 and S2 are installed at the two final positions. These emit a signal for forward and return stroke when contact is made with them.

However, limit switch S1 is only active when switch S3 is closed. The piston therefore travels back and forth. If switch S3 is opened again, no signal can be applied to coil Y1 and the piston remains in the final rear position.

17.2.8 Control of a Double-Acting Cylinder with Latching Action

The piston of a double-acting cylinder is to travel out and remain at the final forward position until a second signal causes the piston to return to its original position.

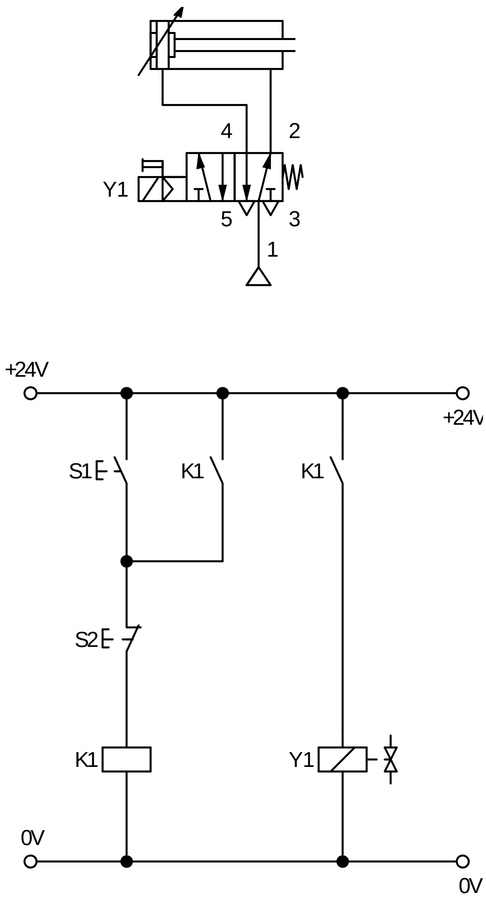


Figure 17.11 – Control with Latching Action

When push button switch S1 is pressed, relay k1 is energised. Connected in parallel is a normally open contact of K1 which is also switched over. This contact maintains the energising power for relay K1 even when the push button switch S1 is released. Another contact of K1 energises coil Y1 and the piston moves to the forward position.

When Push button switch S2 is pressed, the circuit to K1 is interrupted. All functions of relay K1 switches back to its original positions. The coil Y1 is therefore also interrupted, the spring at the 5/2-way directional control valve switches the valve back and the piston travels back to its original position.

17.2.9 Automatic Return Initiated by a Limit Switch

The piston of a double-acting cylinder is to travel out when push button switch S1 is pressed. It is to return automatically when it reaches its forward end position. The push button S1 switch must be released.

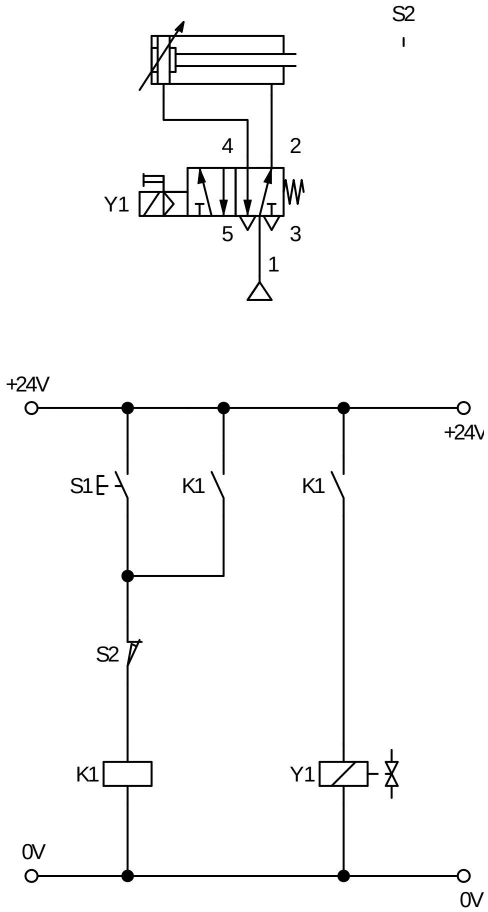


Figure 17.12 – Automatic Return Initiated by Limit Switch

When push button switch S1 is pressed, the piston travels to its forward position. When the piston reaches this position, and if S1 is released, limit switch S2 makes the piston return.

The latching circuit is cleared when contact is made with limit switch S2. Relay K1 switches back to its original position, the normally open contact K1 opens the circuit to coil Y1. The 5/2-way directional control valve changes over and the cylinder travels back.

18.0 Sequencing Electro-Pneumatic Circuits

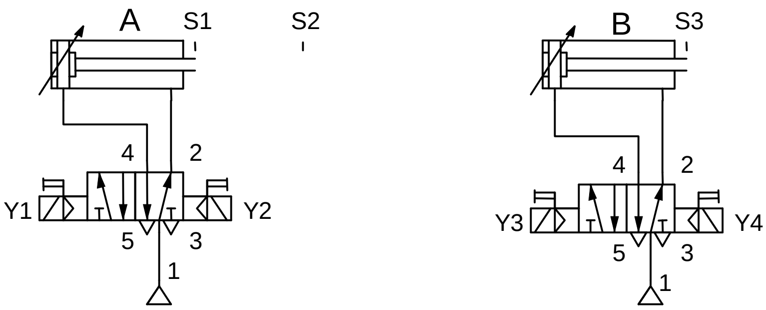
Understanding the basic circuits is essential before moving forward and designing sequencing circuits. For sequencing circuits, we usually have 2 or more cylinders and they will extend and retract in a predefined sequence.

18.1 Using Pneumatic Memory

We will design a sequencing circuit using pneumatic memory for the following sequence: A+ B+ A- B-.

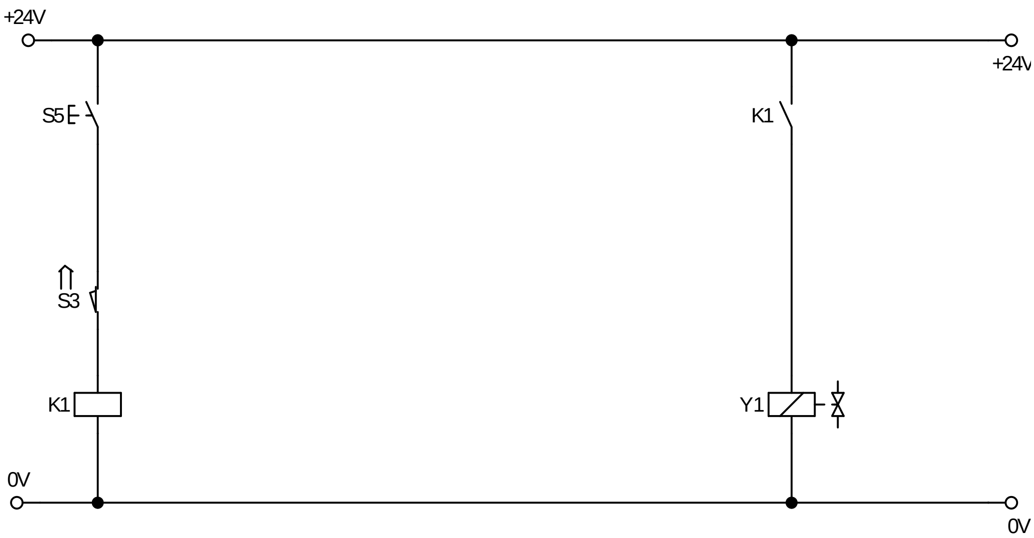
18.1.1 1st Step

Draw cylinders A and B with 5/2-way double solenoid directional control valves. Indicate the position of the limit switches.



18.1.2 2nd Step

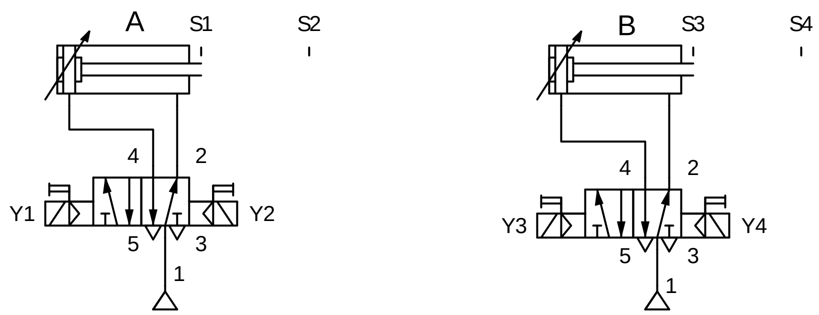
Draw the electrical control circuit and the main circuit.

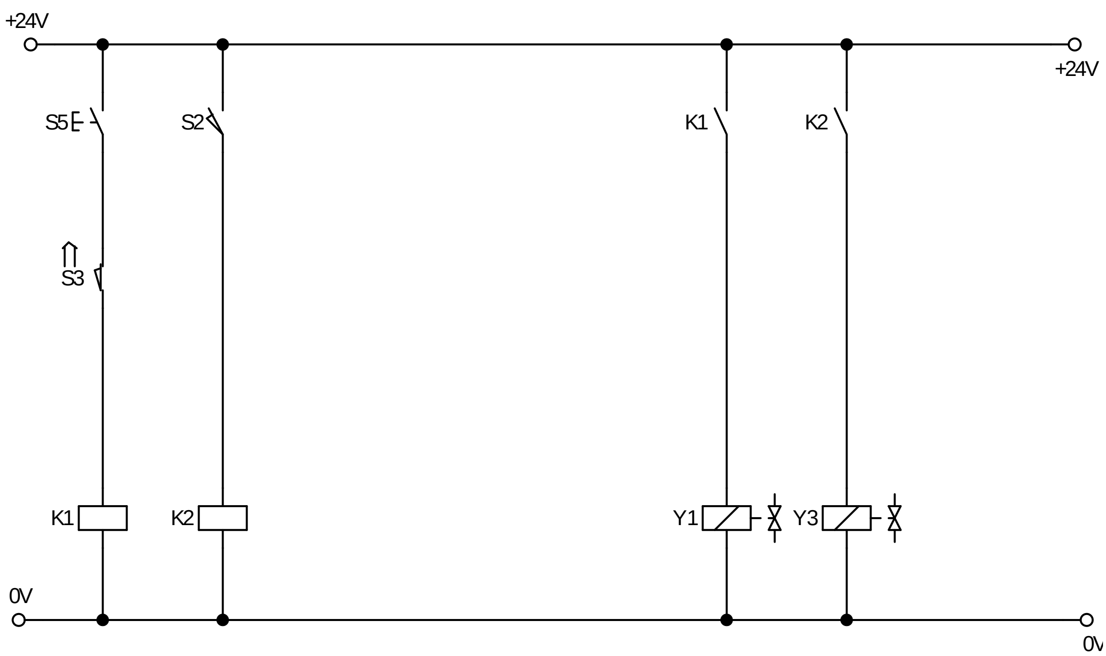


In the control circuit, relay K1 is energised via the “ON” push button switch S5 and registered via limit switch S3. In the main circuit, a normally open contact of K1 closes the circuit. Solenoid Y1 is energised and causes cylinder A to travel out.

18.1.3 3rd Step

Draw the next rung of electrical control circuit and the main circuit.

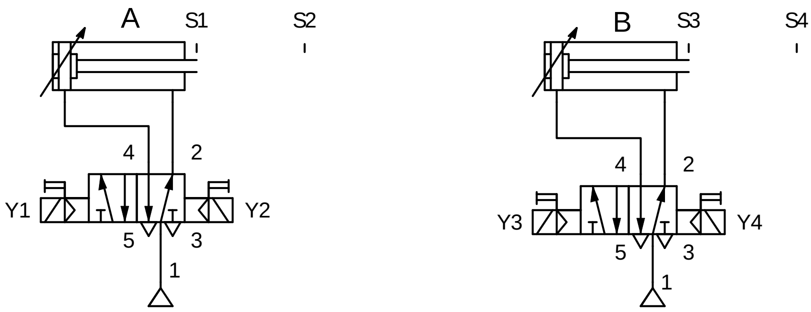


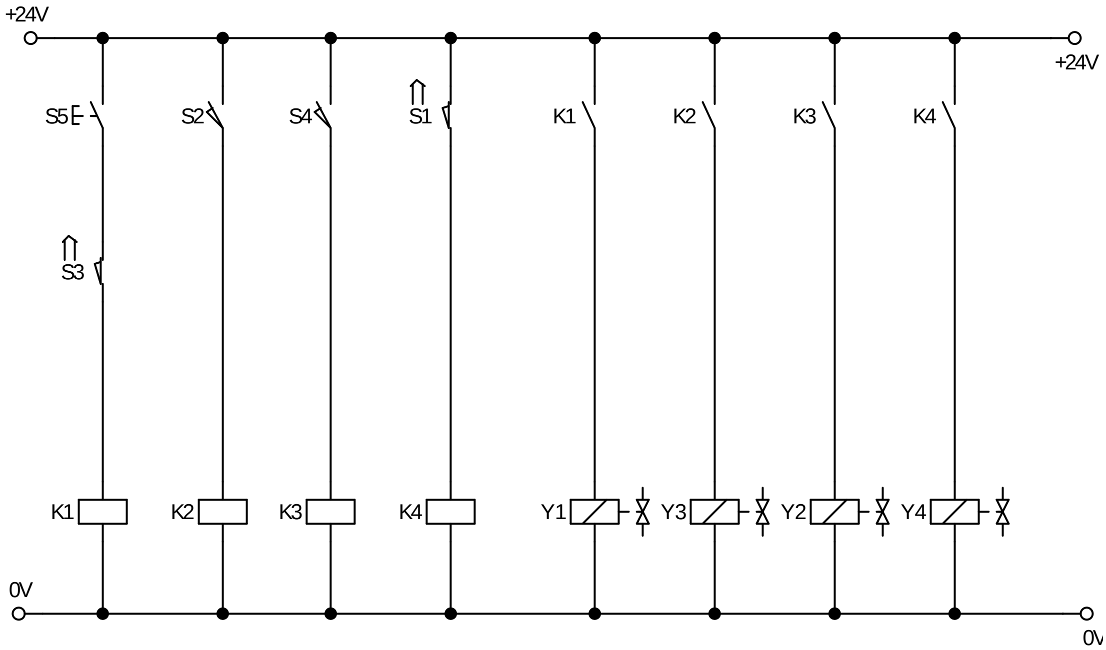


Limit switch S2 is actuated at the final position of cylinder A. These causes relay K2 to energise. A normally open contact of K2 energises solenoid Y3. The valve changes state and cylinder B extends.

18.1.4 4th Step

Draw the next rung of electrical control circuit and the main circuit. It similar to the 3rd step with the different limit switches.





Cylinder B extends, at its forward position it actuates the limit switch S4. S4 energises relay K3 and a normally open contact K3 energises solenoid Y2 and cylinder A retracts.

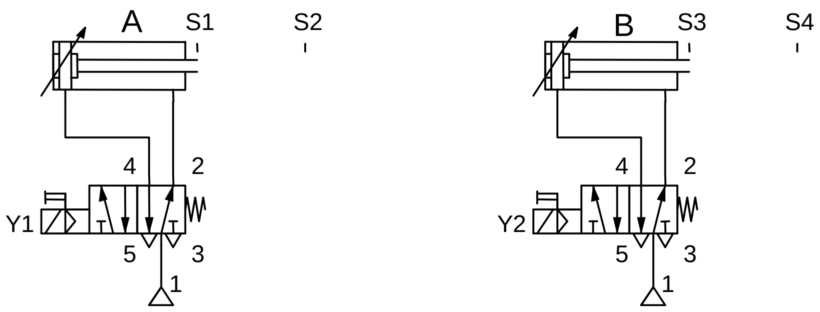
As cylinder A retracts it activates limit switch S1 and energises relay K4 which in turn activates solenoid Y4. Cylinder B then retracts and is it ready for a new cycle. A new cycle can restart with the activation of S5.

You can replace the limit switches with reed switches for this method.

18.2 Using Electrical Memory

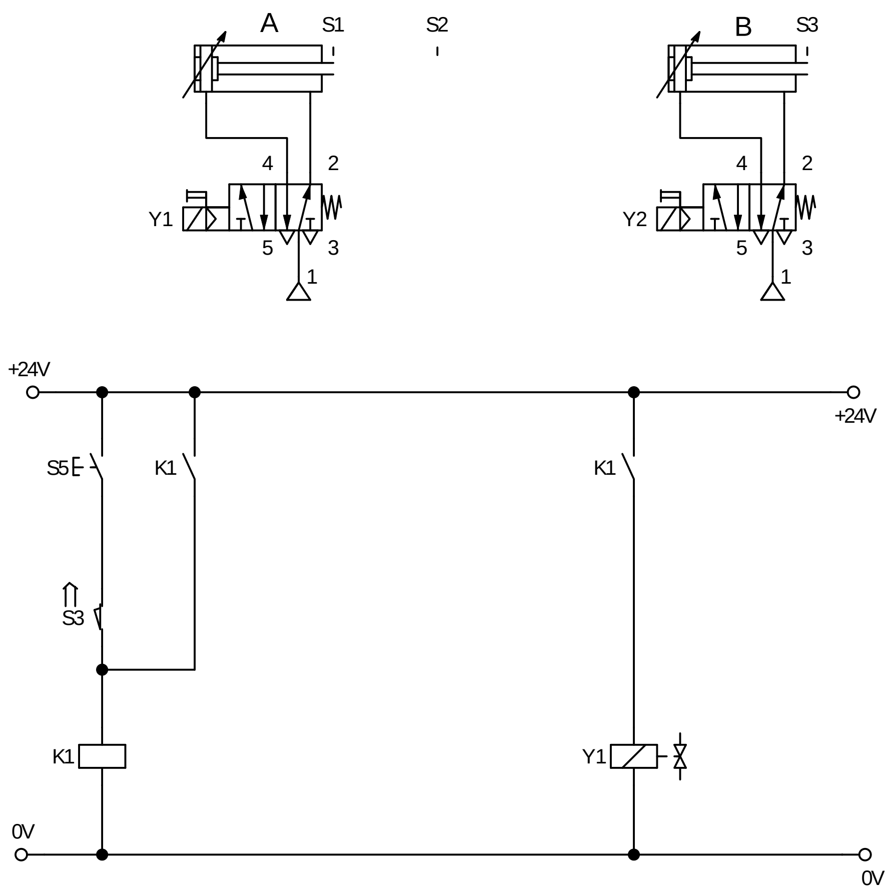
18.2.1 1st Step

Draw cylinders A and B with 5/2-way single solenoid directional control valves. Indicate the position of the limit switches.



18.2.2 2nd Step

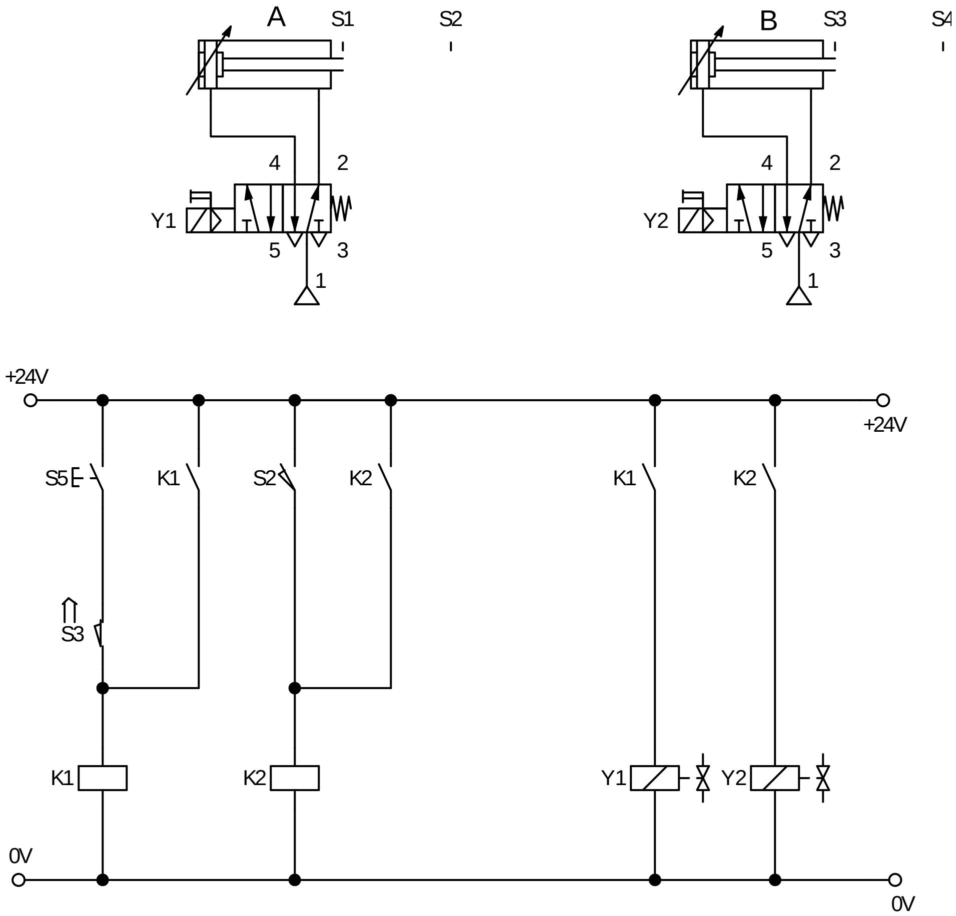
Draw the electrical control circuit and the main circuit for the first relay K1 and the solenoid coil Y1.



The circuit is closed with relay K1 via limit switch S3 which is actuated by cylinder B and start push button switch S5. The circuit is latched with a normally open contact K1. Another normally open contact of K1 is connected to the solenoid coil Y1 in the main circuit. This contact will cause the 5/2-way valve to switch over and cause cylinder A to extend.

18.2.3 3rd Step

Draw in relay K2 and solenoid coil Y2.

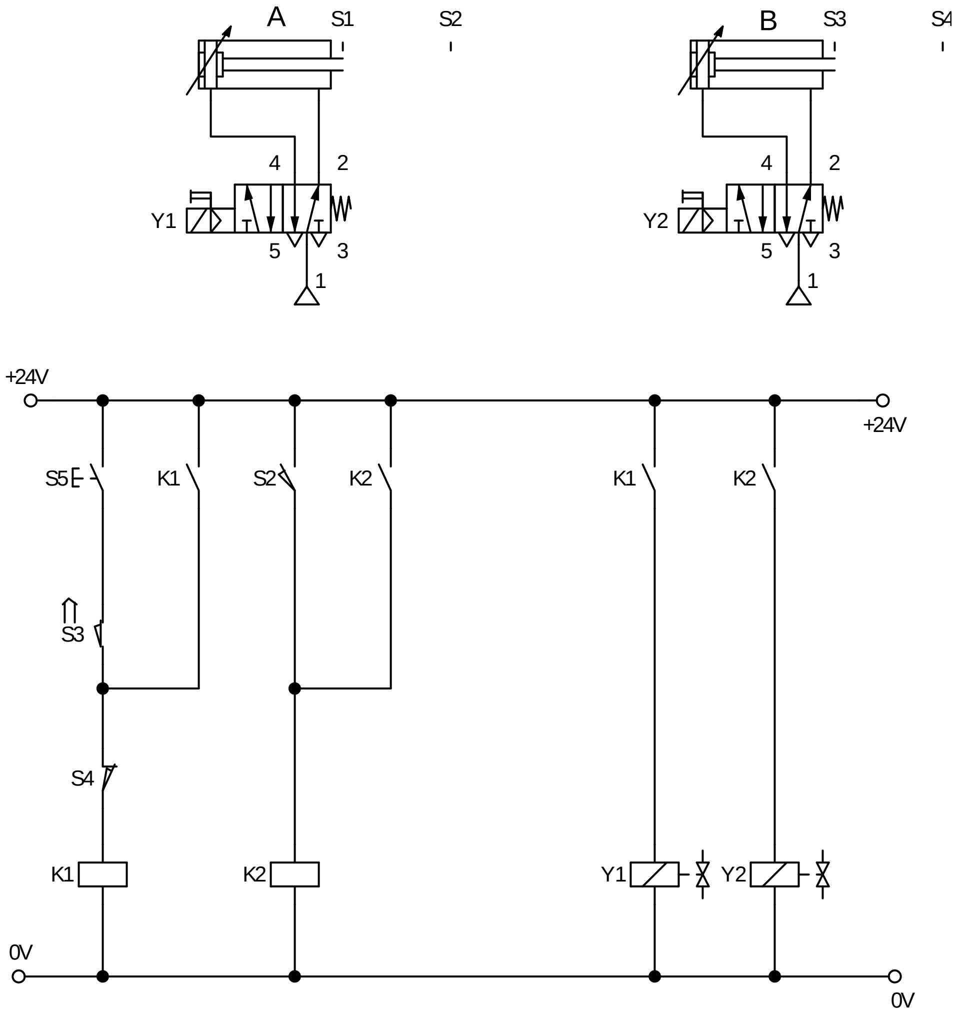


Cylinder A travels to its forward position and makes contact with limit switch S2, which energises K2 in the control circuit. Connected in parallel with this is the latching circuit for relay K2 via a normally open contact of K2.

When the normally open contact of K2 is closed in the main circuit, solenoid coil Y2 is energised and the 5/2-way directional control valve switches over and cylinder B travels out.

18.2.4 4th Step

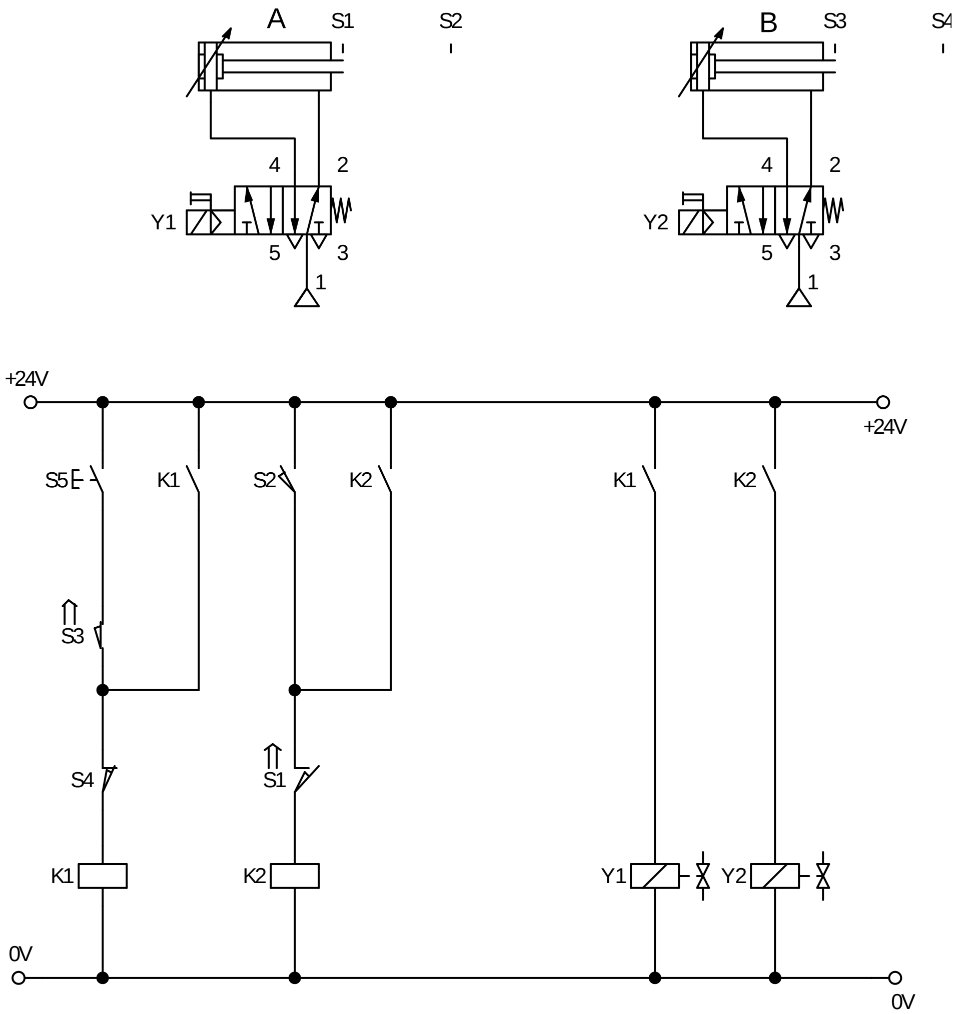
Draw in limit switch S4 and switch off relay K1.



Limit switch S4 is arranged ahead of relay K1. When S4 (Normally closed switch) is actuated by cylinder B, the latching circuit is interrupted and relay K1 is de-energised. The normally open contact of K1 in the main circuit returns to its normal position, coil Y1 is de-energised, the 5/2-way directional control valve switches back and cylinder A retracts.

18.2.5 5th Step

Draw in limit switch S1 and switch off relay K2.



Limit switch S1 is arranged ahead of relay K2. When S1 (Normally closed switch) is actuated by cylinder B, the latching circuit is interrupted and relay K2 is de-energised. The normally open contact of K2 in the main circuit returns to its normal position, coil Y2 is de-energised, the 5/2-way directional control valve switches back and cylinder B retracts.

Limit switch S3 is actuated again and a new cycle can be started with start push button switch S5.

18.3 Circuits with Opposing Signals of Signal Overlap

In the sequence A+ B+ A- B-, the circuit is simple and we do not encounter a signal overlap or there are opposing signals. Opposing signals occurs when we are using double-solenoid directional control valves. It one solenoid is energised, sending a signal to the other solenoid would not switch the valve over as there is an opposing signal.

If there are signal overlaps of opposing signals, we need to use other methods for designing.

18.4 Electrical Cascade Method

The electrical cascade method is almost similar with the cascade system used in conventional pneumatics. There are a few rules to follow:

The cascade system uses signal cut-out by means of relays. Electrical power supply to the various solenoids is no longer derived from the main supply, but through a relay.

In the design of cascades, they work on the principle that at any one time, only one supply line is energised. The procedure for constructing an Electrical Cascade System is as follows:

- Define the Sequence of Motion by Abbreviated Notation.

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

- Divide Them into Groups

Break into groups such that a cylinder operation occurs only Once in a group, and the minimum number of groups is obtained. That is A+ and A- cannot be in the same group. Give each group a number, I, II, III, etc.

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

For each group, a supply is required. For 3 groups, there must be 3 supply lines.

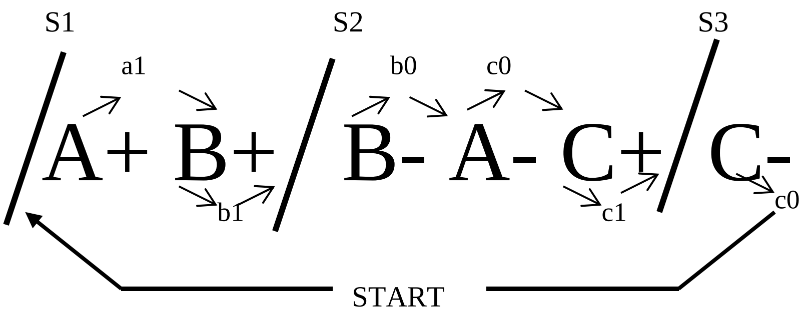
- Relays

The number of relays = Number of groups - 1

Therefore, the number of relays = 3 - 1 = 2

- Limit Switches

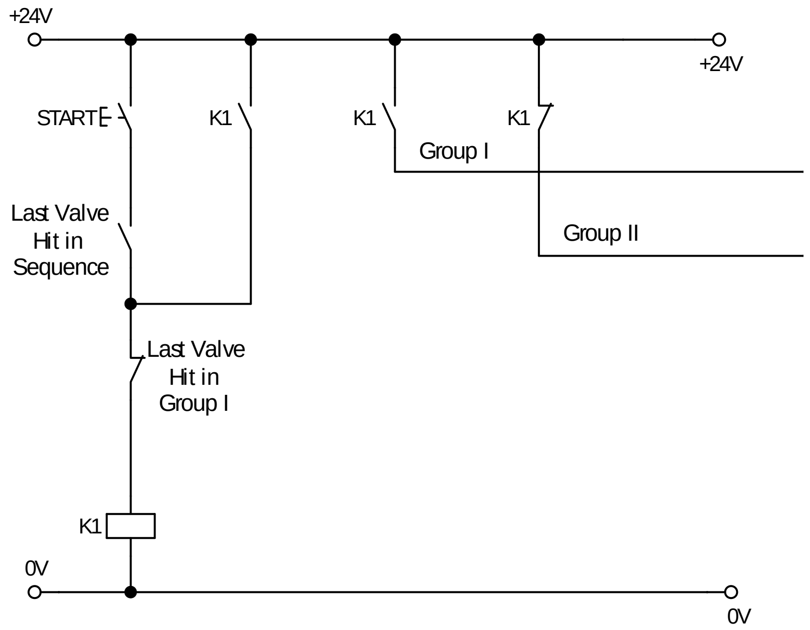
Write on the abbreviated notation, the number of limit switches.



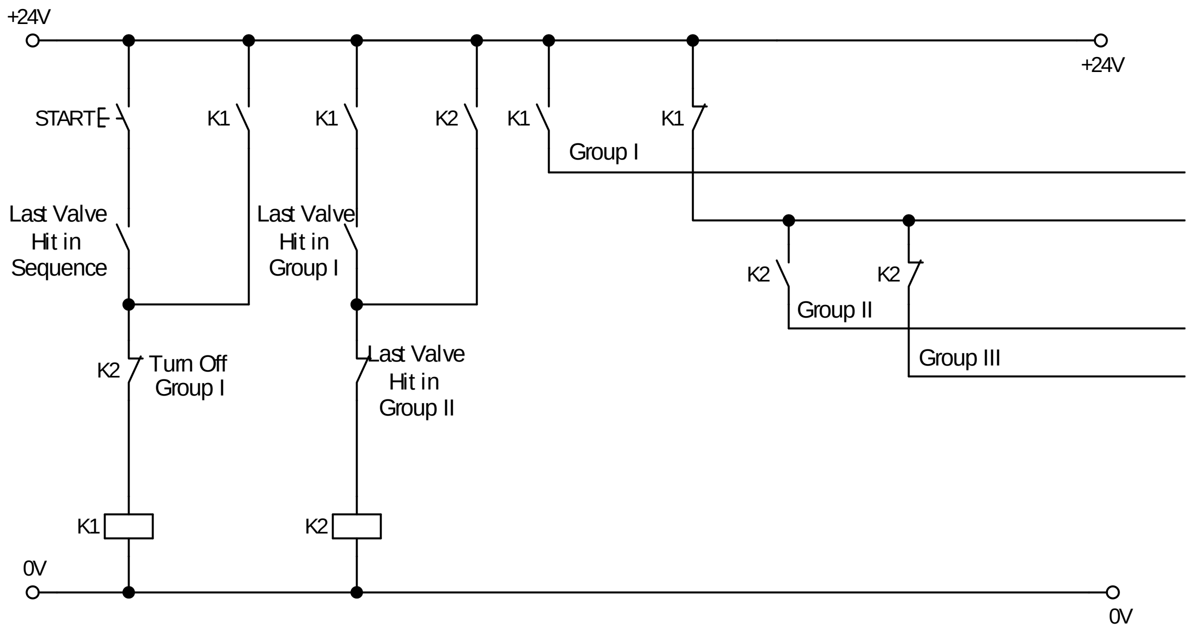
Note:

- Limit switches/valves which cause changeover of groups are designated below the abbreviated notation.
- Limit switches within a group are designated above the abbreviated notation.
- Arrows designate signals which trigger cylinder operation.
- The last group must be "live".

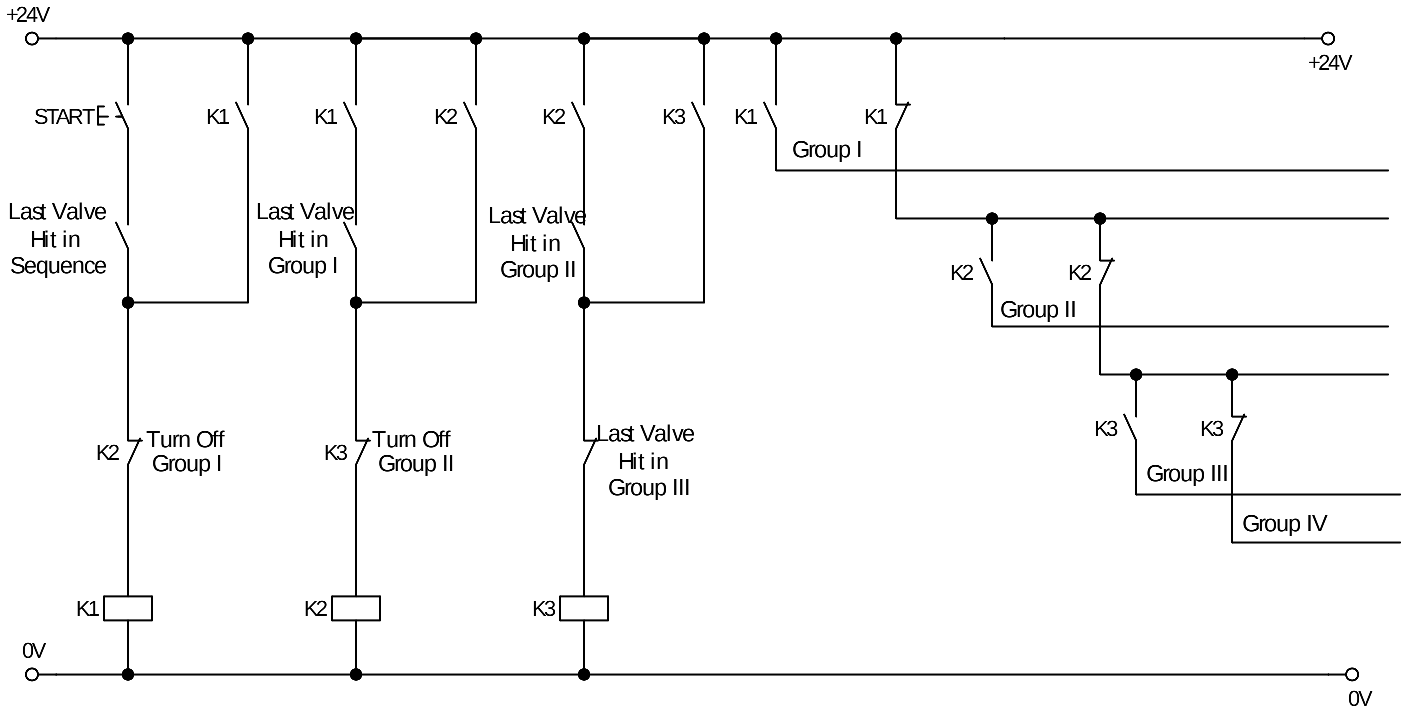
- Arrangement for 2 groups



- Arrangement for 3 groups



- Arrangement for 4 groups

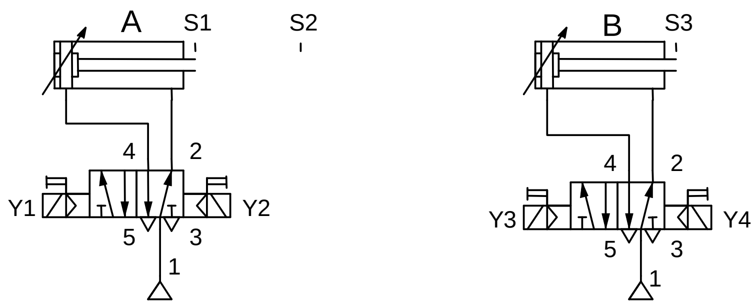


18.5 Control of Two Double-Acting Cylinders using Electrical Cascade

We will design a sequencing circuit using pneumatic memory for the following sequence: A+ B+ B- A-.

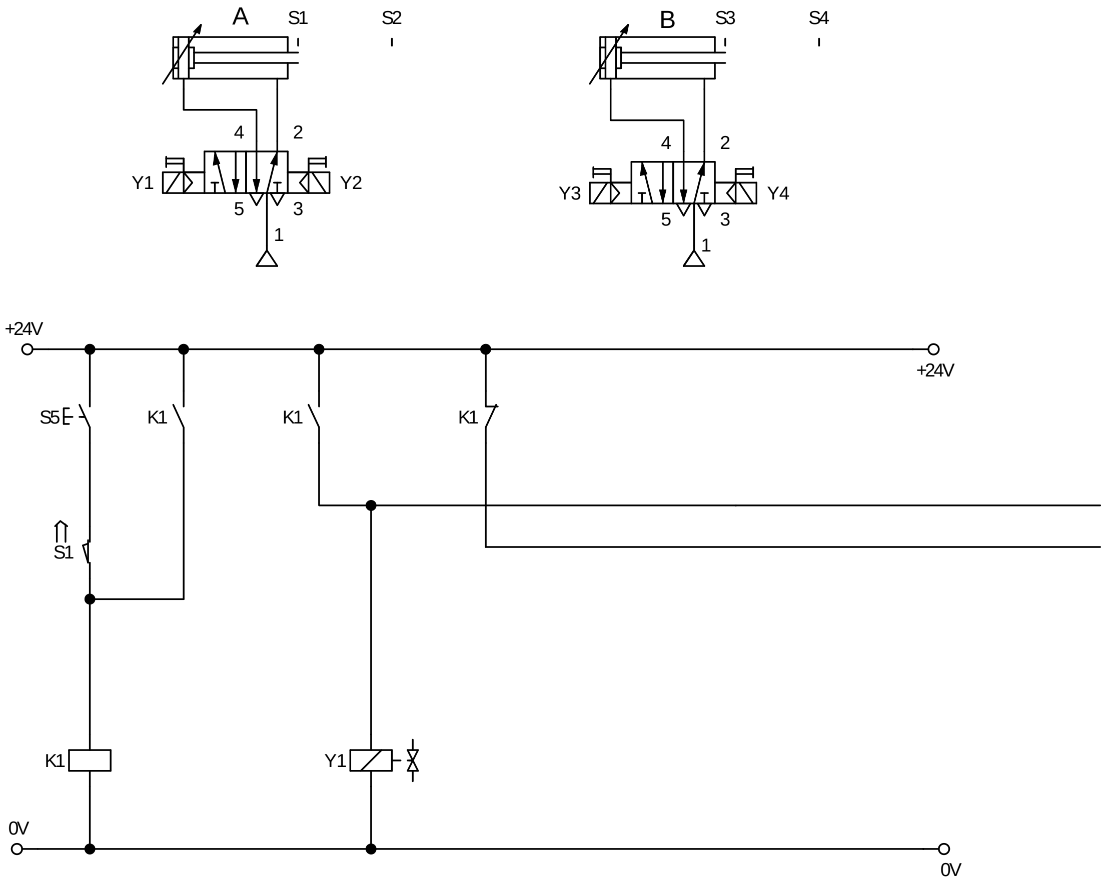
18.5.1 1st Step

Draw cylinders A and B with 5/2-way double solenoid directional control valves. Indicate the position of the limit switches.



18.5.2 2nd Step

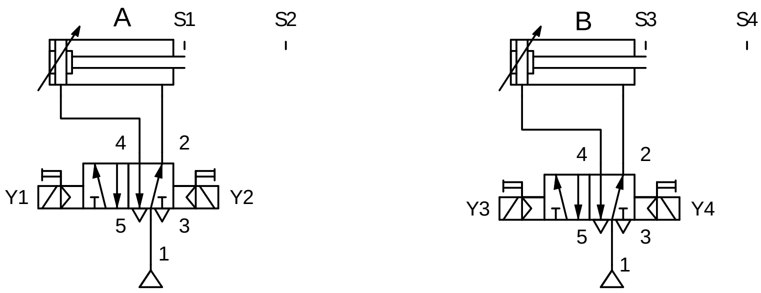
Draw the electrical section.

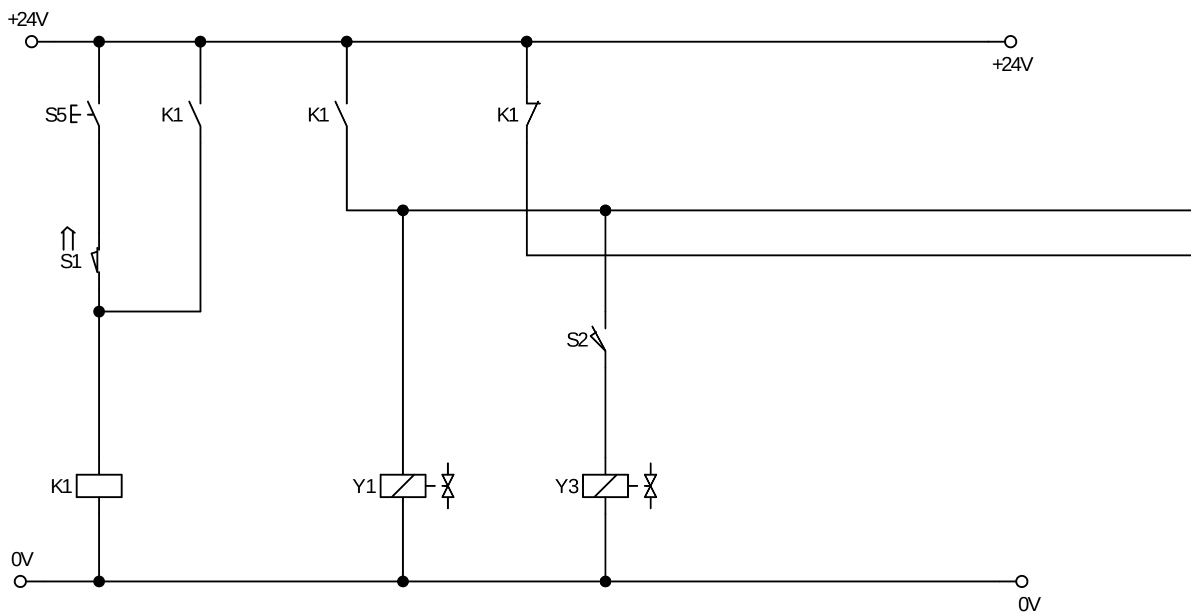


When the start push button switch S5 is actuated, relay K1 will energise and all K1 contacts will switch. This will energise line 1 and solenoid coil Y1 will be energised. The 5/2-way directional control valve will switch and cylinder A will extend.

18.5.3 3rd Step

Draw the electrical section adding in the limit switches.



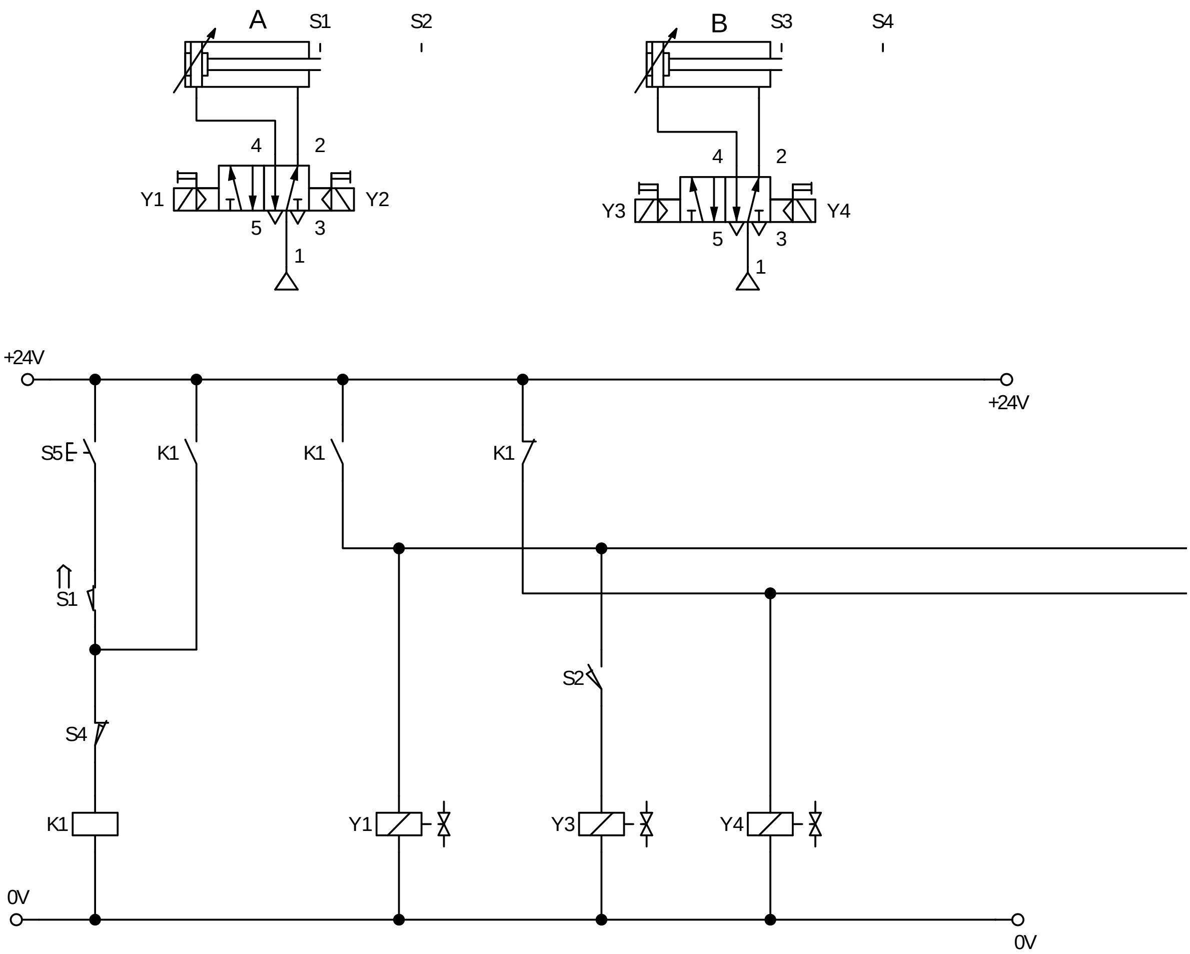


Cylinder A travels to the forward position and actuates limit switch S2. This limit switch must initiate movement B+. The limit switch is installed between line 1 and the solenoid coil Y3. The result is that the 5/2-way directional control valve is switched over and cylinder B extends.

Looking at the abbreviated notation shows a signal overlap here. A signal shutoff circuit must be installed at this point.

18.5.4 4th Step

Draw the electrical section adding in the limit switch S4 to break relay K1 and switch over to group II.



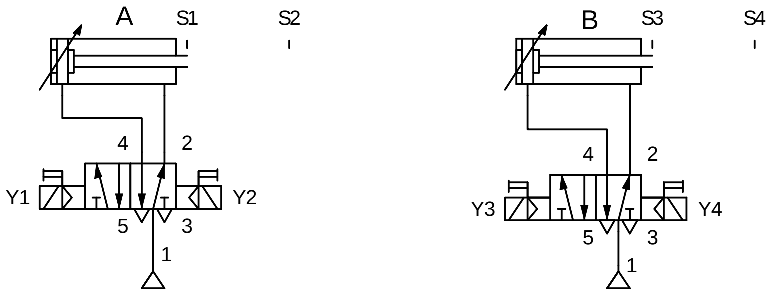
Limit switch S4 is actuated by cylinder B. This limit switch S4 must perform the signal shutoff; for this reason, it is installed as a normally closed switch in the first rung of the control circuit.

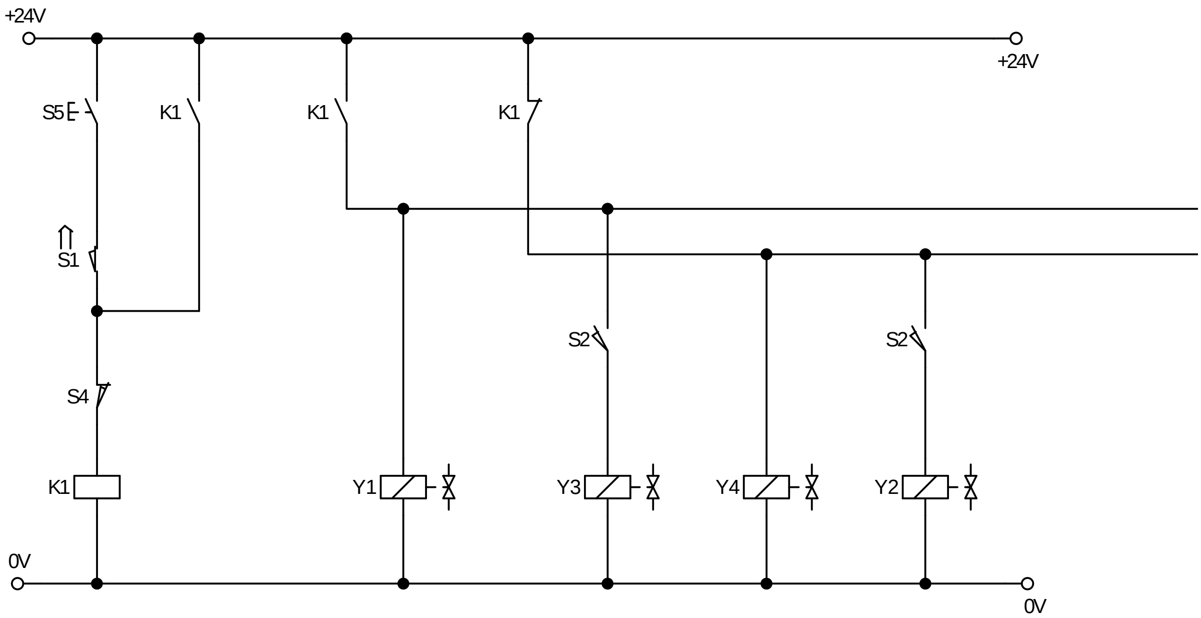
Actuating S4 clears the latching circuit of K1. In the main circuit, this means that line 1 is disconnected by normally open contact K1 and line 2 is supplied current again via normally closed contact of K1.

This changeover of line 1 to line 2 causes solenoid coil Y3 to be disconnected. The 5/2-way directional control valve is switched over via solenoid coil Y4 and cylinder B retracts.

18.5.5 5th Step

Once cylinder B reaches the back position, limit switch S3 is actuated. This ensures that solenoid coil Y2 will be energised as line 2 has power. The valve switches again and cylinder A returns to its back position.

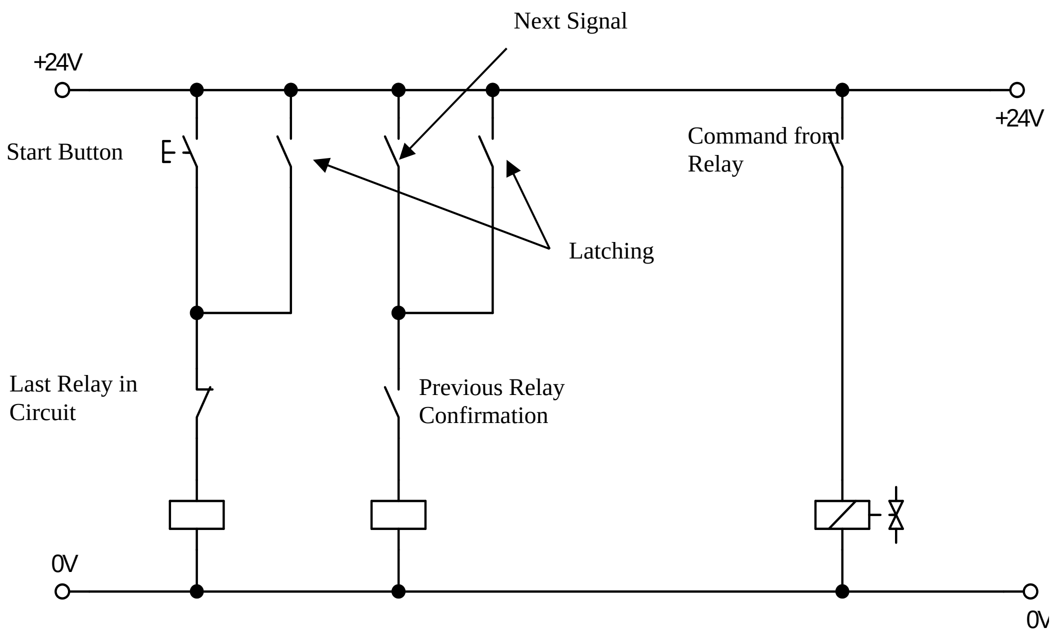




The cycle is completed and you can start again by actuating S5.

18.6 Using Electrical Stepper Control Method

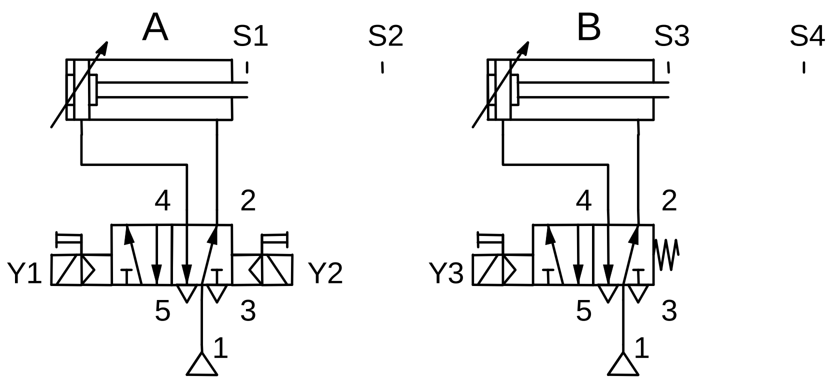
These circuits are designed using a sequence method where the next step needs to be confirmed by the previous step and the activation of the solenoids is done in control section.



18.6.1 1st Step

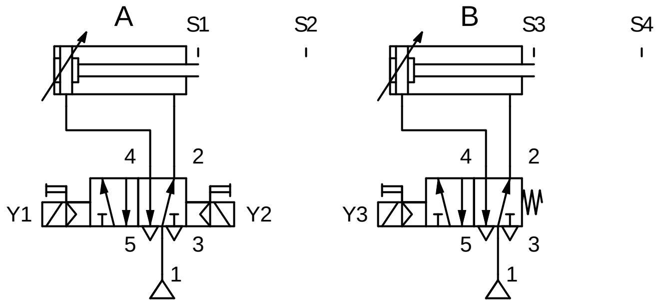
We will use one single solenoid directional control valve and one double solenoid to show that there is no procedure difference when designing the circuit. We will be designing the same sequence of A+B+B-A-.

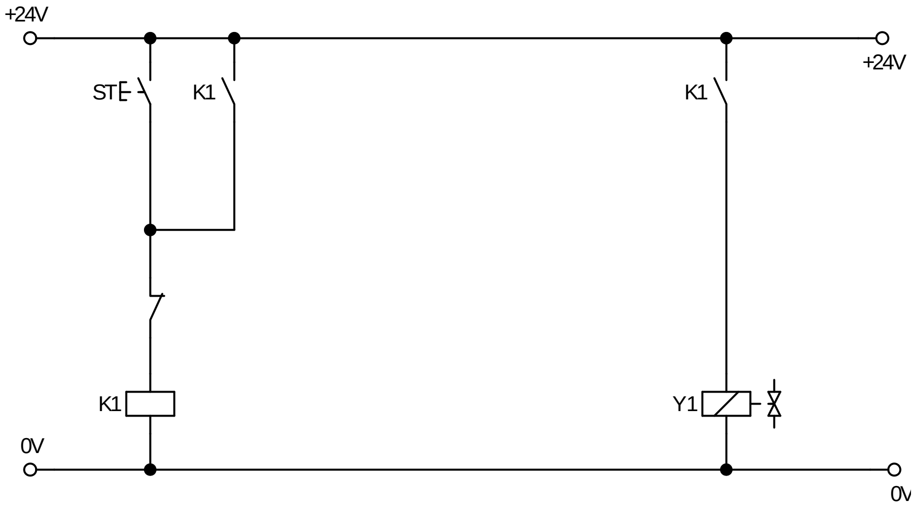
Draw cylinders A and B with 5/2-way single and double solenoid directional control valves. Indicate the position of the limit switches.



18.6.2 2nd Step

Draw the electrical section.

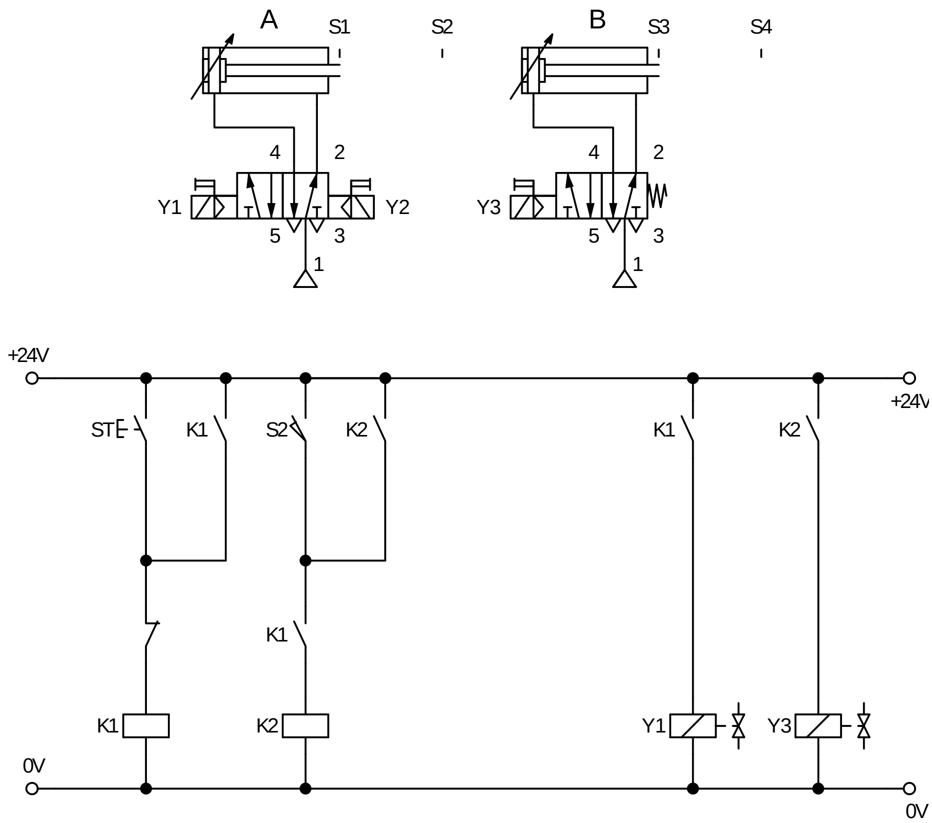




When the start button (ST) is pressed, the circuit is closed with relay K1. The circuit is latched with a normally open contact K1. Another normally open contact of K1 is connected to the solenoid coil Y1 in the main circuit. This contact will cause the 5/2-way valve to switch over and cause cylinder A to extend.

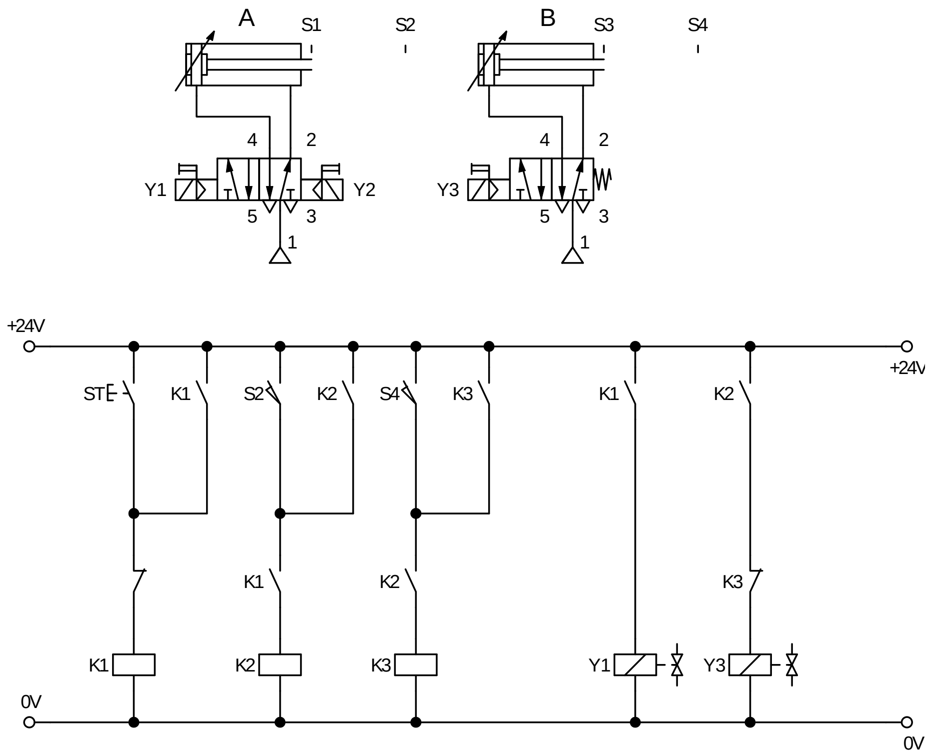
18.6.3 3rd Step

When Cylinder A extends, limit switch S2 is activated. This will energise relay K2. A confirmation signal from K1 is required to ensure that the relays are energised in sequence. Draw in relay K2 and solenoid coil Y3.



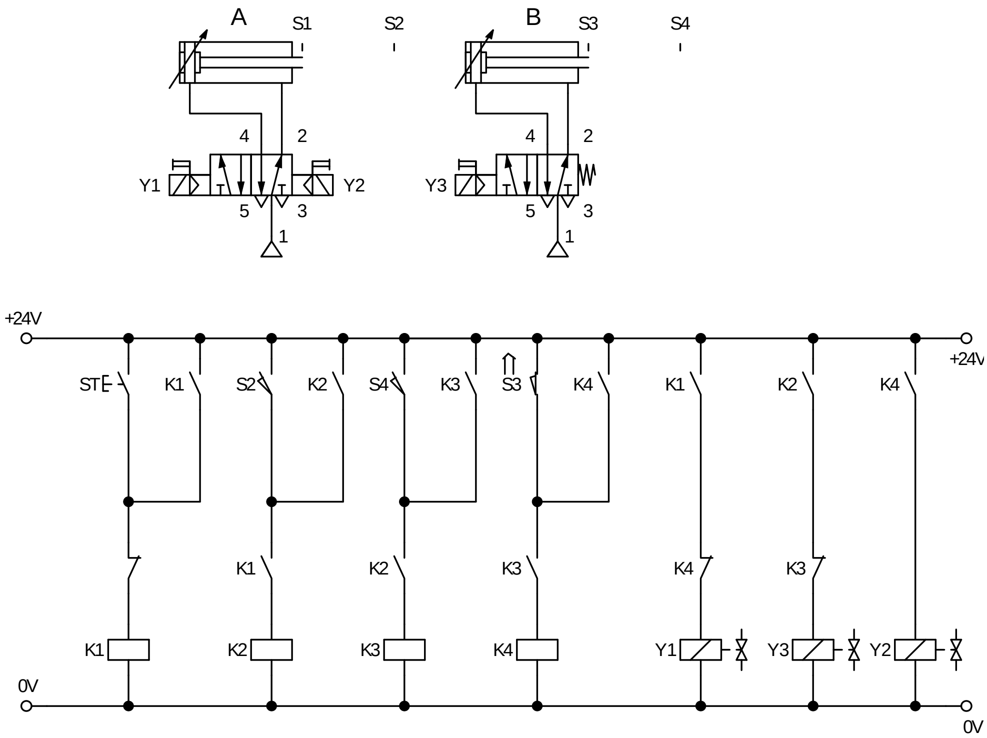
18.6.4 4th Step

When Cylinder B extends, limit switch S4 is activated. This will energise relay K3. As usual, a confirmation signal from K2 is required to ensure that the relays are energised in sequence. Draw in relay K3 and reset (cut-off) solenoid coil Y3, this will switch the directional control valve over.



18.6.5 5th Step

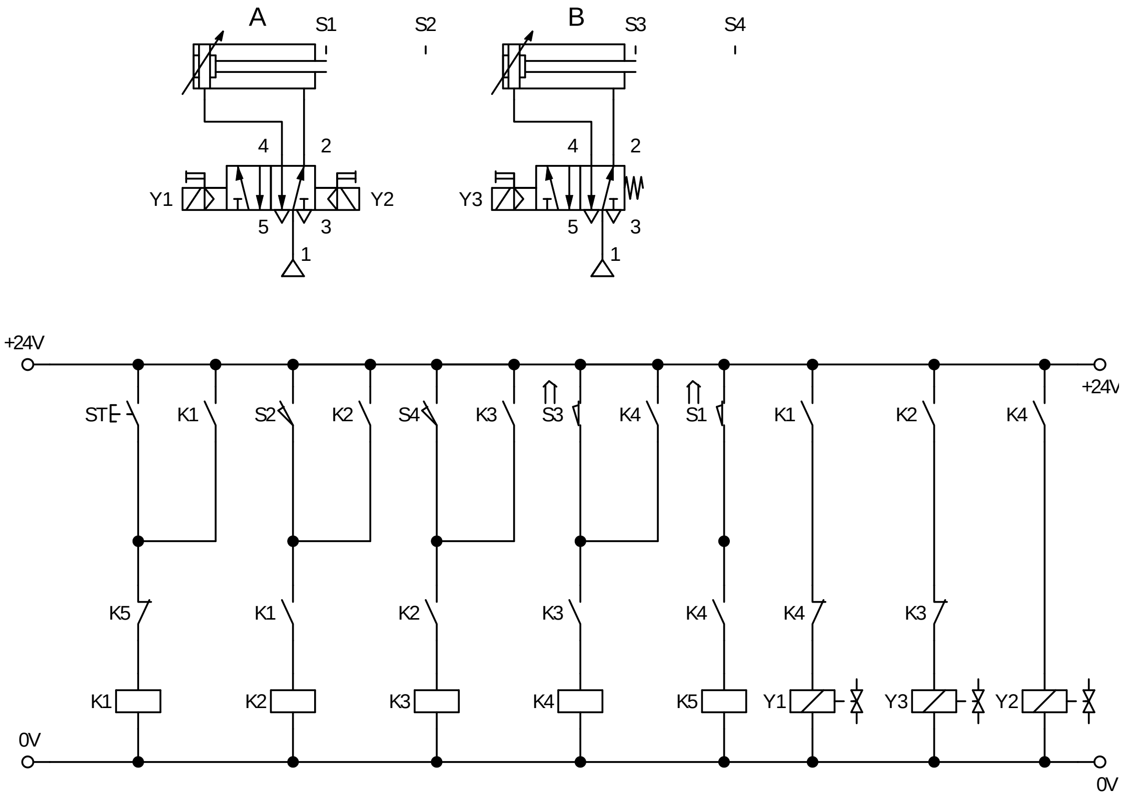
When Cylinder B retracts, limit switch S3 is activated. This will energise relay K4. As usual, a confirmation signal from K3 is required to ensure that the relays are energised in sequence. Draw in relay K4 and solenoid coil Y2. Remember that solenoid coil Y1 needs to be reset (cut-off) so that the valve will switch over.



18.6.6 6th Step

When Cylinder A retracts, limit switch S1 is activated. This signals the end of one cycle, energise relay K5. As usual, a confirmation signal from K3 is required to ensure that the relays are energised in sequence. Draw in relay K5. There is no latching required for this step as it is to end the cycle. The relay K5 will be used to reset relay K1 and thus reset all the other relays.

The cycle is then completed and if you need to restart, press the Start button again.



19.0 Troubleshooting and Rectifying Faults in Electro-Pneumatics

19.1 Introduction

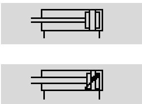
The following sections list the possible causes and remedies we normally encounter when handling electro-pneumatic components.

A good place to start is to use the service manuals which come with the machine; here you can find all the technical data on the components.

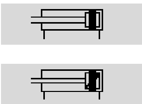
Standard cylinders DNC, ISO 6431 and VDMA 24 562 FESTO

Technical data

Function
DNC-...
without position sensing



DNC-...-A-...
with position sensing



Diameter
32 ... 125 mm

Stroke length
10 ... 2,000 mm

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General technical data								
Piston ∅		32	40	50	63	80	100	125
Stroke [mm]	Basic version	10 ... 2,000						
	Q	10 ... 300	10 ... 400	10 ... 500		10 ... 600		–
	K10	10 ... 1,000						–
	S10	10 ... 500						–
	S11	10 ... 500						
	S20	10 ... 850						
Pneumatic connection		G⅛	G¼	G¼	G⅜	G⅜	G½	G½
Piston rod thread	Basic version	M10x1.25	M12x1.25	M16x1.5	M16x1.5	M20x1.5	M20x1.5	M27x2
	K3	M6	M8	M10	M10	M12	M12	M16
	K5	M10	M12	M16	M16	M20	M20	M27
Constructional design		Piston						
		Piston rod						
		Cylinder barrel						
Cushioning P		Non-adjustable at either end						
Cushioning PPV		Adjustable at both ends						
Cushioning length PPV	[mm]	20	20	22	22	32	32	42
Position sensing		With proximity sensor						
Type of mounting		Via female thread						
		Via accessories						
Assembly position		Any						

Operating conditions								
Piston ∅		32	40	50	63	80	100	125
Operating medium		Filtered compressed air, lubricated or unlubricated						
Operating pressure [bar]	Basic version	0.6 ... 12						0.6 ... 10
	R8	1.5 ... 12						1.5 ... 10
	S11	0.1 ... 12						0.1 ... 10

Figure 19.1 – Sample of a Data Sheet

19.2 Identify and Record

Using the fault-finding guide or flow chart, identify and record all possible signs and symptoms of pneumatic system failures.

An example of a fault-finding guide is shown below for an electro-pneumatic system.

Items to Check		**YES**	**NO**	**Remarks**
1	Pneumatic systems are started when appropriate buttons are activated			
2	Pneumatic systems follow the required sequence as stipulated in the control requirements			
3	Actuators travel their required distance and speed			
4	System cycle is within time limits			
5	Pneumatic systems are stopped by pressing the appropriate buttons			

19.3 Diagnose the Possible Faults

From the checklist, you should be able to identify the possible faults. Below is an example:

1	Compressed air supply is correctly connected to pneumatic systems
2	Compressed air supply is sufficient and set at right pressure
3	Electrical supply is connected and working (if applicable)
4	All connectors are connected correctly and in good working condition
5	Pneumatic and electro-pneumatic components are in working condition
6	Pneumatic systems are able to start when appropriate buttons are activated
7	Pneumatic systems follow the required sequence as stipulated in the control requirements
8	Pneumatic systems are stopped when appropriate buttons are pressed

19.4 Dismantling, Repairing and Assembling

Once the faulty components have been identified, we need to disassemble, repair or replace and reassemble the machine. Some of the guidelines are:

19.4.1 Preparation

- All compressed air supply is removed
- All power supply is switched off
- Correct tools, equipment and spare parts are chosen for the maintenance/repair work
- Tools, equipment and spare parts are in good working condition
- Space around the work area is not obstructed
- Safety shoes are worn by the worker

19.4.2 Dismantling

- Parts are removed in the correct sequence
- Only remove the relevant parts
- Refer to service manual if possible
- Mark and tag removed components
- Use to correct tools and do not use force

19.4.3 Repair/Replace

- The dismantled defective part is checked against the parameters provided by the manufacturer
- If defective, the part is either repaired or replaced
- Make sure that the correct part is replaced

19.4.4 Reassemble

- The serviced or new part is reassembled and connected in the correct location
- Make sure that all parts re reconnected and no leftovers
- The reassembly process should be the reverse of the dismantling process

For electro-pneumatics components, the following are some guidelines:

- For directional control valves, check the solenoid coils
- You can replace just the solenoid coils if it is faulty and need to not replace the complete valve
- Similarly, if the valve is faulty just replace the valve and reuse the solenoid coil
- Check for any faulty relays
- Check the wiring as it might come loose
- Check for continuity in the wiring, using a multimeter

Finally, when replacing faulty components, remember to get the correct part including the correct electrical rating.

19.5 Assessing the Performance

Once you have completed the repair of the component, you now need to assess the performance of the machine. Tests run the machine and check against the specifications given by the manufacturer.

The readings should be within the specifications given.

19.6 Faults in Solenoid Operated Directional Control Valves

- Wire connections are open internally. (Infinite resistance measurement on ohmmeter).
- Direct short (at power supply, electrical bus, load). A direct short is when too much current is sent back to the power supply overloading it, generally blowing a fuse.
- Cross short: A cross short is created by one or more wires (cables) by-passing the load causing a direct short to occur.
- High resistance connections (too many connections at the terminal eye).
- Stuck armature.
- Low voltage or over voltage at solenoid.
- Corrosion.
- Partially or fully blocked hoses.
- Lack of source pressure (at compressor or on the service unit).
- Sticking spool.
- Diaphragm not working.
- Exhaust ports blocked.
- Gaskets mounted incorrectly.
- Faults caused by wear or external influences.
- Caution: Short circuiting of the power supply is not recommended without the installation of a "circuit breaker" to protect the equipment and the user.

19.7 Faults in Relay Coils

<table>
<tr><th>Fault</th><th>Cause</th><th>Remedy</th></tr>
<tr><td rowspan="5">When powered, the relay coil does not function.</td><td>One or more of the wires (leads) has an infinite resistance.</td><td rowspan="5">Use the voltmeter to measure the difference in potential across each cable, and the push button when switch is open, then closed. If the problem is with any of these components, replace them and retry the circuit. If the voltage is too low, check the power supply and the wall outlet.

Use the ohmmeter to measure the resistance of the coil; if you have an infinite resistance (Open), replace the coil and retest the circuit. If the coil is good and the voltage is sufficient, test the ground wire.</td></tr>
<tr><td>Open (infinite resistance) in the coil.</td></tr>
<tr><td>Low voltage – below specifications.</td></tr>
<tr><td>Replace new relay with wrong voltage.</td></tr>
<tr><td>No input signal (ie. Push button switch contact is not closing)</td></tr>
</table>

Fault	Cause	Remedy
Relay coil is not energized by electrical limit switch (or proximity limit switch)	The electrical limit switch is not being activated.	Visually examine the electrical limit switch to make sure the roller is fully activated, if not, reposition the sensor so physical contact is achieved. (or see LED)
		Use the voltmeter to test the difference in potential across the limit switch (24 volts when open, 0 volts when closed) replace if not functioning, or remove the limit switch from the circuit and use the ohmmeter to measure the resistance of the limit switch (infinite pressure when open, approximately 0 when closed)
	One of the cables (wires) is either not connected or there is infinite resistance in the cable (wire).	Use the multimeter to check the difference in potential across each cable (wire) in the corresponding ring. Then remove the suspect cable(s) and use the ohmmeter to confirm your findings, replace the cables if required.
	The relay coil itself is malfunctioning, ie. low voltage, an open (infinite resistance) circuit, loose connection, high resistance connection.	If the voltmeter identifies low voltage, then check the power supply and original source. Replace or modify source as required. If an “open” infinite resistance, loose or high connection is suspected, use the ohmmeter to determine the exact location of the problem and repair/replace as required.

TABLE OF CONTENTS

1.0 Safety Measures and Procedures when Working with Pneumatic and Electro-Pneumatic Systems

1.1 Introduction

When working with pneumatic and electro-pneumatic systems, we must ensure that we follow the safety rule and practices. Do not be deceived that it is quite safe as we are only working with air. The dangers of working with compressed air are numerous and we must be careful.

1.2 Safe Working Practices

The following maintenance work must be carried out frequently and at short intervals:

- Service unit
  – Check the filter
  – Drain water regularly
  – Refill and set lubricator, if a lubricator is used.
- Check signal generators for possible deposits of dirt or swarf

The following maintenance work can be undertaken at greater time intervals:

- Check the seals of the connectors for leaks
- Replace lines connected to moving parts
- Check the rod bearings in the cylinders for wear and replace if necessary
- Clean or replace filter elements
- Check function of safety valves
- Check mountings

1.3 Maintenance Requirements for Pneumatic Systems

Systematic maintenance helps to prolong service life and improve the functional reliability of pneumatic control systems.

A detailed maintenance plan should be drawn up for every pneumatic system. A maintenance plan lists the maintenance tasks and time intervals. In the case of complex control systems, the maintenance documentation must include a function diagram and circuit diagram.

The time intervals between individual maintenance works to be carried out are dependent on the period of use, the wear characteristics of the individual components and the ambient medium.

As with all systems, preventive maintenance is also applicable to pneumatic systems.

Premature wear or failure of components can be the result of design or planning errors. If the following points are taken into consideration during the planning phase, this minimises the risk of premature machine failure.

- Selection of the appropriate components and signal generators. They should be adjusted to suit the environmental and operational conditions of the system (e.g. switching frequency, heavy loads)

- Protection of components against contamination
- Mechanical absorption of the actuating forces through additional shock absorbers
- Short line lengths, fitted with amplifiers where necessary

1.4 Compressed Air Safety

Compressed air is piped around many workplaces in order to drive tools and to provide the air for certain types of equipment. Compressed air is very dangerous when used for anything but the correct purpose.

- Before opening the valve from the air supply line, check that the hose and connections are not damaged and hold the end of the hose to stop it whipping about when you turn on the air.
- Never use compressed air to clean your clothes or hair. Eye damage or ruptured ear drums result from this. Also, air could enter the blood stream through cuts or scratches on the skin.
- Use rubber gloves if components have to be cleaned with compressed air.
- Never blow down a bench or a machine tool with compressed air. It may blow metal filings and chips for 6 to 10 metres or more.
- Before changing an air tool, close the valve at the supply line and release the pressure in the hose.
- Do not use any pneumatic tool which has a faulty operating valve or governor.

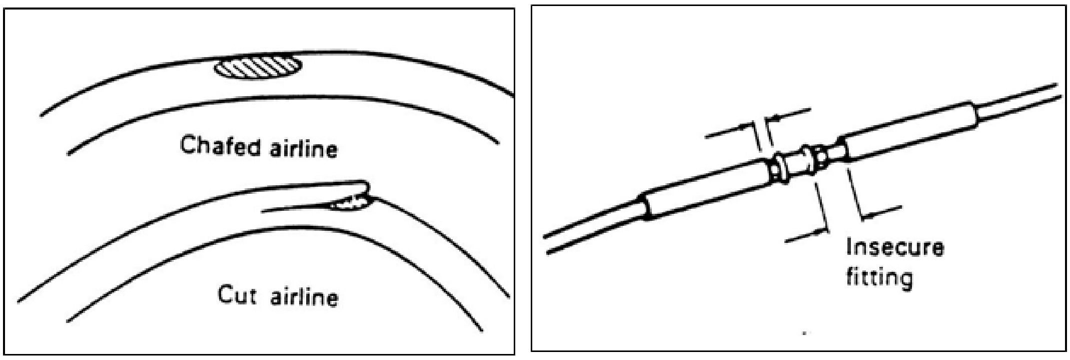


Figure 1.1 - Compressed Air Safety

2.0 Features and Applications of a Pneumatic System

2.1 Introduction

Pneumatics has for some considerable time been used for carrying out the simplest mechanical tasks, but in more recent times has played a more important role in the development of pneumatic technology for automation.

In most of applications compressed air is used for one or more of the following functions:

- To determine the status of processors (sensors)
- Information processing (processors)
- Switching of actuators by means of final control elements
- Carrying out work (actuators)

To be able to control machinery and installations necessitates the construction of a generally complex logic interconnection of statuses and switching conditions. This occurs because of the interaction of sensors, processors, control elements and actuators in pneumatic or partly pneumatic systems.

2.2 Features of a Pneumatic System

The technological progress made in material, design and production processes has further improved the quality and diversity of pneumatic components and thereby contributed to their widely spread use in automation.

Pneumatic components can perform the following types of motion:

- Linear
- Swivel
- Rotary

2.3 Applications of Pneumatic Systems

Some industrial applications employing pneumatics are listed below:

General methods of material handling:

- Clamping
- Shifting
- Positioning
- Orienting

General applications:

- Packaging
- Filling
- Metering
- Driving of axes
- Transfer of materials
- Turning and inverting of parts

- Sorting of parts
- Stacking of components
- Stamping and embossing of components

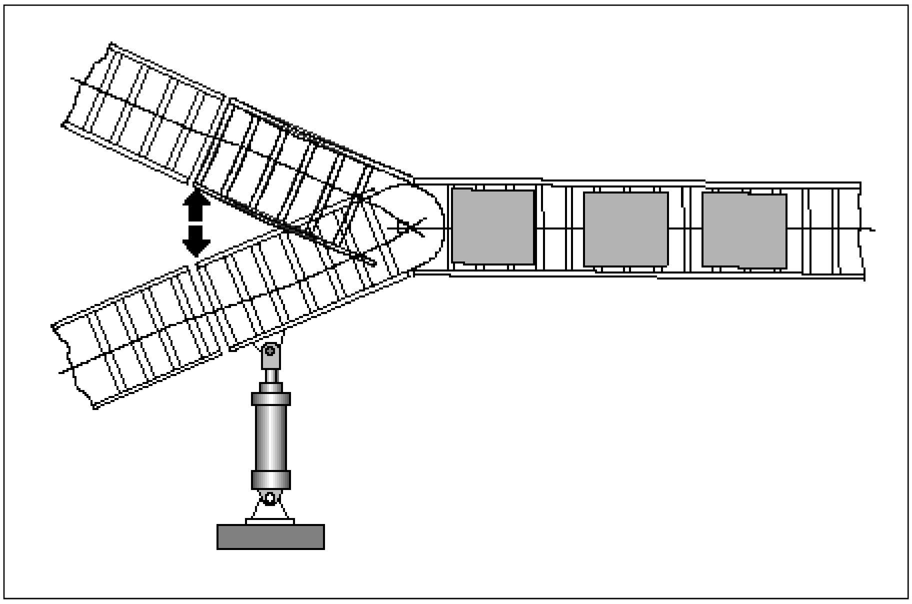


Figure 2.1 – Points Switch for Two Conveyor Belts

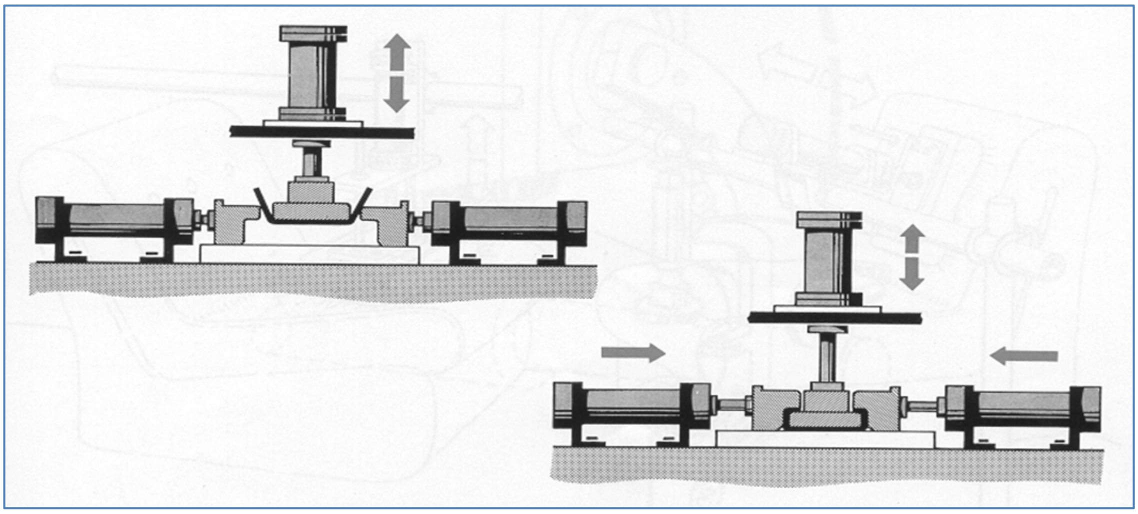


Figure 2.2 – Pneumatics Used in Forming

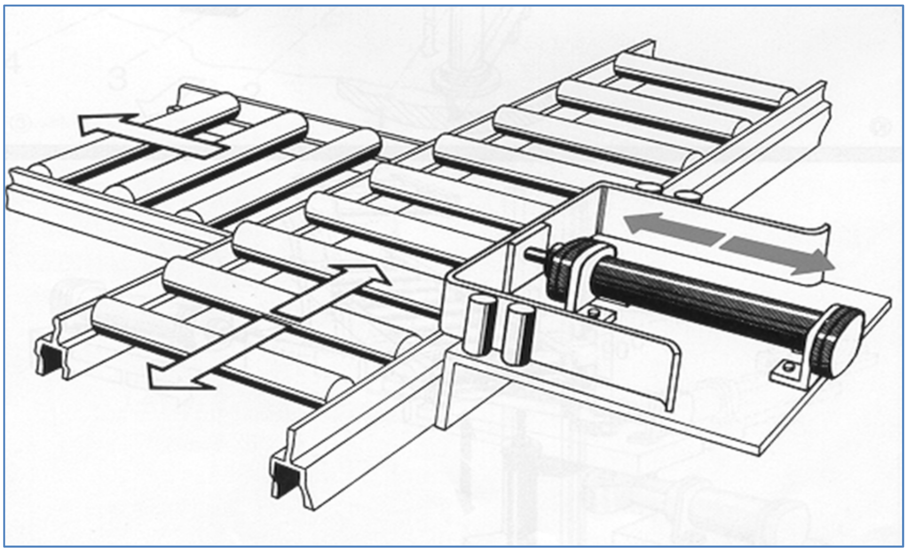


Figure 2.3 – Pneumatics Used in Pushing

Pneumatics is used in carrying out machining and working operations.

For example:

- Drilling
- Turning
- Finishing
- Forming
- Quality control

3.0 Features and Applications of the Compressed Air System

3.1 Introduction

Compressed air is one of the oldest forms of energy known to man and applied to enhance his capability. The deliberate utilization of air as a medium, as well as a more or less deliberate working with this “medium” can be traced back thousands of years. But real practical industrial application of pneumatics in production dates back only to about 1950 where the need for automation and rationalisation of operational sequences continued to increase.

Today, it is not possible to imagine modern factories being without compressed air. For this reason, compressed air devices are installed in the most diverse branches of industry

3.2 Pressure

Pressure is defined as force per unit area.

In mathematical expression:

$$\text{Pressure (P)} = \frac{\text{Force (F)}}{\text{Area (A)}}$$

The unit for pressure is N/m² and is designated Pascal (Pa). Since Pascal denotes such a small pressure, a unit representing KPa or Bar is used.

1 bar = 100000 Pa
= 100 KPa

3.2.1 Atmospheric Pressure

Atmospheric pressure is due to the weight of the mass of air per m^2 on the earth’s surface. Atmospheric pressure at sea level is 1.013 bar.

3.2.2 Gauge Pressure

Pressure gauge measures pressure in a pipeline (or in a container) above or below atmospheric pressure. If the gauge shows a zero reading, then the pressure is atmospheric. If the pressure reading is below atmospheric pressure, it is referred to as vacuum and is negative relative to atmospheric pressure.

3.2.3 Absolute Pressure

Absolute pressure is

- Atmospheric Pressure + Gauge Pressure (Pressure above atmospheric pressure)
- Atmospheric Pressure - Vacuum Pressure (Pressure below atmospheric pressure)

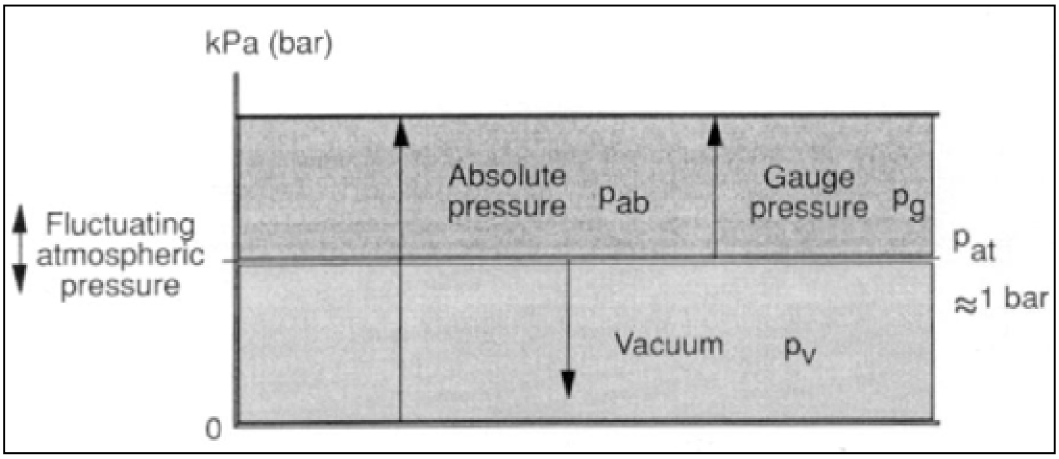


Figure 3.1 - Pressure Differences

3.3 Generation of Compressed Air

The compressed air supply for a pneumatic system should be adequately calculated and made available in the appropriate quality. Air is compressed by the air compressor and delivered to an air distribution system in the factory. To ensure the quality of the air is acceptable, air service equipment is utilised to prepare the air before being applied to the control system.

As a rule, pneumatic components are designed for a maximum operating pressure of 800-1000 kPa (8 - 10 bar) but in practice it is recommended to operate at between 500-600 kPa (5 and 6 bar) for economic use. Due to the pressure losses in the distribution system the compressor should deliver between 650-700 kPa (6.5 and 7) bar to attain these figures.

To understand the need for good air preparation, we will go through the compressed air distribution flow chart.

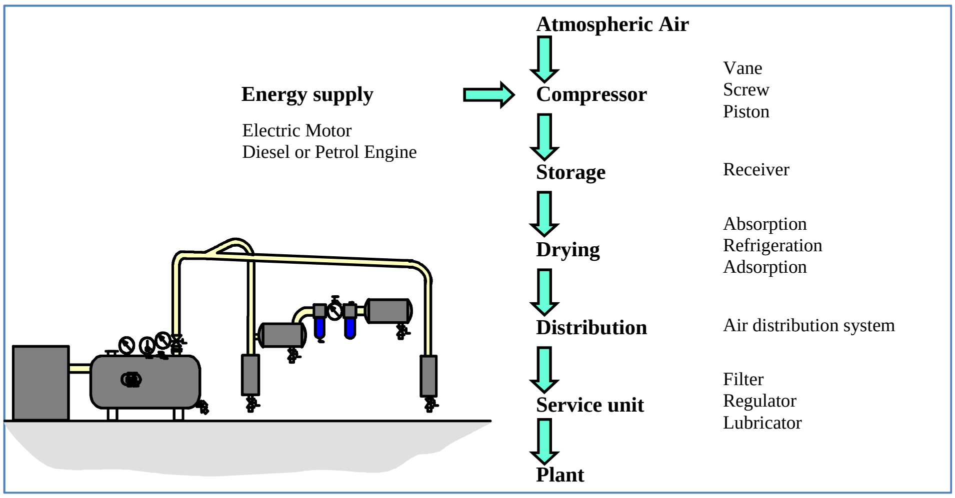


Figure 3.2 – Compressed Air Supply

3.3.1 Air Compressors

The compressor is the first part of the flow chain, it is used to compress the air at atmospheric pressure of about 1 bar to working pressure of 6 to 10 bar. There are a variety of compressors available in the market.

- Reciprocating piston compressor
- Rotary piston compressor
- Flow compressor
- Piston compressor
- Diaphragm compressor
- Radial-flow compressor
- Axial flow compressor
- Sliding vane rotary compressor
- Two-axle screw compressor
- Roots blower

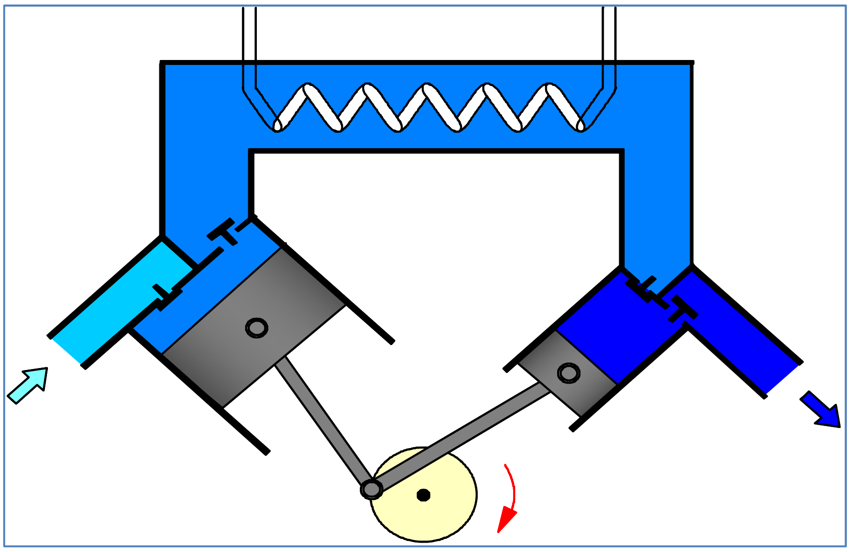


Figure 3.3 – Piston Compressor

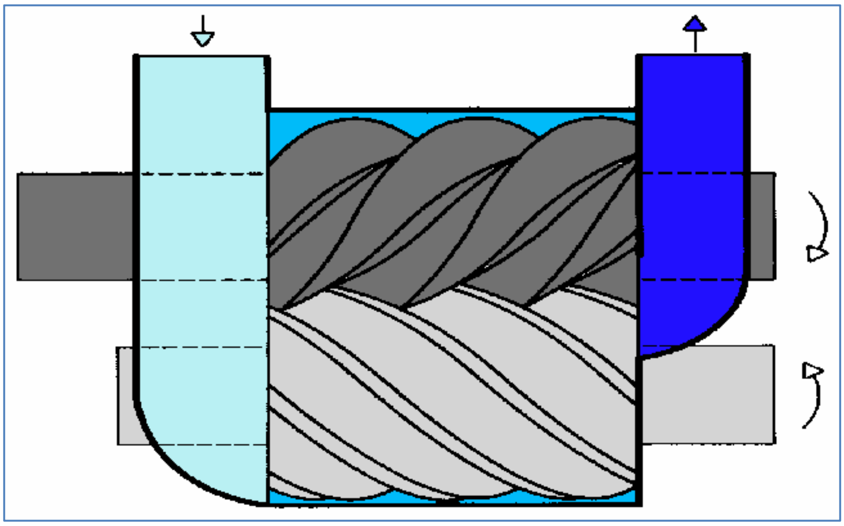


Figure 3.4 – Screw Compressor

3.3.2 Air Receivers

After the compressor has compressed the air to working pressure it is directed to the air receiver. The receiver has several functions:

- Providing constant air pressure in a pneumatic system regardless of fluctuating consumption
- Emergency supply to the system in cases of emergency
- The large surface area cools the air
- Moisture can be separated from the air

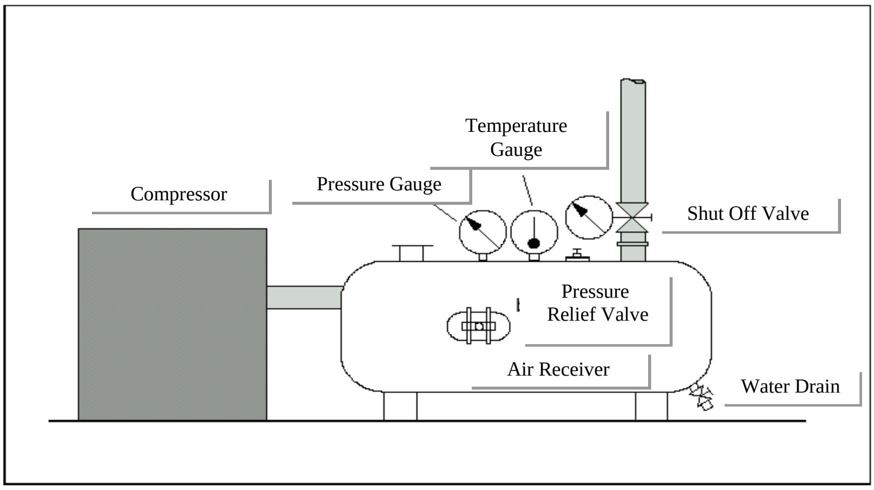


Figure 3.5 – Air Receiver

3.3.3 Air Dryers

Moisture in the system causes considerable damage. If the intercooler and aftercooler do not have the capacity to produce absolute dry compressed air, the air must be put through a further drying process. The three commonly used drying methods are:

- Absorption Drying
- Adsorption Drying
- Low Temperature Drying

a. Low Temperature Drying

If compressed air is cooled down below dew point, condensation occurs and water is precipitated. The compressed air to be cooled flows into the low temperature dryer via the air to air heat exchanger in the first part of the equipment. Here the warm compressed air to be dried is precooled by the cold and dry air flowing out. This causes water and oil to be separated, and thus the refrigerating machinery is required to operate at a capacity of only about 40%. The precooled compressed air enters the refrigerating unit only in the second station. Compressed air is then cooled to a temperature of 1.7°C.

To ensure that the function of the air to air heat exchanger and the refrigerating unit is not affected by oil, a prefilter is provided to ensure that the oil and dirt particles are separated prior to their entry into the drying unit.

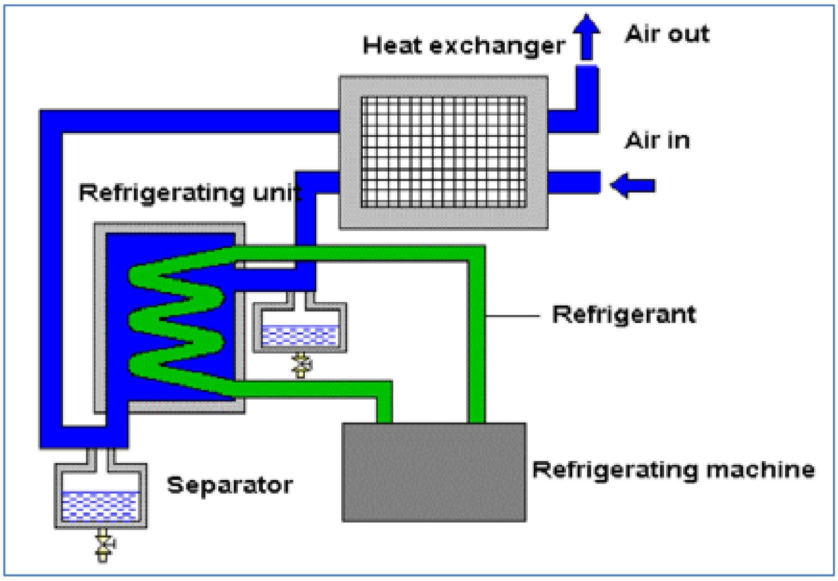


Figure 3.6 – Low Temperature Drying

b. Adsorption Drying

Adsorption drying is based on a physical process. The moisture is deposited onto the surface of a solid body which can be silica gel, activated illumina, or molecular sieves. As the warm moist air passes over the granules, the moisture is removed from the air. The saturated gel bed is generated by a simple method of lowing warm air through the bed and the warm dry air becomes moist as it takes the moisture out of the gel.

The capacity of the gel bed is limited under normal conditions, it will be necessary to replace the drying agent every two to three years.

Once again, a prefilter and a refilter must be used with this system to remove oil at the input and to remove any possible solid material taken from the bed.

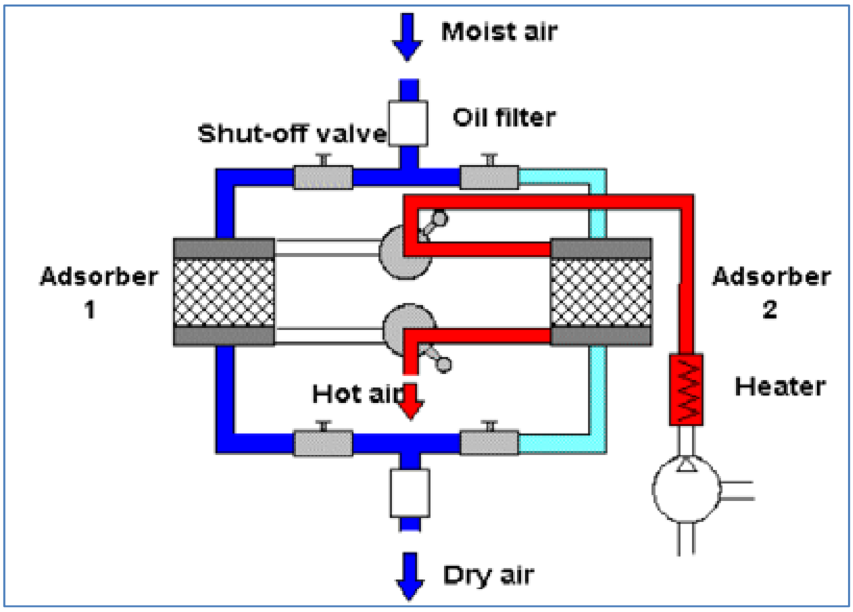


Figure 3.7 – Adsorption Drying

c. Absorption Drying

It is a purely chemical process. The air is guided over a bed containing salt tablets, the tablets will absorb the water vapour from the air and become a liquid which will drop to the bottom of the drying tank.

Unfortunately, most of the drying agents used are strongly corrosive and filtering is necessary to ensure that the drying agent is not carried along with the dried air. Prefiltering is also necessary to prevent the oil from damaging the drying agent. A further problem with this type of drying agent is that at temperatures exceeding 30°C the drying agent will soften and bake, which will lead to increased pressure drop through the dryer.

The special features of the absorption process are:

- Simple installation of the equipment.
- Low mechanical wear as there are no moving parts.
- No external energy requirements.

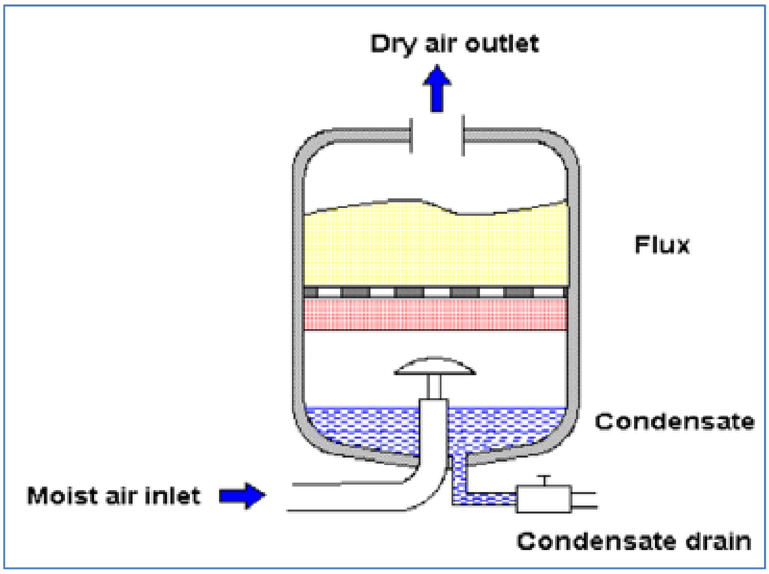


Figure 3.8 – Absorption Drying

The effect of the incorrect preparation of air in the pneumatic system is that we have a loss of repeatability and accuracy of working elements, a loss in the reliability of the operation of valves due to their sticking and the corrosion of metal parts and the inside diameter of cylinder barrels. Thus, it is very important that the preparation of air as outlined is carried out properly and that proper maintenance is conducted on these items to ensure their satisfactory operation.

3.4 Air Service Units

At the plant level, the service unit is the last protection before the air is used in the system.

The Service Unit consists of

- Air Filter
- Pressure Regulator
- Air Lubricator
- Pressure Gauge

3.4.1 Compressed Air Filter

The Air Filter is used for

- Preventing dirt particles from entering into the system
- Separate condensate out of the compressed air.

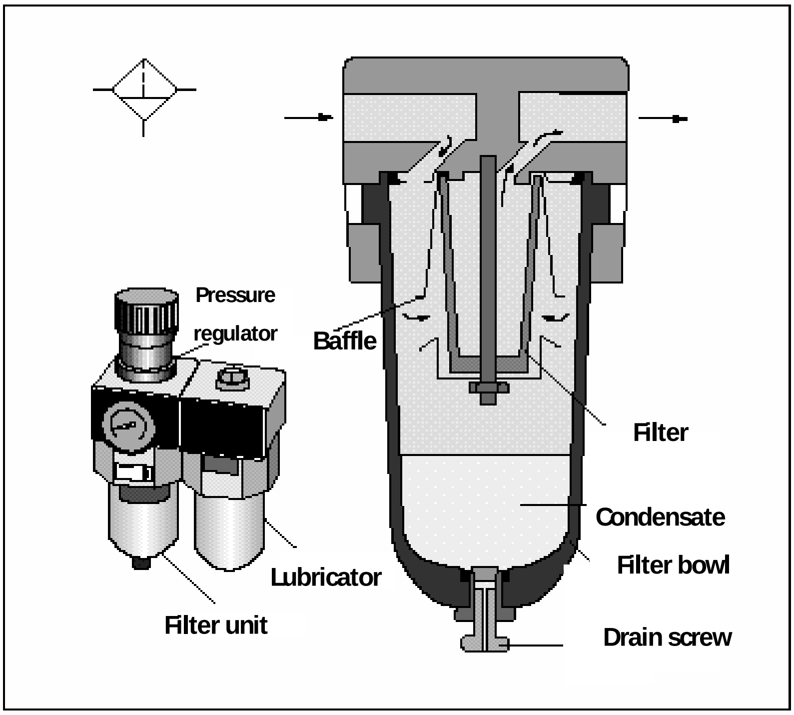


Figure 3.9 – Air Filter

3.4.2 Pressure Regulator

The pressure regulator is used for providing a constant supply pressure irrespective of the pressure fluctuations in the main line

All pneumatic systems have an optimum pressure (6 bar) and is lower than working pressure in the pipeline (10 – 15 bar). Pressure is always fluctuating due to the air being compressible.

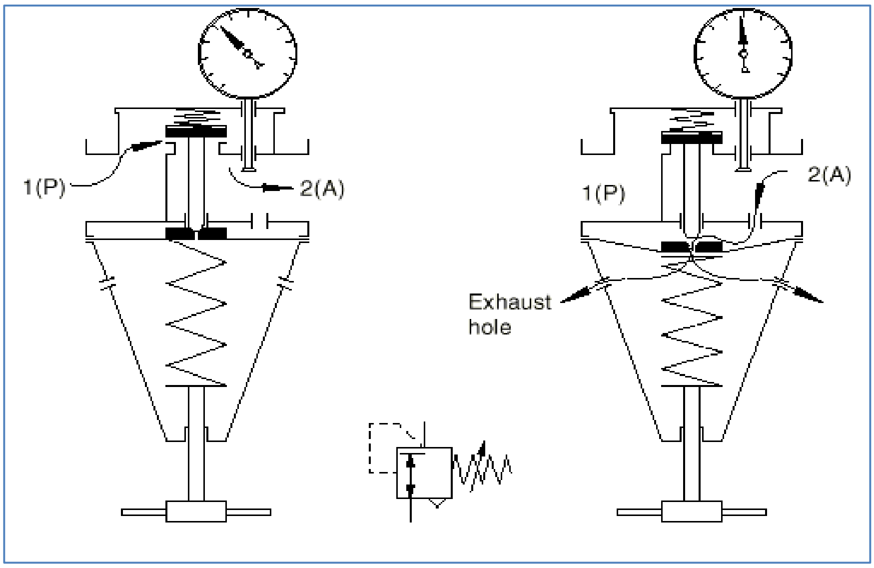


Figure 3.10 – Air Regulator

3.4.3 Compressed Air Lubricator

Lubrication of the compressed air by means of mist lubricators may be necessary in certain cases:

- In cases where extremely rapid oscillating motions are required.
- With cylinders of large diameter, from approximately 125 mm upwards.

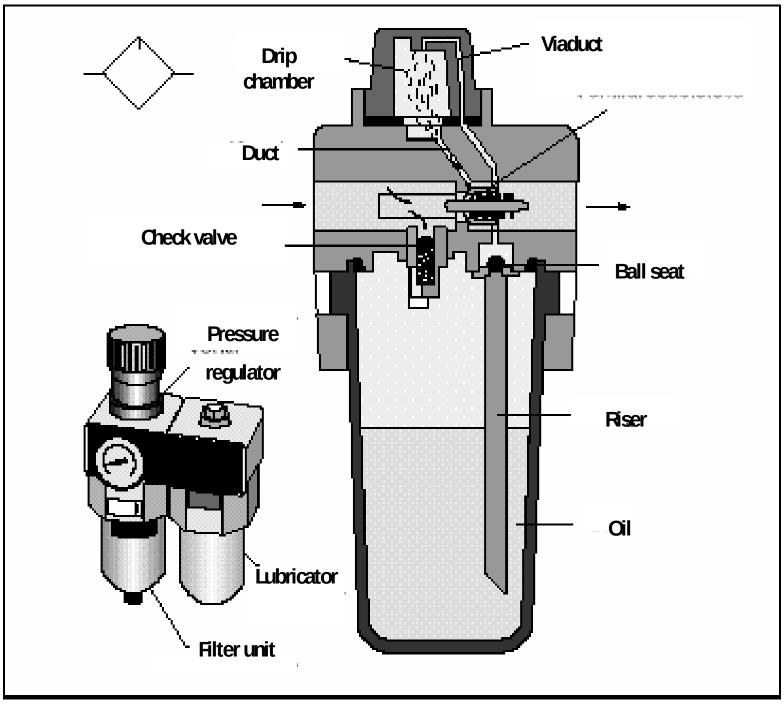


Figure 3.11 – Air Lubricator

3.5 Air Distribution

Owing to the increased rationalization and automation of manufacturing equipment, the air requirement in factories continues to rise. Each machine and each appliance needs a certain volume of air, and is provided with air from the compressor via a pipe system. The pipe diameter should therefore be selected such that the pressure drop between the receiver and user does not exceed 10kPa (0.1 bar). A higher pressure drop endangers the economics of the system and considerably reduces the performance.

When planning a new installation, allowance should be made for a possible later enlargement to the compressor plant, ie. higher air consumption, and the pipelines should therefore be generously dimensioned. Later installation of a larger pipe system is often very expensive.

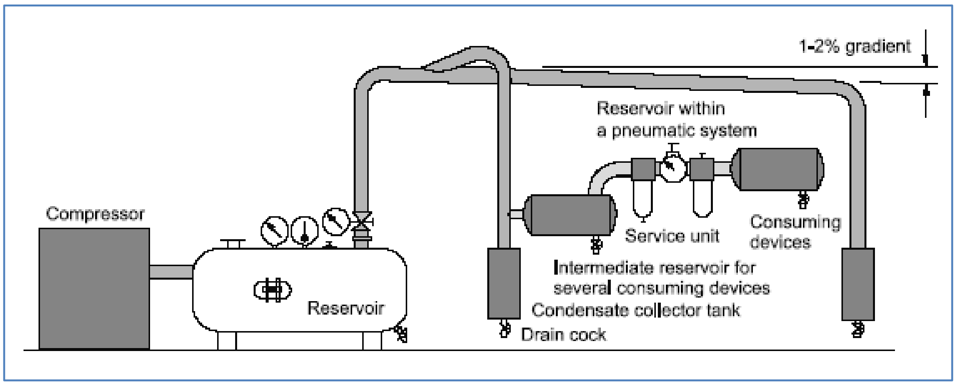


Figure 3.12 – Air Distribution System

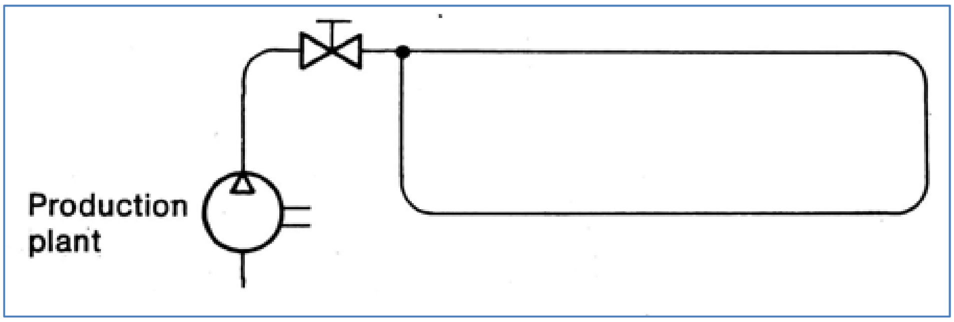


Figure 3.13 – Ring Circuit

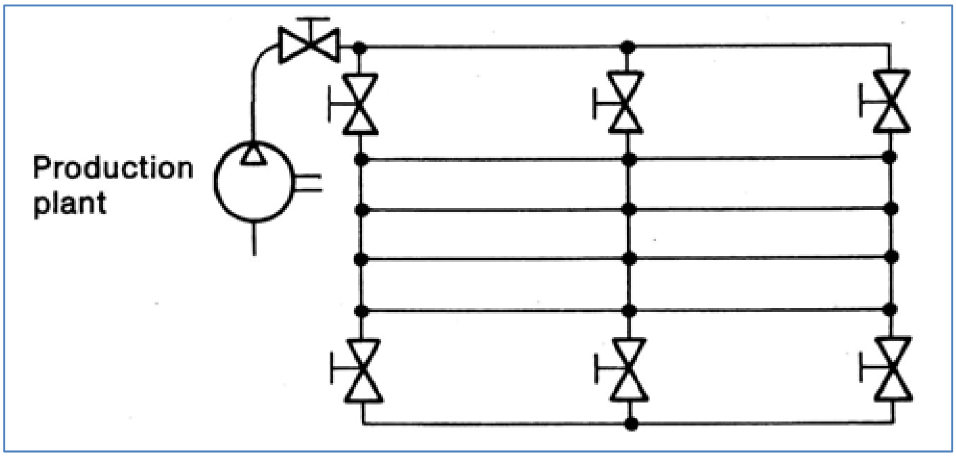


Figure 3.14 – Interconnected Circuit

4.0 Advantages and Disadvantages of Using Compressed Air

4.1 Introduction

Compressed air is essential for pneumatic systems. There are advantages and disadvantages in using compressed air.

4.2 Advantages of Using Compressed Air

4.2.1 Amount

Air is available practically everywhere for compression in unlimited quantities.

4.2.2 Transport

Air can be easily transported in pipelines, even over larger distances. It is not necessary to return the compressed air.

4.2.3 Storage

A compressor need not be in continuous operation. Compressed air can be stored in and removed from a reservoir (eg. Cylinder).

4.2.4 Temperature

Compressed air is insensitive to temperature fluctuations. This ensures reliable operation, even under extreme conditions of temperature.

4.2.5 Explosion Proof

Compressed air offers no risk of explosion or fire, hence no expensive protection against explosion is required.

4.2.6 Cleanliness

Compressed air is clean since any air which escapes through leaking pipes or elements does not cause contamination. This cleanness is necessary, for example, in food, wood, textile and leather industries.

4.2.7 Construction

The operating components are of simple construction and are therefore inexpensive.

4.2.8 Speed

Compressed air is a very fast working medium. This enables high working speeds to be attained. (Pneumatic cylinders have a working speed of 1~2 m/sec)

4.2.9 Overload Safe

Pneumatic tools and operating components can be loaded to the point of stopping and are therefore overload safe.

4.3 Disadvantages

4.3.1 Preparation

The compressed air needs good preparation. Dirt and humidity may not be present. (Wear of pneumatic components).

4.3.2 Compressible

It is not possible to achieve uniform and constant piston speeds with compressed air.

4.3.3 Force Requirement

Compressed air is economical only up to a certain force requirement. Under the normally prevailing working pressure of 700 KPa (7 bar) and dependent on the travel and speed, the limit is between 20,000 N and 30,000 N.

4.3.4 Exhaust Air

The exhaust air is loud. This problem has now, however, been largely solved due to the development of sound absorption material.

5.0 Pneumatic Directional Control Valves

5.1 Introduction

Pneumatic valves provide the interface between compressed air, the control signal and the working elements. Directional control valves are used to direct the flow of compressed air from one place to another in the pneumatic system, to permit the actuating parts to perform the work.

Control valves used in pneumatic systems are identified by four different methods:

- No. of Connecting Ports - 2, 3, 4, or 5-way valves
- No. of Control Positions - 2 or 3
- Type of Control Element - Poppet, Spool and Disc
- Method of Operation - Manual or Automatic

5.2 Types of Directional Control Valves

The design of the directional control valves is categorised as follows:

5.2.1 Poppet Valves

In poppet valves, the connections are opened and closed by means of balls, discs, plates, or cones. The valve seats are usually sealed simply using elastic seals. Seat valves have few parts which are subject to wear, and hence they have a long service life. They are insensitive to dirt and they are robust. The actuating force is relatively high as it is necessary to overcome the force of the built-in reset spring and the air pressure.

- Poppet Valves - Ball seat valve
  - Disc seat valve

5.2.2 Slide Valves

In slide valves, the individual connections are linked together or closed to one another by means of spool slides, spool flat slides or rotary slides.

- Slide Valves - Longitudinal slide valve
  - Longitudinal flat slide valve
  - Plate slide valve (Rotary slide valve)

5.3 Number of Flow Paths and Shifting Conditions

Directional control valves are designated by their flow paths and shifting conditions.

5.3.1 Flow Paths

As directional control valves direct the fluid flow, there are a number of flow paths or ports. These flow paths designate the first number of the valve.

5.3.2 Shifting Conditions

The shifting conditions or positions signify the number of positions the valve can have.
From the flow paths and shifting positions, the directional control valve is identified. For example, a 3/2-way directional control valve has 3 ports and 2 switching positions. At any one time, the valve is in one position, usually the right position

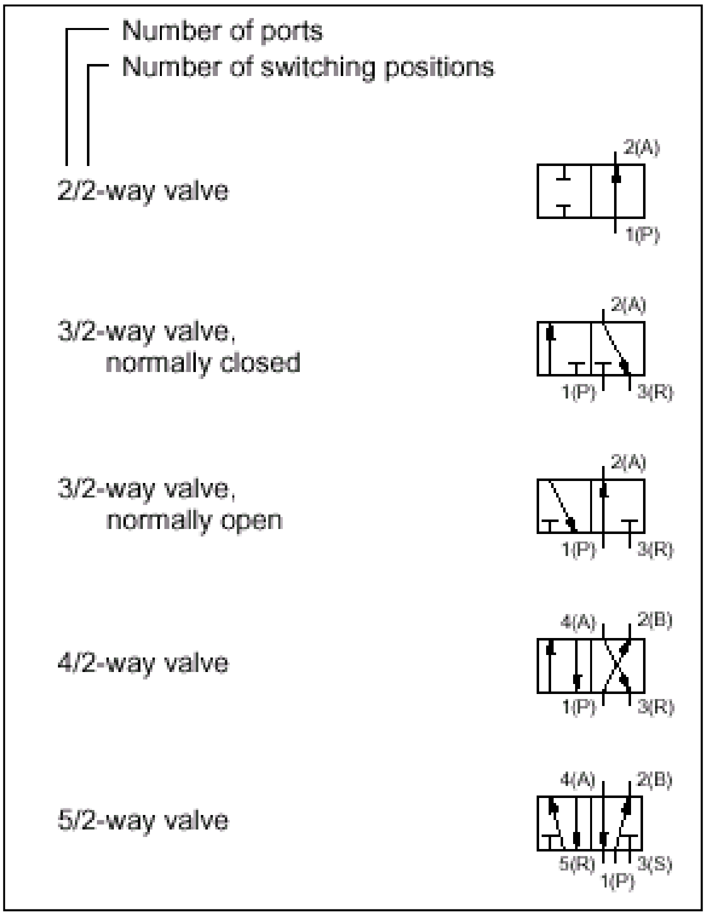


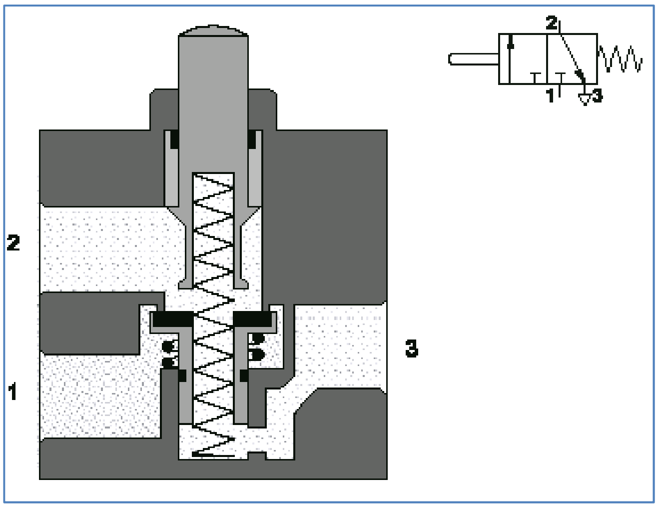
Figure 5.1 – Ports and Positions

5.4 2 Ports, 2 Positions Way Valves (2/2-way DCV)

The 2/2-way valve has two ports and two positions (open, closed). It is rarely used except as an on-off valve, since its only function is to enable signal flow through and cannot release the air to atmosphere once in the closed position in contrast to the 3/2-way valve. The 2/2-way valve is normally of the ball seat construction.

5.5 3 Ports, 2 Positions Way Valves (3/2-way DCV)

It consists of three ports inside the valve. Most 3/2-way valves are shifted backward and forward when they are actuated. This valve may be used as diverter or selector valve, holding valve and directional control valve. Some 3/2-way valve can also be classified as normally open or normally closed. This depends on the position of the valve when it is in the non-actuated position.



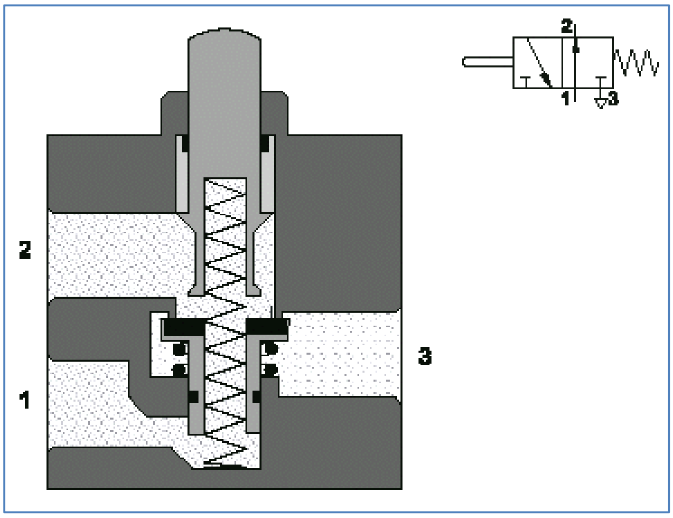


Figure 5.2 - 3/2-way Valves

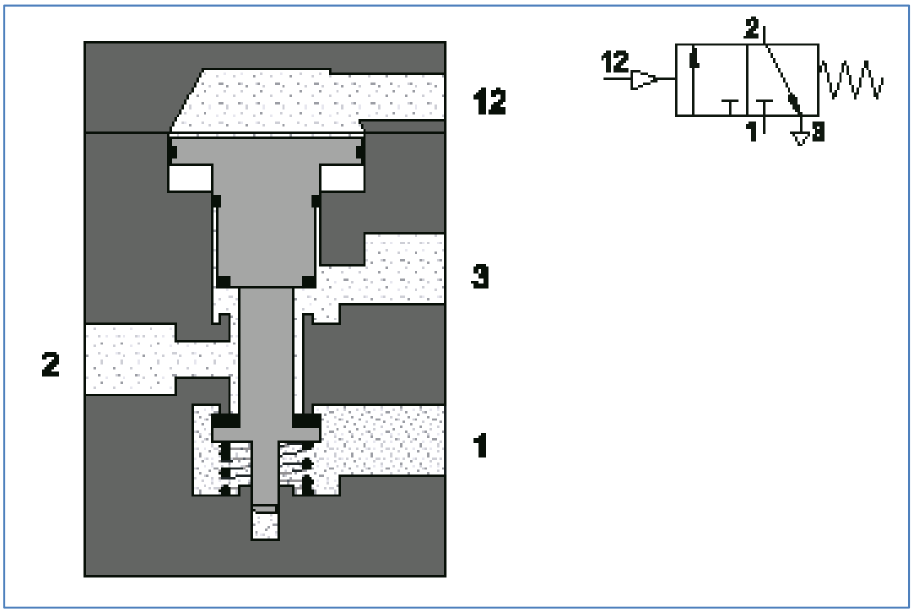


Figure 5.3 - 3/2-way Valve

5.6 4 Ports, 2 Positions Way Valves (4/2-way DCV)

4/2-way valves are used to simplify pneumatic circuits. This 4/2-way valve consists of four primary connections. These include a pressure line, an exhaust line and two actuator connections. A 4/2-way valve supplies compressed air to one chamber while bleeding off air from the other side of the cylinder. When the valve position is reversed, the air flow is also reversed.

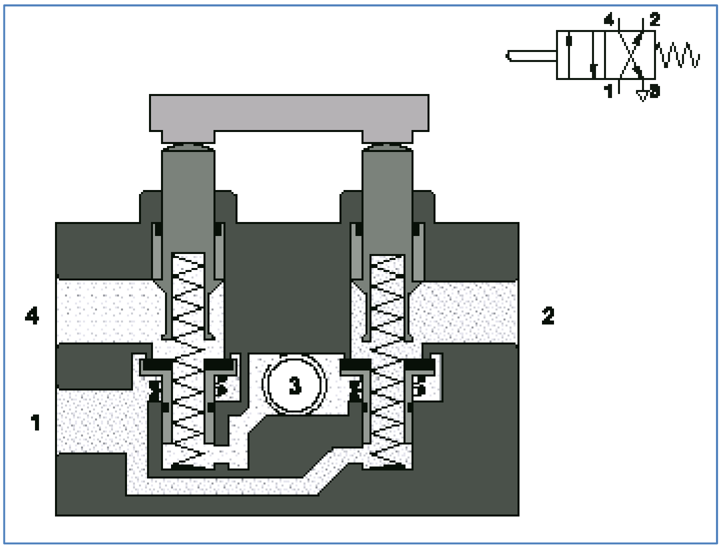


Figure 5.4 - 4/2-way Valves

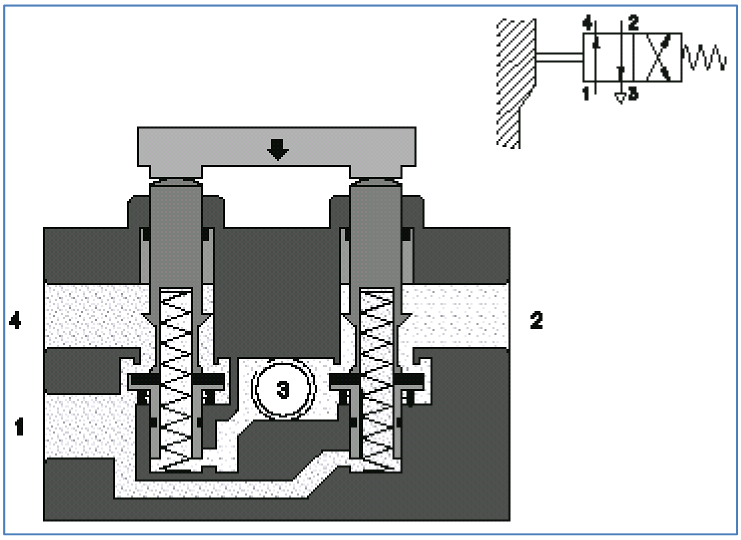


Figure 5.5 - 4/2-way Valves

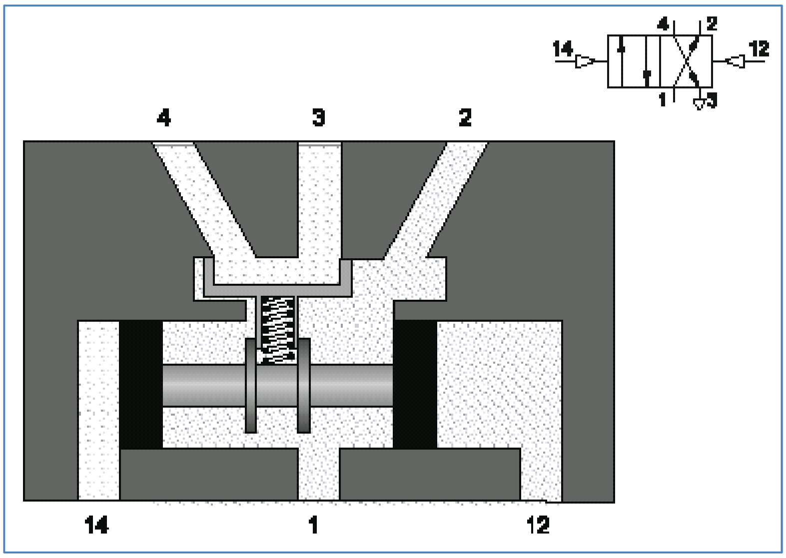


Figure 5.6 - 4/2-way Valves

5.7 4 Ports, 3 Positions Way Valves (4/3-way DCV)

4/3-way valves have 4 ports and 3 positions. The centre position is in its initial position. The valve is either switched to the left or the right when in use.

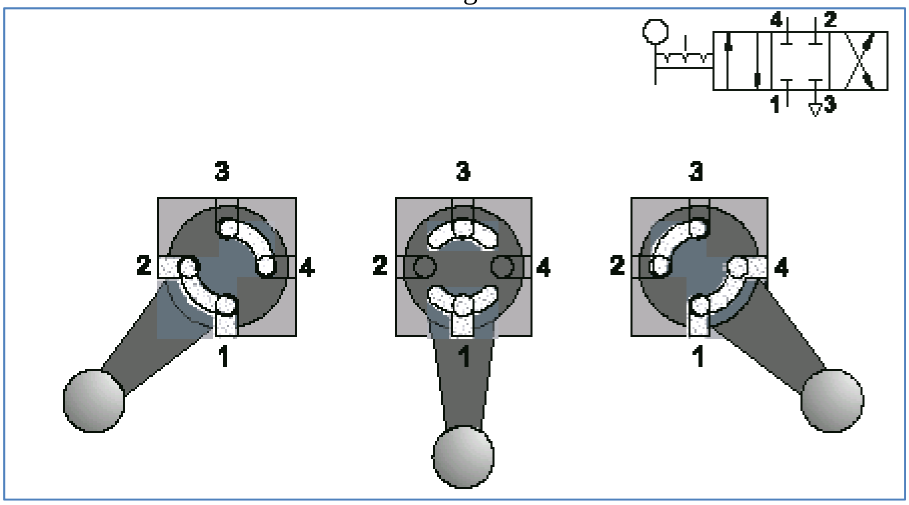


Figure 5.7 – 4/3-way Valve

5.8 5 Ports, 2 Positions Way Valves (5/2-way DCV)

A 5/2-way valve is a special four-way valve with five external connections. It has one power connection, two exhaust connections and two actuator connections.

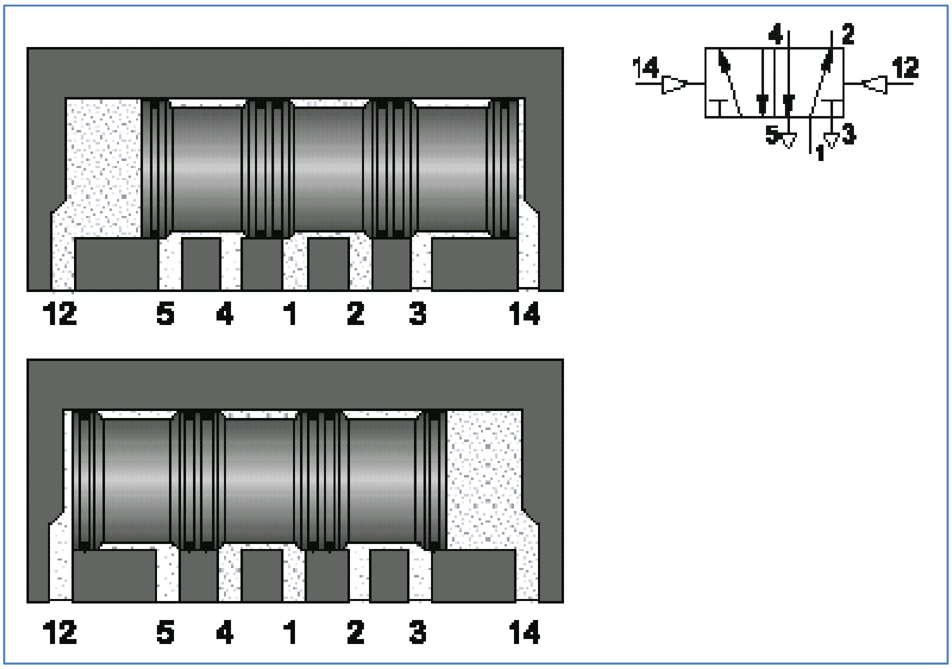


Figure 5.8 - 5/2 Way Valves

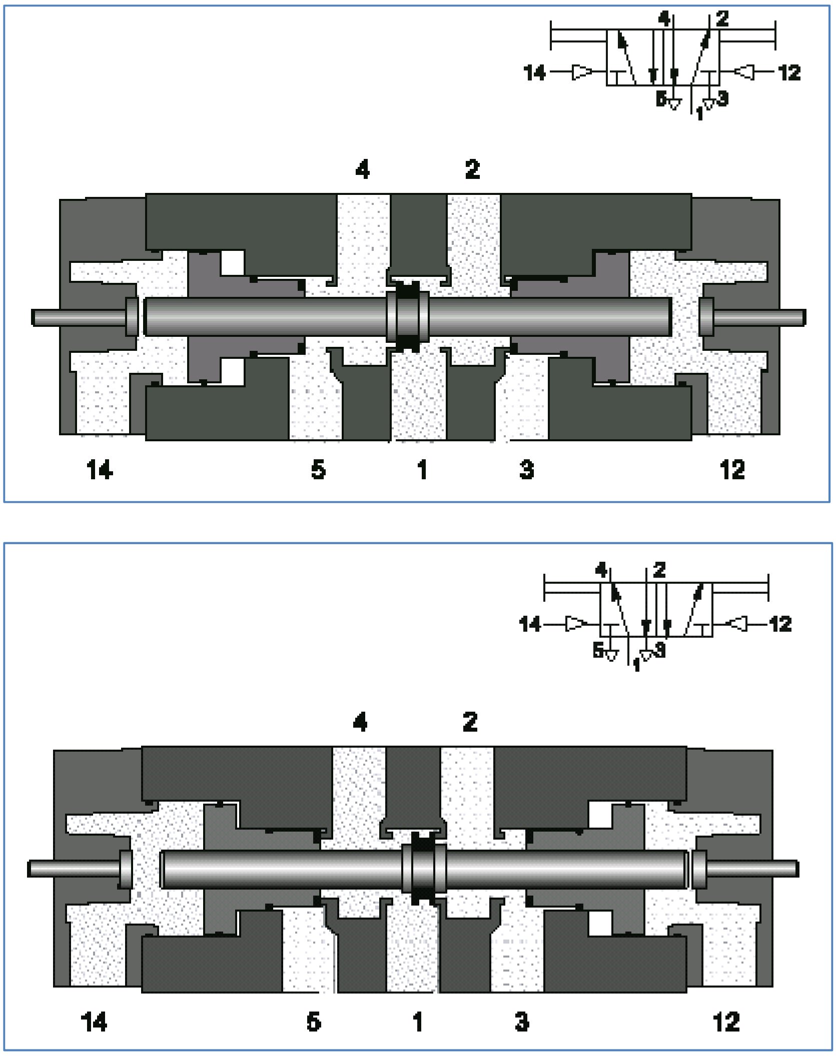


Figure 5.9 - 5/2-way Valves

5.9 5 Ports, 3 Positions Way Valves (5/3-way DCV)

A 5/3-way valve has 5 ports and 3 positions. It can be used to stop cylinders within its stroke length.

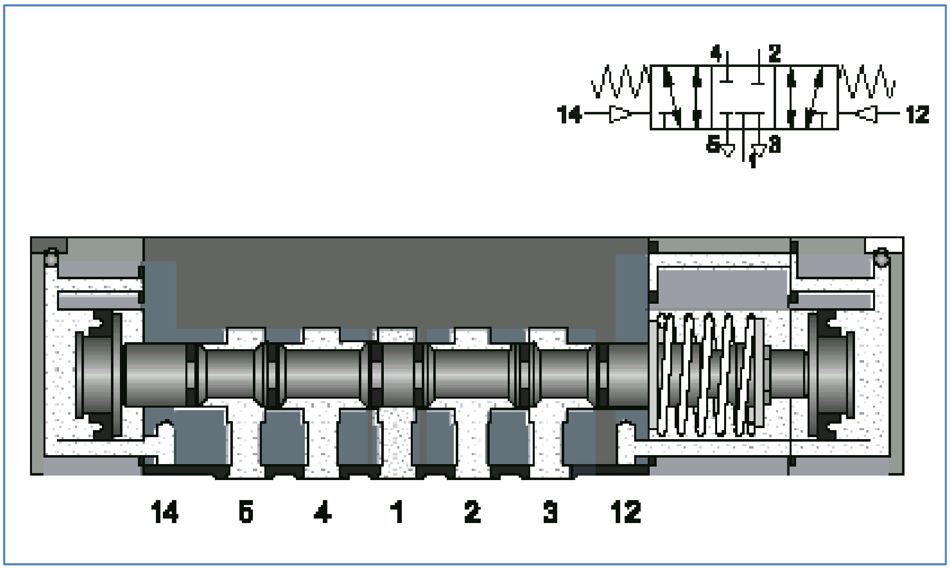


Figure 5.10 – 5/3-way Valve

5.10 Actuation Methods

Having identified the directional control valve, the last item would be the actuation method. The directional control valve can be actuated by:

- Manual
- Mechanical
- Pneumatic
- Electrical

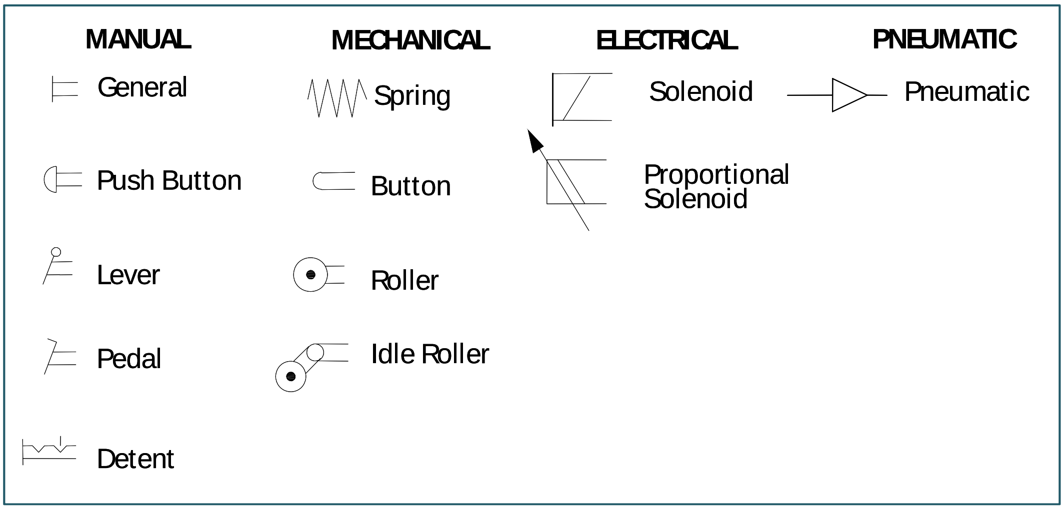


Figure 5.11 – Actuation Methods

6.0 Pneumatic Auxiliary Valves

6.1 Introduction

Besides the directional control valves, there are other pneumatic valves which are used in control applications.

6.2 Shuttle Valve ("OR" element)

This valve is also called double control valve or double check valve. This non-return valve has two inlets P_1 and P_2 and one outlet A. If compressed air is applied to inlet P_1, the ball seals off inlet P_2 and the air flows from P_1 to A. Alternatively, the air flows from P_2 to A when P_1 is closed. When the air flow is reversed, ie. a cylinder or valve is exhausted, the ball remains in its previously assumed position because of the pressure conditions.

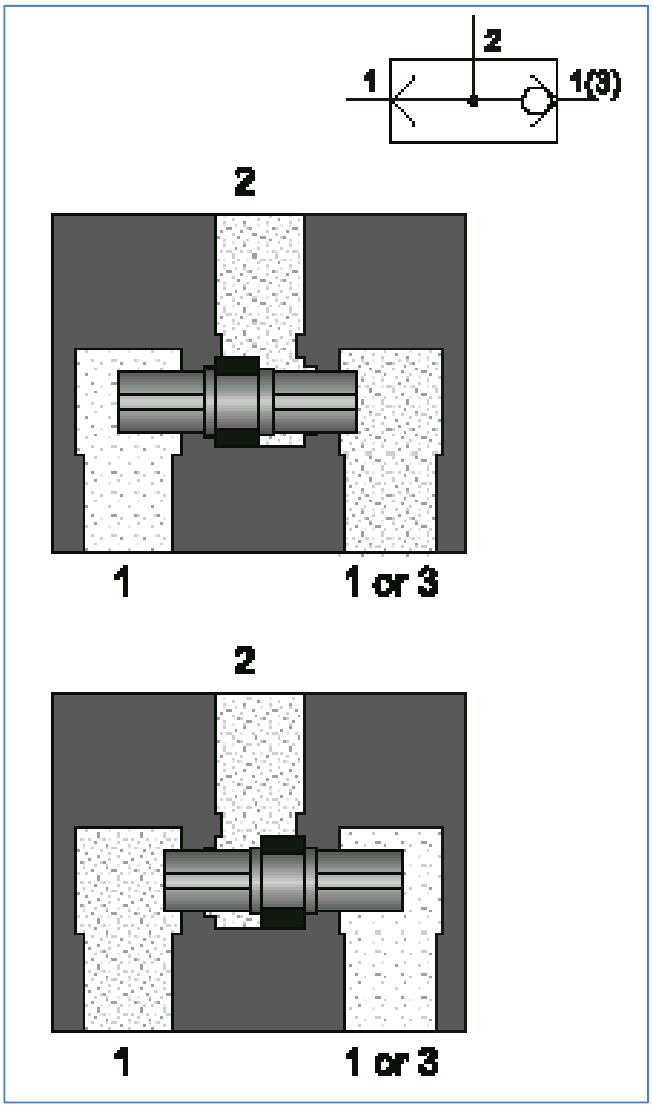


Figure 6.1 - Shuttle Valve

This valve is also called an “OR” component. It separates signal emitted from signal valves in various positions and prevents air from being diverted through a second signal valve. If a cylinder or control valve is to be actuated from two or several positions, a shuttle valve must be used.

6.3 Two-Pressure Valve (“AND” element)

The two-pressure valve has two inlets P_1 and P_2 and one outlet A. Compressed air flows through only if signals are applied to both inlets. One input signal to P_1 and P_2 blocks the flow because of the force differential across the spool. If input signals are applied simultaneously to both sides, the signal which is last applied passes to the outlet. If the input signals are of different pressures, the larger of the two pressures closes the valve and the smaller air pressure is transferred to the outlet. It is used mainly for interlocking controls, safety controls, check functions or logic operations.

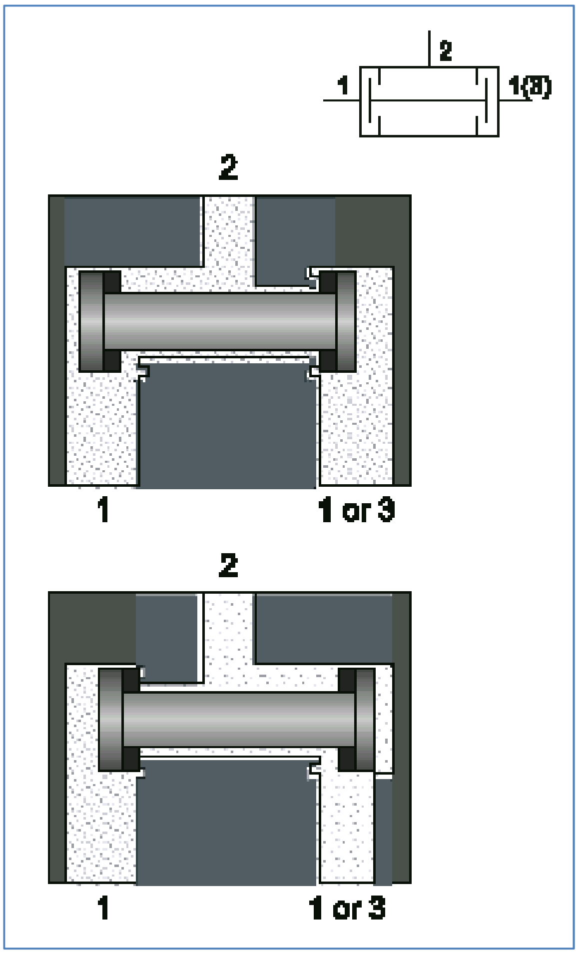


Figure 6.2 – Two-Pressure Valve.

6.4 Flow Control Valves

Flow control valves influence the volumetric flow of the compressed air in both directions. The throttle valve is a flow control valve.

6.4.1 Throttle Valve

Throttle valves are normally adjustable and the setting can be locked in position. Throttle valves are used for speed control of cylinders. Care must be taken that the throttle valve does not close fully, cutting off air from the system.

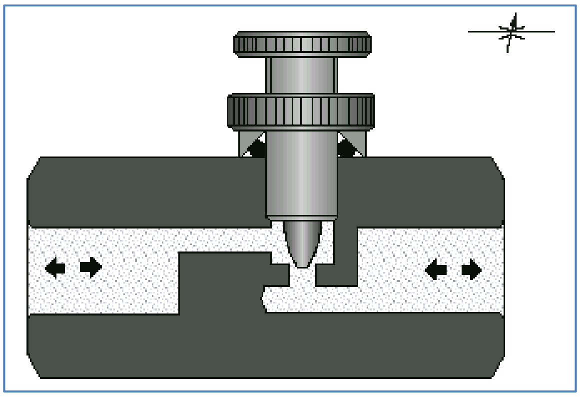


Figure 6.3 – Throttle Valve

6.4.2 One-Way Flow Control Valve

In the case of the one-way flow control valve, the air flow is throttled in one direction only. A check valve blocks the flow of air in the bypass leg and the air can flow only through the regulated cross-section. In the opposite direction, the air can flow freely through the opened check valve. These valves are used for speed regulation of actuators and if possible, should be mounted directly on the cylinder.

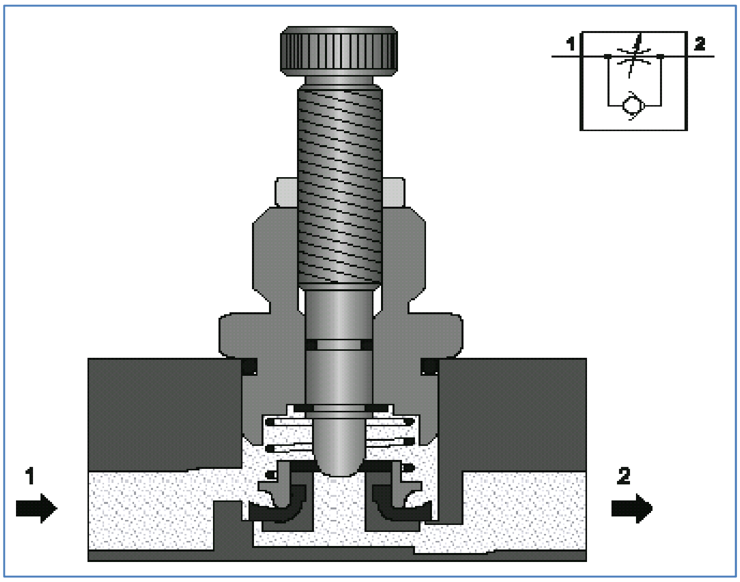


Figure 6.4 – One-way Flow Control Valve

6.5 Quick Exhaust Valve

Quick exhaust valves are used to increase the piston speeds in cylinders. This enables lengthy return times to be avoided, particularly with single-acting cylinders. The valve has a blockable pressure connection P, a blockable exhaust R, and an outlet A.

If pressure is applied at the connection P, the sealing disc completely covers the exhaust orifice R. The compressed air thus flows to A. If the pressure is removed from P, the air coming from A moves the sealing disc against connection P and closes it. The exhaust air can flow directly to atmosphere, without having to follow a long and possibly narrow path through the control lines to the pilot valve. It is best to mount the quick-exhaust valve directly on the cylinder, or as near to it as possible.

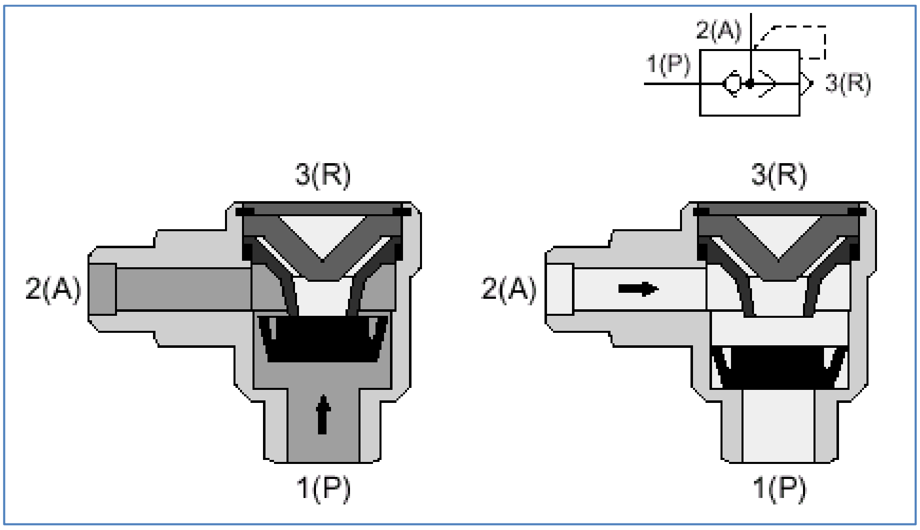


Figure 6.5 - Quick Exhaust Valve

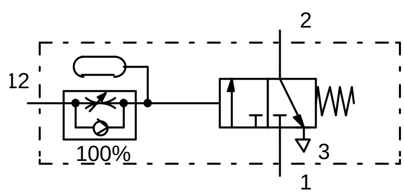
6.6 Time Delay Valve

The time delay valve is a combined 3/2-way valve, one way flow control valve and air reservoir. The 3/2-way valve can be a valve with normal position open or closed. The delay time is generally 0-30 seconds for both types of valves.

The following operational principle applies for a time delay valve with a 3/2-way valve in normally closed position: The compressed air is supplied to the valve at connection 1. The control air flows into the valve at 12 through a one-way flow control valve and depending on the setting of the throttling screw, a greater or lesser amount of air flows per unit of time into the air reservoir. When the necessary control pressure has built up in the air reservoir, the pilot spool of the 3/2-way valve is moved downwards. This blocks the passage from 2 to 3. The valve disc is lifted from its seat and thus air can flow from 1 to 2. The time required for pressure to build up in the air reservoir is equal to the control time delay of the valve.

If the time delay valve is to switch to its initial position, the pilot line 12 must be exhausted. The air flows from the air reservoir to atmosphere through the bypass of the one-way flow control valve and then to the exhaust line. The valve spring returns the pilot spool and the valve disc seat to their initial positions. Working line 2 exhausts to 3 and 1 is blocked.

Besides the normally closed position, there is the normally opened position, the only difference is that it will close when actuated.



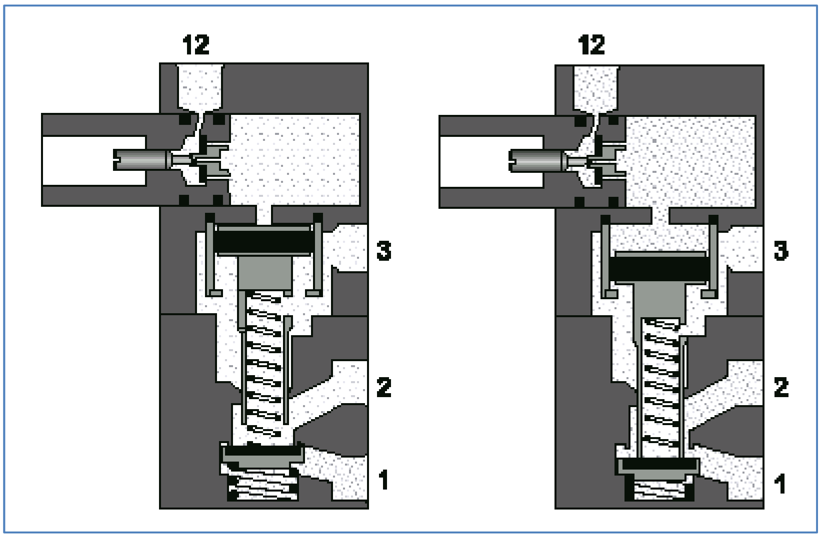


Figure 6.6 – Normally Closed Time Delay Valve

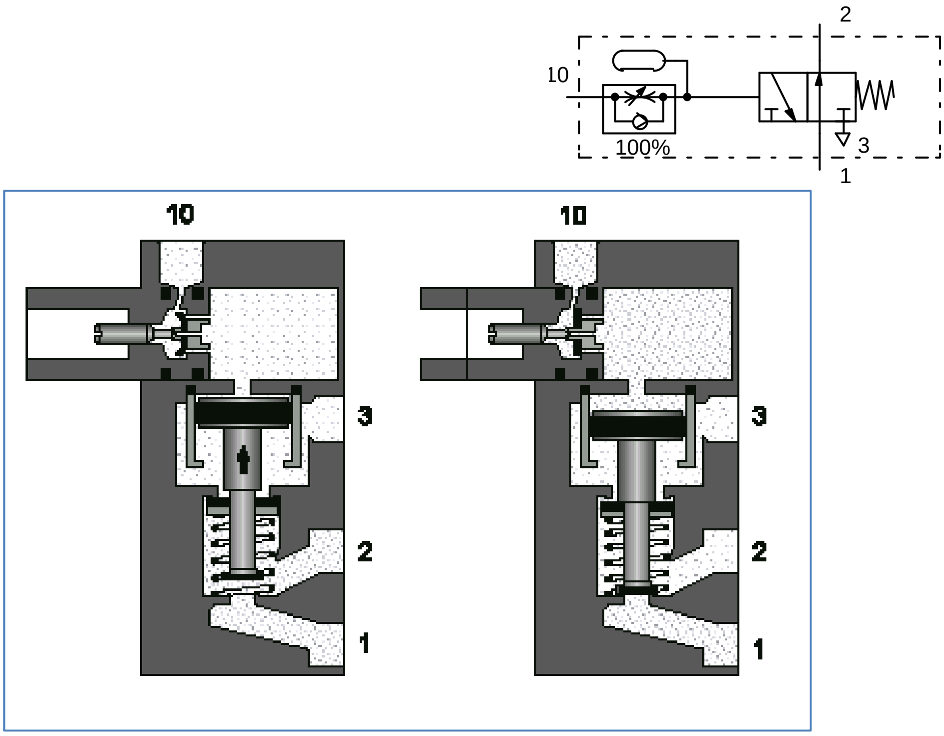


Figure 6.7 – Normally Opened Time Delay Valve

7.0 Pneumatic Actuators

7.1 Introduction

Actuators are the powering elements in a control system. They do the work in terms of generating movements (cylinders, motors) or other types of output/power (electrical, mechanical, thermal or hydraulic). Actuators are the devices at the end of the control chain. They convert the control signal into work (execution of instruction).

Below are some examples of actuators:

Cylinders, motors, lighting devices, heating devices, visual and acoustic alarm devices, etc.

Final control elements are also sometimes called actuators. Examples of final control elements are valves, contactors, power transistors, power thyristor etc.

Conversion of pneumatic, hydraulic & electrical energy into mechanical work is accomplished by actuators.

There are 3 ways to control/power an actuator. They are by:

- Pneumatics
- Hydraulics
- Electrics

Actuators can be categorised into three main areas. They are:

- Linear Motion
- Rotary Motion
- End Effectors

Linear motion can be achieved by pneumatic & hydraulic cylinders and electric actuators. Similarly, rotary motion can be achieved by pneumatic & hydraulic motors and electric motors.

7.2 Features of Pneumatic Cylinders

Pneumatic cylinders are the most widely used devices to produce linear force, work or power. The pressure of the air multiplied by the diameter of the cylinder gives the force and the volume of flow gives the cylinder its speed. The combination of force and motion produces work.

Creating a linear movement with electrically driven mechanical elements is often a complicated matter and requires a lot of power. This means that high current devices are required for such operations.

Pneumatically operated cylinders simplify these kinds of operations and also require less energy. Apart from this, pneumatic devices are safe from electrical hazards that are present in high current electrical devices.

7.2.1 Single-Acting Cylinder

In single acting cylinders compressed air is applied on only at one end. These cylinders can produce work in only one direction. Therefore, air is required for only one direction of movement. Either a built-in spring or an external force moves the piston in the opposite direction.

The spring force of the built-in spring is designed to return the piston to its starting position with a reasonably high speed under no load conditions. In single acting cylinders with built-in spring the stroke is limited by the natural length of the spring. Single acting cylinders are therefore normally only available with stroke lengths of up to approx. 80 -100mm.

The construction and simplicity of operation of the single acting cylinder makes it particularly suitable for compact, short stroke length cylinders for the following types of applications:

- clamping of workpieces
- cutting operations
- ejecting &/or injecting parts
- pressing operations
- feeding & lifting

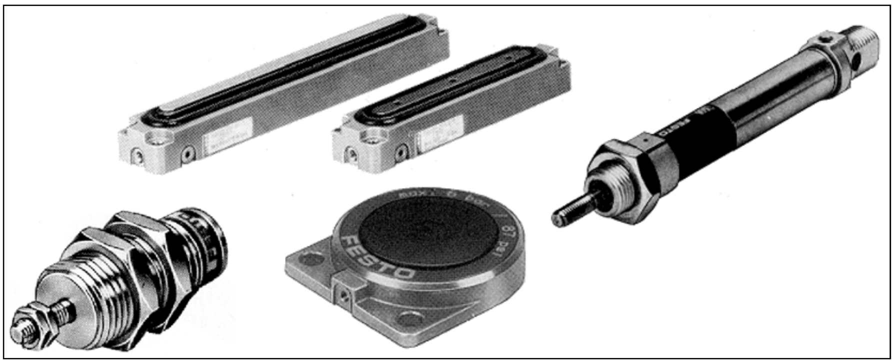


Figure 7.1 – Example of Single Acting Cylinders

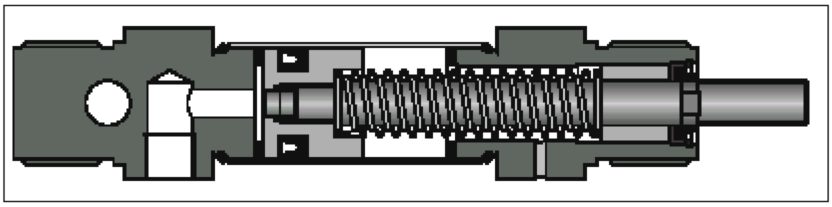


Figure 7.2 – Single Acting Cylinder

Construction of Single Acting Cylinders

The component parts of single acting cylinders are:

Tube, rear cap, bearing cap, piston with packing, piston rod, return spring and bearing bush with scraping ring. If compressed air hits the piston surface the piston rod moves out. When pressure is released the return spring moves the piston to its initial position. Due to the laid length of the return spring the stroke of single acting cylinders is restricted to approximately 100mm.

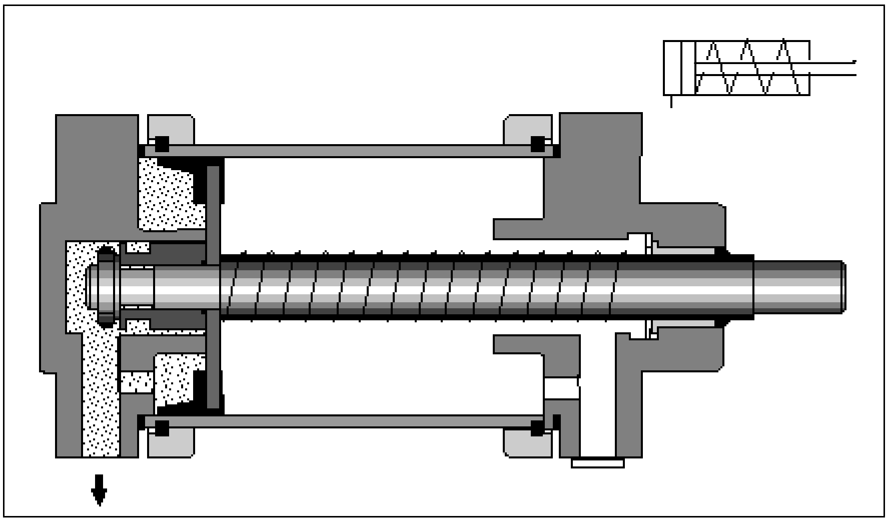


Figure 7.3 – Construction of Single Acting Cylinder

Short stroke clamping cylinders are ideal where there is little space and the cylinder won't fully extend before stopping, because of their compact size and inexpensive design.

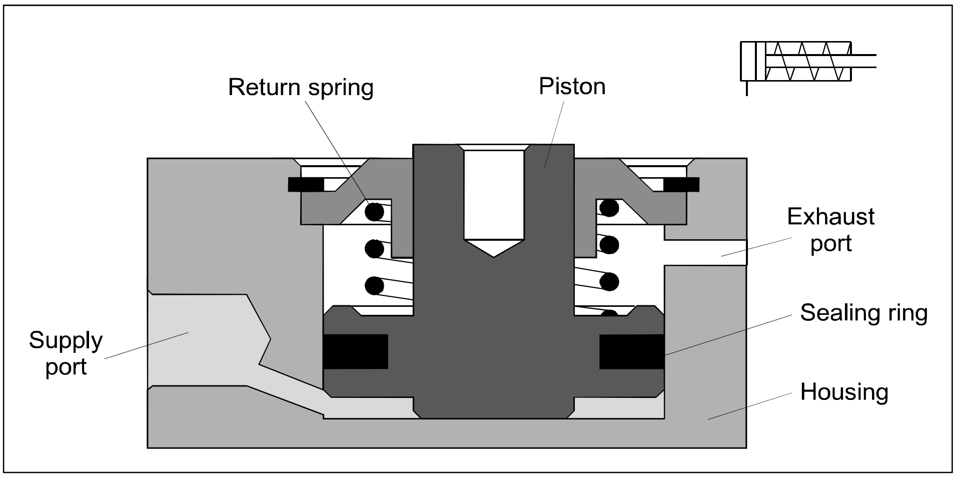


Figure 7.4 – Construction of a Single Acting Short Stroke Cylinder

There is a variety of other designs of single acting cylinders ideally suited to certain applications. These include:

- Compact short stroke cylinders
- Diaphragm cylinders

- Rolling diaphragm cylinders
- Clamping modules
- Cartridge cylinders
- Bellow cylinders
- Rectangular cylinders

Application

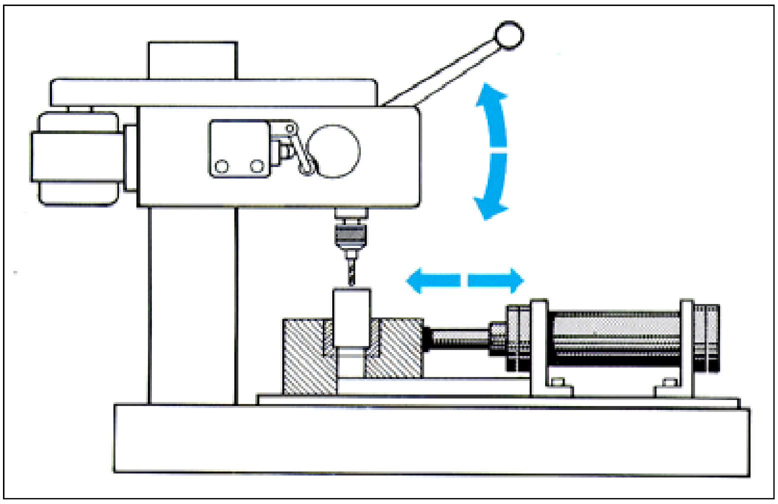


Figure 7.5 – Clamping Device using Single Acting Cylinder

7.2.2 Double-Acting Cylinder

The force exerted by the compressed air moves the piston in a double acting cylinder in two directions. A definite force is applied on both advance and return movements.

Double acting cylinders are used particularly when the piston is required to perform a work function not only on the advance movements but also on the return movement. In principle, the stroke length of the cylinder is unlimited although buckling and bending of the extended piston rod must be allowed for. Here too sealing is by means of sealing rings and pistons or diaphragms/double cup packing.

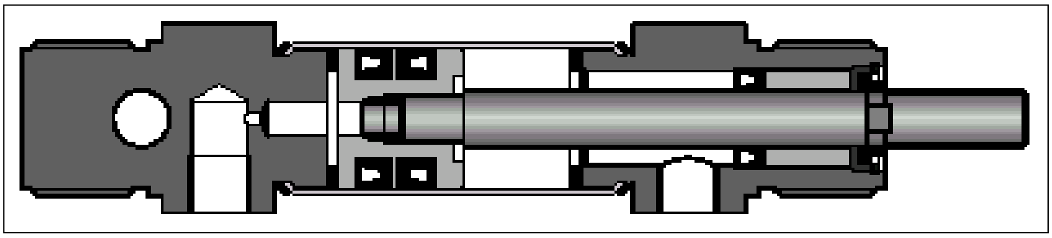


Figure 7.6 – Double Acting Cylinder

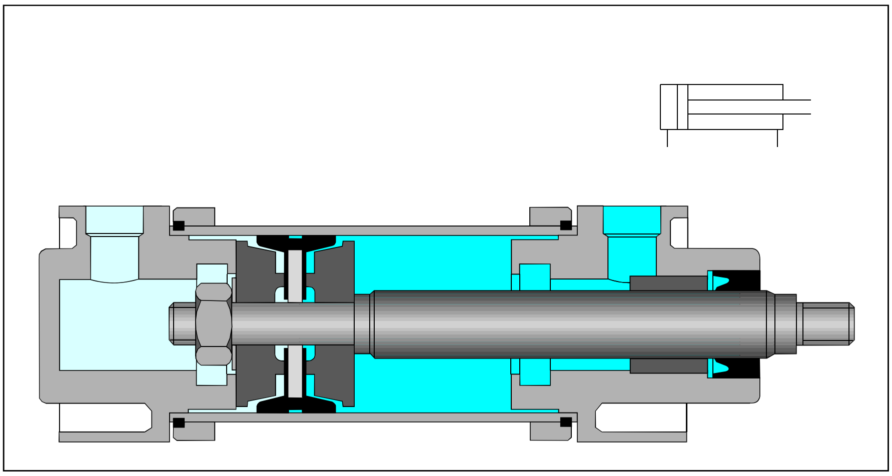


Figure 7.7 – Double Acting Cylinder

Construction of Double Acting Cylinders

Double acting cylinders are used particularly when the piston is required to perform a work function in both directions of motion. The construction principle is similar to that of the single acting cylinder. However, there is no return spring.

In front of the bearing bush is a scraper ring. This ring prevents dust and dirt particles from entering the cylinder space. Bellows are therefore not normally required. A sealing ring is fitted in the bearing cap to seal the piston rod. The bearing bush guides the piston rod and may be made of sintered bronze or plastic-coated metal.

The piston cylinder consists of a cylinder barrel, base and bearing cap, piston with seal (double-cup packing), piston rod, bearing push, scraping ring, in addition there are the connection parts and seals. Steel cylinder barrels are usually made of seamless drawn steel tube. Due to modern production techniques, most new cylinders are having extruded aluminium (anodised) barrels. This reduces cost, increases strength due to profile design and allow corporation of proximity switch mountings into the barrel.

For applications where the operation is infrequent or there are corrosive influences, then the barrel is made of brass or steel with hard chromed or nickel-plated surfaces

The base cap and the bearing cap are for the most part made of cast material (aluminium or malleable cast iron). The two caps can be fastened to the cylinder barrel by tie rods, threads, or flanges.

The piston rod is preferably made from heat-treated steel. A certain percentage of chromium is alloyed with the steel to provide rust protection. The piston rod can be hardened if desired.

Tumbling compacts, the surface and yields a piston rod peak-to-valley height of 0.1 mm. The threads are generally rolled to reduce the danger of fracture.

A sealing ring is fitted in the bearing cap to seal the piston rod. The bearing bush guides the piston rod and may be made of sintered bronze or plastic-coated metal. In front of this bearing bush is a scraping ring. It prevents dust and dirt particles from entering the cylinder space. Bellows are therefore not required.

The double-cup packing seals off the cylinder space. Round-cord rings or 0-rings are used for static sealing because the round-cord ring must be pre-tensioned. This would lead to high frictional losses in dynamic use.

Applications

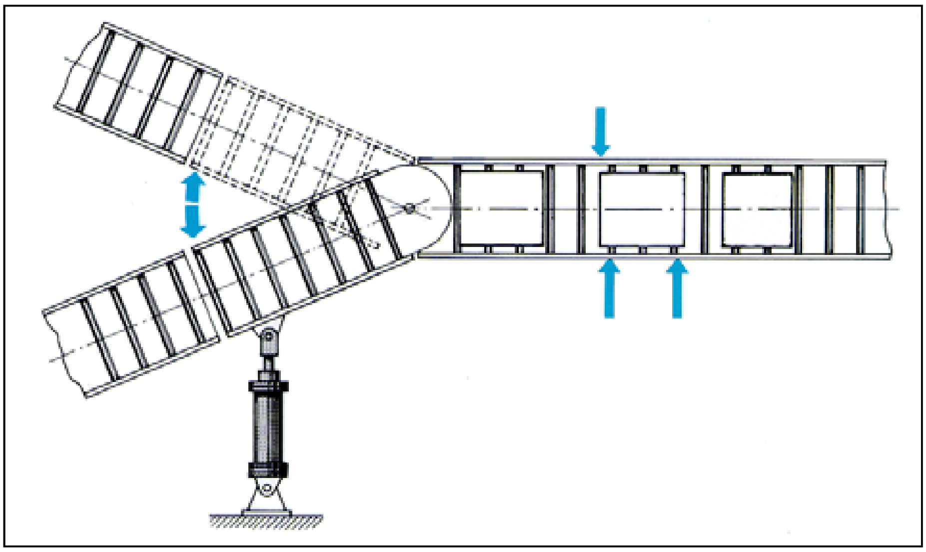


Figure 7.8 – Line Diverter for 2 Tracks

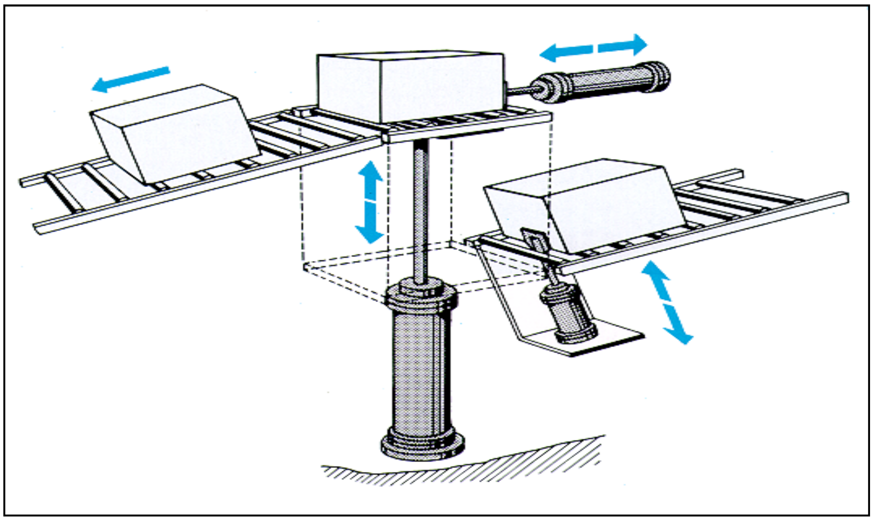


Figure 7.9 – System for Changing or Diverting Conveyors

7.2.3 Cylinder Cushioning

Double Acting Cylinders with End Position Cushioning

If large masses are moved by a cylinder, cushioning is used in the end positions to prevent sudden damaging impacts. Before reaching the end position, a cushioning piston interrupts the direct flow path of the air to the outside. Instead a very small and often adjustable exhaust aperture is open. For the last part of the stroke the cylinder speed is progressively reduced. If the exhaust passage adjustment is too

small or closed off, the cylinder may not reach the end position due to the blockage of air.
When the piston reverses, air flows without resistance through the return valve into the cylinder space. With very large forces and high accelerations extra measure must be taken such as external shock absorbers to assist the load deceleration. When cushioning adjustment is being carried out, it is recommended that to avoid damage, the regulating screw should first be screwed in fully and then backed off to allow the adjustment to be increased slowly to the optimum value.

It is important to consider fitting a magnet to the cylinder piston. Once manufactured the cylinder cannot normally be fitted with sensors magnets due to the difference in construction.

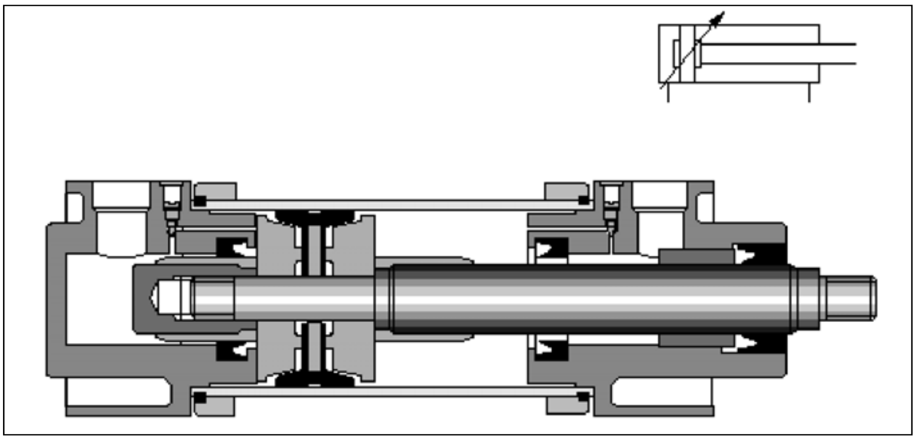


Figure 7.10 – Double Acting Cylinder with End Position Cushioning

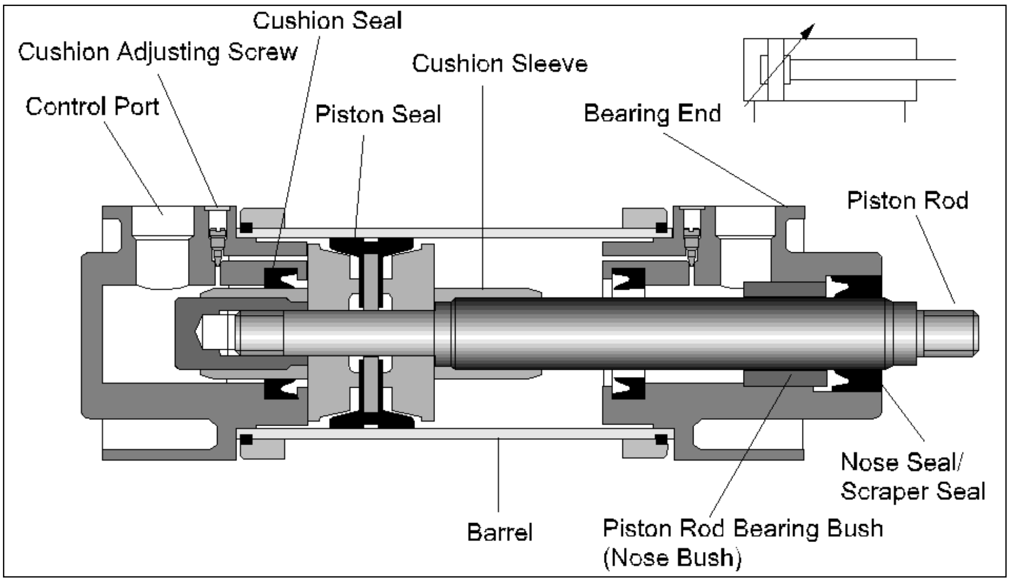


Figure 7.11 – Cylinder Construction for End Position Cushioning

7.3 Types of Pneumatic Cylinders

7.3.1 Cylinder with Double-Sided Piston Rod

This cylinder has a piston rod protruding form both ends. The piston rod passes right through the cylinder. Guidance of the piston rod is better because there are two bearing positions. With this design small lateral loads can also be applied.

Applications: A signal sending unit can be attached to the free side of the piston rod. The force is the same in both directions of motion because the piston area is the same.

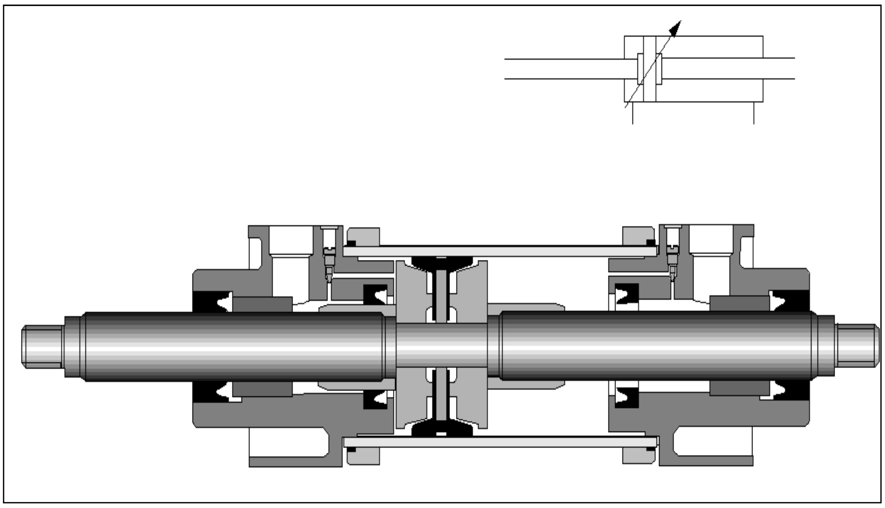


Figure 7.12 – Cylinder with Double Ended Piston Rod

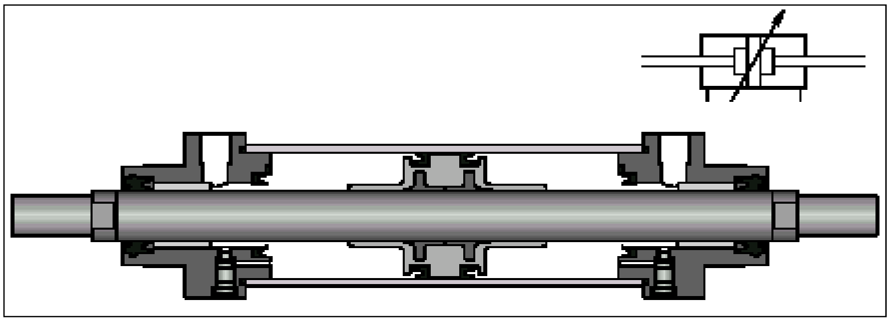


Figure 7.13 – Cylinder with Double Ended Piston Rod

7.3.2 Tandem Cylinder

This design features the characteristics of two double acting cylinders forming a single unit. This increases the effective piston area of the unit for high force applications. The force on the piston rod is almost doubled. It is suitable for applications where a large force is required but the cylinder diameter is restricted.

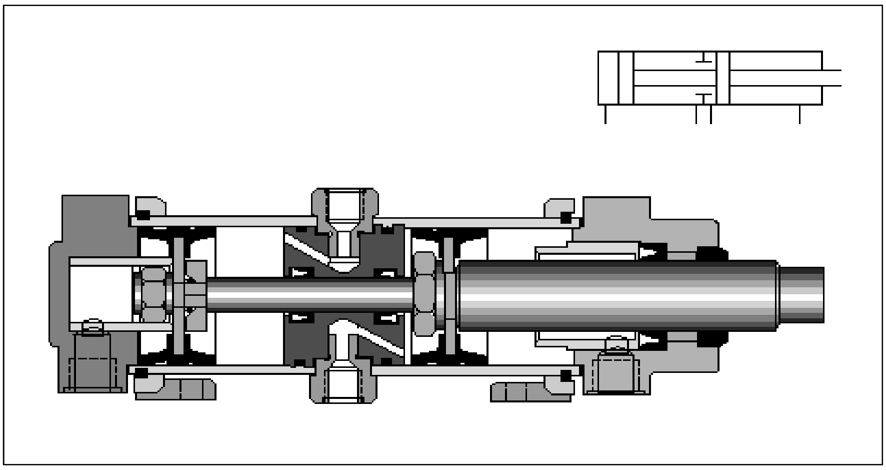


Figure 7.14 – Tandem Double Acting Cylinder

7.3.3 Multi-Position Cylinder

A 3-position or 4-position cylinder consists of two separate cylinders whose piston rods extend in opposite directions. Depending on the triggering and stroke pattern, this cylinder type can assume up to 4 positions. In each case, the cylinder is driven precisely against a stop. It should be noted that, if one end of the piston rod is fixed, the cylinder barrel executes the movement. The cylinder must be connected with flexible line connections.

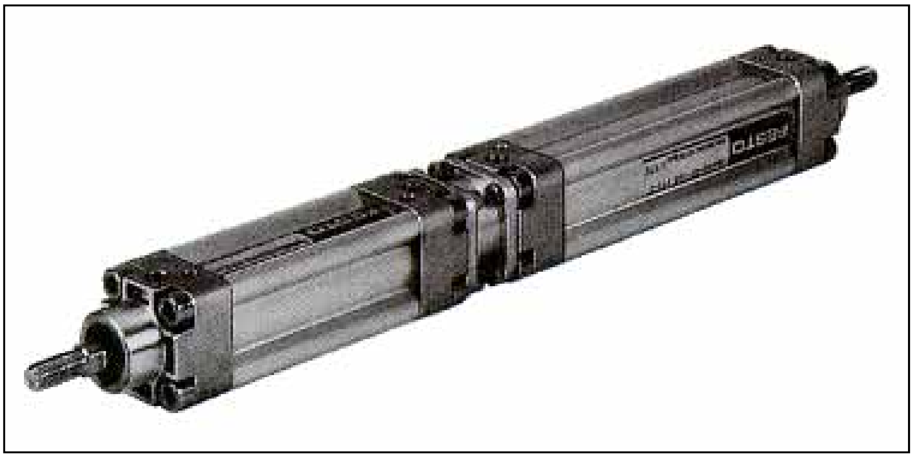


Figure 7.15 – Multi-Position Cylinder (Back to Back Cylinder)

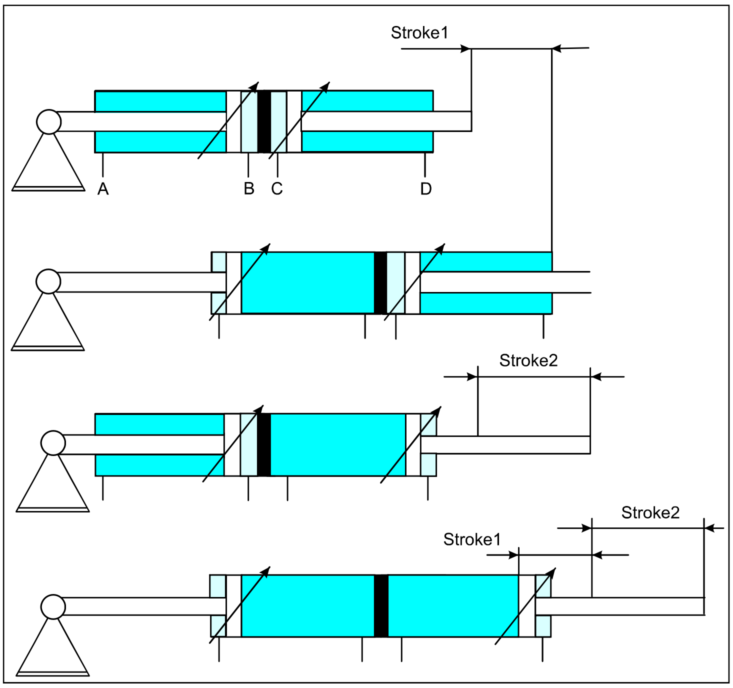


Figure 7.16 – 3-4 Positions are Achieved by Using the Same Stroke or Different Strokes

The multi-position cylinders are ideal for fast positioning with positive end stopping.

7.3.4 Impact Cylinder

If normal cylinders are used for forming operations, the thrust forces of the compressed air are limited. A cylinder producing high kinetic energy is the impact cylinder.

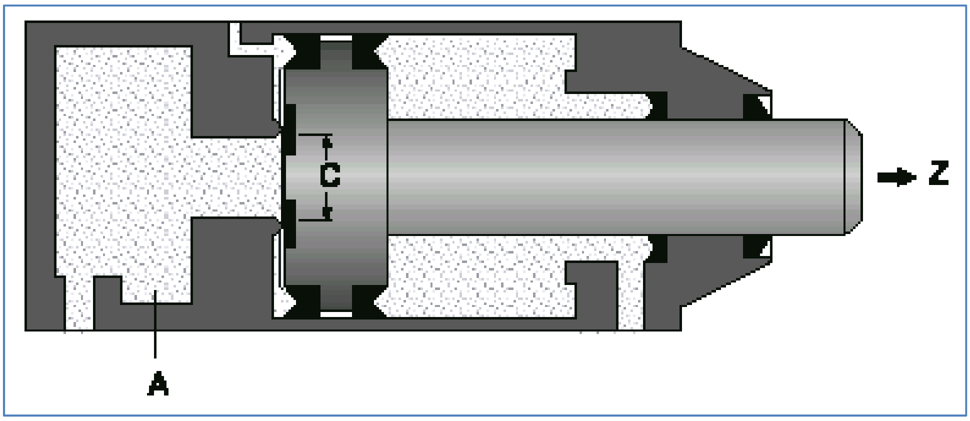


Figure 7.17 - Impact Cylinder

7.4 Cylinder Mountings

The way cylinders are mounted influences the service life, maintenance frequency and the success of the entire installation.

There are three main categories of cylinder mountings:

- Centreline Mounting
- Foot Mounting
- Pivot Mounting

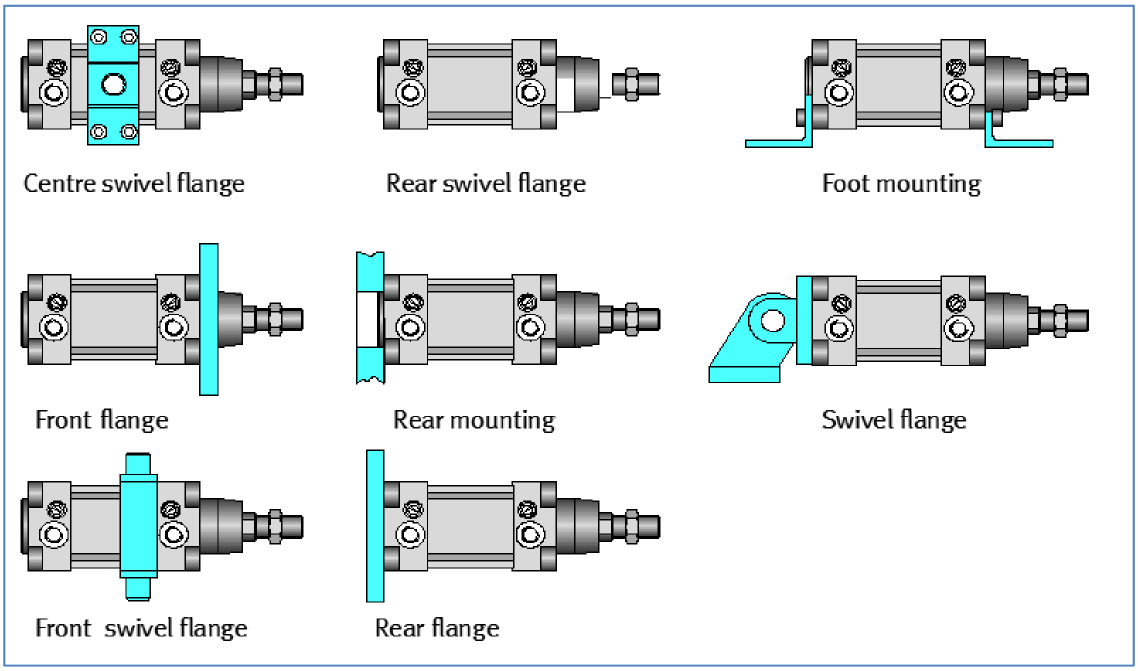


Figure 7.18 - Cylinder Mountings

8.0 Pneumatic Symbols

8.1 Introduction

The development of control systems is assisted by a uniform approach to the representation of the elements and the circuits. The symbols used for the individual elements must display the following characteristics:

- Function
- Actuation and return actuation methods
- Number of connections (all labelled for identification)
- Number of switching positions
- General operating principle
- Simplified representation of the flow path

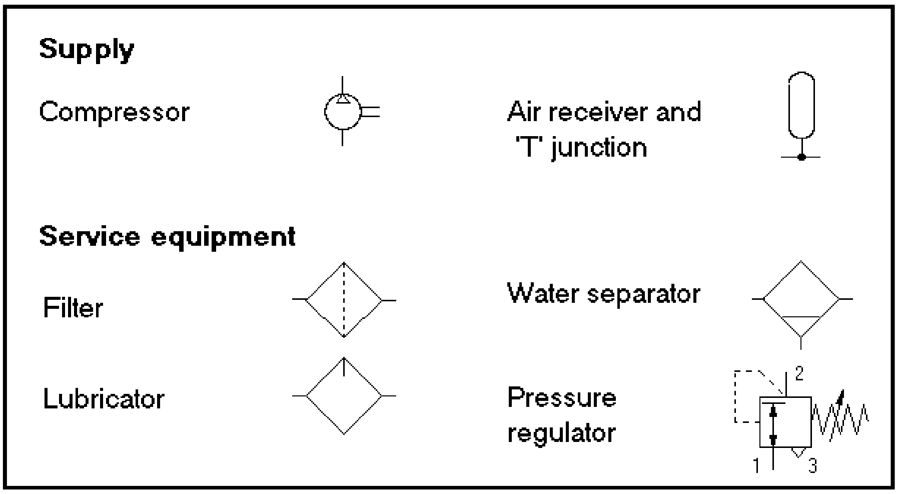
A symbol does not represent the following characteristics:

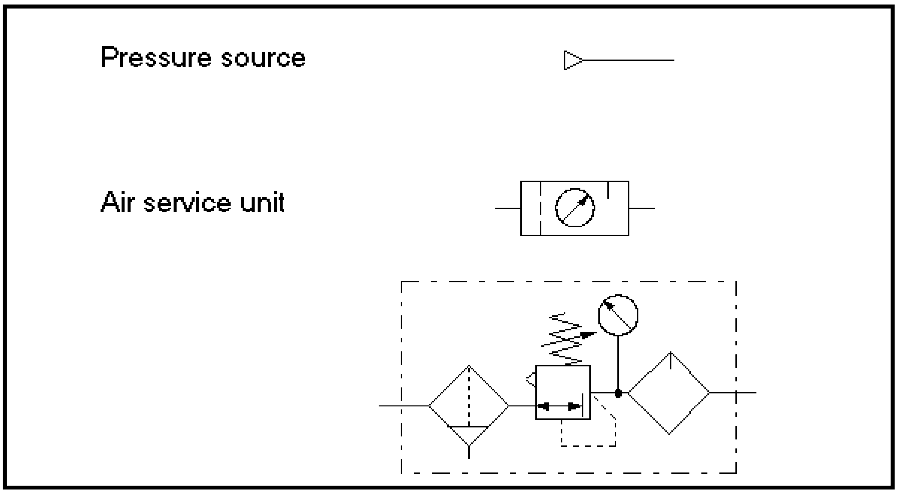
- Size or dimensions of the component
- Manufacturer, methods of construction or costs
- Orientation of the ports
- Any physical details of the element
- Any unions or connections other than junctions

The symbols used in pneumatics are detailed in the standard DIN ISO 1219.

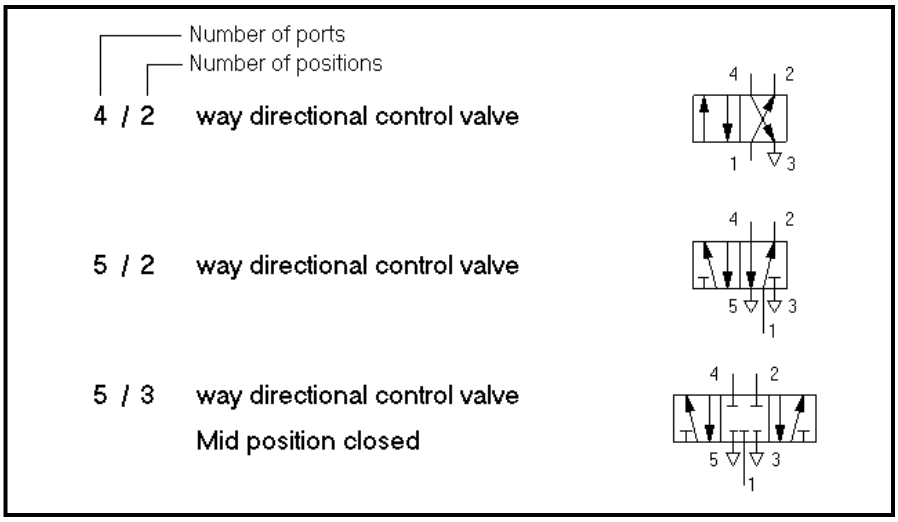
8.2 Symbols and Descriptions of Components

8.2.1 Symbols Used in Energy Conversion and Preparation

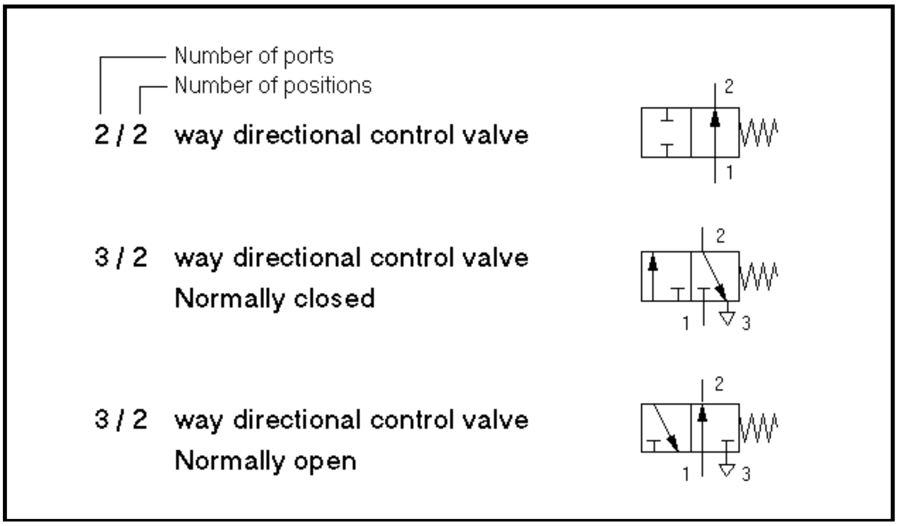




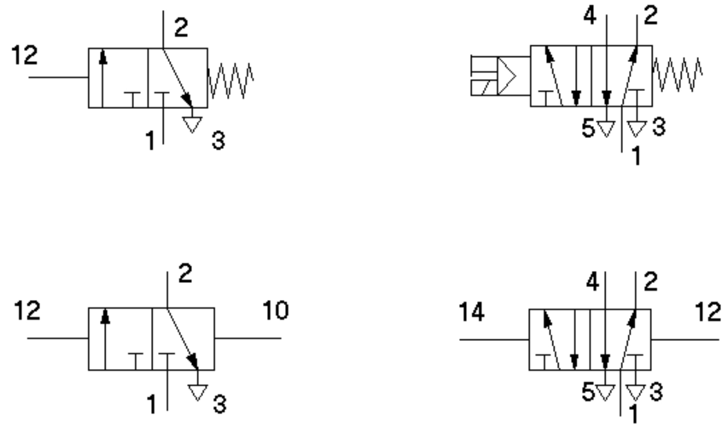
8.2.2 Directional Control Valves – Symbol Development



8.2.3 Directional Control Valves – Ports and Positions

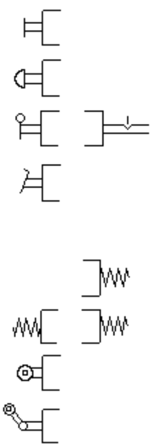


8.2.4 Directional Control Valves – Examples of Designation

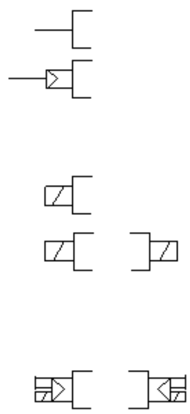


8.2.5 Directional Control Valves – Methods of Actuation

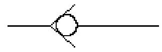
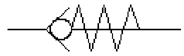
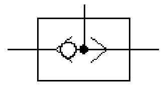
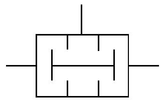
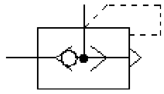
- **Manual**
  - General manual operation
  - Pushbutton
  - Detent lever operation
  - Foot pedal operation
- **Mechanical**
  - Spring return
  - Spring centred
  - Roller operated
  - Idle return roller



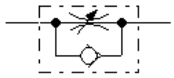
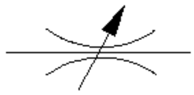
- **Pneumatic**
  - Direct pneumatic actuation
  - Indirect pneumatic actuation (piloted)
- **Electrical**
  - Single solenoid operation
  - Double solenoid operation
- **Combined**
  - Double solenoid and pilot operation with manual override



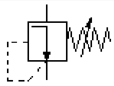
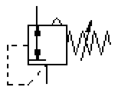
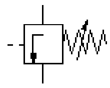
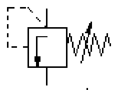
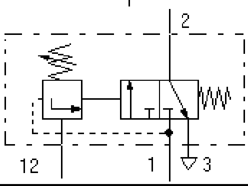
8.2.6 Non-Return Valves and Derivatives

Check valve	
Spring loaded check valve	
Shuttle valve 'OR' function	
Two pressure valve 'AND' function	
Quick exhaust valve	

8.2.7 Flow Control Valves

One-way flow control valve	
Flow control valve adjustable	

8.2.8 Pressure Valves

Adjustable pressure regulating valve Non-relieving type	
Adjustable pressure regulating valve relieving type (overloads are vented)	
Sequence valve external source	
Sequence valve in-line	
Sequence valve combination	

8.2.9 Auxiliary Symbols

Exhaust port

Exhaust port
with threaded connection

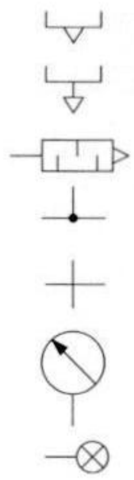
Silencer

Line connection (fixed)

Crossing lines
(not connected)

Pressure gauge

Visual indicator



8.2.10 Linear Actuators

Single acting cylinder

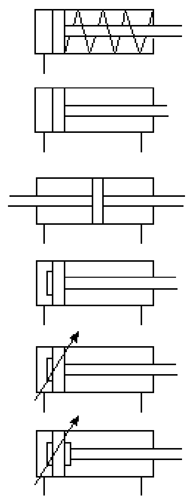
Double acting cylinder

Double acting cylinder
with double ended piston rod

Double acting cylinder with non-adjustable
cushioning in one direction

Double acting cylinder with single adjustable
cushioning

Double acting cylinder with adjustable
cushioning in both directions



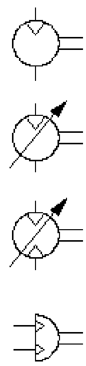
8.2.11 Rotary Motion

Air motor, rotation in one direction
fixed capacity

Air motor, rotation in one direction
variable capacity

Air motor, rotation in both directions
variable capacity

Rotary actuator limited travel
rotation in both directions



9.0 Developing Pneumatic Circuit Diagrams

9.1 Introduction

The solution to a control problem is worked out according to a system with documentation playing an important role in communicating the final result. The circuit diagram should be drawn using standard symbols and labelling. Comprehensive documentation is required including most of the following:

- Function diagram
- Circuit diagram
- Description of the operation of the system
- Technical data on the components

Supplementary documentation comprising

- Parts list of all components in the system
- Maintenance and fault-finding information
- Spare parts list

There are two primary methods for constructing circuit diagrams:

- The so-called intuitive methods
- The methodical design of a circuit diagram in accordance with prescribed rules and instructions

Whereas much experience and intuition is required in the first case and above all, a great deal of time where complicated circuits are concerned; designing circuit diagrams of the second category requires methodical working and a certain amount of basic theoretical knowledge.

Regardless of which method is used in developing the circuit diagram, the aim is to end up with a properly functioning and reliably operating control. Whereas previously emphasis was placed on the least expensive hardware solution, more importance is now attached to operational reliability and ease of maintenance by a clear layout and documentation.

This inevitably leads to increased usage of methodical design processes. In such cases, the control is always constructed in accordance with the given procedure and is less dependent upon personal influences from the designer. In many cases, however, more components will be required for the methodical solution than in a circuit devised by the intuitive method.

This additional material requirement will usually be rapidly compensated for by time-saving at the project stage and also later in terms of maintenance.

Generally, it must be ensured that the time spent in project design and particularly in simplifying the circuit, is in reasonable proportion to the overall effort.

9.2 Control Chain Flow Chart

The control chain is a categorised representation of a control system, from which amongst other things, the signal direction can be determined.

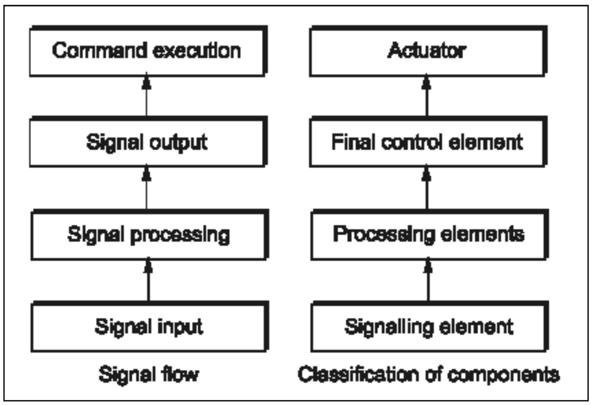


Figure 9.1- Control Chain Flow Chart

With the circuit design, the system breakdown produces a rough separation of signal input, signal processing, signal output and command execution. In practice, this separation can be easily seen. In the case of extensive installations, the control section is generally in a separate area to that of the power section.

The signal flow diagram indicates the path of a signal from signal input through to command execution. The following diagram illustrates a few examples for the allocation of devices to signal flow:

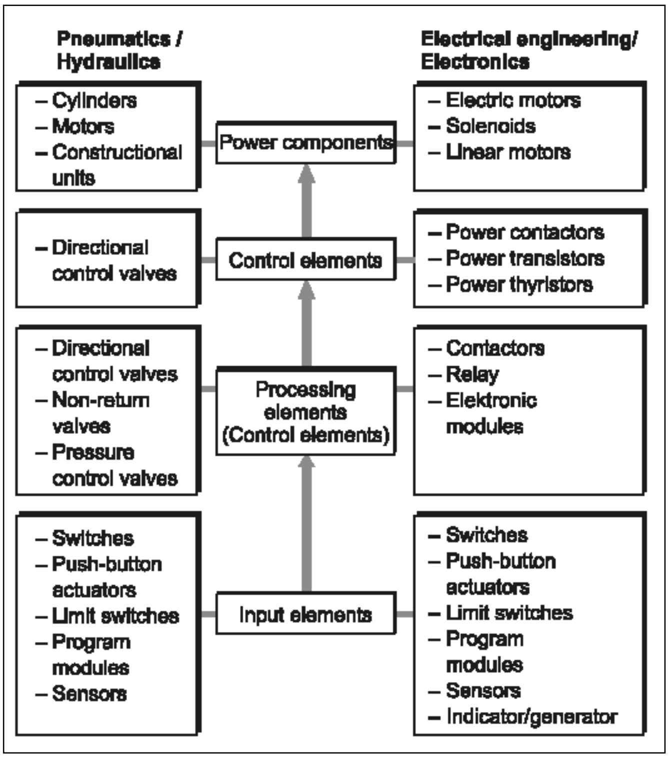


Figure 9.2 – Allocation of Devices to Signal Flow

The illustration below clearly shows the structure of the control chain.

- The input elements are the manually actuated valves 1S1, 1S2 (push-button valves) and the mechanically actuated valve 1S3 (roller lever valve).
- The processing element (processor) is the shuttle valve 1V1,
- The control element is the directional control valve 1V2.
- The power component is the cylinder 1A.

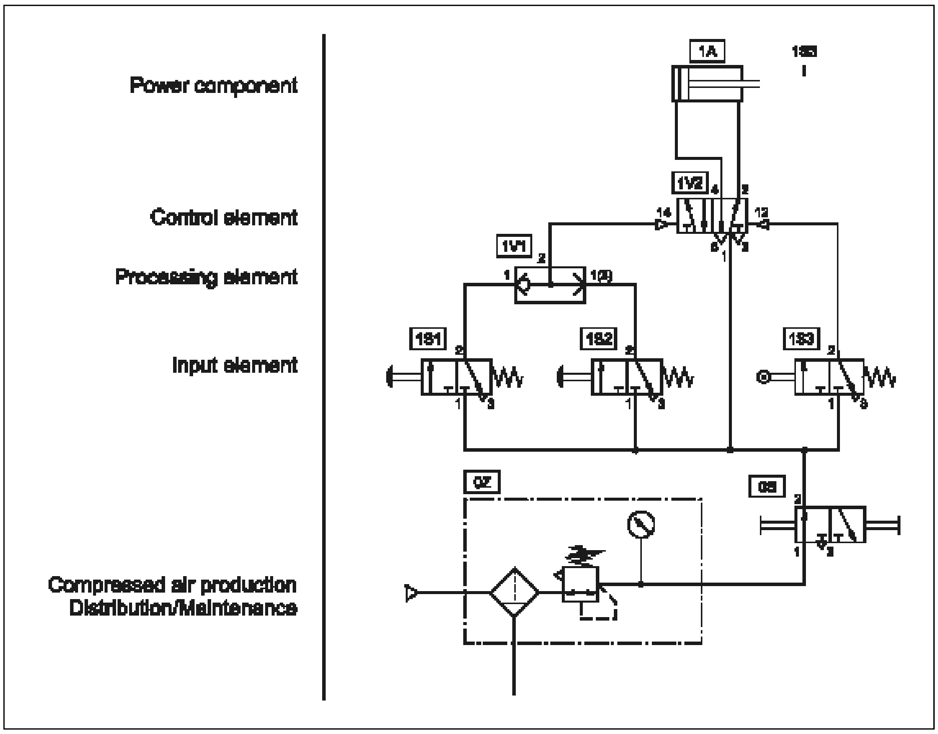


Figure 9.3 – Circuit Diagram

9.3 Circuit Layout

The piston rod of a double-acting pneumatic cylinder advances if either a manual push button or a foot pedal is operated. The cylinder returns to its starting position slowed down after fully extending. The piston rod will return provided the manual actuators have been released.

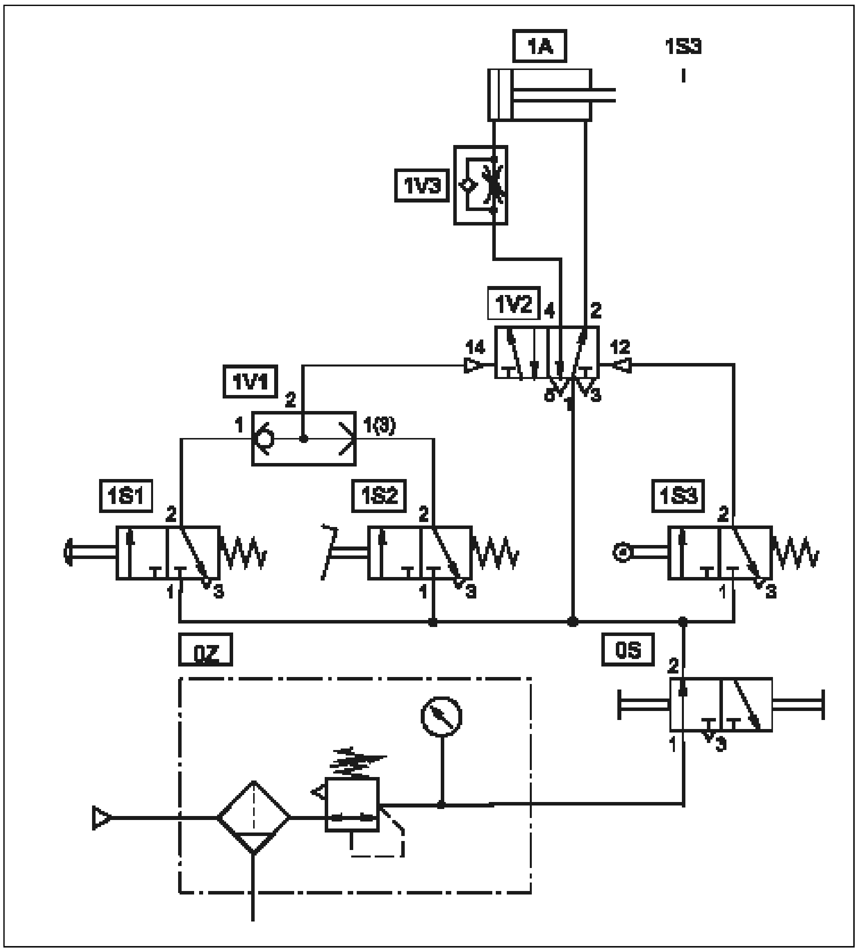


Figure 9.4 – Circuit Diagram

The roller lever valve 1S3 is positioned as a limit switch in the forward end position of the cylinder. The circuit diagram shows this element situated at the signal input level and does not directly reflect the orientation of the valve. The mark on the circuit at the extended cylinder position indicates the physical position of the limit switch 1S3 for circuit operation.

If the control is complex and contains several working elements, the control should be broken down into separate control chains, whereby a chain is formed for each cylinder. Wherever possible, these chains should be drawn next to each other in the same order as the operating sequence.

9.4 Designation of Individual Elements

Signal elements should be represented in the normal position in the circuit diagram. If valves are actuated in the initial position as a start precondition, this must be indicated by the representation of a trip cam. In this case, the actuated switching position must be connected.

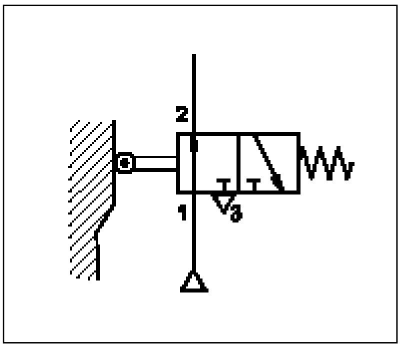


Figure 9.5 – Actuated Initial Position

With this type of designation, elements are divided into groups. Group 0 contains the elements for the power supply, groups 1,2,... designate the individual control chains. One group number is generally allocated for each cylinder.

1A, 2A, etc.	Power components
1S1, 2S1, etc	Limit switches, activated in the retracted end position of cylinders 1A, 2A
1S2, 2S2, etc	Limit switches, activated in the forward end position of cylinders 1A, 2A

Figure 9.6 – Designation by Letters

To summarise:

- Physical arrangement of the elements is ignored.
- Draw the cylinders and directional control valves horizontally wherever possible.
- The energy flow within the circuit moves from the bottom to the top.
- Energy source can be shown in simplified form.
- Show elements in the initial position of the control. Identify actuated elements by a cam.
- Draw pipelines straight without cross-over wherever possible.

9.5 Representing the Working Sequence of a Pneumatic Circuit

There are a number of methods representing the working sequence of a pneumatic circuitry. In order to understand the different methods of representing the working sequence of a pneumatic circuitry we will use the example of a bending and punching fixture.

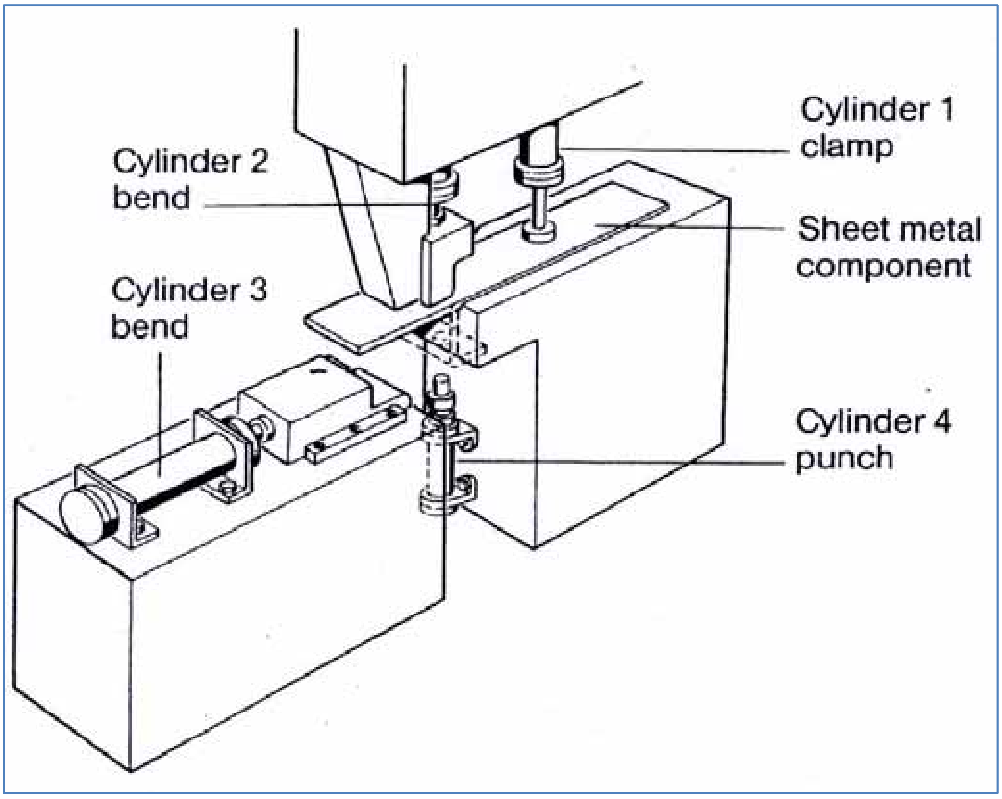
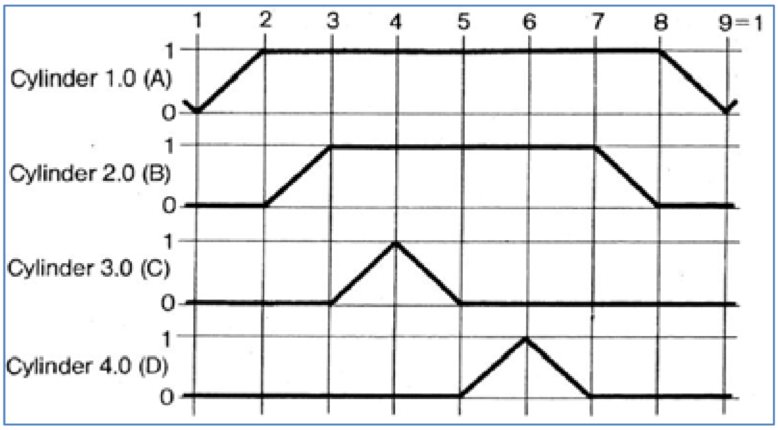


Figure 9.7 - Bending and Punching Fixture

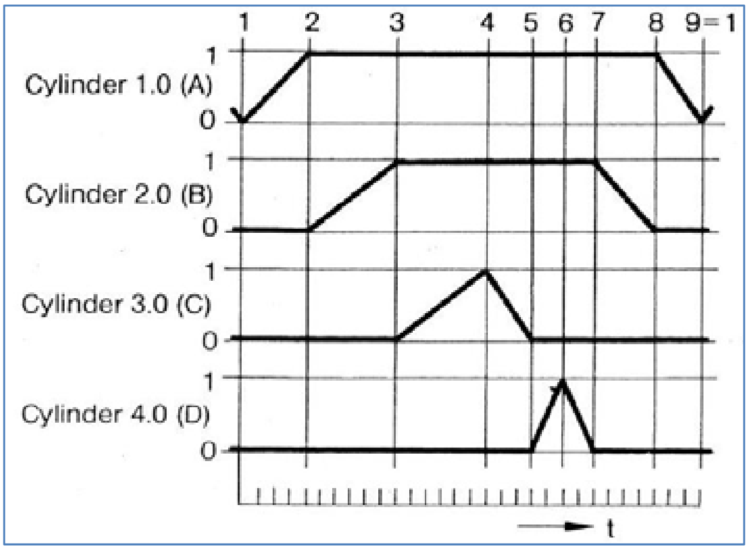
Sheet metal components are placed by hand in a holder. The sheet metal component is clamped by means of a pneumatic cylinder. Two other cylinders bend the component until another cylinder punches a hole.

9.5.1 Graphical Form of Representation

a. Displacement-Step Diagram



b. Displacement-Time Diagram



c. Designations in the Circuit Diagram

Designation	Elements	Example
1.0, 2.0, 3.0, ...	Working Elements	Cylinders, etc
1.1, 2.1, 3.1, ...	Actuating Elements	4/2-way, 5/2-way DCV, etc.
1.2, 1.4, 2.2, 2.4, ... 1.3, 1.5, 2.3, 2.5, ...	Signal Elements (Advance Movement) (Return Movement)	3/2-way DCV, shuttle valve, two-pressure valve, delay valve, etc.
0.1, 0.2, 0.3, ...	Supply Elements	Service Unit, Shut-off Valve and Reversing valve for cascade.
1.02, 1.03, 2.02, ...	Auxiliary Devices	Throttle valve, relief valve, check valve, quick exhaust valve, etc

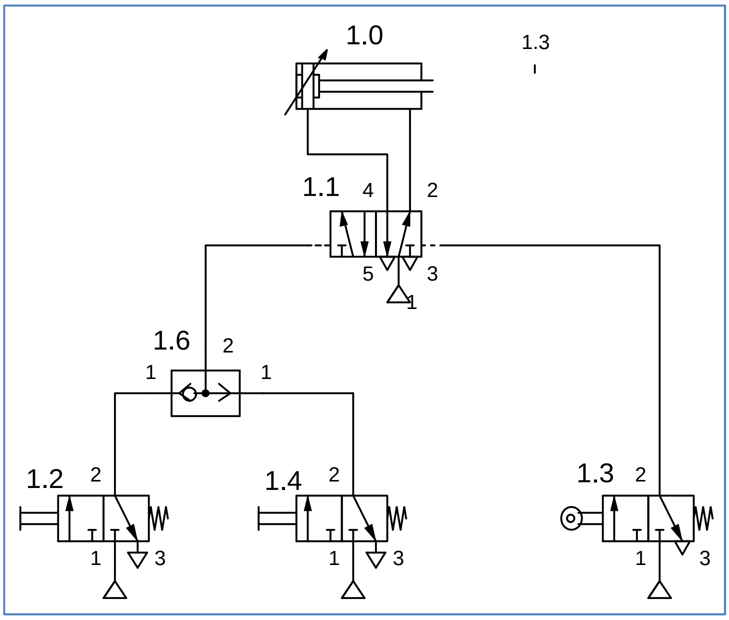


Figure 9.8 - Example 1

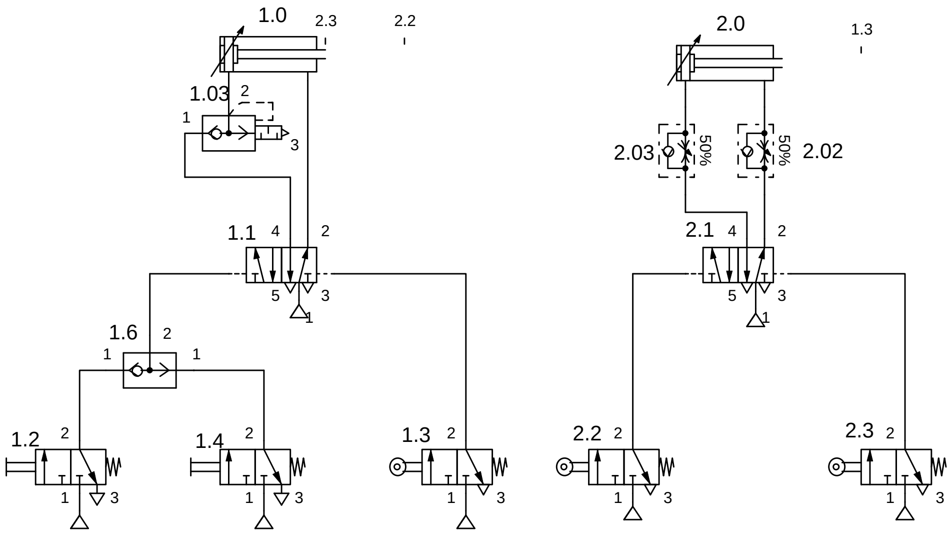
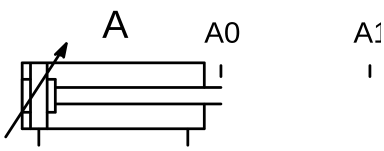


Figure 9.9 - Example 2

9.5.2 Designation Using Alphabetic Characteristics

This type of designation is often used for developing circuit diagrams, but it is also used frequently in the circuit diagram instead of numerical designation. With this method, the working elements are given capital elements and signal elements are given small letters.



A, B, C, ... Allocated to the working elements.
a_1, b_1, c_1, ... Allocated to the signal elements in the forward end position.
a_0, b_0, c_0, ... Allocated to the signal elements in the rear end position.

For the above sequence, it would be

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

10.0 Cascade Control Systems

10.1 Introduction

The cascade system is a method used for designing multiple cylinder circuits. This method is very useful when we encounter signal overlaps of opposing signals.

10.2 Basic Circuits with Single Cylinders

To be able to design pneumatic circuits, it is better for one to have basic knowledge on the designing simple single cylinder circuits. With this foundation, one would be able to move on to the designing more complicated circuits involving many more cylinders.

10.2.1 Control of a Single-Acting Cylinder

When the 3/2-way DCV is actuated, compressed air flows from P to A, and line R is blocked. Resetting by spring causes the cylinder chamber to exhaust from A to R, and the compressed air connection P is blocked.

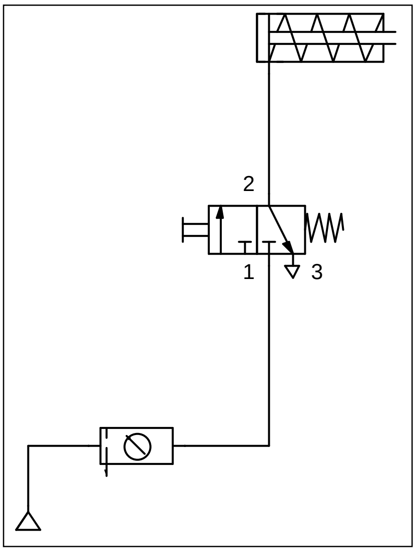


Figure 10.1 - Control of a Single-Acting Cylinder

10.2.2 Control of a Double-Acting Cylinder

Either a 4/2-way or a 5/2-way DCV is used to actuate the double-acting cylinder. When the valve is actuated, compressed air flows from P to A extending the cylinder rod, and the exhaust from B to R. When the valve is released, compressed air flows from P to B retracting the cylinder rod and the exhaust A to R.

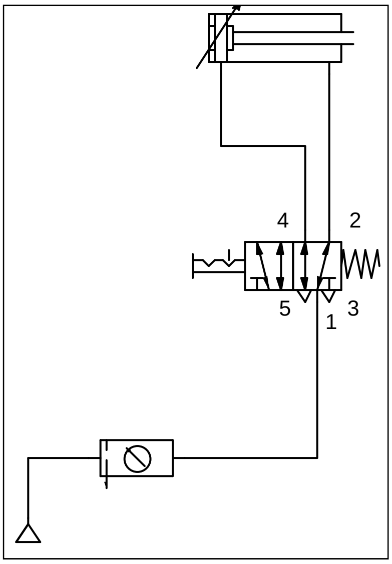


Figure 10.2 - Control of a Double-Acting Cylinder

10.2.3 Indirect Control of a Single-Acting Cylinder

Actuation of valve 1.2 opens the passage from P to A to the compressed air, and hence the signal at Z on the valve 1.1. Owing to valve 1.1 switching over, air flows from P to A and thus to the single-acting cylinder.

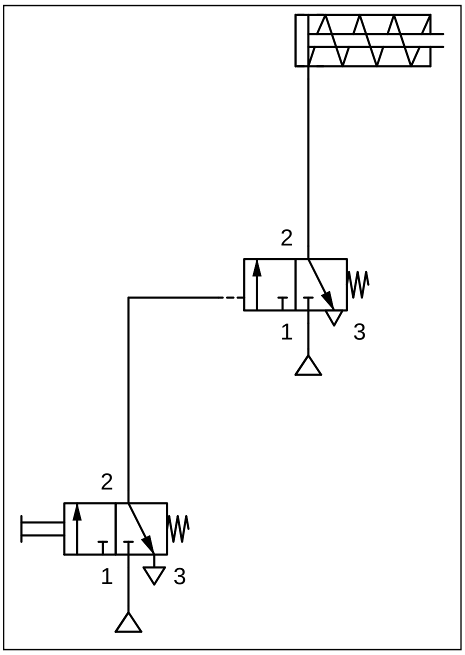


Figure 10.3 - Indirect Control of a Single-Acting Cylinder

10.2.4 Indirect Control of a Double-Acting Cylinder

When valve 1.2 is actuated, it sends a signal to the 5/2-way DCV 1.1 which switches over. The cylinder moves out. It remains in this position until a signal from valve 1.3 switches valve 1.1 back at Y.

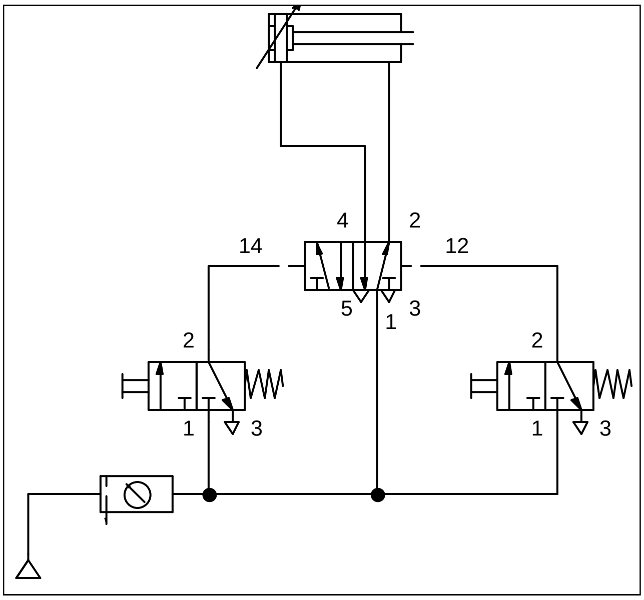


Figure 10.4 - Indirect Control of a Double-Acting Cylinder

10.2.5 Control with Shuttle Valve

On actuating valve 1.2, the compressed air flows from P to A and also from P_1 to A to the cylinder. The same occurs when switched over to valve 1.4. Without the shuttle valve, the air would escape through the exhaust of the other valve when 1.2 or 1.4 is operated.

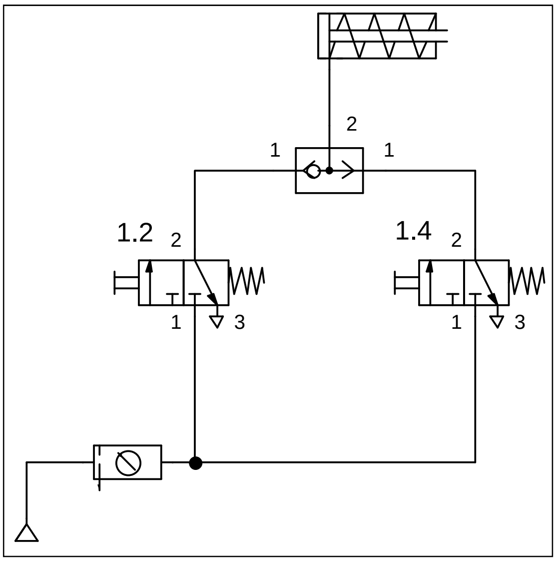


Figure 10.5 - Control with Shuttle Valve

10.2.6 Speed Regulation with Single-Acting Cylinders

By placing the flow control valve in various positions, you can regulate the speed of the cylinder either for the advance stroke or the return stroke. Figure 10.6 shows the speed control for the advance movement and Figure 10.7 for the return movement. By placing two flow control valves, you can control both the advance and return stroke. This is shown in Figure 10.8.

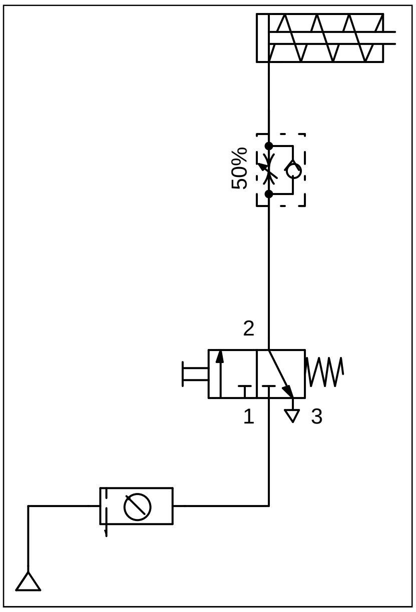


Figure 10.6 - Speed Regulation on Single-Acting Cylinders for Advance Stroke

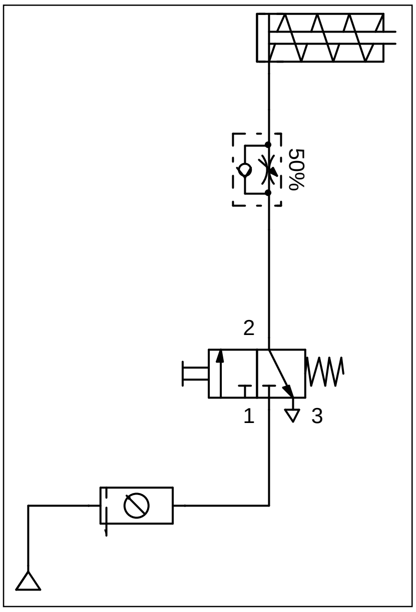


Figure 10.7 - Speed Regulation on Single-Acting Cylinders for Return Stroke

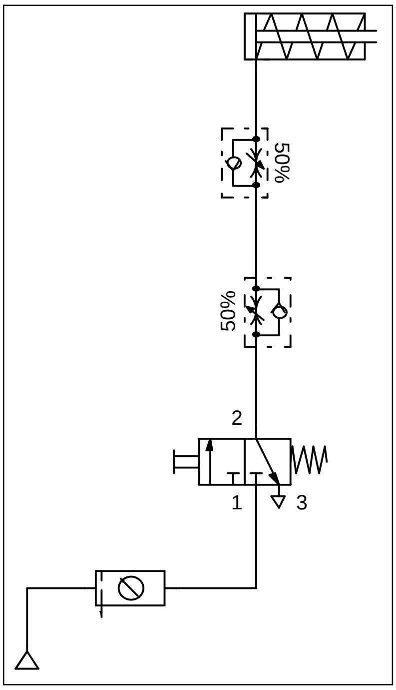


Figure 10.8 - Speed Regulation on Single-Acting Cylinders for Both Strokes

10.2.7 Speed Regulation with Double-Acting Cylinders

There are two ways of regulating the speed for a double-acting cylinder, you can exhaust throttle (meter-out) or supply air throttle (meter-in). For exhaust throttling, there is an initial jolt and then the forces are equalised but it has a better possibility for regulating. For supply air throttling, it has a steady initial motion but poor possibility of regulation. It is used mainly for small cylinders against the load.

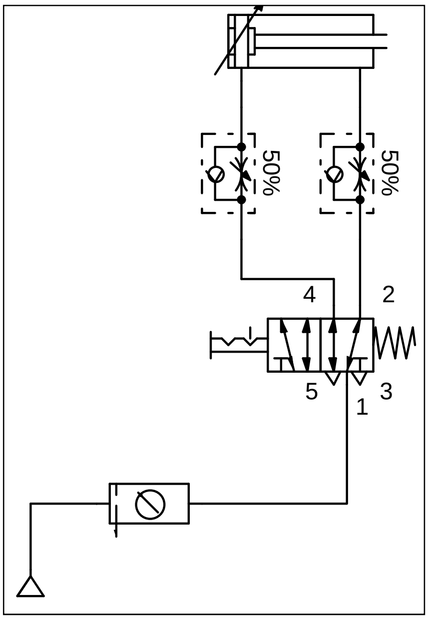


Figure 10.9 - Exhaust Throttling

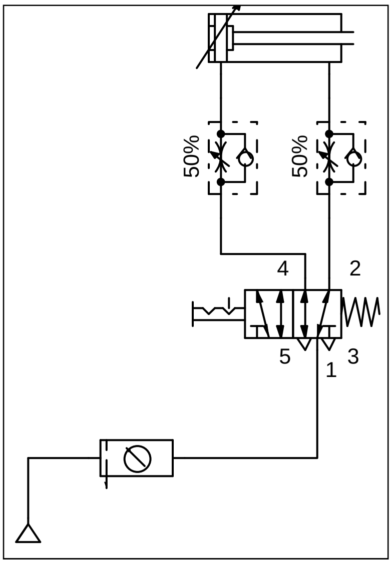


Figure 10.10 - Supply Air Throttling

10.2.8 Raising the Speed on Single-Acting and Double-Acting Cylinders

The speed of either the advance or the return stroke of the cylinder is increased by the use of the quick exhaust valve.

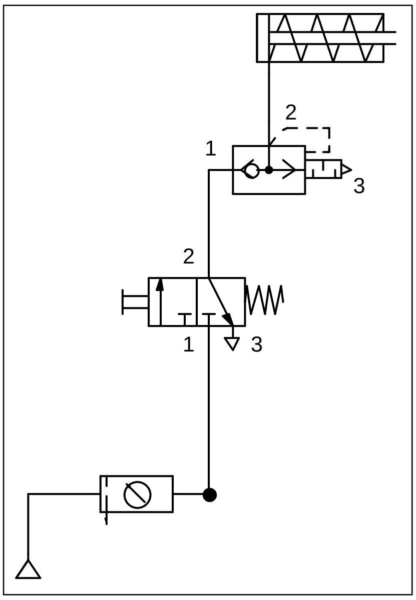


Figure 10.11 - Increasing the Return Speed of a Single-Acting Cylinder

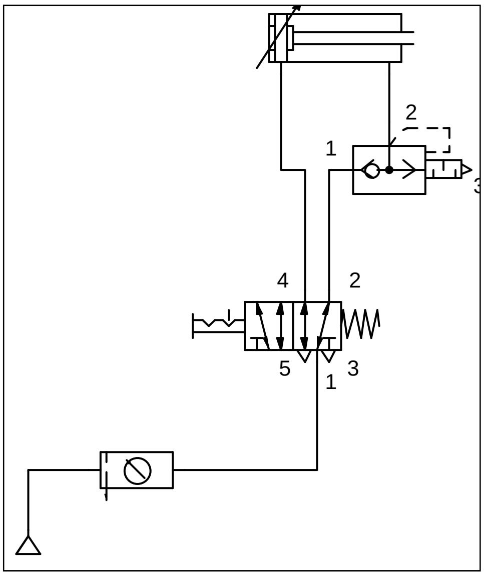


Figure 10.12 - Increasing the Advance Movement of a Double-Acting Cylinder

10.2.9 Control with Two-Pressure Valve

Actuation of valves 1.2 and 1.4 produces the signal at P_1 and P_2, thus permitting compressed air to be applied to the cylinder.

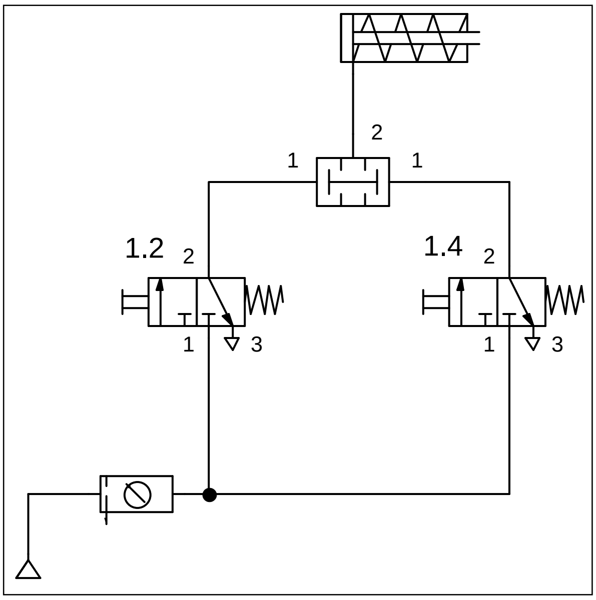


Figure 10.13 - Control with Two-Pressure Valve

10.2.10 Automatic Return Control of a Double-Acting Cylinder Using a Limit Switch

When the piston rod touches the valve 1.3, a signal is provided for the piston to return to its original state.

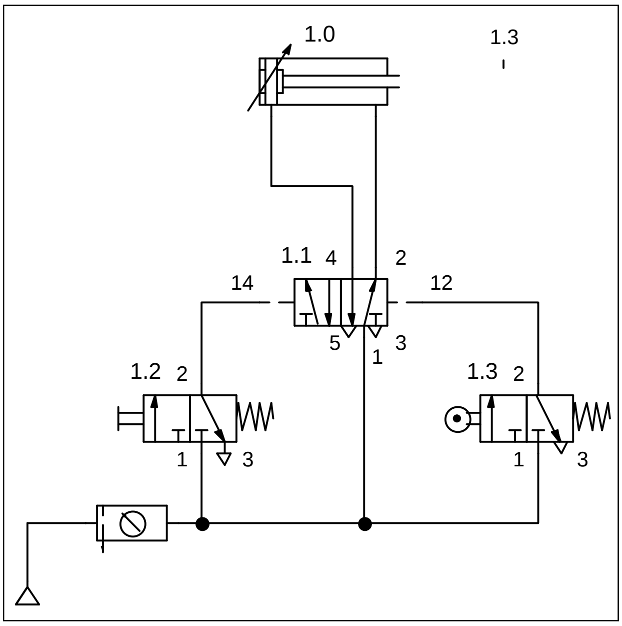


Figure 10.14 - Automatic Return Control of a Double-Acting Cylinder

10.2.11 Automatic Return Control of a Double-Acting Cylinder Using a Limit Switch and a Timer

When the piston rod touches the valve 1.3, a signal is sent to the timer which will return the piston to its original state are a preset time.

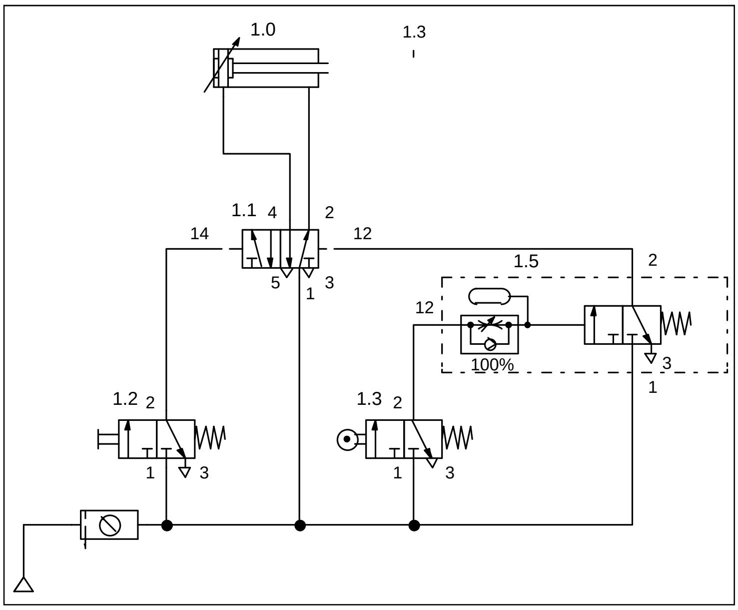


Figure 10.15 - Automatic Return Control of a Double-Acting Cylinder with Timer

10.3 Pneumatic Circuit with Multi-Cylinders

10.3.1 A+ B+ A- B-

In this basic two-cylinder circuit, cylinder A moves out followed by cylinder B. After cylinder B has extended, cylinder A retracts followed by cylinder B. The following circuit shows this.

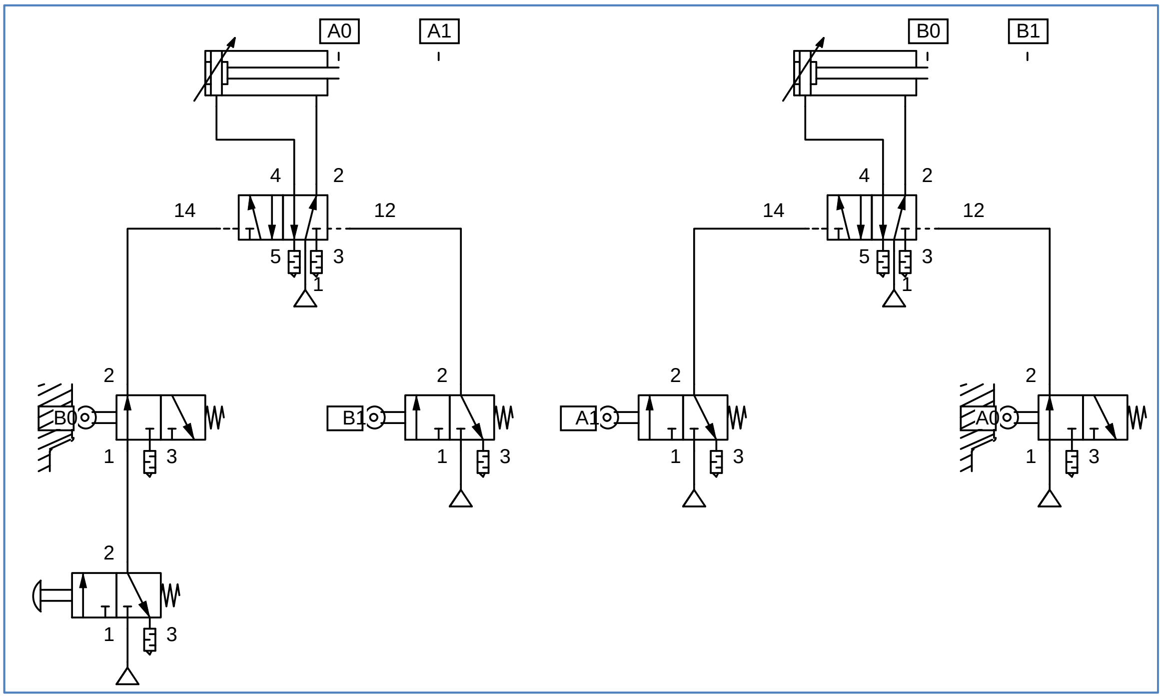


Figure 10.16 - Circuit Diagram for A+ B+ A- B-

10.4 Introduction to Cascade Systems

The cascade system uses signal cut-out by means of reversing valves. Air supply to the various limit switches are no longer derived from the main air supply, but from a reversing valve. These valves are controlled by limit switches.

10.5 Design of a Cascade System

In the design of cascades, they work on the principle that at any one time, only one output line is pressurised. The following arrangements ensure that at any one time, only one output line is pressurised and all others are vented to atmosphere.

10.5.1 Arrangement for 1 Reversing Valve

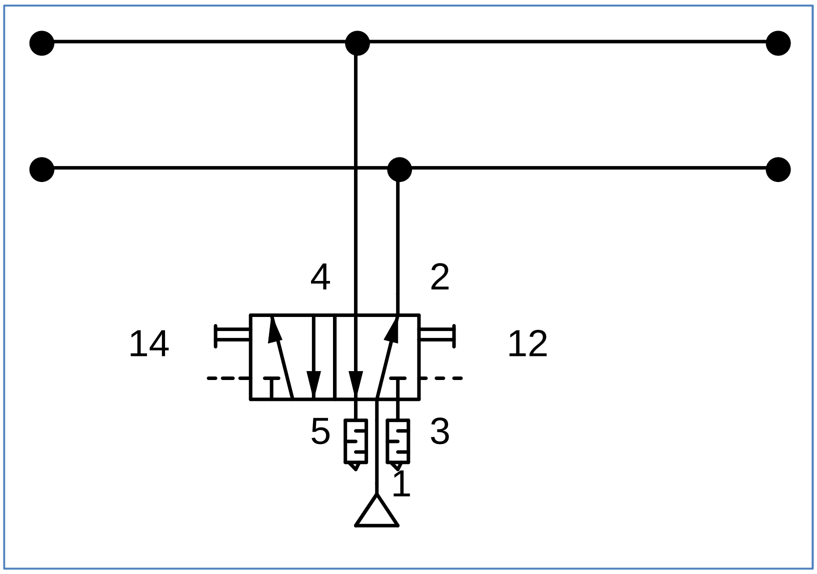


Figure 10.17 - Arrangement for 1 Reversing Valve

10.5.2 Arrangement for 2 Reversing Valves

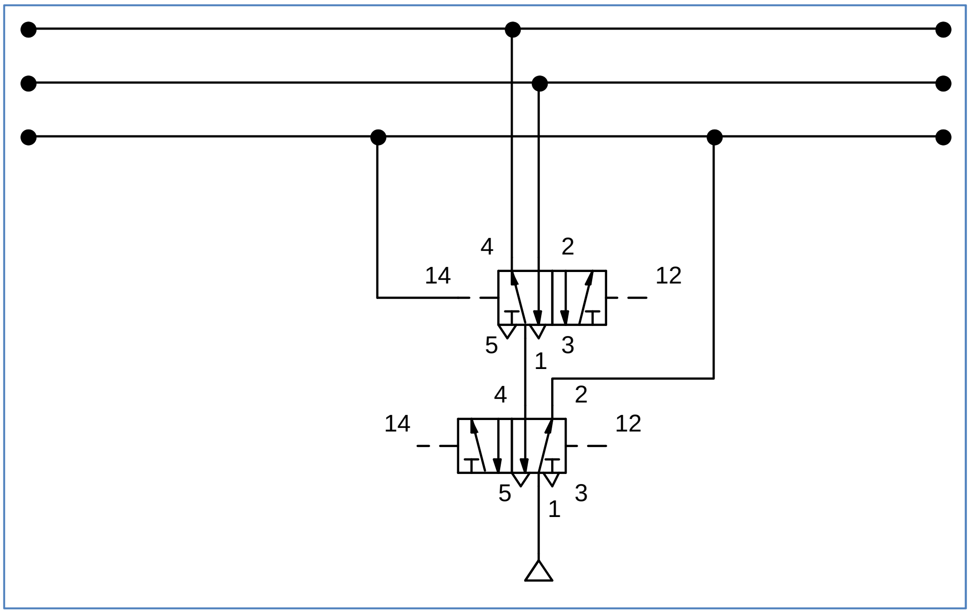


Figure 10.18 - Arrangement for 2 Reversing Valves

10.5.3 Arrangement for 3 Reversing Valves

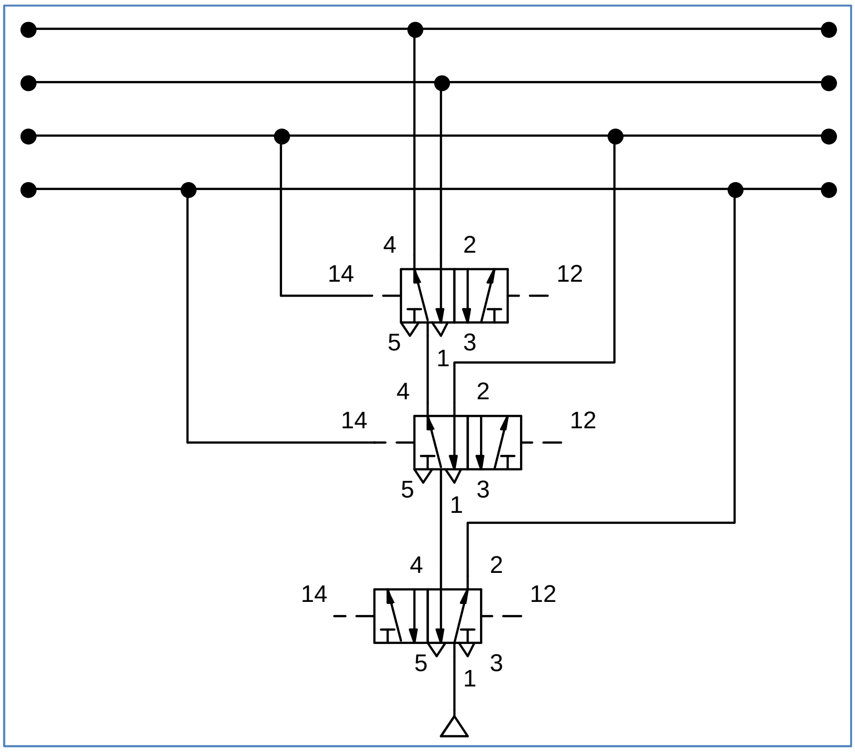


Figure 10.19 - Arrangement for 3 Reversing Valves

10.5.4 Controlling the Reversing Valves with Limit Switches

The switching of groups is done through limit switches.

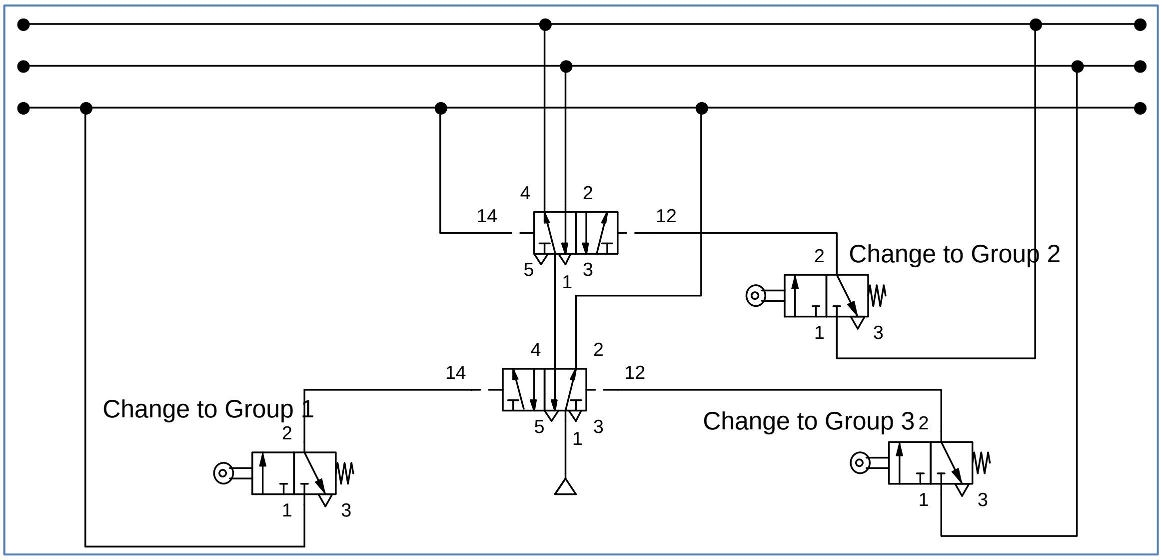


Figure 10.20 - Controlling the Reversing Valves with Limit Switches

10.5.5 Various Stages when Switching through the Cascade

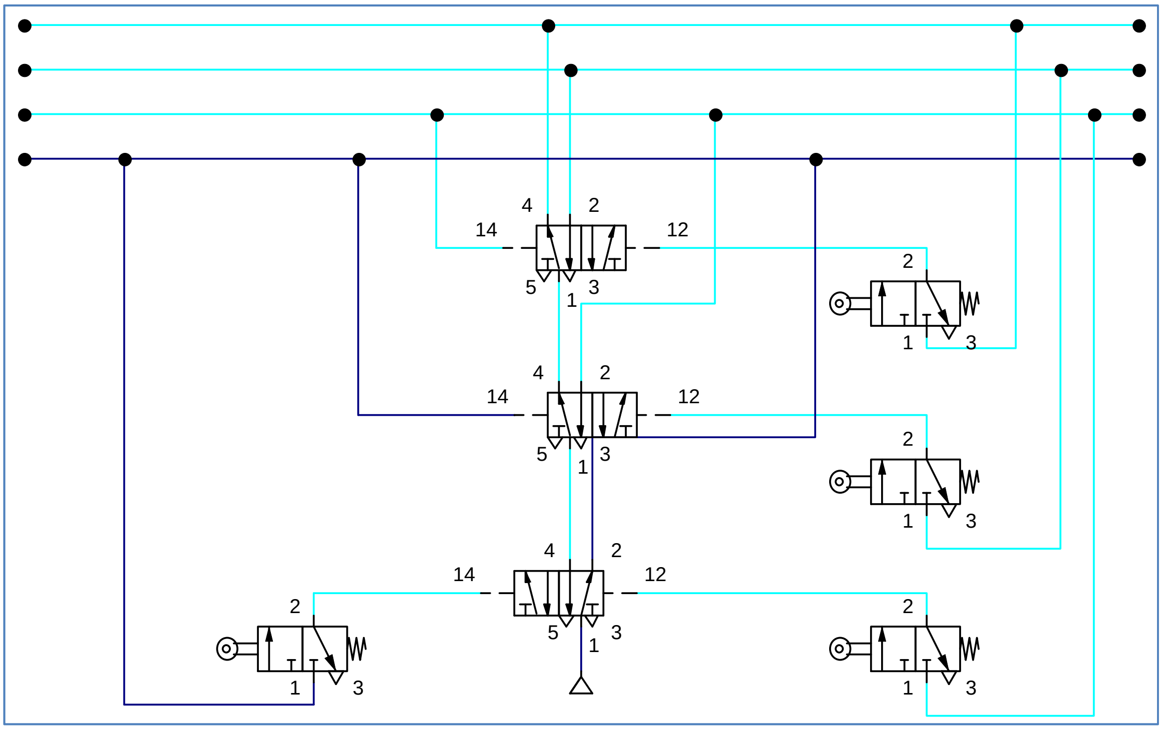


Figure 10.21 – Initial Stage Line 4 is Live

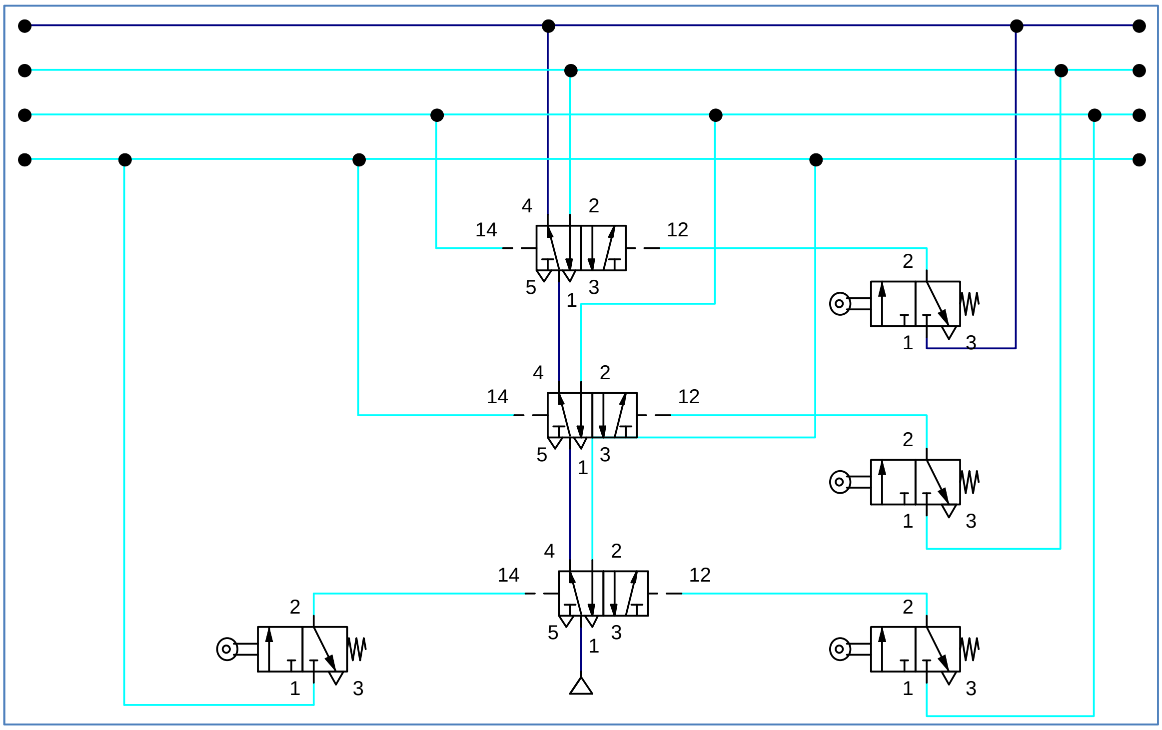


Figure 10.22 – Line 1 is Live

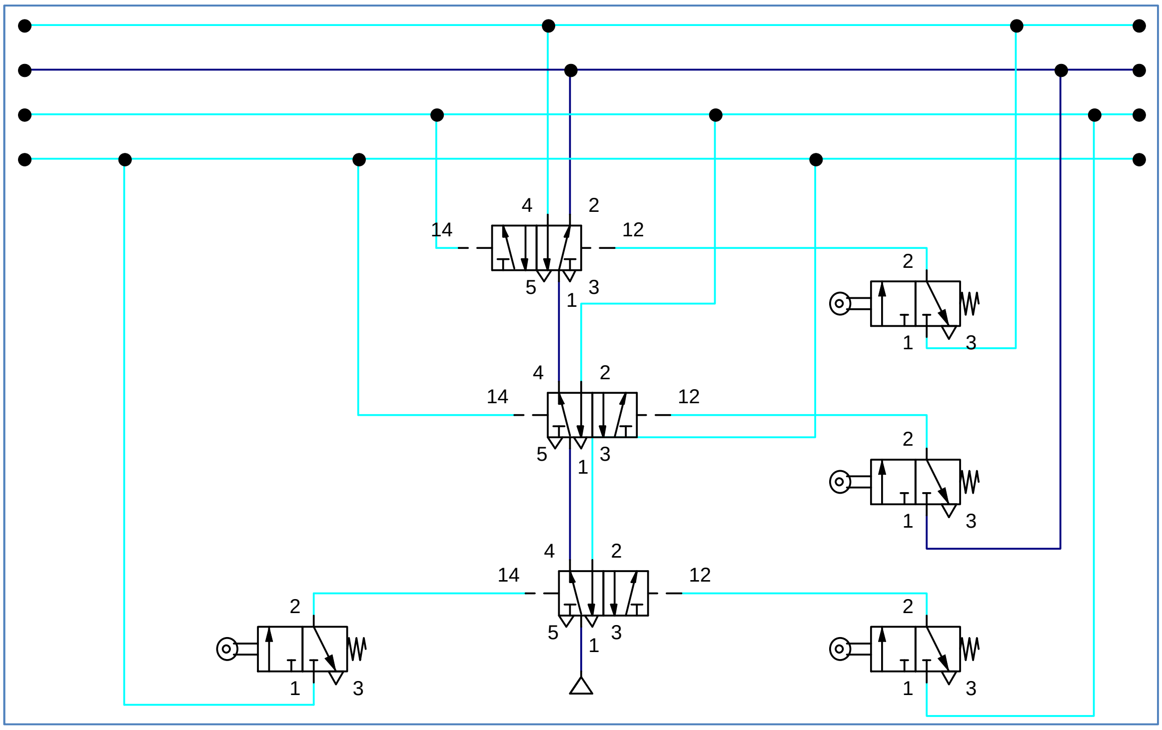


Figure 10.23 – Line 2 is Live

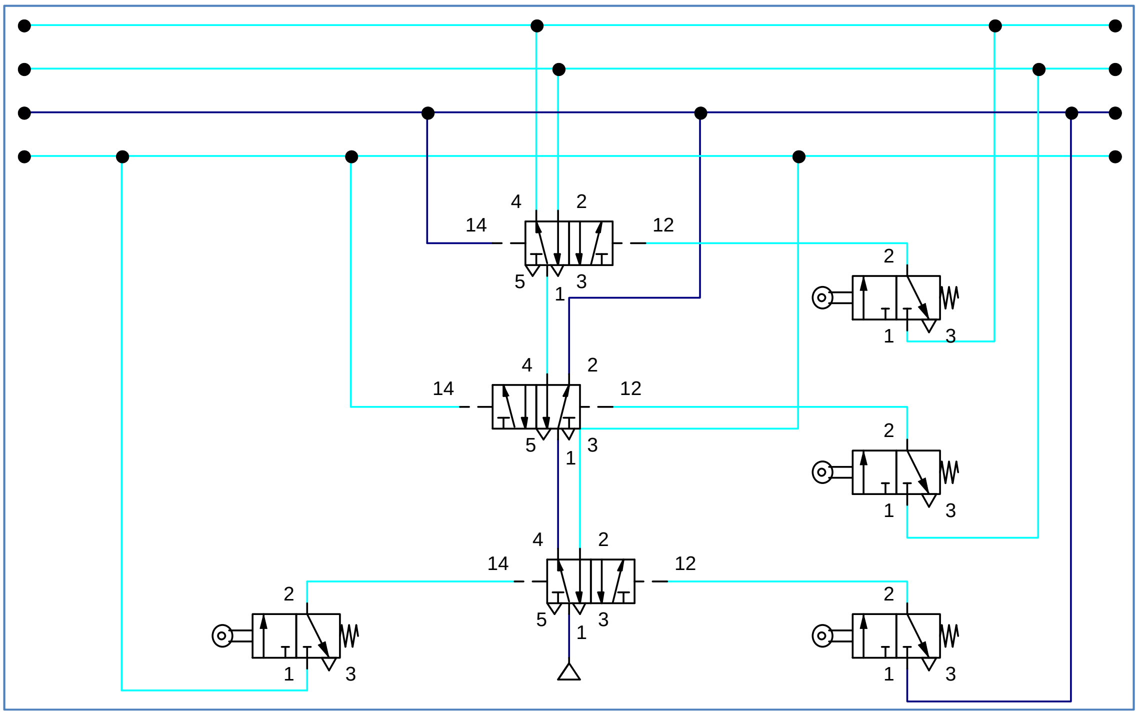


Figure 10.24 – Line 3 is Live

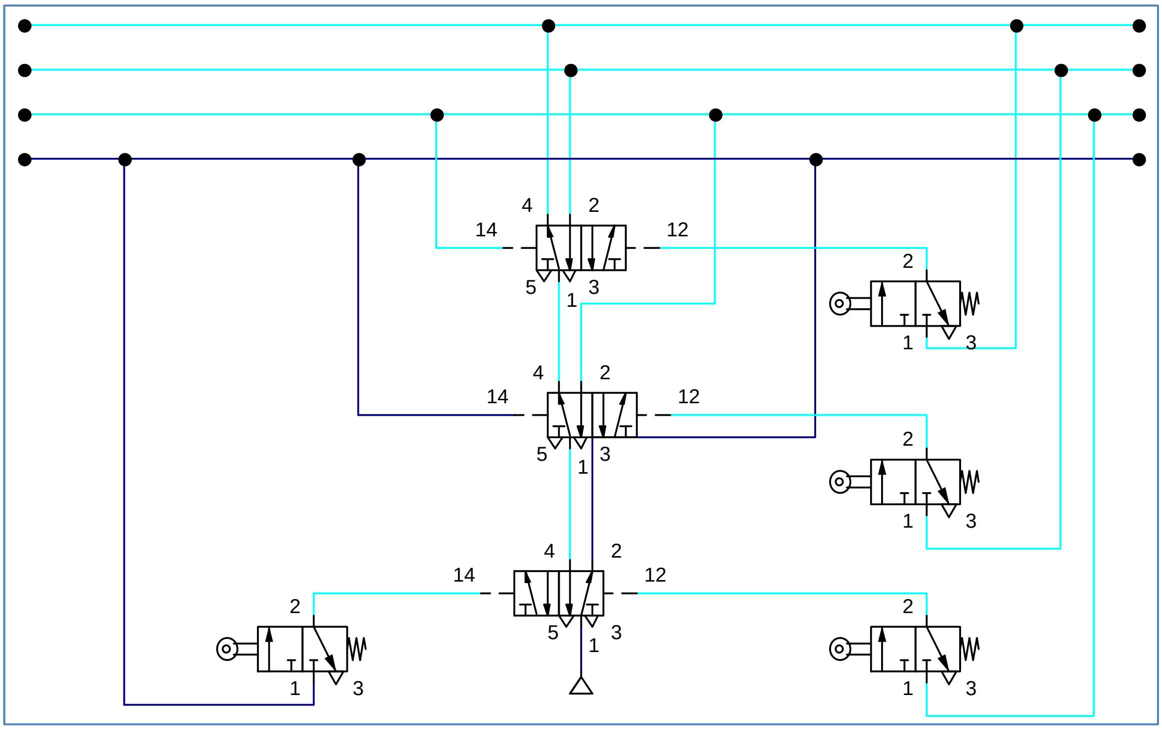


Figure 10.25 – Cycle End

The resultant pressure drop becomes significant if a large number of valves are connected in series and hence the control becomes slower. Therefore, not more than 3 reversing valves or 4 groups should be used.

10.6 Procedure for Constructing a Cascade System

a. Define the Sequence of Motion by Abbreviated Notation.

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

b. Divide Them into Groups

Break into groups such that a cylinder operation occurs only once in a group, and the minimum number of groups is obtained. That is A+ and A- cannot be in the same group. Give each group a number; I, II, III, etc.

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

I II III

c. Supply Lines

For each group, a supply is required. For 3 groups, there must be 3 supply lines.

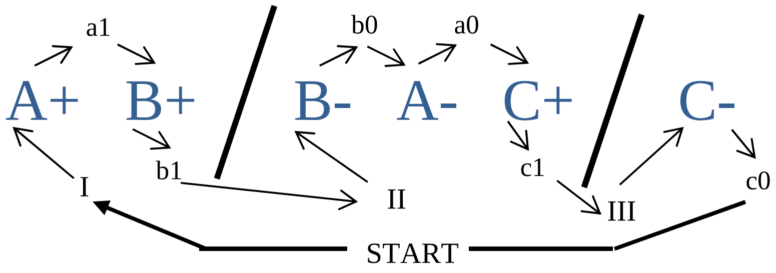
d. Reversing Valves

The number of reversing valves = Number of groups - 1

Therefore, the number of reversing valves = 3 - 1 = 2

e. Limit Switches

Write on the abbreviated notation, the number of limit switches.



Note:

- Limit switches/valves which cause changeover of groups are designated below the abbreviated notation.
- Limit switches within a group are designated above the abbreviated notation.
- Arrows designate signals which trigger cylinder operation.
- The last group must be “Live”.

f. Transposition into the Circuit

When transposition into the circuit, the following points are important:

- Limit switches/valves which cause changeover of groups are drawn below the supply lines.
- If a cylinder extends two or more times during a cycle, limit switch signals must be interlocked by means of two-pressure valves.
- Limit switches within a group are drawn above the supply line.
- Auxiliary conditions and additional interlocks are incorporated only when the basic sequence of the motions has been completely designed.

10.7 Auto Start and Auto Stop Modes in Cascade Control

If you wish to include auto-start and auto-stop modes in the circuit, you have to add the following valves as shown.

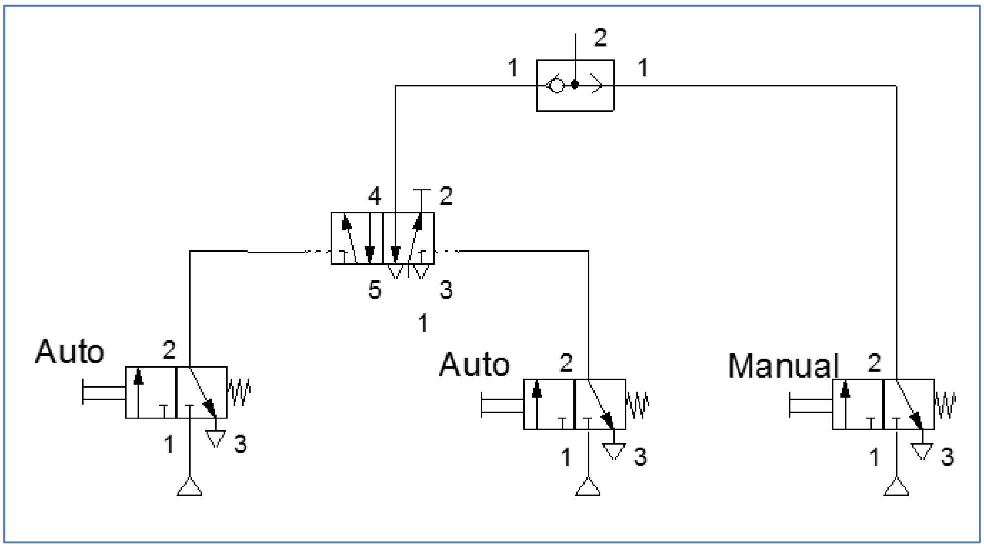


Figure 10.26 - Auto-Start and Auto-Stop Modes

10.8 Advantages and Disadvantages of Cascade Systems

10.8.1 Advantages

- Circuits can be designed and checked quickly.
- Fault tracing is simple. It is easy to determine which valve or group has failed.
- The system ensures that signals are inherently of sufficient duration to perform their required tasks.

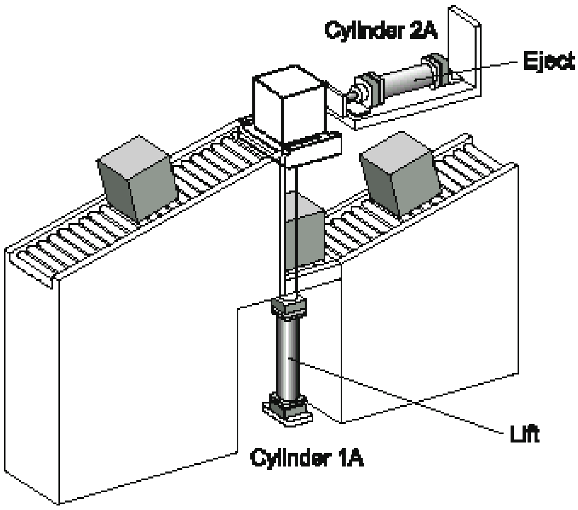
10.8.2 Disadvantages

- For certain circuits, the cascade method may not yield the simplest solution to a control problem.
- The pressure drop becomes significant as the number of stages of the cascade increases.
- When a limit switch is depressed by some external source not dependent on the circuit itself, particularly if held down throughout the cycle, great care should be exercised.

10.9 Examples of Cascade Control Systems

10.9.1 Distributor

Figure 10.27 shows the pictorial view of the distributor and its displacement-step diagram.



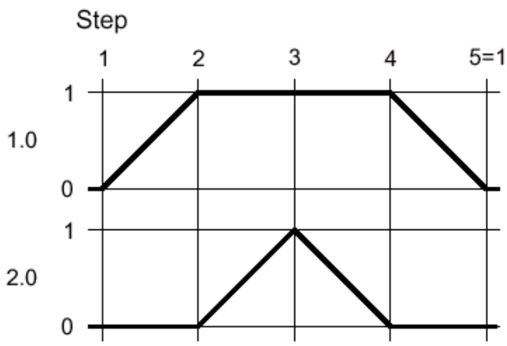
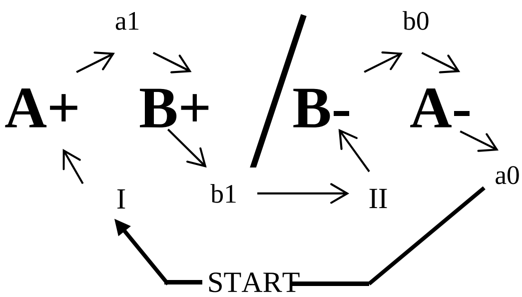


Figure 10.27 – Distributor

-



The design of the cascade with two groups.

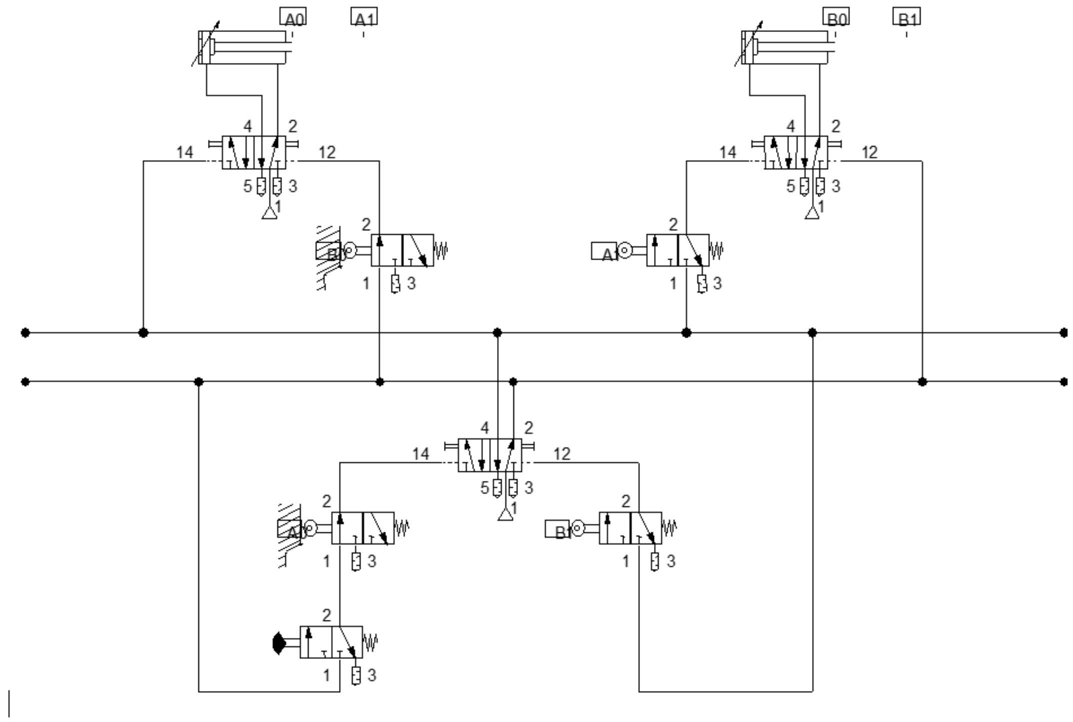
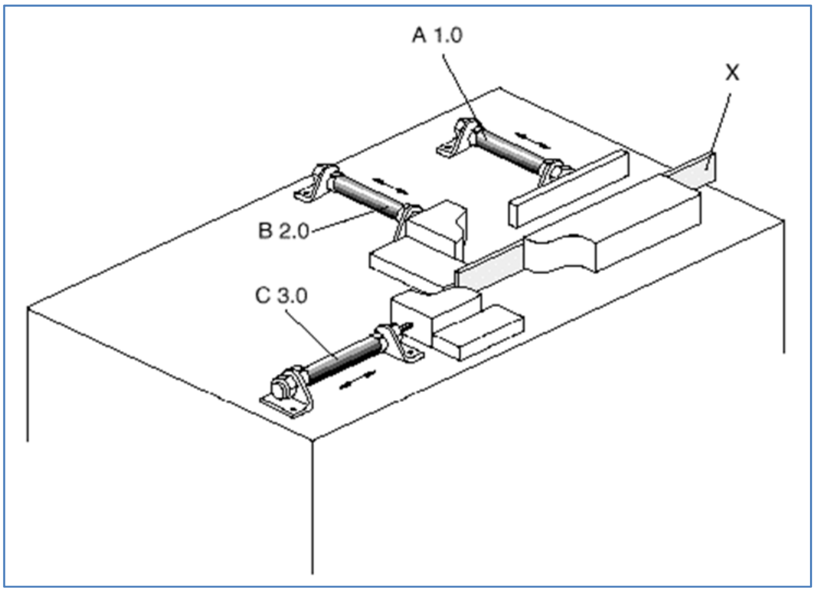


Figure 10.28 - Distributor Circuit Using Cascade System

10.9.2 Bending Device

Metal strips are placed manually in a fixture. Cylinder 1.0 clamps the metal strip when a push button is pressed. Cylinder 2.0 starts the bend and retracts. Cylinder 3.0 completes the bending operation. After Cylinder 3.0 has returned to its initial position, Cylinder 1.0 releases the part.



Displacement-Step Diagram

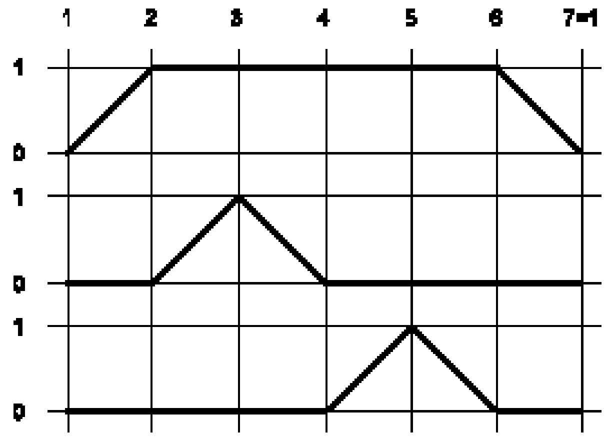
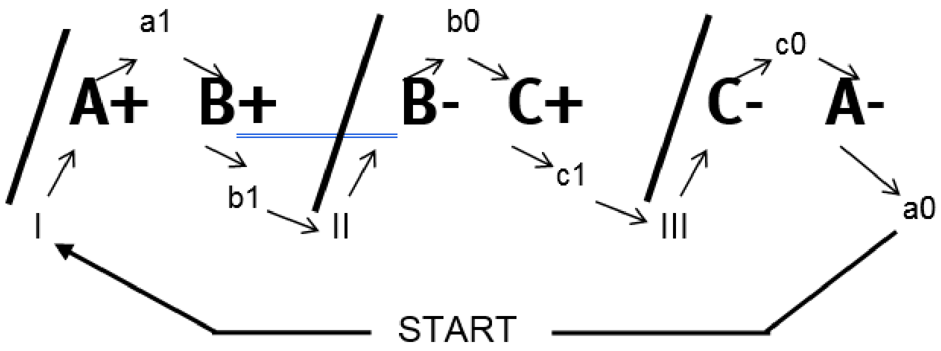


Figure 10.29 – Bending Device



The design of the cascade with three groups.

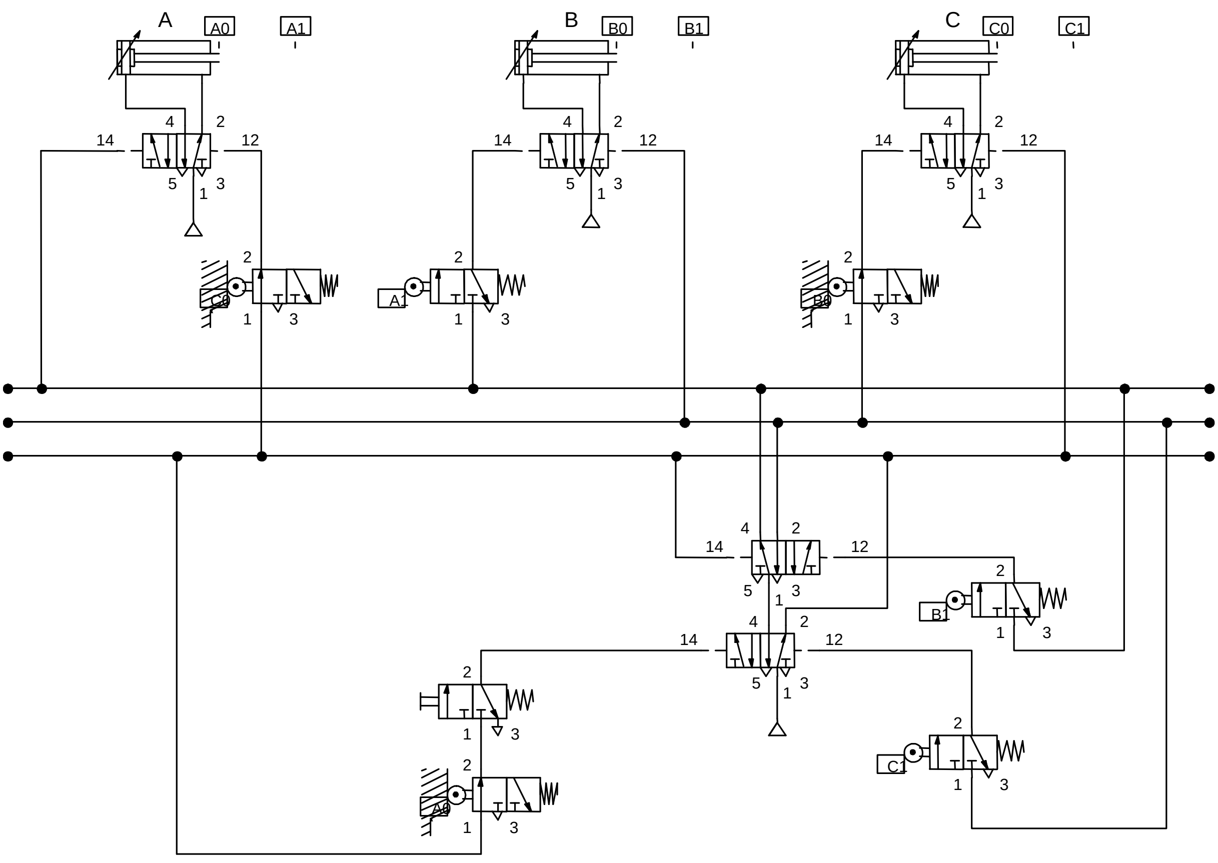


Figure 10.30 – Bending Device using Cascade System

11.0 Failures and Remedies in Pneumatic System Components

11.1 Troubleshooting a Pneumatic System

For all pneumatic systems, general preventive maintenance is essential to ensure that the systems work correctly without any faults and the control sequence is achieved. In the case of problems encountered, we need to troubleshoot the system.

11.2 What is Troubleshooting?

Troubleshooting is the art or skill of solving a problem using:

- An understanding of how the system works.
- Theory of operation of components and the system they are part of.
- Understand the history of the equipment (recurring problems).
- Gather symptoms.
- Using common sense with the first four items and decide where the problem is.

11.3 Seven Basic Steps of Troubleshooting

- Know the system
- Ask the operator questions
- Operate the machine
- Inspect the machine
- List possible causes of problems
- Reach a conclusion
- Test your conclusion

11.3.1 Know the System

The first step is that you need to know and understand the system, how it works and what it does. With this knowledge, it would be easy for you to troubleshoot the machine.

11.3.2 Ask the Operator Questions

As the operator is one using the machine, most of the time, he is the best person to give you information such as symptoms of the fault. Check with the operator on any occurrence which is out of the ordinary.

11.3.3 Operate the Machine

If it is safe, run the machine to locate the fault. This is the best method to identify the fault.

11.3.4 Inspect the Machine

Once you think you know where the problem is, do an inspection of the machine.

11.3.5 List Possible Causes of Problems

Make a list of all the possible causes of the fault.

11.3.6 Reach a Conclusion

From the list of the fault, try to eliminate the unlikely fault and decide on what you think the cause of the fault is. You need not try to identify all the faults but only the major ones as fixing one fault may also remedy other minor faults.

11.3.7 Test Your Conclusion

Having decided on the fault or faults, take remedy action and check if the problem has been resolved.

11.4 Terms Used in Troubleshooting

In troubleshooting, we usually hear three terms:

11.4.1 Symptom

It is an indication that there is a disturbance to normal operations which may be attributed to either a fault in the system of its devices.

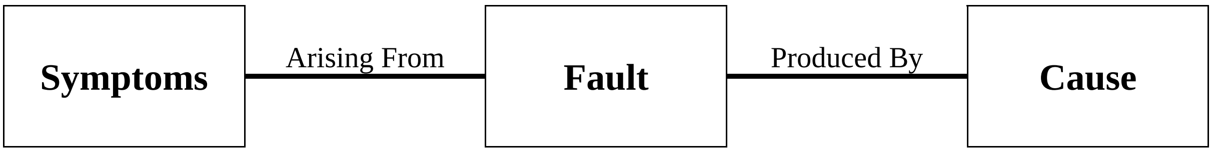
11.4.2 Fault

It is a defect in the system or devices which caused the symptom to appear.

11.4.3 Cause

It is the reason for the fault.

There is a logical approach to follow in order to recognise all the signs that indicate a fault and find its cause.



For example; a compressed air system

11.5 Maintaining a Pneumatic System

11.5.1 Daily Maintenance

Drain condensate from the filters if the air has a high-water content and if no automatic condensate drainage has been provided. With large reservoirs, a water separator with automatic drain should be fitted as a general principle. Check the oil level in the compressed-air lubricator, and check the setting of the oil metering.

11.5.2 Weekly Maintenance

Check signal generators for possible deposits of dirt and swarf. Check the pressure gauge of the pressure regulators. Check that the lubricator is functioning correctly.

11.5.3 Quarterly Maintenance

Check the seals of the connectors for leaks. If necessary, re-tighten the connectors. Replace lines connected to the moving parts.

Check the exhaust ports of the valves for leaks. Clean filter cartridges with soapy water (do not use solvents), and blow them out with compressed air in the reverse of the normal flow direction. Check the function of the automatic exhaust valves.

11.5.4 Half-Yearly Maintenance

Check the rod bearings in the cylinders for wear, and replace if necessary, also replace the scraper and sealing rings.

12.0 Diagnosing and Rectifying Faults in Pneumatic Systems

12.1 Introduction

When handling pneumatic systems, there might be cases where faults occur. In these cases, we need to diagnose and rectify the faults

12.2 Methods Used

There are several methods used, we will cover only two:

- Fault finding charts and guides
- Flow chart diagram

12.2.1 Fault Finding Charts

Many manufacturers' manuals include a section, which contains fault finding, or troubleshooting charts covering many known faults. The information contained in these charts is based on previous experience of the equipment in service. Predicted or possible faults may also be included based upon the knowledge and experience of the design engineer.

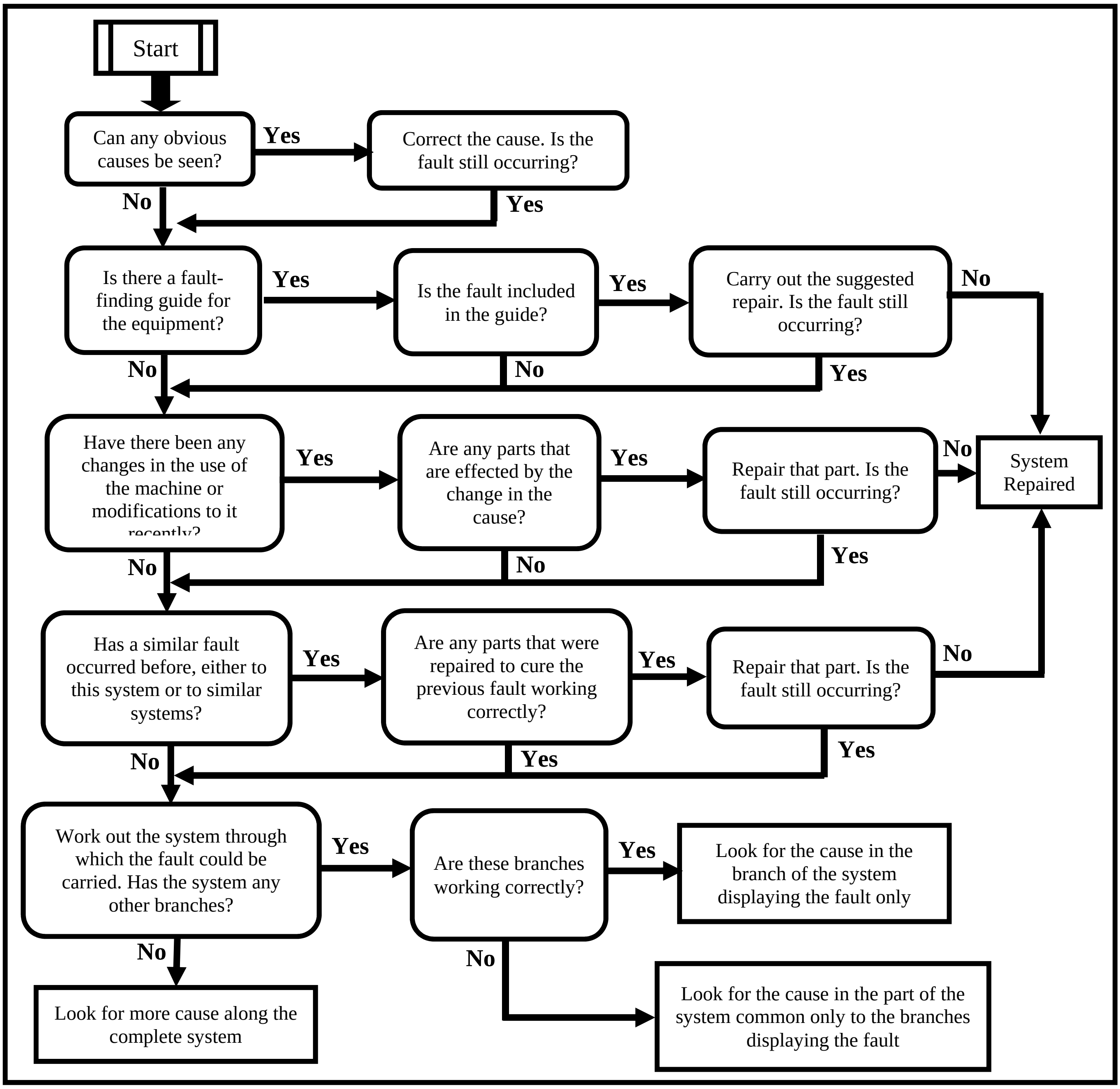


Figure 12.1 - Fault Finding Chart

These charts normally contain the fault, its possible causes and the remedy recommended. Despite the confusion caused by the different terminology used, these charts are a useful aid to fault diagnosis, particularly in relation to product or process faults. Where these chats are available, they should always be used.

12.2.2 Flow Chart Diagrams

A flow chart shows the flow path and progress through the chart is determined by the awareness to a series of questions. The questions are formed in such a way that the only possible answers are “yes” or “no”. The design of flow charts can be difficult as their usefulness depends upon the designer’s ability to anticipate and accommodate a wide range of possible thoughts. They can however, be effectively used by persons with a limited knowledge of the system or equipment.

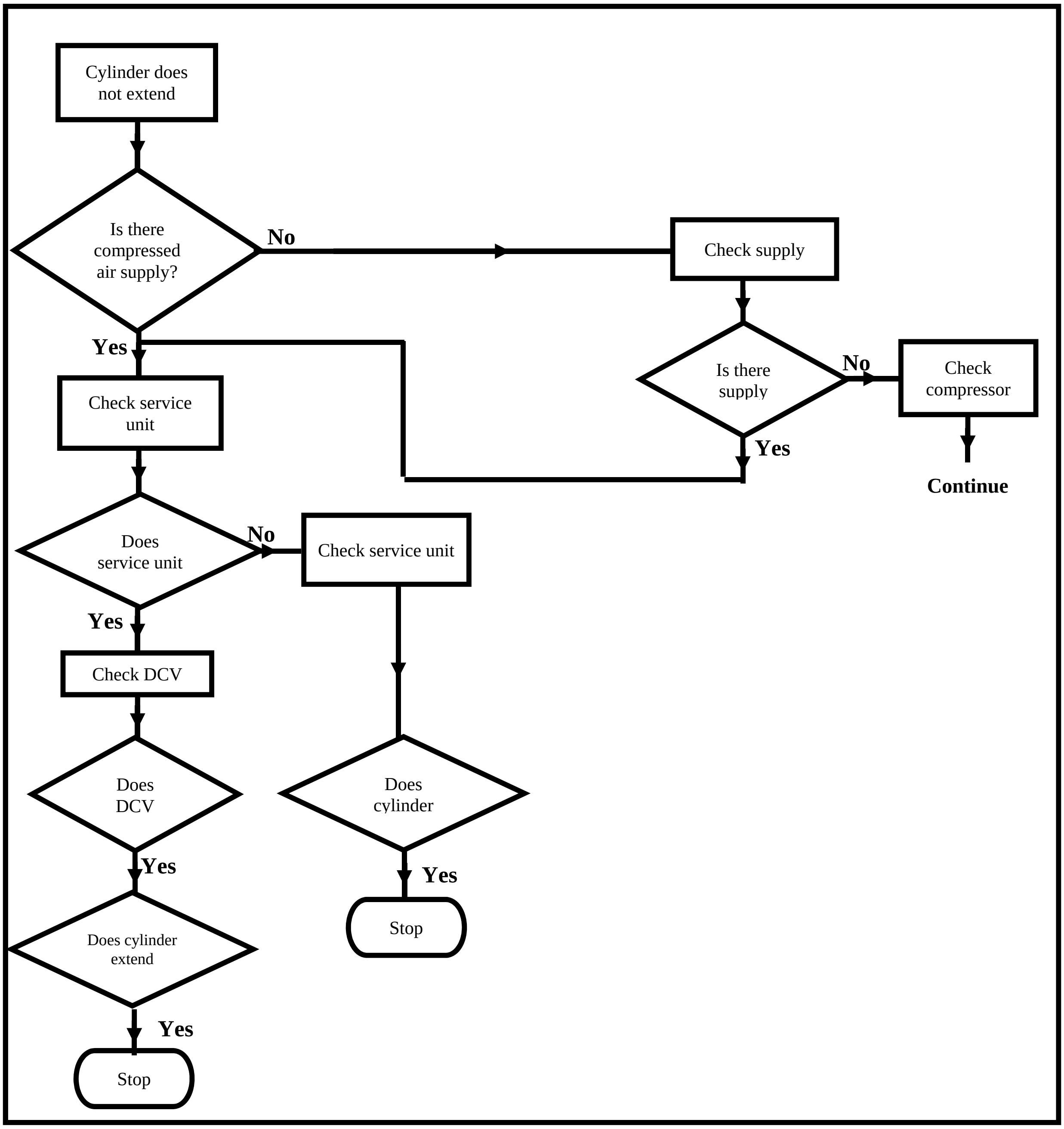


Figure 12.2 – Flow Chart

12.3 Malfunctions in Compressed Air Preparation

Malfunctions and failures may be caused by the following:

- Natural wear and tear of components and lines. The effects of external and internal environmental influences considerably accelerate natural wear and tear.
- Wear of units may lead to breakage, seizure of units, functional failures, leakage, etc.
- Contaminated air may lead to component failure caused by blockages.
- Lines may become blocked, split or bent, or may age prematurely due to external influences.
- Deposits may cause additional resistance in lines and components that may cause a marked pressure drop and possibly incorrect switching.

- Incorrect switching can also be expected in cases where a pressure drop is caused by leaks or by fluctuating supply pressure. Filter elements that have not been correctly serviced can be a further cause of pressure drop of this kind.
- Incorrect fitting of cylinders and incorrect loads lead to premature wear.
- Limit valves have not been mounted correctly, or signal lines are too long (sluggish signals).

Compressed Air Which is Poorly Prepared Will Lead to Malfunctions in Pneumatic Equipment

- Rapid wear of seals, O-rings and moving parts in the cylinders and valves.
- "Sticking effect" in control valves.
- Dirty and contaminated silencers.
- Elevated level of condensate in the air filter.
- Corrosion of metal parts.

12.3.1 Malfunctions Caused by Undersized Air Supply

It frequently occurs that sections of pneumatic systems are extended without enlarging the necessary air supply. Malfunctions that can be caused by under-sized air supply are:

- The piston rod speed is not always correct
- The force at the power cylinder drops for a short time during a pressure drop.
- Switching times are too long

The same symptoms may occur as the result of changes in orifice cross-sections caused by contamination or kinked lines or if leakage is causing a pressure drop.

12.3.2 Malfunctions Caused by Condensate

Apart from the corrosive damage caused to surfaces by condensate which is, in many cases extremely aggressive, there is the considerable danger of seizure of valve components if they need to be reset by spring force after being held in one switching position for a considerable time. Lubricants without additives have a tendency to emulsify and create resin or gumming. All close-tolerance sliding fits in valves are particularly susceptible to these resistances to movement.

12.3.3 Malfunctions Caused by Contamination

In a pneumatic system, a service unit should generally be connected upstream in the compressed air supply section. This filters the dirt particles from the compressed air supply.

During assembly or maintenance work, dirt particles (e.g. thread particles, sealing agents, etc.) may remain in the pressure lines and get into the valve during operation.

In the case of systems which have been in service for some time, may find their way into the lines. This contamination of the lines may produce the following effects:

- Sticking or seizure of slide-valve seats
- Leaks in poppet valves
- Blockage of flow control valve nozzles

12.4 Possible Faults in Air Service Units

Fault	Cause	Remedy
Air filter does not separate dirt and water.	Filter has been fitted incorrectly.	Fit and connect filter behind the direction of flow. (the sintered cartridge in the filter must be cleaned after a lengthy period of time)
	Condensate level is higher than the marking line.	Drain condensate by turning the screw clockwise, fit automatic water separator.
The air flows to atmosphere at the pressure regulating valve.	Pressure regulator is fitted incorrectly with respect to the direction of flow.	Refit the regulator.
Resinfication of the lubricator.	Wrong oil used.	Wash out lubricator. Select and replace with correct oil.
The lubricator does not function properly.	The lubricator is mounted incorrectly.	Remount the lubricator according to the arrow. The arrow specifies the direction of flow.
There is too much oil in the system.	Lubricator is set incorrectly.	Reset the lubricator.
	The oil is filled over the marked line.	Drain the oil. (Check oil level and the oil bowl should be kept clean in order to allow oil level to be checked at any time)
The oil is used up quickly in the lubricator.	The O-ring is not tight.	Exchange and fit new O-ring.
	Lubricator is set incorrectly.	Set lubricator properly.

12.5 Possible Faults in Pneumatic Cylinders

Before failure of pneumatic cylinder occurs, damage often becomes noticeable in a stage in which the cylinders still operate correctly. Here, regular inspections allow imminent failures to be recognise in appropriate time.

- Visual Inspection

If increasingly heavy longitudinal scoring is discovered on the piston rods of pneumatic cylinders, it can be expected that the rod seals will soon fail due to wear. The presence of black, dry stuck-on lubricant on large areas of the piston rods indicates an unstable condition, as the result of which the piston rod seals and bearings can quickly become unserviceable.

With low operating pressures, this factor will also increase the tendency to judder. Smooth running may also be impaired by wear of the piston seal, causing a dry mixture of grease and rubber particles to be deposited on the cylinder barrel.

- Acoustic Check

If the cylinders are already leaking to such an extent that the hiss of air can be heard clearly as it discharges, action must be taken immediately. Continuous blow-off of air at switching valves under idling conditions is also a warning signal that either the piston seals of cylinders or even the sealing elements in the valves have suffered damage.

- Measuring Response Times

If, under the same conditions, it is noticed that the response time of slide valves with elastic rubber seals has suddenly become noticeably longer, this is an indication that a malfunction is imminent.

Fault	Cause	Remedy
The air escapes to atmosphere at the bearing bushing.	Packing not tight, packing worn, packing mounted incorrectly	Replace bearing
Piston rod is not guided smoothly.	Bearing bushings worn	Replace bearing
With the valve connected, air blow out of the vent hole	Packing leaks or is loose	Replace packing
Piston travels out slowly.	Too much oil in the cylinder barrel, due to one way flow control valve	Adjust flow control valve
Air escapes at the piston rod.	Groove ring is defective	Replace groove ring
For single-acting cylinders, piston rod does not return to the end position	Compression spring damaged, air filter is blocked	Clean air filter and replace spring if damaged
For double-acting cylinder, end position cushioning in a cylinder does not respond.	Lip seal on the cushioning plunger leaks or has been fitted in the wrong way	Replace lip seals
Wear is increased.	Water in the cylinder	Check air supply

12.6 Possible Faults in Directional Control Valves

Fault	Cause	Remedy
Valve is sluggish (Slow moving)	Dirt in the valve especially in the groove ring.	Replace groove rings, clean valve. If there is a lot of dirt and oil, functioning of the pilot valve cannot be guaranteed.
Valve does not switch properly.	Control pressure too low.	Set control pressure properly (Regulator).
	Groove rings are defective.	Replace rings
Valve leaks	Groove ring has been damaged, valve discs worn.	Replace damaged parts.
Spool does not reverse.	Control pressure too low.	Check regulator and reset.
	Overlapping signals.	Check control signals to solenoids to eliminate overlapping signals.
	Spool jams in the upper part of the housing; mounting surface not quite level, valve distorts when installed.	Check the spool and the sealing rings; rework mounting surface.
Spool does not completely reverse.	Switching plunges has broken, blocking the travel of the spool.	Dismantle valve, remove defective switching plunger; fit new one.
Air escapes from the armature tube.	Sliding surface on housing damaged; sealing washer in armature damaged.	Replace part.
Noises (Humming) from the solenoid head.	Dirt between coil and armature tube; excessive play in the armature and armature tube.	Clean the solenoid head.
Air escapes at exhaust.	Ports (1) P and (4) A are interchanged.	Reconnect lines if connected improperly. Make sure the supply voltage is correct.

12.7 Replacing Pneumatic Components

When the damaged parts are found and dismantled, you may be required to order the part as replacement. When ordering parts, you need to refer to the manufacturer’s catalogue. It is important to take note of the following when ordering:

- For pneumatic cylinders
  - Correct diameter
  - Correct length
  - Correct accessories, such as mountings
  - Special requirements, such as corrosion resistance

- For directional control valves
    - Correct function, such as 3/2-way, 5.2-way, etc.
    - Normally open or normally closed where appropriate
    - Correct size

The above are the basic requirements, depending on the usage, more information might be required.

13.0 Pneumatic Solenoid Valves

13.1 Introduction

Directional control valves used in electro-pneumatics are like those used in conventional pneumatics. The only difference being the mode of actuation. Directional control valves used in electro-pneumatics are usually actuated by solenoids.

They can be divided into two groups:

- Spring-return valves only remain in the actuated position as long as current flows through the solenoid.
- Double solenoid valves retain the last switched position even when no current flows through the solenoid.

In the initial position, all solenoids of an electrically actuated directional control valve are de-energised and the solenoids are inactive. A double solenoid valve has no clear initial position, as it does not have a return spring.

The following figures show the application of solenoid operated directional control valves.

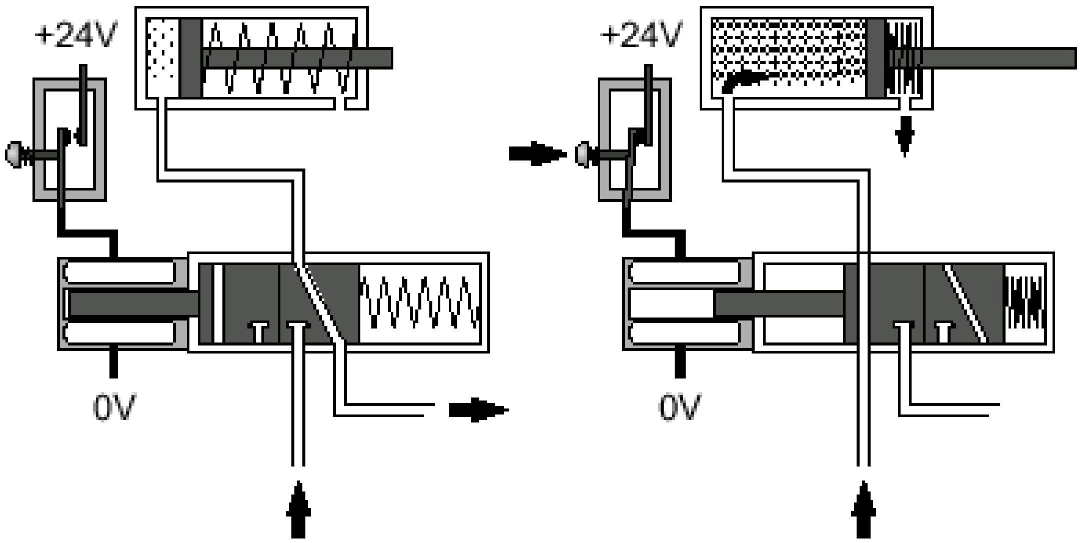


Figure 13.1 – Actuation of a Single-Acting Cylinder using a 3/2-way Solenoid Operated Directional Control Valve

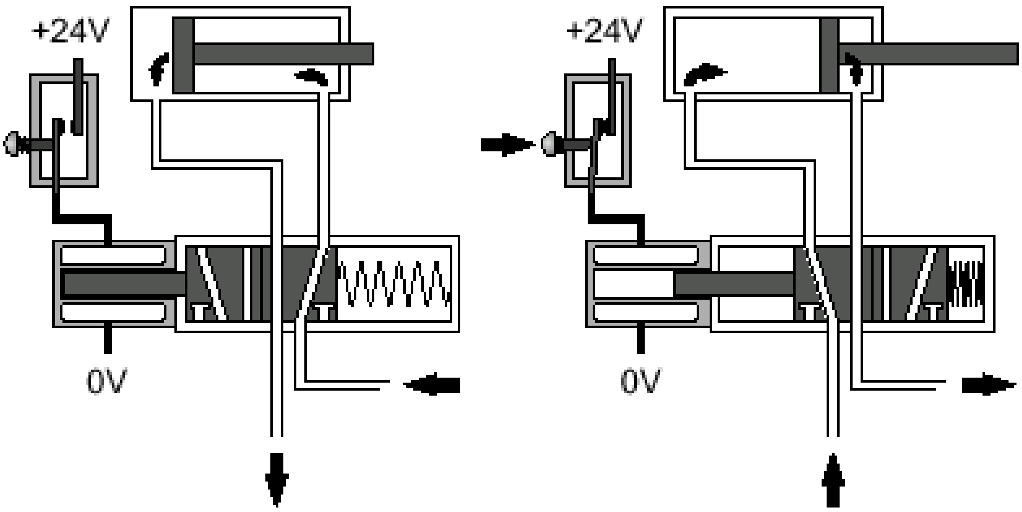


Figure 13.2 – Actuation of a Double-Acting Cylinder using a 5/2-way Solenoid Operated Directional Control Valve

13.2 Components Used in Electro-Pneumatics

In a basic electro-pneumatic system, there are certain additional components which are not used in conventional pneumatics.

The additional components are:

- 24V DC power supply
- Electrical switches
- Electrical contacts
- Electrical relays
- Solenoid operated valves
- Sensors

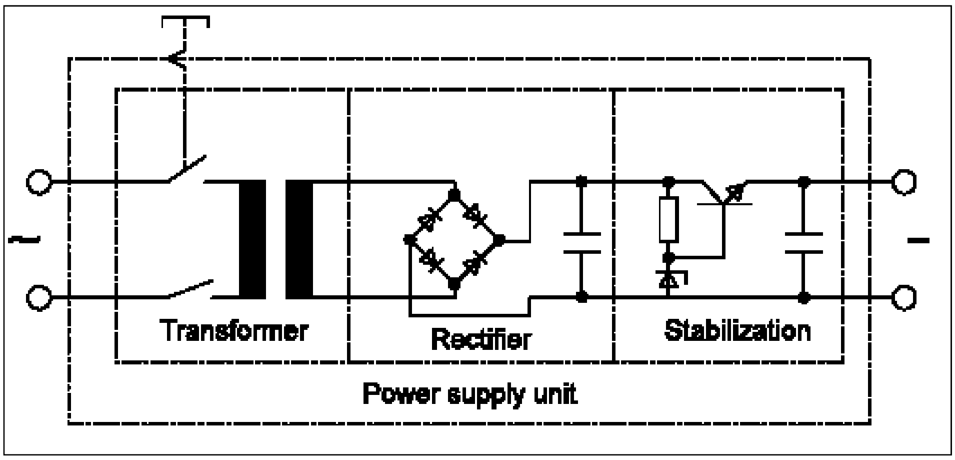


Figure 13.3 – Electrical 24V DC Power Supply

13.3 Solenoid Actuated Directional Control Valves

These solenoid coils are then attached to the valves to actuate them. It is basically the same as the valves used conventionally but now instead of a push button switch it is replaced by a solenoid.

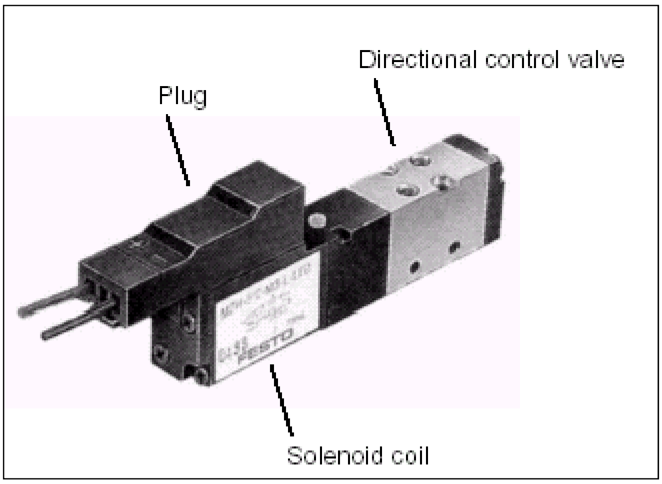


Figure 13.4 – Example of a Pneumatic Valve Activated by a Solenoid Coil

Solenoid actuated valves employ the advantages of pneumatic and electrical energy and can be described as electro-pneumatic converters. They consist of a pneumatic valve as the signal output medium and an electrical switching part called a solenoid.

An electric current applied to the solenoid generates an electromagnetic force (EMF) which moves an armature connected to the valve stem.

When current is removed from the solenoid coil, the EMF is dissipated allowing the internal spring to return the valve stem to the neutral position.

13.3.1 Operating Principle of a Solenoid

When a solenoid is energised, electro-magnetic forces are created and this will pull the soft iron core inwards. If this is attached to the spool, it will actuate the directional control valve.

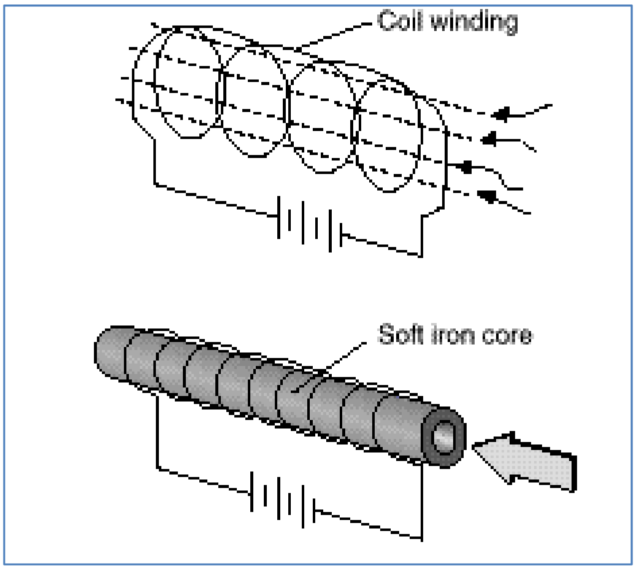


Figure 13.5 – Operational Principle of a Solenoid

13.4 Types of Solenoid Operated Directional Control Valves

13.4.1 2/2-Way Directional Control Valve

The 2/2-way valve illustrated has 2 ports. Input connection 1 and output connection 2. There are 2 switching positions, idle or neutral position and the actuated position. You will notice that when this valve is in the closed position, air cannot escape to atmosphere. Therefore, the application of this valve is somewhat limited and is primarily used as a shut off valve.

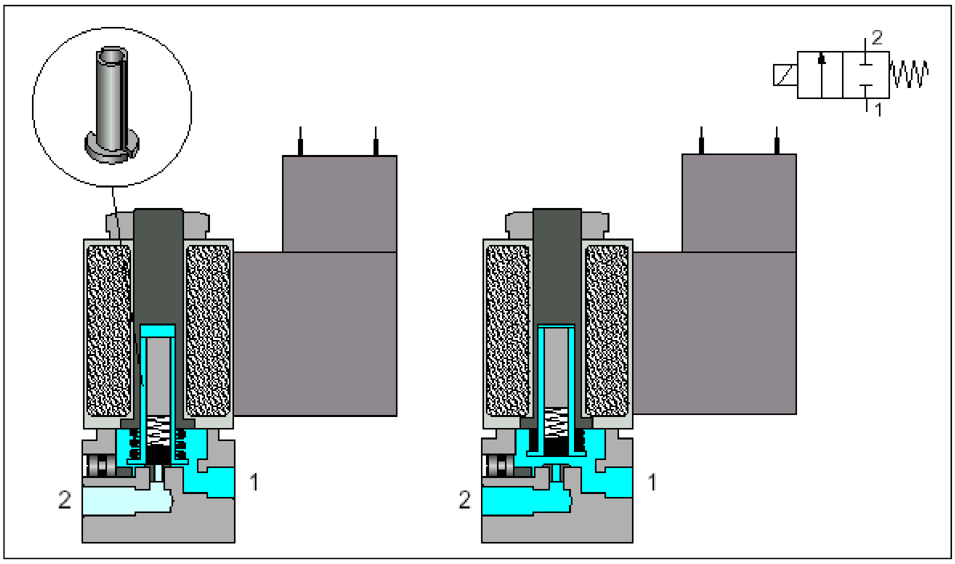


Figure 13.6 – 2/2-Way Single Solenoid Directional Control Valve

13.4.2 3/2-Way Directional Control Valve

This normally closed (NC) poppet valve is directly actuated by a solenoid and is returned to the idle position by spring return. Usually this valve incorporates the solenoid armature and valve stem as one unit and is therefore referred to as an armature or armature tube (the armature is hollow). The aperture of the armature is generally referred to as the bleed hole or exhaust aperture.

Operating Method

When an electric current (signal) is applied to the coil, an electromotive force (EMF) is generated which lifts the bottom sealing face of the armature from the valve sealing seat. Compressed air then flows from input 1 to output 2 and the exhaust aperture 3 is blocked by the top sealing faces of the armature. The armature is forced against the exhaust seal.

Rotation of the eccentric screw against the armature flange provides a manual override facility. Rotation of the screw from the zero (0) to the one (1) position places the valve in an override actuation position.

It is important to return the screw to the (0) position when normal solenoid operation is required.

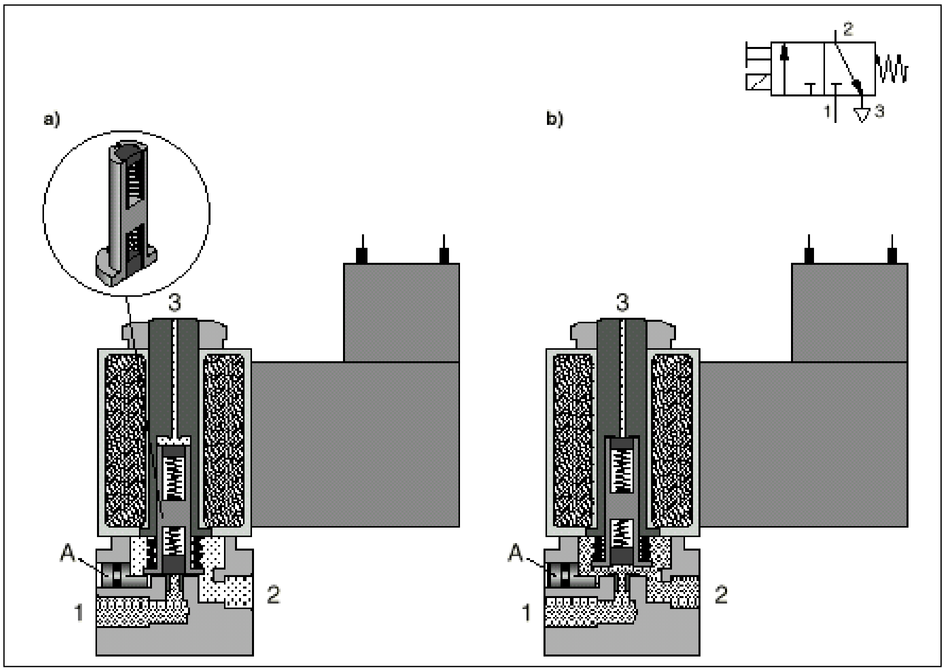


Figure 13.7 – 3/2-Way Single Solenoid Directional Control Valve, Normally Closed

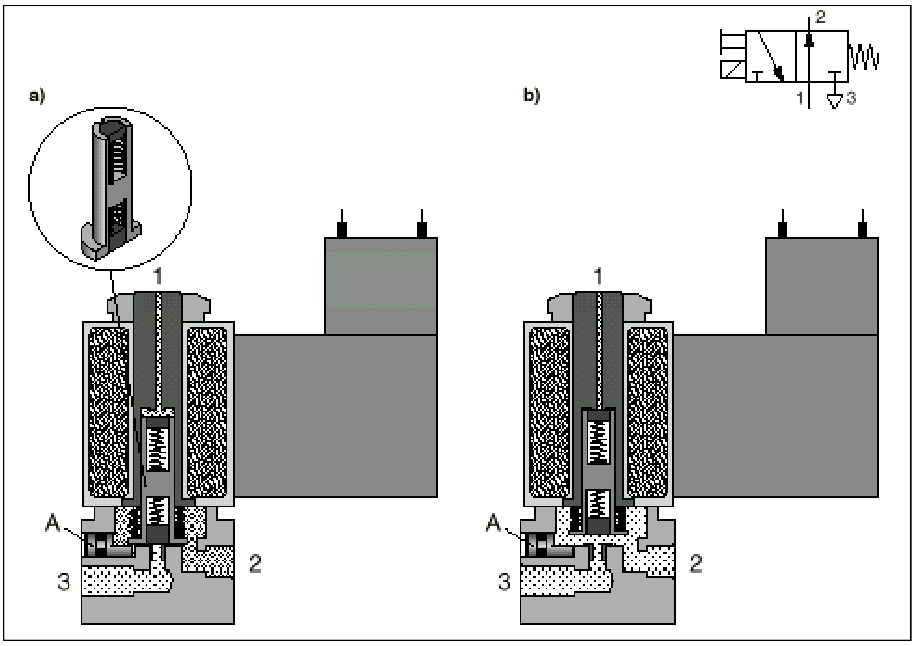


Figure 13.8 – 3/2-Way Single Solenoid Directional Control Valve, Normally Open

13.4.3 Pilot Operated Valve Solenoid Valves

By using pilot control, the size of the solenoid can be kept to a minimum. From an electrical point of view, this has two main advantages:

- Reduced power consumption
- Reduced heat generation

Pneumatically, the advantage is that the valve switching is positive. The electrical signal is applied to the solenoid which actuates the pilot valve armature. The pilot valve signal operates the main valve.

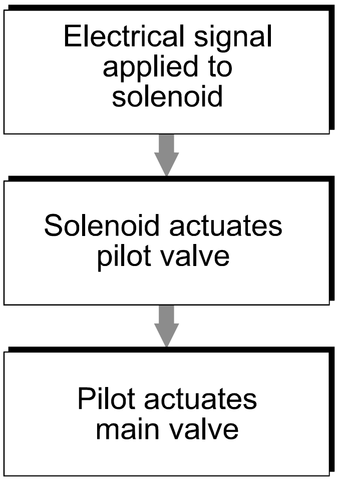


Figure 13.9 – Pilot Signal Flow

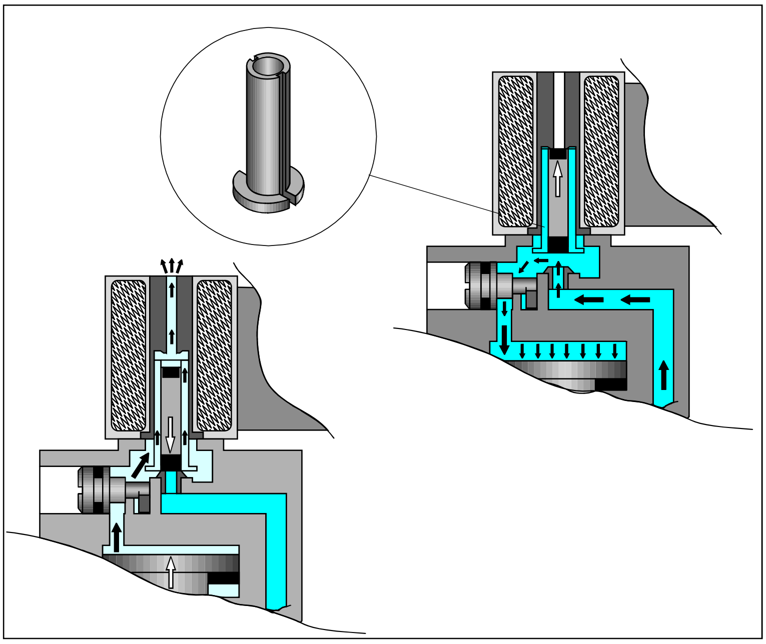


Figure 13.10 – Pilot Control

13.4.4 3/2-Way Pilot Controlled Directional Control Valve

The primary difference between this valve and the direct controlled design is the addition of an internal pilot. The pilot valve can be considered as an amplifier that is the force applied by the solenoid's EMF is amplified by the pilot valve providing a very positive switching characteristic. In the neutral position, the supply pressure at 1 act on the lower side of the piston forcing it against the sealing seat which blocks the flow of air from 1 to 2. The passage from the output 2 is open to atmosphere via the exhaust port 3.

Application of an electrical signal lifts the lower sealing face of the armature, opening the passage of air from 1 via the pilot air duct to the end face of the valve piston. As the piston surface area is greater than that of the lower seal, the resultant force acting against the supply pressure moves the piston. The lower seal lifts from its seat. The air flows from 1 to 2. At the same time, the piston stem is forced against the top face of the bottom seal blocking the escape of air atmosphere via 3.

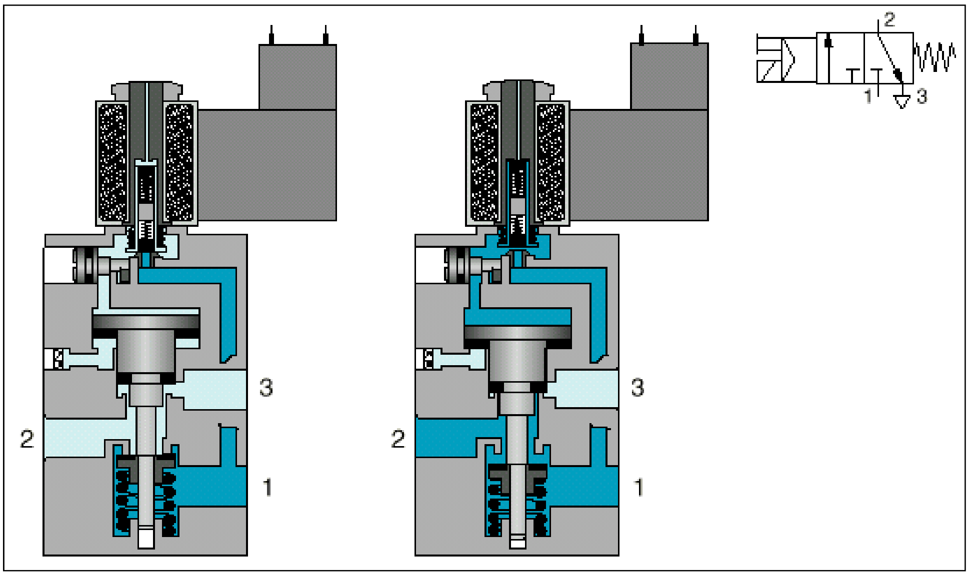


Figure 13.11 – 3/2-Way Single Solenoid Valve, Pilot Operated

When the solenoid is de-energised, the pilot signal is relieved through the stem of the solenoid allowing the piston to return. The supply pressure 1 is blocked and the passages 2 to 3 are interconnected. Note: It is important to ensure that the pilot exhaust path through the stem is not blocked to allow the valve to return to the neutral state.

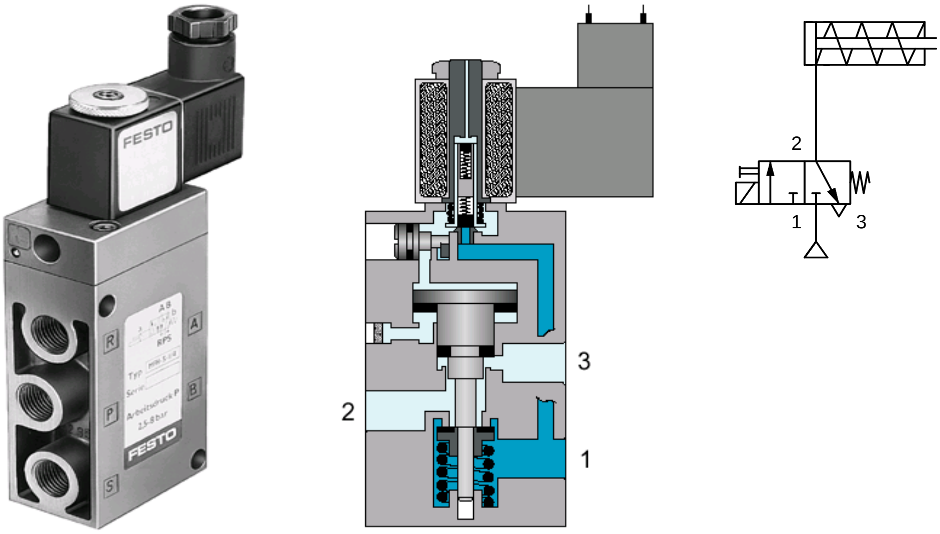


Figure 13.12 – Before Activation

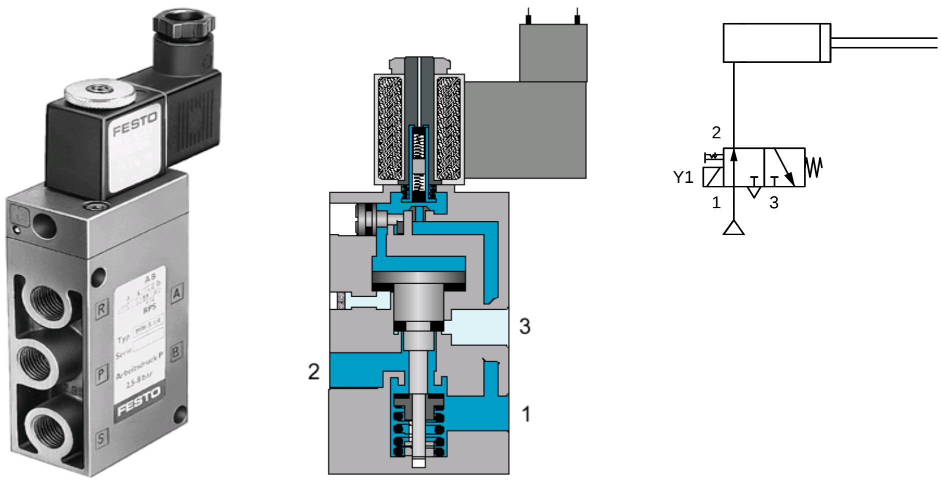


Figure 13.13 – After Actuation

13.4.5 5/2-Way Pilot Controlled Single Solenoid Directional Control Valve

The 5/2-way valve performs a similar function as the 4/2-way valve. The main difference is that this valve has two exhaust ports, whereas the 4/2-way valve has one exhaust port.

In the neutral state, the spring return forces the large diameter seal at the spring end against its seat, blocking airflow from 1 to 3. The spring force also loads the suspended disc against port 4 blocking the passage of air from 1 to 4. The opposite seal (solenoid end) lifts from its seat and exhausts air from 4 to 5. The suspended disc opens the air flow from 1 to 2.

Energising the solenoid moves the armature and opens the pilot air passage. The pilot air applies pressure to the right side of the valve piston, in turn forcing the suspended disc against the opposite sealing seat, resulting in:

- Air exhausts from 2 to 3
- Exhaust port 5 is blocked
- Air flows from 1 to 4

With the small switching movement, low frictional forces, and pilot actuation, this design can utilise the small solenoid as the means of actuation resulting in a fast-positive switching action.

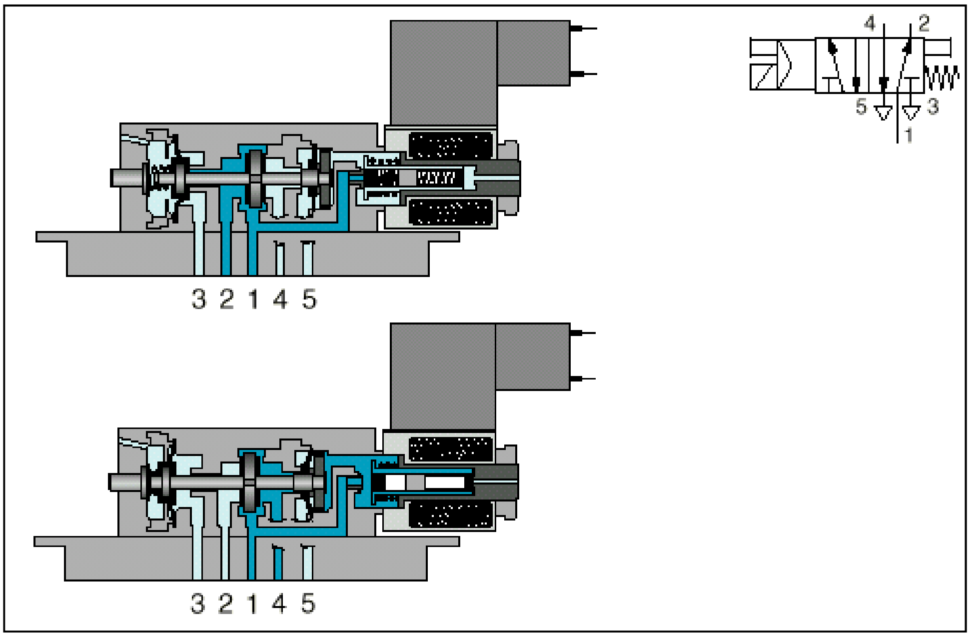


Figure 13.14 – 5/2-Way Single Solenoid Valve, Pilot Operated

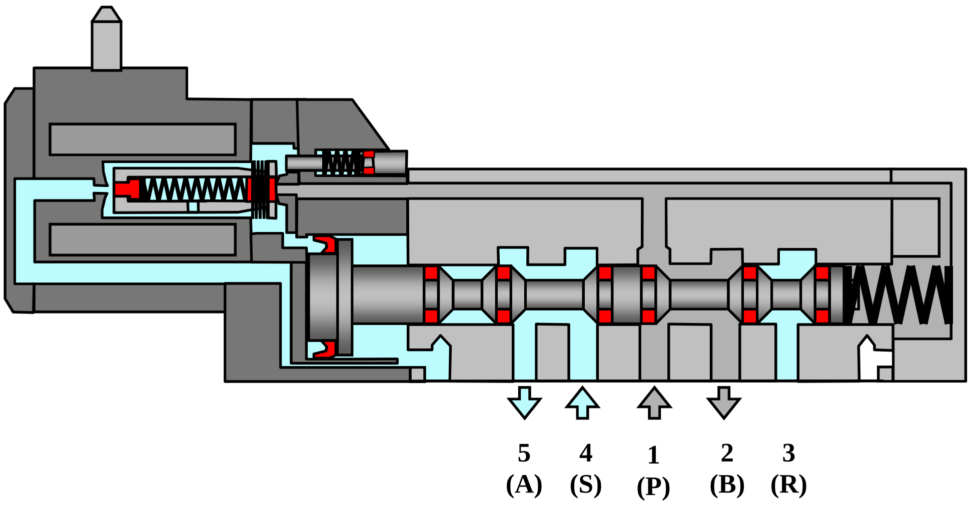


Figure 13.15 – Before Activation

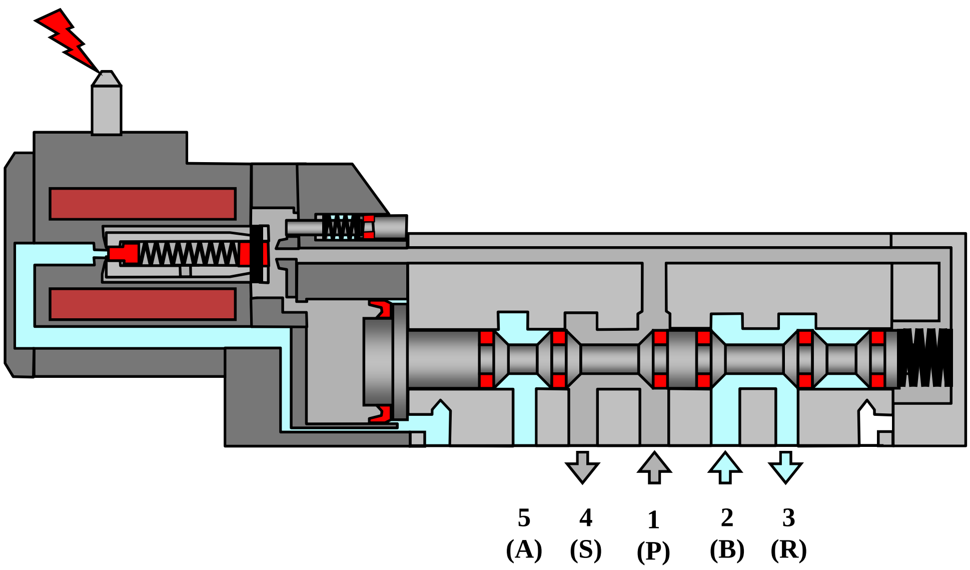


Figure 13.16 – After Actuation

13.4.6 5/2-Way Pilot Controlled Double Solenoid Directional Control Valve

The valves in the previous illustrations used a spring as the method of returning the valve to its neutral state, i.e. the solenoid actuated the valve in one direction and the spring provided actuation in the opposite direction. Of course, this means that whenever power is removed from the solenoid, the valve returns to its neutral state. This characteristic must be taken into consideration when designing a circuit.

In the case of a double solenoid valve, the spring return has been replaced by a second solenoid. If the last signal applied was at solenoid Y1, air flows from 1 to 2 and 4 is exhausted via 5. When the signal is removed from Y1 the suspended disc remains stationary and no change occurs in the switched state of the valve.

A signal applied at solenoid Y2 reverses the valve and air flows from 1 to 4 and 2 is exhausted via 3.

Unlike the valve with a spring return, this double solenoid valve remains in its last switched position, even with power removed from both solenoids, until an opposing signal is applied. Effectively this means that this valve has memory characteristics.

In electro-pneumatic circuits, this characteristic has many advantages, i.e. only a very short duration signal applied to the solenoid (10-25 ms) is necessary to switch the valve. Demand on the electric power supply can be minimised. In circuits with complex sequences of action, cylinder positions can be retained without the need for complicated switching arrangements, to latch the valves and cylinders in position.

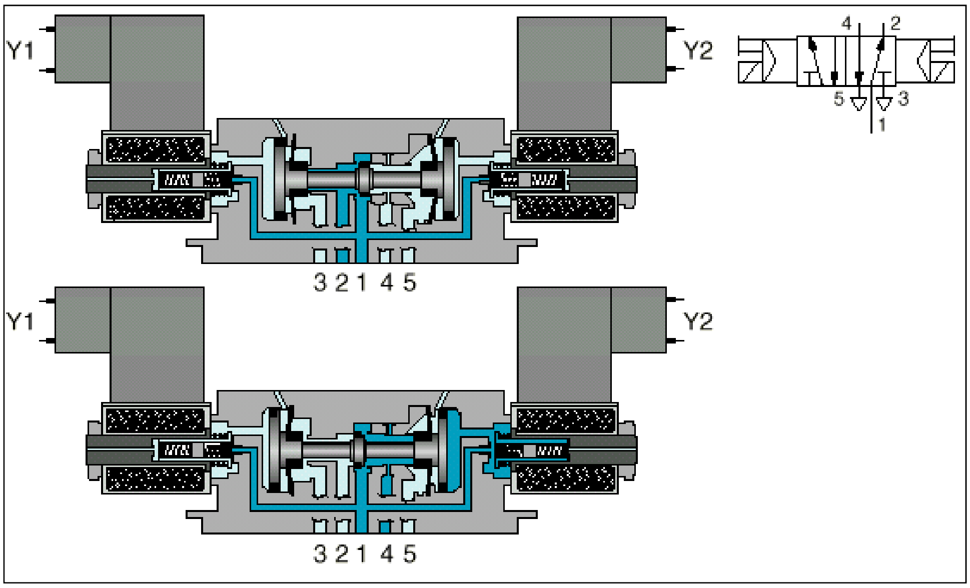


Figure 13.17 – 5/2-Way Double Solenoid Valve, Pilot Operated

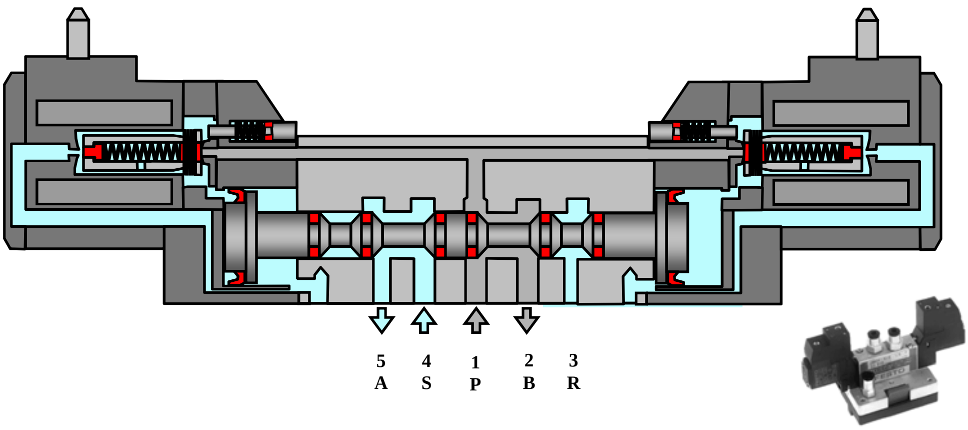


Figure 13.18 – 5/2-Way Double Solenoid Valve, Pilot Operated

13.4.7 5/3-Way Pilot Controlled Double Solenoid Directional Control Valve

Like the 5/2-way valve, with the only difference is the additional centre position. When the valve is in the neutral position, the centre position is active. To move to the left and right position, the respective solenoid is activated. The solenoid needs to be energised to remain in that position.

When purchasing 5/3-way valves, remember that there are different centre positions available and needs to be identified when ordering. There are different centre positions, namely:

- Closed
- Open
- Tandem
- Float

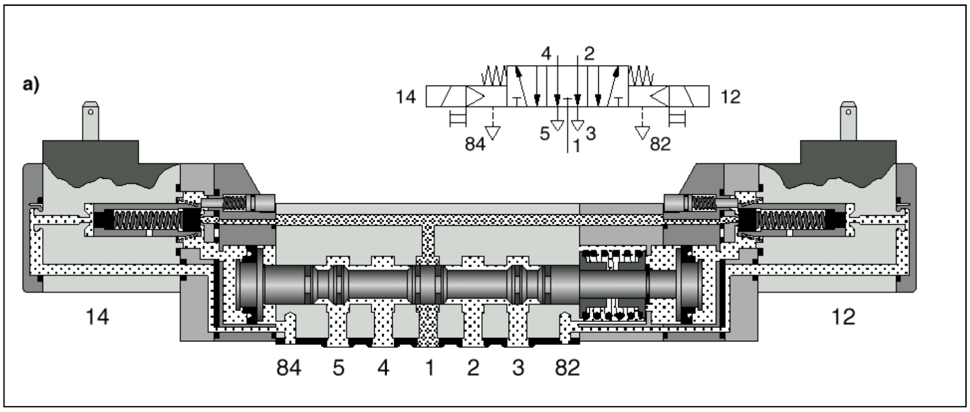


Figure 13.19 – Centre Position

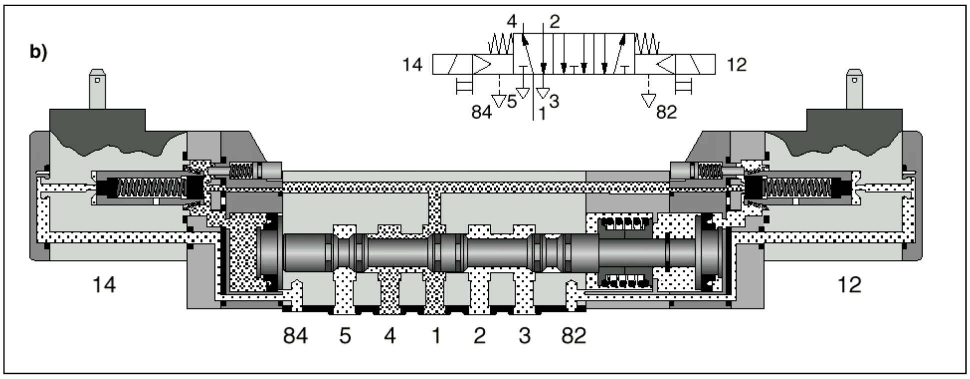


Figure 13.20 – Left Position

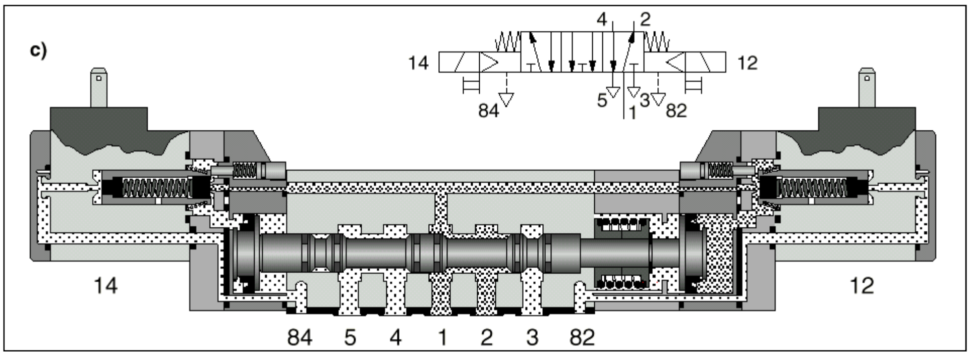


Figure 13.21 – Right Position

14.0 Switches, Relays and Electronic Sensors

14.1 Introduction

The main purpose of the signal input devices is to transfer electrical signals from various points of a control system to the area of signal processing. The input devices used are switches, relays and electronic sensors.

14.2 Electrical Switches

Switches are installed in a circuit to open or close the flow of current to the consuming device. There are two common types; one, which is momentarily activated, and the other mechanically interlocked (detented).

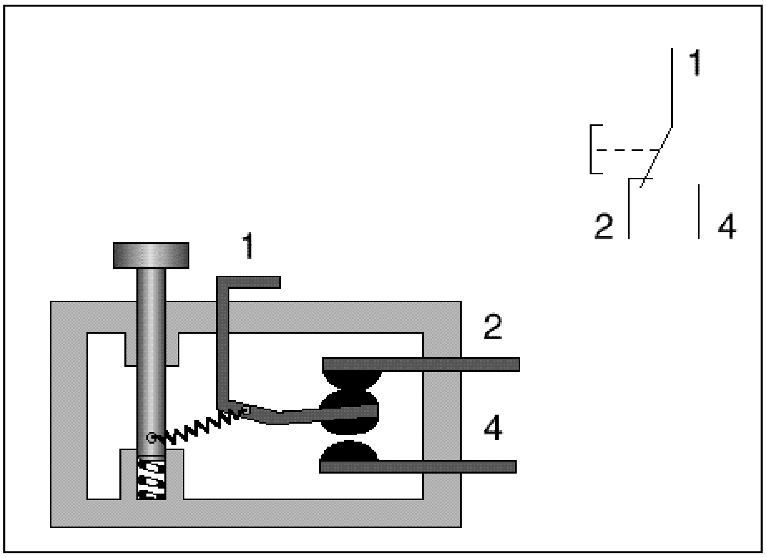


Figure 14.1 – Momentary Switch

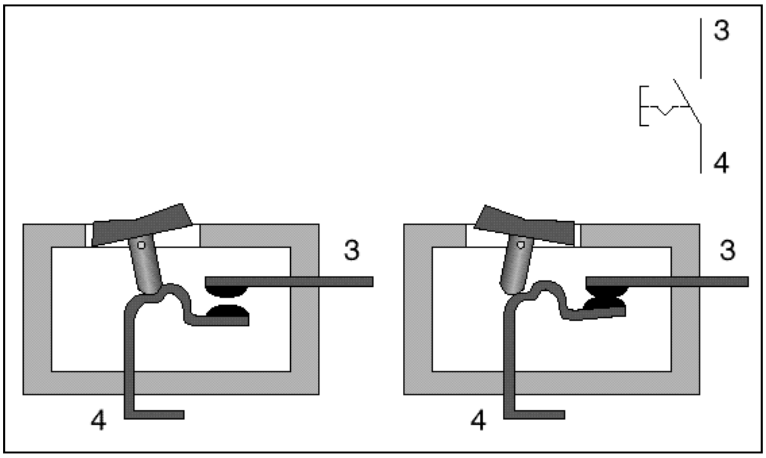


Figure 14.2 – Detented Switch

Both types are available for the operations with normally closed, normally open and changeover types.

14.2.1 Normally Open Switch

For this switch, the circuit is open when the push button is in the normal position; ie. not pressed. The circuit is closed when the control stem is actuated; the current then flows to the consuming device.

When the push button is released, the control stem is released and is returned to its original position, breaking the contact.

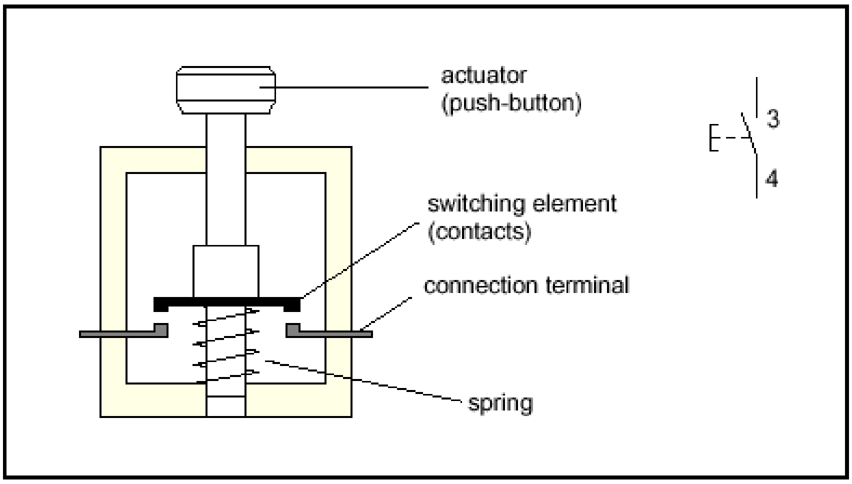


Figure 14.3 – Normally Open Switch

14.2.2 Normally Closed Switch

In the normally closed version, the circuit is closed when the push button is in the normal position. The spring action ensures that the contacts remain closed until the push button is pressed. The current flow is interrupted when the push button is pressed.

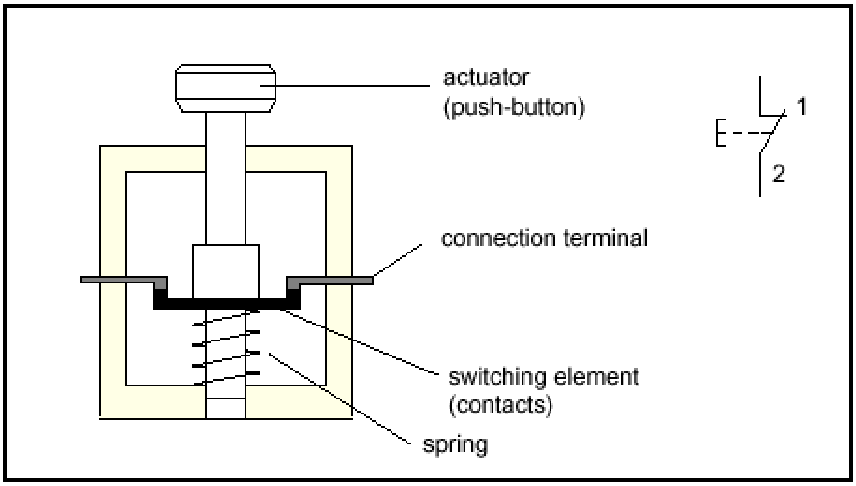


Figure 14.4 – Normally Closed Switch

14.2.3 Changeover Switch

The third version is the changeover switch. These switches combine the functions of both the open and closed switch in one unit. Changeover switches are used to close one circuit and open another at the same time.

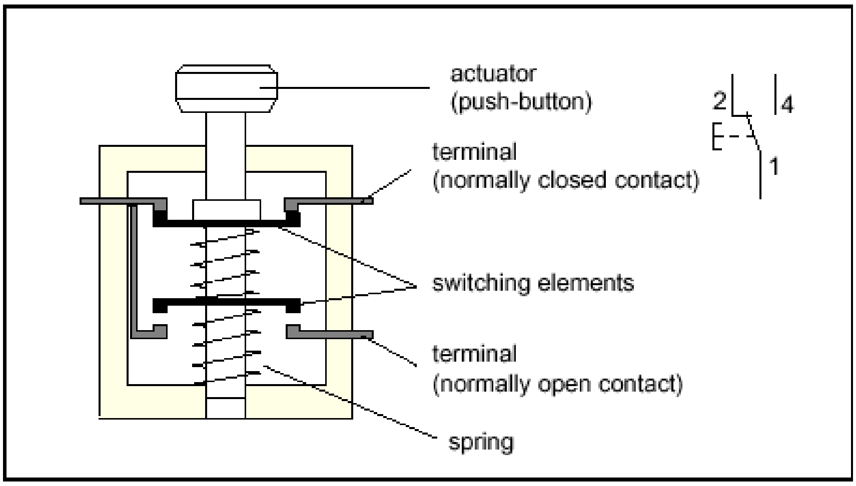


Figure 14.5 – Changeover Switch

14.3 Electrical Contacts

Contacts are basically made up of two elements; a terminal and a moving switch. They are also designed with normally open, normally closed and changeover contacts.

Contacts are different from switches in that they are activated by electrical means such as relays or contactors.

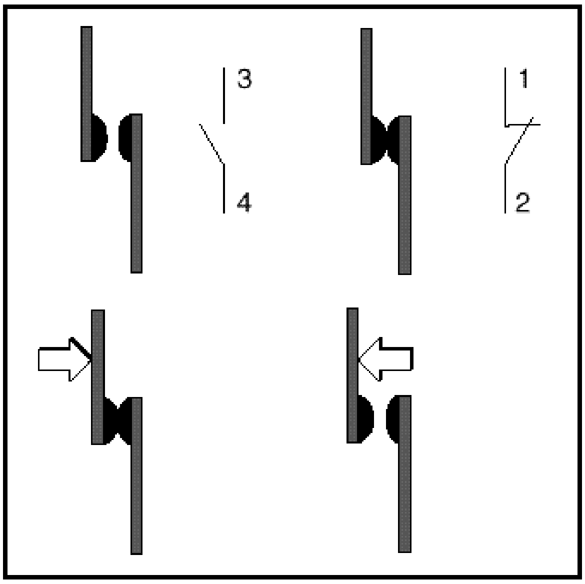


Figure 14.6 – Normally Open and Normally Closed Contacts

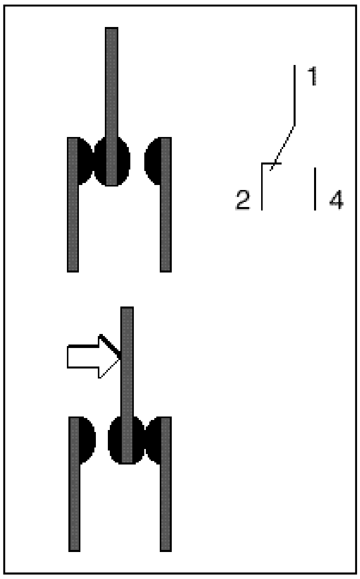


Figure 14.7 – Changeover Contact

14.4 Electrical Relays

Relays are used for switching and controlling electrical circuits requiring only a low amount of energy. They can be considered as an electro-magnetic switch. A small amount of energy applied to the coil can control a larger flow through the relay contacts.

Relays are generally used as signal processors in electro-pneumatic and circuits.

A relay has certain characteristics:

- Low maintenance.
- Able to switch a number or independent circuit paths.
- Easily adaptable to various operating voltages.
- Higher operating speed, ie. short switching time.

When voltage is applied to the coil (2), an electrical current flow through the winding; a magnetic field builds up and pulls the armature (1) against the core (4) of the coil. The armature is mechanically joined to contact 1 and is pulled against contact 4.

The switching position is maintained as long as the voltage is applied. When the voltage is removed, the armature is restored to its original position by spring (3). In the initial position, contact 2 is active.

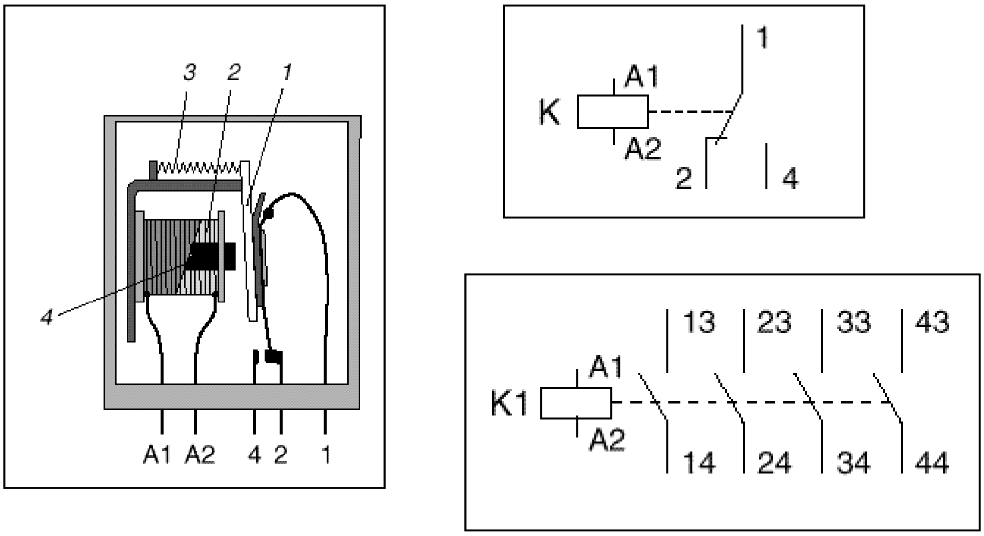


Figure 14.8 – Electrical Relays

14.5 Electrical Contactors

Contactors are similar to relays and work on the same principle but are used to switch higher loads. They are used for higher current usually above 20A.

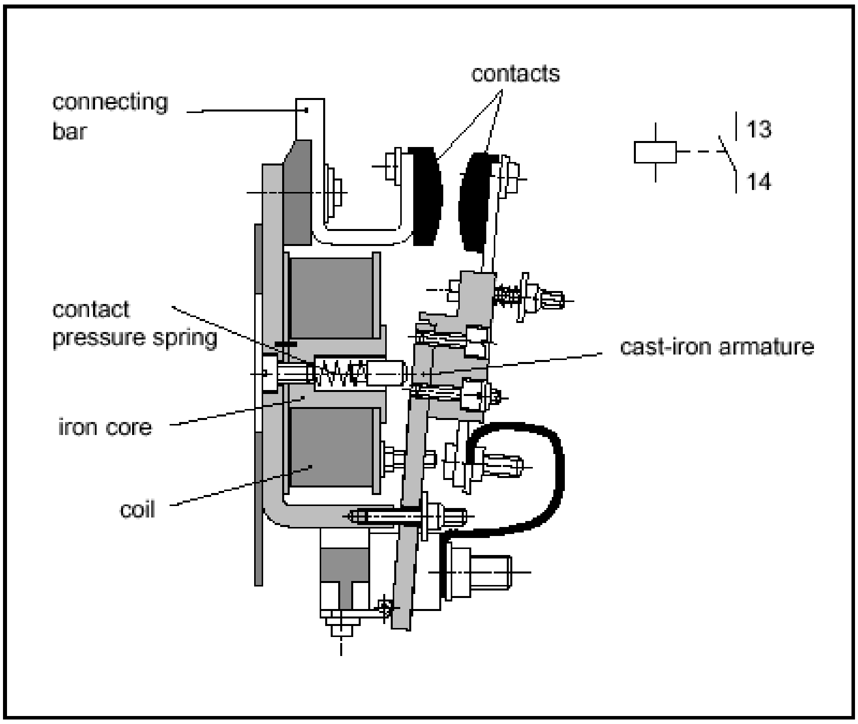


Figure 14.9 – Electrical Contactor

14.6 Electrical Sensors

Sensors are used to provide an input to the electrical system. They are used generally for detecting components or cylinder positioning.

14.6.1 Electrical Limit Switches

A limit switch is actuated when a machine part or workpiece is in a certain position. Normally, actuation is effected by a cam. Limit switches are normally changeover contacts.

They can then be connected
- as required
- as a normally open contact, normally closed contact or changeover contact.

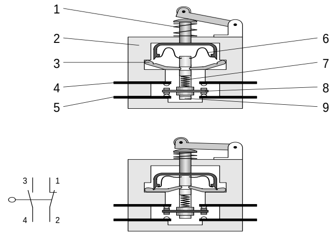


Figure 14.10 – Electrical Limit Switch

14.6.2 Reed Switches

Reed switches are also known as magnetically actuated proximity switches. In electro-pneumatic control circuits, reed switches are commonly used to sense the positions of cylinder piston rods and the angle of rotation of the shaft in rotary actuators. Reed switches are characterised by their small size and fast switching time. Since they are actuated by a magnetic field rather than by mechanical contact, the reed switch is reliable in operation providing the specified electrical connection and mounting requirements are adhered to.

In its basic form, the reed switch has a contact pair fused into an inert gas filled glass tube. In this configuration, the switch would be vulnerable to mechanical damage, therefore in industrial applications the switch is encapsulated in epoxy resin.

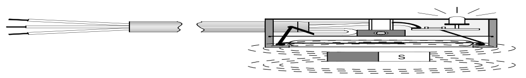


Figure 14.11 - Magnetic Reed Proximity Sensors

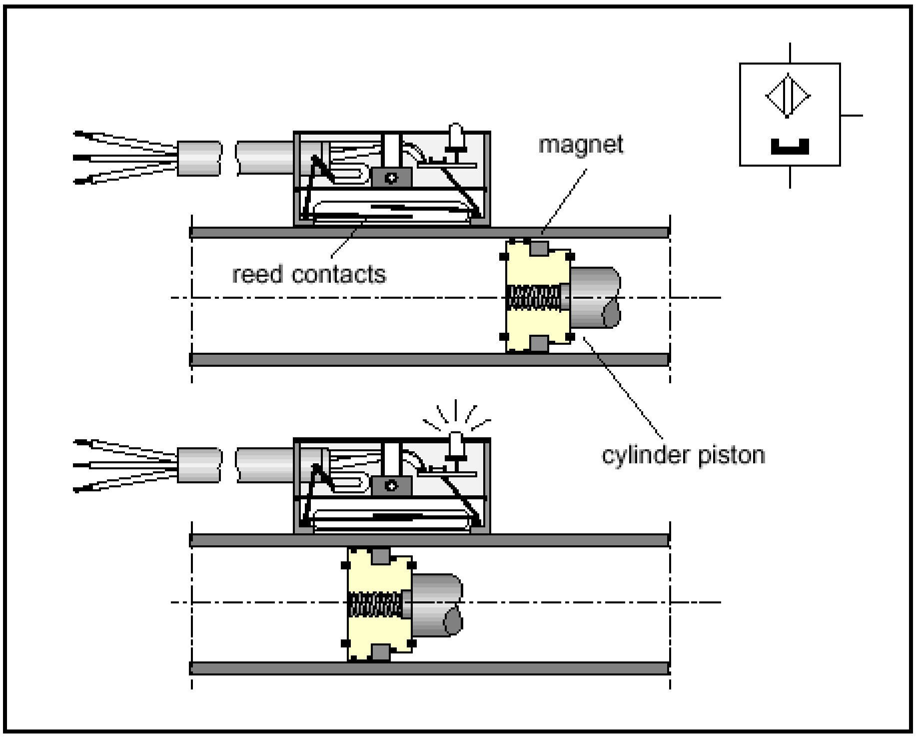


Figure 14.12 – Reed Switches

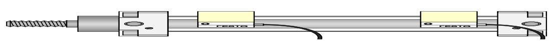


Figure 14.13 - Pneumatic Cylinder with Magnetic Proximity Sensors.

14.6.3 Pressure Switches

Pressure switches are used to convert pneumatic pressure to electrical signals. They can be used to open, close or change between circuits when a pre-set pressure is reached.

In general, the supply pressure acts on a piston surface. The resulting force acts against an adjustable spring pressure. If the pressure is greater than the force of the spring, the piston is moved and actuates contact assembly.

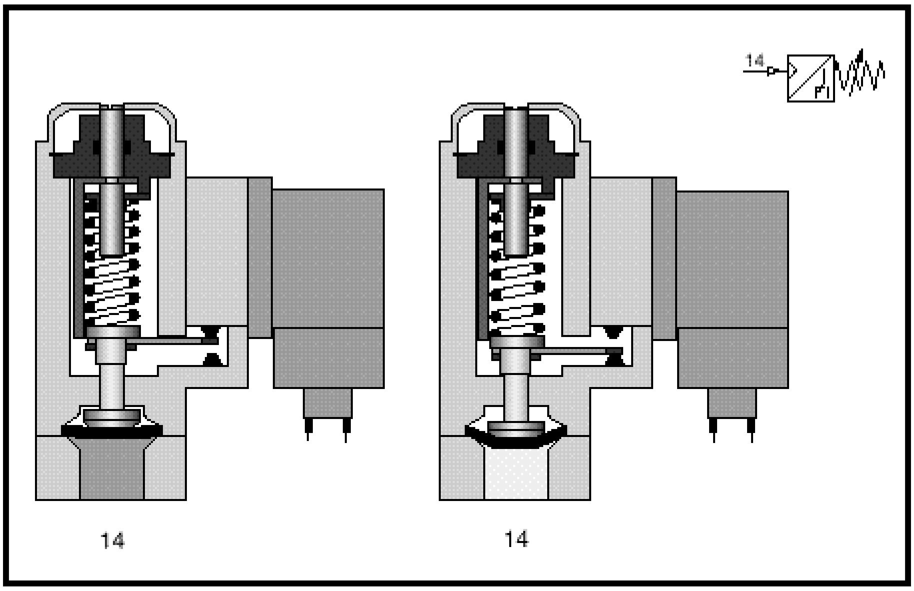


Figure 14.11 – Pressure Switches

14.6.4 Inductive Proximity Sensors

An inductive proximity sensor consists of an oscillating circuit (1), a triggering stage (2) and an amplifier (3). When a voltage is applied to the terminals, the oscillating circuit generates a high-frequency electro-magnetic field which is emitted from the end face of the proximity sensor. If a good electrical conductor is introduced into this oscillating magnetic field, the oscillating circuit is dampened. The downstream triggering stage evaluates the oscillating circuit signal and activates the switching output via the amplifier.

Inductive proximity sensors can only detect metals.

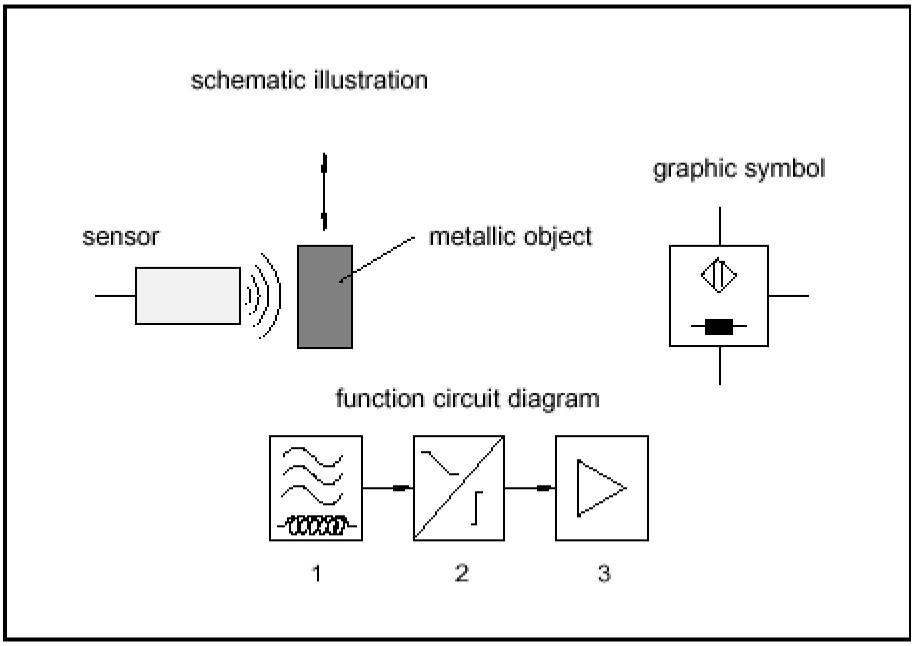


Figure 14.12 – Inductive Proximity Sensors

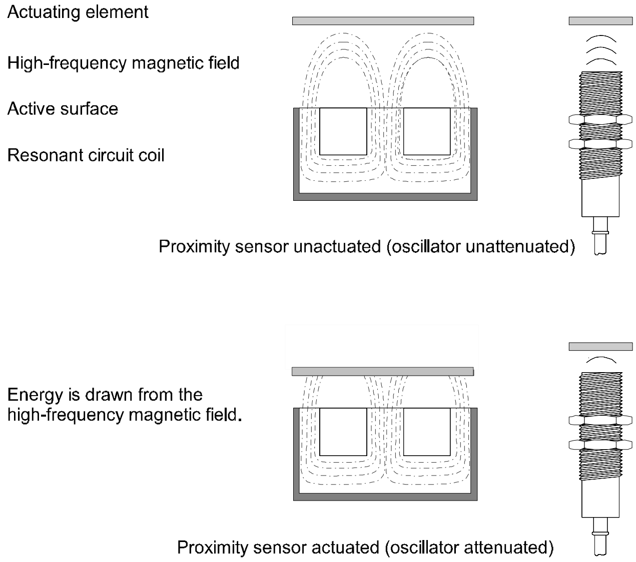


Figure 14.13 - Method of Operation of an Inductive Proximity Sensor

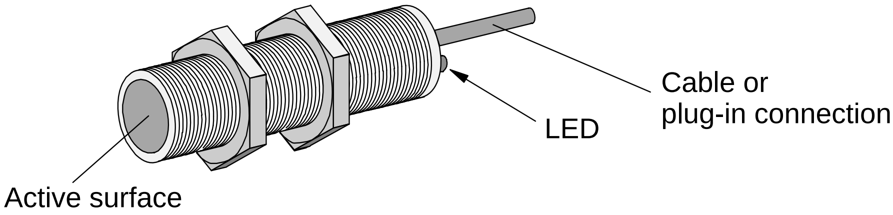


Figure 14.14 - Inductive Proximity Sensor in Threaded Design

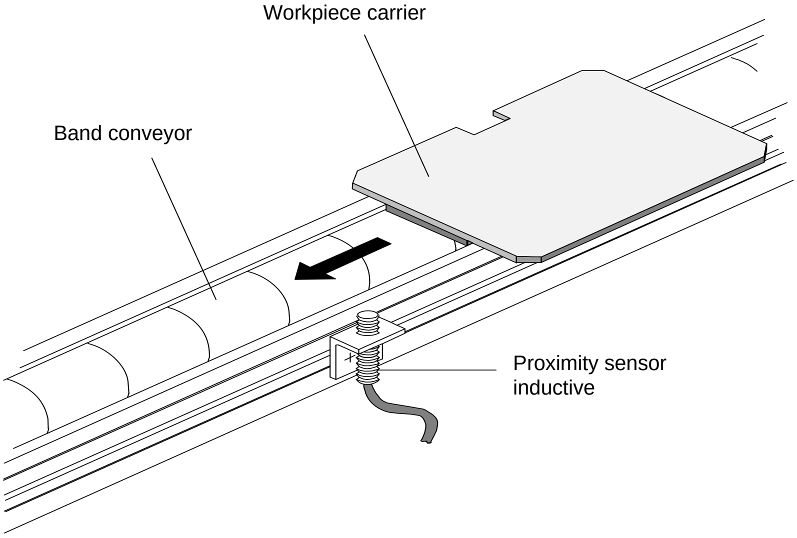


Figure 14.15 - Detection of Metallic Workpiece Carriers on a Band Conveyor

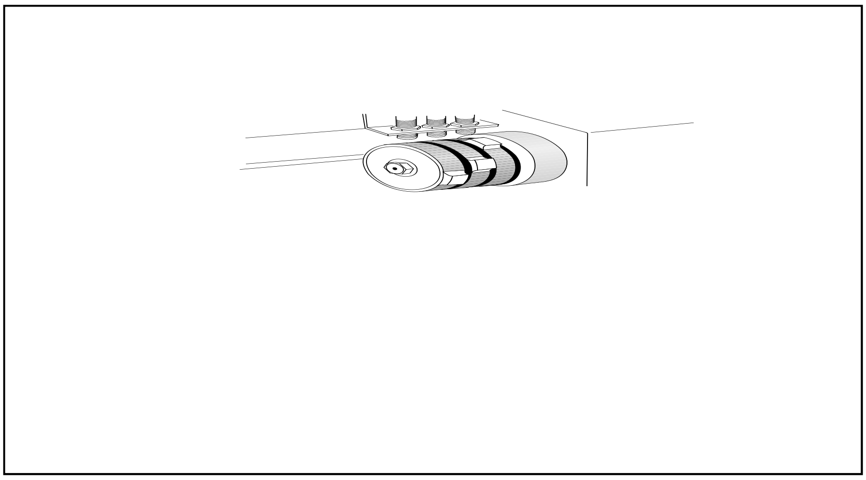


Figure 14.16 - Sensing a Cam Controller

14.6.5 Capacitive Proximity Sensors

Capacitive proximity sensors measure the change in capacitance in the electrical field of a capacitor caused by the approach of an object. The proximity sensor consists of an ohmic resistor, a capacitor (RC oscillating circuit) and an electronic circuit. An electrostatic field is built up in the space between active electrode and earth electrode.

If an object is then introduced into this stray field, the capacitance of the capacitor increases, thus detecting not only highly conductive materials, but also all insulators which possess a high dielectric constant, such as plastics, glass, ceramics, liquids and wood.

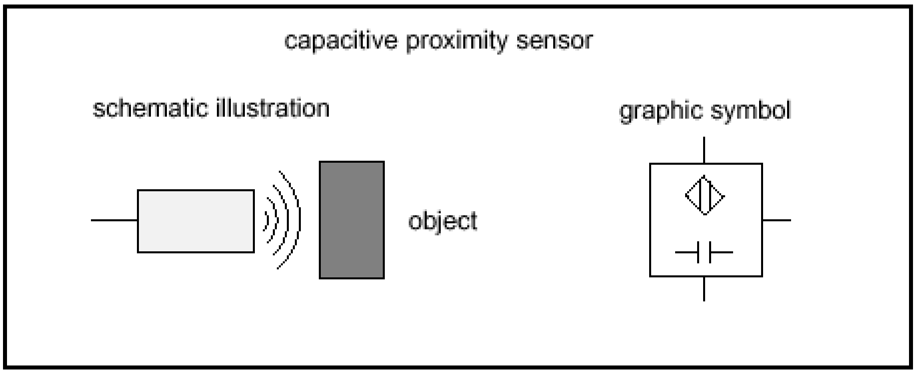


Figure 14.17 – Capacitive Proximity Sensor

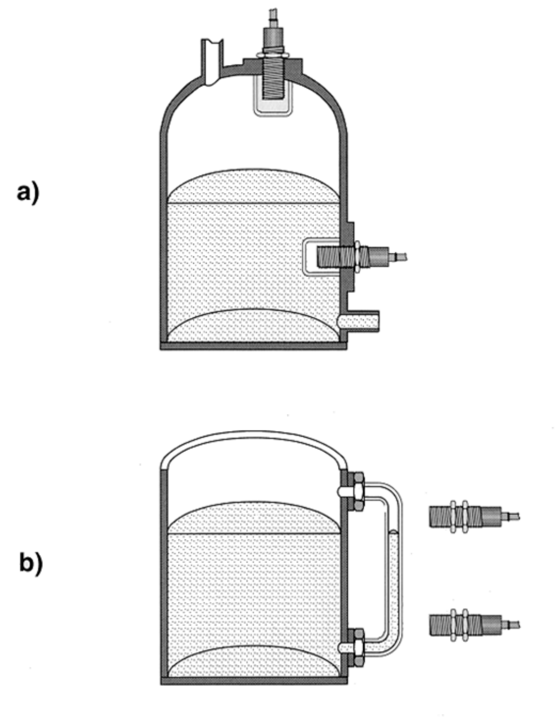


Figure 14.18 - Detection of Filling Level Inside a Steel Container

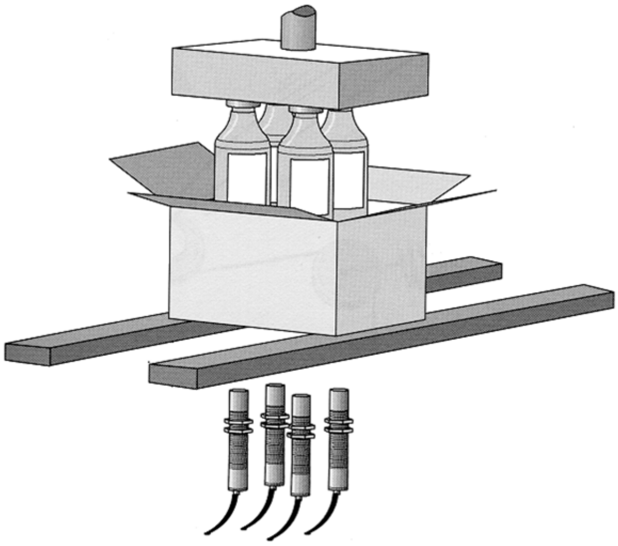
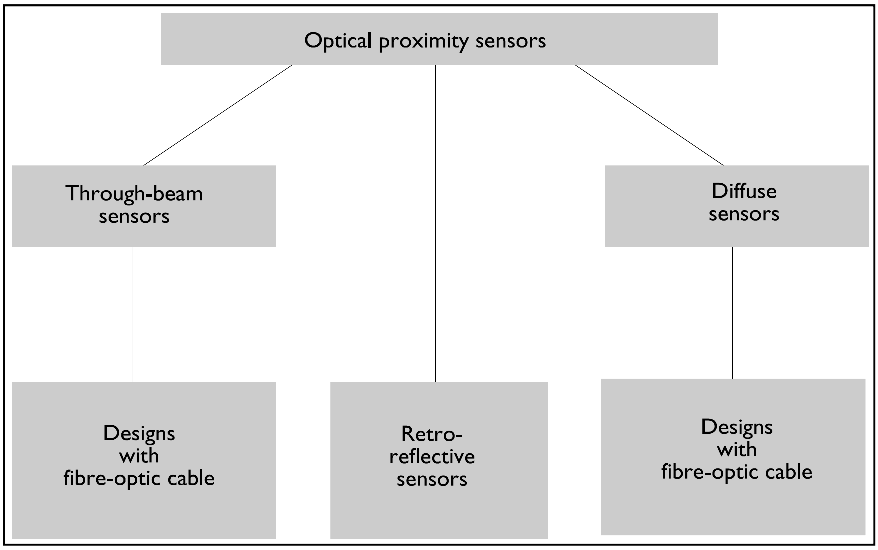


Figure 14.19 - Checking of Packaging Contents through Cardboard

14.6.6 Optical Proximity Sensors

Optical proximity sensors employ optical and electronic means for the detection of objects. Red or infrared light is used for this purpose. Semiconductor light emitting diodes (LED's) are a particularly reliable source of red and infrared light. They are small and robust, have a long service life and can be easily modulated.

There are three types of Optical proximity sensors:



a. Through Beam Sensors

The through-beam sensor consists of spatially separated transmitter and receiver units. The components are mounted in such a way that the transmitter is aimed directly at the receiver. If the light beam is interrupted, the contacts will either open or close.

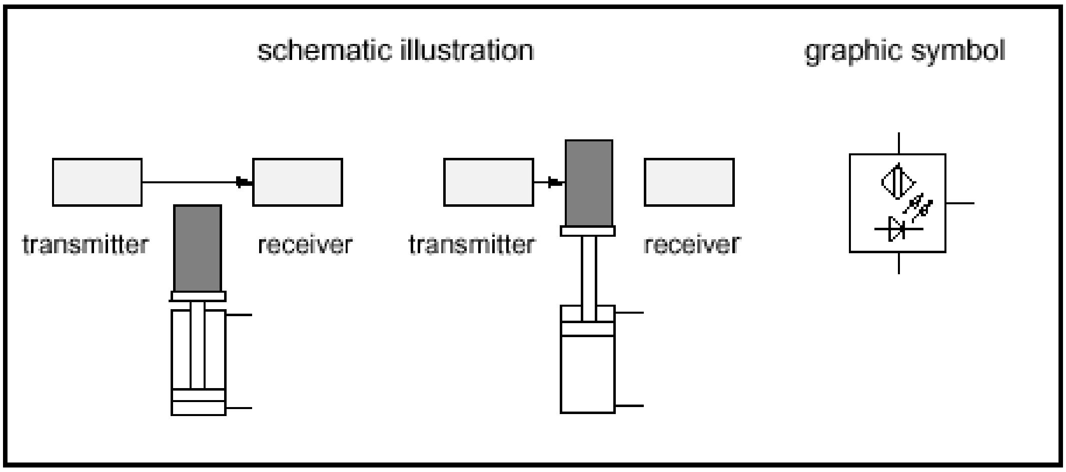


Figure 14.20 – Through Beam Sensor

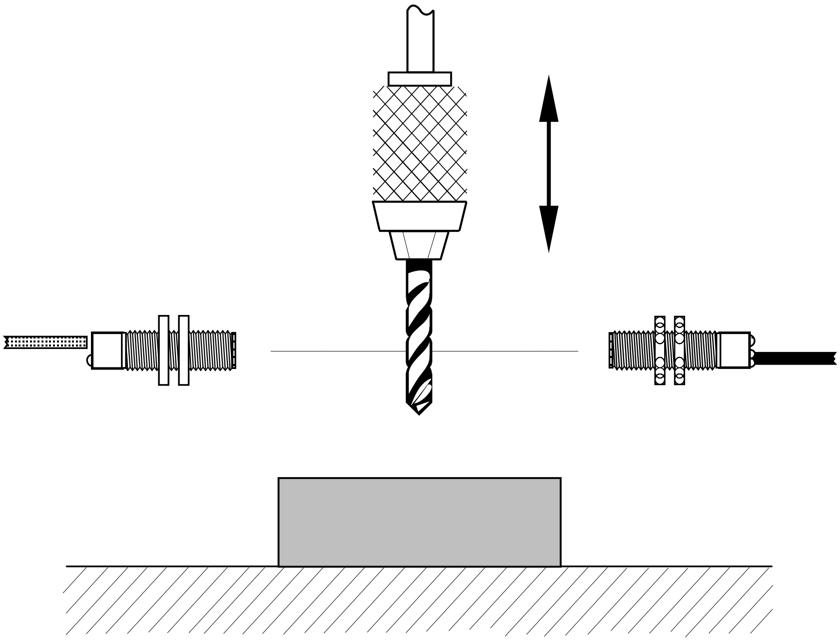


Figure 14.21 - Checking for Broken Drills with a Through-beam Sensor

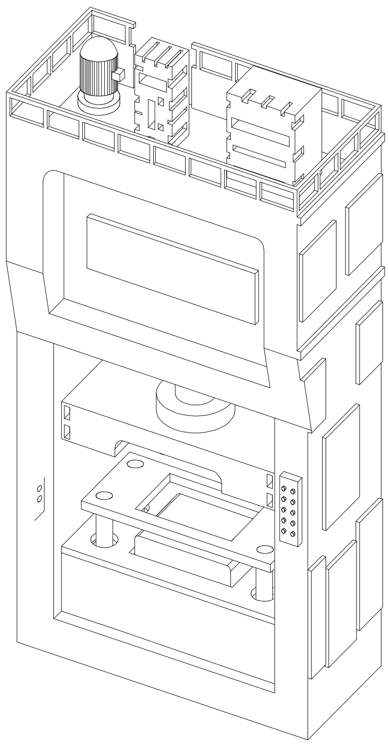


Figure 14.22 - Accident Prevention on a Press by Means of a Through-beam Sensor

b. Retro Reflective Sensors

In retro-reflective sensors, the transmitter and the receiver are mounted side by side in a common housing. For the correct function of these sensors, a reflector must be mounted in such a way that the light beam emitted by the transmitter is more or less totally reflected onto the receiver. Interruption of the light beam causes the sensor to switch.

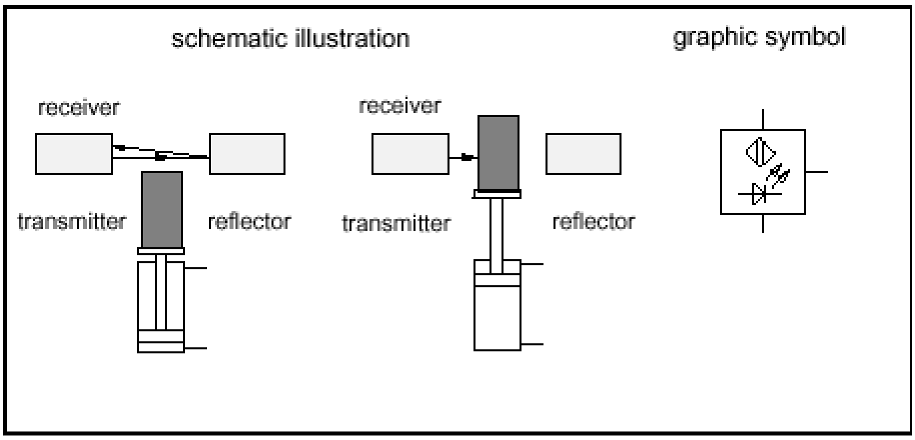


Figure 14.23 – Retro-Reflective Sensor

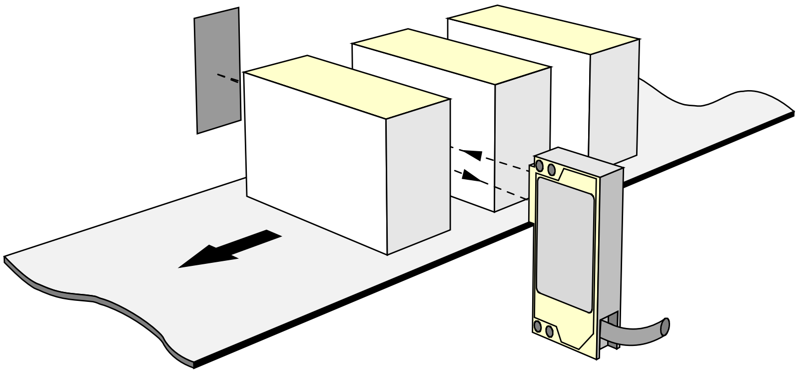


Figure 14.24 - Monitoring Build-up and Counting of Objects

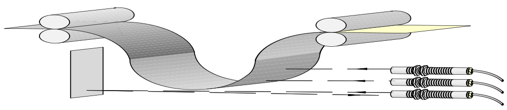


Figure 14.25 - Slack Control

c. Diffuse Sensors

The transmitter and receiver of the diffuse sensor are mounted in a similar way to that of the retro-reflective sensor. If the transmitter is aimed at a reflecting object, the reflected light is absorbed by the receiver and a switching signal is generated. The greater the reflection properties of the object in question, the more reliably the object can be detected.

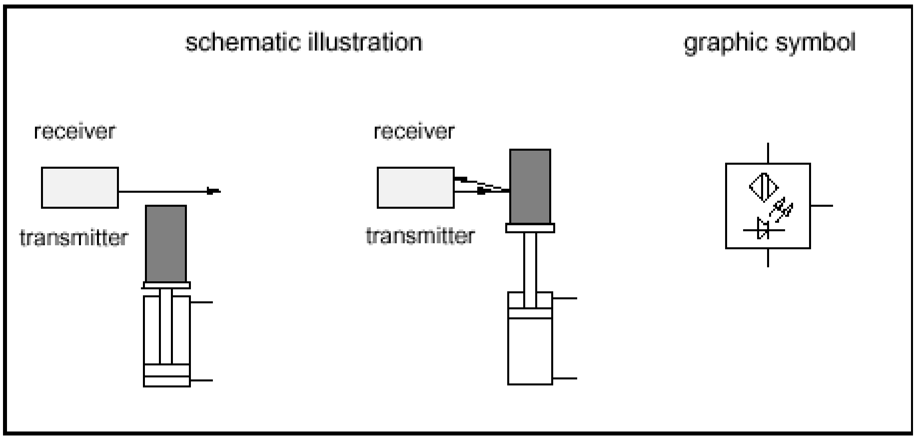


Figure 14.26 – Diffuse Sensor

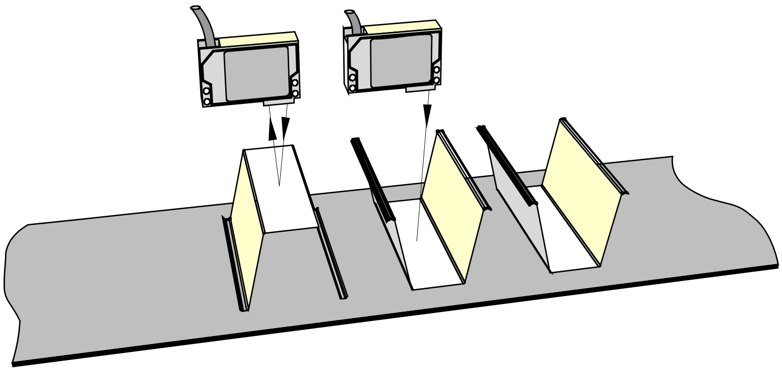


Figure 14.27 - Monitoring the Position of a Workpiece

15.0 Electro-Pneumatic Graphical Symbols

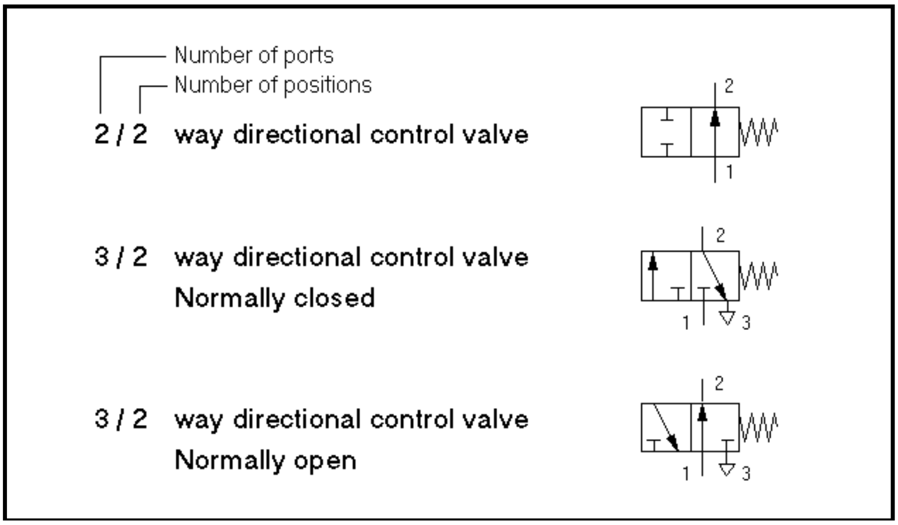
15.1 Introduction

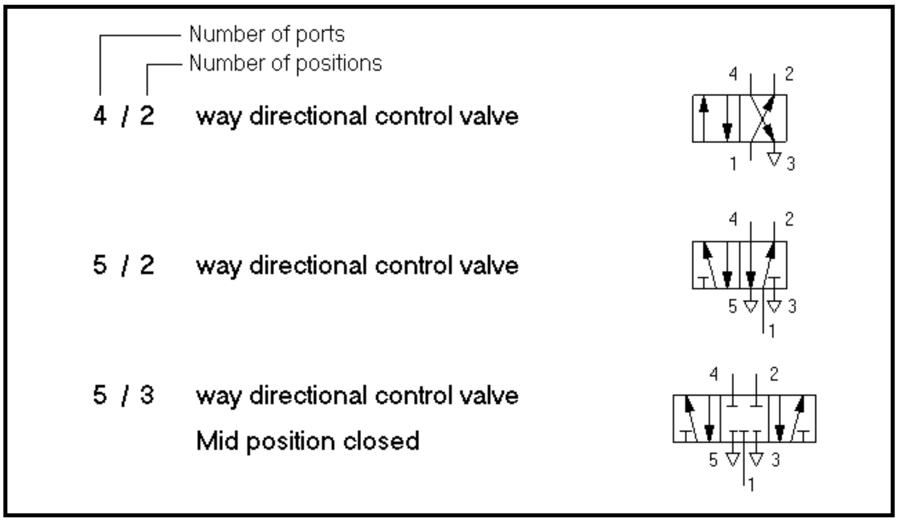
To simplify the presentation of electro-pneumatic systems in circuit diagrams, we use simple symbols (also called graphic and circuit symbols) for the various components.

A symbol is used to identify a component and its function, but tells us nothing about the design of the component. DIN ISO 1219 contains regulations on circuit symbols. The most important graphic symbols are explained below.

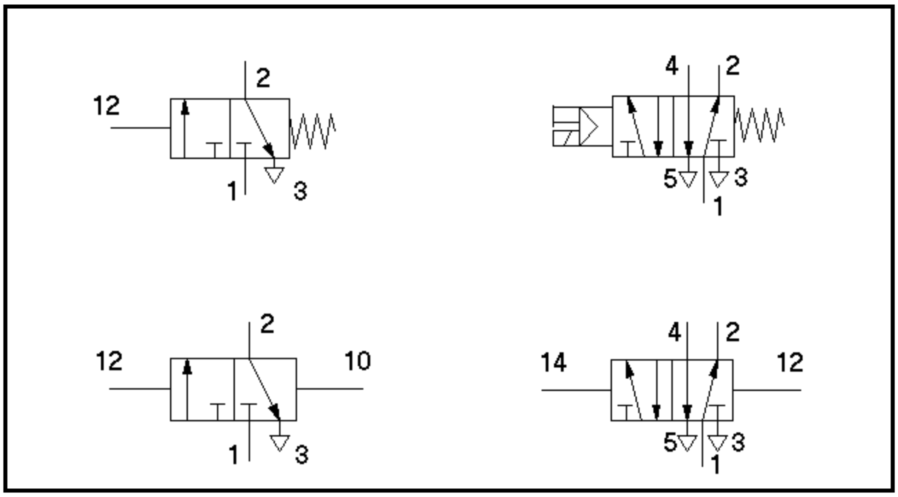
15.2 Directional Control Valves

15.2.1 Symbol Development

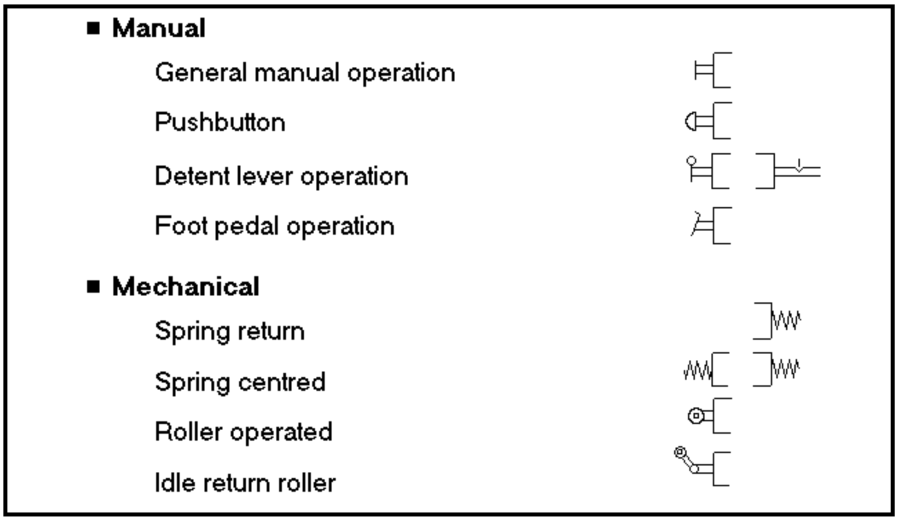


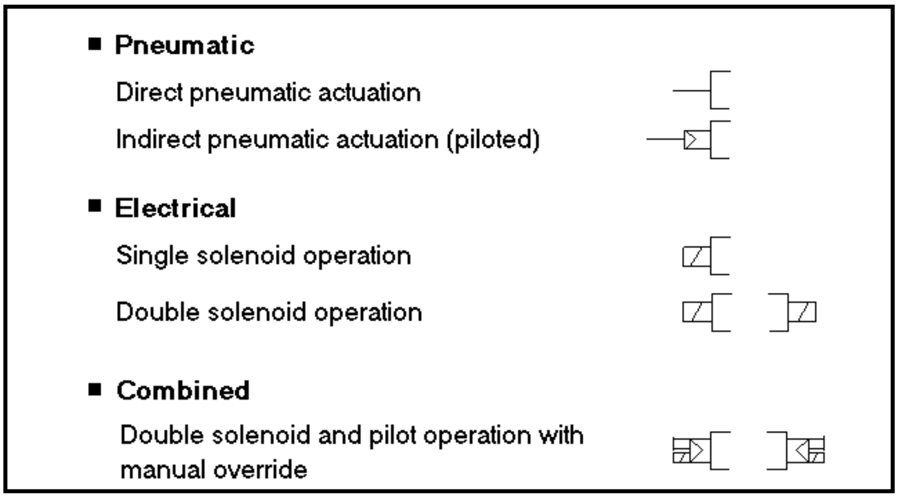


15.2.2 Examples of Designation

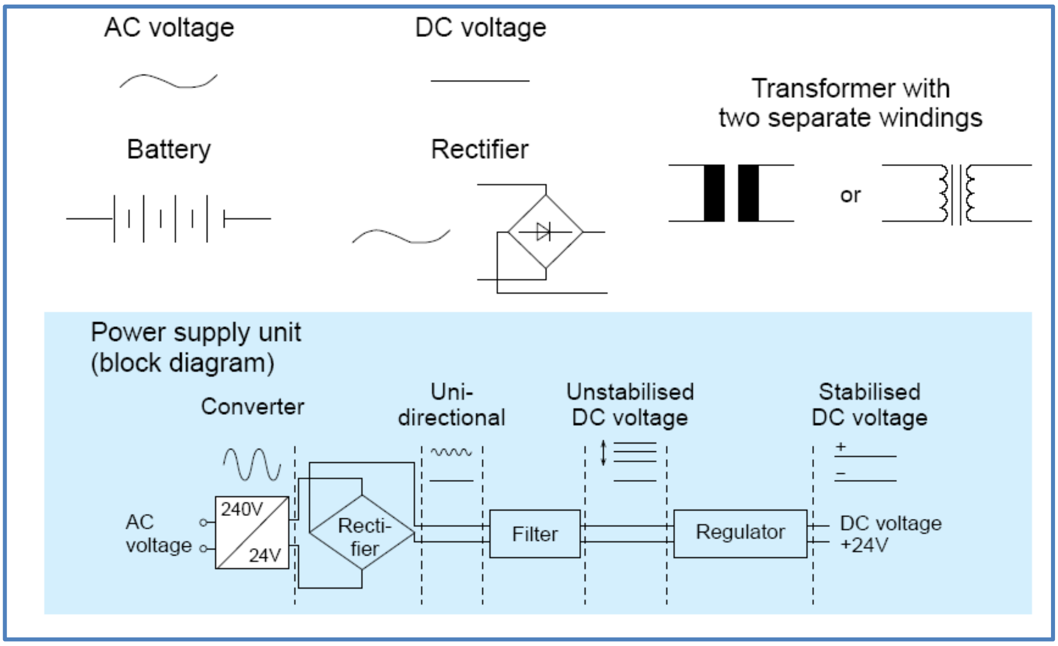


15.2.3 Method of Actuation

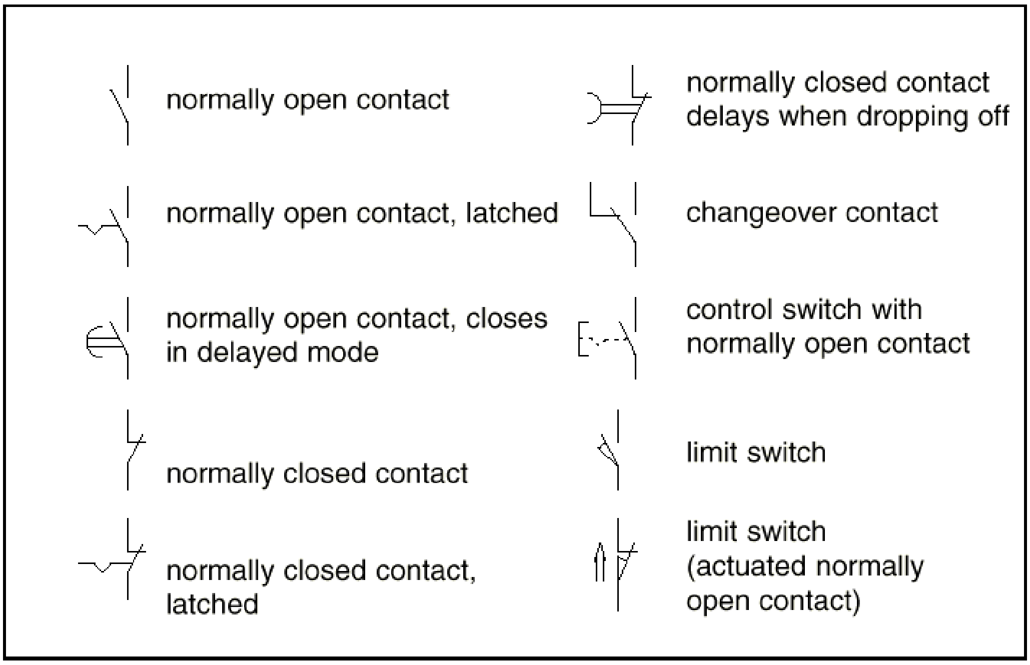


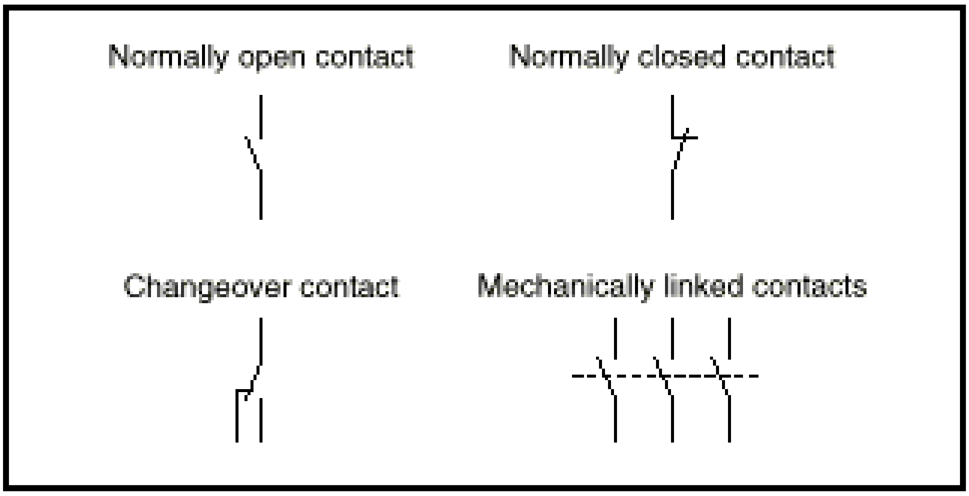


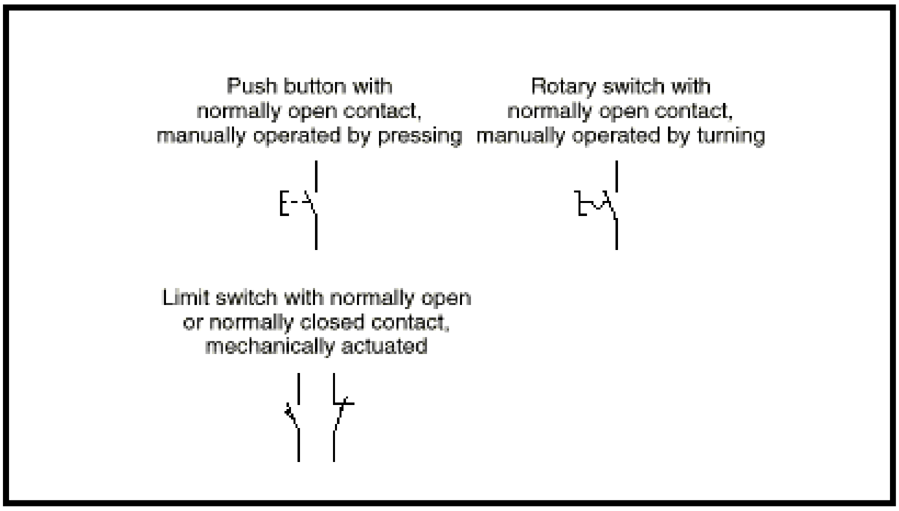
15.3 Power Supply Units



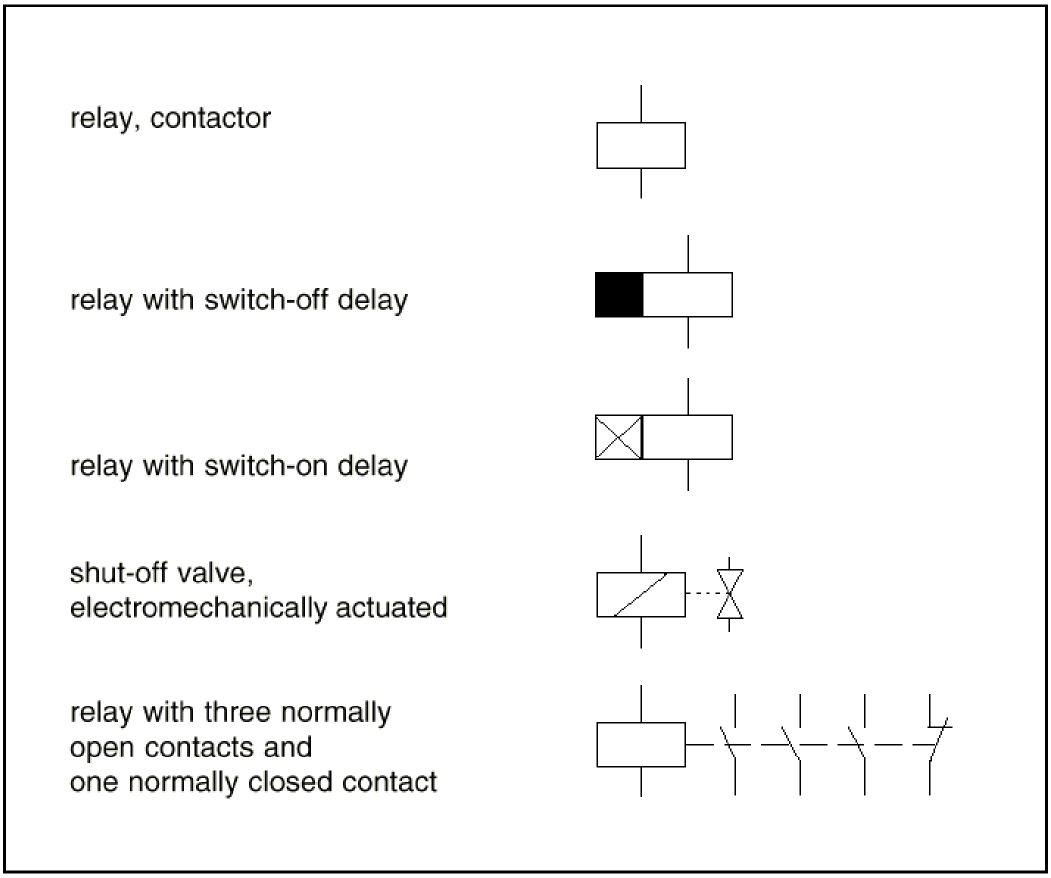
15.4 Switch, Contacts and Types of Actuation

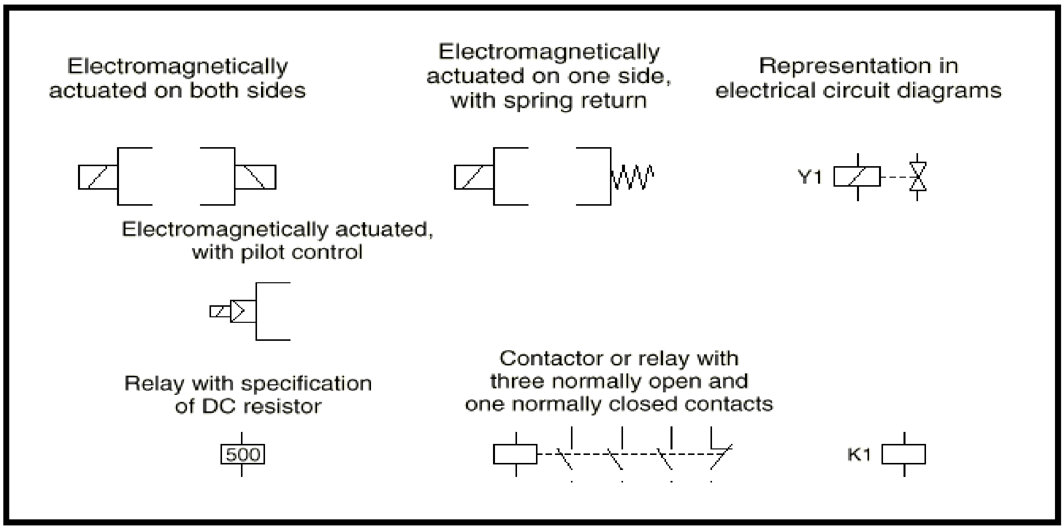



Normally open contact
Normally closed contact
Changeover contact
Mechanically linked contacts

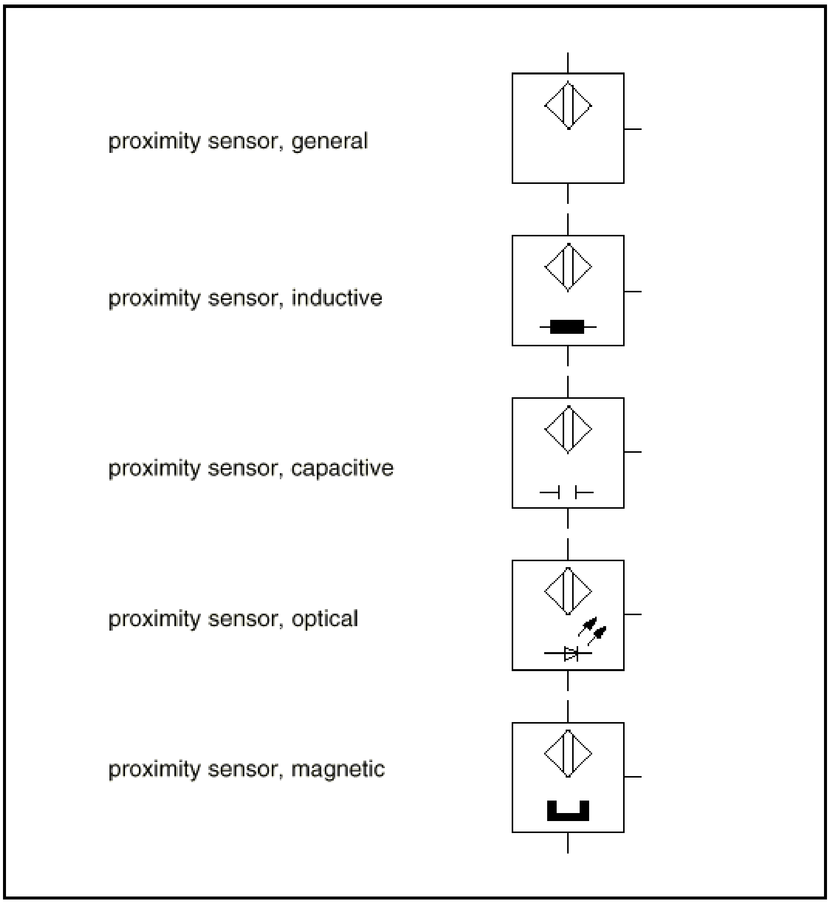

Push button with
normally open contact,
manually operated by pressing
Rotary switch with
normally open contact,
manually operated by turning
Limit switch with normally open
or normally closed contact,
mechanically actuated

15.5 Relays, Timers and Solenoids





15.6 Sensors


proximity sensor, general
proximity sensor, inductive
proximity sensor, capacitive
proximity sensor, optical
proximity sensor, magnetic

16.0 Logic Functions

16.1 Introduction

Electro-pneumatic circuits are developed depending on size and complexity, either on one drawing sheet or on separate sheets cross referenced to each other. The circuits can be divided into two groups:

- Pneumatic Circuit Diagram
- Electrical Circuit Diagram

There exists an interface between the pneumatic and electrical elements. These elements will appear on both the pneumatic and the electrical circuit diagrams with common identification markings.

16.2 Designing Electro-Pneumatic Circuits

16.2.1 Development Steps

The steps in development of basic circuits are:

- Describe the operation of the circuit.
- Develop a displacement-step diagram of the process.
- Draw the pneumatic components of the diagram.
- Draw the electrical portion of the diagram.
- Document maintenance information.
- Document component spares and technical data.

16.2.2 System Structure

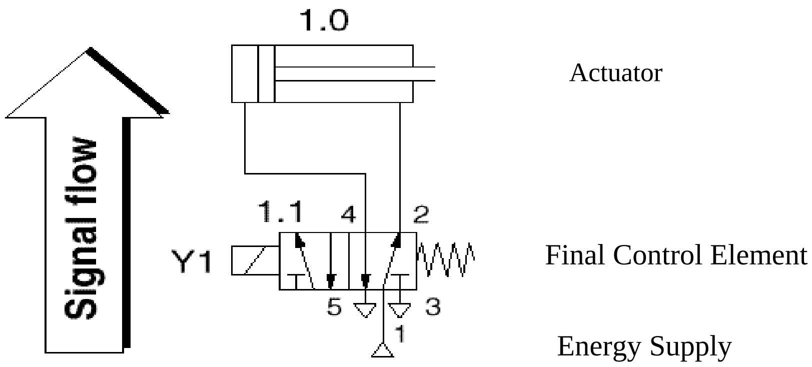
Components in a control system belongs to four basic groups:

- Energy Supply
- Input Elements
- Processing Elements
- Final Control Elements and Actuators

16.2.3 Development Guide

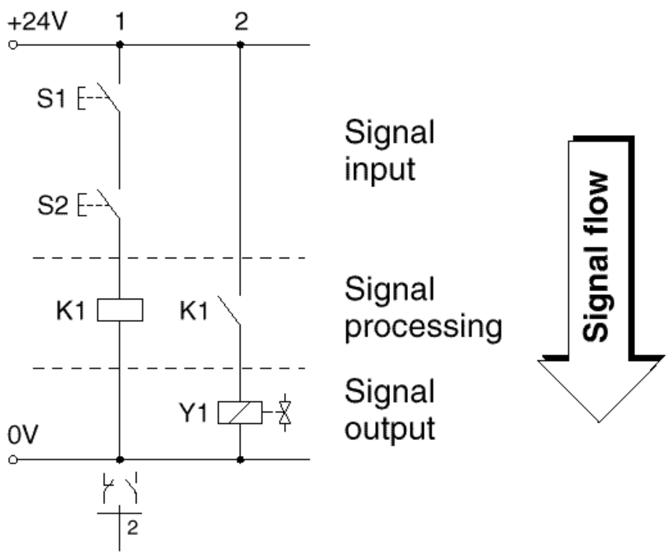
a. Pneumatic

- Circuit layout should follow the signal flow through the control chain from bottom to top.
- Cylinders and directional control valves are drawn horizontally with the cylinders operating from left to right.



b. *Electrical*

- Layout should where possible follow the signal flow through the control chain from top to bottom.
- Circuits with intermediate or relay control can be further divided into a control section and a power section and components placed in these sections from left to right according to the sequence of operations. These processes should be treated as a guide only, as a clear division of these functions is not always possible.



16.3 Logic Functions

There are seven commonly used logic functions in Electro-Pneumatics.

- YES Function
- NOT Function
- OR Function
- AND Function
- NOR Function
- NAND Function
- Memory Function

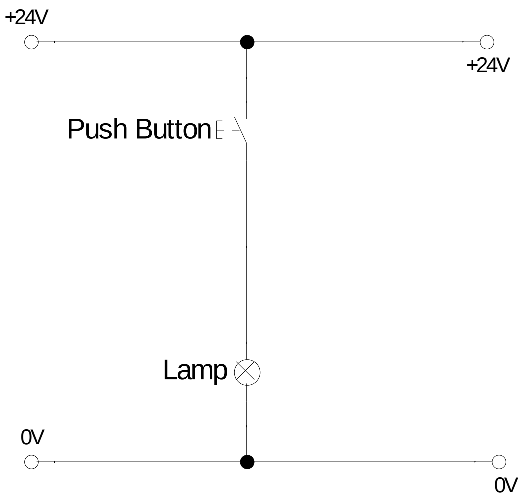
When designing circuits, you can do it directly or indirectly. When doing it indirectly, a relay is often used. The indirect method is commonly used in designing electro-pneumatic circuits.

16.3.1 YES Logic

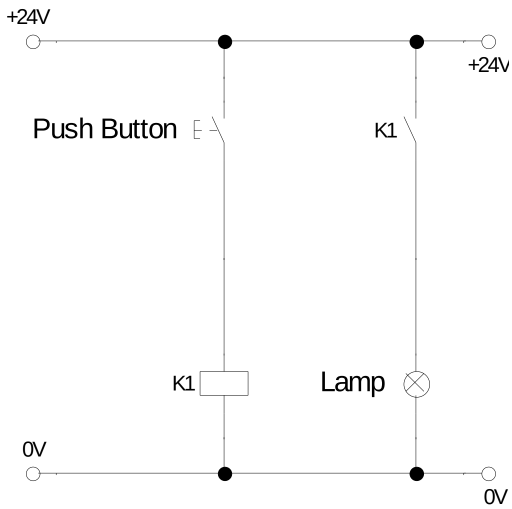
Truth Table

S1	Lamp
0	0
1	1

For the YES Logic, the Load (in this example we are using the Lamp) is not activated in the normal position. When Switch S1 is pressed, the Load will be "On".



Direct Method



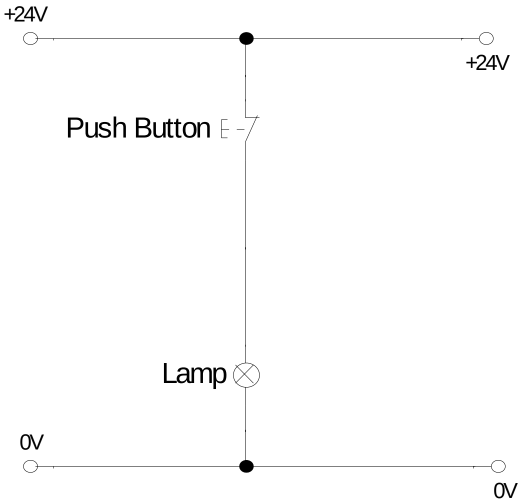
Indirect Method

16.3.2 NOT Logic

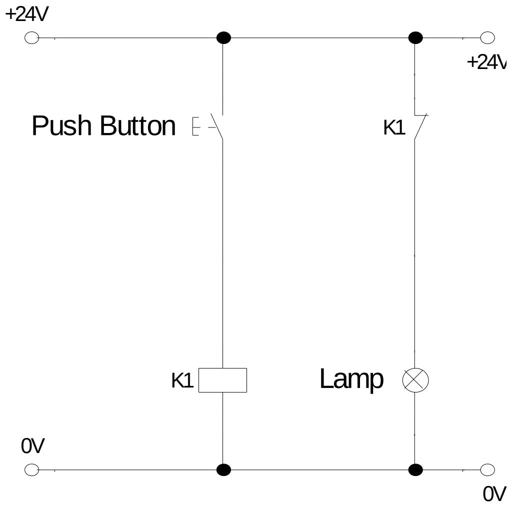
Truth Table

S1	Lamp
0	1
1	0

For the NOT Logic, the Load is activated in the normal position. When Switch S1 is pressed, the Load will be "Off". In the Indirect method, take note that the switch should not be normally closed but use a normally closed relay contact. This is to protect the relay from being energised always.



Direct Method



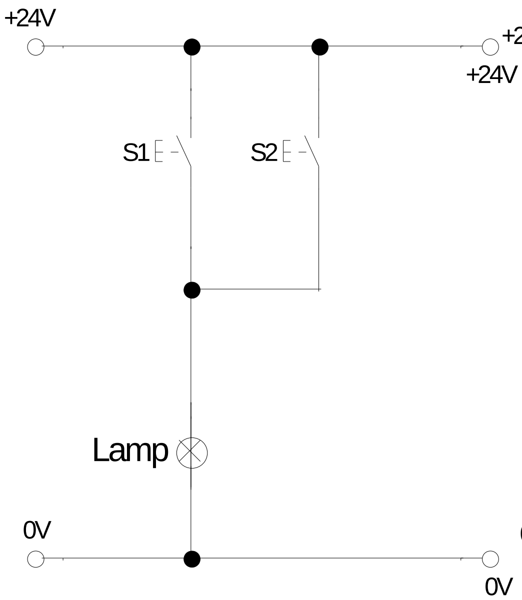
Indirect Method

16.3.3 OR Logic

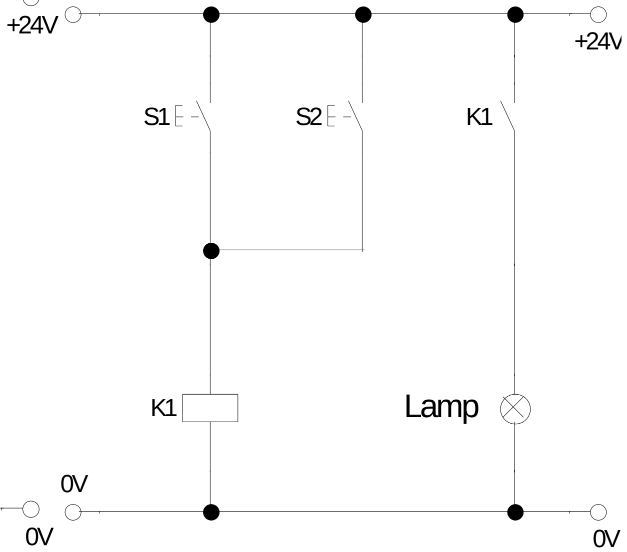
Truth Table

S1	S2	Lamp
0	0	0
1	0	1
0	1	1
1	1	1

For the OR Logic, the Load is "Off" in the normal position. When either Switch S1 or Switch S2 is pressed, the Load will be "On". The Load will also be "On" when both switches are pressed. The truth table above reflects this.



Direct Method



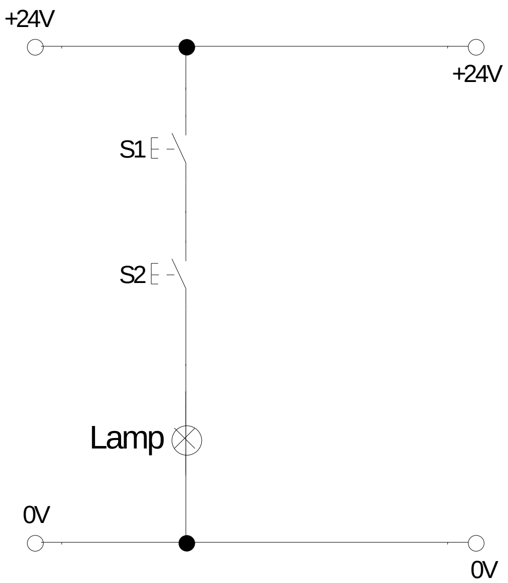
Indirect Method

16.3.4 AND Logic

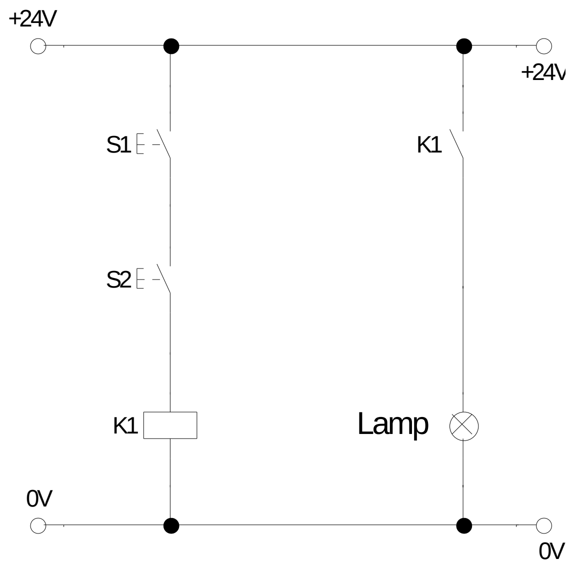
Truth Table

S1	S2	Lamp
0	0	0
1	0	0
0	1	0
1	1	1

For the AND Logic, the Load is "Off" in the normal position. When both Switch S1 and Switch S2 are pressed, the Load will be "On".



Direct Method



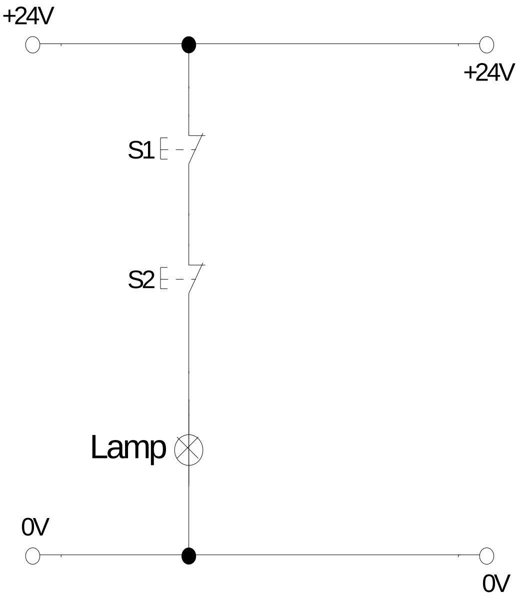
Indirect Method

16.3.5 NOR Logic

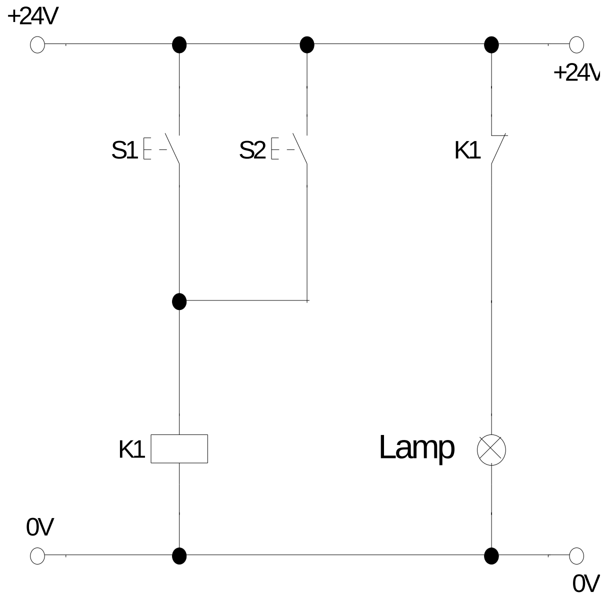
Truth Table

S1	S2	Lamp
0	0	1
1	0	0
0	1	0
1	1	0

The NOR Logic is a combination of NOT and OR, the Load is activated in the normal position. When either Switch S1 or Switch S2 are pressed, the Load will be "Off".



Direct Method



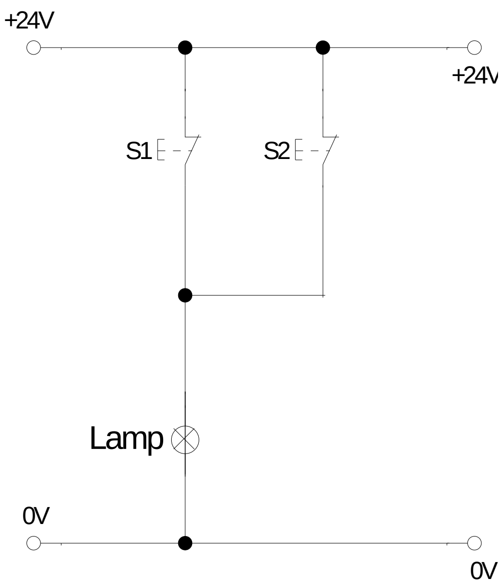
Indirect Method

16.3.6 NAND Logic

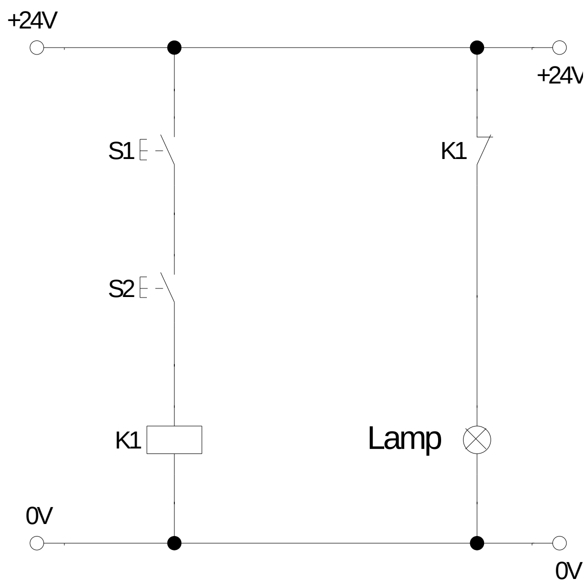
Truth Table

S1	S2	Lamp
0	0	1
1	0	1
0	1	1
1	1	0

The NAND Logic is a combination of NOT and AND, the Load is activated in the normal position. When both Switch S1 and Switch S2 are pressed, the Load will be "Off".



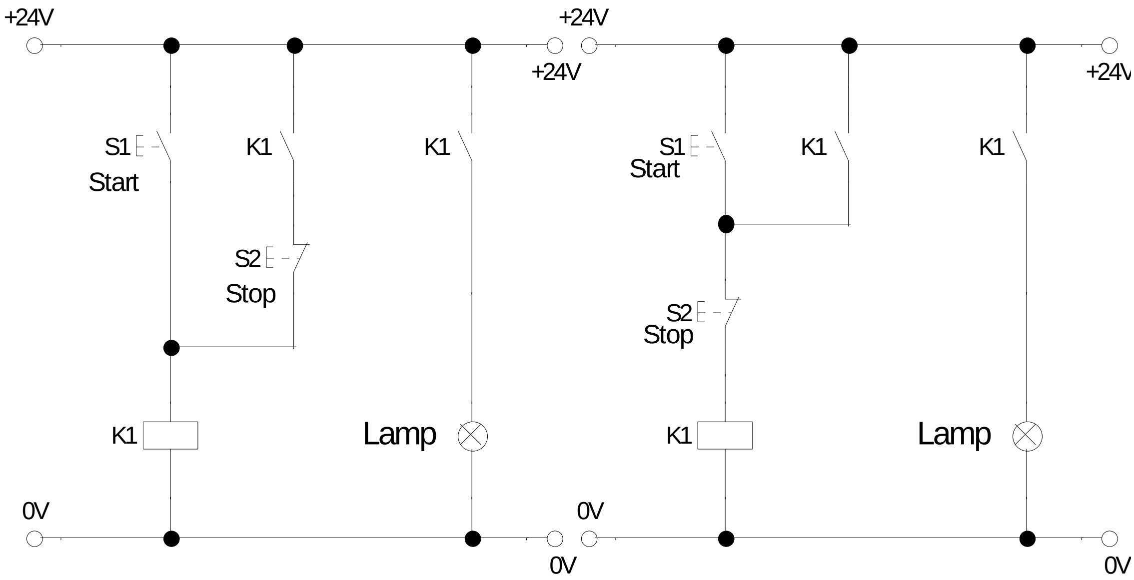
Direct Method



Indirect Method

16.3.7 Memory or Latching Function

So far, the following logic circuits needs the user to press the switches and hold on to it during usage. This is of course not practical in designing systems. It is usually the case where the switch is pressed once and the entire system runs without holding on to it. This latching system is very useful for sequencing circuits and is often used in electro-pneumatic circuit designs. There are two forms; Dominant On and Dominant Off. In dominant on, the "On" switch is dominant and the opposite for dominant off.



Dominant On Dominant Off

17.0 Basic Electro-Pneumatic Circuits

17.1 Controlling Circuits Remotely

Besides the logic functions, there are certain circuits which are controlled remotely. These enable the actuators to return automatically or to stop the actuators automatically.

These circuit designs can also be used to make or break certain parts of the electrical circuit.

It depends on:

- Position - Limit Switches
- Pressure - Pressure Switches (PE Switch)

17.1.1 Position

Actuators can use their position to activate either a limit switch or proximity sensor to make or break an electrical circuit. It is similar to the above logic circuits with the limit switches or proximity sensors replacing the push button switch.

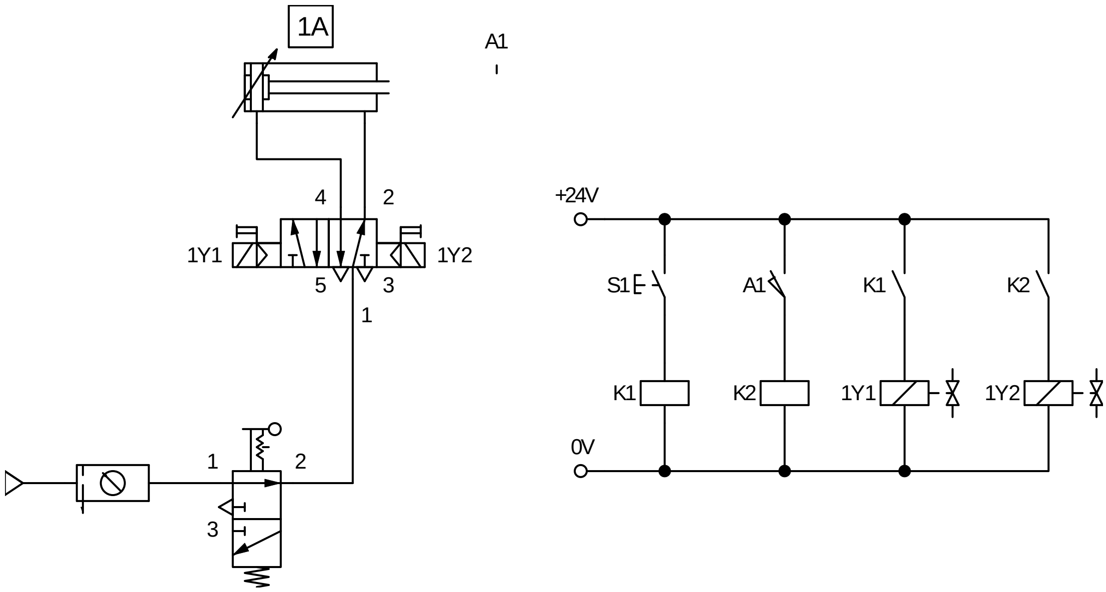


Figure 17.1 – Position

In this circuit, the limit switch A1 is activated once the cylinder extends. Once the limit switch A1 is activated, it will energise relay K2 and subsequently energise Y2 which will cause the cylinder to return automatically.

17.1.2 Pressure

Another method is the use of pressure to make or break the electrical circuit. Once, the pressure builds up to the required pressure setting of the pressure switch, it will be activated and works like the limit switch.

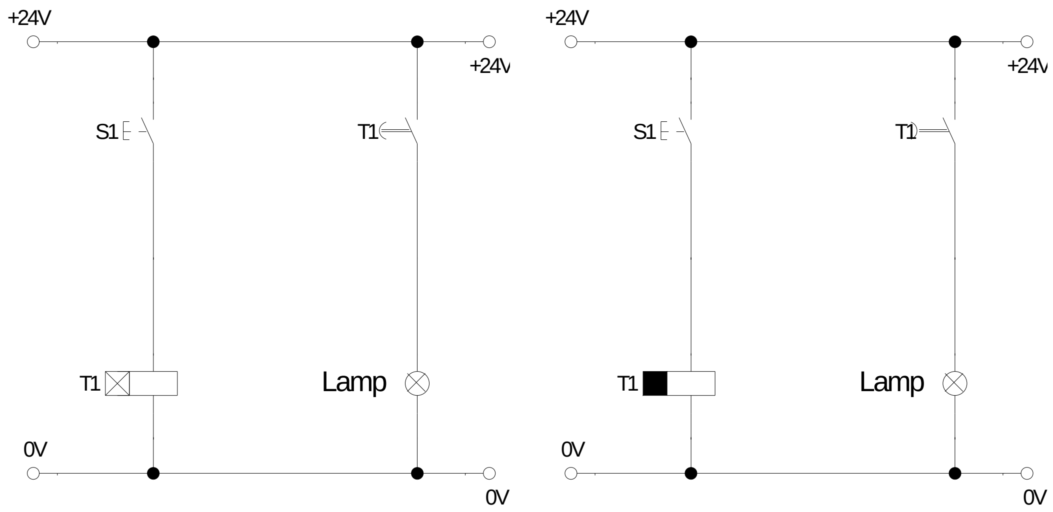
17.1.3 Time

Electrical timers are used to make or break electrical circuits once the preset time has expired. There are two different ways to set electrical timers; either “Delay On Timer” or “Delay Off Timer”.

For “Delay On Timer”, the signal must be present all the time and once the time has expired, the contact will switch over.

For “Delay Off Timer”, once the signal is received, the contact will switch over immediately and will switch back once the preset time is up. For “Delay Off Timer”, the signal must not be present all the time.

For the electrical timer, there are normally closed and normally open contacts available.



Delay On Timer   Delay Off Timer

Figure 17.2 – Time

17.1.4 Count

Like the electrical timer, the electrical counter is used to make or break the electrical circuit. The electrical counter is pre-set with the desired number and once the counter reaches this pre-set number, the contact will switch over. There are normally closed and normally open contacts available.

Remember, that you need to give the electrical counter pulses for it to count; a long signal would just jump once. You would also have to design the circuit to reset the counter once it has completed its task, this can be done manually or automatically.

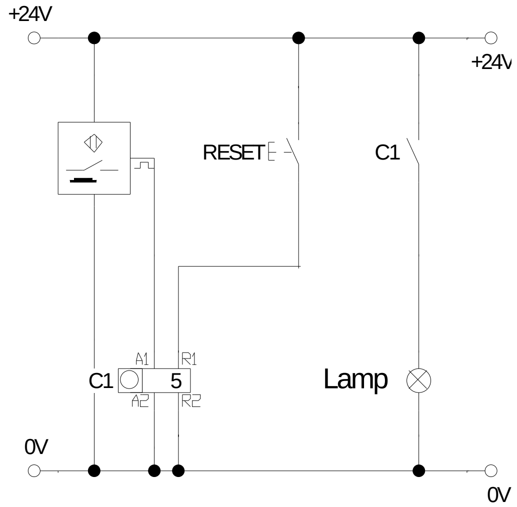


Figure 17.3 – Count

17.2 Basic Electro-Pneumatic Circuits

17.2.1 Control of a Single-Acting Cylinder

The piston of a single-acting cylinder is to travel out when a push button switch is pressed. When the button is released, the cylinder is to return to the final rear position.

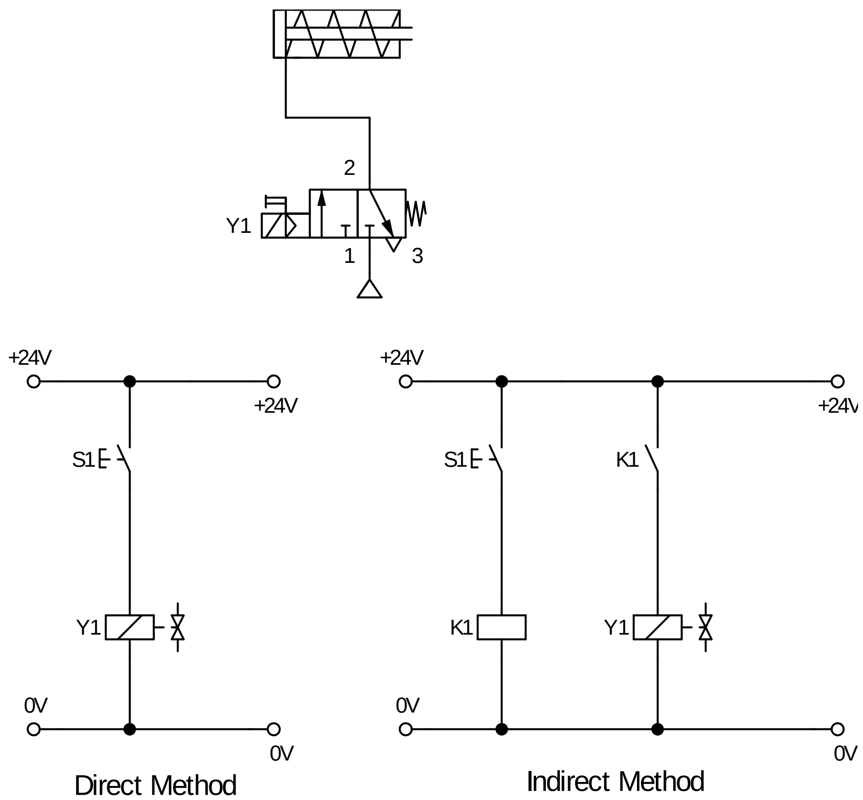


Figure 17.4 – Control of a Single-Acting Cylinder

a. Direct Method

The circuit is closed when push button switch S1 closes. A magnetic field is produced in coil Y1. The armature in the coil opens the passage for the compressed air. The compressed air flows from 1 to 2 to the cylinder, which travels to the final forward position.

When push button switch S1 is released, the circuit is interrupted. The magnetic field at coil Y1 collapses, the 3/2-way valve switches back to its original position and the cylinder travels to the final rear position.

b. Indirect Method

With the indirect method, the push button switch S1 energises a relay K1. The coil Y1 is energised via a normally open contact of K1 (indirect energising). Otherwise the sequence is the same as the direct method.

The indirect method must be applied when the switching capacity of signalling device (S1) is not sufficient to switch coil Y1, or if further processing is required with a different voltage (230V).

17.2.2 Control of a Double-Acting Cylinder

The piston of a double-acting cylinder is to travel out when a push button switch is pressed. It is to return when the push button switch is released.

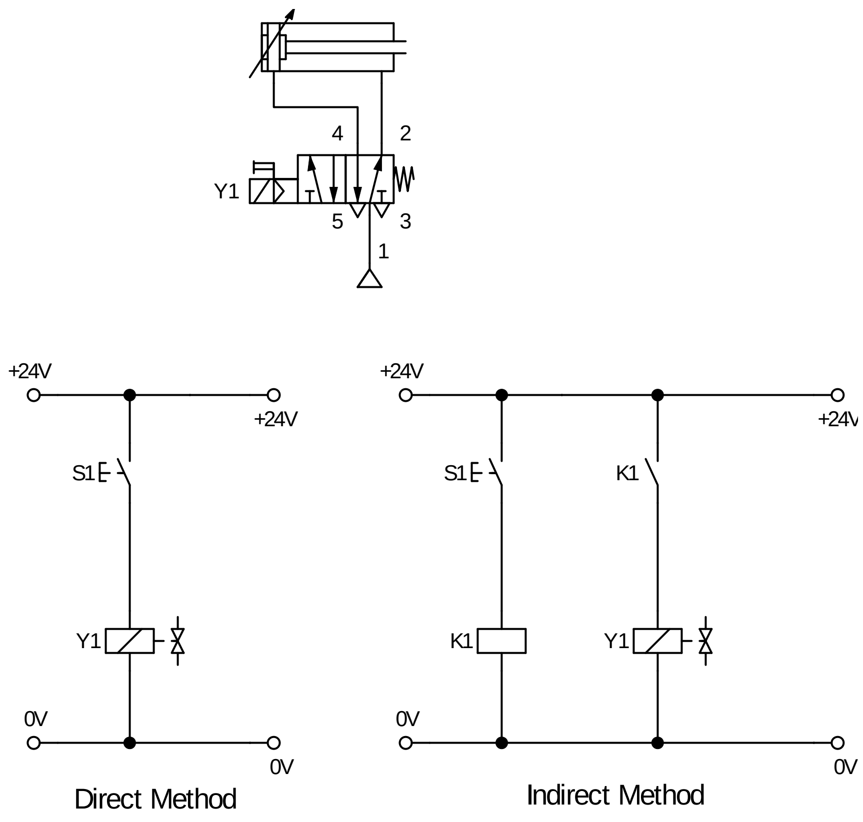


Figure 17.5 – Control of a Double-Acting Cylinder

The double-acting cylinder is controlled via a 5/2-way valve. When push button switch S1 is pressed, coil Y1 is energised and the directional control valve is activated by compressed air via pilot control. The piston travels to the final forward position. When S1 is released, the return spring at the directional control valve becomes active and the piston returns to its original position.

17.2.3 Parallel Circuit (OR Logic)

The piston of a double-acting cylinder is to travel out when either one of two push button switches is pressed. It is to return when the both push button switches are released.

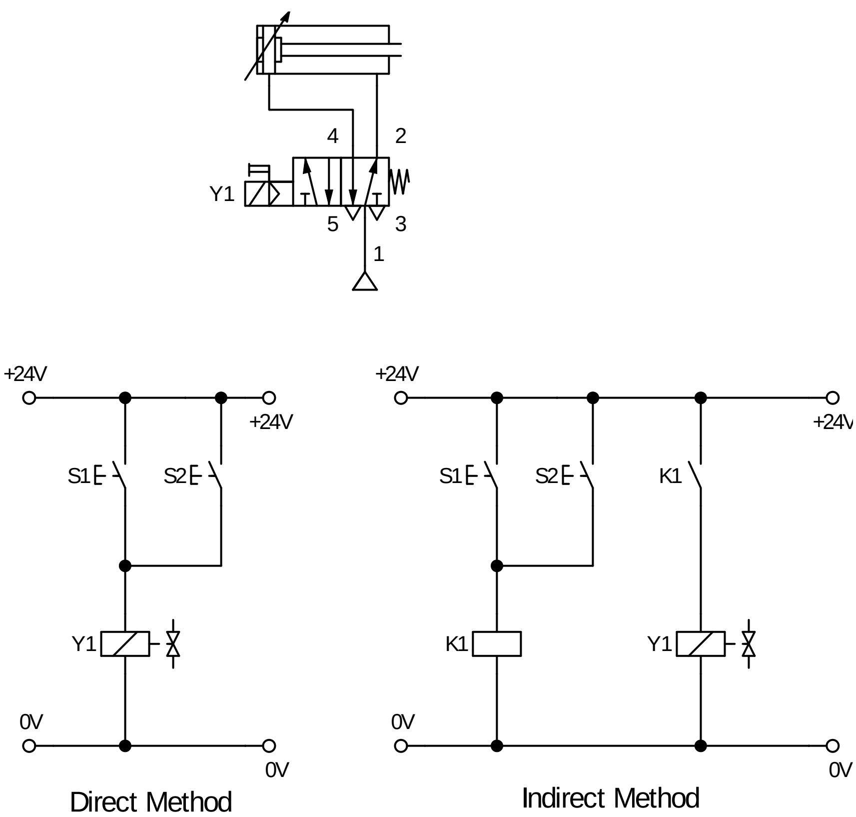


Figure 17.6 – Parallel Circuit (OR Logic)

When push button switches S1 or S2 are pressed, coil Y1 is energised. The directional control valve switches over and the piston travels to the final forward position. When both the push button switches are released, the signal is removed from Y1 and the cylinder travels back to its original position.

17.2.4 Series Circuit (AND Logic)

The piston of a double-acting cylinder is to travel out when both push button switches are pressed. It is to return when either one of the push button switch is released.

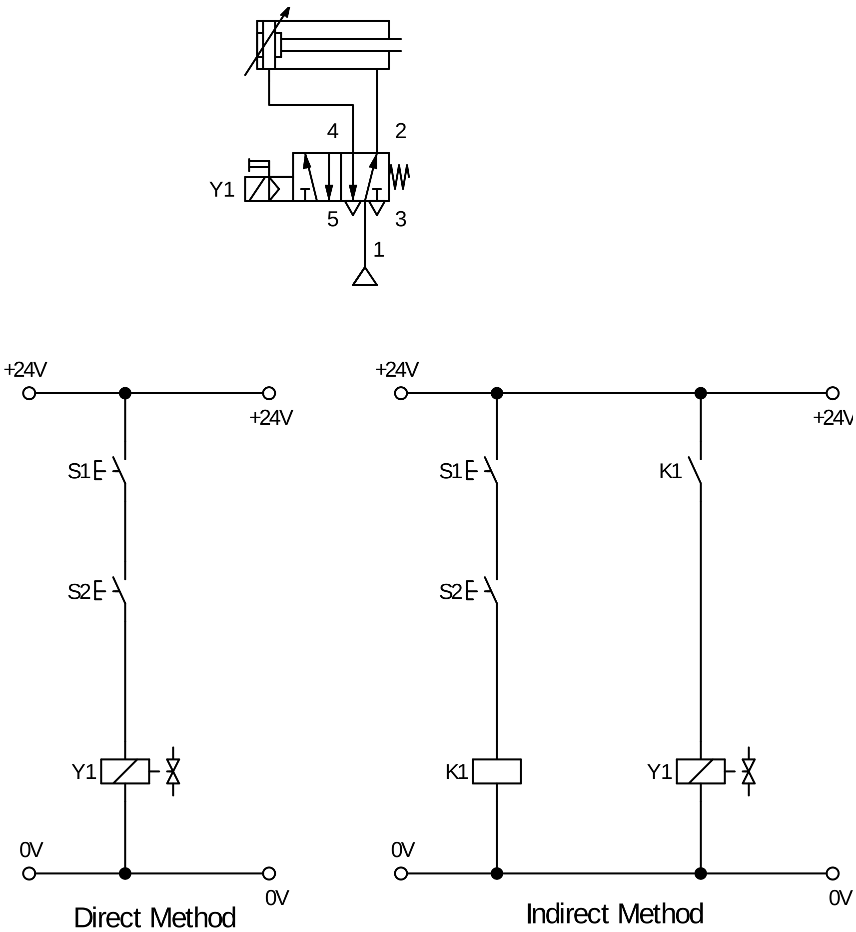


Figure 17.7 – Series Circuit (AND Logic)

If both push button switches S1 and S2 are pressed, the circuit closes. Coil Y1 is energised and the valve switches over. The piston travels to its final forward position. If either one of the push button switch is released, there is no longer a signal at Y1. The piston will return to its original position because the directional control valve has changed back.

17.2.5 Indirect Control of a Double-Acting Cylinder

The piston of a double-acting cylinder is to travel to the final forward position when push button switch S1 is pressed. It is to remain there until the return stroke is activated via push button switch S2.

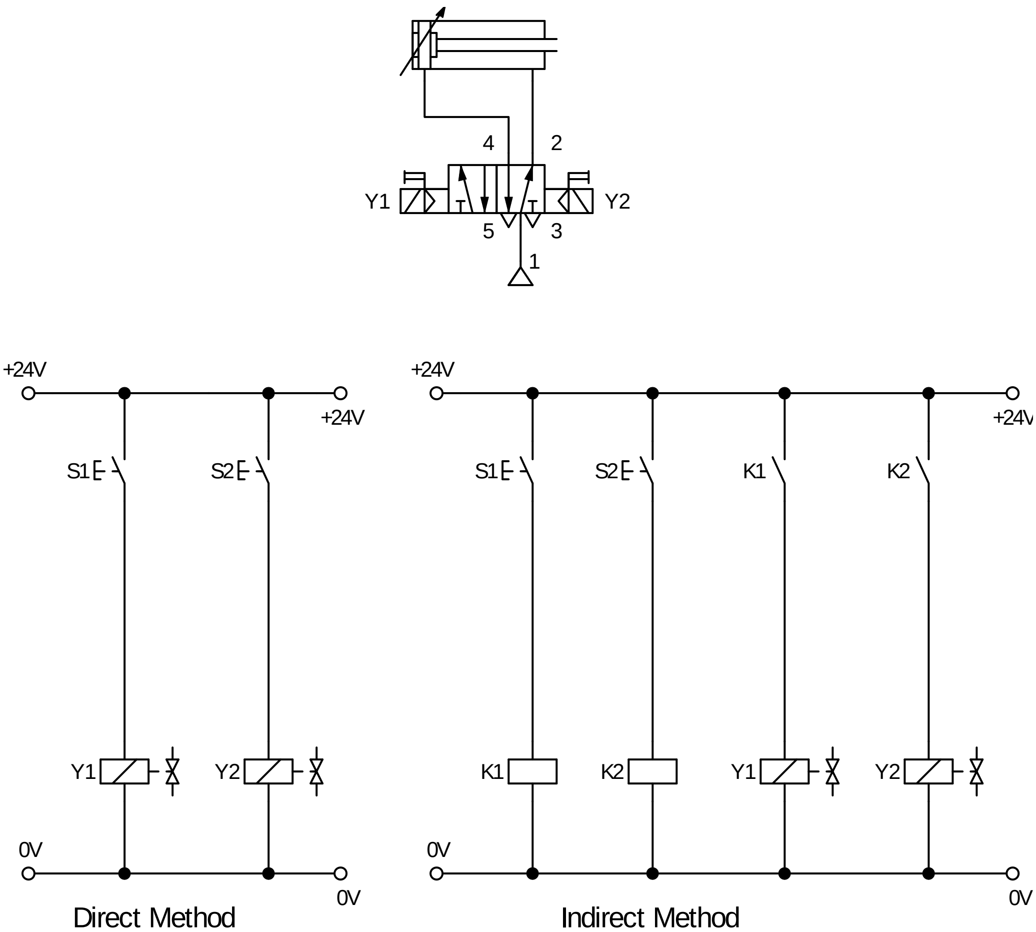


Figure 17.8 – Indirect Control of a Double-Acting Cylinder

When S1 is pressed, coil Y1 is energised and the 5/2-way directional control valve changes over. The piston travels out and remains in the final forward position until a signal is applied to coil Y2 via push button switch S2. Coil Y2 is energised and the piston returns to its original position because of the changeover of the 5/2-way valve.

Note:

- The 5/2-way directional control valve will remain in the last position until a new signal is given as it is a double solenoid valve and has no return spring.
- The 5/2-way directional control valve will not switch over if there is an active opposing signal. For example, if Y1 is switched on and a signal is given to switch Y2, there will be no reaction as there would be an opposing signal.

17.2.6 Automatic Return of a Double-Acting Cylinder

The piston of a double-acting cylinder is to travel to the final forward position when push button switch S1 is pressed. When it reaches this position, it is to return automatically to its original position.

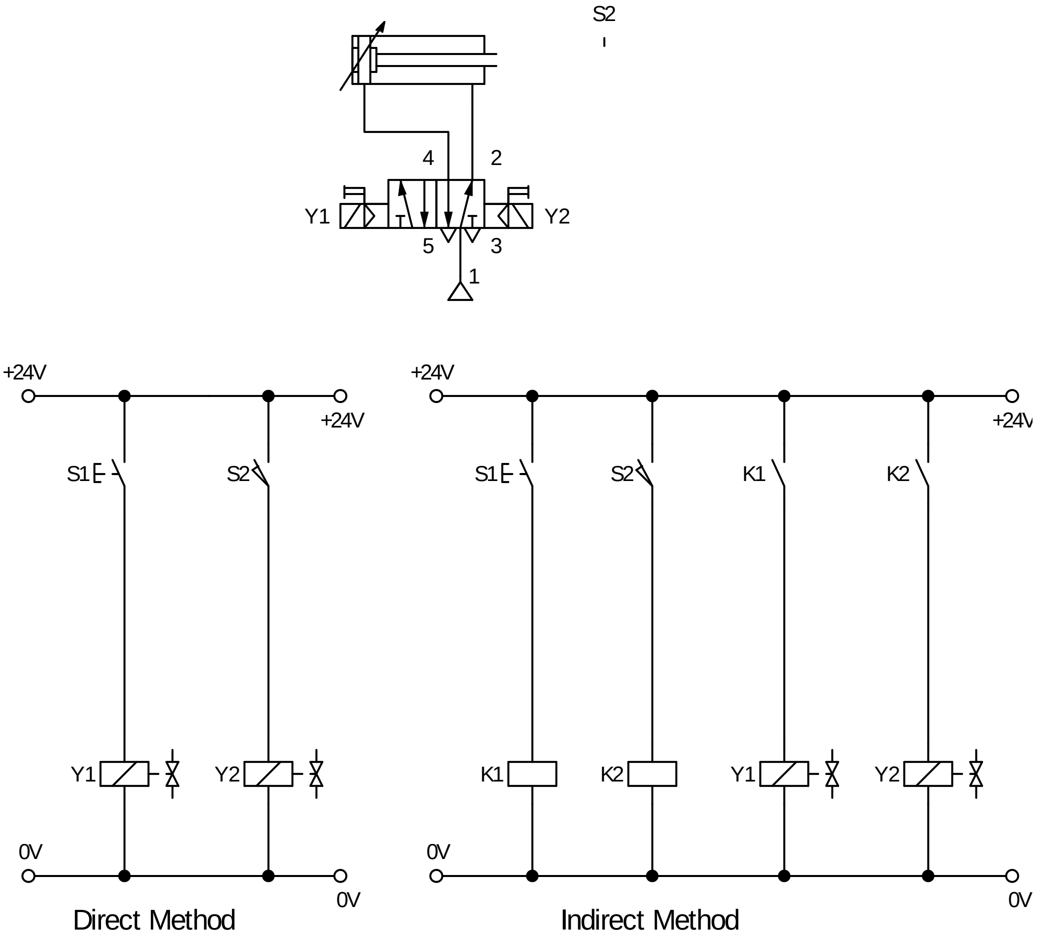


Figure 17.9 – Indirect Control of a Double-Acting Cylinder

When push button switch S1 is pressed, coil Y1 is energised and the piston travels to the final forward position. Once the piston reaches the final position, it actuates limit switch S2 which is installed there.

The limit switch S2 switches the 5/2-way directional control valve over and energises coil Y2. The piston returns to its original position. Remember that S1 must already be released.

17.2.7 Oscillating Motion of a Double-Acting Cylinder

When a sustained push button switch is closed, the piston is to travel back and forth until the switch is released. The piston must travel back to its original position (final rear position).

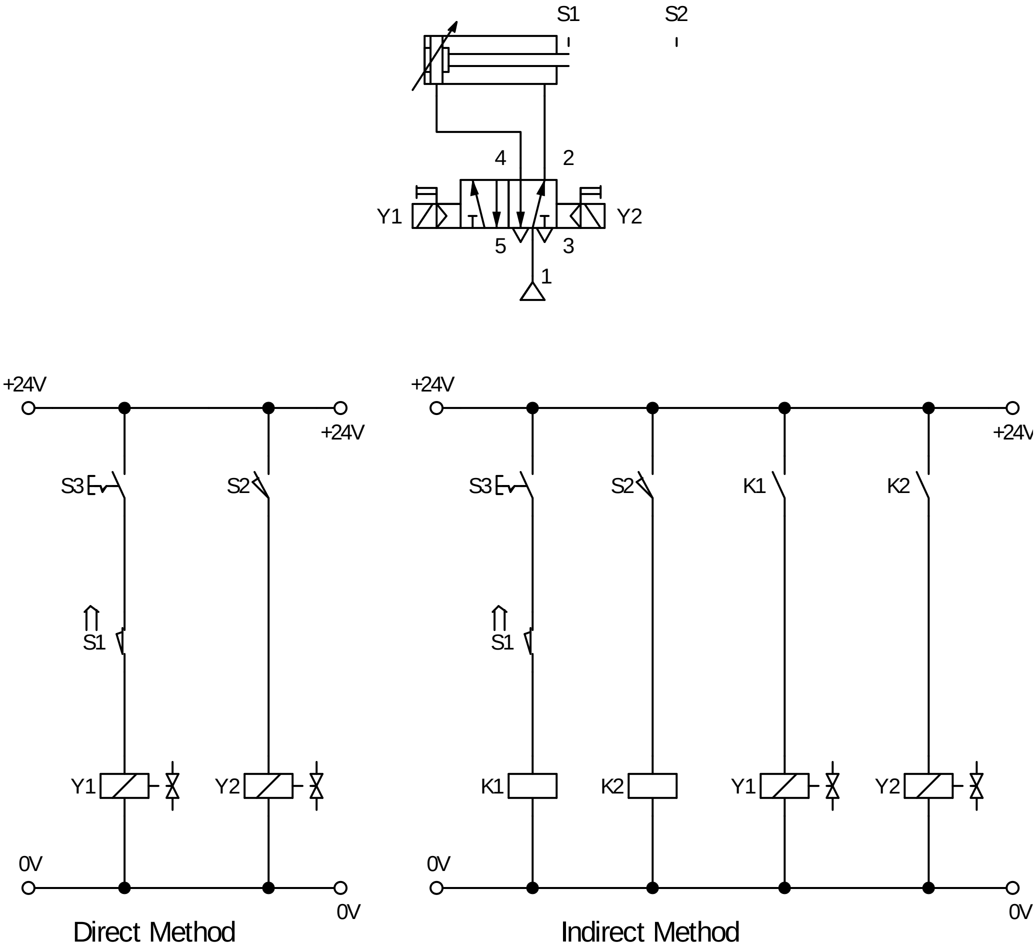


Figure 17.10 – Oscillating Motion of a Double-Acting Cylinder

Two mechanically-actuated limit switches S1 and S2 are installed at the two final positions. These emit a signal for forward and return stroke when contact is made with them.

However, limit switch S1 is only active when switch S3 is closed. The piston therefore travels back and forth. If switch S3 is opened again, no signal can be applied to coil Y1 and the piston remains in the final rear position.

17.2.8 Control of a Double-Acting Cylinder with Latching Action

The piston of a double-acting cylinder is to travel out and remain at the final forward position until a second signal causes the piston to return to its original position.

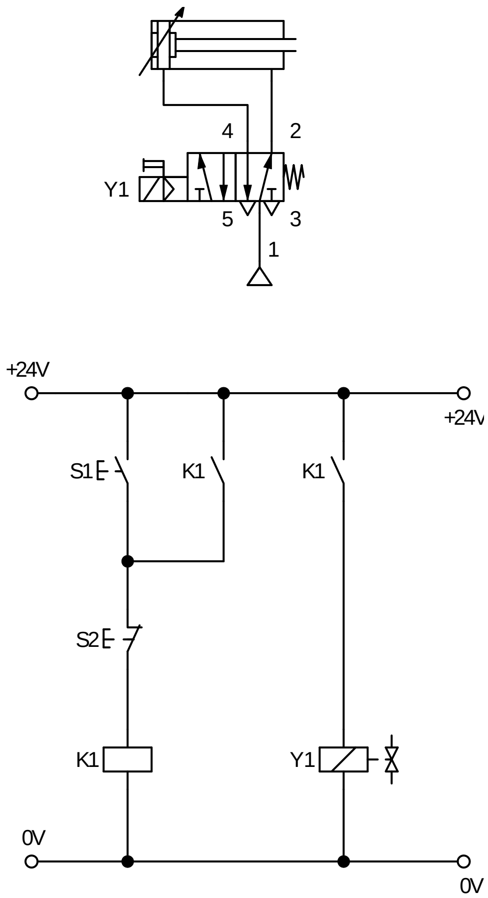


Figure 17.11 – Control with Latching Action

When push button switch S1 is pressed, relay k1 is energised. Connected in parallel is a normally open contact of K1 which is also switched over. This contact maintains the energising power for relay K1 even when the push button switch S1 is released. Another contact of K1 energises coil Y1 and the piston moves to the forward position.

When Push button switch S2 is pressed, the circuit to K1 is interrupted. All functions of relay K1 switches back to its original positions. The coil Y1 is therefore also interrupted, the spring at the 5/2-way directional control valve switches the valve back and the piston travels back to its original position.

17.2.9 Automatic Return Initiated by a Limit Switch

The piston of a double-acting cylinder is to travel out when push button switch S1 is pressed. It is to return automatically when it reaches its forward end position. The push button S1 switch must be released.

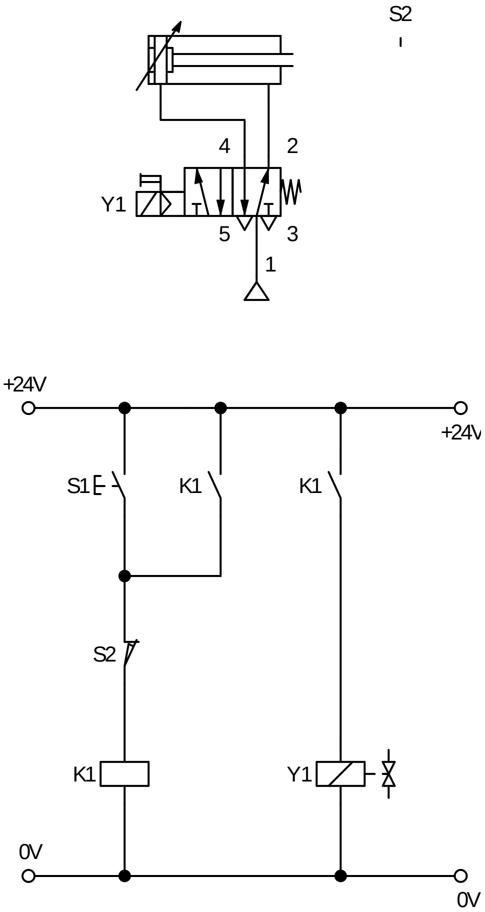


Figure 17.12 – Automatic Return Initiated by Limit Switch

When push button switch S1 is pressed, the piston travels to its forward position. When the piston reaches this position, and if S1 is released, limit switch S2 makes the piston return.

The latching circuit is cleared when contact is made with limit switch S2. Relay K1 switches back to its original position, the normally open contact K1 opens the circuit to coil Y1. The 5/2-way directional control valve changes over and the cylinder travels back.

18.0 Sequencing Electro-Pneumatic Circuits

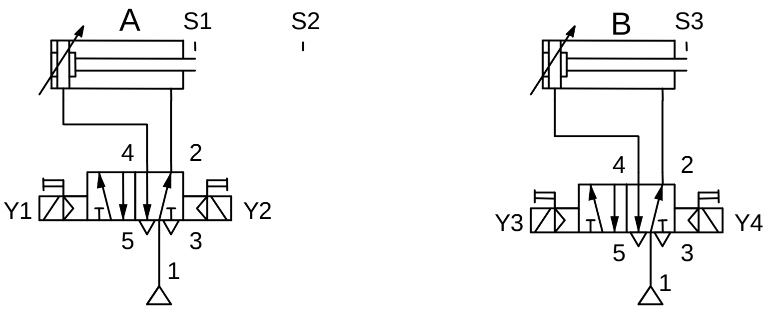
Understanding the basic circuits is essential before moving forward and designing sequencing circuits. For sequencing circuits, we usually have 2 or more cylinders and they will extend and retract in a predefined sequence.

18.1 Using Pneumatic Memory

We will design a sequencing circuit using pneumatic memory for the following sequence: A+ B+ A- B-.

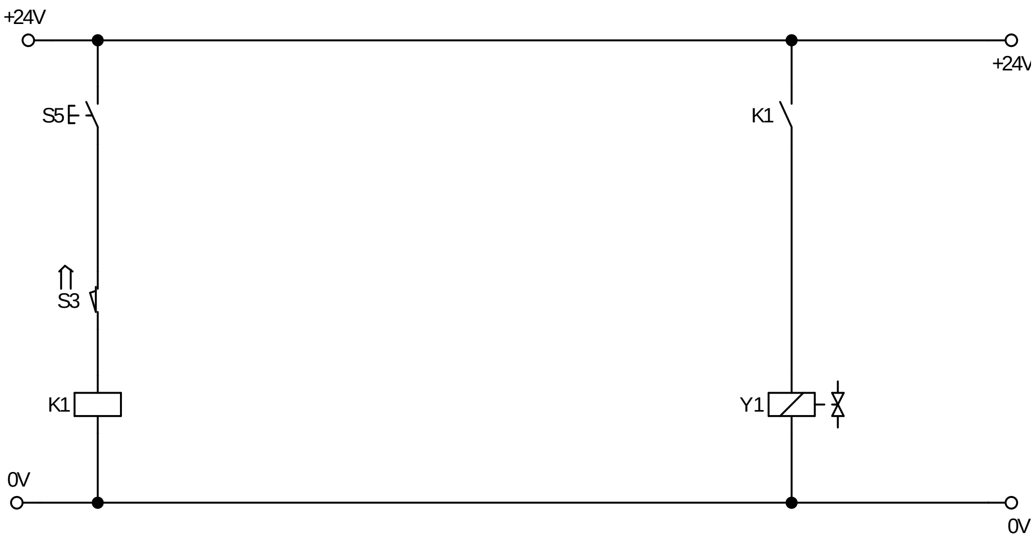
18.1.1 1st Step

Draw cylinders A and B with 5/2-way double solenoid directional control valves. Indicate the position of the limit switches.



18.1.2 2nd Step

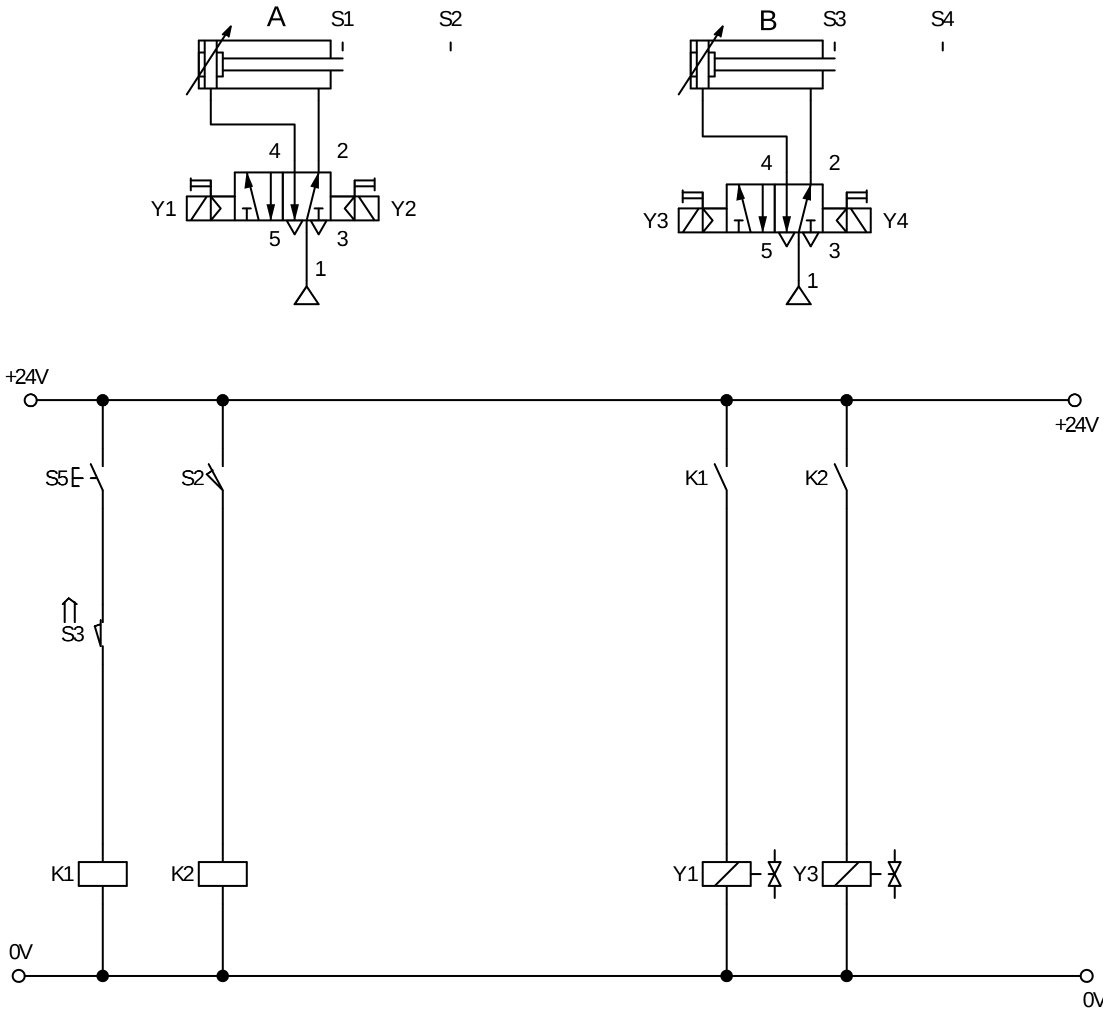
Draw the electrical control circuit and the main circuit.



In the control circuit, relay K1 is energised via the "ON" push button switch S5 and registered via limit switch S3. In the main circuit, a normally open contact of K1 closes the circuit. Solenoid Y1 is energised and causes cylinder A to travel out.

18.1.3 3rd Step

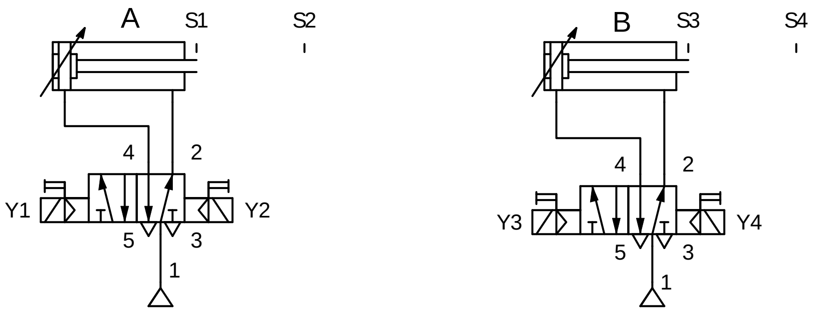
Draw the next rung of electrical control circuit and the main circuit.

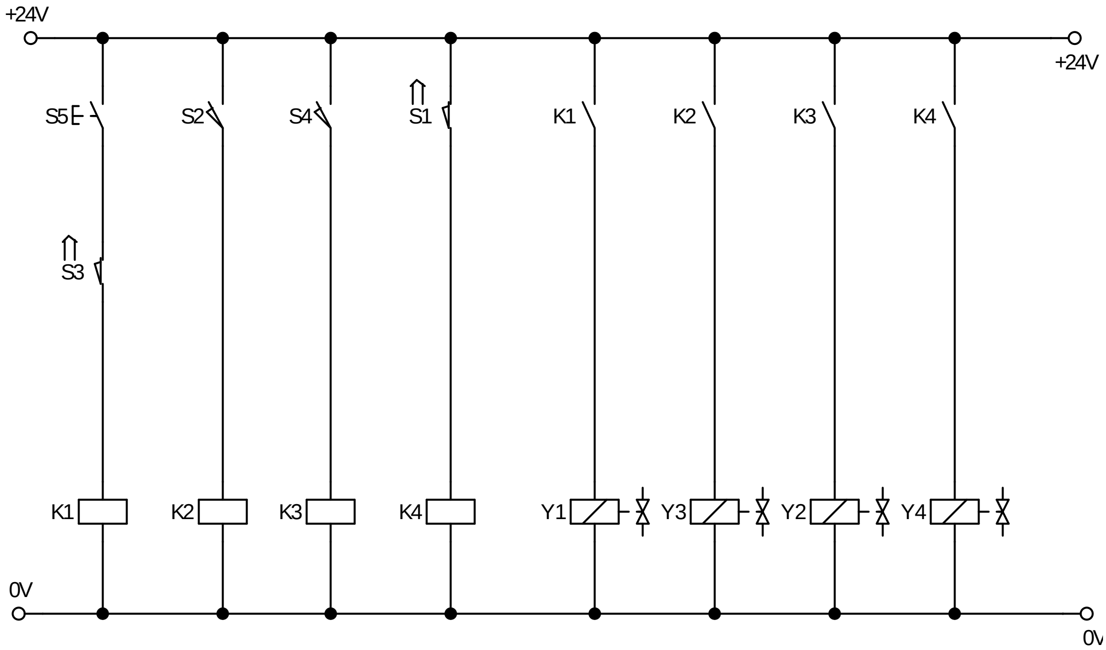


Limit switch S2 is actuated at the final position of cylinder A. These causes relay K2 to energise. A normally open contact of K2 energises solenoid Y3. The valve changes state and cylinder B extends.

18.1.4 4th Step

Draw the next rung of electrical control circuit and the main circuit. It similar to the 3rd step with the different limit switches.





Cylinder B extends, at its forward position it actuates the limit switch S4. S4 energises relay K3 and a normally open contact K3 energises solenoid Y2 and cylinder A retracts.

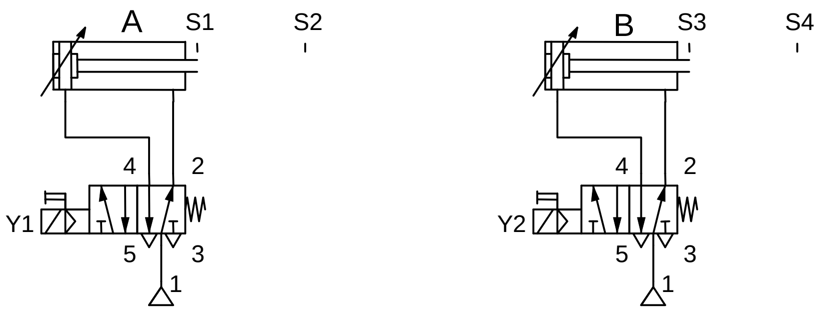
As cylinder A retracts it activates limit switch S1 and energises relay K4 which in turn activates solenoid Y4. Cylinder B then retracts and is it ready for a new cycle. A new cycle can restart with the activation of S5.

You can replace the limit switches with reed switches for this method.

18.2 Using Electrical Memory

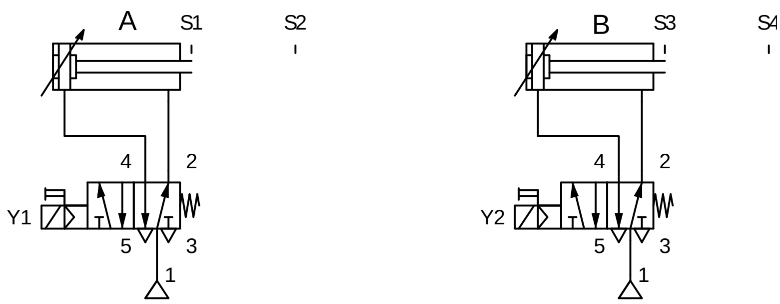
18.2.1 1st Step

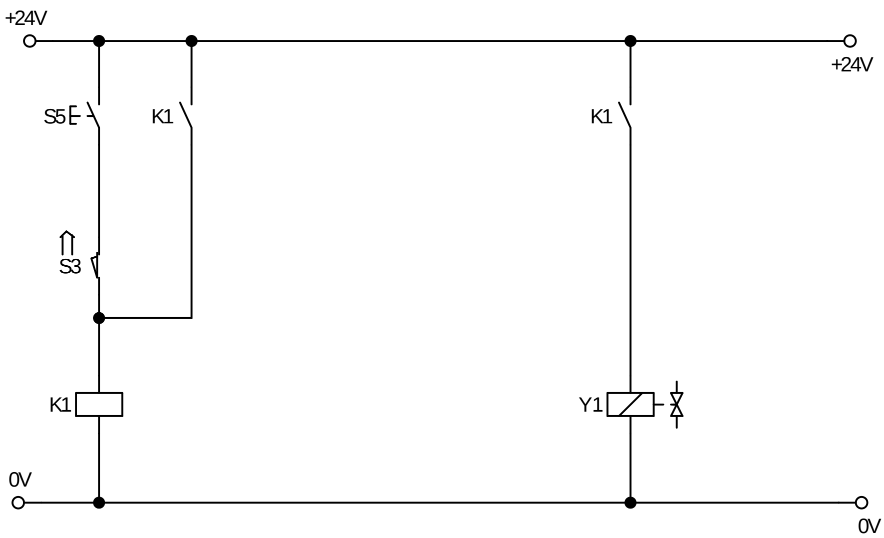
Draw cylinders A and B with 5/2-way single solenoid directional control valves. Indicate the position of the limit switches.



18.2.2 2nd Step

Draw the electrical control circuit and the main circuit for the first relay K1 and the solenoid coil Y1.

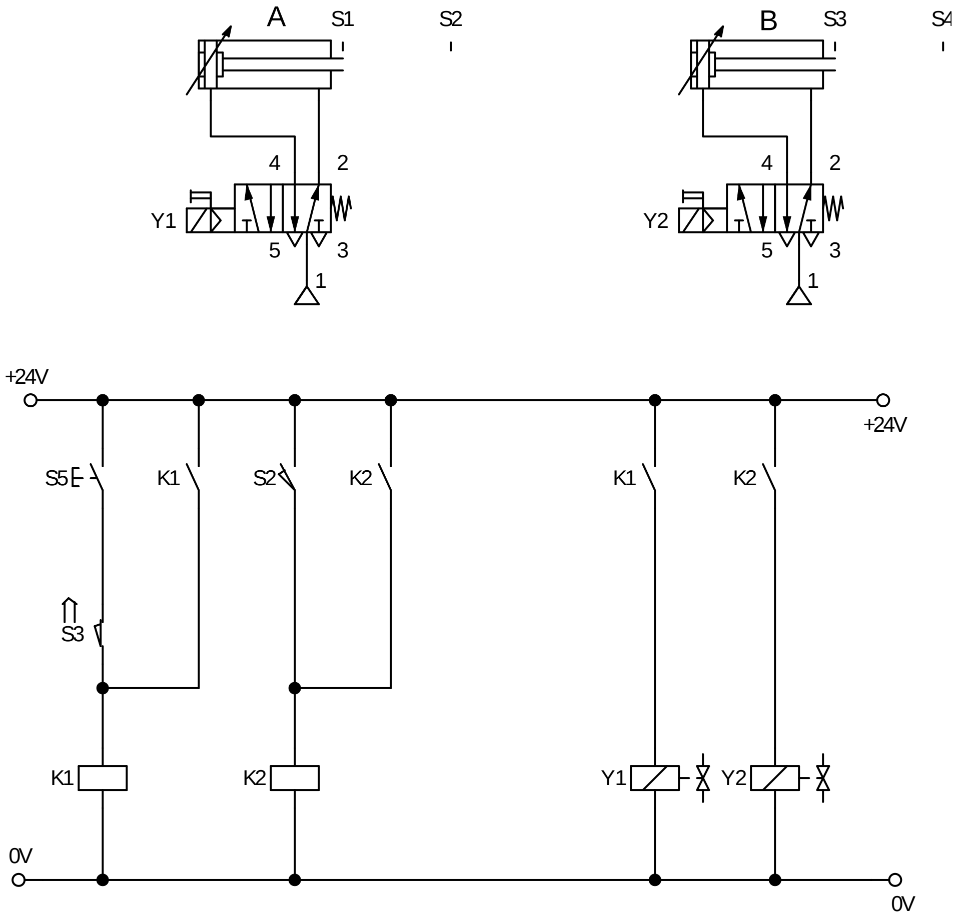




The circuit is closed with relay K1 via limit switch S3 which is actuated by cylinder B and start push button switch S5. The circuit is latched with a normally open contact K1. Another normally open contact of K1 is connected to the solenoid coil Y1 in the main circuit. This contact will cause the 5/2-way valve to switch over and cause cylinder A to extend.

18.2.3 3rd Step

Draw in relay K2 and solenoid coil Y2.

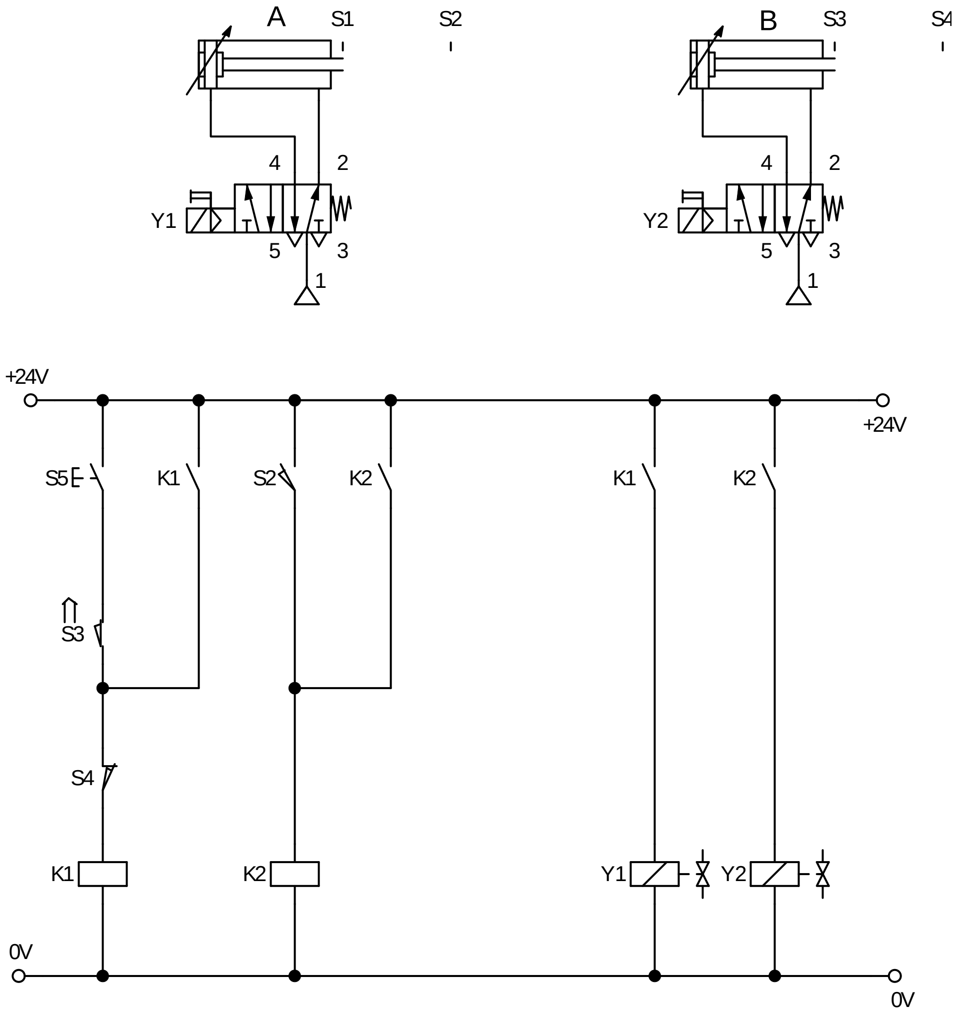


Cylinder A travels to its forward position and makes contact with limit switch S2, which energises K2 in the control circuit. Connected in parallel with this is the latching circuit for relay K2 via a normally open contact of K2.

When the normally open contact of K2 is closed in the main circuit, solenoid coil Y2 is energised and the 5/2-way directional control valve switches over and cylinder B travels out.

18.2.4 4th Step

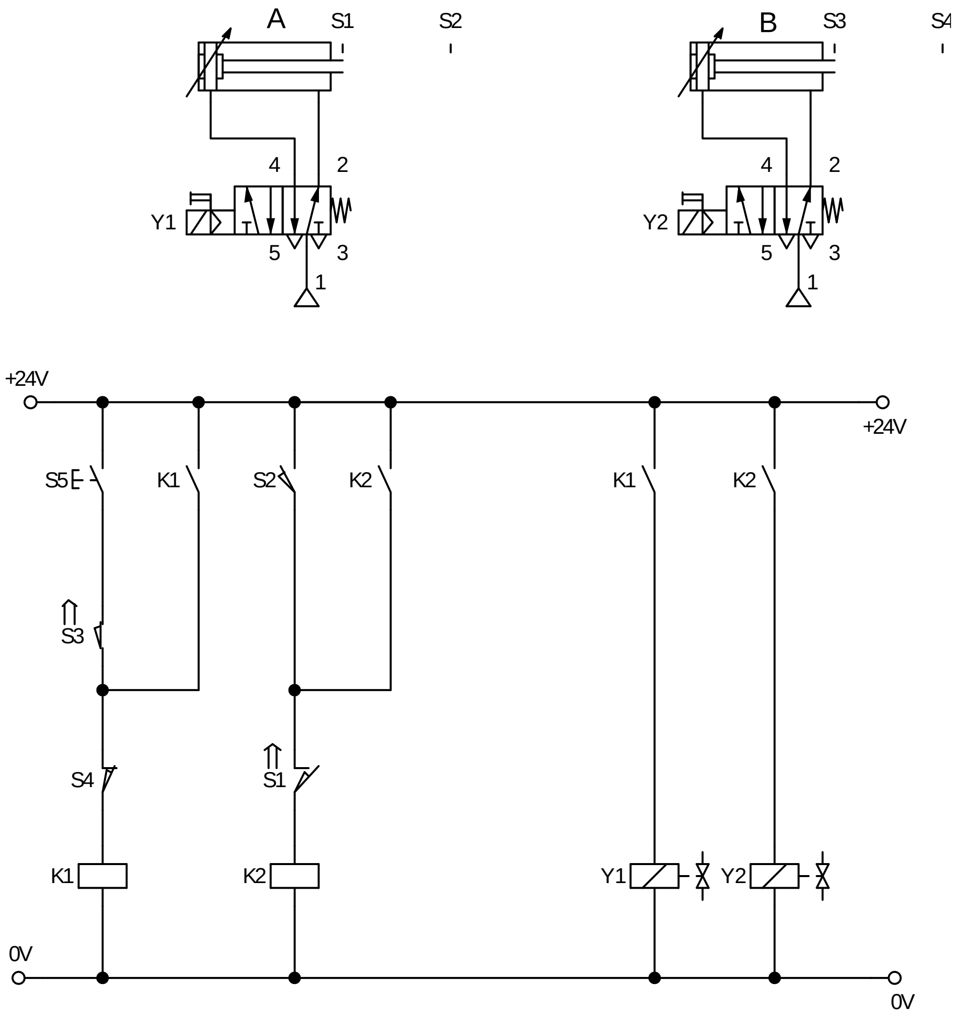
Draw in limit switch S4 and switch off relay K1.



Limit switch S4 is arranged ahead of relay K1. When S4 (Normally closed switch) is actuated by cylinder B, the latching circuit is interrupted and relay K1 is de-energised. The normally open contact of K1 in the main circuit returns to its normal position, coil Y1 is de-energised, the 5/2-way directional control valve switches back and cylinder A retracts.

18.2.5 5th Step

Draw in limit switch S1 and switch off relay K2.



Limit switch S1 is arranged ahead of relay K2. When S1 (Normally closed switch) is actuated by cylinder B, the latching circuit is interrupted and relay K2 is de-energised. The normally open contact of K2 in the main circuit returns to its normal position, coil Y2 is de-energised, the 5/2-way directional control valve switches back and cylinder B retracts.

Limit switch S3 is actuated again and a new cycle can be started with start push button switch S5.

18.3 Circuits with Opposing Signals of Signal Overlap

In the sequence A+ B+ A- B-, the circuit is simple and we do not encounter a signal overlap or there are opposing signals. Opposing signals occurs when we are using double-solenoid directional control valves. It one solenoid is energised, sending a signal to the other solenoid would not switch the valve over as there is an opposing signal.

If there are signal overlaps of opposing signals, we need to use other methods for designing.

18.4 Electrical Cascade Method

The electrical cascade method is almost similar with the cascade system used in conventional pneumatics. There are a few rules to follow:

The cascade system uses signal cut-out by means of relays. Electrical power supply to the various solenoids is no longer derived from the main supply, but through a relay.

In the design of cascades, they work on the principle that at any one time, only one supply line is energised. The procedure for constructing an Electrical Cascade System is as follows:

- Define the Sequence of Motion by Abbreviated Notation.

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

- Divide Them into Groups

Break into groups such that a cylinder operation occurs only Once in a group, and the minimum number of groups is obtained. That is A+ and A- cannot be in the same group. Give each group a number, I, II, III, etc.

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

For each group, a supply is required. For 3 groups, there must be 3 supply lines.

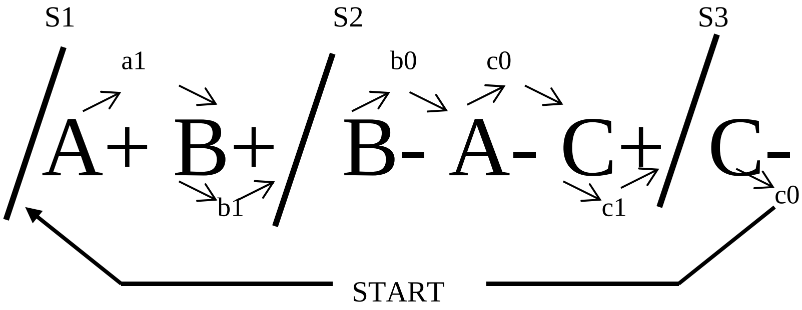
- Relays

The number of relays = Number of groups - 1

Therefore, the number of relays = 3 - 1 = 2

- Limit Switches

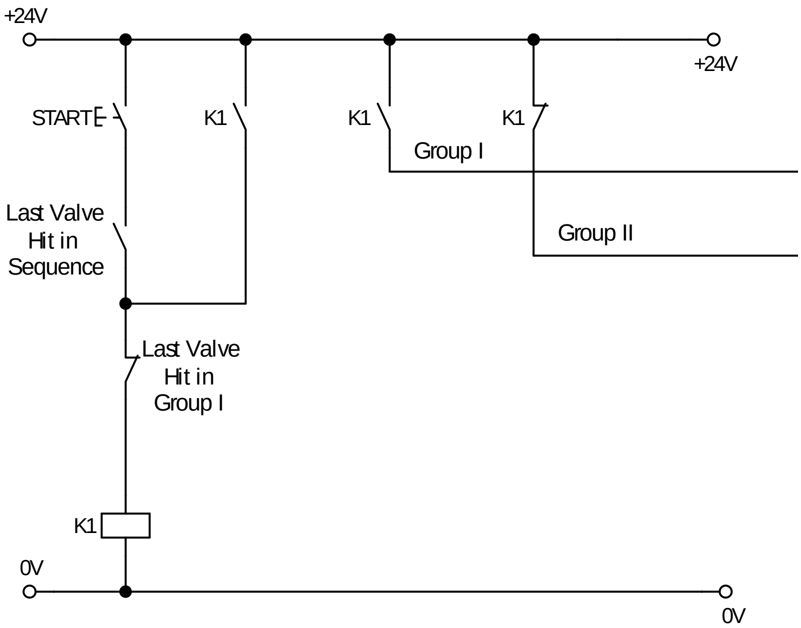
Write on the abbreviated notation, the number of limit switches.



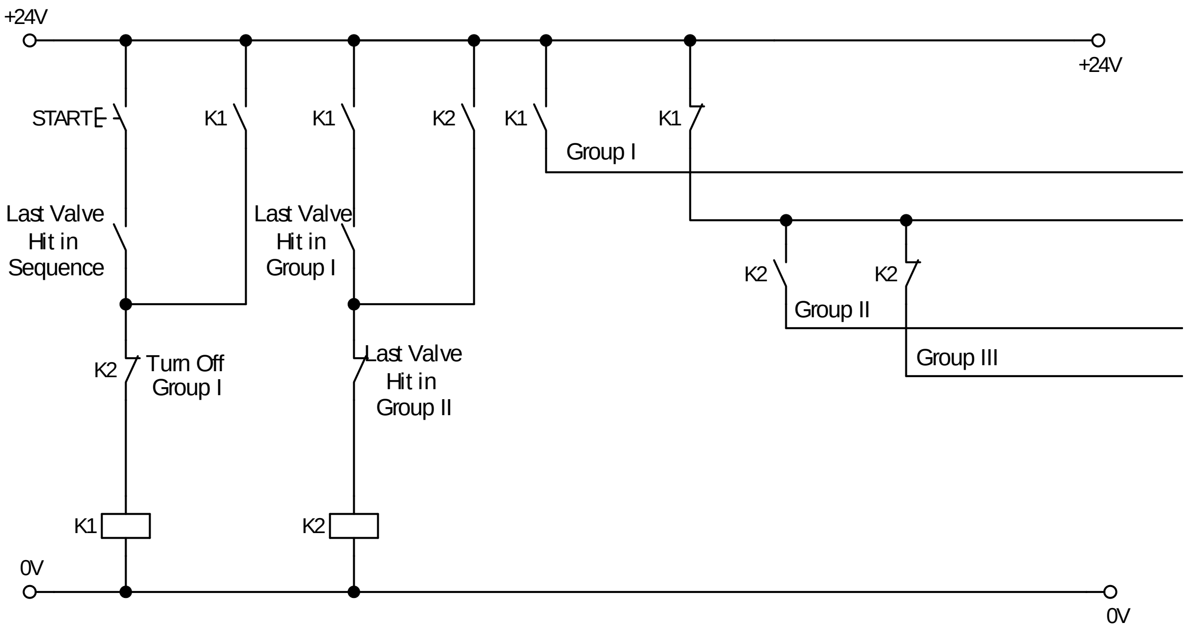
Note:

- Limit switches/valves which cause changeover of groups are designated below the abbreviated notation.
- Limit switches within a group are designated above the abbreviated notation.
- Arrows designate signals which trigger cylinder operation.
- The last group must be "live".

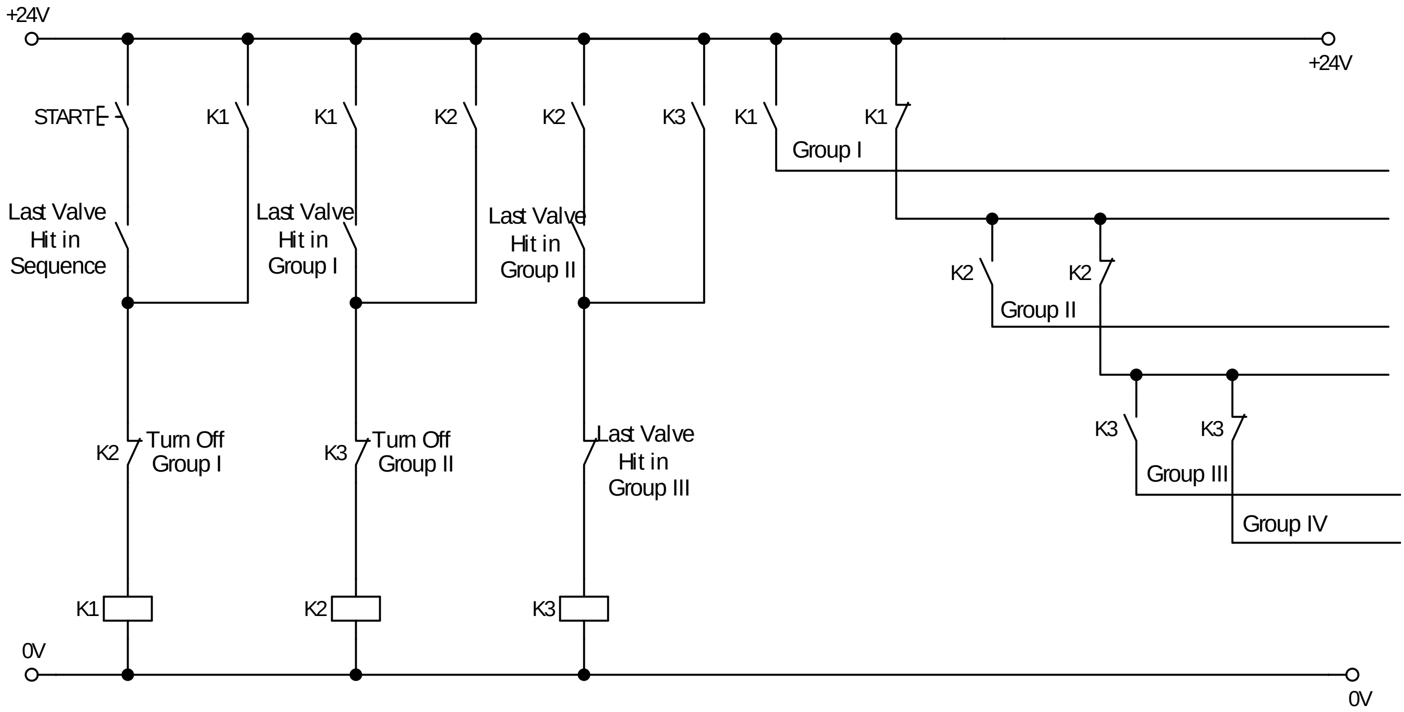
- Arrangement for 2 groups



- Arrangement for 3 groups



- Arrangement for 4 groups

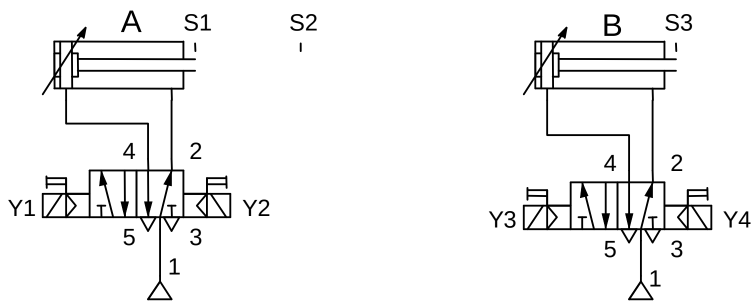


18.5 Control of Two Double-Acting Cylinders using Electrical Cascade

We will design a sequencing circuit using pneumatic memory for the following sequence: A+ B+ B- A-.

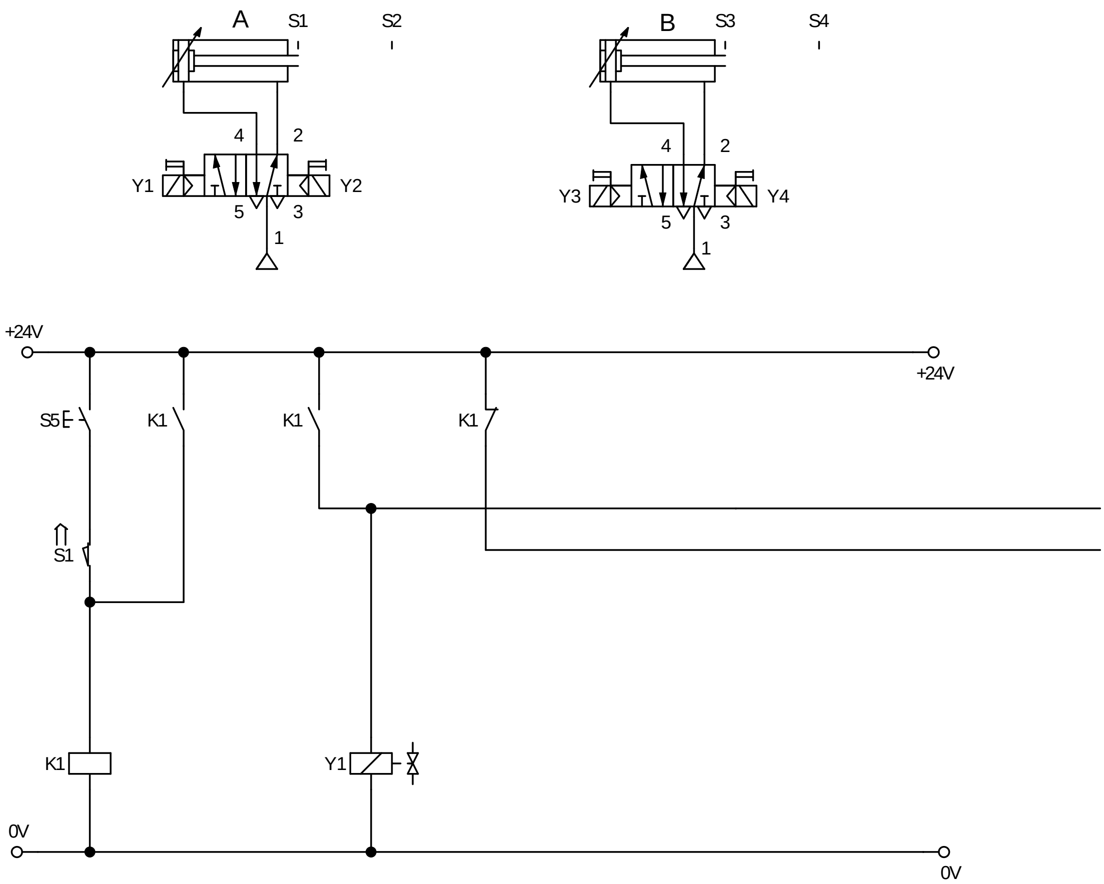
18.5.1 1st Step

Draw cylinders A and B with 5/2-way double solenoid directional control valves. Indicate the position of the limit switches.



18.5.2 2nd Step

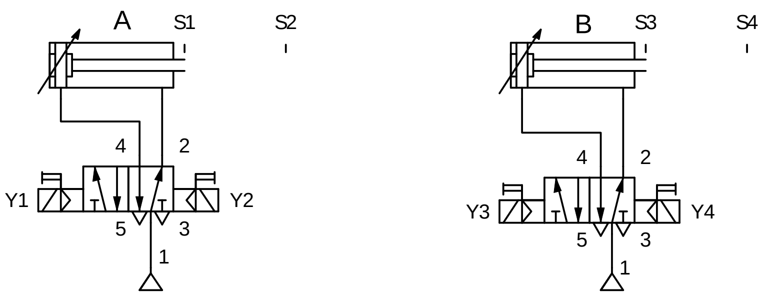
Draw the electrical section.

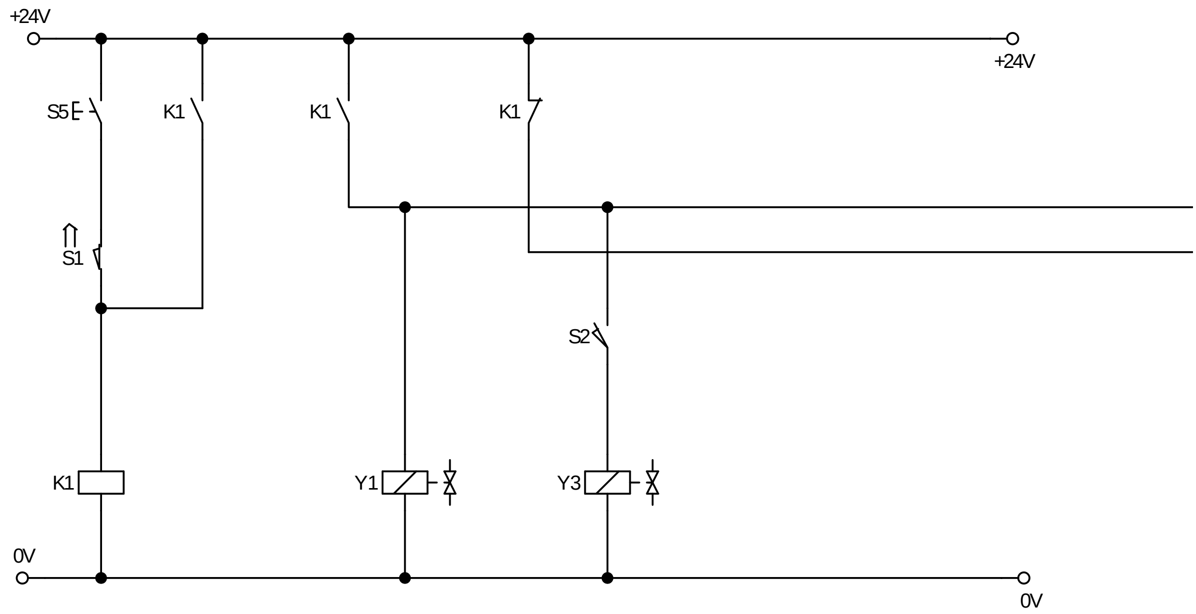


When the start push button switch S5 is actuated, relay K1 will energise and all K1 contacts will switch. This will energise line 1 and solenoid coil Y1 will be energised. The 5/2-way directional control valve will switch and cylinder A will extend.

18.5.3 3rd Step

Draw the electrical section adding in the limit switches.



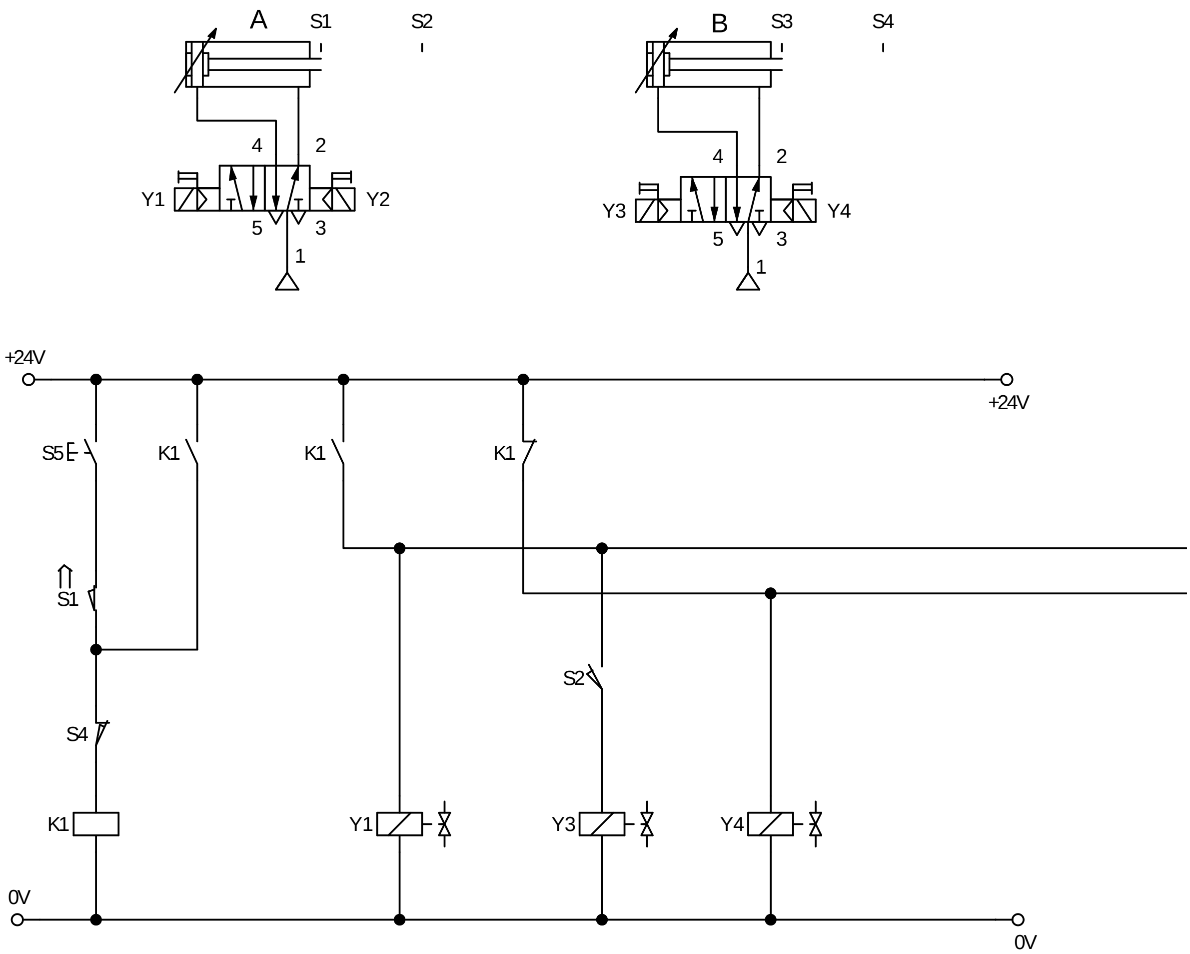


Cylinder A travels to the forward position and actuates limit switch S2. This limit switch must initiate movement B+. The limit switch is installed between line 1 and the solenoid coil Y3. The result is that the 5/2-way directional control valve is switched over and cylinder B extends.

Looking at the abbreviated notation shows a signal overlap here. A signal shutoff circuit must be installed at this point.

18.5.4 4th Step

Draw the electrical section adding in the limit switch S4 to break relay K1 and switch over to group II.



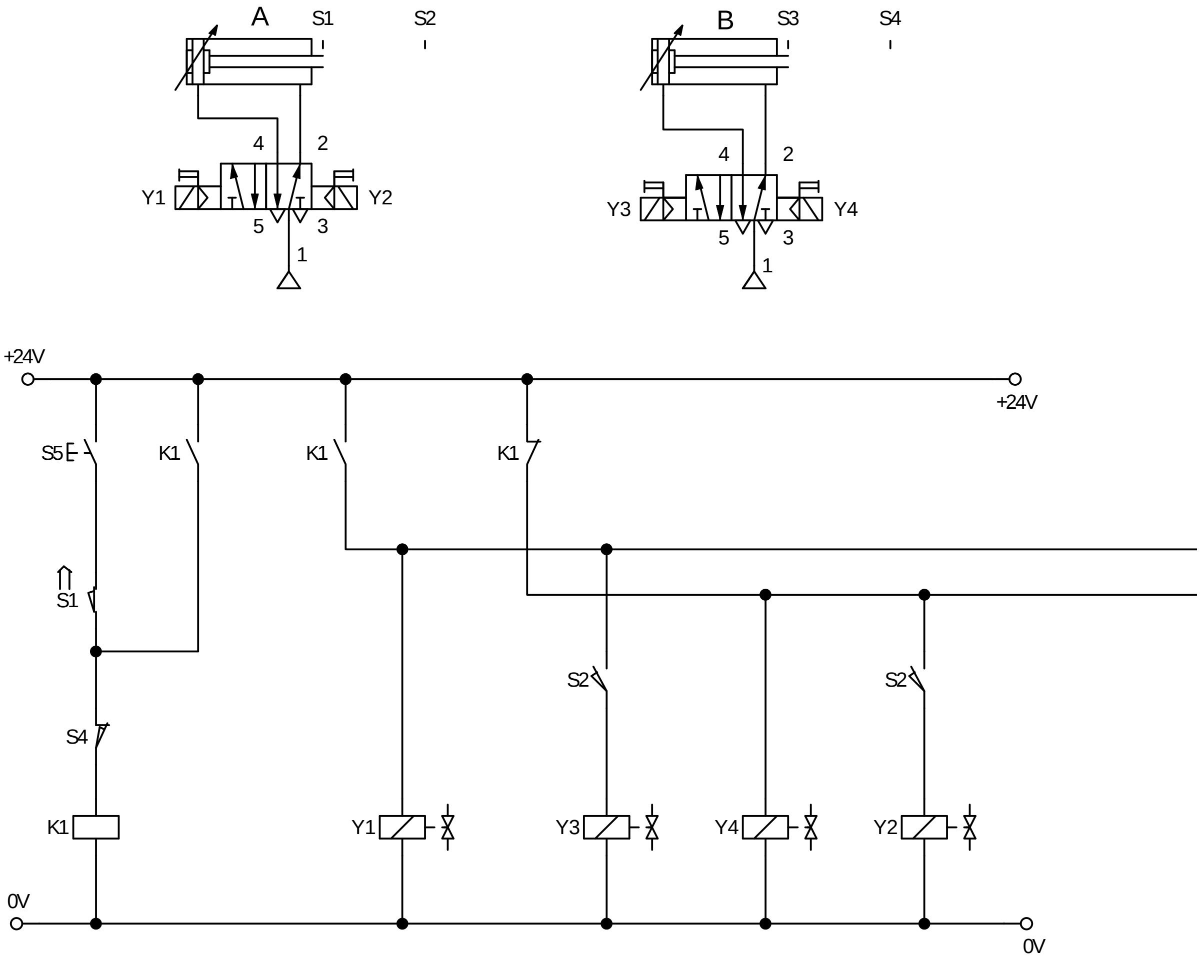
Limit switch S4 is actuated by cylinder B. This limit switch S4 must perform the signal shutoff; for this reason, it is installed as a normally closed switch in the first rung of the control circuit.

Actuating S4 clears the latching circuit of K1. In the main circuit, this means that line 1 is disconnected by normally open contact K1 and line 2 is supplied current again via normally closed contact of K1.

This changeover of line 1 to line 2 causes solenoid coil Y3 to be disconnected. The 5/2-way directional control valve is switched over via solenoid coil Y4 and cylinder B retracts.

18.5.5 5th Step

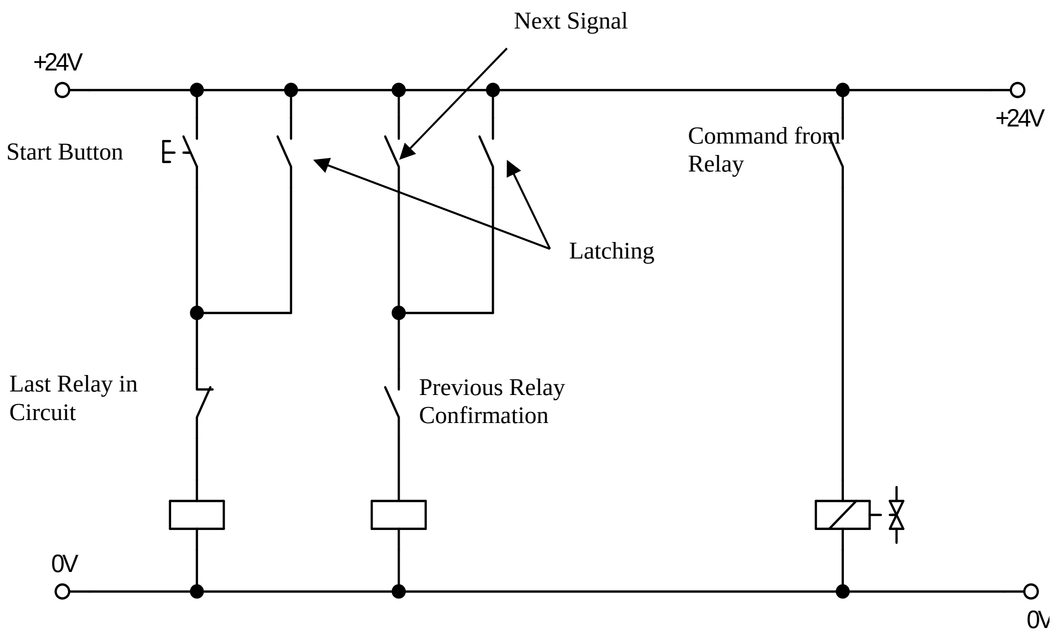
Once cylinder B reaches the back position, limit switch S3 is actuated. This ensures that solenoid coil Y2 will be energised as line 2 has power. The valve switches again and cylinder A returns to its back position.



The cycle is completed and you can start again by actuating S5.

18.6 Using Electrical Stepper Control Method

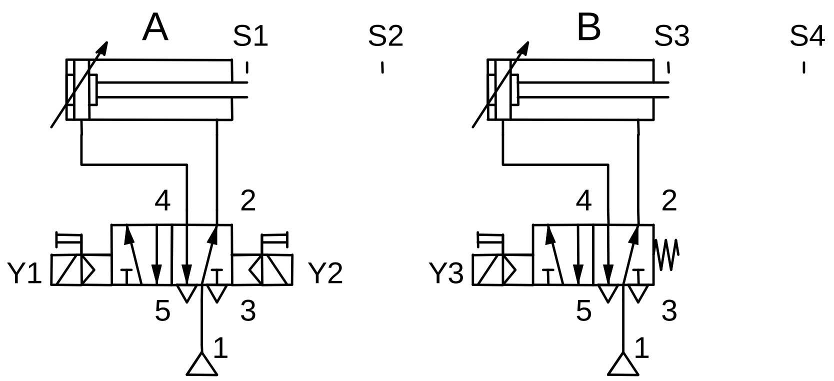
These circuits are designed using a sequence method where the next step needs to be confirmed by the previous step and the activation of the solenoids is done in control section.



18.6.1 1st Step

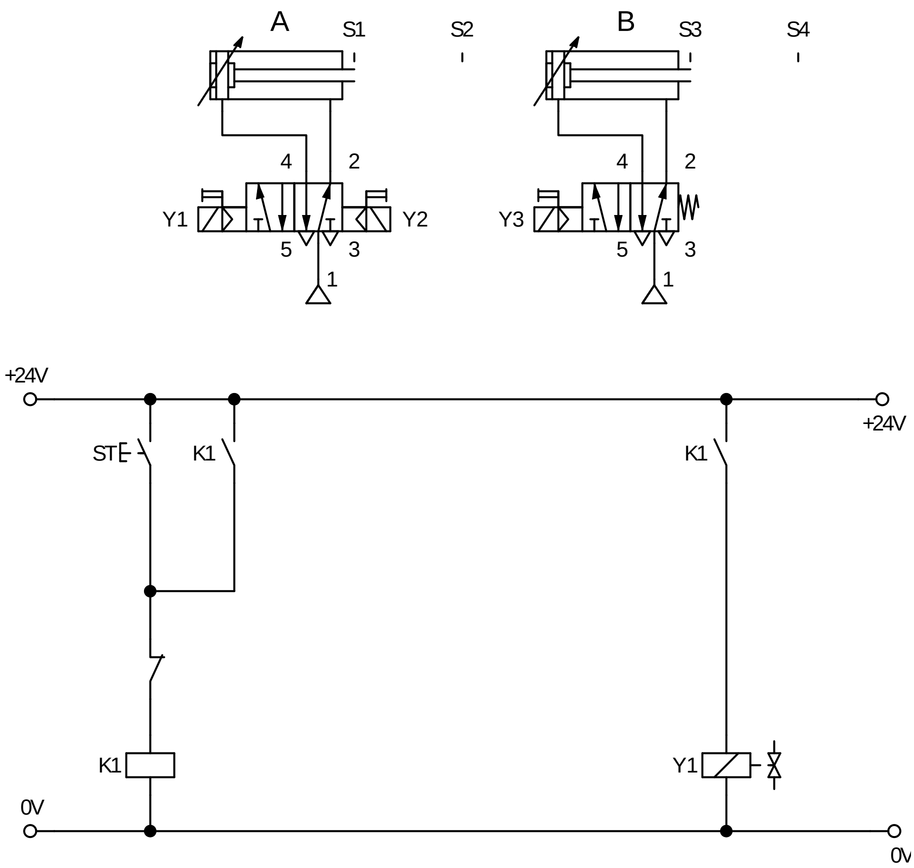
We will use one single solenoid directional control valve and one double solenoid to show that there is no procedure difference when designing the circuit. We will be designing the same sequence of A+B+B-A-.

Draw cylinders A and B with 5/2-way single and double solenoid directional control valves. Indicate the position of the limit switches.



18.6.2 2nd Step

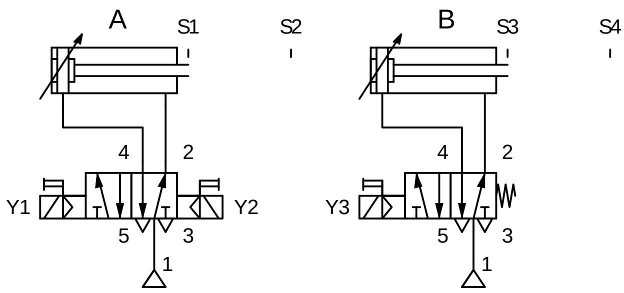
Draw the electrical section.

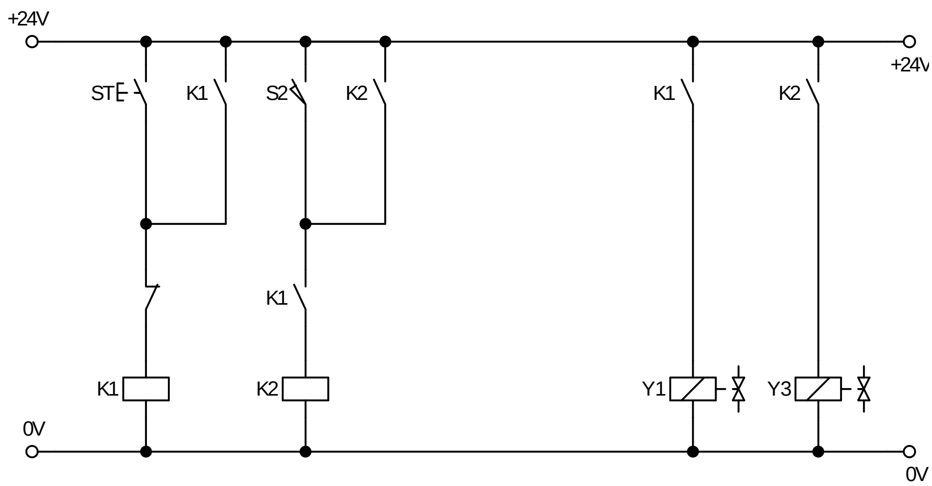


When the start button (ST) is pressed, the circuit is closed with relay K1. The circuit is latched with a normally open contact K1. Another normally open contact of K1 is connected to the solenoid coil Y1 in the main circuit. This contact will cause the 5/2-way valve to switch over and cause cylinder A to extend.

18.6.3 3rd Step

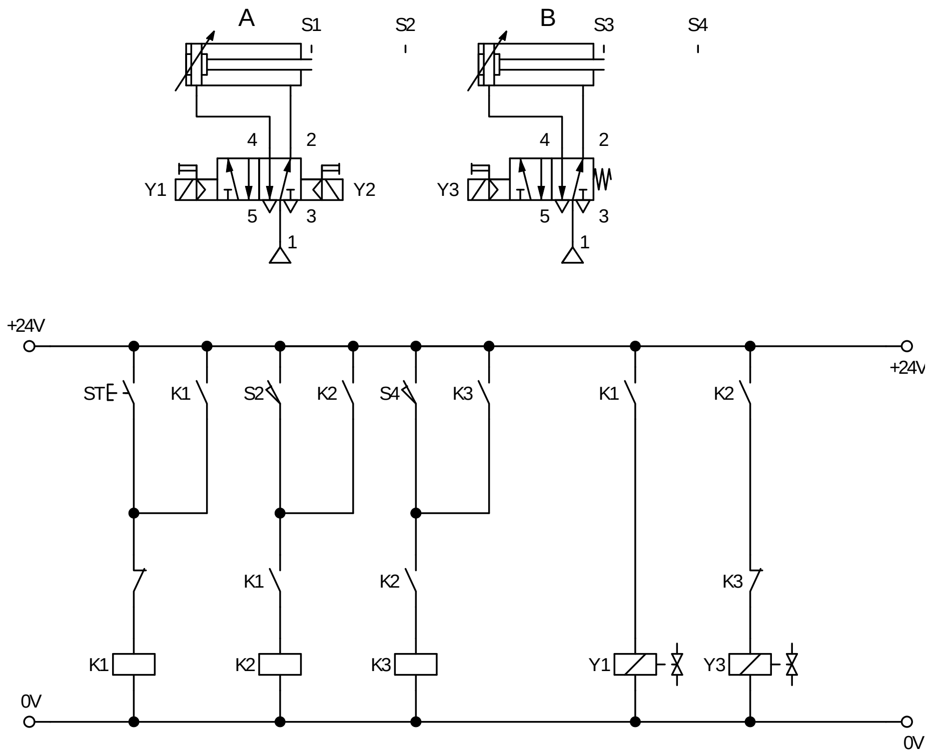
When Cylinder A extends, limit switch S2 is activated. This will energise relay K2. A confirmation signal from K1 is required to ensure that the relays are energised in sequence. Draw in relay K2 and solenoid coil Y3.





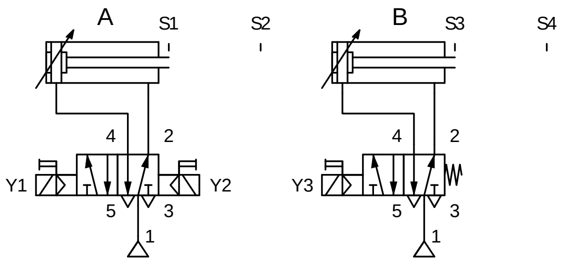
18.6.4 4th Step

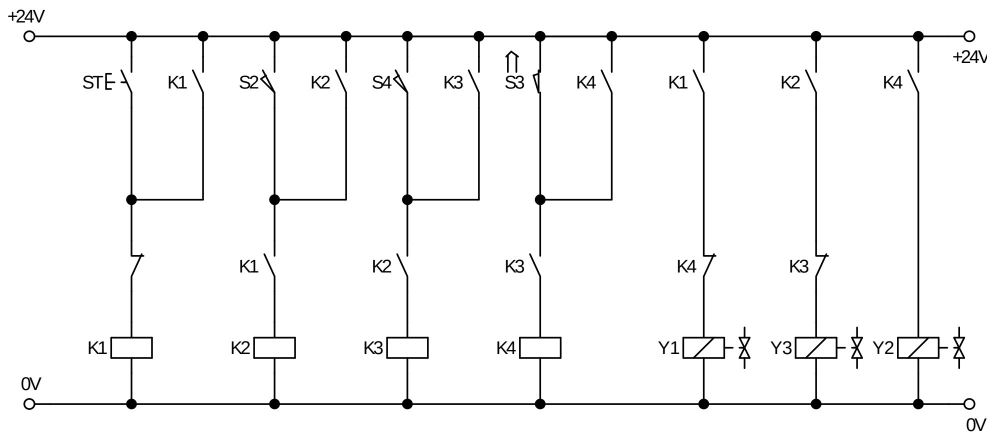
When Cylinder B extends, limit switch S4 is activated. This will energise relay K3. As usual, a confirmation signal from K2 is required to ensure that the relays are energised in sequence. Draw in relay K3 and reset (cut-off) solenoid coil Y3, this will switch the directional control valve over.



18.6.5 5th Step

When Cylinder B retracts, limit switch S3 is activated. This will energise relay K4. As usual, a confirmation signal from K3 is required to ensure that the relays are energised in sequence. Draw in relay K4 and solenoid coil Y2. Remember that solenoid coil Y1 needs to be reset (cut-off) so that the valve will switch over.

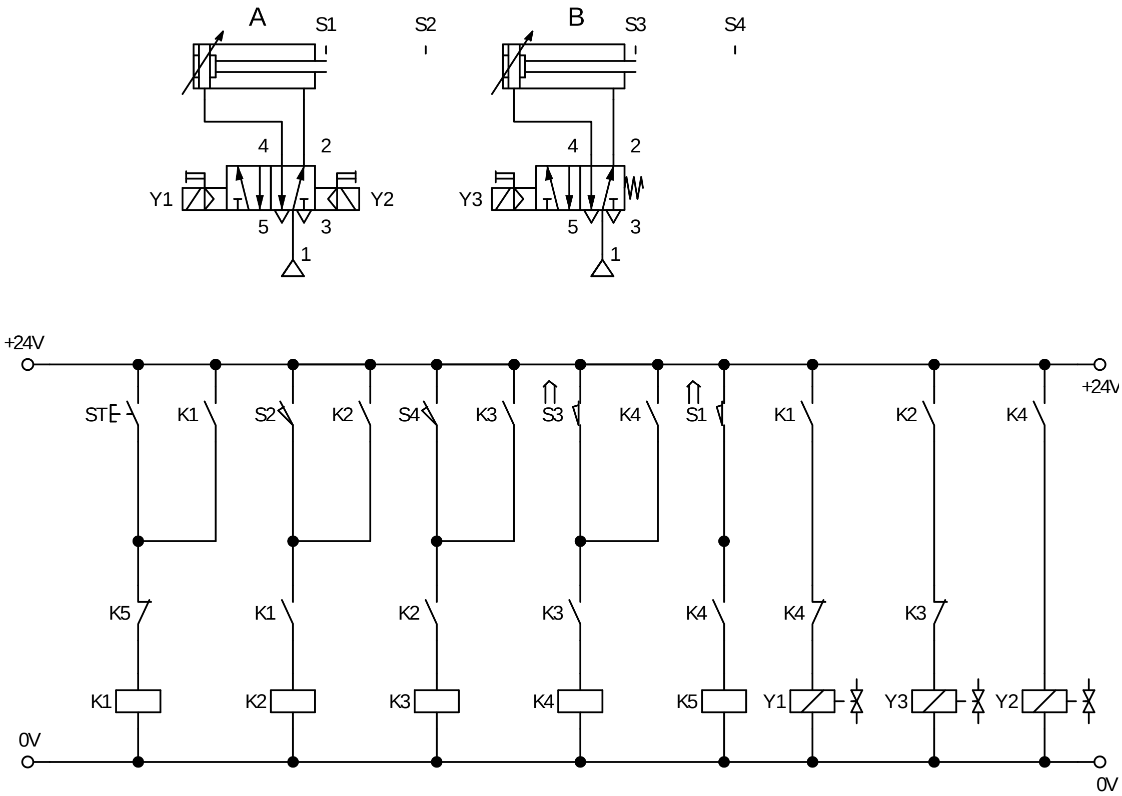




18.6.6 6th Step

When Cylinder A retracts, limit switch S1 is activated. This signals the end of one cycle, energise relay K5. As usual, a confirmation signal from K3 is required to ensure that the relays are energised in sequence. Draw in relay K5. There is no latching required for this step as it is to end the cycle. The relay K5 will be used to reset relay K1 and thus reset all the other relays.

The cycle is then completed and if you need to restart, press the Start button again.



19.0 Troubleshooting and Rectifying Faults in Electro-Pneumatics

19.1 Introduction

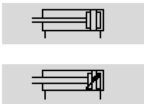
The following sections list the possible causes and remedies we normally encounter when handling electro-pneumatic components.

A good place to start is to use the service manuals which come with the machine; here you can find all the technical data on the components.

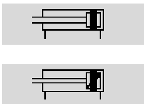
Standard cylinders DNC, ISO 6431 and VDMA 24 562
Technical data

FESTO

Function
DNC-...
without position sensing



DNC-...-A-...
with position sensing



Diameter
32 ... 125 mm

Stroke length
10 ... 2,000 mm

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General technical data								
Piston ∅		32	40	50	63	80	100	125
Stroke [mm]	Basic version	10 ... 2,000						
	Q	10 ... 300	10 ... 400	10 ... 500		10 ... 600		–
	K10	10 ... 1,000						–
	S10	10 ... 500						–
	S11	10 ... 500						
	S20	10 ... 850						
Pneumatic connection		G⅛	G¼	G¼	G⅜	G⅜	G½	G½
Piston rod thread	Basic version	M10x1.25	M12x1.25	M16x1.5	M16x1.5	M20x1.5	M20x1.5	M27x2
	K3	M6	M8	M10	M10	M12	M12	M16
	K5	M10	M12	M16	M16	M20	M20	M27
Constructional design		Piston						
		Piston rod						
		Cylinder barrel						
Cushioning P		Non-adjustable at either end						
Cushioning PPV		Adjustable at both ends						
Cushioning length PPV	[mm]	20	20	22	22	32	32	42
Position sensing		With proximity sensor						
Type of mounting		Via female thread						
		Via accessories						
Assembly position		Any						

Operating conditions								
Piston ∅		32	40	50	63	80	100	125
Operating medium		Filtered compressed air, lubricated or unlubricated						
Operating pressure [bar]	Basic version	0.6 ... 12						0.6 ... 10
	R8	1.5 ... 12						1.5 ... 10
	S11	0.1 ... 12						0.1 ... 10

Figure 19.1 – Sample of a Data Sheet

19.2 Identify and Record

Using the fault-finding guide or flow chart, identify and record all possible signs and symptoms of pneumatic system failures.

An example of a fault-finding guide is shown below for an electro-pneumatic system.

Items to Check		YES	NO	Remarks
1	Pneumatic systems are started when appropriate buttons are activated			
2	Pneumatic systems follow the required sequence as stipulated in the control requirements			
3	Actuators travel their required distance and speed			
4	System cycle is within time limits			
5	Pneumatic systems are stopped by pressing the appropriate buttons			

19.3 Diagnose the Possible Faults

From the checklist, you should be able to identify the possible faults. Below is an example:

1	Compressed air supply is correctly connected to pneumatic systems
2	Compressed air supply is sufficient and set at right pressure
3	Electrical supply is connected and working (if applicable)
4	All connectors are connected correctly and in good working condition
5	Pneumatic and electro-pneumatic components are in working condition
6	Pneumatic systems are able to start when appropriate buttons are activated
7	Pneumatic systems follow the required sequence as stipulated in the control requirements
8	Pneumatic systems are stopped when appropriate buttons are pressed

19.4 Dismantling, Repairing and Assembling

Once the faulty components have been identified, we need to disassemble, repair or replace and reassemble the machine. Some of the guidelines are:

19.4.1 Preparation

- All compressed air supply is removed
- All power supply is switched off
- Correct tools, equipment and spare parts are chosen for the maintenance/repair work
- Tools, equipment and spare parts are in good working condition
- Space around the work area is not obstructed
- Safety shoes are worn by the worker

19.4.2 Dismantling

- Parts are removed in the correct sequence
- Only remove the relevant parts
- Refer to service manual if possible
- Mark and tag removed components
- Use to correct tools and do not use force

19.4.3 Repair/Replace

- The dismantled defective part is checked against the parameters provided by the manufacturer
- If defective, the part is either repaired or replaced
- Make sure that the correct part is replaced

19.4.4 Reassemble

- The serviced or new part is reassembled and connected in the correct location
- Make sure that all parts re reconnected and no leftovers
- The reassembly process should be the reverse of the dismantling process

For electro-pneumatics components, the following are some guidelines:

- For directional control valves, check the solenoid coils
- You can replace just the solenoid coils if it is faulty and need to not replace the complete valve
- Similarly, if the valve is faulty just replace the valve and reuse the solenoid coil
- Check for any faulty relays
- Check the wiring as it might come loose
- Check for continuity in the wiring, using a multimeter

Finally, when replacing faulty components, remember to get the correct part including the correct electrical rating.

19.5 Assessing the Performance

Once you have completed the repair of the component, you now need to assess the performance of the machine. Tests run the machine and check against the specifications given by the manufacturer.

The readings should be within the specifications given.

19.6 Faults in Solenoid Operated Directional Control Valves

- Wire connections are open internally. (Infinite resistance measurement on ohmmeter).
- Direct short (at power supply, electrical bus, load). A direct short is when too much current is sent back to the power supply overloading it, generally blowing a fuse.
- Cross short: A cross short is created by one or more wires (cables) by-passing the load causing a direct short to occur.
- High resistance connections (too many connections at the terminal eye).
- Stuck armature.
- Low voltage or over voltage at solenoid.
- Corrosion.
- Partially or fully blocked hoses.
- Lack of source pressure (at compressor or on the service unit).
- Sticking spool.
- Diaphragm not working.
- Exhaust ports blocked.
- Gaskets mounted incorrectly.
- Faults caused by wear or external influences.
- Caution: Short circuiting of the power supply is not recommended without the installation of a "circuit breaker" to protect the equipment and the user.

19.7 Faults in Relay Coils

<table>
<tr><th>Fault</th><th>Cause</th><th>Remedy</th></tr>
<tr><td rowspan="5">When powered, the relay coil does not function.</td><td>One or more of the wires (leads) has an infinite resistance.</td><td rowspan="5">Use the voltmeter to measure the difference in potential across each cable, and the push button when switch is open, then closed. If the problem is with any of these components, replace them and retry the circuit. If the voltage is too low, check the power supply and the wall outlet.

Use the ohmmeter to measure the resistance of the coil; if you have an infinite resistance (Open), replace the coil and retest the circuit. If the coil is good and the voltage is sufficient, test the ground wire.</td></tr>
<tr><td>Open (infinite resistance) in the coil.</td></tr>
<tr><td>Low voltage – below specifications.</td></tr>
<tr><td>Replace new relay with wrong voltage.</td></tr>
<tr><td>No input signal (ie. Push button switch contact is not closing)</td></tr>
</table>

Fault	Cause	Remedy
Relay coil is not energized by electrical limit switch (or proximity limit switch)	The electrical limit switch is not being activated.	Visually examine the electrical limit switch to make sure the roller is fully activated, if not, reposition the sensor so physical contact is achieved. (or see LED)
		Use the voltmeter to test the difference in potential across the limit switch (24 volts when open, 0 volts when closed) replace if not functioning, or remove the limit switch from the circuit and use the ohmmeter to measure the resistance of the limit switch (infinite pressure when open, approximately 0 when closed)
	One of the cables (wires) is either not connected or there is infinite resistance in the cable (wire).	Use the multimeter to check the difference in potential across each cable (wire) in the corresponding ring. Then remove the suspect cable(s) and use the ohmmeter to confirm your findings, replace the cables if required.
	The relay coil itself is malfunctioning, ie. low voltage, an open (infinite resistance) circuit, loose connection, high resistance connection.	If the voltmeter identifies low voltage, then check the power supply and original source. Replace or modify source as required. If an “open” infinite resistance, loose or high connection is suspected, use the ohmmeter to determine the exact location of the problem and repair/replace as required.