Lecture 41

ELECTRO – PNEUMATIC CONTROL

Learning Objectives

Upon completion of this chapter, Student should be able to

- Explain the various steps involved in electro pneumatics
- List seven basic electrical devices used in electro pneumatics
- Describe the constructional details of solenoid valves
- Explain the operations of control devices like limit switches, sensors, timers , counters and pressure switches
- Differentiate between capacitive and inductive proximity sensors
- Differentiate between dominant on and off latching circuits
- Design single actuator electro pneumatic circuits
- Design a sequence circuits using two and three cylinders

1.1 INTRODUCTION

Electro pneumatics is now commonly used in many areas of Industrial low cost automation. They are also used extensively in production, assembly, pharmaceutical, chemical and packaging systems. There is a significant change in controls systems. Relays have increasingly been replaced by the programmable logic controllers in order to meet the growing demand for more flexible automation.

Electro-pneumatic control consists of electrical control systems operating pneumatic power systems. In this solenoid valves are used as interface between the electrical and pneumatic systems. Devices like limit switches and proximity sensors are used as feedback elements.

Electro Pneumatic control integrates pneumatic and electrical technologies, is more widely used for large applications. In Electro Pneumatics, the signal medium is the electrical signal either AC or DC source is used. Working medium is compressed air. Operating voltages from around 12 V to 220 Volts are often used. The final control valve is activated by solenoid actuation

The resetting of the valve is either by spring [single Solenoid]or using another solenoid [Double solenoid Valve] . More often the valve actuation/reset is achieved by pilot assisted solenoid actuation to reduce the size and cost of the valve

Control of Electro Pneumatic system is carried out either using combination of Relays and Contactors or with the help of Programmable Logic Controllers [PLC]. A Relay is often is used to convert signal input from sensors and switches to number of output signals [either normally closed or normally open] .Signal processing can be easily achieved using relay and contactor combinations

A Programmable Logic Controller can be conveniently used to obtain the out puts as per the required logic, time delay and sequential operation.. Finally the out put signals are supplied to the solenoids activating the final control valves which controls the movement of various cylinders. The greatest advantage of electro pneumatics is the integration of various types of proximity sensors [electrical] and PLC for very effective control. As the signal speed with electrical signal, can be much higher, cycle time can be reduced and signal can be conveyed over long distances.

In Electro pneumatic controls, mainly three important steps are involved:

- **Signal input devices -**Signal generation such as switches and contactor, Various types of contact and proximity sensors
- **Signal Processing** – Use of combination of Contactors of Relay or using Programmable Logic Controllers
- **Signal Out puts** – Out puts obtained after processing are used for activation of solenoids, indicators or audible alarms

1.2 SEVEN BASIC ELECTRICALDEVICES

Seven basic electrical devices commonly used in the control of fluid power systems are

1. Manually actuated push button switches
2. Limit switches
3. Pressure switches
4. Solenoids
5. Relays
6. Timers
7. Temperature switches

Other devices used in electro pneumatics are

1. Proximity sensors
2. Electric counters

1.2.1 Push button switches

A push button is a switch used to close or open an electric control circuit. They are primarily used for starting and stopping of operation of machinery. They also provide manual override when the emergency arises. Push button switches are actuated by pushing the actuator into the housing. This causes set of contacts to open or close.

Push buttons are of two types

i) Momentary push button
ii) Maintained contact or detent push button

Momentary push buttons return to their unactuated position when they are released. Maintained (or mechanically latched) push buttons has a latching mechanism to hold it in the selected position.

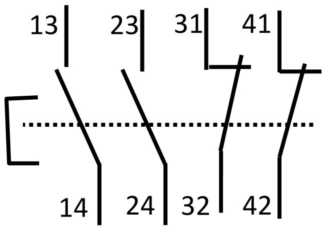
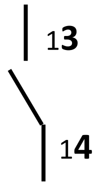
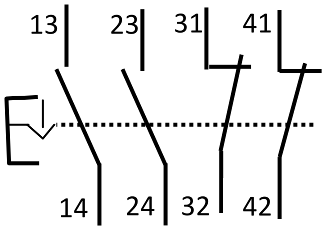
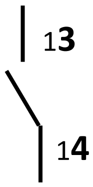
The contact of the push buttons, distinguished according to their functions,

i) Normally open (NO) type
ii) Normally closed (NC) type
iii) Change over (CO) type.

The cross section of various types of push buttons in the normal and actuated positions and their symbols are given in the Figure 1.1 In the NO type, the contacts are open in the normal position, inhibiting the energy flow through them. But in the actuated position, the contacts are closed, permitting the energy flow through them. In the NC type, the contacts are closed in the normal position, permitting the energy flow through them. And, the contacts are open in the actuated position, inhibiting the energy flow through them. A changeover contact is a combination of NO and NC contacts.

Type of devices	***Terminal Numbers***	
	Normally closed contacts	**Normally open contacts**
Push buttons and Relays	1 and 2	3 and 4
Timers and Counters	5 and 6	7 and 8

Designation of the pushbuttons

Type of contact	Designation
Momentary contact type PB station (2 NO +2 NC) 	First digit indicates the function of contact. Second digit represents a serial ordering. 3 and 4 represents **NO** contacts and 1 is the serial no. 
Maintained Contact type PB station (2NO+2 NC) 	First digit indicates the function of contact. Second digit represents a serial ordering. 3 and 4 represents **NO** contacts and 1 is the serial no. 

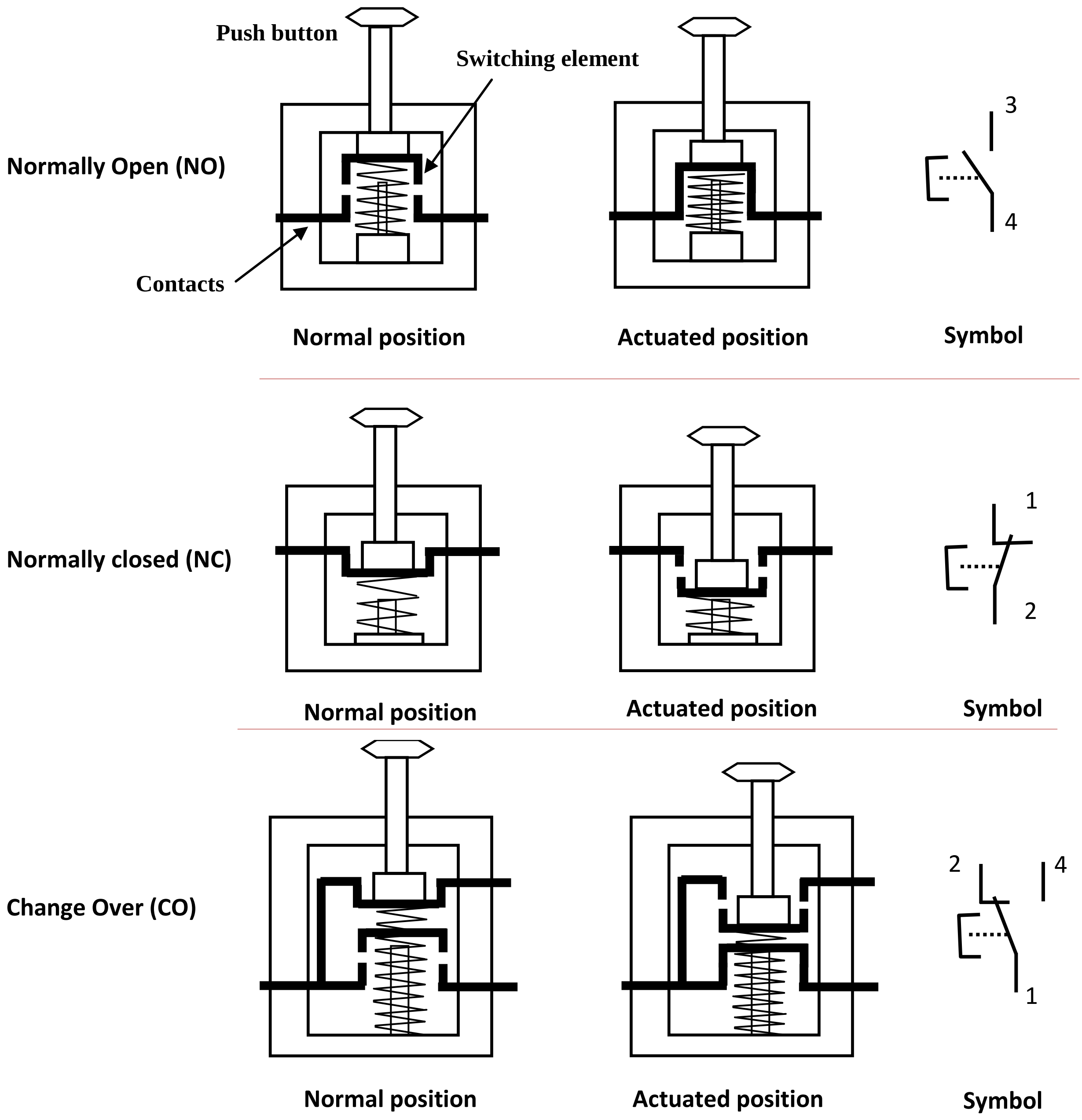


Figure 1.1 : Pushbuttons and their symbols

1.2.2 Limit switches

Any switch that is actuated due to the position of a fluid power component (usually a piston rod or hydraulic motor shaft or the position of load is termed as limit switch. The actuation of a limit switch provides an electrical signal that causes an appropriate system response.

Limit switches perform the same function as push button switches. Push buttons are manually actuated whereas limit switches are mechanically actuated.

There are two types classification of Limit switches depending upon method of actuations of contacts

a) Lever actuated contacts
b) Spring loaded contacts

In lever type limit switches, the contacts are operated slowly. In spring type limit switches, the contacts are operated rapidly. **Figure 1.2** shows a simplified cross sectional view of a limit switch and its symbol.

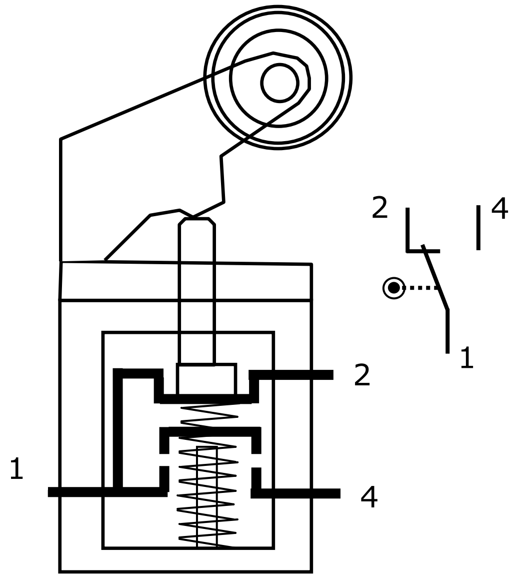


Figure 1.2: Cross sectional view of a limit switch

1.2.3 Pressure switches

A pressure switch is a pneumatic-electric signal converter. Pressure switches are used to sense a change in pressure, and opens or closes an electrical switch when a predetermined pressure is reached. Bellow or diaphragm is used to sense the change of pressure. Bellows or Diaphragm is used to expand or contract in response to increase or decrease of pressure. **Figure 1.3** shows a diaphragm type of pressure switch. When the pressure is applied at the inlet and when the pre-set pressure is reached, the diaphragm expands and pushes the spring loaded plunger to make/break contact.

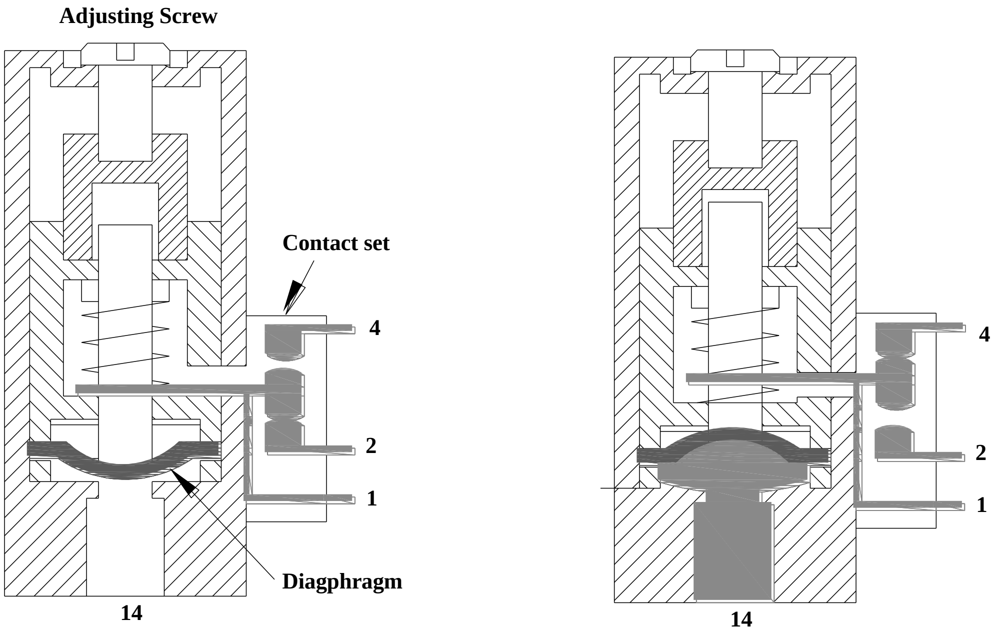


Figure 1.3: Cross sectional view of a pressure switch

1.2.4 Solenoids

Electrically actuated directional control valves form the interface between the two parts of an electro-pneumatic control. The most important tasks of electrically actuated DCVs include.

i) Switching supply air on or off
ii) Extension and retraction of cylinder drives

Electrically actuated directional control valves are switched with the aid of solenoids. They can be divided into two groups:

i) Spring return valves only remain in the actuated position as long as current flows through the solenoid
ii) 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 DCVs are de-energised and the solenoids are inactive. A double valve has no clear initial position, as it does not have a return spring. The possible voltage levels for solenoids are 12 V DC, 12V AC, 12 V 50/60 Hz, 24V 50/60 Hz, 110/120V 50/60 Hz, 220/230V 50/60 Hz.

a) 3/2 Way single solenoid valve, spring return.

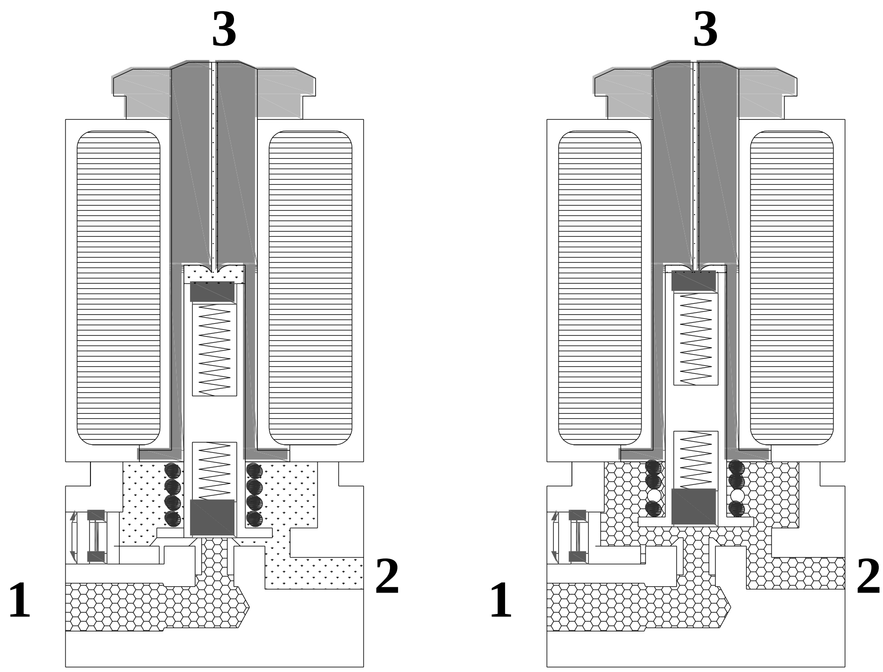


Figure 1.4: Cross sectional view of a 3/2 single solenoid valve

The cross sectional view of 3/2 way single solenoid valve in the normal and actuated positions are shown in **Figure 1.4**. In the normal position, port 1 is blocked and port 2 is connected to port 3 via back slot (details shown in the circle) When the rated voltage is applied to coil, armature is pulled towards the centre of the coil and in the process the armatures is lifted away from the valve seat. The compressed air now flows from port 1 to port 2, and ports 3 is blocked. When the voltage to the coil is removed, the valve returns to the normal position. **Figure 1.5** shows 2/2 solenoid operated valve

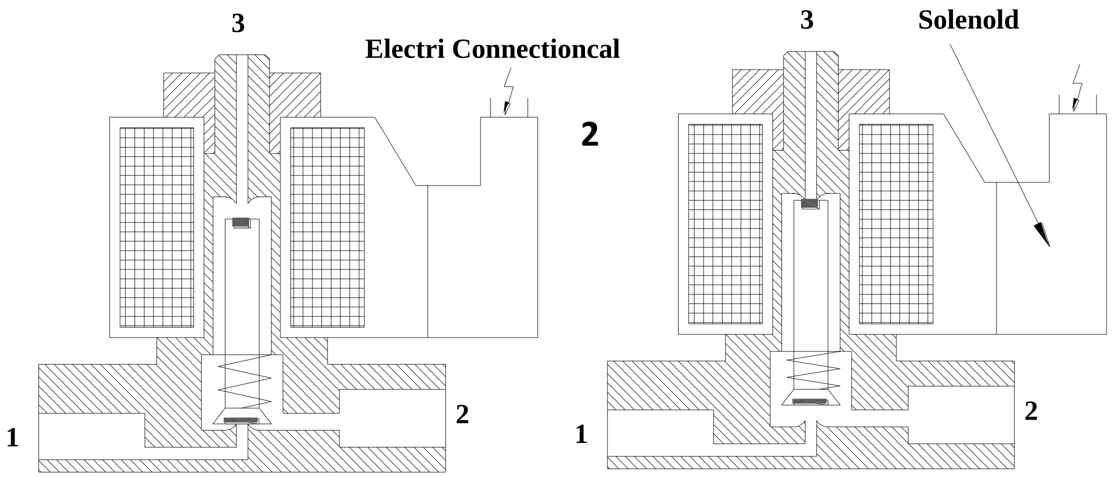


Figure 1.5: Cross sectional view of a 2/2 way solenoid operated valve

b) 5/2 Way single solenoid valve, spring return.

The cross section view of 5/2 way single solenoid in the normal and actuated positions are shown in **Figure 1.6.** In normal position, port 1 is connected to port 2, port 4 is connected to port 5, and port 3 is blocked. When the rated voltage is applied to coil 14, the valve is actuated through an internal pilot valve. In actuated position, port 1 is connected to port 4 , port 2 is connected to port 3, and port 5 is blocked. The valve returns to the normal position when the voltage to the armature coil is removed. This type of valves is normally used as final valve to control double acting cylinders.

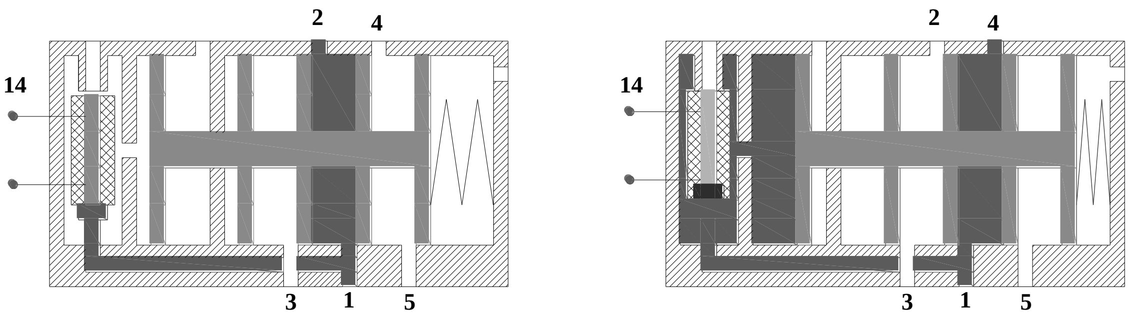


Figure 1.6: Cross sectional view of a 5/2 way solenoid operated valve

c) 5/2 Way single double solenoid valve

The cross section view of 5/2 way double solenoid in the normal and actuated positions are shown in the **Figure 1.7** when the rated voltage is applied to coil 14, the valve is actuated to a one switch in position with port 1 connected to port 4, port 2 connected to port 3, and port 5 blocked. When the rated voltage is applied to the coil 12, the valve is actuated to the other switching position with port 1 connected to port 2, port 4 connected to port 5 and port 3 blocked.

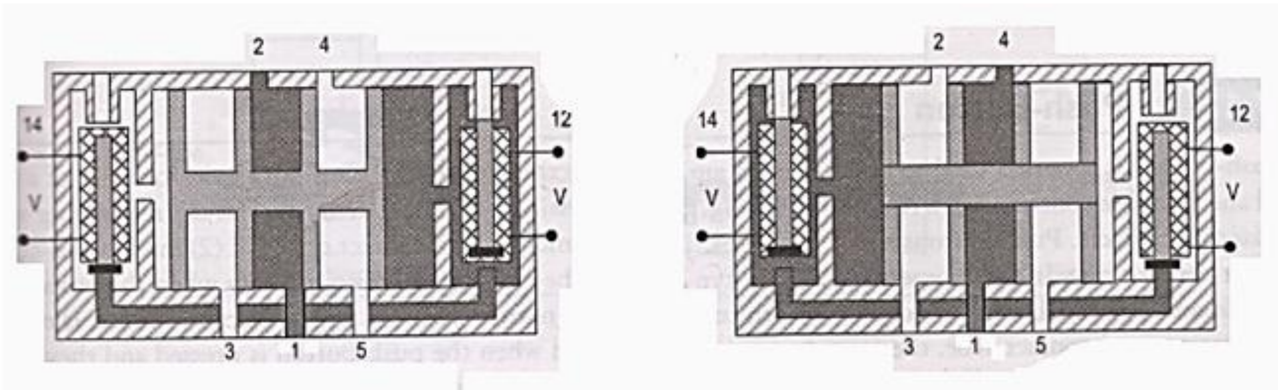
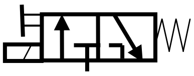
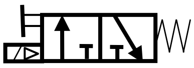
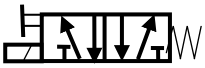
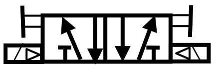


Figure 1.7: Cross sectional view of a 5/2 way double solenoid operated valve

The symbols for the various solenoid/pilot actuated valves are given in **Table 1.1**

Table 1.1 Various symbols for DCVs

Symbol	Details
	**3/2 way Single solenoid valve (spring return)**
	**3/2 way pilot operated single solenoid valve(spring return)**
	**5/2 way single solenoid Valve (spring return)**
	**5/2 way double solenoid valve.**
	**5/2 way piloted operated double solenoid valve.**

1.2.5 Relays

A relay is an electro magnetically actuated switch. It is a simple electrical device used for signal processing. Relays are designed to withstand heavy power surges and harsh environment conditions. When a voltage is applied to the solenoid coil, an electromagnet field results. This causes the armature to be attracted to the coil core. The armature actuates the relay contacts, either closing or opening them, depending on the design. A return spring returns the armature to its initial position when the current to the coil is interrupted. Cross sectional view of a relay is shown in **Figure 1.8**

A large number of control contacts can be incorporated in relays in contrast to the case of a push button station. Relays are usually designated as K1, K2, and K3 etc. Relays also possess interlocking capability that is an important safety feature in control circuits. Interlocking avoids simultaneous switching of certain coils.

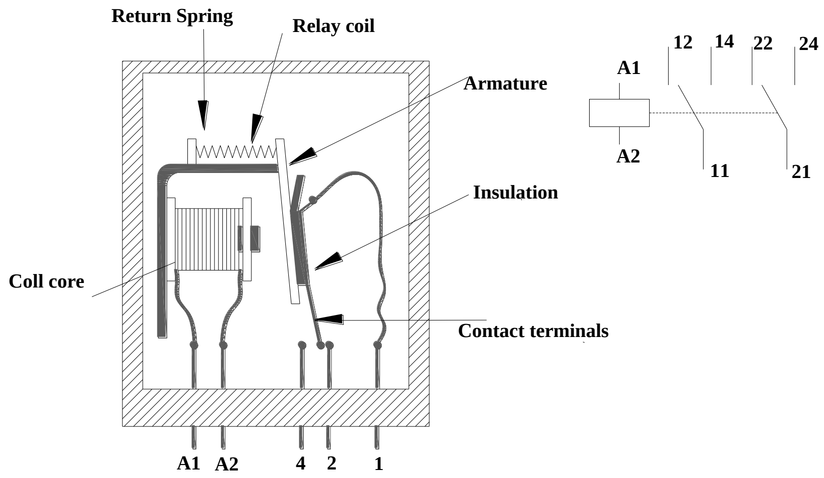


Figure 1.8: Cross sectional view of a relay

1.2.6 Timer Or Time delay relays

Timers are required in control systems to effect time delay between work operations. This is possible by delaying the operation of the associated control element through a timer. Most of the timers we use is Electronic timers. There are two types of time relay

i) Pull in delay (on –delay timer)

ii) Drop –out delay (off delay timer)

In the on-delay timer, shown in Figure cc, when push button PB is pressed (ON), capacitor C is charged through potentiometer R1 as diode D is reverse –biased. The time taken to charge the capacitor, depends on the resistance of the potentiometer (R1) and the capacitance(C) of the capacitor. By adjusting the resistance of the potentiometer, the required time delay can be set. When the capacitor is charged sufficiently, coil K is energised, and its contacts are operated after the set time delay. When the push button is released (OFF), the capacitor discharges quickly through a small resistance (R2) as the diode by passes resistor R1, and the contacts of relay (K) return to their normal position without any delay.

In the off-delay timer, the contacts are operated without any delay when the push button is pressed (ON). The contacts return to the normal position after the set delay when the push button is released (OFF).

The construction and symbols of the on-delay and off-relay timers are given in **Figure1.9**. Timing diagram is shown in **Table 1.2**

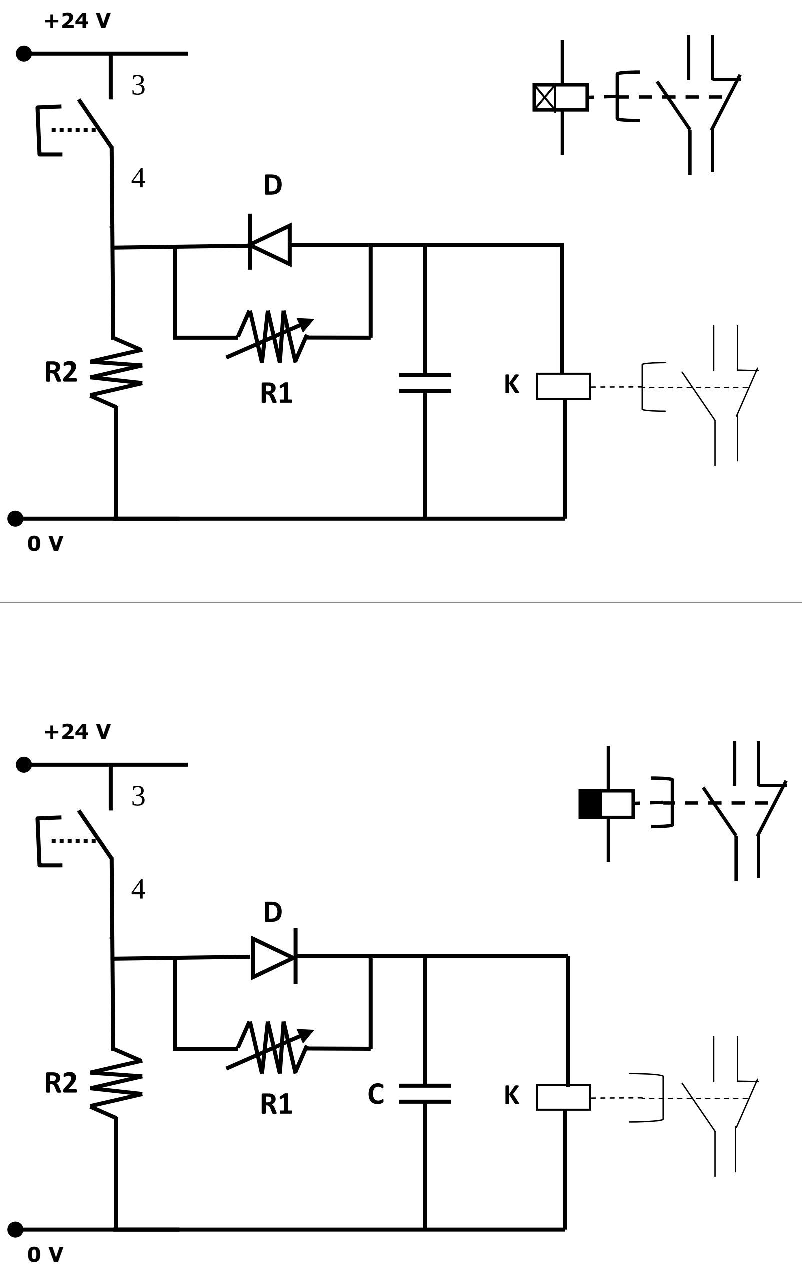
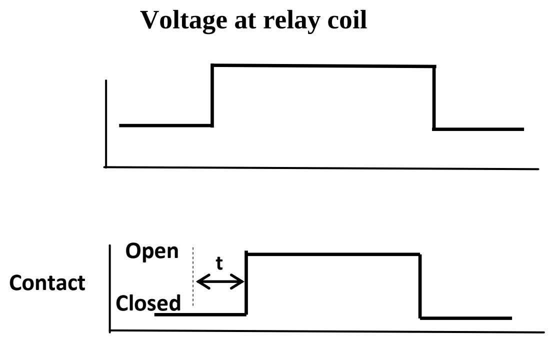
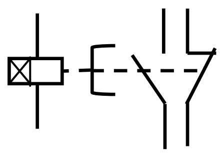
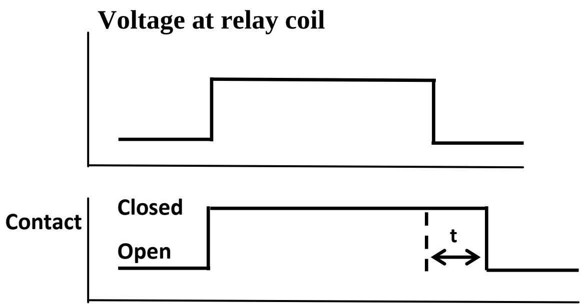
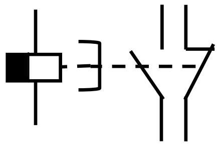


Figure 1.9: Construction features of timer and its symbols

Table 1.2: Timing diagram for on and off delay timer

Timing diagram	Symbol
	On-delay timer circuit 
	Off-delay timer circuit 

1.2.7 Temperature Switch

Temperature switches automatically senses a change in temperature and opens or closes an electrical switch when a predetermined temperature is reached. This switch can be wired either normally open or normally closed.

Temperature switches can be used to protect a fluid power system from serious damage when a component such as a pump or strainer or cooler begins to malfunction.

1.2.8 Reed Proximity switches

Reed switches are magnetically actuated proximity switches. Reed switches are similar to relays, except a permanent magnet is used instead of a wire coil. Schematic diagram of reed switch is shown in **Figure 1.1.** The reed switches comprise two ferromagnetic reeds placed with a gap in between and hermetically sealed in a glass tube. The glass tube is filled with inert gas to prevent the activation of the contacts. The surfaces of the reed contacts are plated with rhodium or iridium. Whole unit is encapsulated in epoxy resin to prevent mechanical damage to the switch. They are also provided with LED indicator to show its switching status.

When the magnet is away the switch is open, but when the magnet is brought near the switch is closed. The reed switch is operated by the magnetic field of an energized coil or a permanent magnet which induces north (N) and south (S) poles on the reeds. The reed contacts are closed by this magnetic attractive force. When the magnetic field is removed, the reed elasticity causes the contacts to open the circuit. The transfer type reed switch is normally ON, due to mechanical bias of the common (COM) lead, which is between the normally closed (N.C) reed contact and the normally open (N.O) reed contacts. When an external magnetic field is induced, the N.C blade is not affected because it is non-magnetic but the COM lead is attracted by the N.O lead and moves. When the magnetic field is removed, COM lead again moves to the N.C lead by mechanical.

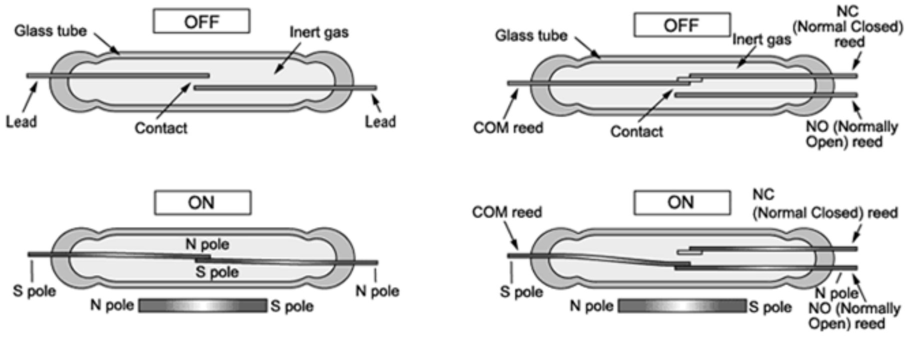


Figure 1.10: Construction features of reed switch

The two wire reed switch consists of two reeds. One of reed is connected to positive terminal of electric supply and other is connected to signal output. The three wire reed wire consists of three reed contacts. One is connected to positive terminal of electric supply. Second one is connected to negative terminal of the electric supply and third one is connected to the signal output. Symbol of the three wire reed switch and two wire reed switch is shown in Figure 1.11

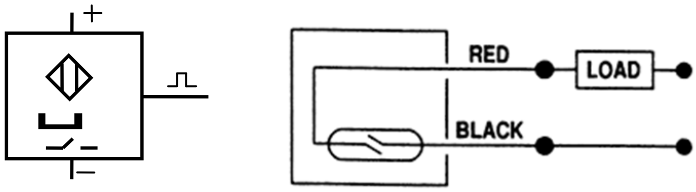


Figure 1.11: Symbol of 3 wire and 2 wire reed switch

Advantages of reed switches are

1. Reed switches are cheap.
2. They have long service life
3. They have shorter switching time (in the order of 0.2 to 0.3 millis seconds)
4. They are compact and maintenance frees

Disadvantages of reed switches are

1. They cannot be used in environments subjected to magnetic fields (like resistance welding machine)
2. Closing of contacts in reed switch is not bounce free

1.2.9 Electronic sensors

Inductive, Optical and capacitive proximity switches are electronic sensors. They normally have three electrical contacts. One contact for supply voltage , other for ground and third for output signal.

In these sensors, no movable contact is switched. Instead, the output is either electrically connected to supply voltage or to ground. There are two types of electronic sensors with regard to the polarity of output voltage.

Positive switching sensors: In this output voltage is zero if no part is detected in the proximity. The approach of a work piece or machine part leads to switch over of the output, applying the supply voltage.

Negative switching sensors: In this the supply voltage are applied to the output if no part is detected in the proximity. The approach of a work piece or machine part leads to switch over of the output, switching the output voltage to 0 volts.

a) Inductive sensors

Inductive sensor use currents induced by magnetic field to detect the nearby metal objects. The inductive sensor uses a coil or inductor to generate a high frequency magnetic field as shown in **Figure 1.12**. If there is a metal object near the changing magnetic field, current will flow in the object. This resulting current flow sets up a new magnetic field that opposes the original magnetic field. The net effect is that it changes the inductance of the coil in the inductive sensor. By measuring the inductance the sensor can determine when a metal have been brought nearby.

These sensors will detect any metals, when detecting multiple types of metal multiple sensors are used. In addition to metals, graphite also can be sensed. It is important to note that these work by setting up a high frequency field. If a target nears the field will induce eddy currents. These currents consume power because of resistance, so energy is in the field is lost, and the signal amplitude decreases . The detector examines filed magnitude to determine when is has decreased enough to switch.

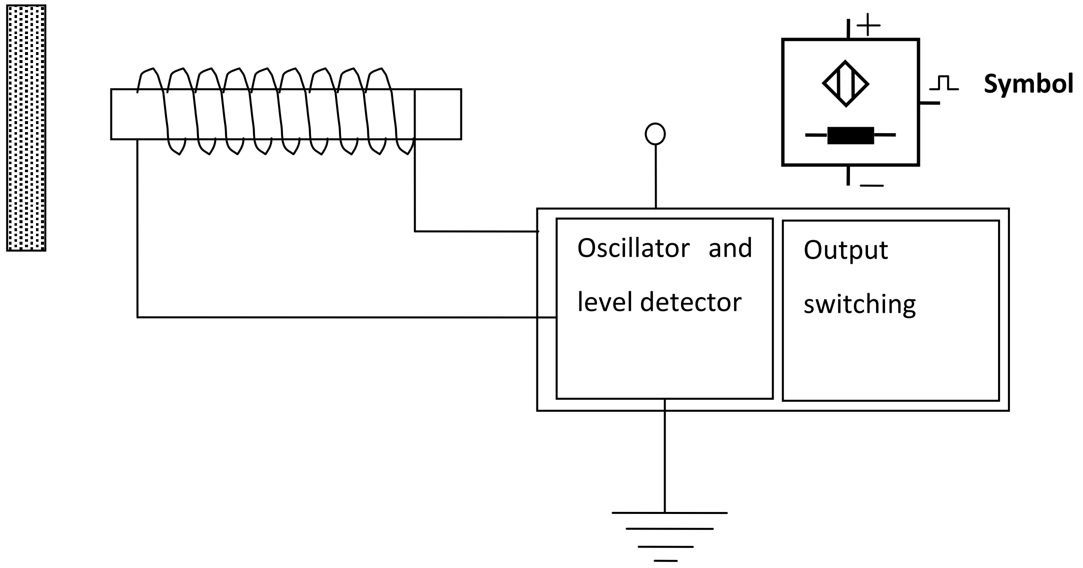


Figure 1.12: Inductive sensor

The sensors can detect objects a few centimetres away from the end. But, the direction to the object can be arbitrary as shown in **Figure 1.13**. The magnetic field of the unshielded sensors covers a large volume around the head of the coil. By adding a shield (a metal jacket around the sides of the coil) the magnetic field becomes smaller, but also more directed. Shields will often be available for inductive sensors to improve their directionality and accuracy.

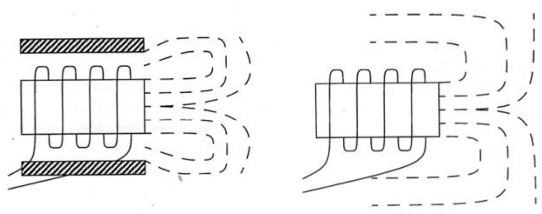


Figure 1.13: Shielded versus unshielded Inductive sensors

Advantages of proximity sensors are

1. They are self contained, rugged and extremely reliable
2. They have long service life
3. They have shorter switching time
4. They are compact and maintenance frees

Disadvantages of proximity sensors are

1. Like reed switches , they cannot be used in environments subjected to magnetic fields (like resistance welding machine)

Applications of proximity sensors

The proximity sensors can be used for various applications, These include:

- Sensing of end position of linear actuators like cylinders and semi rotary actuators
- They are used to detect metallic pieces on conveyor. That is presence or absence of work piece on conveyor
- They are used in press to detect the end position
- They are used to monitor drill breakage while drilling.
- They are also used as feed back devices in speed measuring devices

Factors influences the sensing distance

The switching distance of inductive sensors depends on the conductivity and permeability of the metal part whose presence or absence to be detected. This distance varies with the material composition of the target object, with mild steel takes as the material for standard reference (**Table 1.3**.) This is described by the reduction factor. The reduction factor is the factor by which the sensing range of the inductive sensor is reduced based on material composition of the objected to be sensed , compared to steel [FE 360] as the standard reference .

Table 1.3 Reduction factors for various materials

Material	**Reduction factor**
Stainless steel	0.80 to 0.85
Nickel steel	0.70 to 0.90
Aluminium and brass	0.35 -0.50
Copper	0.25 -0.40

Another factor which affects the sensing range of inductive sensors is the diameter of sensing coil. A small sensor with a coil diameter 0f 18mm has a typical range of 1mm, while a large sensor with core diameter of 75mm has a sensing range up to 50mm or even more

b) Capacitive sensors

Capacitive sensors are able to detect most materials at distances upto a few centimetres.

We know that

$$capacitance = \frac{Area\ of\ plates\ \times dielectric\ constant}{distance\ between\ plates\ (\ electrodes)}$$

In the sensor the area of the plates and distance between them is fixed. But, the dielectric constant of the space around them will vary as different material is brought near the sensor. An illustration of a capacitive sensor is shown **Figure 1.14** an oscillating field is used to determine the capacitance of the plates. When this changes beyond selected sensitivity the sensor output is activated.

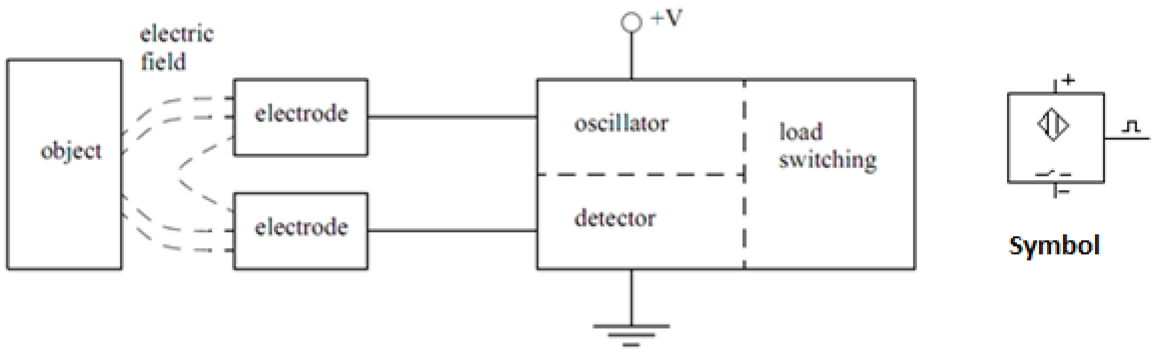


Figure 1.14: Capacitive sensors

For capacitive sensor the proximity of any material near the electrodes will increase the capacitance. This will vary the magnitude of the oscillating signal and the detector will decide when this is great enough to determine proximity.

These sensors work well for insulators (such as plastics) that tend to have high dielectric coefficients, thus increasing the capacitance. But, they also work well for metals because the conductive materials in the target appear as larger electrodes, thus increasing the capacitance as shown in **Figure 1.15**. In total the capacitance changes are normally in the order of pF.

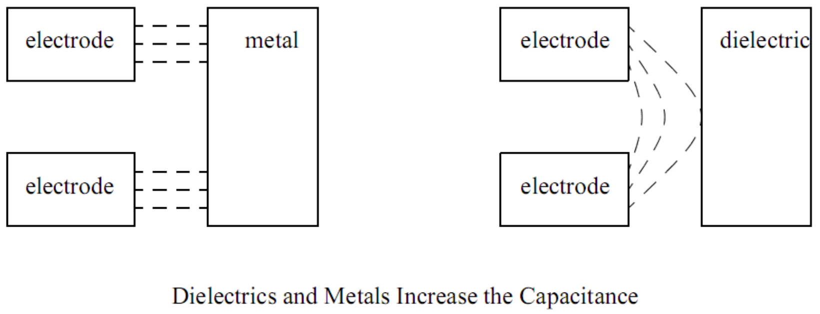


Figure 1.15: Capacitive sensors for metals and dielectrics

Advantages of proximity sensors are

1. They are widely used because of their ability to react with wide range of materials
2. They are suitable for detecting non metallic objects
3. They can be used to sense and monitor level in storage containers

Disadvantages of proximity sensors are

1. They are sensitive especially in humid environment
2. Without the compensator ring, the sensor would be very sensitive to dirt, oil and other contaminants that might stick to the sensor.

c) **Optical proximity sensors**

Light sensors have been used for almost a century - originally photocells were used for applications such as reading audio tracks on motion pictures. But modern optical sensors are much more sophisticated

Optical sensors require both a light source (emitter) and detector. Emitters will produce light beams in the visible and invisible spectrums using LEDs and laser diodes. Detectors are typically built with photodiodes or phototransistors. The emitter and detector are positioned so that an object will block or reflect a beam when present. A basic optical sensor is shown in **Figure 1.16**

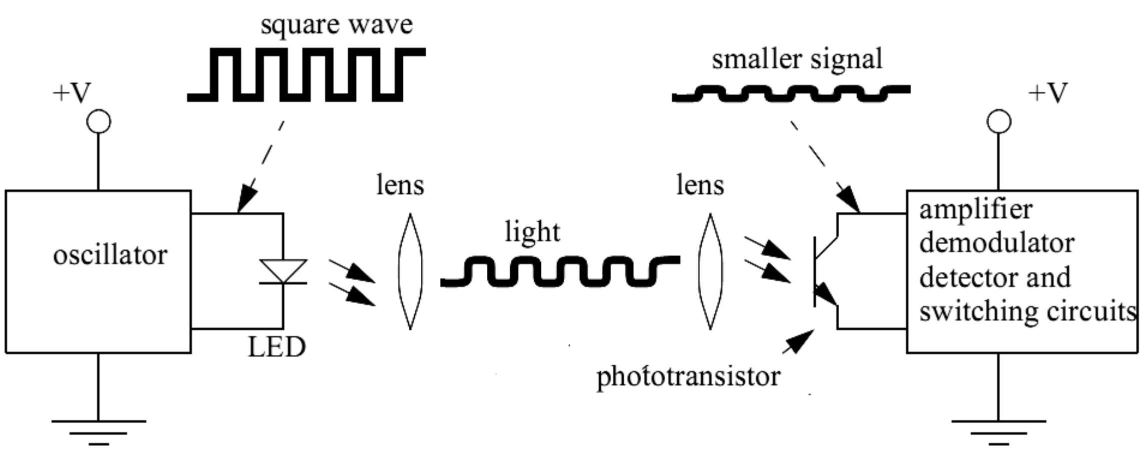


Figure 1.16: A Basic Optical sensor

In the figure the light beam is generated on the left, focused through a lens. At the detector side the beam is focused on the detector with a second lens. If the beam is broken the detector will indicate an object is present. The oscillating light wave is used so that the sensor can filter out normal light in the room. The light from the emitter is turned on and off at a set frequency. When the detector receives the light it checks to make sure that it is at the same frequency. If light is being received at the right frequency then the beam is not broken. The frequency of oscillation is in the KHz range, and too fast to be noticed. A side effect of the frequency method is that the sensors can be used with lower power at longer distances

An emitter can be set up to point directly at a detector, this is known as opposed mode. When the beam is broken the part will be detected. This sensor needs two separate components, as shown in **Figure 1.17** This arrangement works well with opaque and reflective objects with the emitter and detector separated by distances of up to hundreds of feet

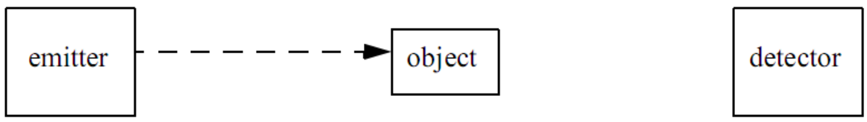


Figure 1.17: Opposed mode optical sensor

Having the emitter and detector separate increases maintenance problems and alignment is required. A preferred solution is to house the emitter and detector in one unit. But, this requires that light be reflected back as shown in **Figure 1.18**. These sensors are well suited to larger objects up to a few feet away.

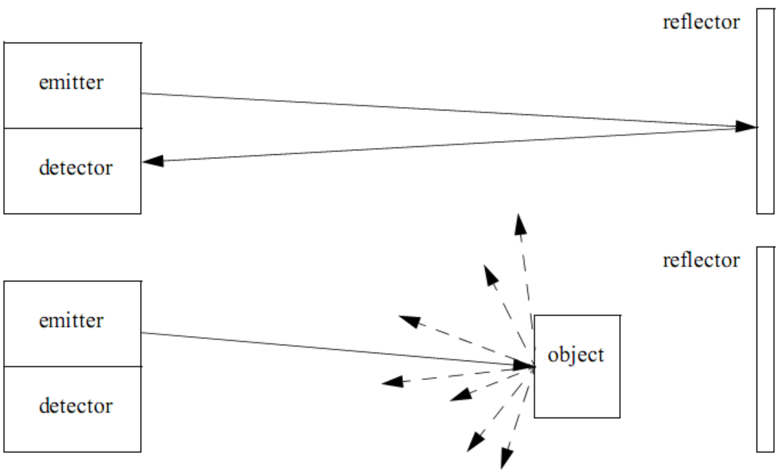


Figure 1.18: Emitter and detector in one unit

The reflector is constructed with polarizing screens oriented at 90 deg. angles. If the light is reflected back directly the light does not pass through the screen in front of the detector. The reflector is designed to rotate the phase of the light by 90 deg., so it will now pass through the screen in front of the detector.

In the figure, the emitter sends out a beam of light. If the light is returned from the reflector most of the light beam is returned to the detector. When an object interrupts the beam between the emitter and the reflector the beam is no longer reflected back to the detector, and the sensor becomes active. A potential problem with this sensor is that reflective objects could return a good beam. This problem is overcome by polarizing the light at the emitter (with a filter), and then using a polarized filter at the detector. The reflector uses small cubic reflectors and when the light is reflected the polarity is rotated by 90 degrees. If the light is reflected off the object the light will not be rotated by 90 degrees. So the polarizing filters on the emitter and detector are rotated by 90 degrees, as shown in **Figure 1.19** The reflector is very similar to reflectors used on bicycles

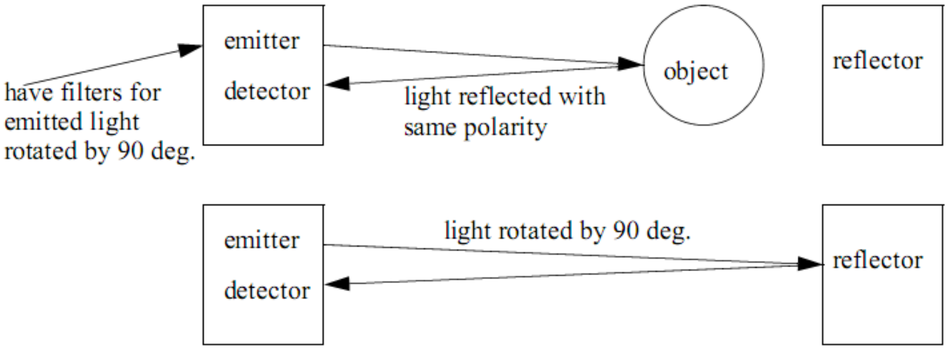


Figure 1.19: Polarized light in retroreflective sensors

For retro reflectors the reflectors are quite easy to align, but this method still requires two mounted components. A diffuse sensors is a single unit that does not use a reflector, but uses focused light as shown in **Figure 1.20**

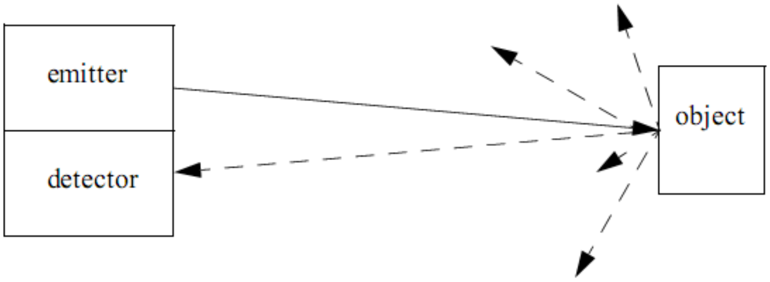


Figure 1.20: Diffuse sensor

With diffuse reflection the light is scattered. This reduces the quantity of light returned. As a result the light needs to be amplified using lenses

Diffuse sensors

Diffuse sensors use light focused over a given range, and a sensitivity adjustment is used to select a distance. These sensors are the easiest to set up, but they require well controlled conditions. For example if it is to pick up light and dark colored objects problems would result.

When using opposed mode sensors the emitter and detector must be aligned so that the emitter beam and detector window overlap, as shown in **Figure 1.21**. Emitter beams normally have a cone shape with a small angle of divergence (a few degrees of less). Detectors also have a cone shaped volume of detection. Therefore when aligning opposed mode sensor care is required not just to point the emitter at the detector, but also the detector at the emitter. Another factor that must be considered with this and other sensors is that the light intensity decreases over distance, so the sensors will have a limit to separation distance

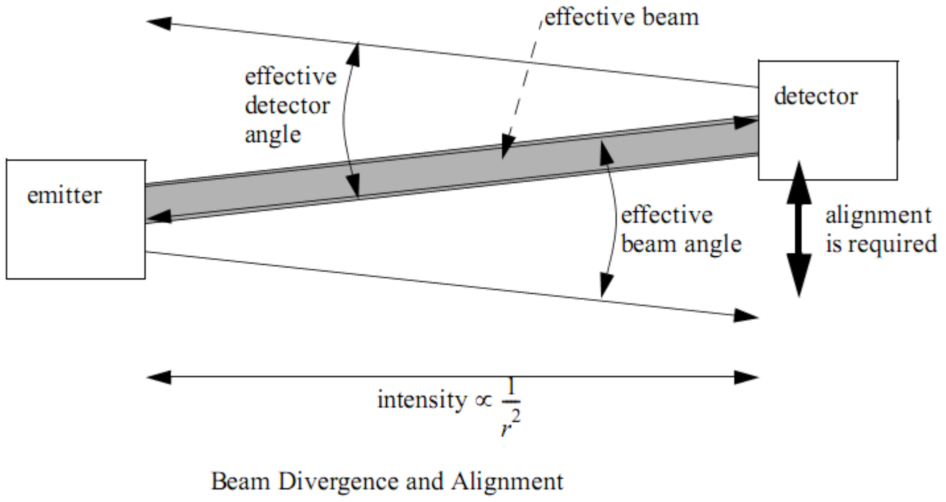


Figure 1.21: Beam divergence and alignment

If an object is smaller than the width of the light beam it will not be able to block the beam entirely when it is in front as shown in **Figure 1.22.** This will create difficulties in detection, or possibly stop detection altogether. Solutions to this problem are to use narrower beams, or wider objects. Fiber optic cables may be used with an opposed mode optical sensor to solve this problem, however the maximum effective distance is reduced to a couple feet

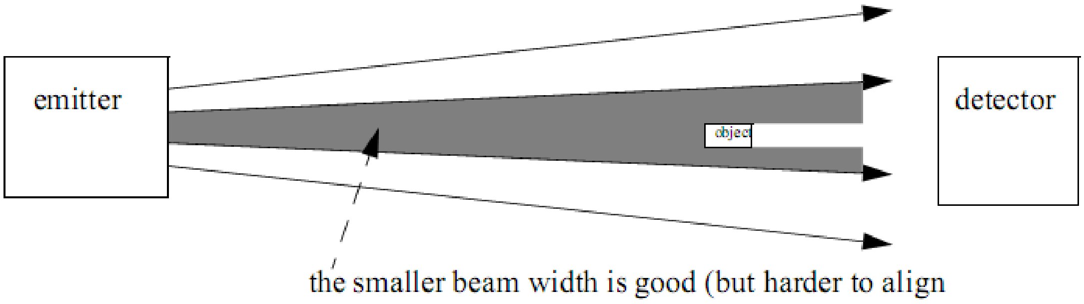


Figure 1.22: The relationship between beam width and object size

Separated sensors can detect reflective parts using reflection as shown in **Figure 1.23**. The emitter and detector are positioned so that when a reflective surface is in position the light is returned to the detector. When the surface is not present the light does not return

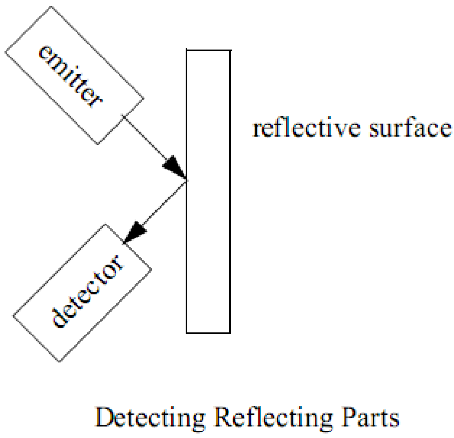


Figure 1.23: separated sensors

Other types of optical sensors can also focus on a single point using beams that converge instead of diverge.(**Figure 1.24**) The emitter beam is focused at a distance so that the light intensity is greatest at the focal distance. The detector can look at the point from another angle so that the two centerlines of the emitter and detector intersect at the point of interest. If an object is present before or after the focal point the detector will not see the reflected light. This technique can also be used to detect multiple points and ranges, as shown in **Figure 1.25** where the net angle of refraction by the lens determines which detector is used. This type of approach, with many more detectors, is used for range sensing systems

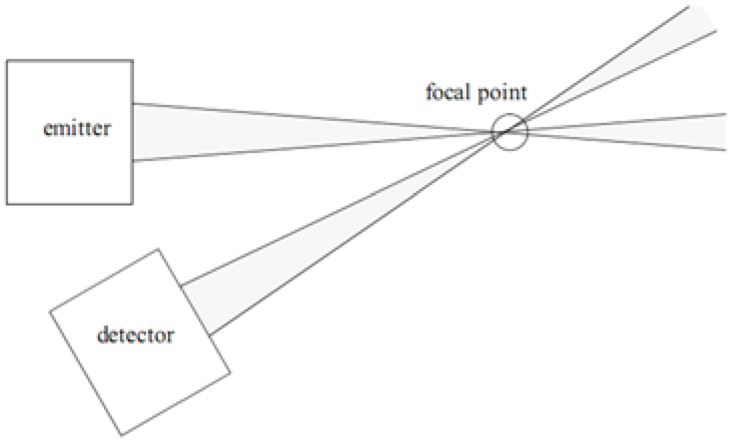


Figure 1.24: Point detection using focused optics

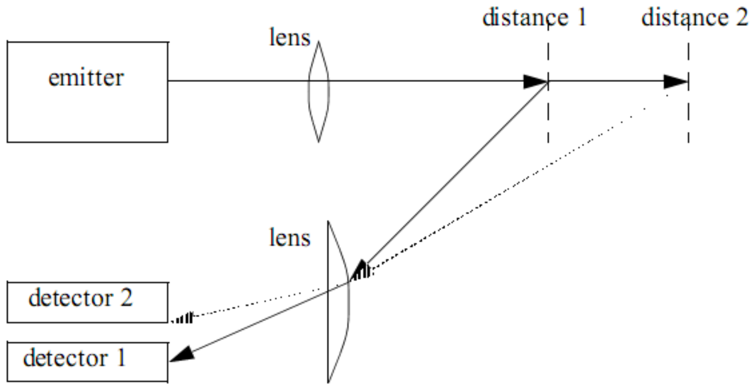


Figure 1.25: Multiple point detection using optics

Some applications do not permit full sized photo optic sensors to be used. Fiber optics can be used to separate the emitters and detectors from the application. Some vendors also sell photosensors that have the phototransistors and LEDs separated from the electronics.

1.2.10 Electric counters

An electric counter consist of a coil, associated circuits and contacts, a reset coil, manual reset, release button and a display window. Pressure the release button of the counter and entering the desired count valve set the pre-determining counter. The pre-determined count valve is displayed in the window. There are two types of counters

1. Up counter
2. Down counter

Up counter: An up counter counts electrical signal upwards from zero. For each electrical counting pulse input to an up-counter coil, the counter value is incremented by 1. When the predetermined valve has been reached, the relay picks up and the contact set is actuated.

Down counter: An down counter counts electrical signal downwards from preset valve. If the count valves of zero is reached the relay picks up and the contact set is actuated. The counter can be reset manually by pressing the reset button or electrically by applying a reset pulse to the reset coil. The pre-determined value is maintained when the counter is reset. The symbols of up counter and down counter is shown in **Figure 1.26(a) and Figure 1.26(b)**

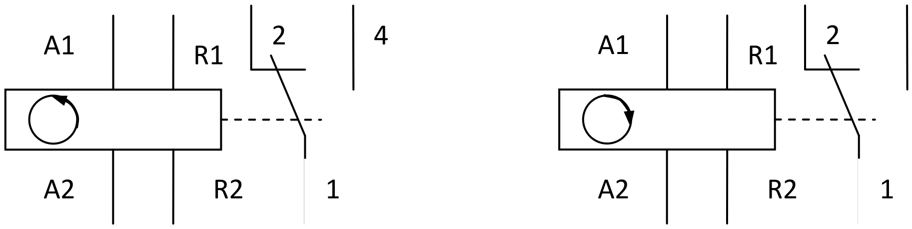


Figure 1.26: a) up counter b) down counter

1.3 Electro pneumatics circuits for single actuator

Control of single cylinders using electro pneumatics

Forward stroke: The circuit is closed when push button PB closes. A magnetic field is produced in the coil Y. The armature in the coil opens the passage for the compressed air. The compressed air flows from 1 to 2 of the 3/2 DCV to cylinder, which travels to the final forward position.

Return stroke: When the push button PB is released, the circuit is interrupted. The magnetic field at coil Y collapses, the 3/2 way valve switches back to its original position as shown in **Figure 1.27.** The compressed air in the cylinder then exhausts through port 3 of the DCV and the cylinder travel to the final rear position.

10.3.1 Direct Control of single acting cylinder (Figure 1.27)

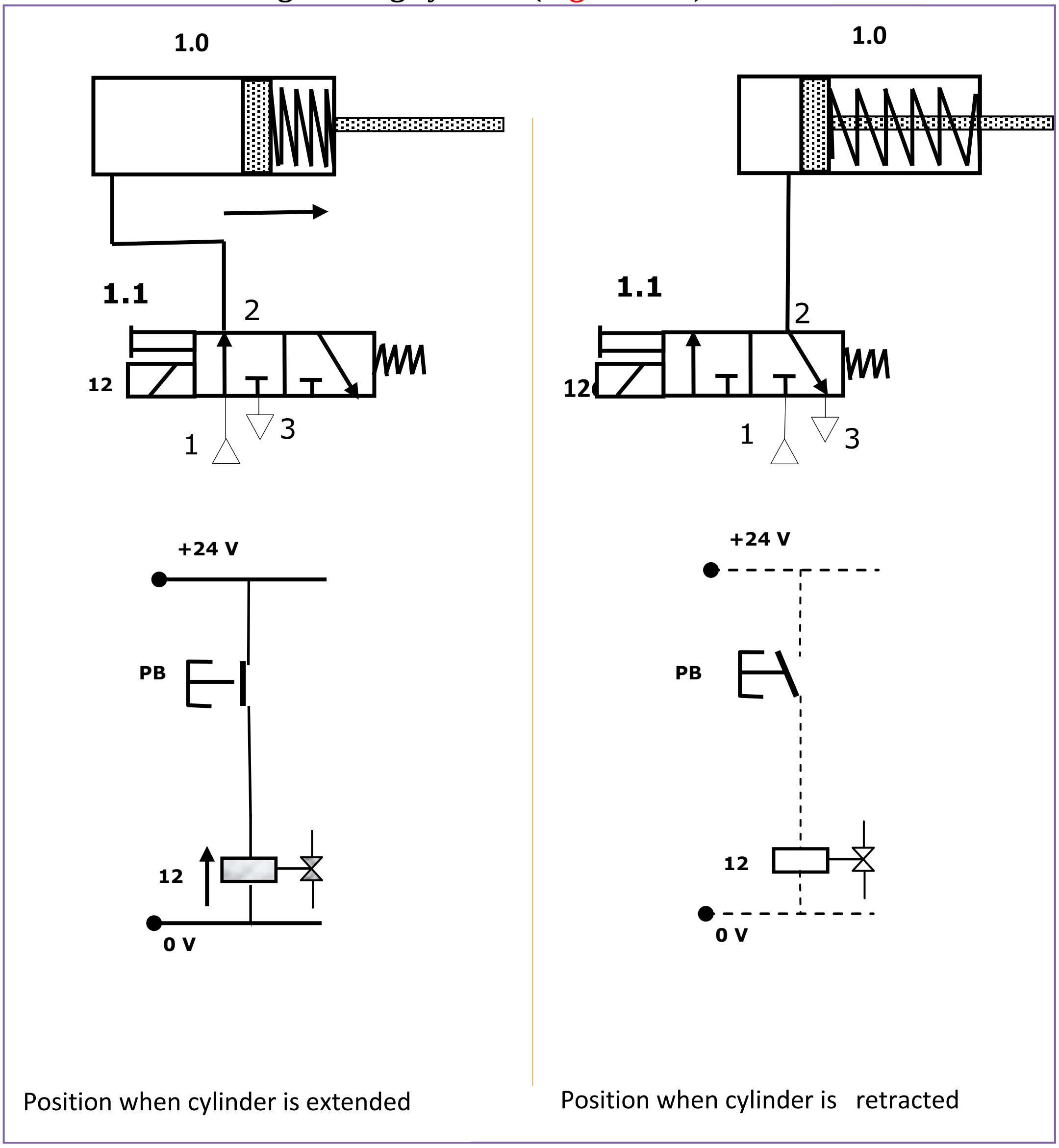


Figure 1.27: Direct control of single acting cylinder

1.3.2. Indirect Control of single acting cylinder (Figure 1.28)

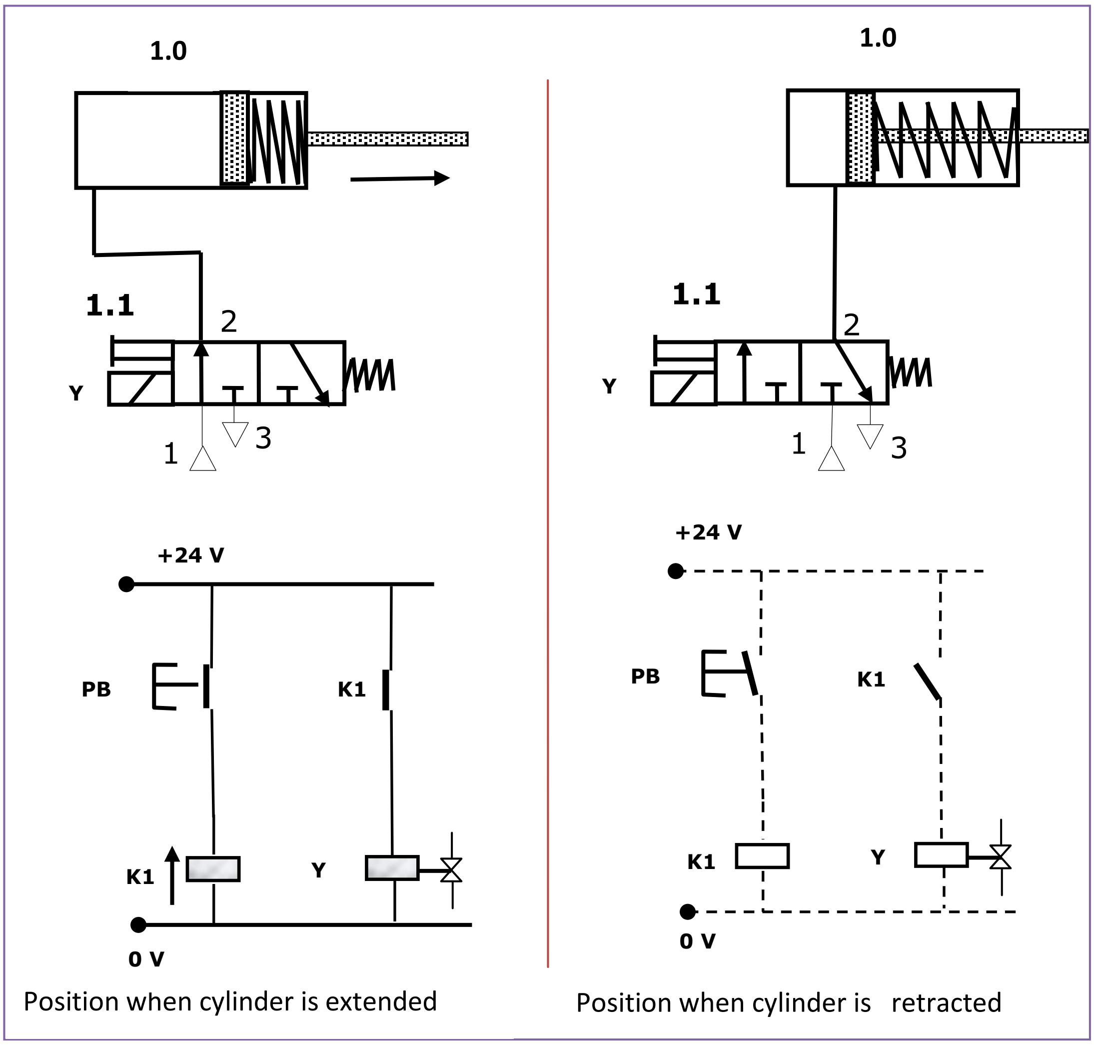


Figure 1.28: Indirect control of single acting cylinder

Forward stroke: The circuit is closed when push button PB closes. Closing of Push button PB energises a relay K1. The coil Y is energised via normally open contact K1 (indirect energising).

A magnetic field is produced in armature of the coil Y opens the passage for the compressed air. The compressed air flows from 1 to 2 of the 3/2 DCV to cylinder, which travels to the final forward position.

Return stroke: When the push button PB is released, the circuit is interrupted. Opening of Push button PB de-energises a relay K1. The magnetic field at coil Y is collapses due to the opening of contact K1 the 3/2 way valve switches back to its original position as shown in **Figure 1.28**. The compressed air in the cylinder then exhausts through port 3 of the DCV and the cylinder travel to the final rear position.

1.3.3 Direct Control of double acting cylinder (Figure 1.29)

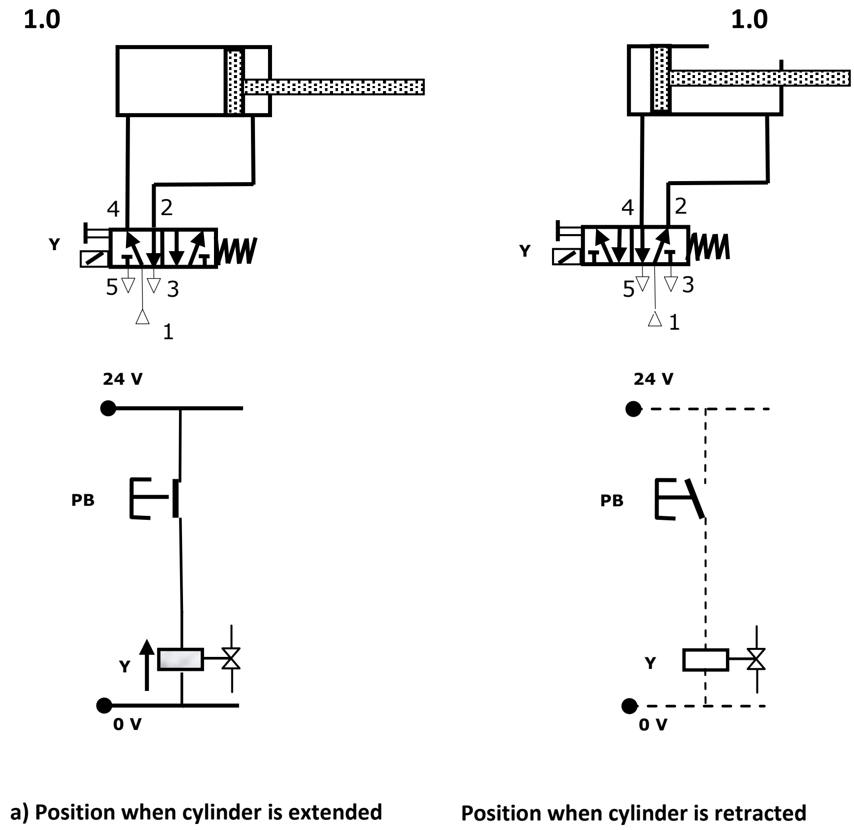


Figure 1.29: direct control of double acting cylinder

Forward stroke: The double acting cylinder is controlled by 5/2 way valve. When the pushbutton PB is pressed, coil Y is energised and the directional control valve is activated by compressed air via pilot control. The piston travels to the final forward position.

Return stroke: When the push button PB is released, the circuit is interrupted. The magnetic field at coil Y collapses, the return spring of 5/2 becomes active and the 5/2 way valve switches back to its original position as shown in **Figure 1.29**. The compressed air in the cylinder then exhausts through port 5 of the 5/2 DCV and the cylinder travel to the final rear position.

1.3.4 Indirect Control of double acting cylinder (using 5/2 way, single solenoid)

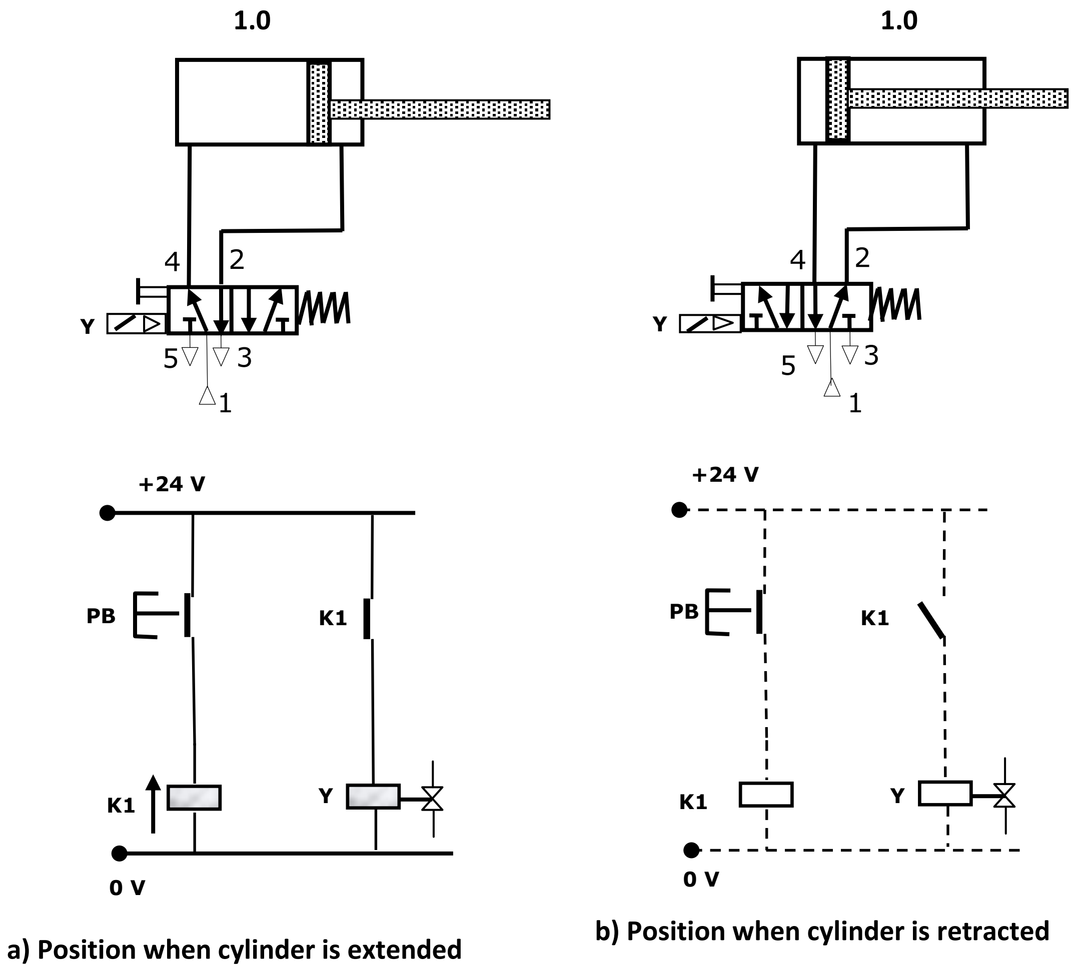
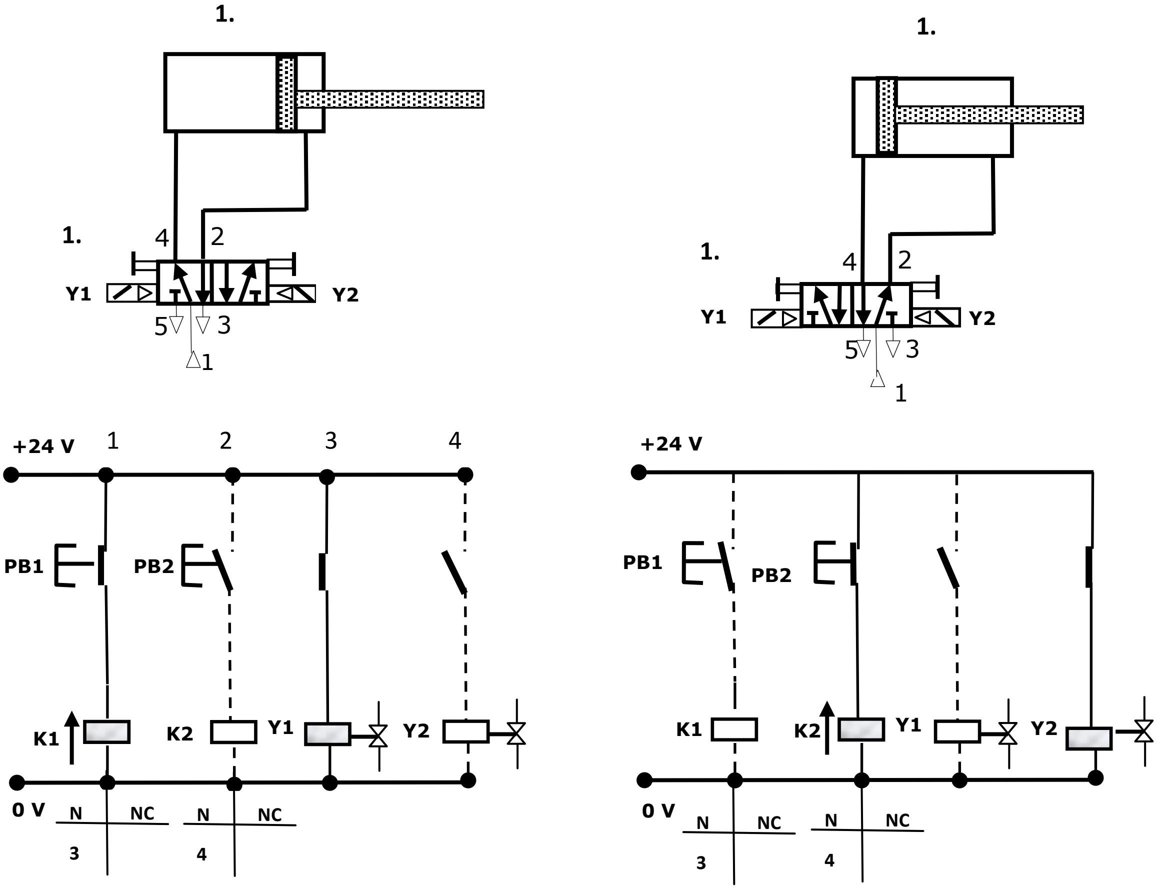


Figure 1.30: Indirect control of double acting cylinder

Forward stroke: The circuit is closed when push button PB closes. Closing of Push button PB energises a relay K1. The coil Y is energised via normally open contact K1 (indirect energising).
A magnetic field is produced in armature of the coil Y opens the passage for the compressed air through internal pilot. The compressed air flows from 1 to 4 of the 5/2 DCV to cylinder, which travels to the final forward position.

Return stroke: When the push button PB is released, the circuit is interrupted. Opening of Push button PB de-energises a relay K1. The magnetic field at coil Y is collapses due to the opening of contact K1 the 5/2 way valve switches back to its original position as shown in **Figure 1.30**. The compressed air in the cylinder then exhausts through port 5 of the DCV and the cylinder travel to the final rear position.

1.3.5 Indirect Control of double acting cylinder (using 5/2 way, double solenoid) (Figure 1.31)



a) Position when cylinder is extended

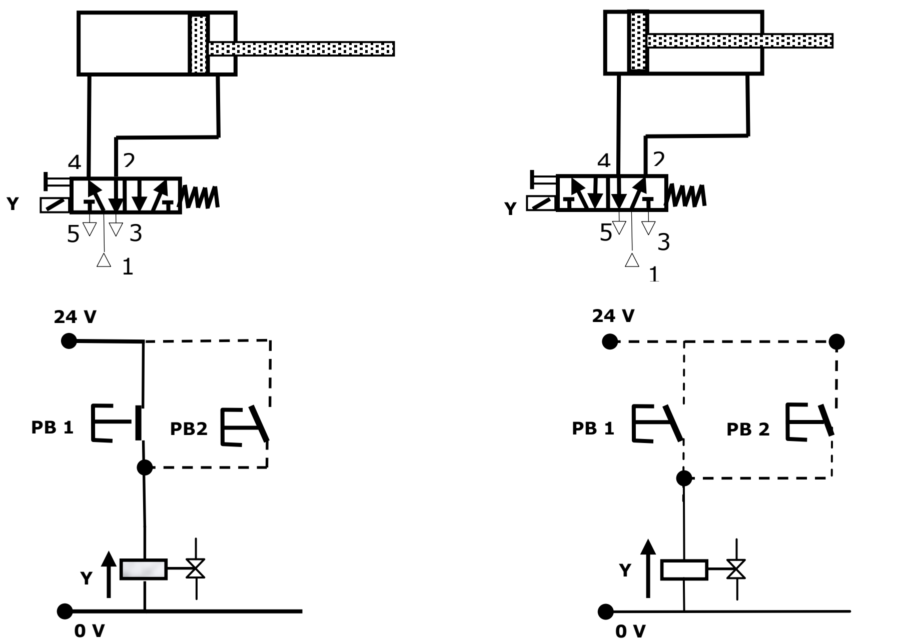
b) Position when cylinder is

Figure 1.31: Indirect control of double acting cylinder (using 5/2 way vavle)

Forward stroke: when push button PB1 is pressed, coil Y1 is energised and 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. The 5/2 directional control valve will remain in the last position because it is double solenoid valve and has no return spring.

Return stroke: When the push button PB1 is released and PB2 is pressed. Opening of Push button PB1 de-energises a relay K1. The magnetic field at coil Y1 is collapses due to the opening of contact K1. Closing of PB2 energises Y2 and the piston returns to its original position as a result of changeover of the 5/2 way valve. 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 Y2, there will be no reaction as there would be an opposing signal

1.3.6 Control of double acting cylinder OR logic (Parallel circuit) (Figure 1.32)



a) Cylinder is extended using PB1

b) Cylinder is retracted (both PB released)b)

Figure 1.32: OR logic

The piston of a double acting cylinder is to travel out when either one of two pushbutton switch is pressed. It is to return when both are released. When push button PB1 or PB2 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.

1.3.7 Control of double acting cylinder AND logic (Figure 1.33)

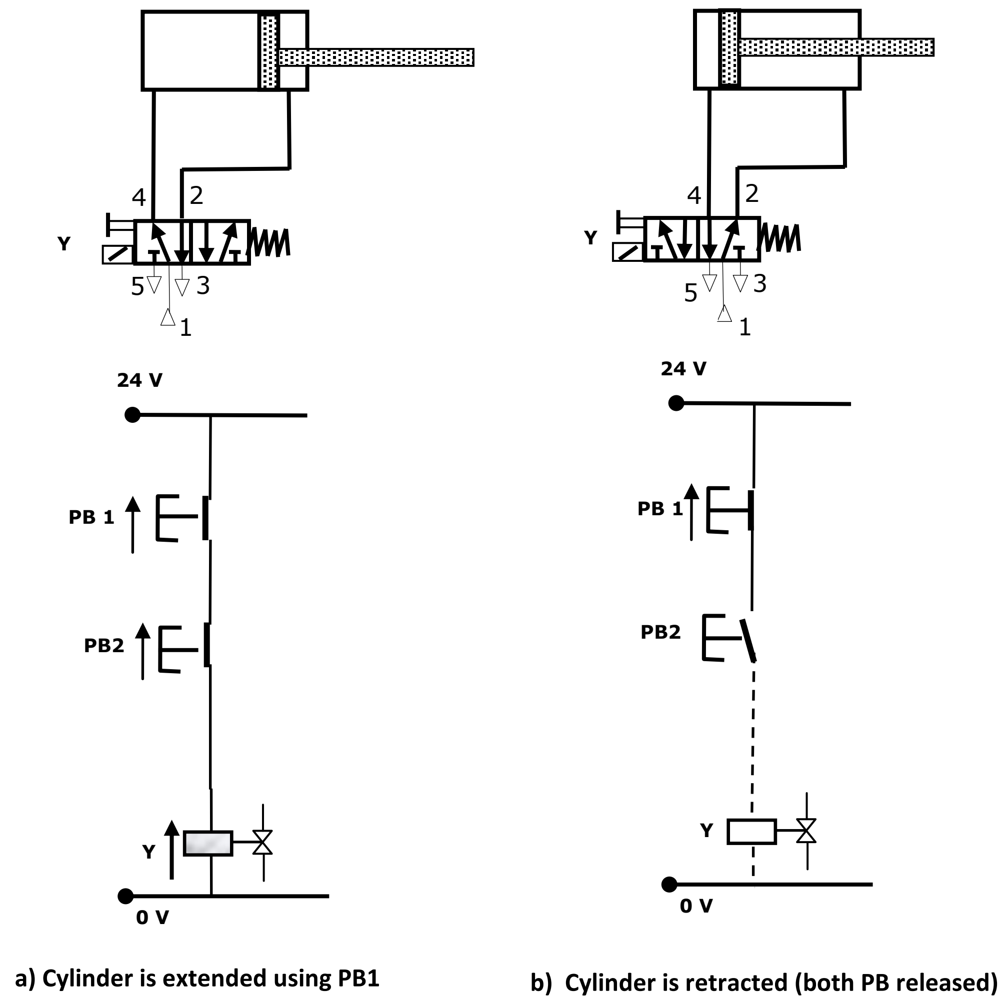


Figure 1.33: AND logic

1.3.8 Latching circuits

Double acting cylinder is to be controlled using 5/2 directional control valve , single solenoid, spring return. When push button PB1 is pressed, cylinder should extend and remains in that position when PB1 is released. The cylinder is to retract completely when PB2 is pressed. In addition, the cylinder is to remain in the retracted postion even when PB2 is released. Develop a Electro-pneumatic control circuit with an electrical latching with a) dominant off b) dominant On

Solution

In the following pneumatic circuit a double acting cylinder is controlled by 5/2 way valve.When Y1 is energised cylinder moves forward. When Y1 is deenergised cylinder retracts to its iniatil position.

We can construct the latching circui using the following electrical components

1. Use NO pustton button for ON or Start button control
2. Use NC push button for the OFF or stop control
3. Use a relay

Latching circuit can be dominatn ON or dominant Off. Dominnat position refer to stauts of relay coil (circuit) when both the start and stop signals are applied simultaneously

a) **Latching circuit with Dominant OFF**

When Start button (PB1) and Stop button (PB2) are pressed simultaneously, if the circuit goes to OFF position , then such a circuit is called Dominant OFF latching circuit. Refer to **Figure 1.34** ,

a) When we press START push button PB1 is pressed and released , following operations occurs:
   1. Relay coil K1 in branch 1 (vertical) is energised. All Contact K1 closes
   2. Notice that there is a NO contact of K1 in branch 2 , which is connected parallel to PB1. This NO contact of K1 latches the start push button. Therefore even if the PB1 is released, NO contact of K1 in branch 2 keeps coil K1 energised.
   3. There is another NO contact in branch 3, which is connected to Y1. When push button PB1 is pressed this also remain closed, as a result cylinder moves forward and remains there until stop button PB2 is pressed.
b) When we press STOP push button PB2 is pressed momentarily and released , following operations occurs:
   1. Relay coil K1 in branch 1 (vertical) is de-energised. All Contact K1 opens
   2. NO contact of K1 in branch 2 , which is connected parallel to PB1 is now open. This NO contact of K1 no more latches the start push button.

3. NO contact in branch 3 is also open now, which is denergises. As a resutl cylinder moves back to its home position and remains there until start button PB1 is pressed again.

When Start button (PB1) and Stop button (PB2) are pressed simultaneously, K1 contacts are open and the circuit goes to OFF position . That is why this circuit is called Dominant OFF latching circuit.

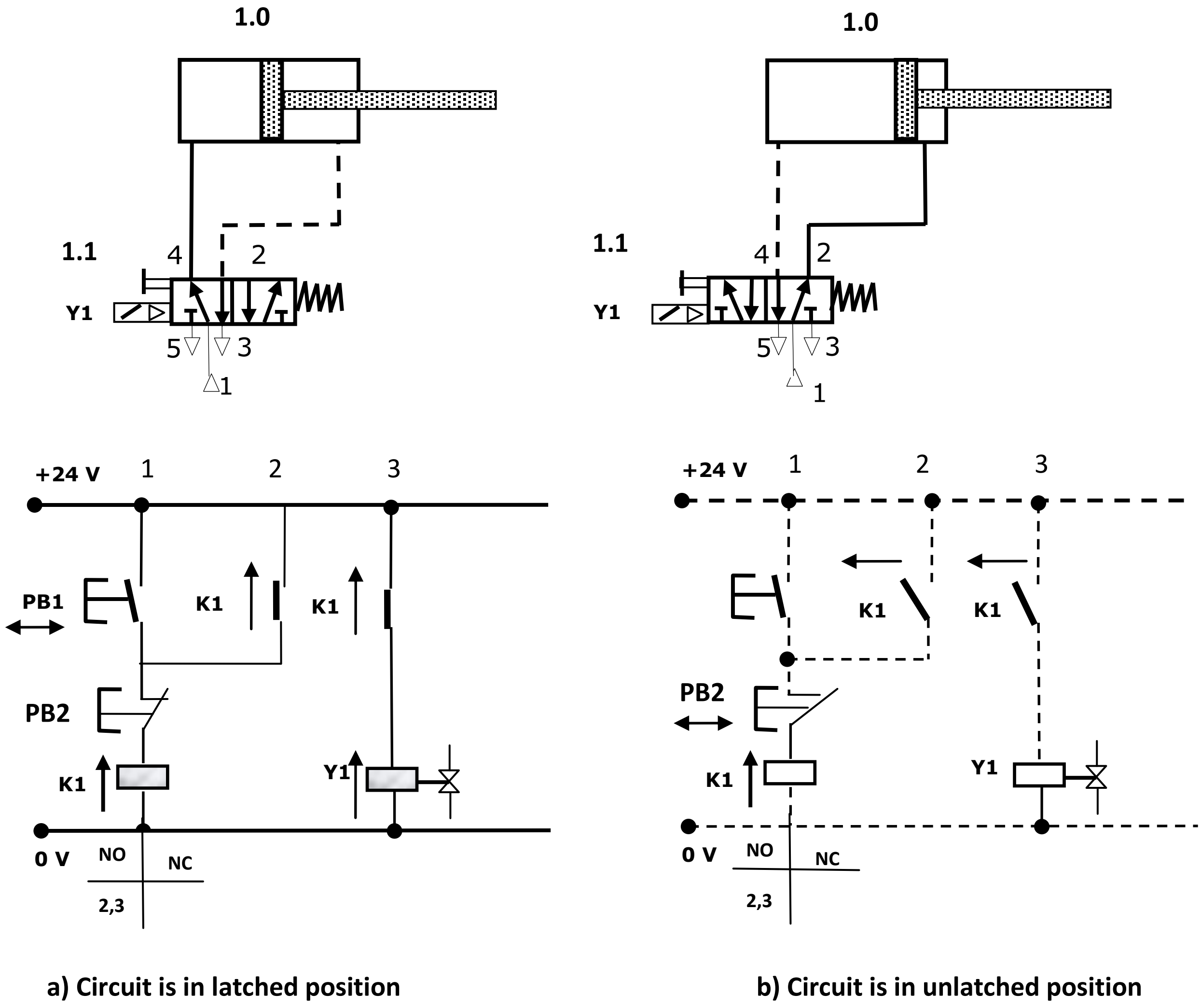


Figure 1.33: Dominant OFF ciricuit

b) Latching circuit with Dominant ON

When Start button (PB1) and Stop button (PB2) are pressed simultaneously, if the circuit goes to ON position , then such a circuit is called Dominant ON latching circuit. Refer to **Figure 1.34** ,

a) When we press START push button PB1 is pressed and released , following operations occurs:

4. Relay coil K1 in branch 1 (vertical) is energised. All Contact K1 closes
5. Notice that there is a NO contact of K1 in branch 2 , which is connected parallel to PB1 and in series with PB2. This NO contact of K1 latches the start push button. Therefore even if the PB1 is released, NO contact of K1 in branch 2 keeps coil K1 energised.
6. There is another NO contact in branch 3, which is connected to Y1. When push button PB1 is pressed this also remain closed, as a result cylinder moves forward and remains there until stop button PB2 is pressed.

b) When we press STOP push button PB2 is pressed momentarily and released , following operations occurs:

1. Relay coil K1 in branch 1 (vertical) is de-energised. All Contact K1 opens
2. NO contact of K1 in branch 2 , which is connected parallel to PB1 is now open. This NO contact of K1 no more latches the start push button.
3. NO contact in branch 3 is also open now, which is denergises. As a resutl cylinder moves back to its home position and remains in home position until start button PB1 is pressed again.

When Start button (PB1) and Stop button (PB2) are pressed simultaneously, K1 contacts are open and the circuit goes to OFF position . That is why this circuit is called Dominant OFF latching circuit.

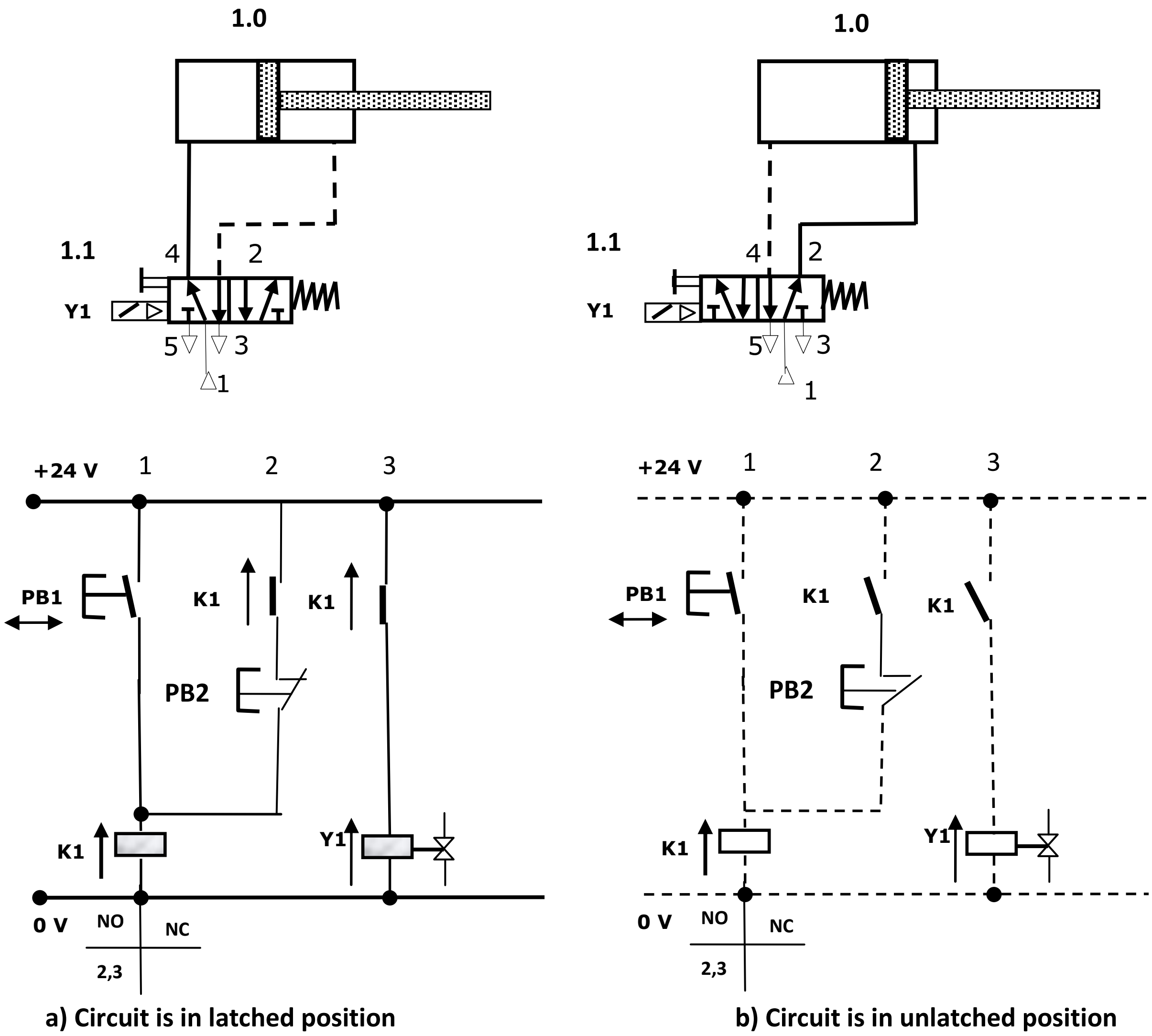
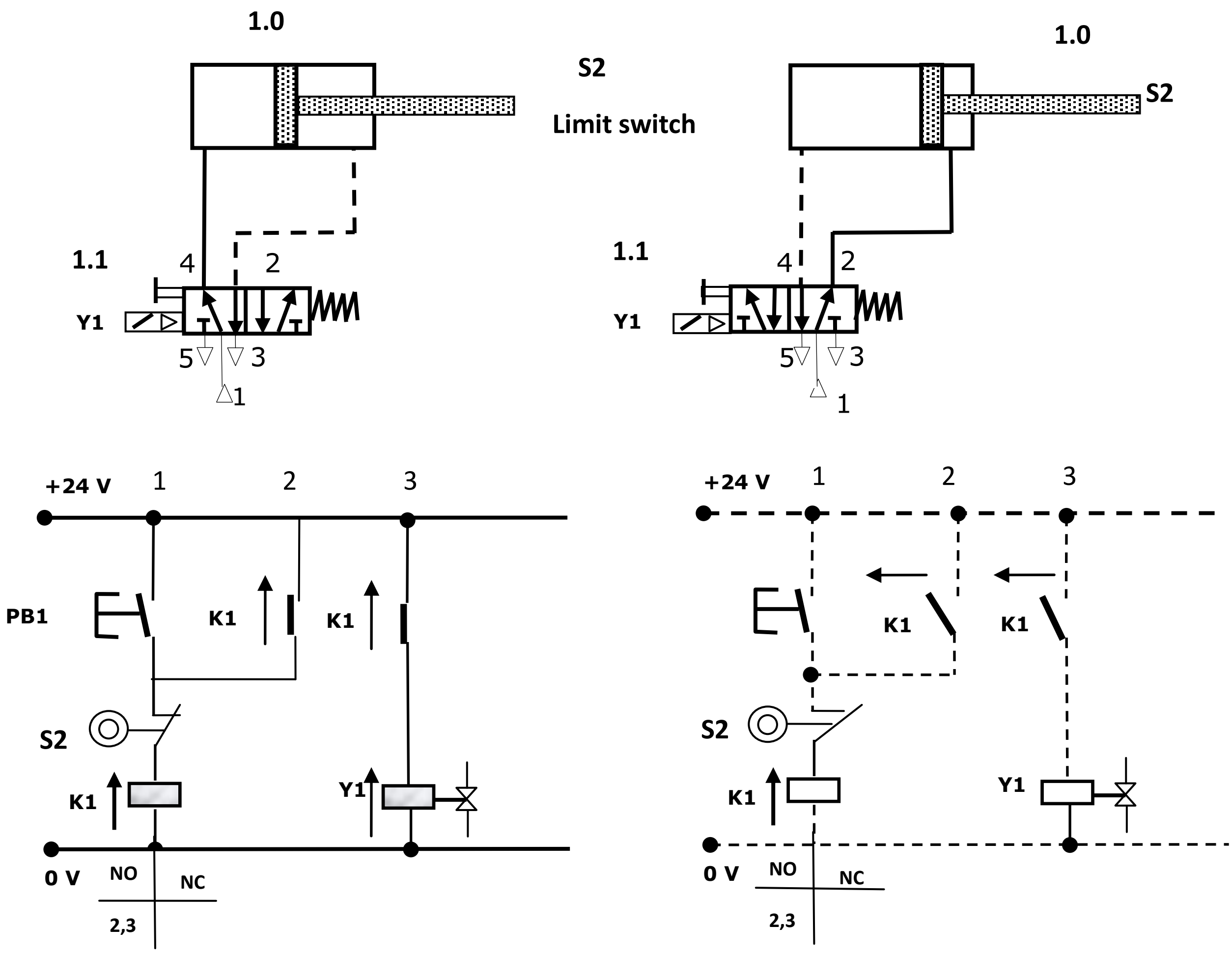


Figure 1.34: Dominant ON circuit

1.3.9 Automatic return of a double acting cylinder (spring return) (Figure 1.35)

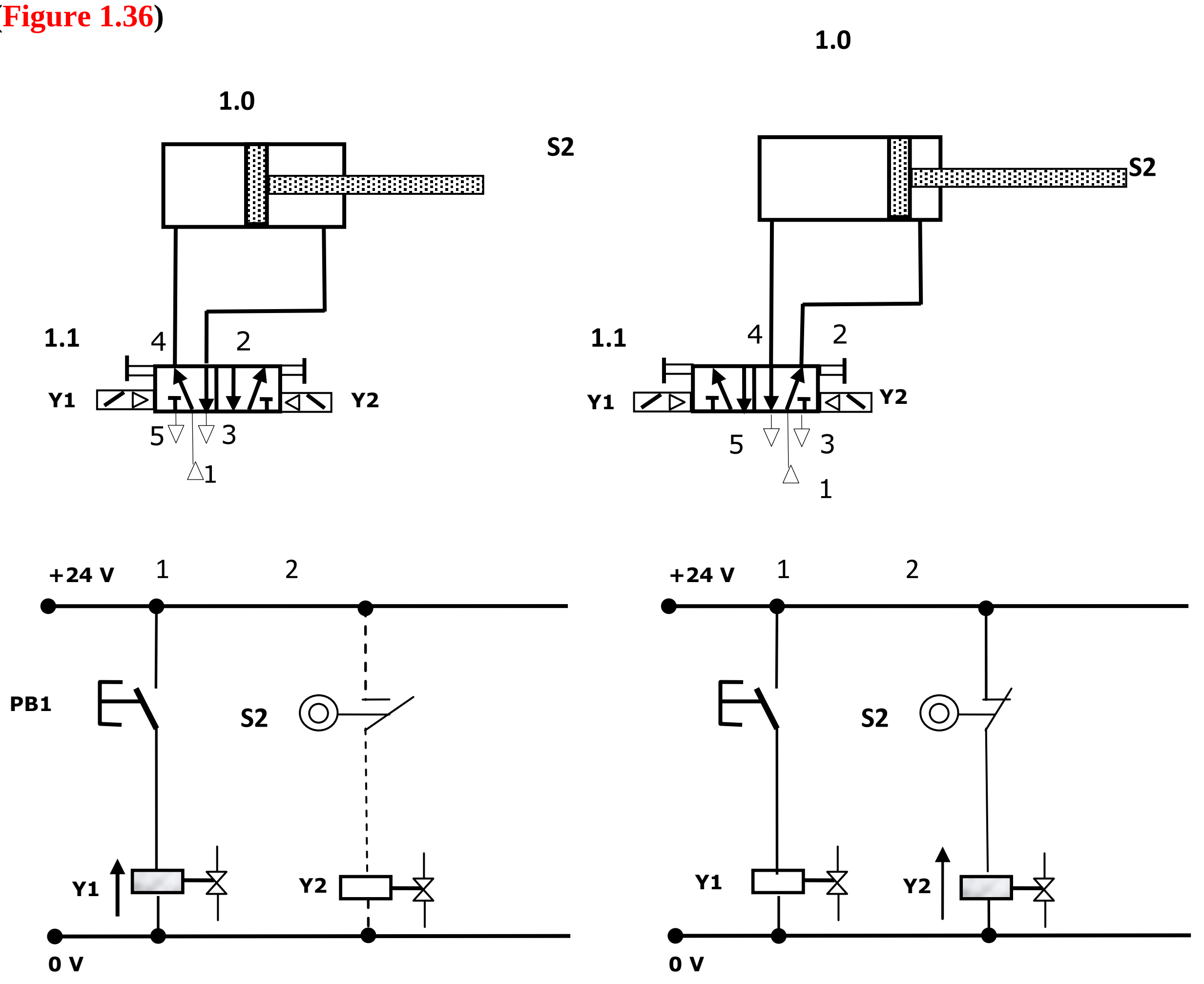


a) Cylinder while extending

b) Position when S2 just pressed

Figure 1.35: Automatic return of double acting cylinders using single solenoid

1.3.10 Direct control of automatic return of a double acting cylinder (double solenoid) (Figure 1.36)



a) Cylinder while extending

b) Position when S2 just pressed

Figure 1.36: Automatic return of double acting cylinder using double solenoid

1.3.11 Indirect control of automatic return of a double acting cylinder (double solenoid) (Figure 1.37)

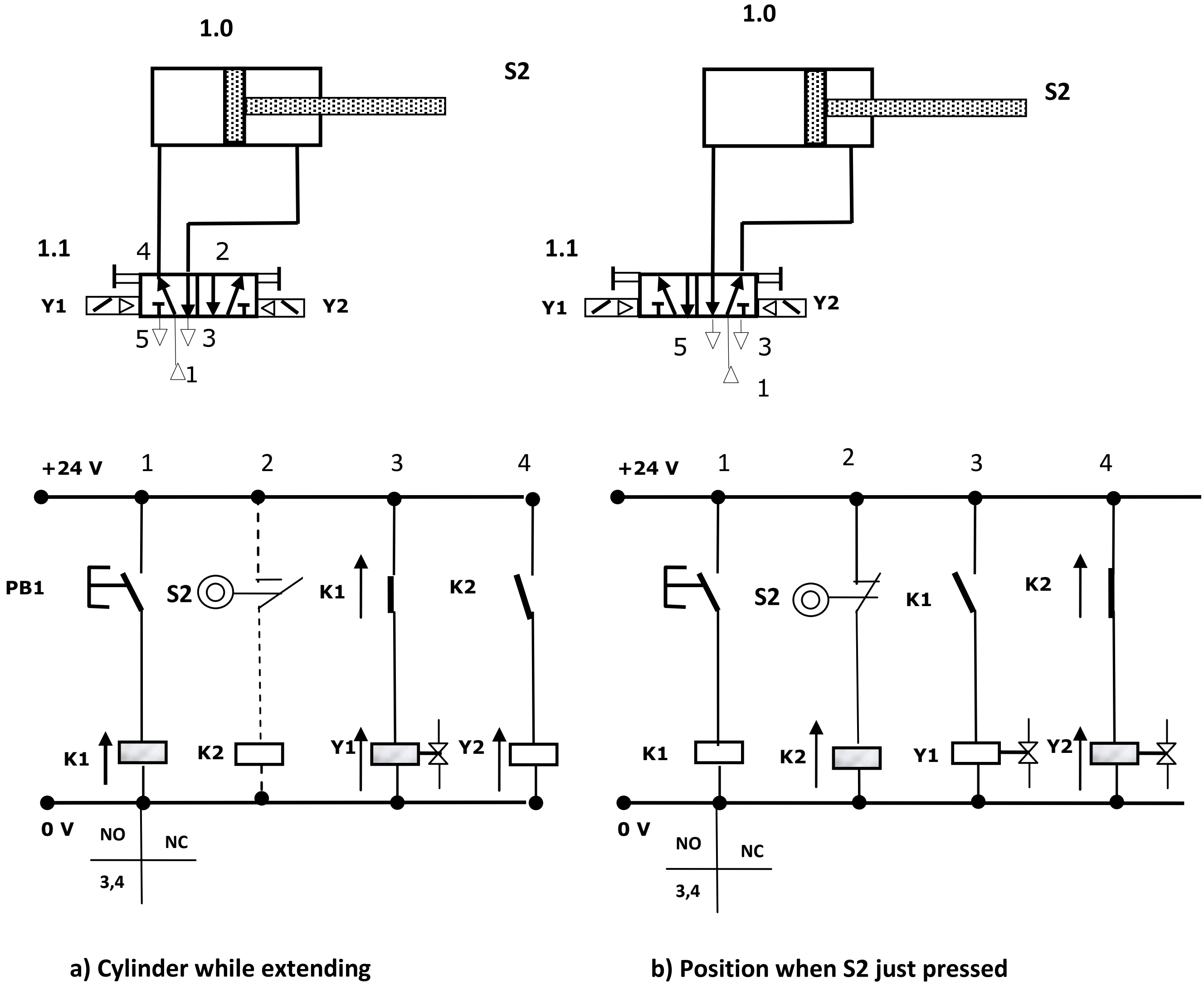


Figure 1.37: Indirect Automatic return of double acting cylinder using double solenoid

1.3.12 Automatic return of a double acting cylinder (using proximity switch) (Figure 1.38)

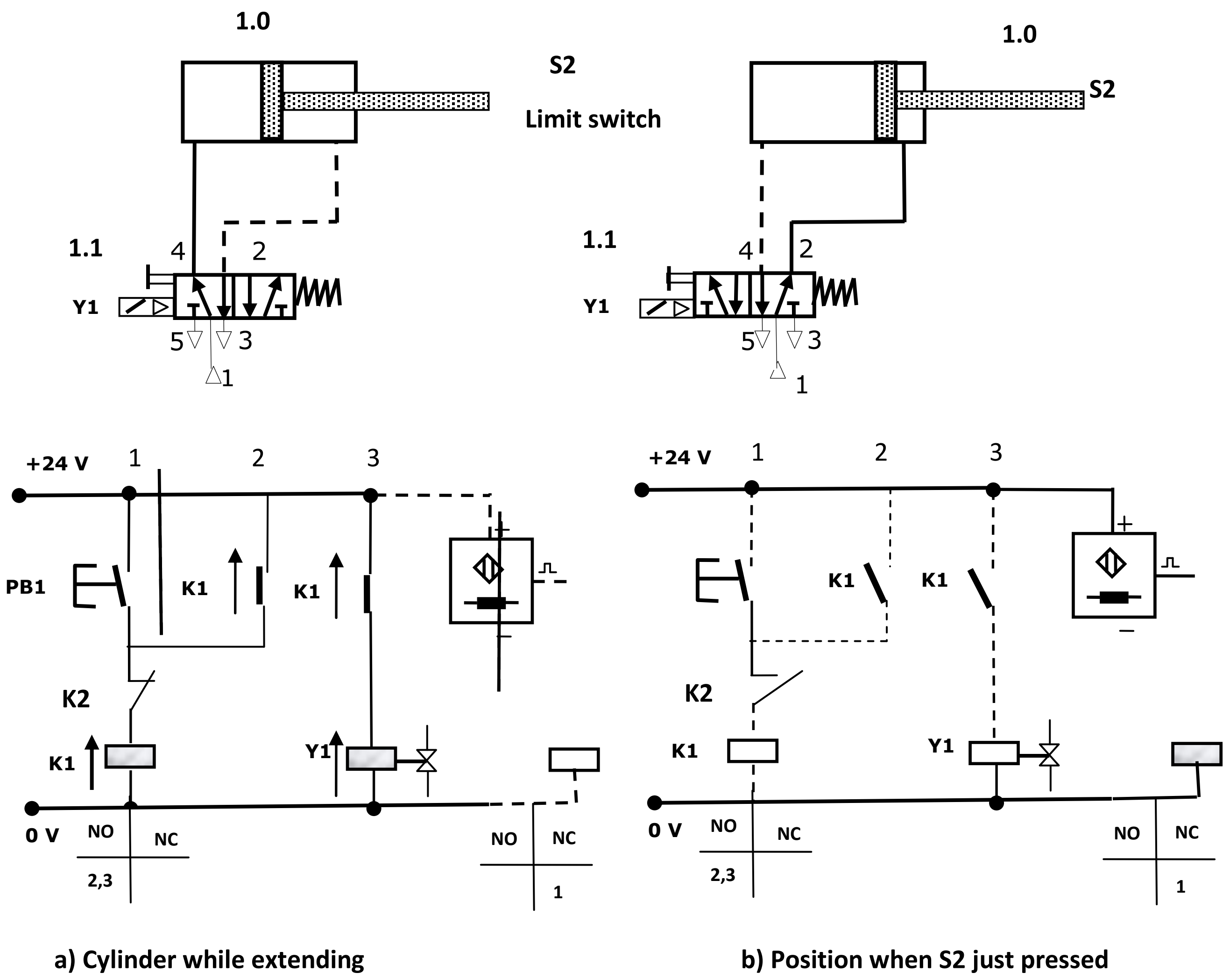
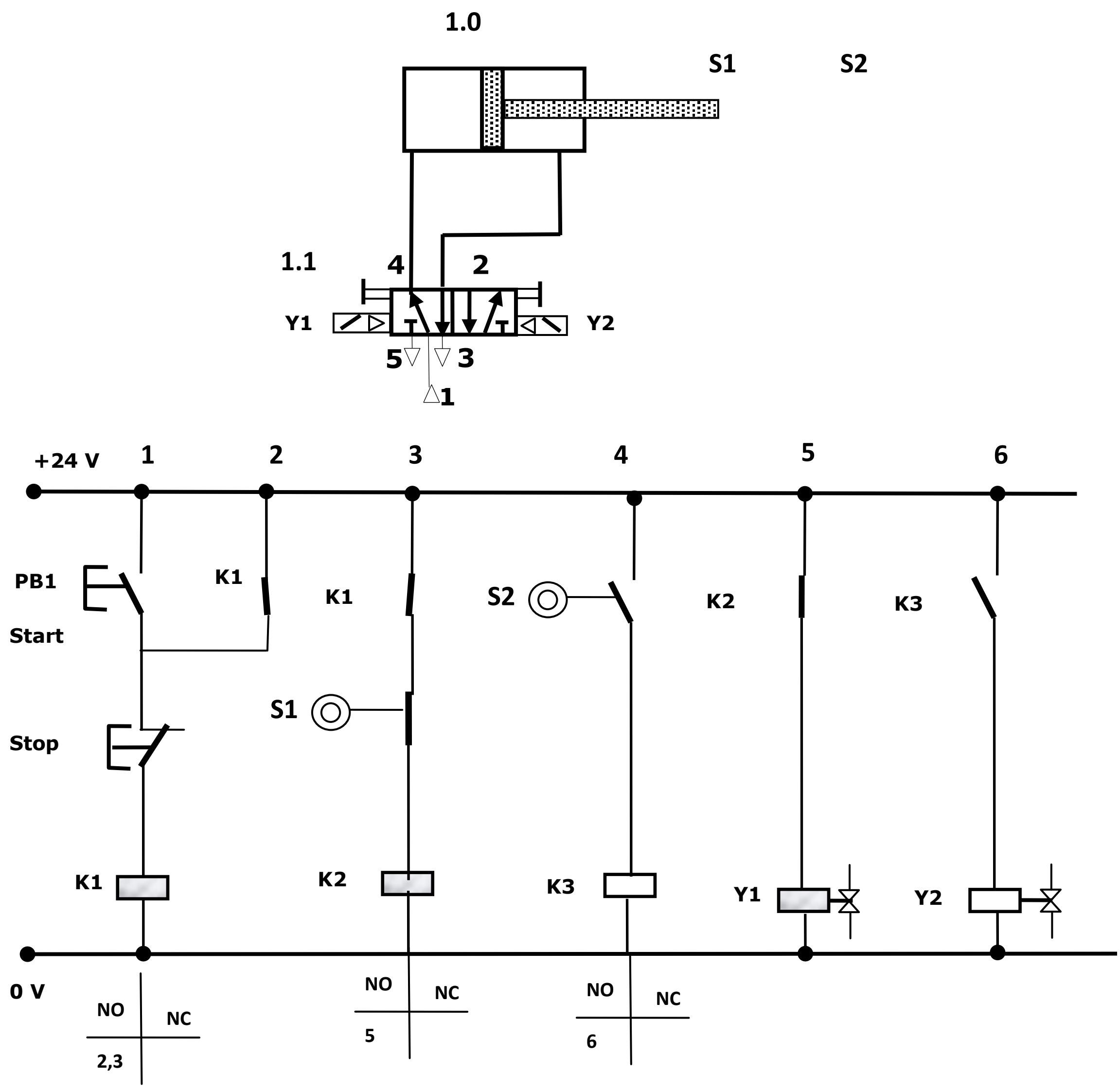


Figure 1.38: Automatic return of double acting cylinder using proximity switch

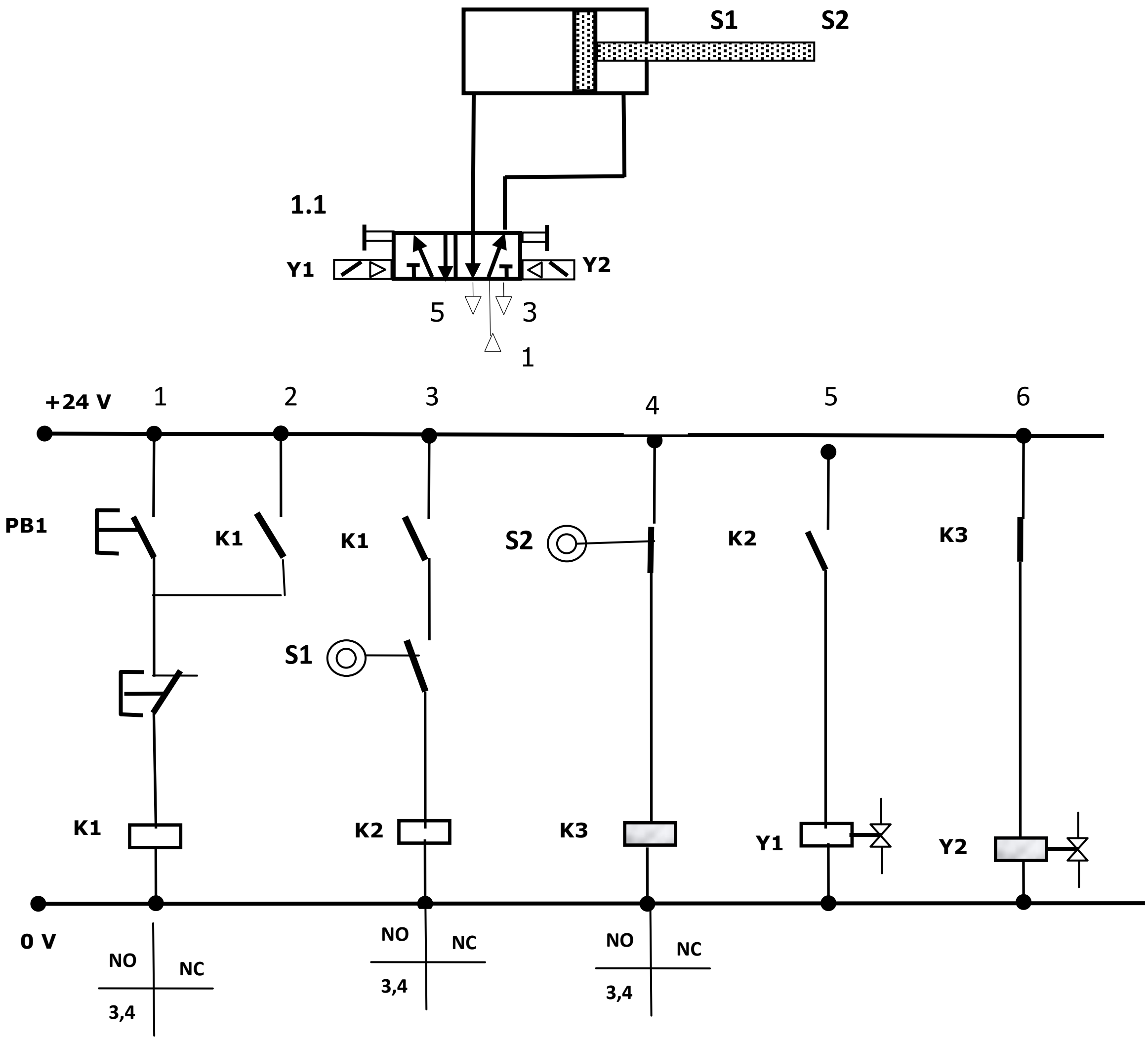
1.3.13 Oscillating motion of a double acting cylinder (Forward) (Figure 1.39)



a) Cylinder while extending

Figure 1.39: Oscillating motion of double acting cylinder (forward motion)

1.3.14 Oscillating motion of a double acting cylinder (Return) (Figure 1.40)



b) Position when S2 just pressed

Figure 1.40: Oscillating motion of double acting cylinder (return motion)

1.3.15 Control of system with timed response

Control systesm which are assinged a particular timing sequence must be equipped with electrical time lag relays. There are control systems which are purely affected by time or combination of path scanning and time.

These time-lag relays , which are usually electronic time lagg relays nowadays, have two basic types of timed response. They are referred to as time-lag relays with energising delay and de-energising dealy. Time lag-relay with energising delay and Time lag-relay with de-energising delays are shown in Figure 1.41 and 1.42.

a) **Time lag-relay with energsing delay**

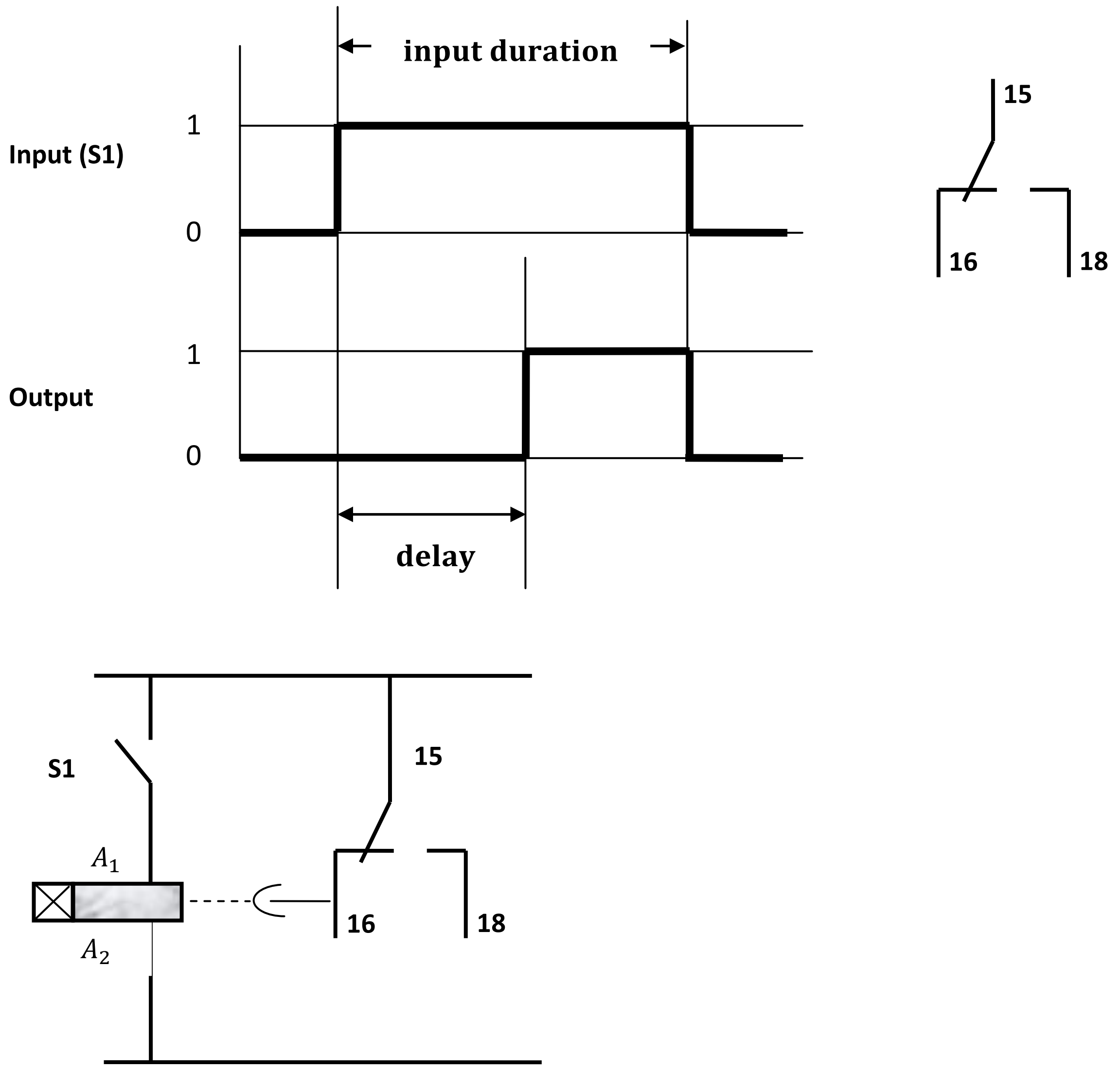


Figure 1.41:   **Time lag-relay with energsing delay**

b) Time lag relay with de-energixing delay

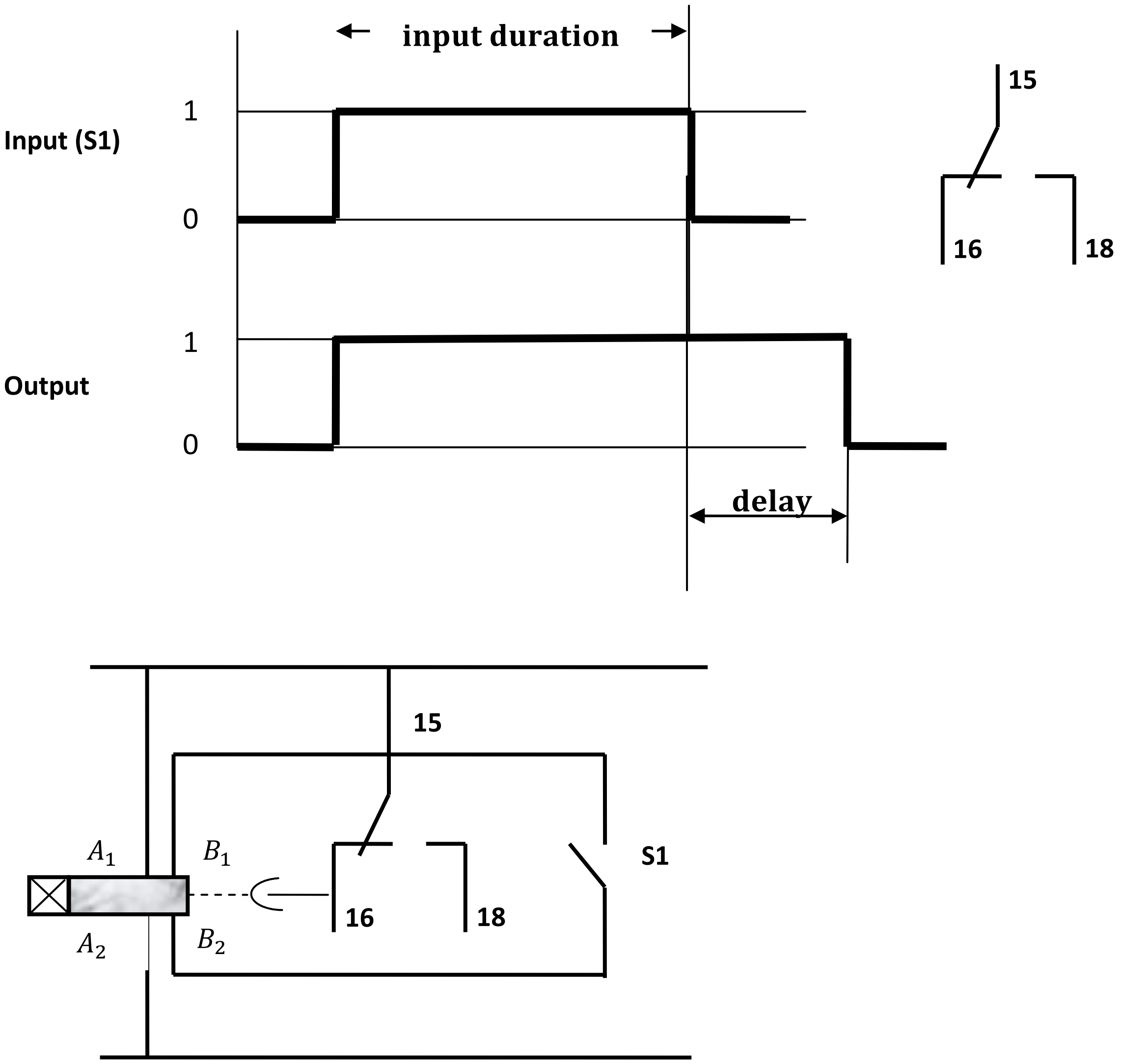


Figure 1.42: Time lag relay with de-energixing delay

c) Control of double acting cylinder with time delay (Double solenoid) (Figure 1.43)

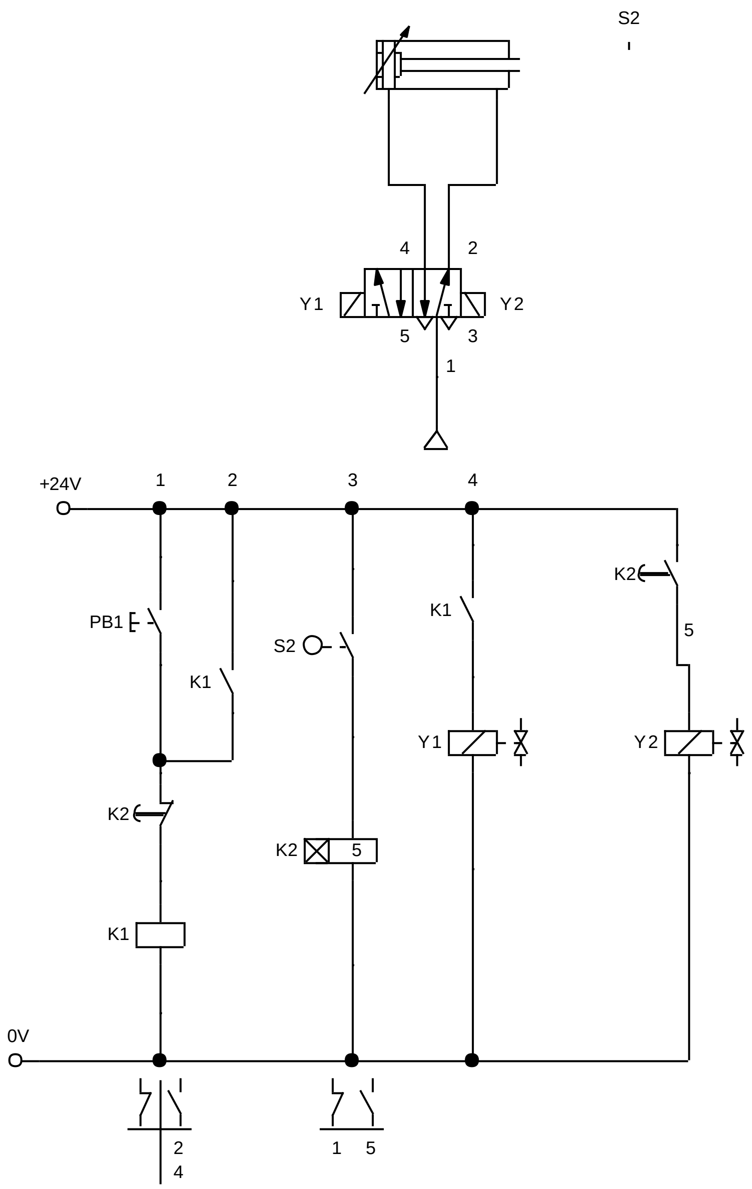


Figure 1.43 Control of double acting cylinder with time delay

When manual pushbutton PB1 is pressed, relay K1 changes state and the normally open contact k1 of relay is connected to solenoid coil Y1. When the normally open contact closes , the solenoid valve changes state,

The cylinder travels to its final forward position where it actuates limit switch S2. This limit switch stats the time lag relay K2 (with energising delay)

After 5 seconds the normally open contact of time lag relay energises the solenoid coil Y2 of the directional control valve. The vavle changes over and causes the piston to travel to its final rear position.

d) Control of double acting cylinder using timer(single solenoid) (Figure 1.44)

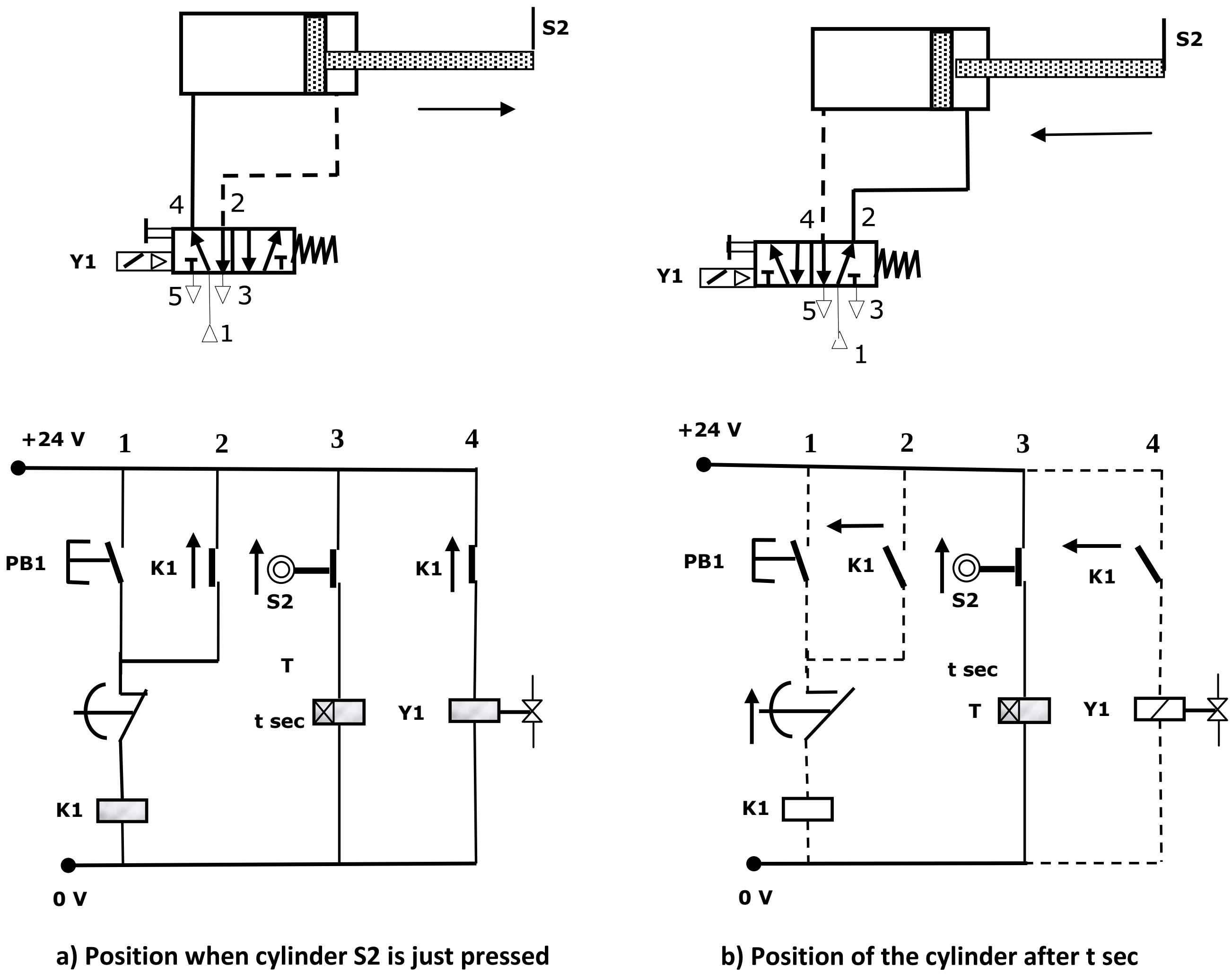


Figure 1.44 Control of double acting cylinder with time delay

A latching circuit is used to obtain the necessary memory function. The position of the circuit when push button PB1 is pressed and then released is given in Figure xx. The cylinder extends to its forward-end position and actuates limit switch S2 automatically. As the return motion is to be delayed, on –delay timer is used to obtain the necessary time delay. The required time delay should be set on the timer. Limit switch S2 controls the timer coil T. After the set delay, the timer contact interrupts the latching circuit, thus causing the return motion of the cylinder as shown in Figure…

1.3.17 Control of double acting cylinder using electric counter with two end sensors (Figure 1.45)

Design a electro pneumatic circuit for a double acting cylinder to perform a continuous to and fro motion. The cylinder has to stop automatically after performing 50 cycles operations

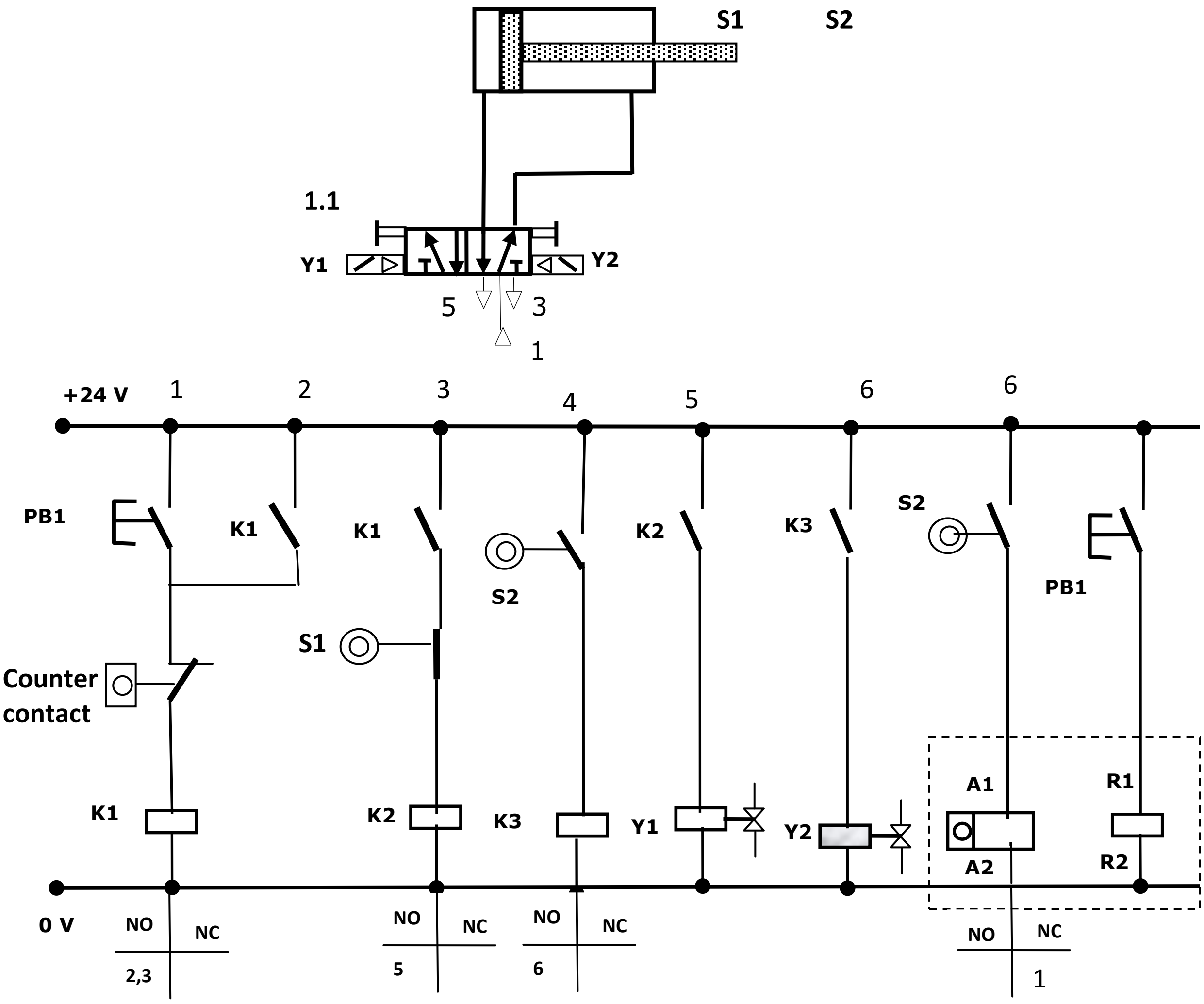


Figure 1.45 Control circuit using timer

When push button PB1 is pressed, it energises the coil K1 in branch 1. K1 in branch 2 is latched with PB1. Contact K1 in branch 3 energises the coil K2 in branch 3, which in turn closes contact K2 in branch 5 causing solenoid coil Y1 in branch 5 to energise and move the direction control valve. Cylinder moves forward.

When cylinder touches the limit switch S2 in branch 7, it sends a signal pulse to counter coil (A1 andA2) in branch 7. After a desired number of cycles is reached (50 cycles), then counter contact C in branch 1 opens and de-energises the K1 and cylinder stops.

1.3.18 Oscillation of double acting cylinder using end positioning with proximity switches

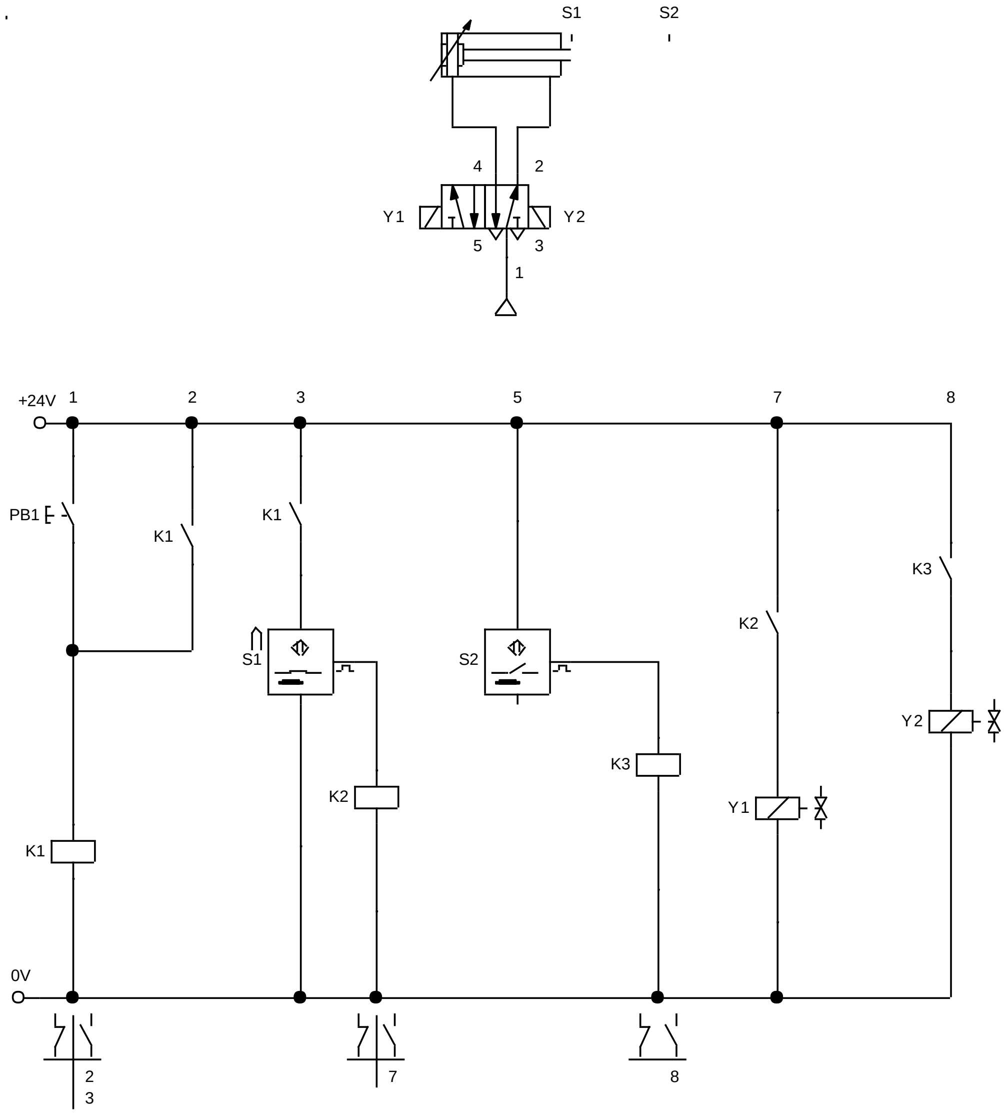


Figure 1.46 Oscillation of double acting using proximity switches

1.3.19 Control of double acting cylinder using pressure switch

Components are to be stamped using stamping machine. A double acting cylinder is used to push the die attached down to a fixture when two push buttons are pressed simultaneously. The die is to return to the initial position upon reaching sufficient stamping pressure as sensed by a pressure switch and one second delay. Develop an electro pneumatic control circuit to implement the control task for the stamping operation.

Solution is shown in the **Figure 1.47**, which is self explanatory

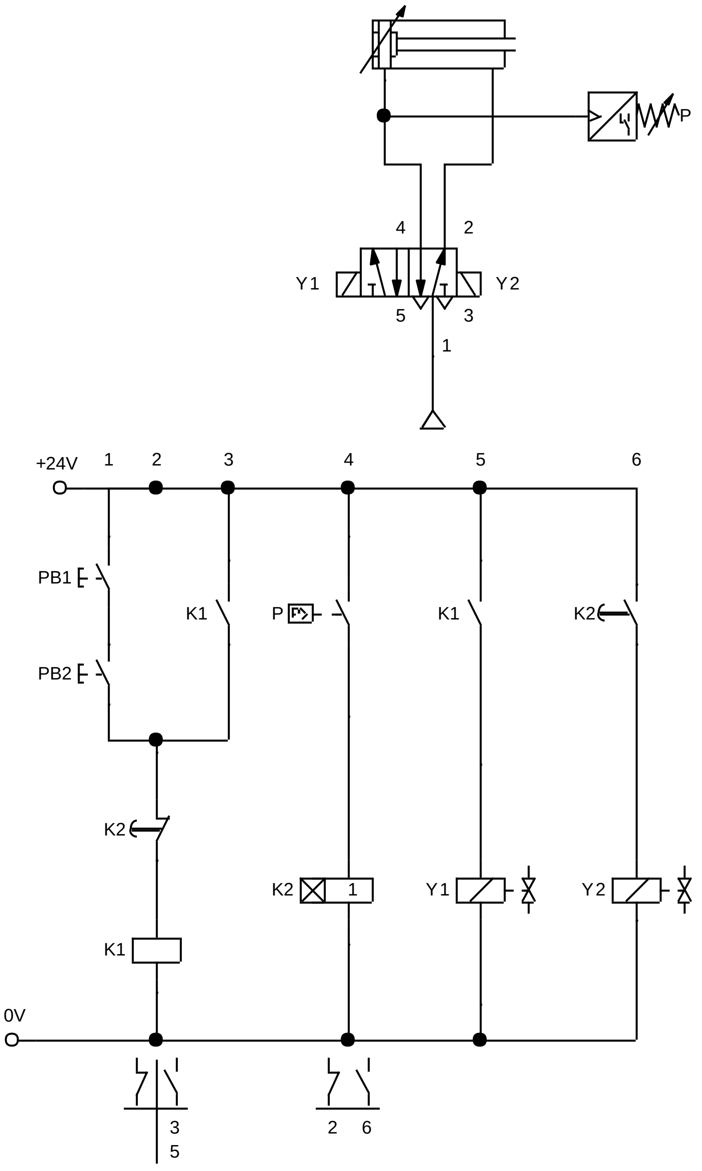


Figure 1.47 Control of double acting cylinder using pressure switch

1.3.20 Control of double acting cylinder using delay on and off timer and counter

Components are to be stamped using stamping machine. A double acting cylinder is used to push the die attached down to a fixture one second after push button is pressed. The die is to return to the initial position upon reaching sufficient stamping time of two seconds is reached. This automatic cycle should stop after 5 cycles. Start button should reset the counter. Develop an electro pneumatic control circuit to implement the control task for the stamping operation.

Solution is shown in the **Figure 1.48**, which is self explanatory

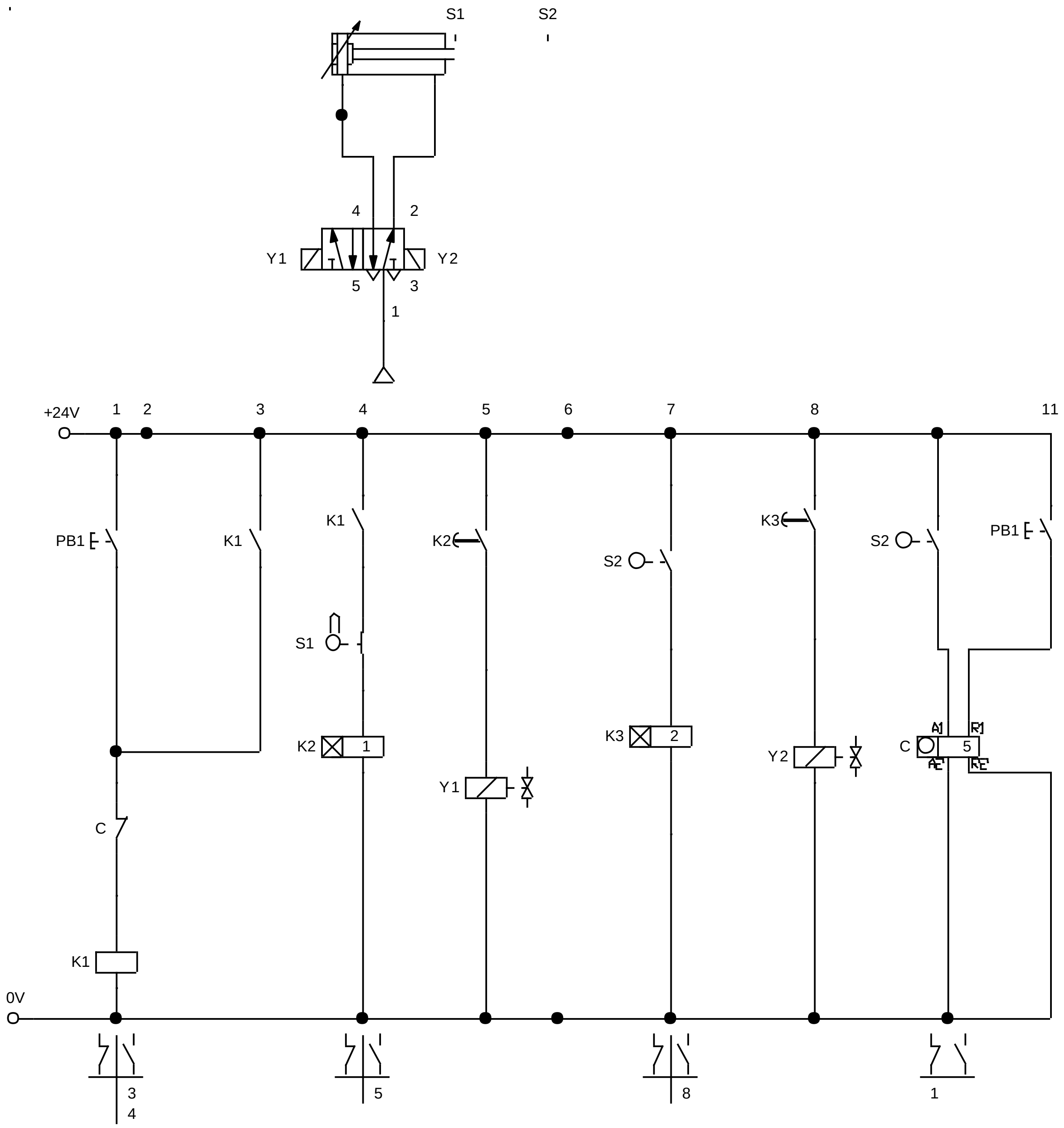


Figure 1.48 Control of double acting cylinder using counter and delay

1.3.21 Control of double acting cylinder using delay on and off timer and counter

Components are to be stamped using stamping machine. A double acting cylinder is used to push the die attached down to a fixture one second after push button is pressed. The die is to return to the initial position upon reaching sufficient stamping time of two seconds is reached. This automatic cycle should stop after 5 cycles. Start button should reset the counter. Initial position sensing is through magnetic reed switch. Develop an electro pneumatic control circuit to implement the control task for the stamping operation.

Solution is shown in the **Figure 1.49**, which is self explanatory

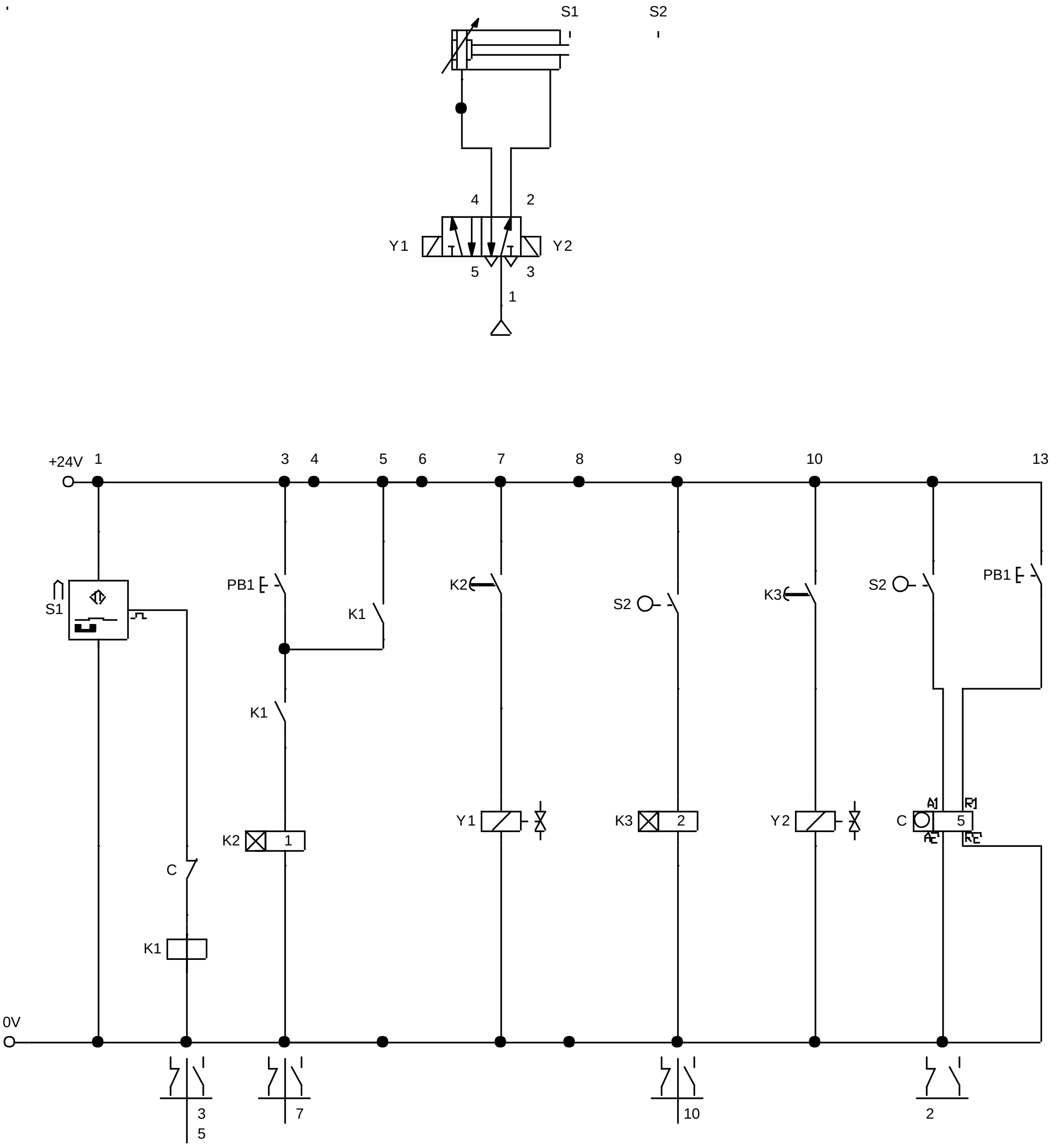


Figure 1.49 Control of double acting cylinder using reed switch for initial sensing

Objective Type Questions

1. A relay is considered as an electro -------------- actuated switch
2. When both start and stop buttons are pressed simultaneously, circuits goes to OFF condition in Dominant ------ circuit.
3. Inductive sensors cannot be used to detect ………………….. materials.
4. Push buttons are operated manually, where as limit switches are operated ----------------------
5. --------------- switches are magnetically actuated proximity switch

State True or False

1. Electro pneumatic circuits are less reliable than pure pneumatic circuits.

2. A pressure switch is electric – pneumatic signal convertor

3 A relay is electro pneumatically operated switch that operates under the control of additional electrical circuits.

4. An electrical latching relay circuit is an example of memory function

5. Limit switches are usually operated manually.

Review Questions

1. Explain briefly the working principle of an electro magnetic relay

2. Draw the symbol for an electromagnetic relay with 2 NO and 1 NC

3. What are the different ways to implement memory function in electro pneumatic circuits?

4. Explain the step displacement diagram for A+B+B-A- sequence.

5. List few disadvantages of using electro pneumatic circuits.

6. Explain the principle of cascade method using electro pneumatics with a suitable sequence example

7. What are the functions of sensors

8. Explain the working principle of a limit switch

9. Explain the working principle of a reed switch

10. Draw the symbols for the following

a) limit switch b) Inductive type proximity switch c) capacitive type proximity switch d) optically operated sensor

11. Differentiate between through beam sensors and diffuse sensors

12. Compare inductive , capacitive and optical types of sensors

13. Explain the functions of on delay timers with suitable circuit.

14. Explain the functions of an off delay timers with suitable circuit.

15. Differentiate between the behaviours of on timer delay and off timer delay with the help of a timing diagram.

16. Explain the function of a pressure switch

17. Explain the function of up counter and down counter.

18. Draw a group changing cascade circuit for two groups, three groups, and four groups

19. Explain with the help of neat sketch the construction and working of pressure sequence valve

20. What are the different ways to sense the end position and movement of cylinders

Answers

Fill in the Blanks

1. magnetic
2. off
3. non-metallic
4. automatically
5. reed

State True or False

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