

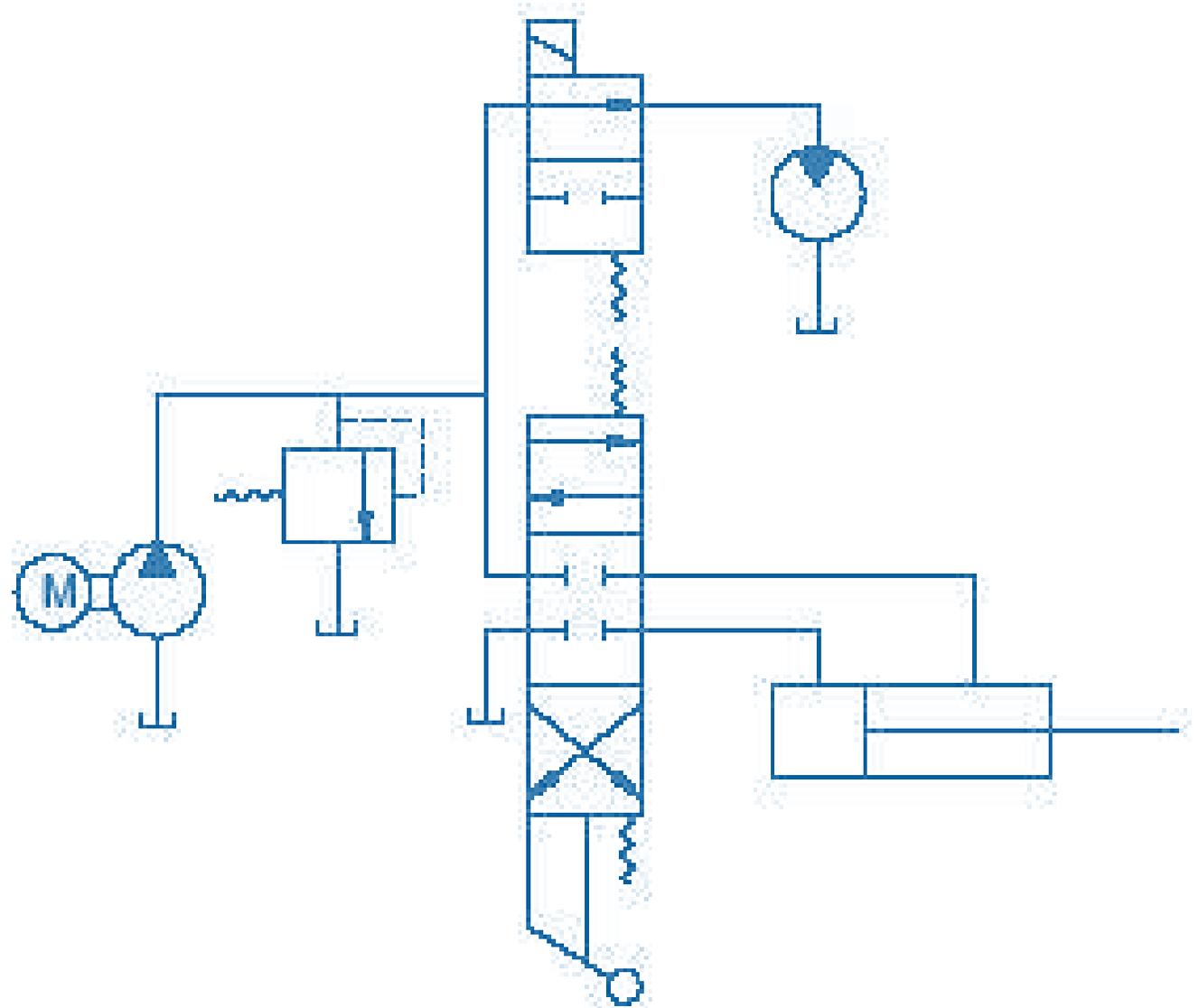
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FLUID POWER CONTROL SYSTEMS

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QUIZ

Name the components and explain the working of the circuit.



UNIT 5 PNEUMATIC SYSTEMS AND COMPONENTS

Pneumatic Components: Properties of air - Compressors - Filter, Regulator, Lubricator Unit - Pneumatic system, pneumatic components - pressure - flow - direction controls valves, Air control valves, Quick exhaust valves, pneumatic actuators. (3)

PNEUMATIC SYSTEMS

- Pneumatics is the use of gas or pressurized air in mechanical systems.
- Pneumatic systems used in industry are commonly powered by compressed air or compressed inert gases.
- A centrally located and electrically-powered compressor powers cylinders, air motors, pneumatic actuators, and other pneumatic devices.
- A pneumatic system is selected when it provides a lower-cost, more flexible, or safer alternative to electric motors, and hydraulic actuators.
- Pneumatics also has applications in dentistry, construction, mining, and other areas

PNEUMATIC SYSTEMS

Common Pneumatic Fluids:

1. Compressed Air:

1. Most widely used fluid.
2. Readily available, non-toxic, non-flammable, and economical.

2. Inert Gases (Nitrogen, CO₂):

1. Used when air is not suitable (e.g., in clean rooms or hazardous environments).
2. Reduces the risk of combustion or contamination.

PNEUMATIC SYSTEMS

Desirable Properties of Pneumatic Fluids

- 1. Cleanliness:** The fluid (usually air) should be free from dust, dirt, and solid particles to avoid wear and blockage in components.
- 2. Dryness:** Moisture should be removed to prevent corrosion, freezing, and malfunction of valves and actuators.
- 3. Non-Corrosive:** The fluid must not react chemically with system components or seals.
- 4. Non-Toxic & Safe:** The fluid should be safe for operators and the environment.
- 5. Stable at Operating Conditions:** Should maintain its properties under varying temperatures and pressures.

PNEUMATIC SYSTEMS

Main Components:

- **Compressor:** Generates compressed air.
- **Air Receiver (Tank):** Stores compressed air.
- **FRL Unit:** Filters, regulates, and lubricates the air supply.
- **Valves:** Control the direction, pressure, and flow of compressed air.
- **Actuators:** Pneumatic cylinders or motors convert air pressure into mechanical motion.

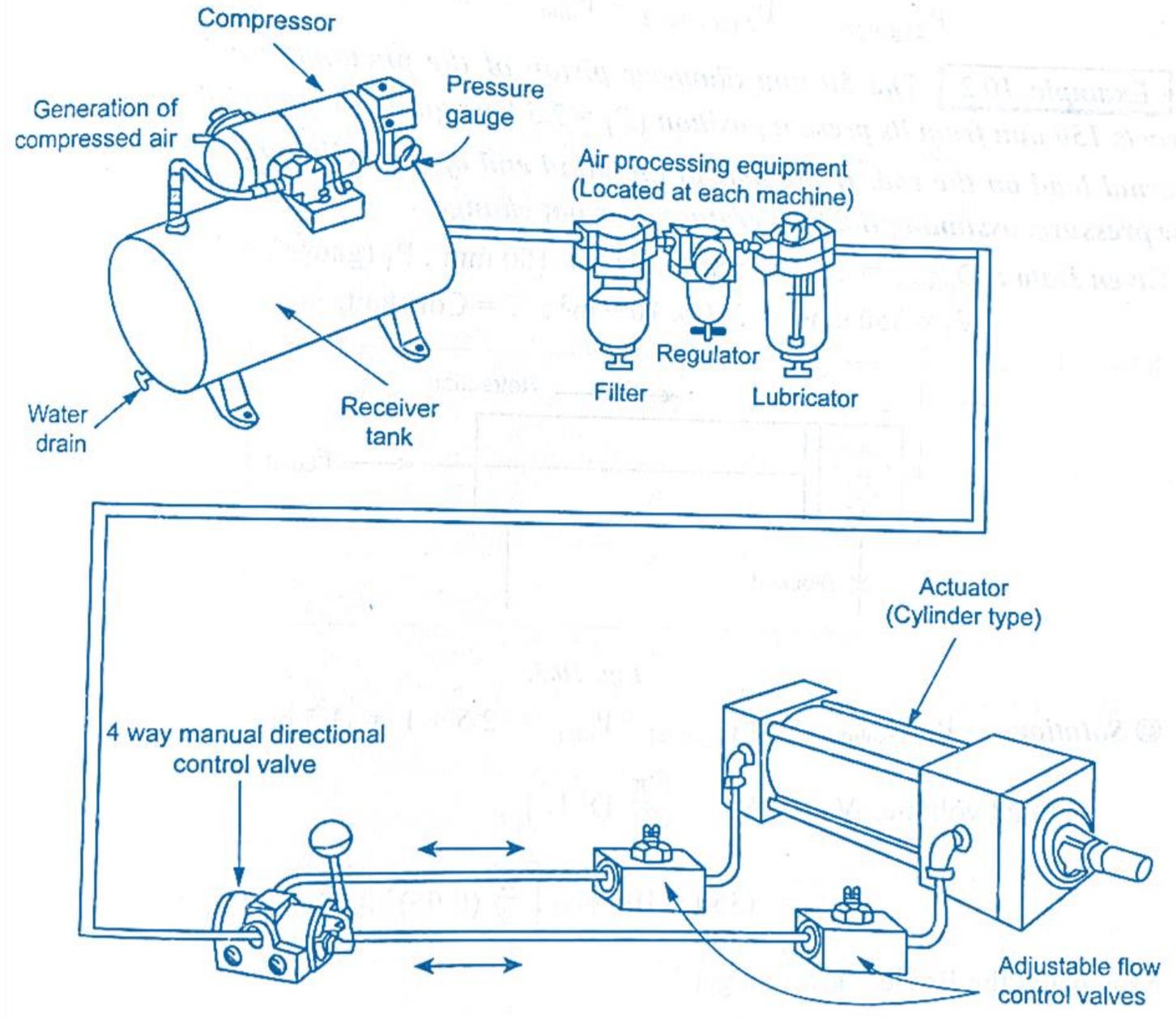
PNEUMATIC SYSTEMS

Advantages of pneumatic System

- More cost-effective than hydraulics – air is free
- Pneumatic safety – the system can be used in inflammable environments and does not
- More power in a smaller and lighter unit compared to most other technology systems
- Cleaner technology
- The fluid used absorbs excessive force, which means fewer threats of damage to equipment

Hydraulic System	Pneumatic System
Employs a pressurized liquid	Employs a compressed gas, usually air
Operates at pressures up to 700 bar	Operates at 5-10 bar
Generally designed as closed system	Usually designed as open system
The system slows down if leakage occurs	Leakage does not affect the system much
Valve operations are difficult	Valve operations are easy
Heavier in weight	Lighter in weight
Pumps are used to pressurize liquids	Compressors are used to compress gases
The system is unsafe to fire hazards	The system is free from fire hazards
Automatic lubrication is provided	Special arrangements for lubrication are needed

PNEUMATIC SYSTEMS



COMPRESSORS

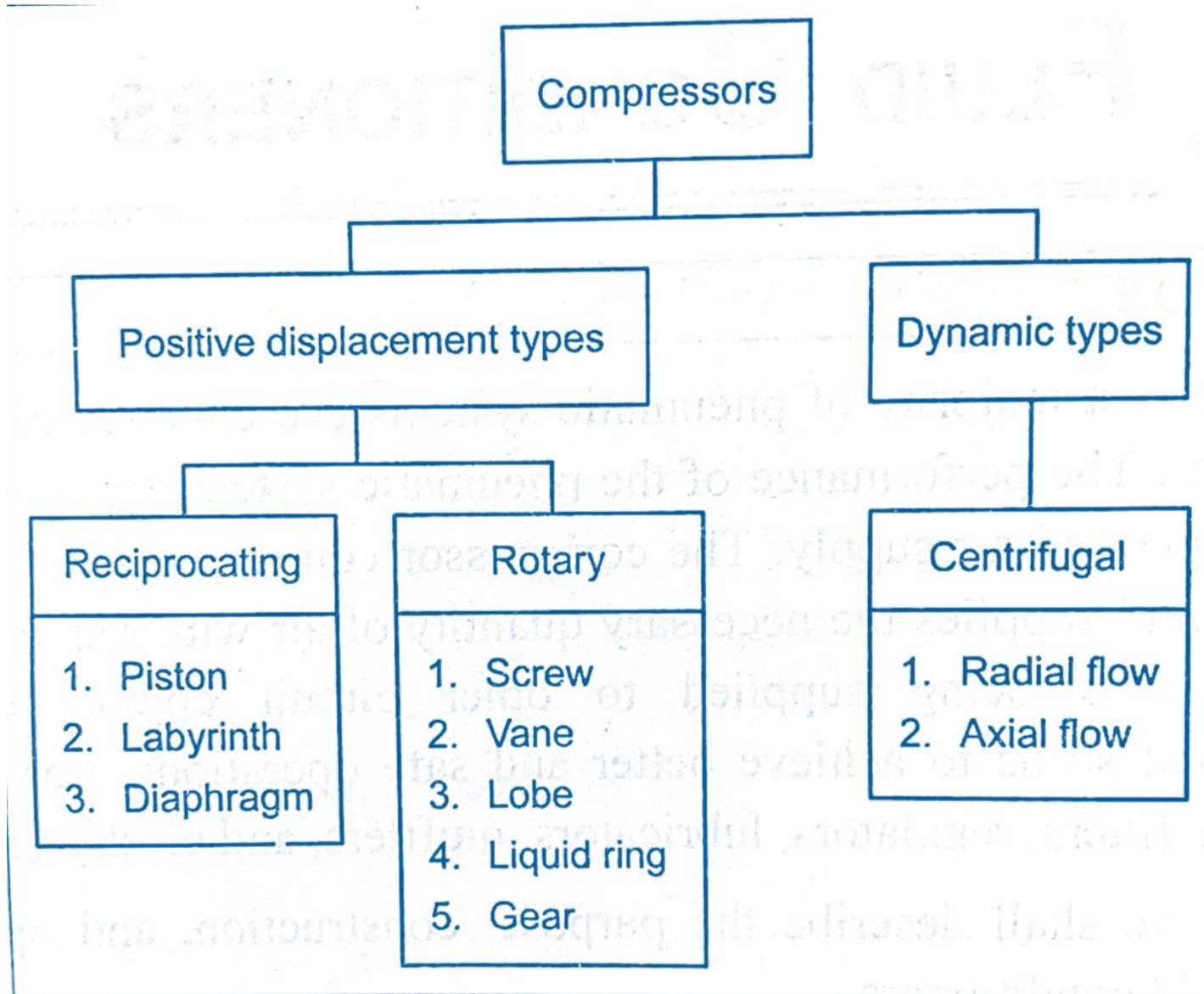


Fig. 11.1. Types of air compressors

COMPRESSORS

11.5.7. Analysis of Air Capacity Rating of Compressors

Q_1 and Q_2 = Volume flow rate of air at the compressor inlet and outlet respectively (m^3/min),

P_1 and P_2 = Absolute pressure of air at the compressor inlet and outlet respectively (kPa abs),

and T_1 and T_2 = Absolute temperature of air at the compressor inlet and outlet respectively ($^{\circ}\text{K}$).

Then,
$$Q_1 = Q_2 \left(\frac{P_2}{P_1} \right) \left(\frac{T_1}{T_2} \right) \quad \dots (11.1)$$

COMPRESSORS

11.5.8. Analysis of Sizing of Air Receivers

The air receiver size can be determined by using the following equation :

$$V_r = \frac{P_a t (Q_r - Q_c)}{P_{max} - P_{min}}$$

where

V_r = Receiver size (m³),

t = Time that receiver can supply required amount of air (min),

Q_r = Consumption rate of pneumatic system (standard m³/min)[†],

Q_c = Output flow rate of compressor (standard m³/min),

P_{max} = Maximum pressure level in receiver (kPa), and

P_{min} = Minimum pressure level in receiver (kPa).

COMPRESSORS

11.5.9. Analysis of Power Required to Drive Compressors

The theoretical power required to drive an air compressor can be determined by using the following equations :

$$(i) \quad \text{Theoretical power (kW)} = \frac{P_{in} Q}{17.1} \left[\left(\frac{P_{out}}{P_{in}} \right)^{0.286} - 1 \right] \quad \dots (11.3)$$

where P_{in} = Inlet atmospheric pressure (kPa abs),

P_{out} = Outlet pressure (kPa abs), and

Q = Flow rate (standard m³/min).

$$(ii) \quad \text{Actual power (kW)} = \left\{ \begin{array}{c} \text{Overall compressor} \\ \text{efficiency } (\eta_o) \end{array} \right\} \times \left\{ \begin{array}{c} \text{Theoretical} \\ \text{power} \end{array} \right\} \quad \dots (11.4)$$

FRL UNIT

1. Filter:

- i) To prevent entrance of solid contaminants to the system.
- ii) To condensate and remove the water vapour that is present in the air.
- iii) To arrest submicron particles that may pose a problem in the system components.

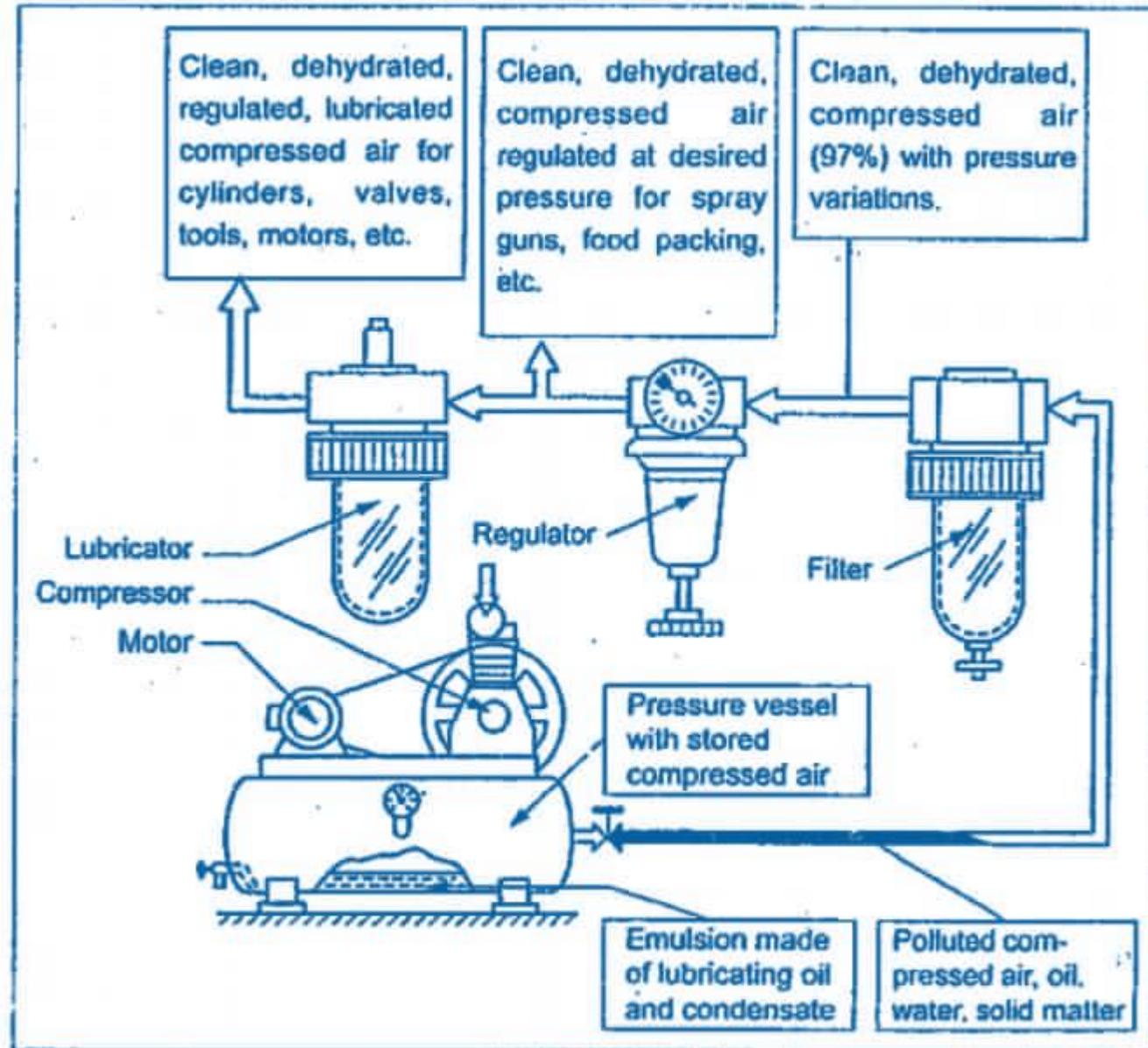
2. Regulator:

To regulate the incoming pressure to the system so that the desired air pressure is capable of flowing at a steady condition.

3. Lubricator:

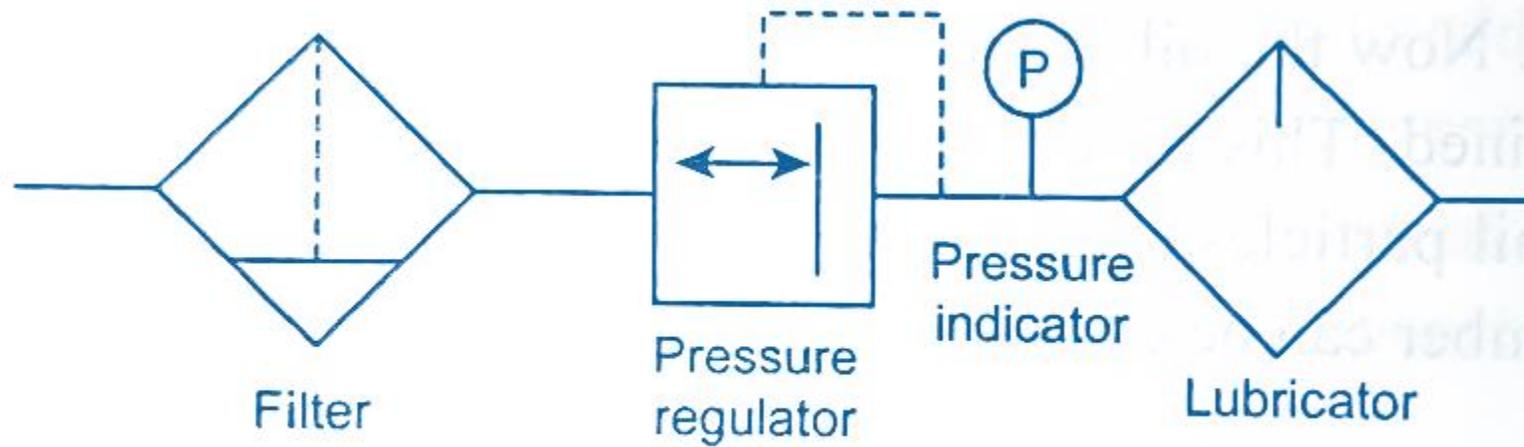
To provide lubrication for mating components of valves, cylinders etc. by forming a mist of oil and air.

FRL UNIT

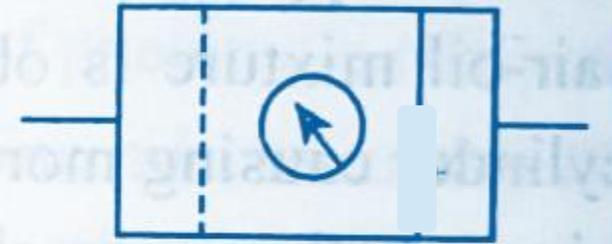


Compressed air generation and distribution system showing a FRL unit

FRL UNIT



(a) Graphic symbols for individual components



(b) Composite symbol

Types of Pneumatic Valve & Their Uses



Sequence Valve



Pressure Reducing Valve



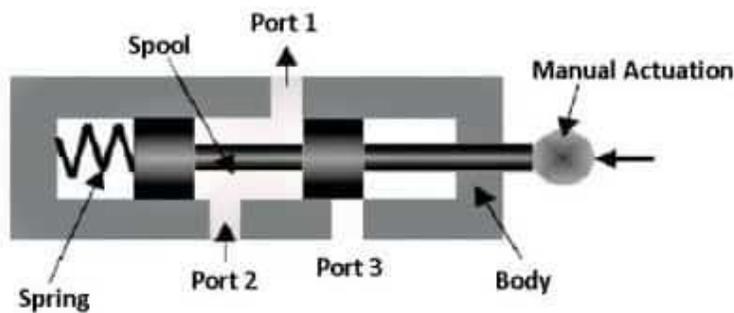
Pressure Regulator Valve



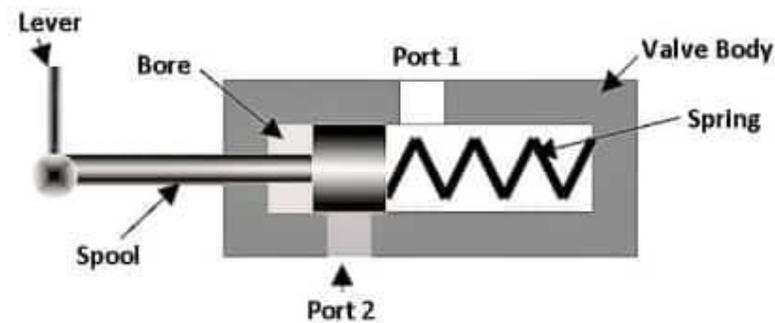
Direction Control Valve



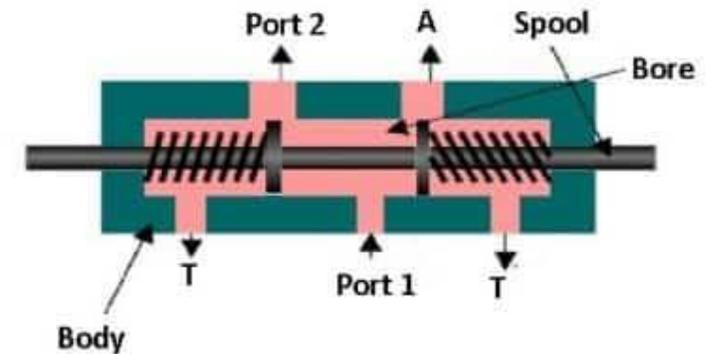
Flow Control Valve



3-way Direction Control Valve

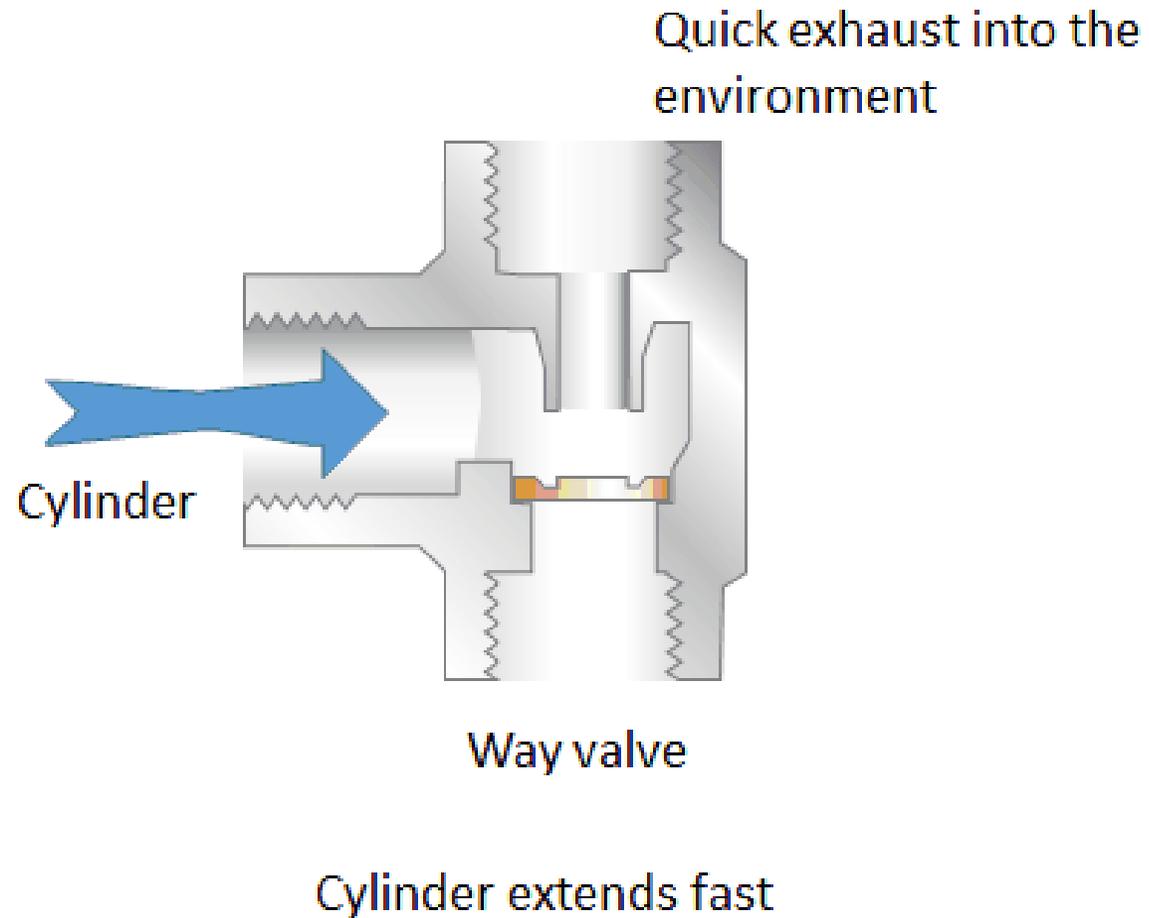


2-way Direction Control Valve



4-way Direction Control Valve

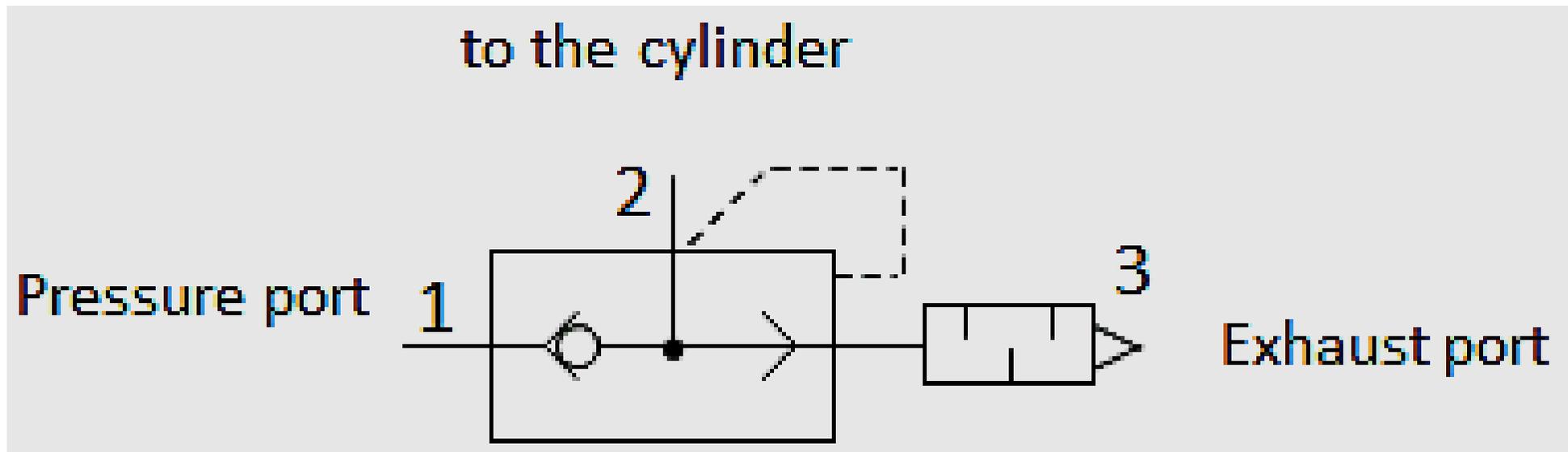
QUICK EXHAUST VALVE



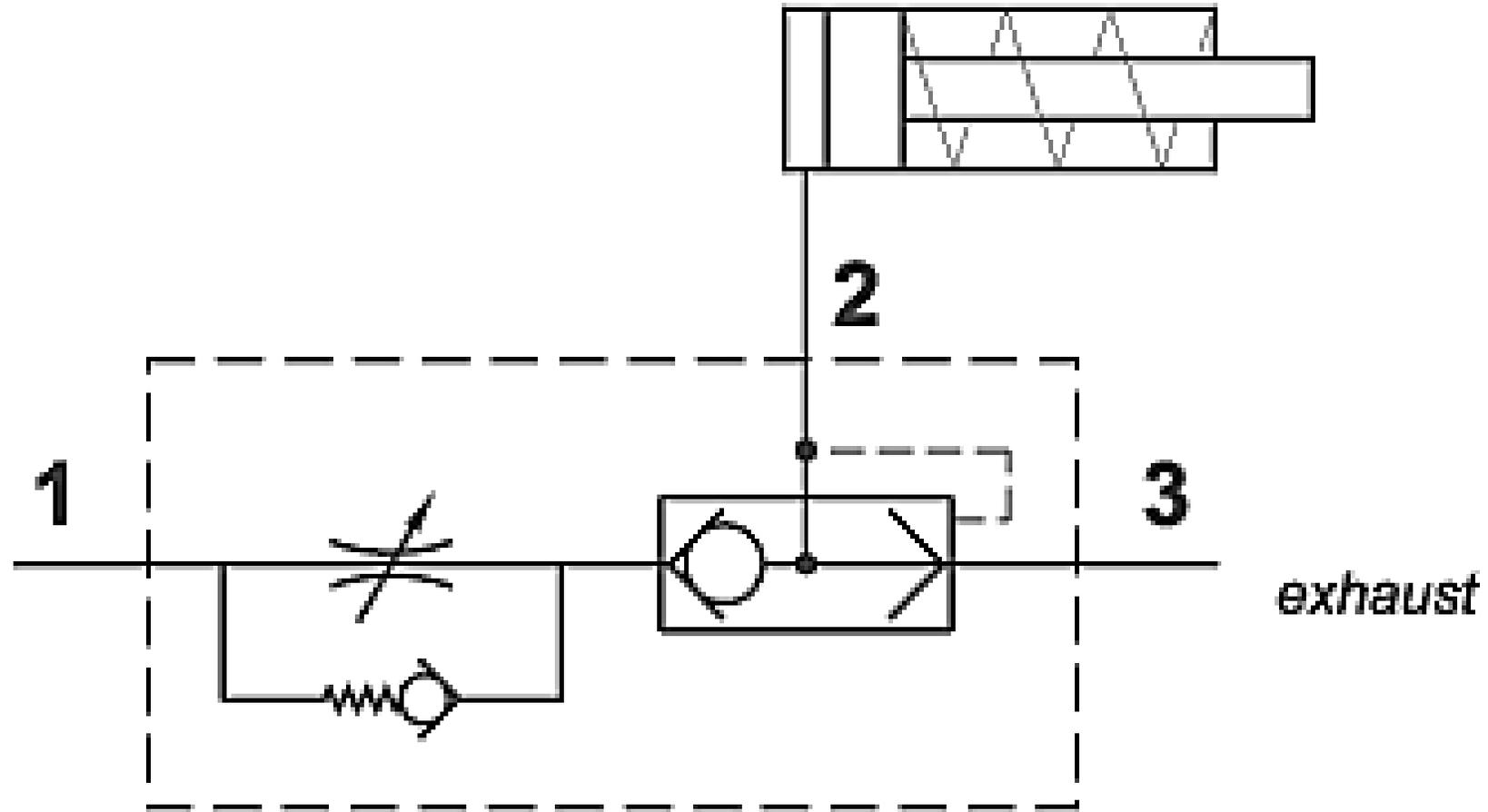
QUICK EXHAUST VALVE

- Quick exhaust valves are pneumatic components designed to rapidly vent air from a system, typically used in cylinder applications to speed up the return stroke or increase actuation speed.
- When air is supplied to a cylinder through the valve, it flows normally.
- When the supply is cut and the valve senses backflow pressure, it opens a port directly to the atmosphere, allowing the air to exhaust quickly instead of travelling all the way back through the control valve.

QUICK EXHAUST VALVE



QUICK EXHAUST VALVE



SHUTTLE VALVE

- It allows flow from two alternate sources to a single output while preventing backflow between the sources.
- The shuttle valve selects whichever input has higher pressure and routes it to the output port. It's called a "shuttle" because it has a small internal piston or ball that shifts between the two inlets.

SHUTTLE VALVE

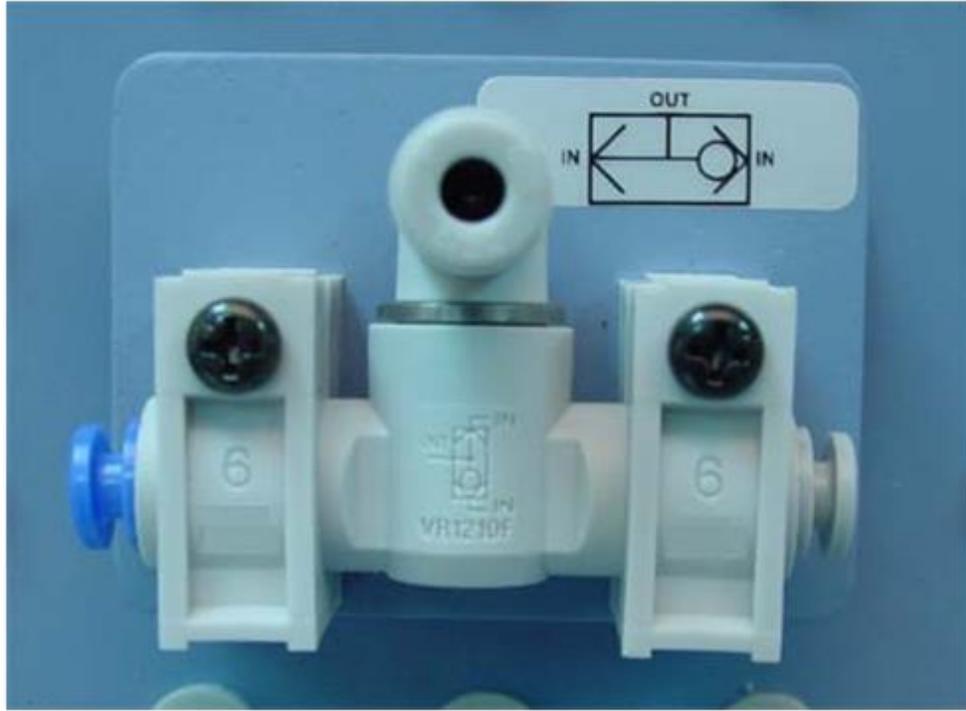
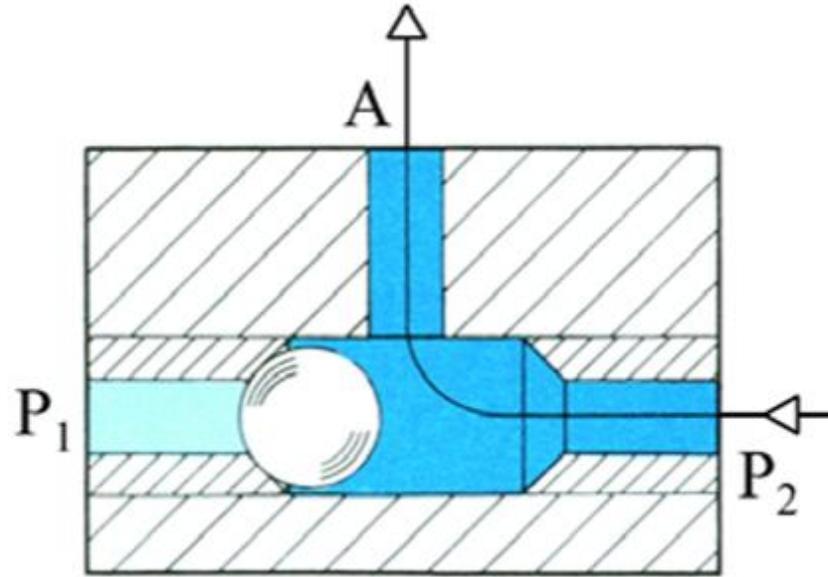
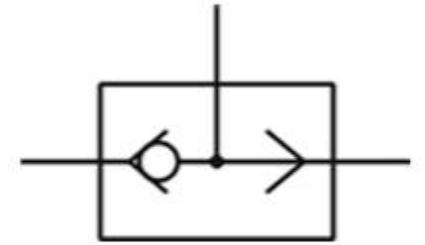


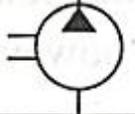
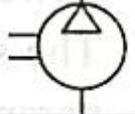
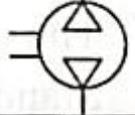
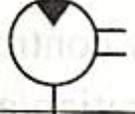
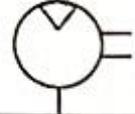
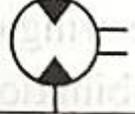
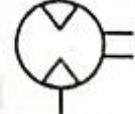
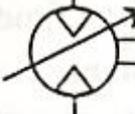
Fig. 15 (a) Shuttle valve



(b) Cross section



(c) Pneumatic symbol

Description	Symbol	Diagram	
		Hydraulic	Pneumatic
Fixed displacement, unidirectional pump	S1		
Fixed displacement, bidirectional pump	S2		
Variable displacement, unidirectional pump	S3		
Variable displacement, bidirectional pump	S4		
Fixed displacement, unidirectional motor	S5		
Fixed displacement, bidirectional motor	S6		
Variable displacement, unidirectional motor	S7		
Variable displacement, bidirectional motor	S8		
Oscillating motor	S9		

UNIT 6 PNEUMATIC CIRCUITS DESIGN

Design of pneumatic circuits for automation, selection and specification of circuit components, sequencing circuits, cascade, and karnaugh - Veitch map method - Regenerative, speed control, synchronizing circuits. (8)

BASIC PNEUMATIC CIRCUITS DESIGN

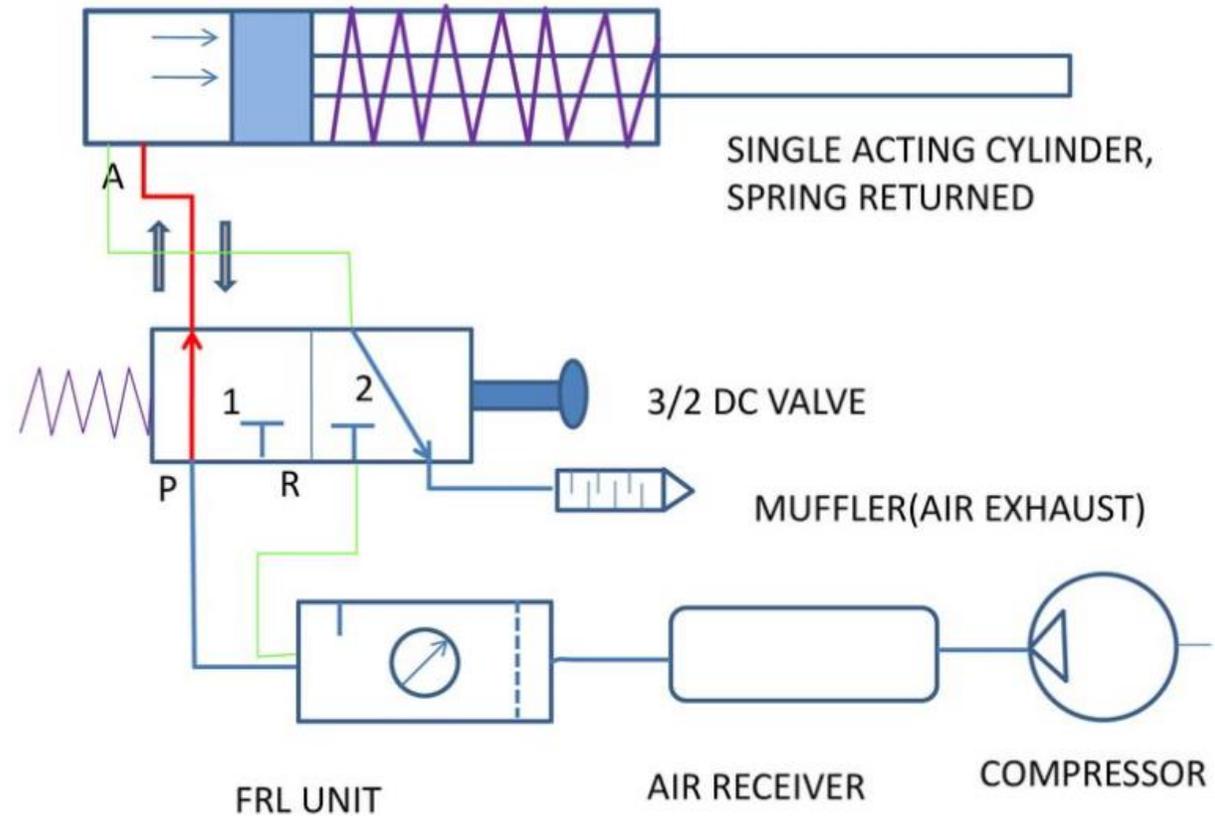
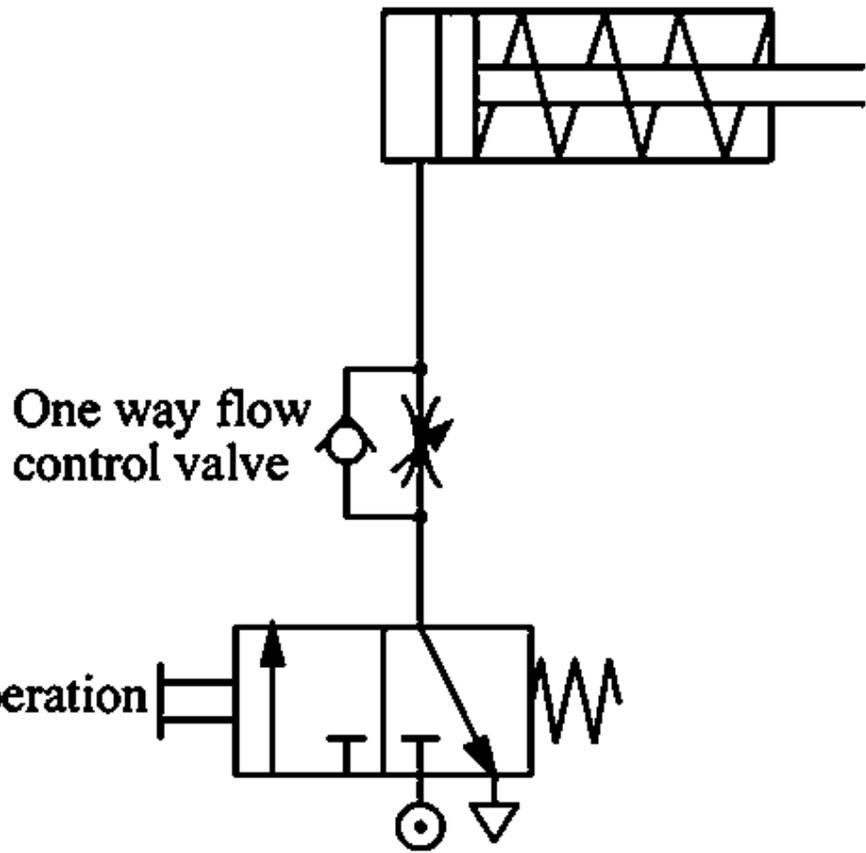
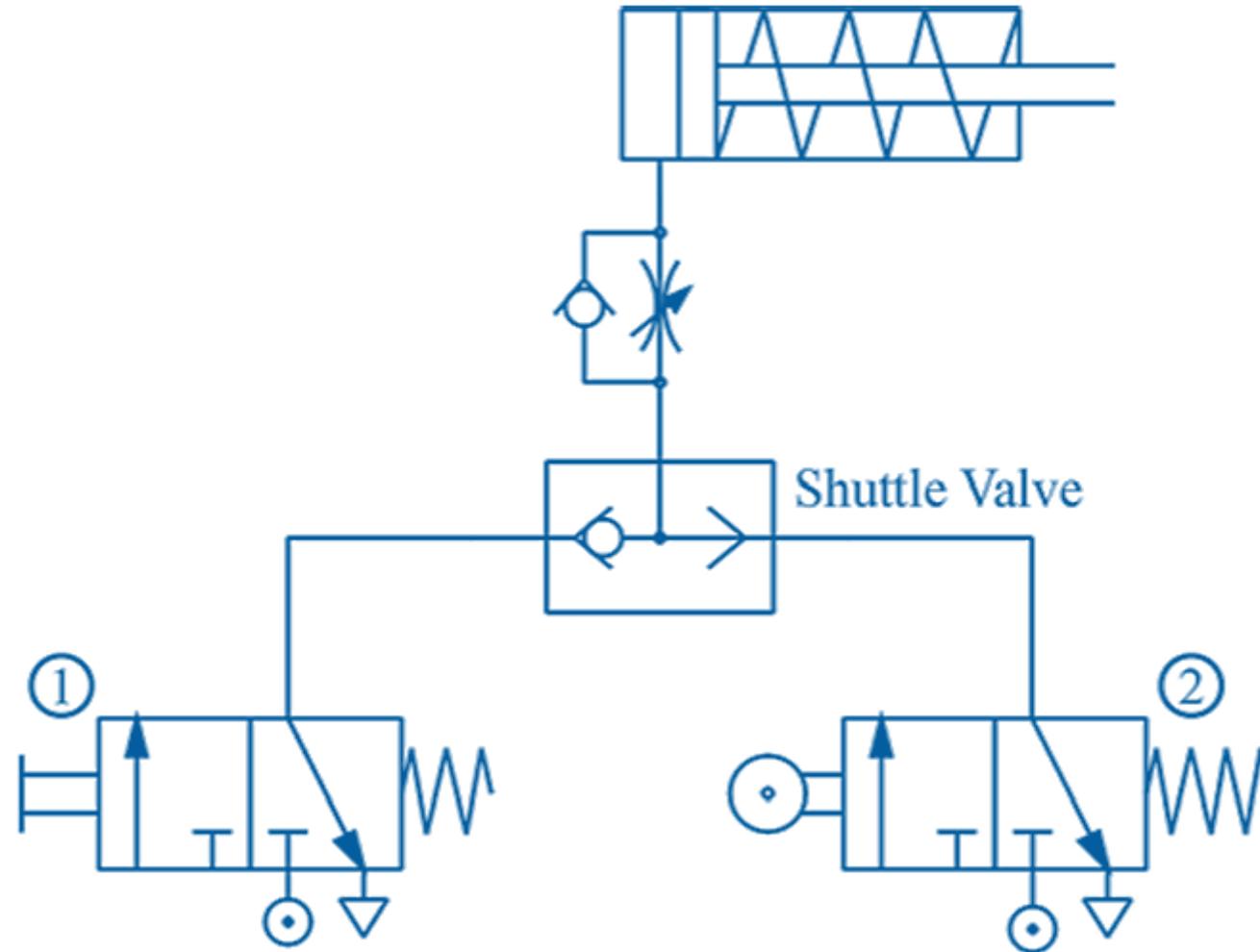


Fig. 28 Direct control of a single acting cylinder

BASIC PNEUMATIC CIRCUITS DESIGN



BASIC PNEUMATIC CIRCUITS DESIGN

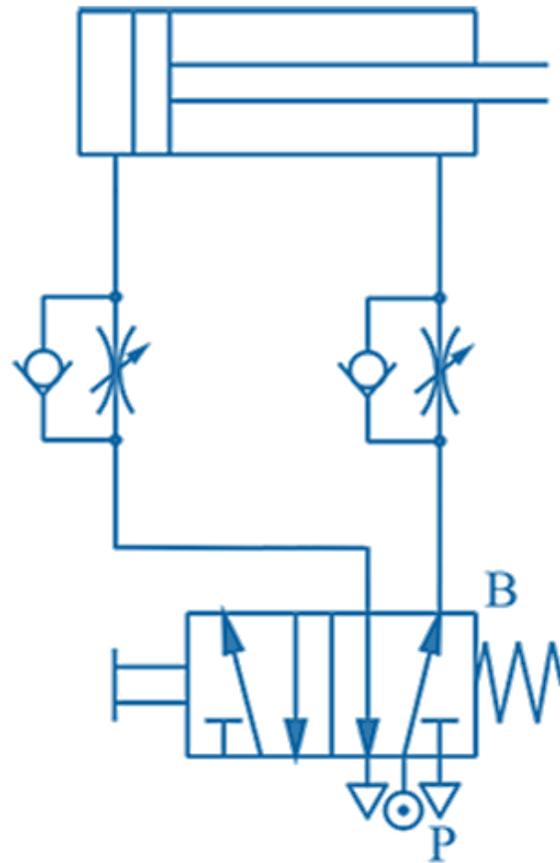
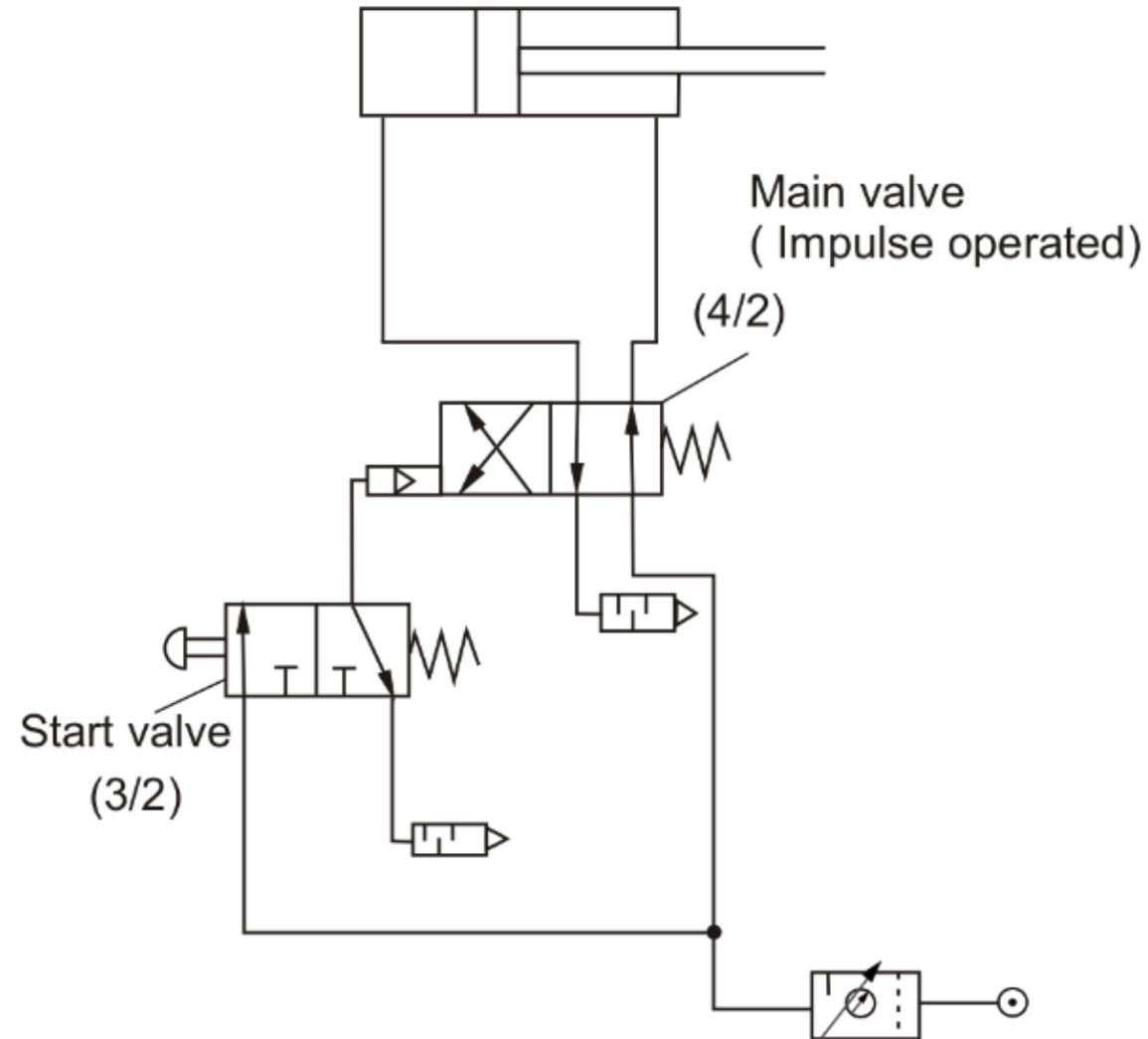


Fig. 32 Circuit diagram of a double acting cylinder direct control circuit

BASIC PNEUMATIC CIRCUITS DESIGN



PNEUMATIC CIRCUIT DESIGN

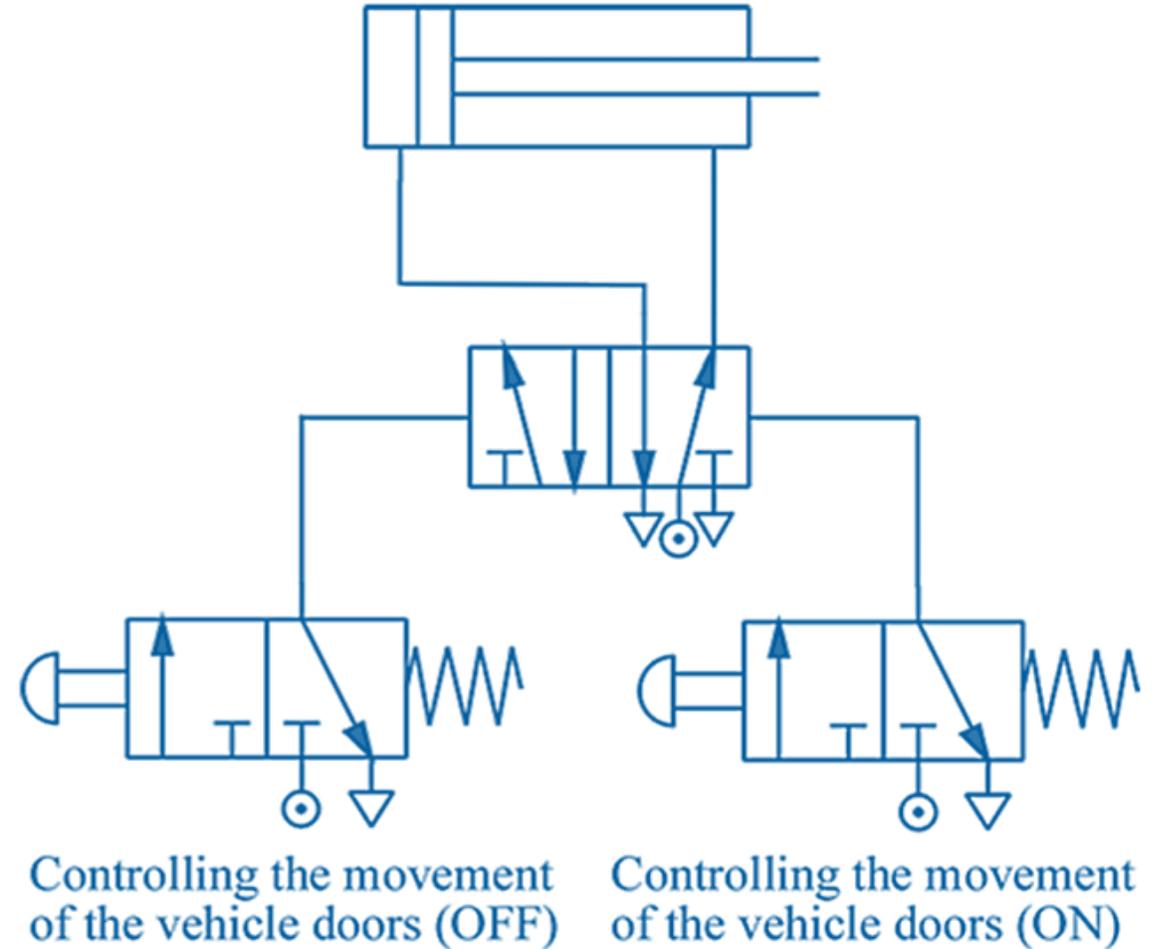
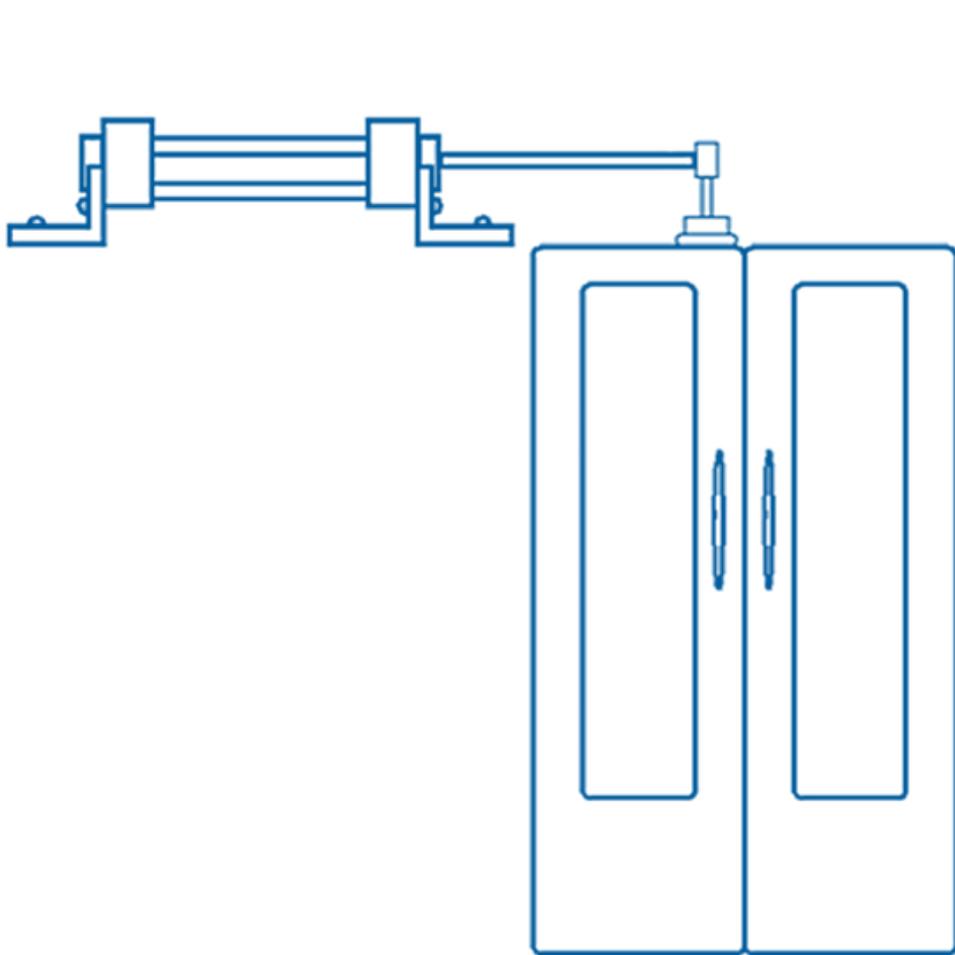
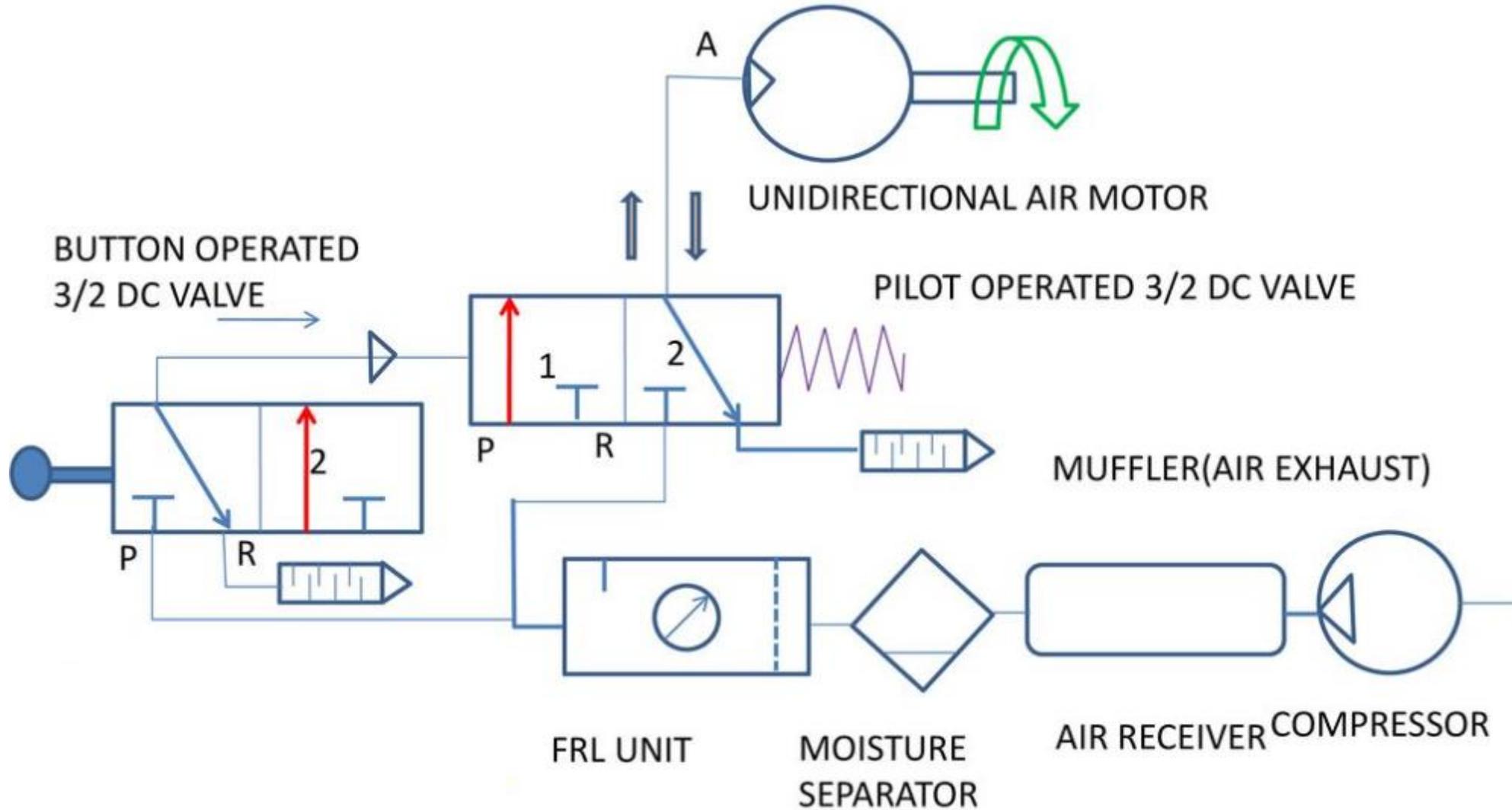


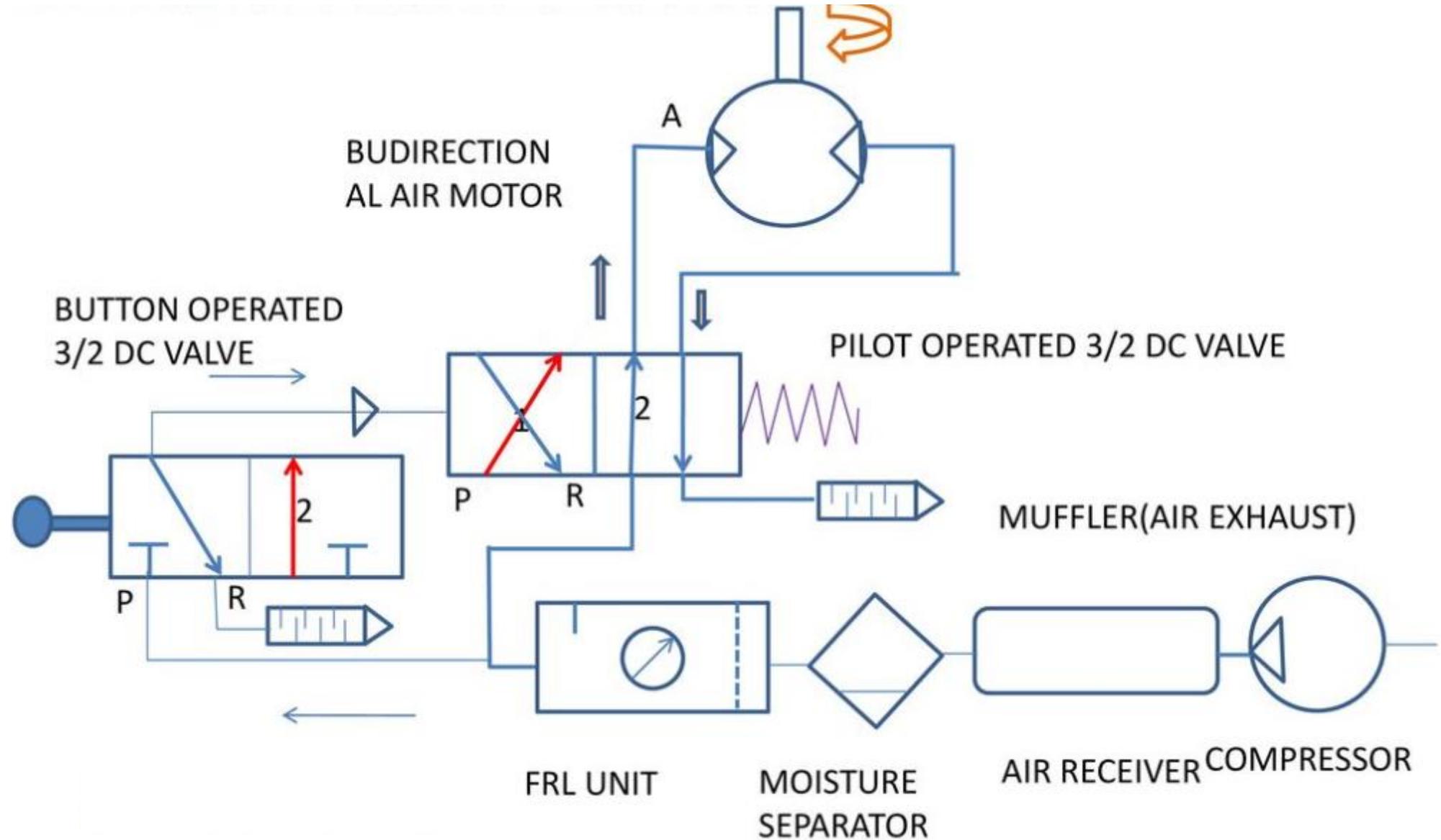
Fig. 35 (a) Operation of a pneumatic system that controls the movement of vehicle doors

(b) Pneumatic circuit diagram

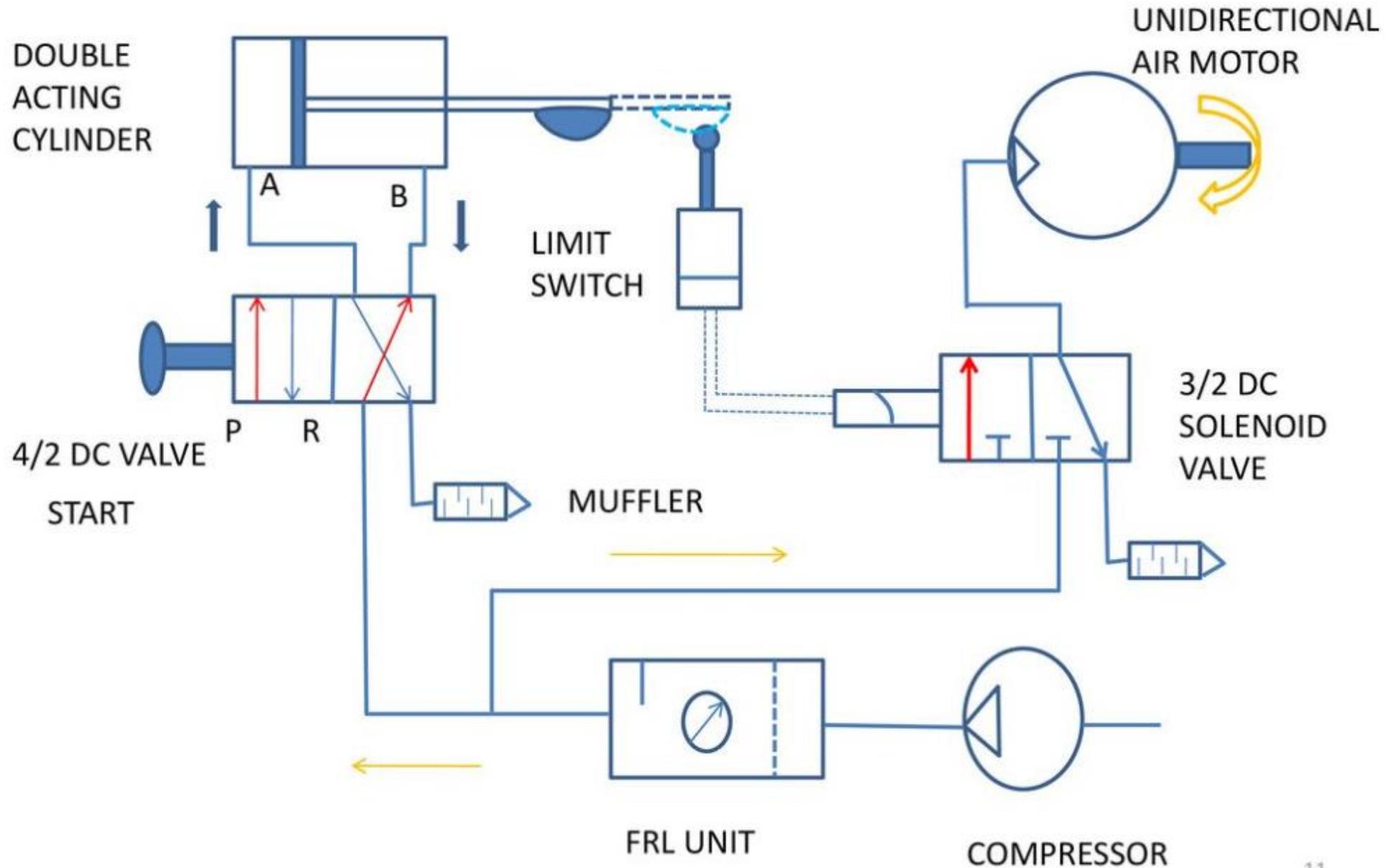
PNEUMATIC CIRCUIT DESIGN



PNEUMATIC CIRCUIT DESIGN



SEQUENCING OF DOUBLE ACTING CYLINDER WITH UNIDIRECTIONAL AIR MOTOR



ELECTRO-HYDRAULIC COMPONENTS

Electrical control, solenoid valves, relays, switches

1. Electrical Control

- Converts electrical input signals into commands that operate hydraulic components.
- Enables precise automation, safety, and integration with control systems like PLCs or ECUs.

Example: In a forklift, joystick input (electrical) activates solenoid valves for hydraulic movement.

2. Solenoid Valves

- **Electromechanical devices** that control fluid flow by energizing a coil to move a spool or plunger.
- Can be **on/off** (digital) or **proportional** (analog) to allow variable control.

Example: Activating the hydraulic lift in an excavator using a solenoid valve.

ELECTRO-HYDRAULIC COMPONENTS

Electrical control, solenoid valves, relays, switches

3. Relays

- Electrically operated switches used to control high-power solenoids or motors using low-power signals.
- Provide **isolation and protection** between control and power circuits.

Example: A relay activates a pump motor when a limit switch is triggered in a press machine.

4. Switches

- Devices that **manually or automatically open/close circuits** to initiate or interrupt electrical control.
- Types include **push buttons, limit switches, pressure switches, and float switches.**

Example: A pressure switch activates a solenoid valve when system pressure drops below a set value.

ELECTRO-PNEUMATIC COMPONENTS

Electrical timers, switches, solenoid, relays, proximity sensors etc.

1. Electrical Timers

- **Function:** Delay or control the timing of pneumatic actions.
- Used to turn devices ON or OFF after a set time.
- **Example:** Delay the retraction of a pneumatic cylinder by 5 seconds.

2. Switches

- Used to **manually or automatically** start/stop electrical circuits.
- Types: Push-button, limit switch, toggle, pressure switch.
- **Example:** Push-button switch starts a pneumatic press cycle.

ELECTRO-PNEUMATIC COMPONENTS

Electrical timers, switches, solenoid, relays, proximity sensors etc.

3. Solenoids (Pneumatic Solenoid Valves)

- Electromagnetic coils control valves to **direct compressed air**.
- When energized, the solenoid shifts the valve to allow airflow.
- **Example:** A 5/2 solenoid valve controls a double-acting pneumatic cylinder.

4. Relays

- **Electromagnetic switches** that control high-power devices using low-power control.
- Provide logic-based switching or sequence control.
- **Example:** Relay turns ON a solenoid valve when two conditions are met.

ELECTRO-PNEUMATIC COMPONENTS

Electrical timers, switches, solenoid, relays, proximity sensors etc.

5. Proximity Sensors

- **Detect object presence** without contact (inductive or capacitive types).
- Send signals to trigger actions like cylinder extension.
- **Example:** Sensor detects a metal part and activates an air blower.

ELECTRO-PNEUMATIC COMPONENTS



Electrical timers



Switches



Relays



Solenoids

ELECTRO-PNEUMATIC COMPONENTS

Electrical timers, switches, solenoid, relays, proximity sensors etc. Electro pneumatic

How They Work Together – Example Cycle

- 1.Start:** The operator presses a **push-button switch**.
- 2.Timer** delays action by 3 seconds.
- 3.Relay** receives signal and activates the **solenoid valve**.
- 4.Solenoid valve** directs air to extend the cylinder.
- 5.Proximity sensor** confirms part placement → next action begins.

DESIGN OF PNEUMATIC LOGIC CIRCUITS

1. **Cascade method,**
2. Classic or intuitive method,
3. Step-counter method,
4. **Karnaugh-Veitch (K-V) mapping method,** and
5. Combinational circuit design.

PNEUMATIC CIRCUIT DESIGN — CASCADE METHOD

PROCEDURE

Step 1:

- Each cylinder is given individual letters (say A, B, C, etc.).
- The given sequence is written first with '+' representing extension (forward) stroke of the cylinder and '-' representing retraction (return) stroke of the cylinder.

(For example, A+, B+, A-, B-, etc.)

PNEUMATIC CIRCUIT DESIGN — CASCADE METHOD

PROCEDURE

Step 2:

The given sequence is split into the minimum number of groups. The grouping can be done as below :

- (i) The first group is split where the change in stroke occurs.
- (ii) The second, third and subsequent groups are formed such that a maximum of one change occurs within the group.
- (iii) **No letter should be repeated within any group.**
- (iv) The groups are identified by letters like I, II, III, etc.

Illustration:

- Let us assume the sequence $A+ B+ B- C+ C- A-$.
- This sequence can be split into three groups as shown below:

A+ B+ , B- C+ , C- A-
I II III

PNEUMATIC CIRCUIT DESIGN — CASCADE METHOD

PROCEDURE

Step 3:

- Each group is assigned a pressure manifold line, which must be pressurised only during the time the particular group is active.

Number of pressure lines = Number of groups

PNEUMATIC CIRCUIT DESIGN — CASCADE METHOD

PROCEDURE

Step 4:

Selection of valves :

- Each cylinder is provided with a pilot-operated 4/2 DC valve.
Number of pilot control DCVs = Number of cylinders
- Limit valves are positioned at either end and actuated by the piston rod to identify the extension and retraction of cylinders.
- The limit valves are denoted by a_0 , a_1 , b_0 , b_1 , etc., where the suffix '0' corresponds to valves which are actuated at the end of the return stroke and the suffix '1' corresponds to valves which are actuated at the end of the forward stroke.

- Each cylinder requires two limit valves.

Number of limit valves (DCVs) = 2 × Number of cylinders

- Each manifold line supplies air pressure to those limit valves within its particular group.
- In order to pressurize the various manifold lines in the proper order, one or more group changing valves or cascade valves are used.

Number of cascade (or group changing) valves (DCV) = Number of groups – 1

PNEUMATIC CIRCUIT DESIGN — CASCADE METHOD

PROCEDURE

Step 5:

The valve connections are made as follows :

- The output of each limit valve is connected to the pilot input corresponding to the next sequence step.
- The limit valve corresponding to the last step of the given group is 'not' connected to the pilot actuation of the DC valve of the next cylinder. Instead, it is connected to the pilot line of the group changing or cascade valve to pressurise the manifold of the subsequent group.
- This manifold line is then connected to the pilot line corresponding to the first step of the next group.

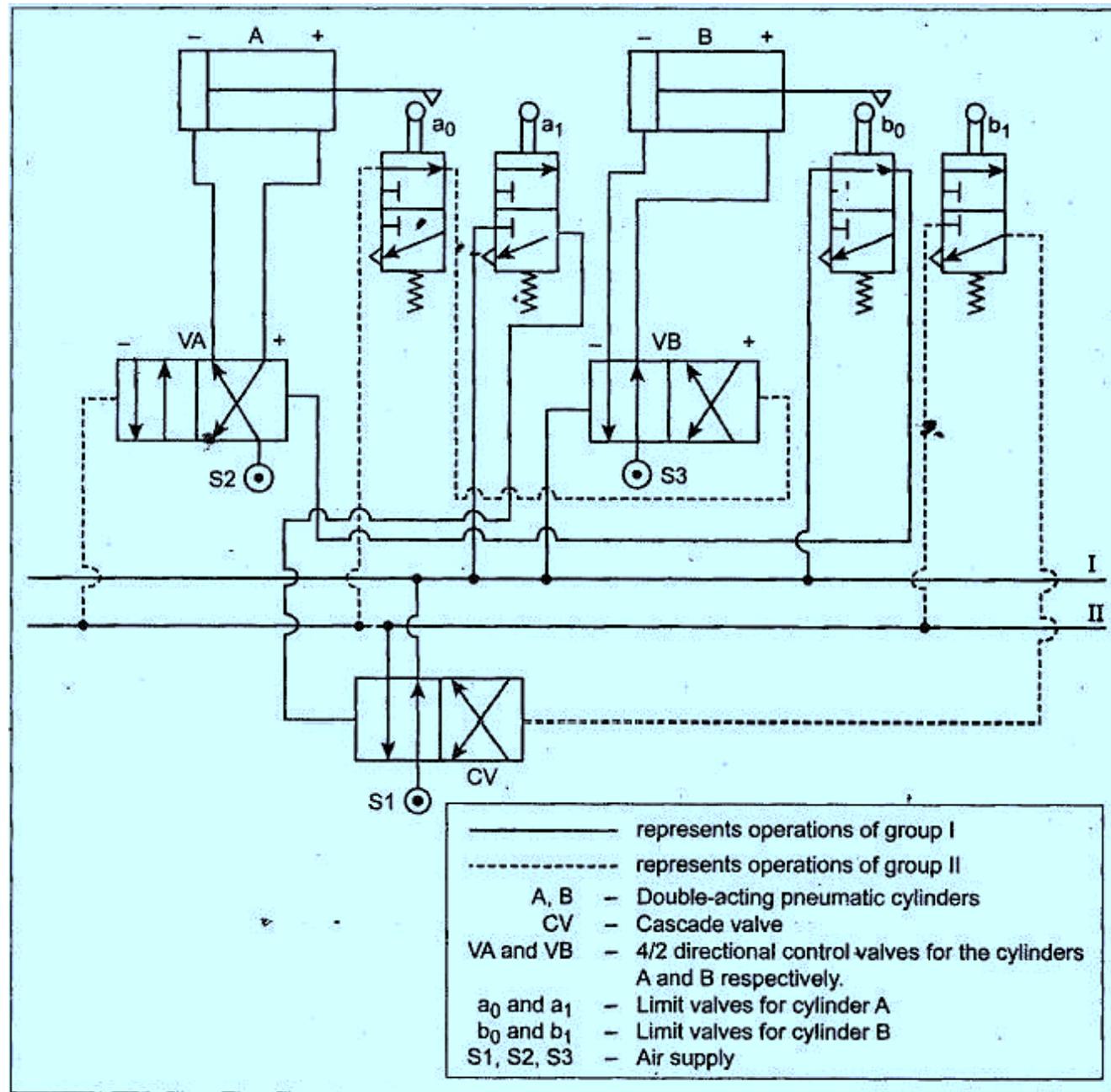


Fig. 13.19. Cascade circuit for A⁺ A⁻ B⁺ B⁻ sequence

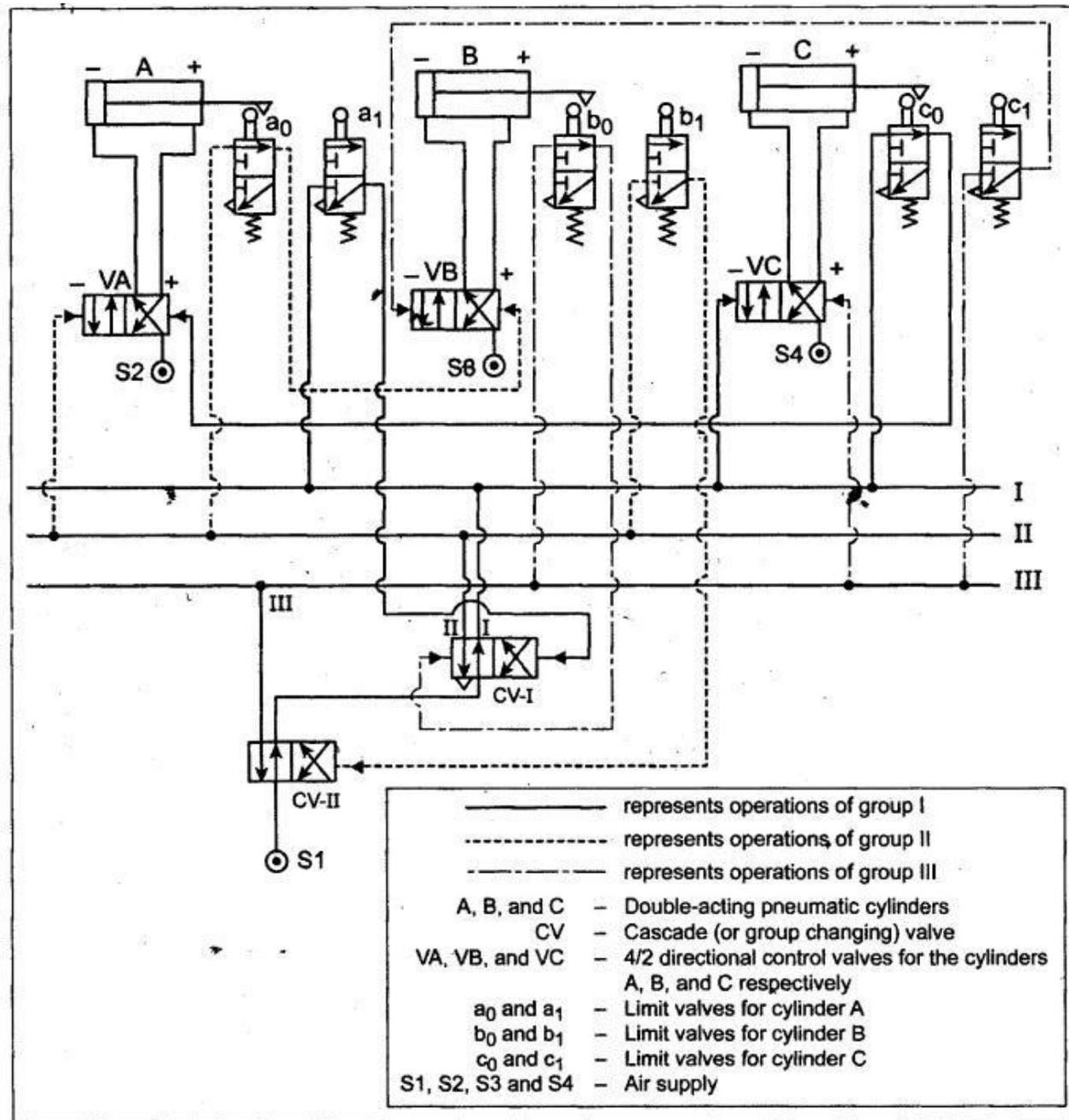


Fig. 13.21. Cascade circuit for the sequence $A^+A^-B^+C^+B^-C^-/C^-A^+A^-B^+C^+B^-$.

UNIT 7 ELECTRO PNEUMATICS AND PLC CIRCUITS

Use of electrical timers, switches, solenoid, relays, proximity sensors etc. electro pneumatic sequencing Ladder diagram – PLC-elements, functions and selection - PLC programming - Ladder and different programming methods - Sequencing circuits. (6)

PROGRAMMABLE LOGIC CONTROLLER (PLC)

- It is a specialized industrial computer used to automate machinery, processes, and systems in manufacturing, production, and other industrial settings.
- Executes logic-based programs to automate tasks like motor control, valve switching, etc.
- Has input/output modules to interact with sensors and actuators.
- Supports multiple programming languages, including Ladder Diagram (LD), Function Block Diagram (FBD), Structured Text, etc.
- Think of a PLC as the “brain” that executes control logic.

PROGRAMMABLE LOGIC CONTROLLER (PLC)



PROGRAMMABLE LOGIC CONTROLLER (PLC)



PROGRAMMABLE LOGIC CONTROLLER (PLC)



PROGRAMMABLE LOGIC CONTROLLER (PLC)

Key Features of a PLC

- **Programmable:** You can write logic using programming languages like Ladder Diagram, Function Block, or Structured Text.
- **Logic Controller:** It makes decisions based on input signals and controls output devices.
- **Reliable and Rugged:** Designed to withstand harsh industrial environments (heat, dust, vibration).

PROGRAMMABLE LOGIC CONTROLLER (PLC)

How a PLC Works (Components):

1. Inputs: Receives signals from sensors (e.g., temperature, pressure, proximity switches).

2. Processor (CPU): Processes logic written by the user.

3. Outputs: Sends signals to actuators (e.g., motors, solenoids, lights) based on logic.

4. Programming Software: Used to write and upload programs to the PLC.

PROGRAMMABLE LOGIC CONTROLLER (PLC)

Example Applications:

- Automatic bottling or packaging machines
- Traffic light control systems
- Elevator operation
- Industrial robotic arms

PLC PROGRAMMING LANGUAGES

Five main PLC programming languages:

1. Ladder Diagram (LD)
2. Function Block Diagram (FBD)
3. Structured Text (ST)
4. Instruction List (IL) (obsolete)
5. Sequential Function Chart (SFC)

PLC PROGRAMMING LANGUAGES

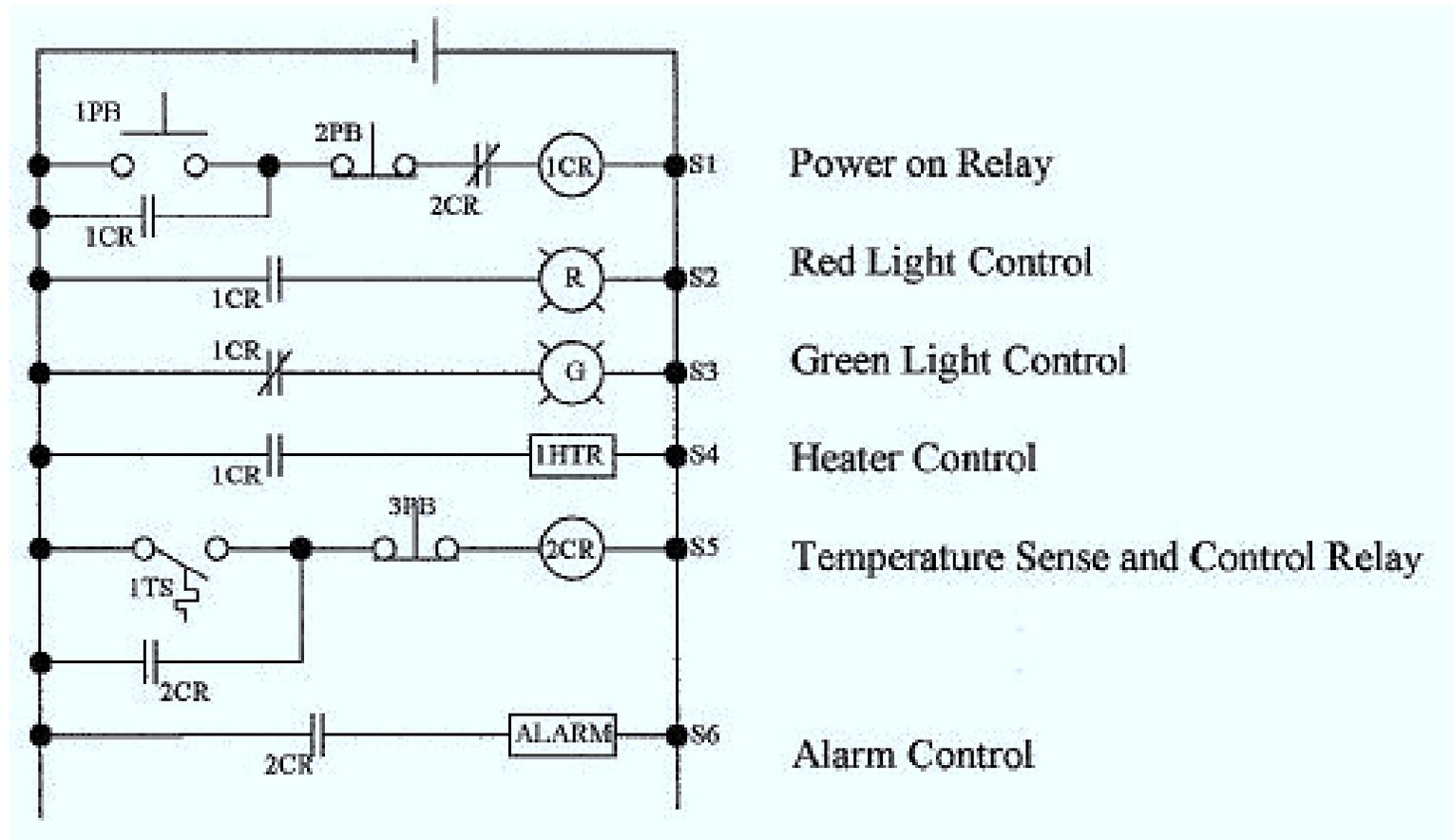
1. Ladder Diagram (LD)

- **Most commonly used** in industrial automation.
- Resembles electrical relay logic with “rungs” and “rails.”
- Uses **contacts (inputs)** and **coils (outputs)**.
- Easy for electricians and technicians to understand.

Example use: Start/Stop motor control circuit.

PLC PROGRAMMING LANGUAGES

1. Ladder Diagram (LD)



PLC PROGRAMMING LANGUAGES

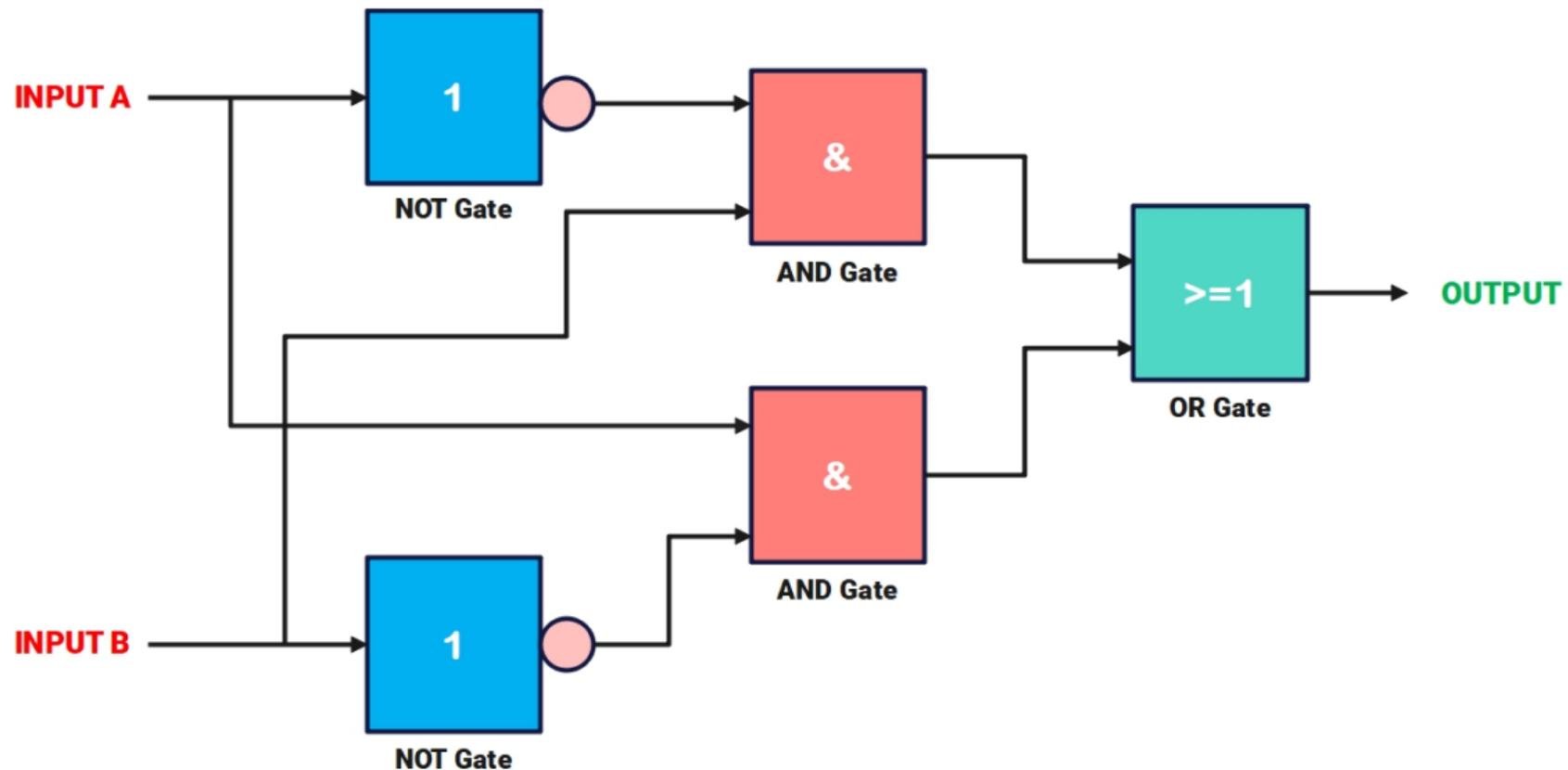
2. Function Block Diagram (FBD)

- Graphical language showing logic as **function blocks**.
- Each block represents operations like AND, OR, timers, counters.
- Good for **continuous and analog processing**.

Example use: HVAC systems or PID control.

PLC PROGRAMMING LANGUAGES

2. Function Block Diagram (FBD)



PLC PROGRAMMING LANGUAGES

3. Structured Text (ST)

- High-level, **text-based language** similar to Pascal or C.
- Best for **complex math, data processing, and loops**.
- Used in advanced applications like robotics or motion control.

Example use: Complex sorting logic or calculations.

PLC PROGRAMMING LANGUAGES

3. Structured Text (ST)

```
1  preset_temp:=12;           //Immediate Expression
2  pushbutton:=1;           //Immediate Expression
3  new_preset_temp:=preset_temp; //Tag Expression
4  timer_value:=ton1.ACC;    //Tag Expression
5  timer_done:=ton1.DN;     //Tag Expression
6  //timer operation
7  TONR_01.PRE := 500;
8  TONR_01.Reset := Reset;
9  TONR_01.TimerEnable := input3;
10 input3:=1;
11 if TONR_01.ACC >= 500 & TONR_01.DN then //A conditional statement
12     input3:=0;
13 end_if;
14 TONR(TONR_01); //Function Expression
15 timer_state := TONR_01.DN;
16 total:=add1+12+13+add2; //Operators Expression
```

PLC PROGRAMMING LANGUAGES

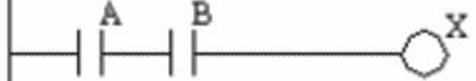
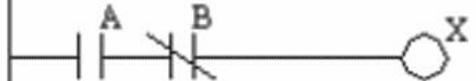
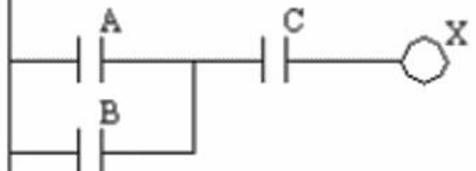
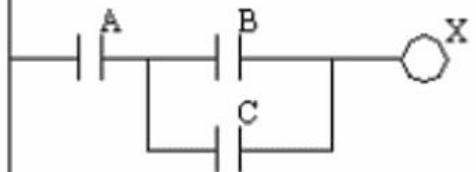
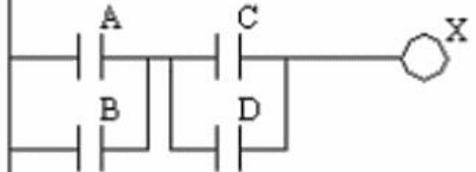
4. Instruction List (IL) (*Obsolete in newer standards*)

- Low-level, assembly-like language.
- Compact and fast, but harder to read and maintain.

Example use: Legacy systems.

PLC PROGRAMMING

4. Instruction List (IL)

Ladder	Instruction List (IL)	
	LD A ST X	
	LDN A ST X	
	LD A LD B ANB ST X	LD A AND B ST X
	LD A LDN B ANB ST X	LD A ANDN B ST X
	LD A LD B ORB LDC ANB ST X	LD A ORB AND C ST X
	LD A LD B LDC ORB ANB ST X	LD A LD B ORC ANB ST X
	LD A LD B ORB LDC LDD ORB ANB ST X	LD A ORB LDC ORD ANB ST X

PLC PROGRAMMING LANGUAGES

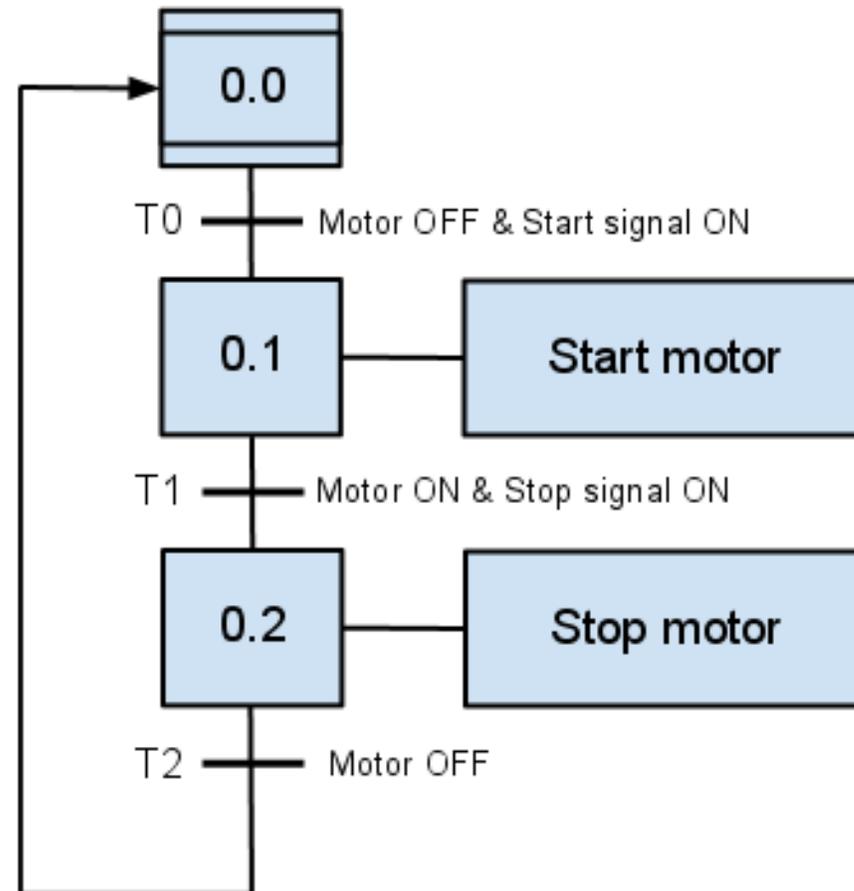
5. Sequential Function Chart (SFC)

- Used for **step-by-step operations**.
- Represents the process flow as **steps and transitions**.
- Ideal for batch processing or multi-stage sequences.

Example use: Filling, heating, and emptying tanks in order.

PLC PROGRAMMING LANGUAGES

5. Sequential Function Chart (SFC)



PLC PROGRAMMING LANGUAGES

Language	Type	Best For
LD	Graphical	Simple logic, relay-based circuits
FBD	Graphical	Analog processing, reusable logic
ST	Text-based	Complex logic, math-heavy processes
IL	Text-based	Legacy, low-level instructions
SFC	Graphical	Step-wise or sequential control

ELECTRICAL CONTROLS FOR FLUID POWER SYSTEMS

The most commonly used electrical control devices are :

1. Push-button switches,
2. Limit switches,
3. Pressure switches,
4. Temperature switches,
5. Solenoids,
6. Relays, and
7. Timers.

ELECTRICAL CONTROLS FOR FLUID POWER SYSTEMS

Fig.9.1 shows the symbolic representation for the above types of push-button switches.

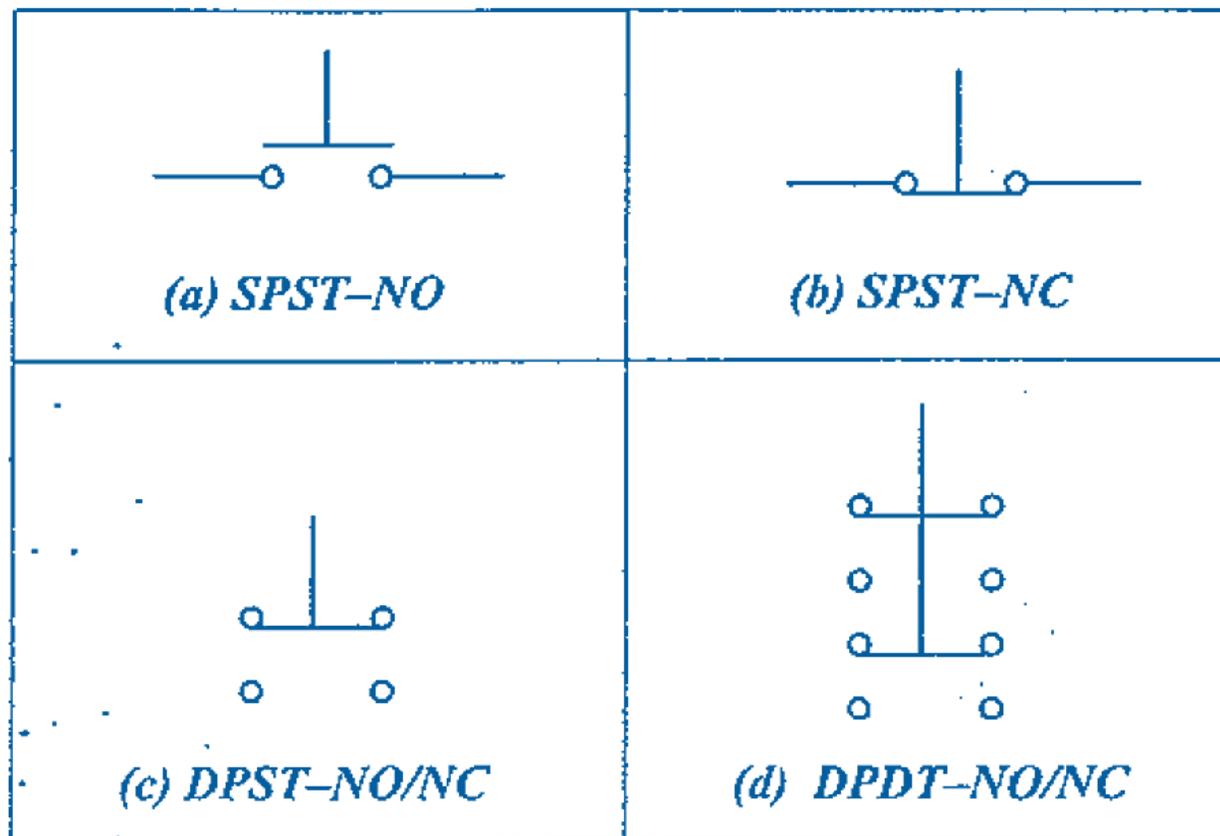


Fig. 9.1. Graphic symbols for push-button switches

ELECTRICAL CONTROLS FOR FLUID POWER SYSTEMS

✓ *Types* : Fig.9.2 shows the graphic symbols for the commonly used limit switches.

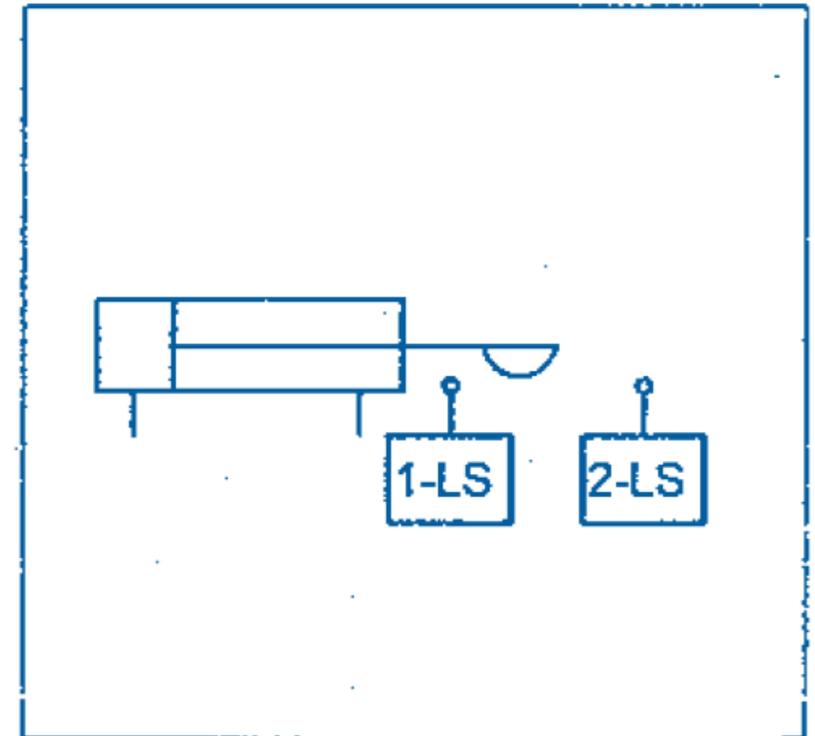
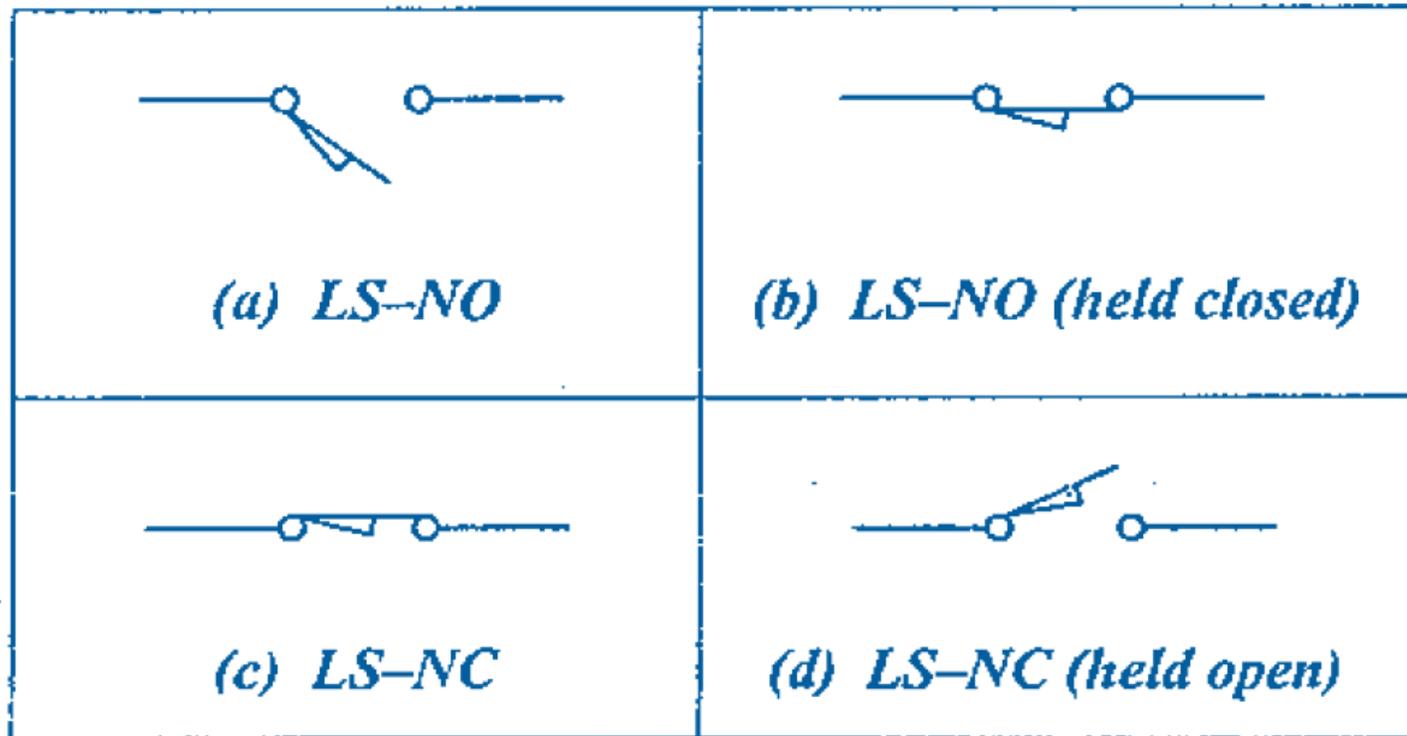


Fig. 9.2. Graphic symbols for limit switches

Fig. 9.3. Cylinder with built-in limit switches

ELECTRICAL CONTROLS FOR FLUID POWER SYSTEMS



Fig. 9.4. Graphic symbols for pressure switches

ELECTRICAL CONTROLS FOR FLUID POWER SYSTEMS

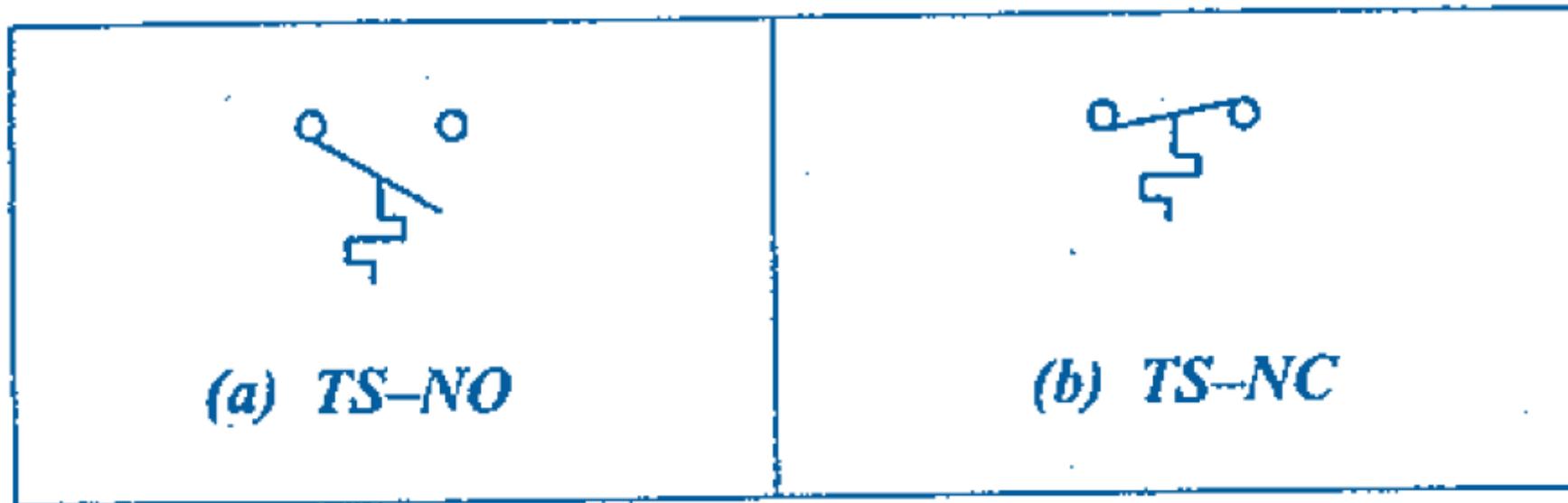


Fig. 9.5. Graphic symbols for temperature switches

ELECTRICAL CONTROLS FOR FLUID POWER SYSTEMS

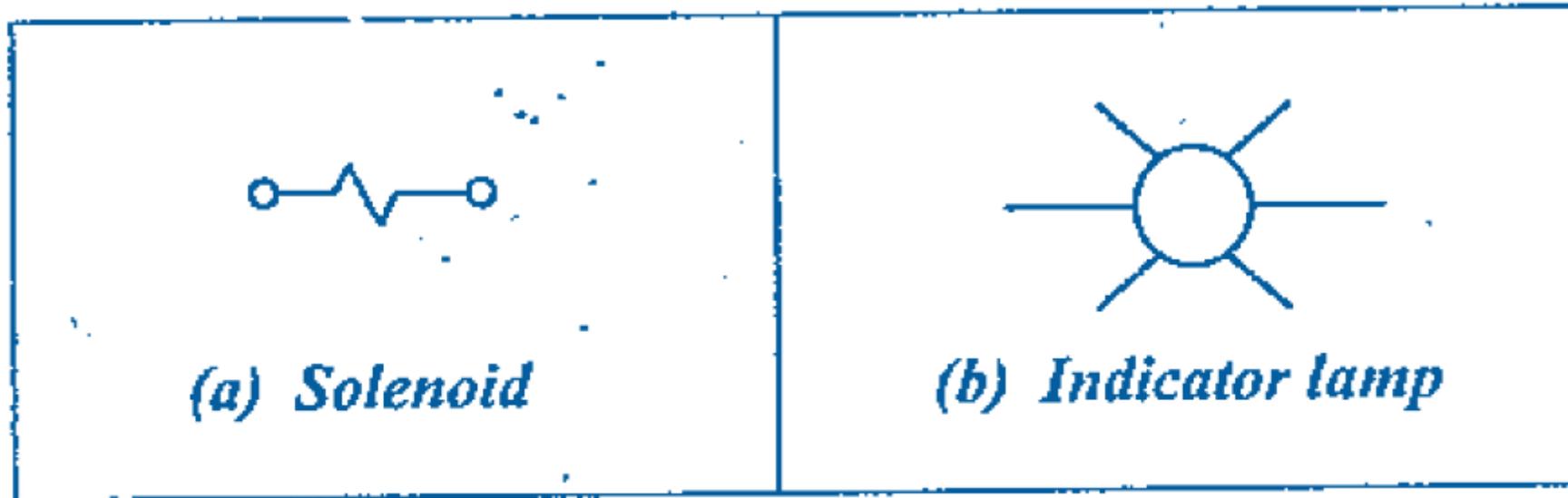


Fig. 9.6. Graphic symbols for solenoid and indicator lamp

ELECTRICAL CONTROLS FOR FLUID POWER SYSTEMS

9.2.6.1. What are Relays ?

- ✓ The electrical relays offer simple ON/OFF switching action in response to a signal issued by a control system.
- ✓ In other words, relays are nothing but electrically operated switches.
- ✓ Relays are commonly used to open or close the contacts and thereby energize or de-energize solenoids which operate at a high current level. A low-voltage circuit can be used to energize relay coils that control high-voltage contacts used to open and close circuits containing the solenoids.

ELECTRICAL CONTROLS FOR FLUID POWER SYSTEMS

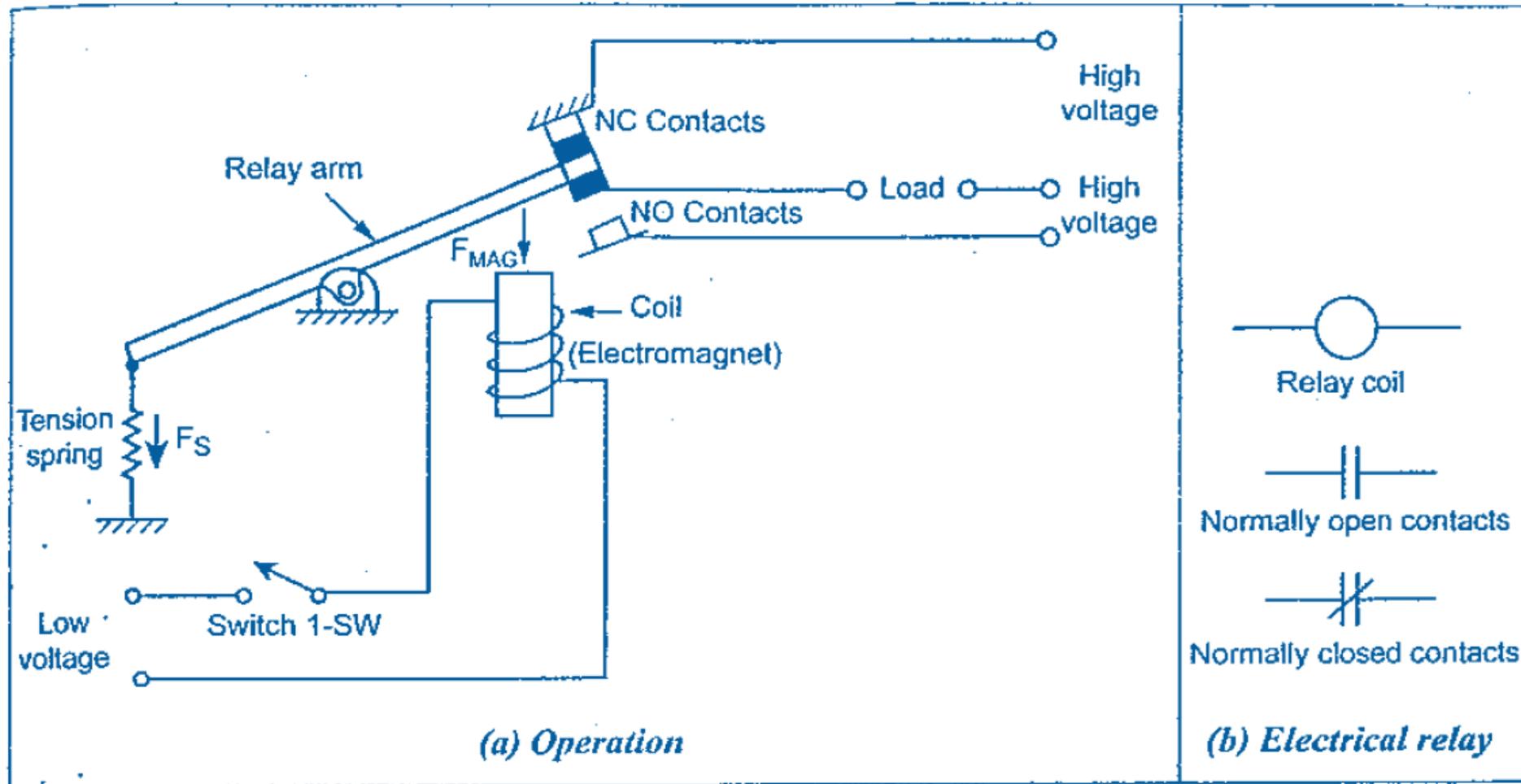


Fig. 9.7. Electrical relay

ELECTRICAL CONTROLS FOR FLUID POWER SYSTEMS

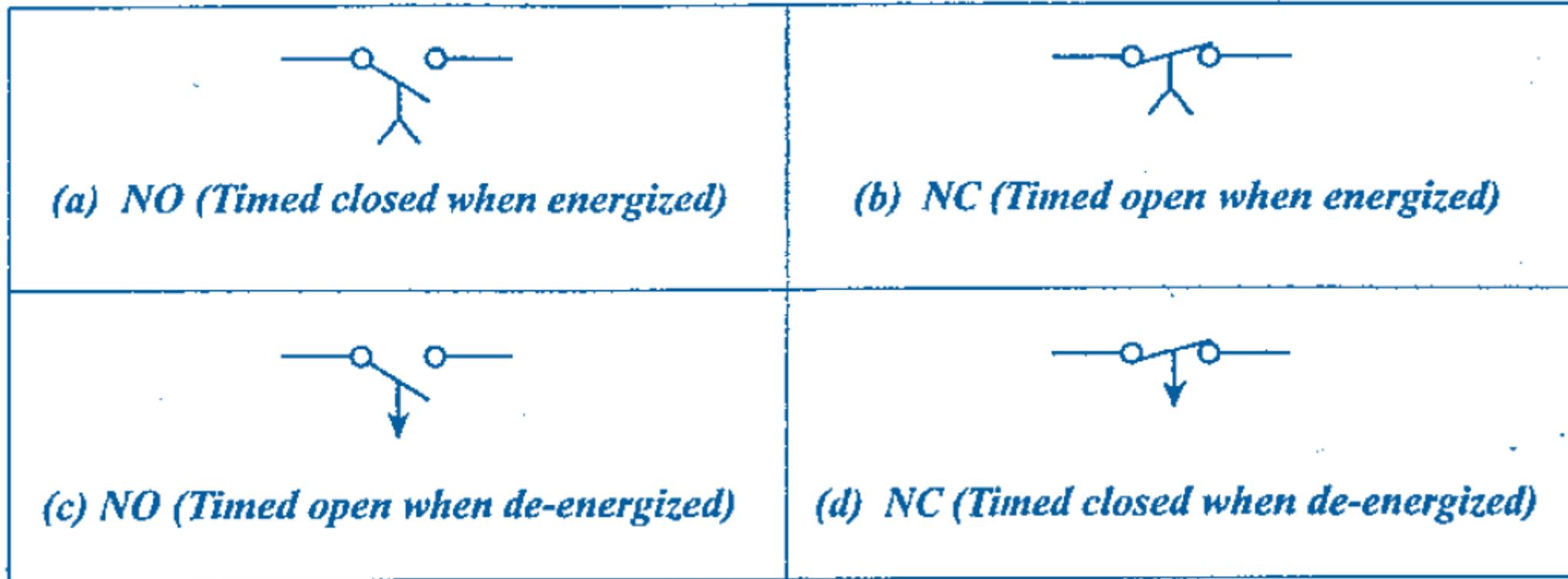


Fig. 9.8. Electrical timer symbols

LADDER DIAGRAM

It should be noted that while drawing any electrohydraulic (or electropneumatic) circuits, separate circuits should be drawn for the fluid system and the electrical system. Also each components should be labeled so that one can understand exactly how the two systems interfaced. The second circuit showing the electrical system is known as ladder diagram. Thus the operation of the total system can be understood by examination of both the fluid power circuit and ladder diagram (*i.e.*, electrical circuit).

9.3.2. What is Meant by a Ladder Diagram ?

- ✓ A ladder diagram is a representation of hardware connections between switches, relays, solenoids, *etc.*, which constitute the basic components of an electrical control system.
- ✓ In other words, *a ladder diagram is nothing but an electrical diagram showing the hardware connections between the various electrical control devices.*

LADDER DIAGRAM

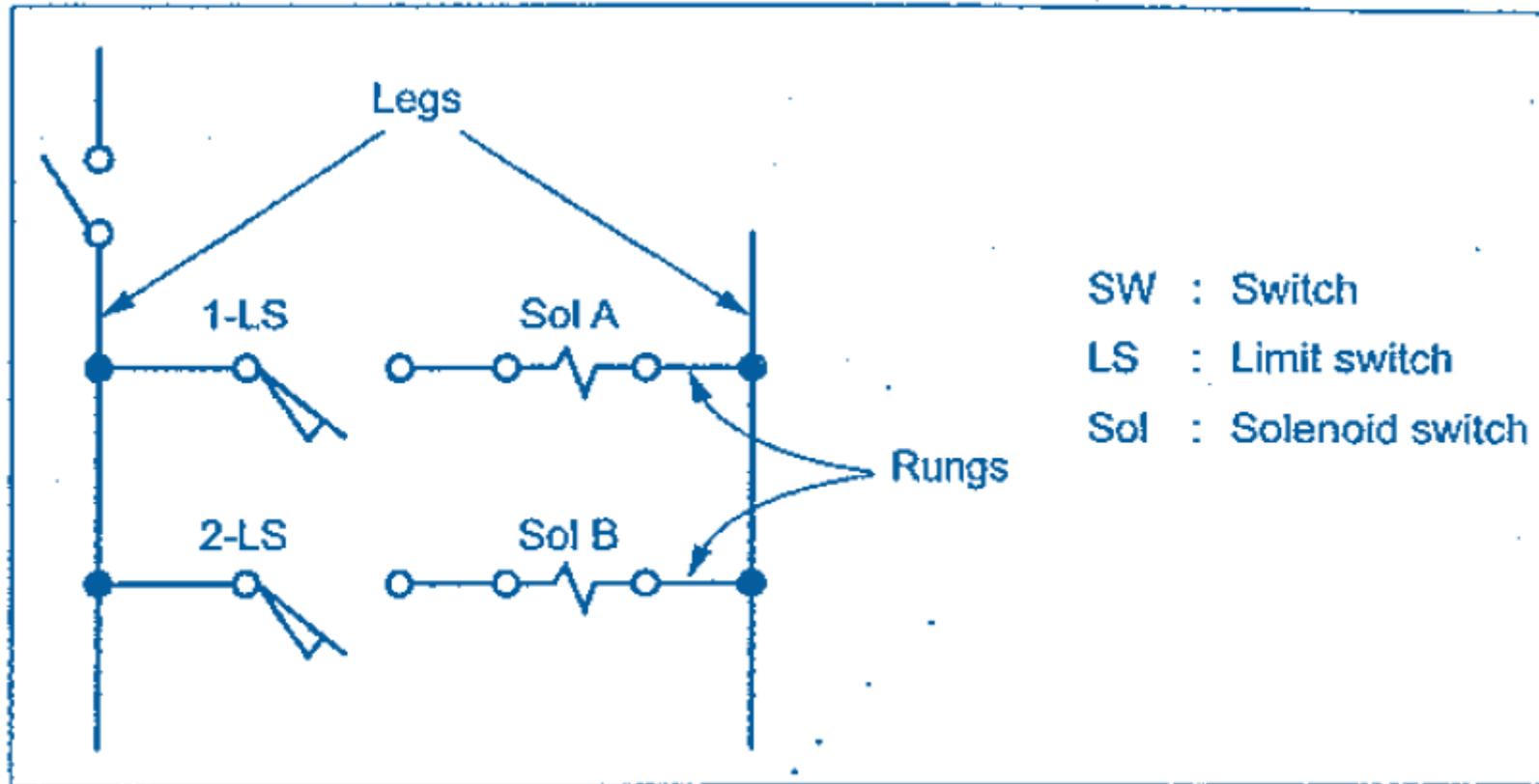


Fig. 9.9. Typical ladder diagram

LADDER DIAGRAM

9.3.3. Details of a Ladder Diagram

Consider a typical ladder diagram as shown in Fig.9.9 for some application.

- ✓ *Legs and Rungs* : In Fig.9.9, the two vertical electrical power supply lines are called 'legs', and the horizontal lines containing electrical components are called 'rungs'.
- ✓ In ladder diagrams, always the power is connected to the left leg and the ground is connected to the right leg.
- ✓ It should be noted that always the switches should be shown in their unactuated (*i.e.*, open) mode in the ladder diagrams.
- ✓ *Since the electric circuit diagram resembles to a ladder, this diagram is called a 'ladder diagram'.*
- ✓ *Uses* : Ladder diagrams provide a circuit designer with a practical means to examine input process and output functions to quickly plan the circuit layout design for a particular hydraulic or pneumatic application.

LADDER DIAGRAM

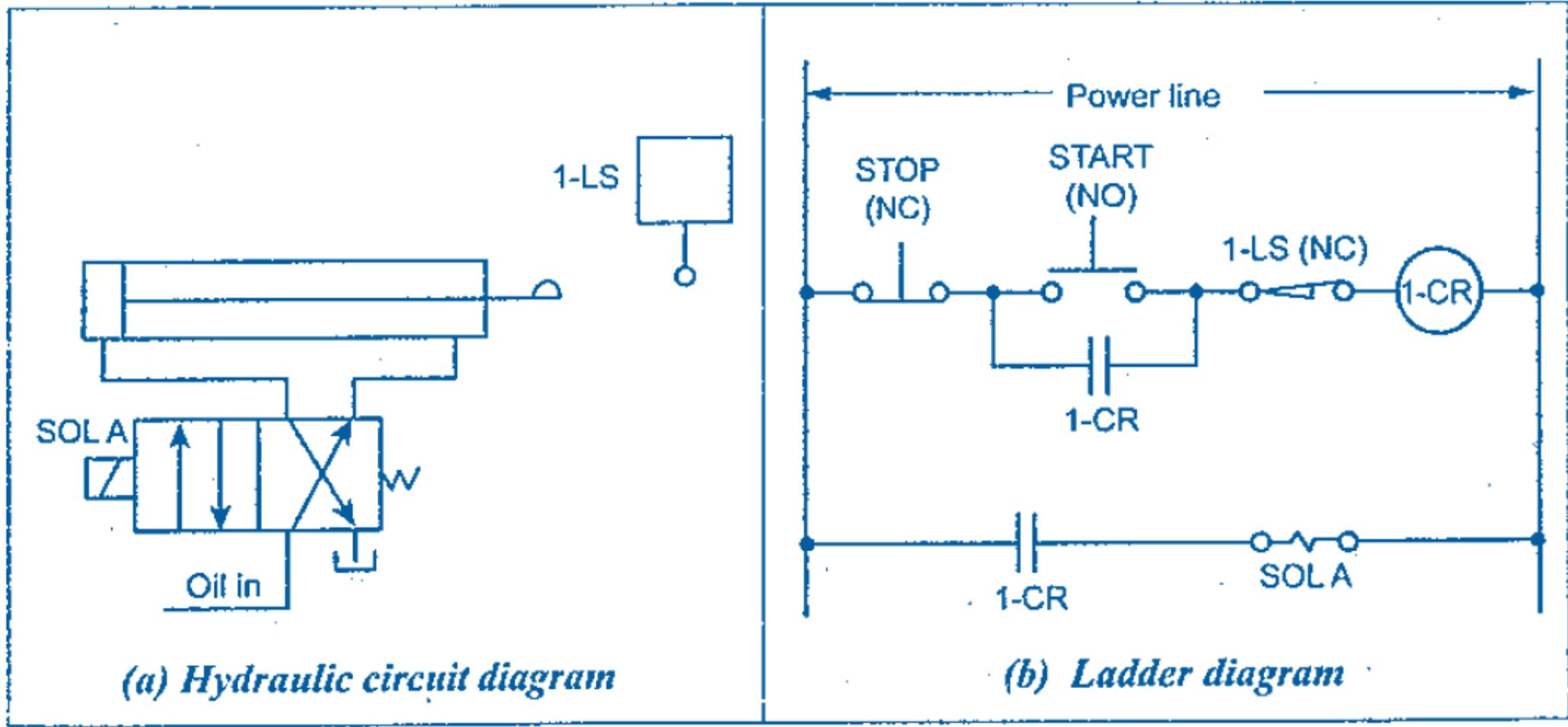


Fig. 9.10. Control of hydraulic cylinder using single limit switch

LADDER DIAGRAM

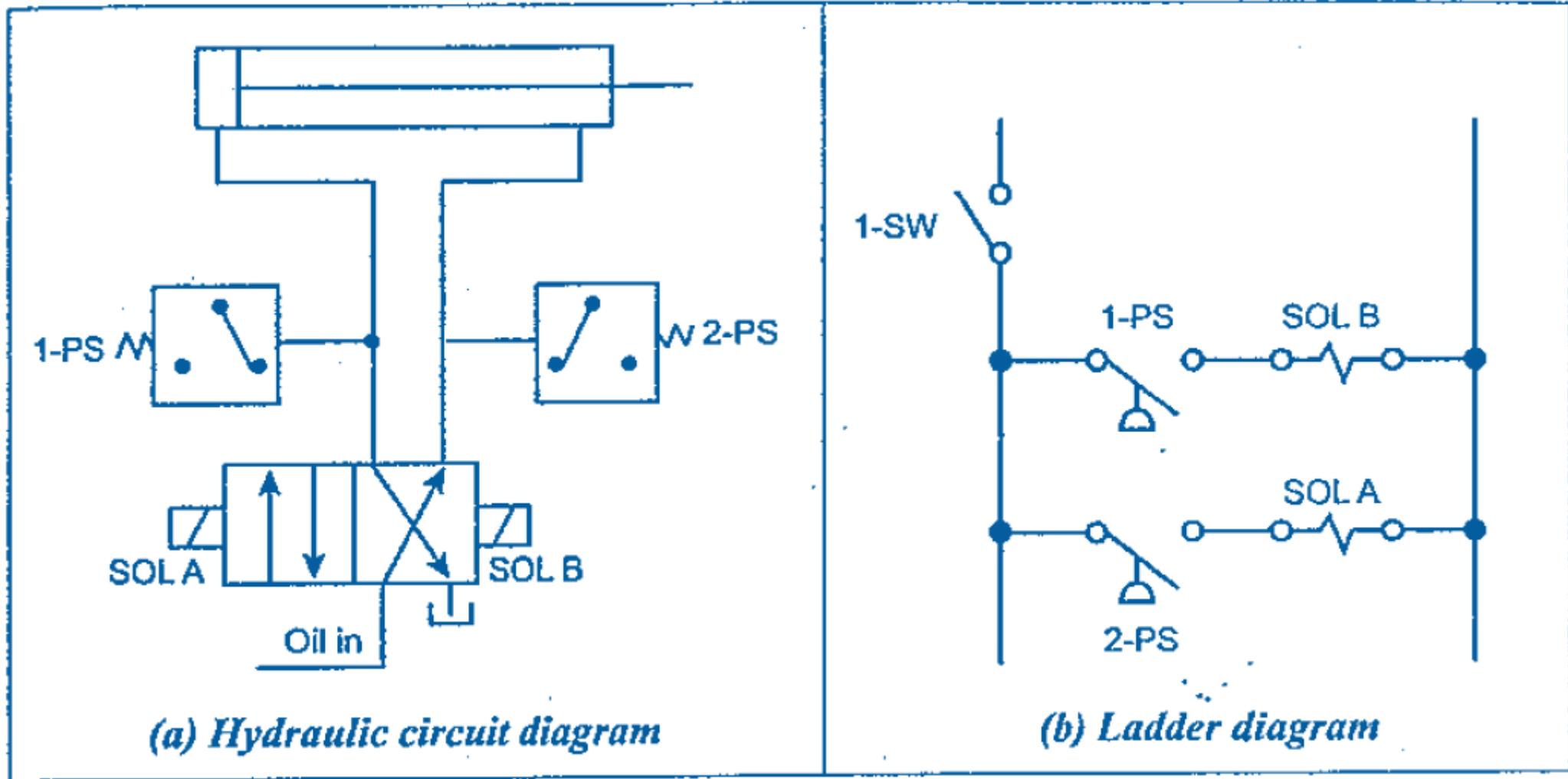


Fig. 9.11. Reciprocation of cylinder using pressure switches

LADDER DIAGRAM

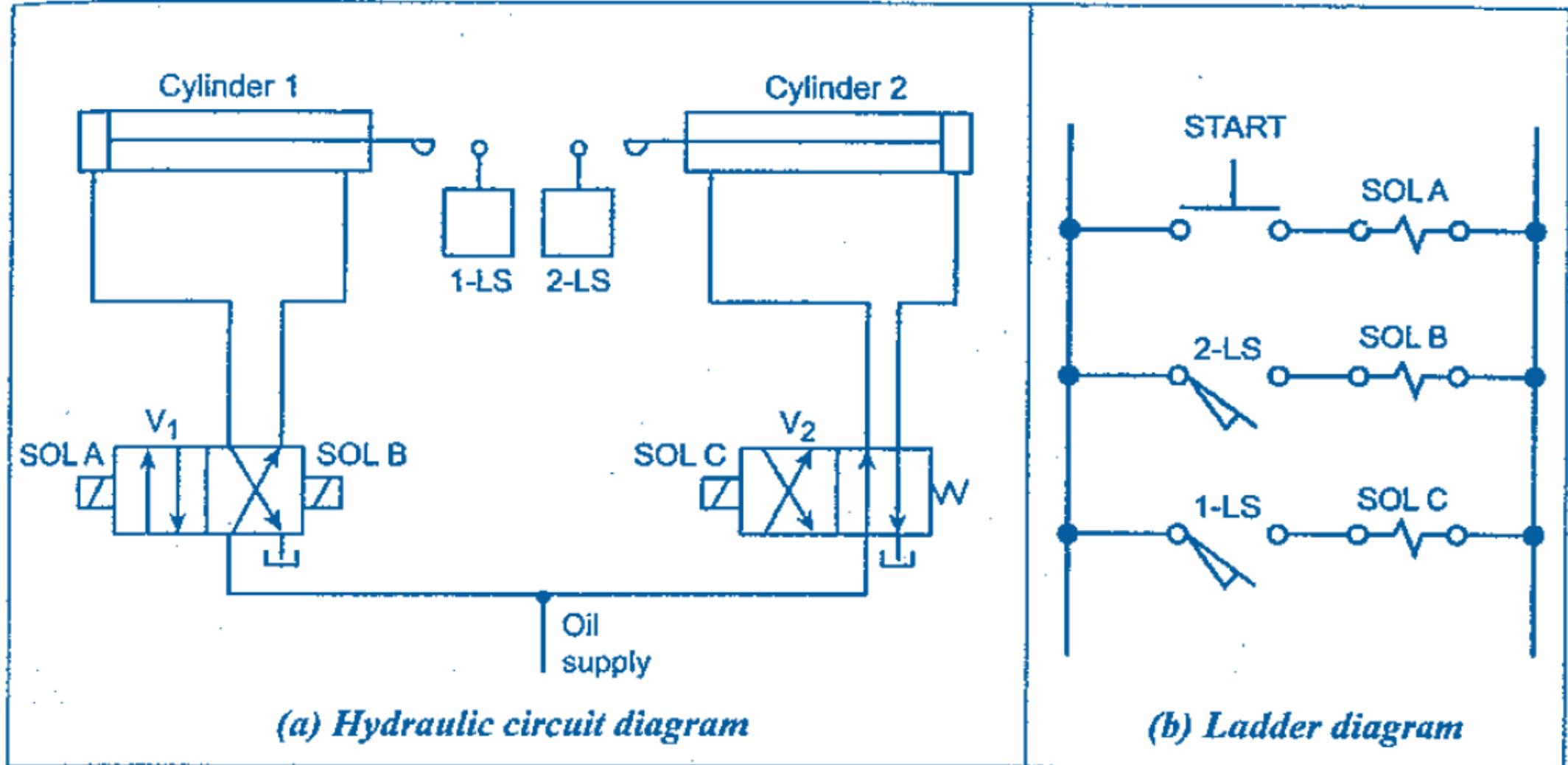


Fig. 9.13. Dual-cylinder sequencing circuit

LADDER DIAGRAM

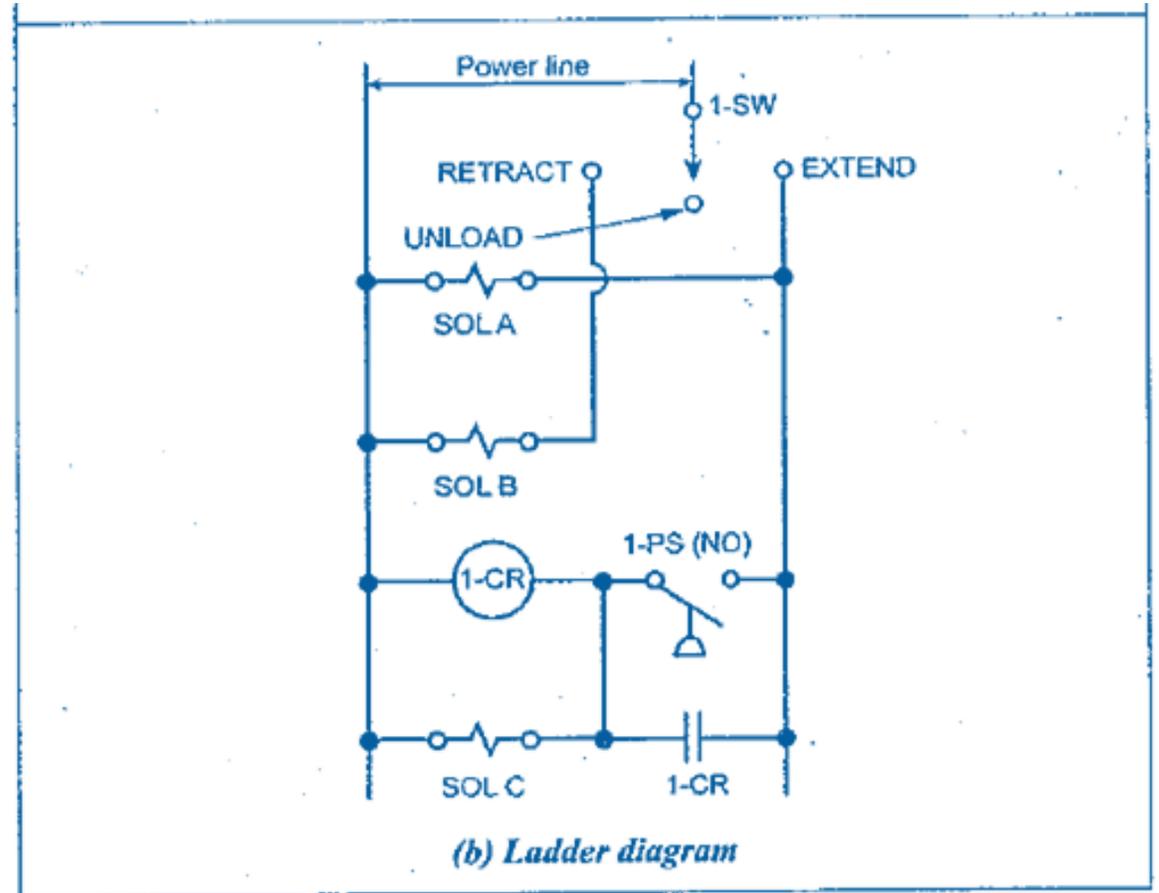
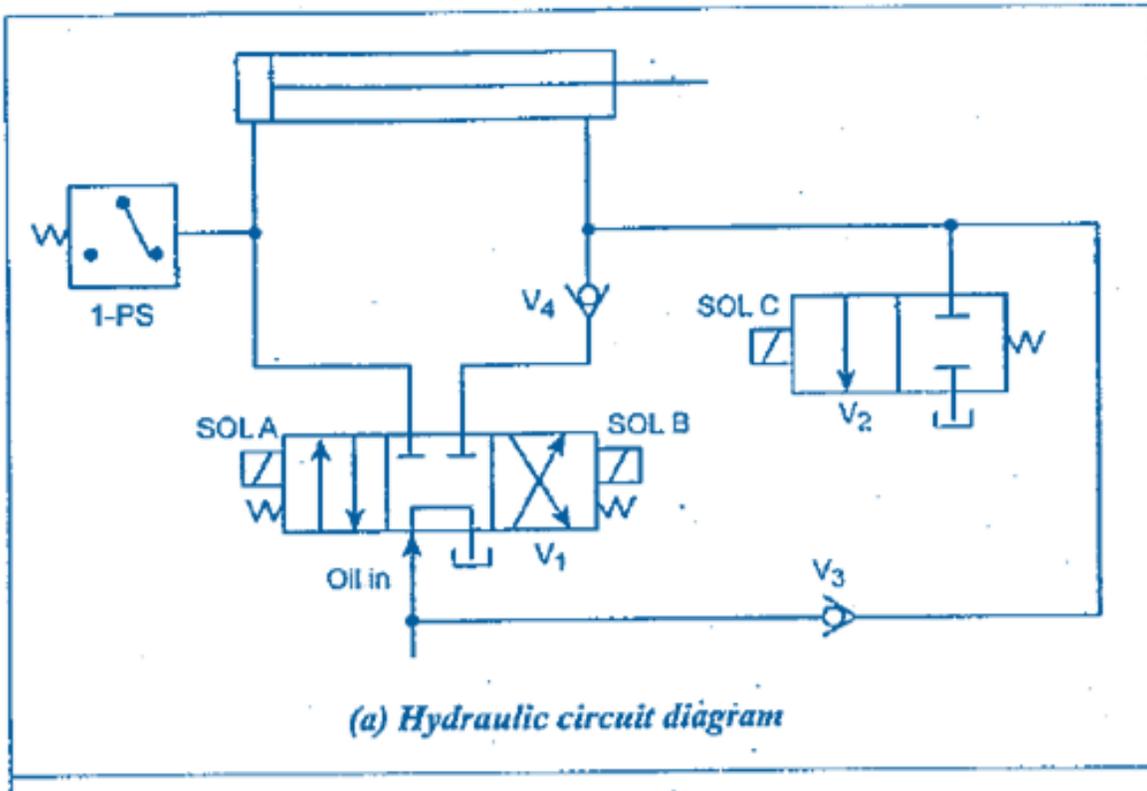


Fig. 9.14. Electrical control of regenerative circuit

KARNAUGH—VEITCH (K-V) MAP METHOD

- The **Karnaugh—Veitch (K-V) Map** Method in fluid power systems is a systematic technique used to simplify sequential operations and design control logic for pneumatic or hydraulic circuits, especially in automation involving multiple actuators (cylinders).
- **Purpose:** It helps design logic control circuits by minimizing Boolean expressions that represent the sequential operation of actuators.
- **Application:** Used when the number of steps or actuators becomes large and complex — the method simplifies the control logic, aiding in the design of electro-pneumatic or electro-hydraulic circuits.

KARNAUGH—VEITCH (K-V) MAP METHOD

- **Advantages:**

Reduces design errors.

Minimizes the number of control components (like relays).

Simplifies wiring and logic understanding.

KARNAUGH—VEITCH (K-V) MAP METHOD

1. Define the Sequence of Operations

- Write down the required sequence of actuator movements.
- Use symbols like A+, A−, B+, B− to indicate actuator extension and retraction.
- Example:

A+ B+ B− C+ A− C−

(Where A, B, C are actuators, + means forward stroke, and − means return stroke)

KARNAUGH—VEITCH (K-V) MAP METHOD

2. Assign Binary Codes to Each Step

- Count the number of steps and determine how many binary digits are needed.
- Example: 6 steps \rightarrow 3 binary bits (as $2^3 = 8$ covers up to 8 steps).
- Assign binary codes:
 - Step 1: 000 \rightarrow A+
 - Step 2: 001 \rightarrow B+
 - Step 3: 010 \rightarrow B-
 - Step 4: 011 \rightarrow C+
 - Step 5: 100 \rightarrow A-
 - Step 6: 101 \rightarrow C-

KARNAUGH—VEITCH (K-V) MAP METHOD

3. Create Truth Tables

- List outputs (A+, A−, B+, etc.) as rows.
- List binary inputs (step codes) as columns.
- Place "1" in the cell where the action occurs at a particular step.

4. Construct Karnaugh Maps (K-Maps)

- Draw a separate K-map for each actuator output.
- Enter "1" in the cells corresponding to the binary code for steps where that output is active.
- For example, the K-map for A+ will have a "1" in the cell for binary 000.

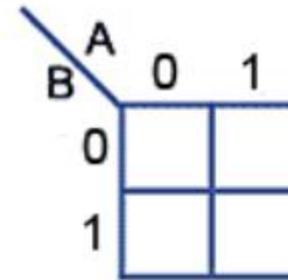
KARNAUGH—VEITCH (K-V) MAP METHOD

4. Construct Karnaugh Maps (K-Maps)

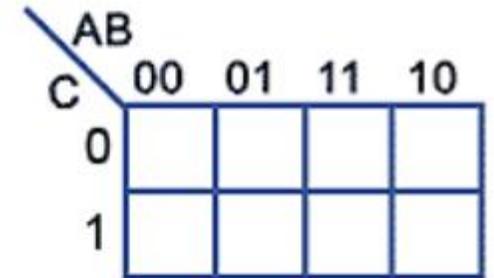
2 input circuits with inputs A and B require maps with $2^2 = 4$ cells (Fig 2.4.1a).

3 input circuits with inputs A B and C require maps with $2^3 = 8$ cells (Fig 2.4.1b).

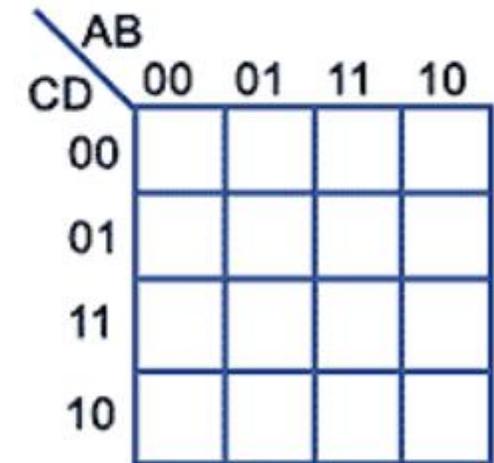
4 input circuits with inputs A B C and D require maps with $2^4 = 16$ cells (Fig 2.4.1c).



(a)



(b)



(c)

Fig.2.4.1 Karnaugh Maps

KARNAUGH—VEITCH (K-V) MAP METHOD

4. Construct Karnaugh Maps (K-Maps)

A	B	Output
0	0	α
0	1	β
1	0	γ
1	1	δ

		B	
		0	1
A	0	α	β
	1	γ	δ

KARNAUGH—VEITCH (K-V) MAP METHOD

5. Group the 1s in the K-Maps

- Group the 1s into powers of 2 (1, 2, 4...) to simplify the logic.
- Follow standard K-map grouping rules (adjacent cells, horizontal/vertical wraparound allowed).

MC \ A	00	01	11	10
0			1	1
1		1	1	1

4 Typical Karnaugh Groups

6. Derive Simplified Boolean Expressions

- From each K-map, write the minimized Boolean equation for the output.
- These equations determine when each actuator should be activated.

7. Design the Control Circuit

- Use the simplified Boolean expressions to design the relay logic or PLC program.
- Connect outputs to solenoid valves that control the actuators.