Lecture 6

PLC programming

LOGICAL ACTUATORS

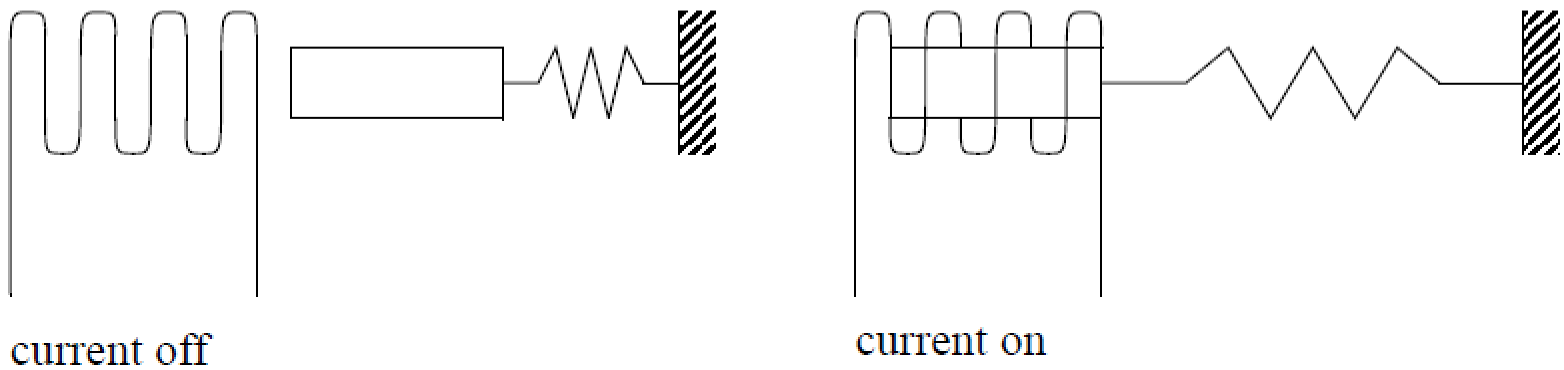
Topics:

- Solenoids, valves and cylinders
- Hydraulics and pneumatics

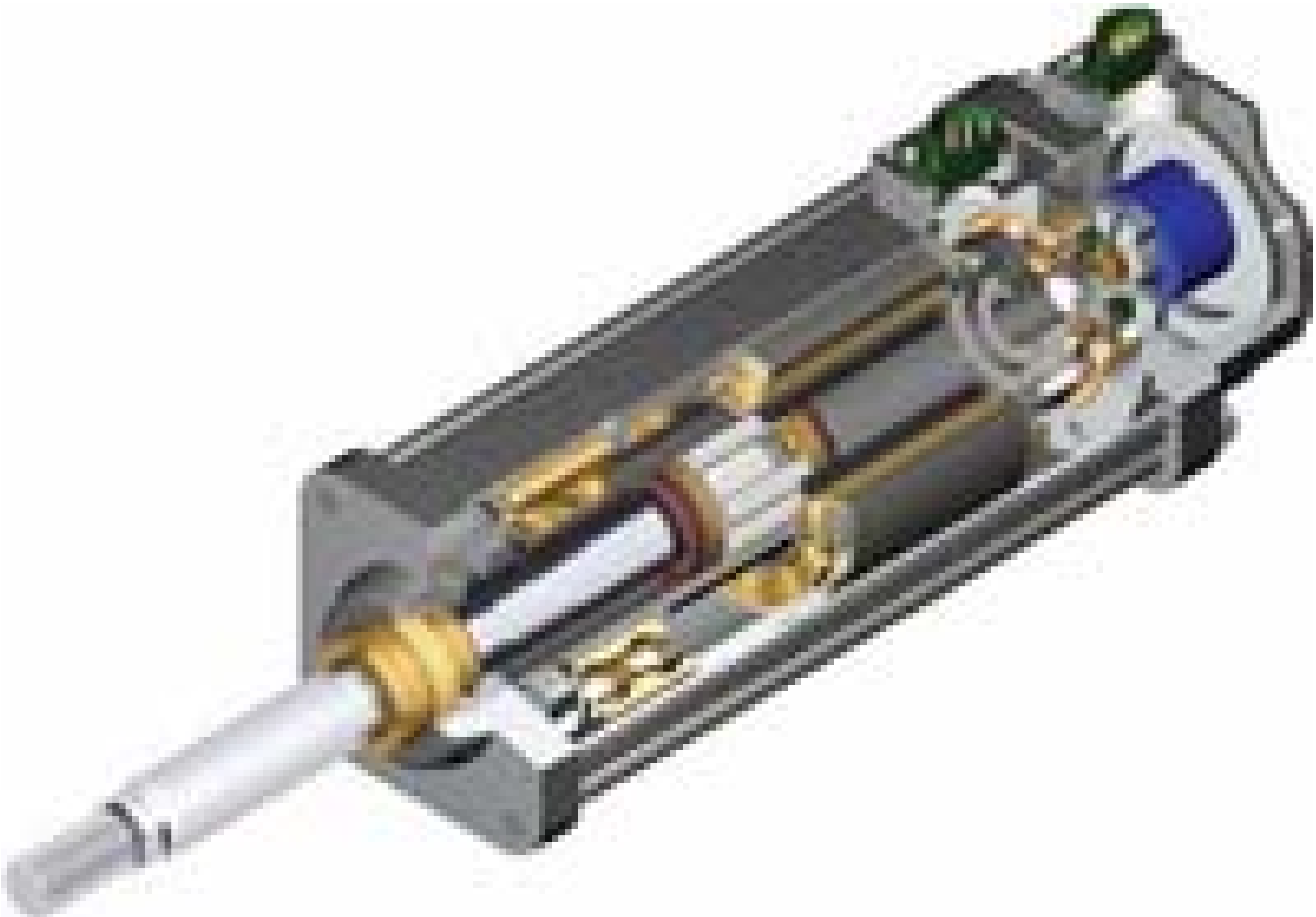
Objectives:

- To have knowledge about various actuators available.

- **Actuators** Drive motions in mechanical systems. Most often this is by converting electrical energy into some form of mechanical motion.
- **Solenoids** are the most common actuator components.
- The basic principle of operation is there is a moving ferrous core (a piston) that will move inside wire coil as shown below.

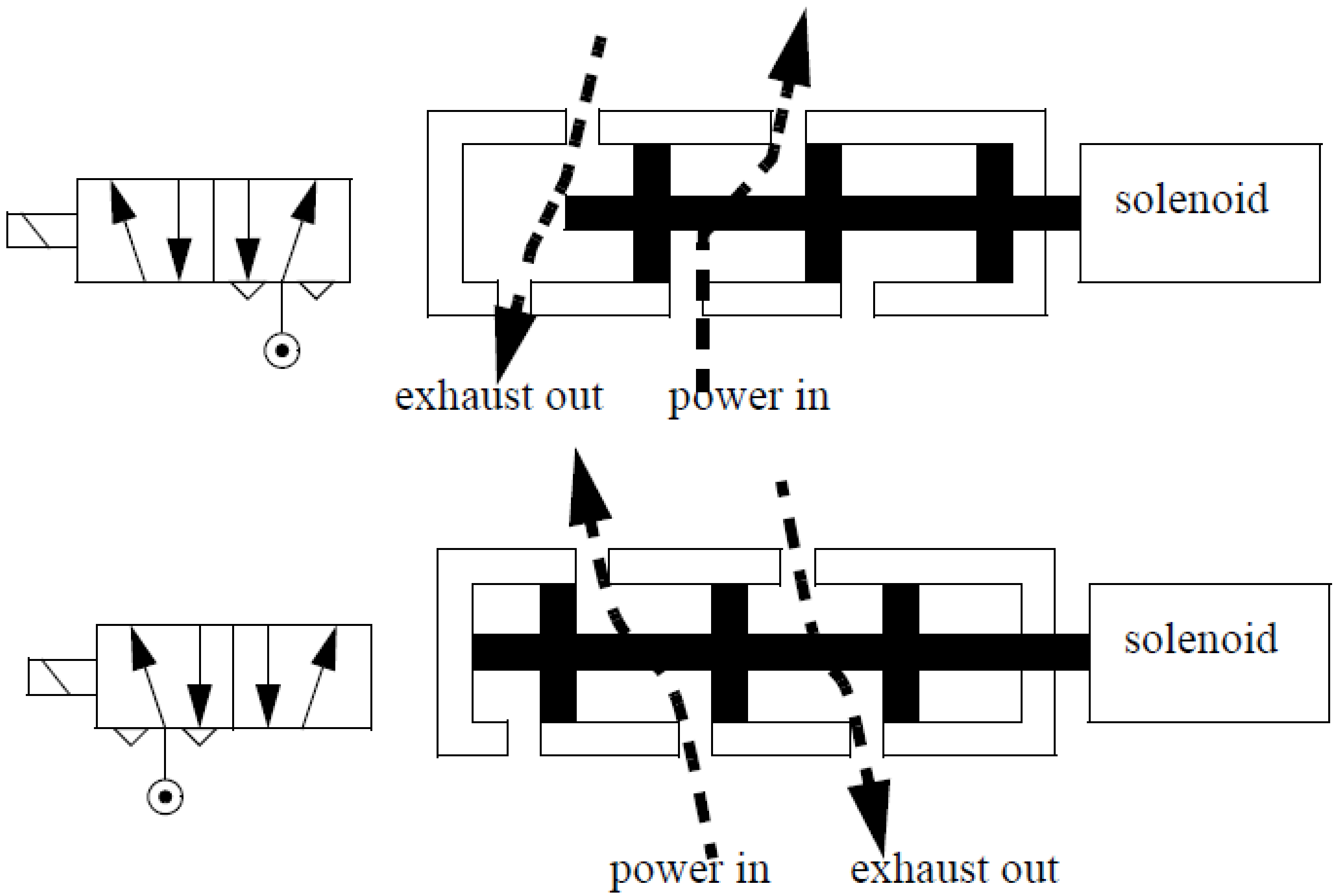


- Normally the piston is held outside the coil by a spring.
- When a voltage is applied to the coil and current flows, the coil builds up a magnetic field that attracts the piston and pulls it into the center of the coil.
- The piston can be used to supply a linear force.
- Well known applications of these include pneumatic values and car door openers.
- Most industrial applications have low enough voltage and current ratings they can be connected directly to the PLC outputs.
- Most industrial solenoids are powered by 24Vdc and draw a few hundred mA.



VALVES

The flow of fluids and air can be controlled with solenoid controlled valves. An example of a solenoid controlled valve is shown below.



A Solenoid Controlled 5 Ported, 4 Way 2 Position Valve

- The solenoid is mounted on the side.
- When actuated it will drive the central spool left.
- The top of the valve body has two ports that will be connected to a device such as a hydraulic cylinder.
- The bottom of the valve body has a single pressure line in the center with two exhausts to the side.
- In the top drawing the power flows in through the center to the right hand cylinder port.
- The LH cylinder port is allowed to exit through an exhaust port.
- In the bottom drawing the solenoid is in a new position and the pressure is now applied to the left hand port on the top, and the right hand port can exhaust.

- The symbols to the left of the figure show the schematic equivalent of the actual valve positions.
- Valves are also available that allow the valves to be blocked when unused.

- In the standard terminology, the ’n-way’ designates the number of connections for inlets and outlets.
- In some cases there are redundant ports for exhausts.
- The normally open/closed designation indicates the valve condition when power is off.
- Some valves are listed below.

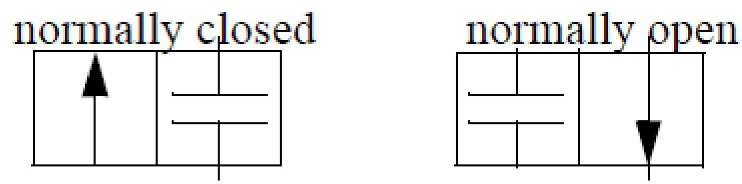
1. 2-way normally closed - these have one inlet, and one outlet. When unenergized, the valve is closed. When energized, the valve will open, allowing flow. These are used to permit flows.

2. 2-way normally open - these have one inlet, and one outlet. When unenergized, the valve is open, allowing flow. When energized, the valve will close. These are used to stop flows. When system power is off, flow will be allowed.
3. 3-way normally closed - these have inlet, outlet, and exhaust ports. When unenergized, the outlet port is connected to the exhaust port. When energized, the inlet is connected to the outlet port. These are used for single acting cylinders.
4. 3-way normally open - these have inlet, outlet and exhaust ports. When unenergized, the inlet is connected to the outlet. Energizing the valve connects the outlet to the exhaust. These are used for single acting cylinders

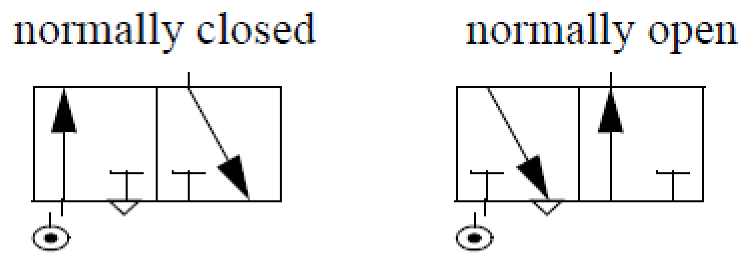
5. 3-way universal - these have three ports. One of the ports acts as an inlet or outlet, and is connected to one of the other two, when energized/unenergized. These can be used to divert flows, or select alternating sources.
6. 4-way - These valves have four ports, two inlets and two outlets. Energizing the valve causes connection between the inlets and outlets to be reversed. These are used for double acting cylinders.

- Some valve symbols are shown below.
- When using the symbols in drawings the connections are shown for the unenergized state.
- The arrows show the flow paths in different positions.
- The small triangles indicate an exhaust port.

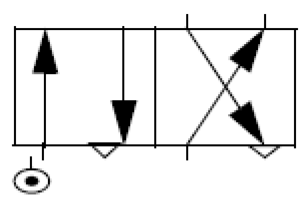
Two way, two position



Three way, two position



Four way, two position



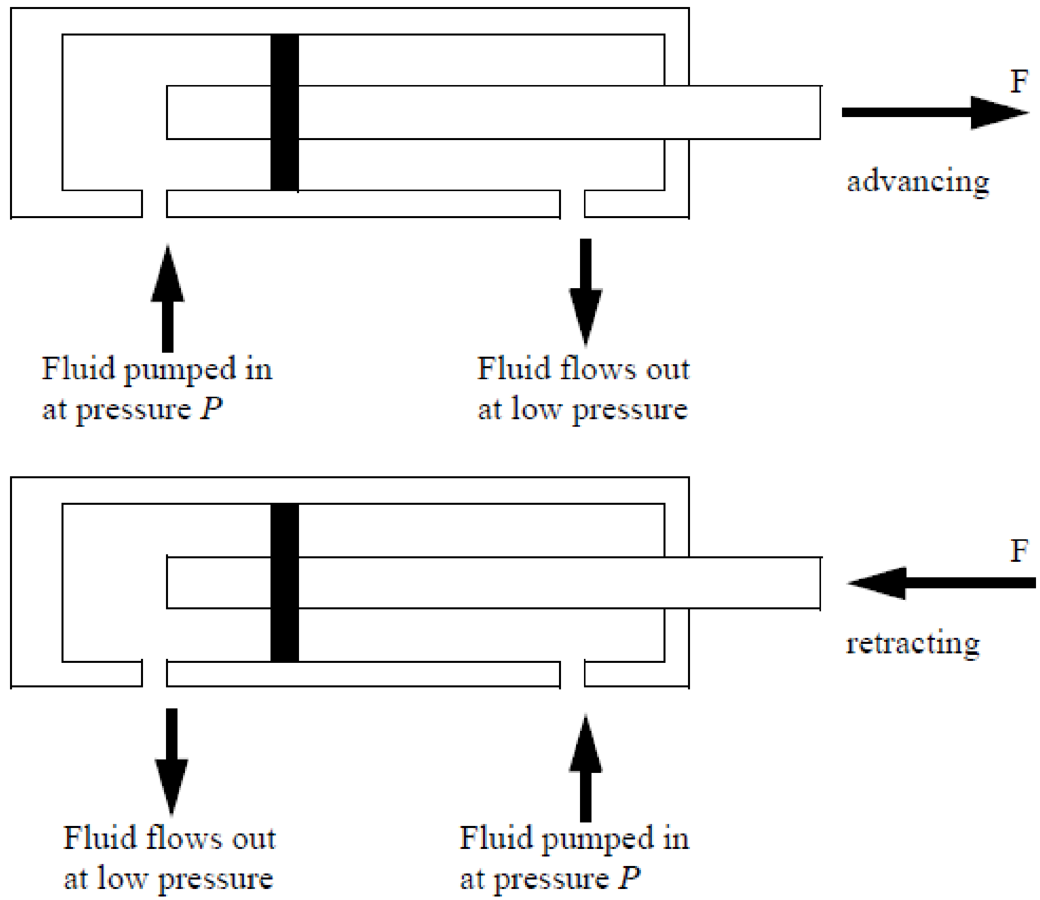
When selecting valves there are a number of details that should be considered, as listed below.

1. Pipe size - inlets and outlets are typically threaded to accept NPT (national pipe thread).
2. Flow rate - the maximum flow rate is often provided to hydraulic valves.
3. Operating pressure - a maximum operating pressure will be indicated. Some valves will also require a minimum pressure to operate.
4. Electrical - the solenoid coil will have a fixed supply voltage (AC or DC) and current.

5. Response time - this is the time for the valve to fully open/close. Typical times for valves range from 5ms to 150ms.
6. Enclosure - the housing for the valve will be rated as,
   - type 1 or 2 - for indoor use, requires protection against splashes
   - type 3 - for outdoor use, will resists some dirt and weathering
   - type 3R or 3S or 4 - water and dirt tight
   - type 4X - water and dirt tight, corrosion resistant

CYLINDERS

- A cylinder uses pressurized fluid or air to create a linear force/motion as shown below.



- In the figure a fluid is pumped into one side of the cylinder under pressure, causing that side of the cylinder to expand, and advancing the piston.
- The fluid on the other side of the piston must be allowed to escape freely.
- If the incompressible fluid was trapped the cylinder could not advance.
- The force the cylinder can exert is proportional to the cross sectional area of the cylinder.

- Cylinder force (F)

$$F = PA$$

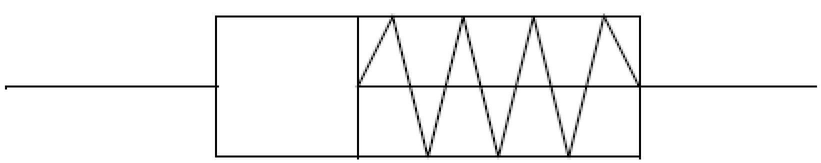
Where: P = the pressure of the hydraulic fluid

A = the area of the piston

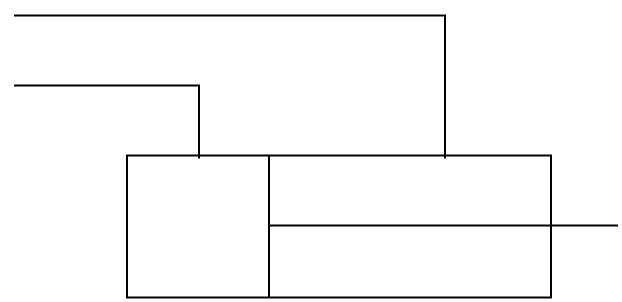
F = the force available from the piston rod

- Single acting cylinders apply force when extending and typically use a spring to retract the cylinder.
- Double acting cylinders apply force in both direction.

single acting spring return cylinder



double acting cylinder

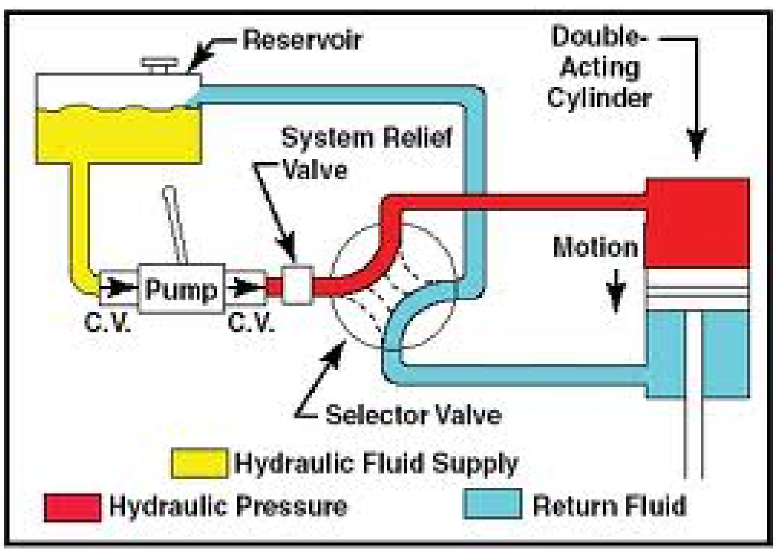


HYDRAULICS

- Hydraulics use incompressible fluids to supply very large forces at slower speeds and limited ranges of motion.
- If the fluid flow rate is kept low enough, many of the effects predicted by Bernoulli's equation can be avoided.
- The system uses hydraulic fluid (normally an oil) pressurized by a pump and passed through hoses and valves to drive cylinders.
- At the heart of the system is a pump that will give pressures up to hundreds or thousands of psi.
- These are delivered to a cylinder that converts it to a **linear force and displacement.**

Hydraulic systems normally contain the following components:

1. Hydraulic Fluid
2. An Oil Reservoir
3. A Pump to Move Oil, and Apply Pressure
4. Pressure Lines
5. Control Valves - to regulate fluid flow
6. Piston and Cylinder - to actuate external mechanisms



- The hydraulic fluid is often a noncorrosive oil chosen so that it lubricates the components.
- A flow regulator is normally placed at the high pressure outlet from the pump.
- If fluid is blocked in other parts of the system this will allow fluid to re-circulate back to the reservoir to reduce wear on the pump.
- The high pressure fluid is delivered to solenoid controlled valves that can switch fluid flow on or off.
- From the valves fluid will be delivered to the hydraulics at high pressure, or exhausted back to the reservoir.
- Hydraulics can be very effective for high power applications, but the use of fluids, can make mess and noise for other applications.

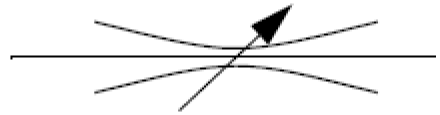
PNEUMATICS

- Pneumatic systems have much in common with hydraulic systems with a few key differences.
- The reservoir is eliminated as there is no need to collect and store the air between uses in the system.
- Air is a gas and it is compressible and regulators are not needed to re-circulate flow. But, the compressibility also means that the systems are not as stiff or strong.
- Pneumatic systems respond very quickly, and are commonly used for low force applications in many locations on the factory floor.

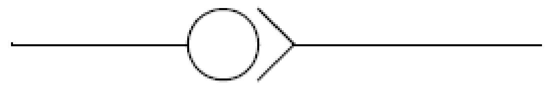

Some basic characteristics of pneumatic systems are:

1. Stroke from a few millimeters to meters in length
2. The actuators will give a bit - they are springy
3. Pressures are typically up to 85psi above normal atmosphere
4. The weight of cylinders can be quite low
5. Additional equipment is required for a pressurized air supply- linear and rotary actuators are available.
6. Dampers can be used to cushion impact at ends of cylinder travel.

Some symbols for pneumatic systems are shown below..

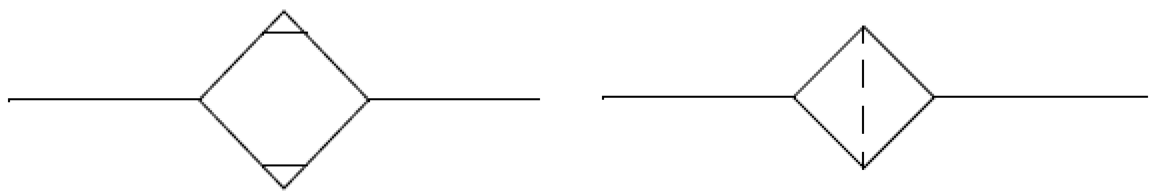


Flow control valve (restrict the flow) or to slow motions

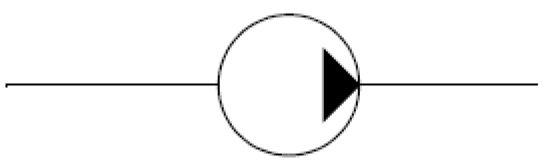


Shuttle valve allows flow in one direction, but blocks it in the other.

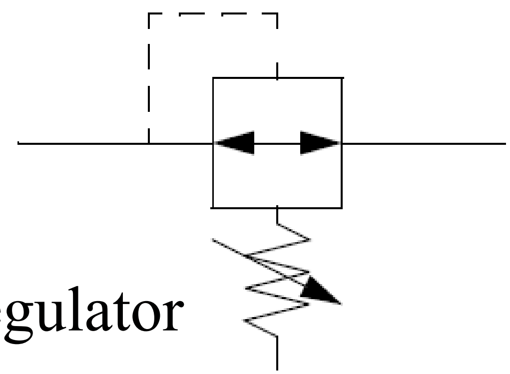
Receiver tank (allows pressurized air to be accumulated)



Dryer and filter help remove dust and moisture from the air, prolonging the life of the valves and cylinders.



Pump



Pressure regulator

Other actuators

There are many other types of actuators, some are listed below.

- **Heaters** - They are often controlled with a relay and turned on and off to maintain a temperature within a range (part washers).
- **Lights** - Lights are used on almost all machines to indicate the machine state and provide feedback to the operator. Most lights are low current and are connected directly to the PLC.

- **Sirens/Horns** - Sirens or horns can be useful for unattended or dangerous machines to make conditions well known. These can often be connected directly to the PLC.
- **Computers** - some computer based devices may use TTL 0/5V logic levels to trigger actions. Generally these are prone to electrical noise and should be avoided if possible.

Example 1: A piston is to be designed to exert an actuation force of 120 lbs on its extension stroke. The inside diameter of the cylinder is 2.0” . What air pressure will be required to provide this actuation force?

$A = \pi r^2 = 3.14159 \text{ in}^2$

$P = F/A = 120/3.14159 = 49.7 \text{ psi}$

Example 2: Draw a simple hydraulic system that will advance and retract a cylinder using PLC outputs. Sketches should include details from the PLC output card to the hydraulic cylinder.