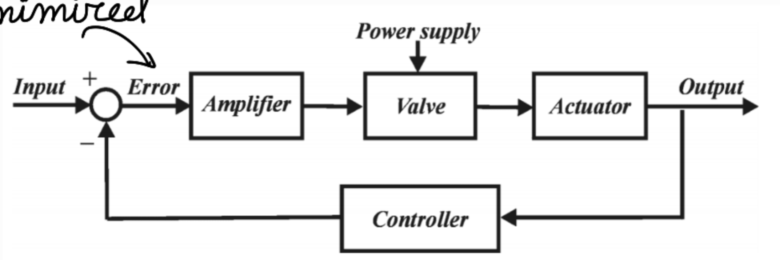
# Control systems

<u>Servo</u> control systems
↳ amplified input signal (Conditioning)
↳ Feedback signal from output to input

Minimized




Follow – up System

**valve operated servo**

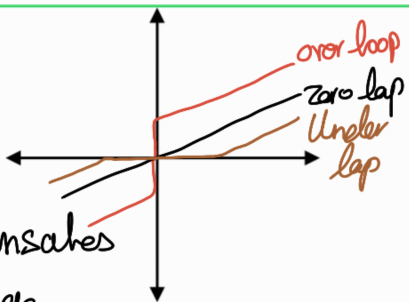
- lower power applications
- operates with a constant or variable displacement pump
- Inefficient since valve acts as an orifice which increases resistance in the system → Temp ↑
- feed back is to valve
- Spool valve can be:
  - zero lap
  - under lap
  - over lap

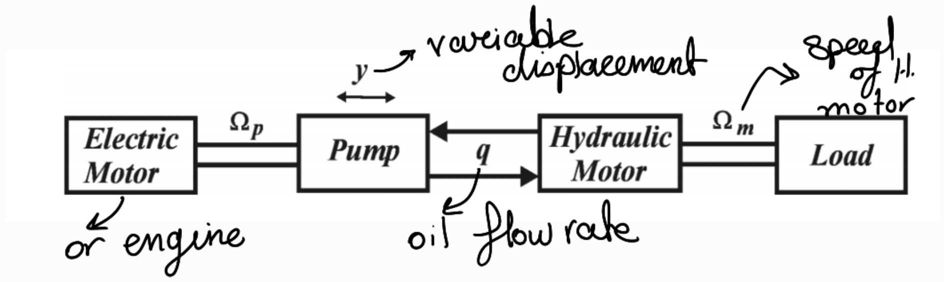
  } See Book

**pump operated servo**

- large power applications
- feed back to the pump
- pump displacement is changed
- Good for high inertia loads
- higher efficiency since less friction
- used for hydrostatic power transmission

- Zero lap : hard to achieve so overlap with notches are used
- Underlap : null point → spool is in midpoint
  Gives high response at null point / compensates for loss in fluid when there is leakage






## Conditions of system

1- No leakage, No compressibility effect
2- leakage, No compressibility effect
3- leakage, compressibility effect

## 1- No leakage, No compressibility effect

$$q_{pump} = q_{motor}$$

$$\Omega_p d_p = \Omega_m d_m$$

$\Omega$: angular speed; $d$: displacement/rad

$$q_{pump} = K_p y$$

$K_p$: pump flow constant; $y$: displacement

So $\frac{\Omega_m}{y} = \frac{K_p}{d_m}$ → constants ($\frac{\Omega_m}{y}$: outputs)

Ideal but not real


## 2- leakage, No compressibility effect

$\lambda_p$: pump leakage coefficient
$\lambda_m$: motor leakage coefficient

Pump leakage $= \lambda_p P_p$

$$q_p = K_p y - \lambda_p P_p$$

Motor leakage $= \lambda_m P_m$

$$q_m = \Omega_m d_m = q_p - \lambda_m P_m$$

$$\Omega_m d_m = K_p y - \lambda_p P_p - \lambda_m P_m$$

- Pressure drop is negligible → $P_p = P_m = P$

- leakage coefficient : $\lambda = \lambda_p + \lambda_m$

So, $q_m = K_p y - \lambda P$

- Output power $= T_m \Omega_m = P\, q_m$ ($q_m$ → $\Omega_m d_m$)

→ $T_m = P\, d_m = \frac{d\Omega_m}{dt} I$ (See Book p69)

- Transfer function $= \frac{\Omega_m(s)}{y(s)} = \frac{K_p}{d_m}\left(\frac{1}{1+\tau s}\right)$ , $\tau = \frac{\lambda I}{d_m^2}$

Gain ($\frac{K_p}{d_m}$); low pass filter

3- leakage, compressibility effect

Bulk modulus : measures flexibility of fluids

$$B = \frac{\text{Volumetric stress}}{\text{Volumetric strain}} = \frac{P}{\Delta V / V}$$

V → original volume of fluid between pump & motor

$$q_c = \left(\frac{V}{B}\right)\frac{dP}{dt}$$

$q_c$ → flow rate loss due to comp.

$$\Omega_m d_m = K_p y - \lambda P - \left(\frac{V}{B}\right)\frac{dP}{dt}$$ (See Book p71)

$$\frac{\Omega_m(s)}{y(s)} = \frac{K_p}{d_m}\left(\frac{B d_m^2 / VI}{s^2 + (\lambda B/V)s + (B d_m^2/VI)}\right)$$

$(B d_m^2/VI)$ → $\sqrt{\omega}$

We want to increase $\omega$ ⇒ (See Book p72)

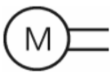
Taking $d_m$ → 1 radians : $T_m = K_H \times \theta$ → angle of rotation = 1 rad

($K_H$: hydraulic stiffness)

So $\omega = \sqrt{\dfrac{B d_m^2}{V I}}$

make motor closer to pump → $V \downarrow$ → $\omega \uparrow$

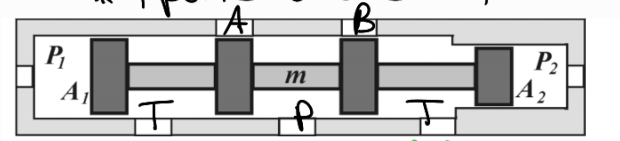
## Fluid power symbols

| Symbol | Definition |
|---|---|
|  | Single direction, fixed displacement pump |
|  | Reversible, fixed displacement pump |
|  | Reversible, variable displacement pump |
|  | Air compressor |
|  | Electric motor |
|  | Internal combustion engine |

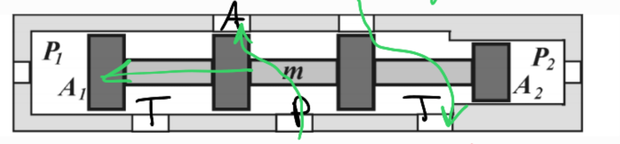
| Symbol | Definition |
|---|---|
|  | Main line — high pressure |
|  | Pilot line — low pressure |
|  | Enclosure outline — grouping |
|  | Hydraulic flow direction |
|  | Pneumatic flow direction |
|  | Flexible pipe line — بربيش |
|  | Constant flow restriction — محبس |
|  | Variable flow restriction (متغير) |
|  | Pressure Compenation (small perpendicular arrow) |
|  | Temperature effect |
|  | Vented reservoir (hydraulic) |

3 positions, 4 ports, spring centered, solenoid controlled valve

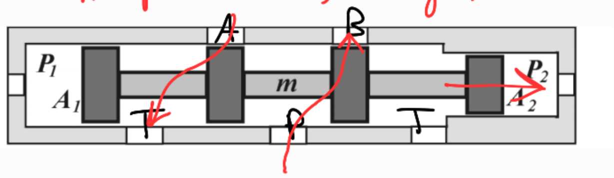
* 4 ports are closed

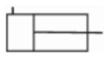
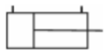
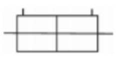
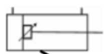


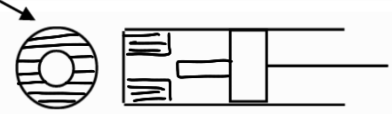

* Spool to the left

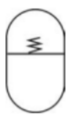
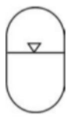
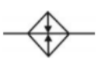
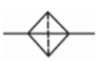


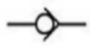
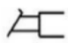
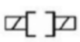
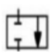
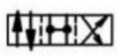

* Spool to the right




| Symbol | Definition |
|---|---|
|  | Single direction, fixed displacement hydraulic motor |
|  | Reversible, fixed displacement hydraulic motor |
|  | Reversible, variable displacement hydraulic motor |
|  | Single acting spring loaded actuator |
|  | Simplified symbol of single acting actuator |
|  | Double acting, single end rod actuator |
|  | Double acting, double end rod actuator |
|  | Double acting actuator with adjastable cushion |



| Symbol | Definition |
|---|---|
|  | Potential energy لتخزين ال<br>Spring loaded accumulator |
|  | Gas loaded accumulator |
|  | Heater |
|  | Cooler |
|  | Filter or strainer |
|  | Pressure indicator |
|  | Temperature indicator |
|  | Filter Regulator Lubricator (FRL) → pneumatic<br>unit كاملة |

| Symbol | Definition |
|---|---|
|  | Butterfly manual ON-OFF valve |
|  | Non return (check) valve |
|  | يخفف الضغط<br>Pressure relief valve |
|  | Manual hand control |
|  | Pedal foot control |
|  | ضغط زيت او هوا<br>Pressure pilot control<br>يحرك ال spool |
|  | electric solenoid control |
|  | One position of a control valve |
|  | Two position four port valve |
|  | Three position four port valve |