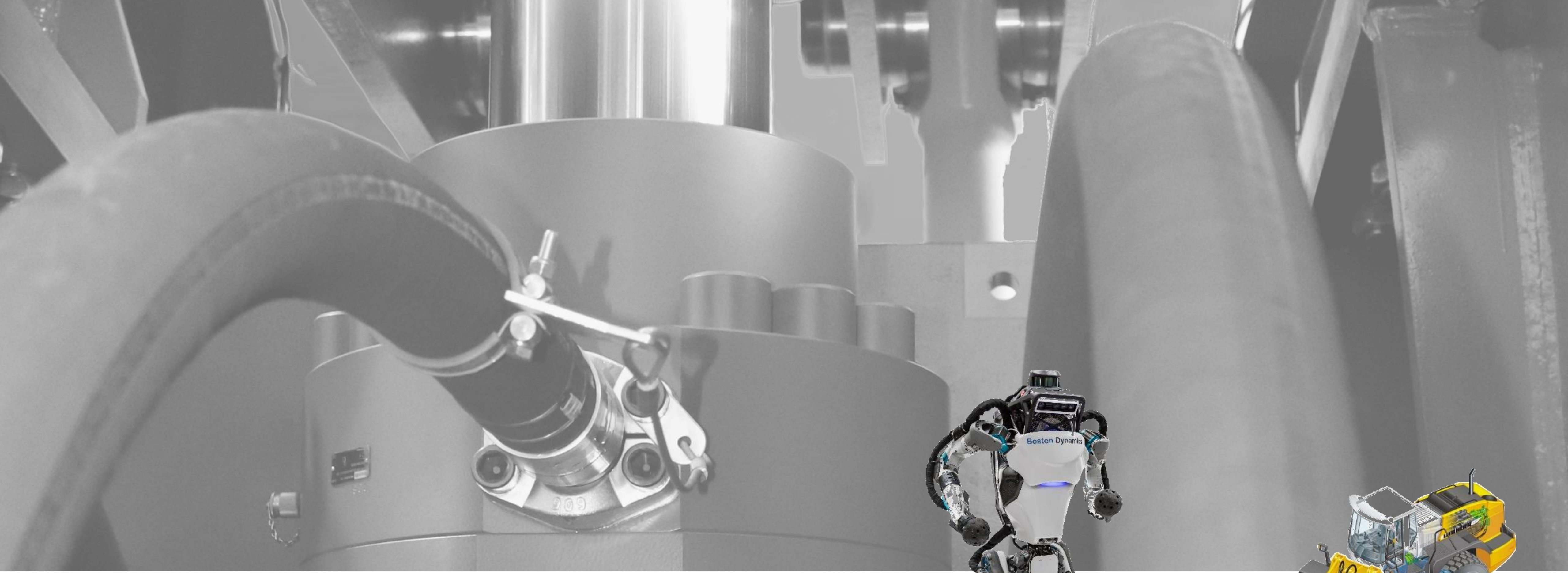


Fundamentals of Fluid Power

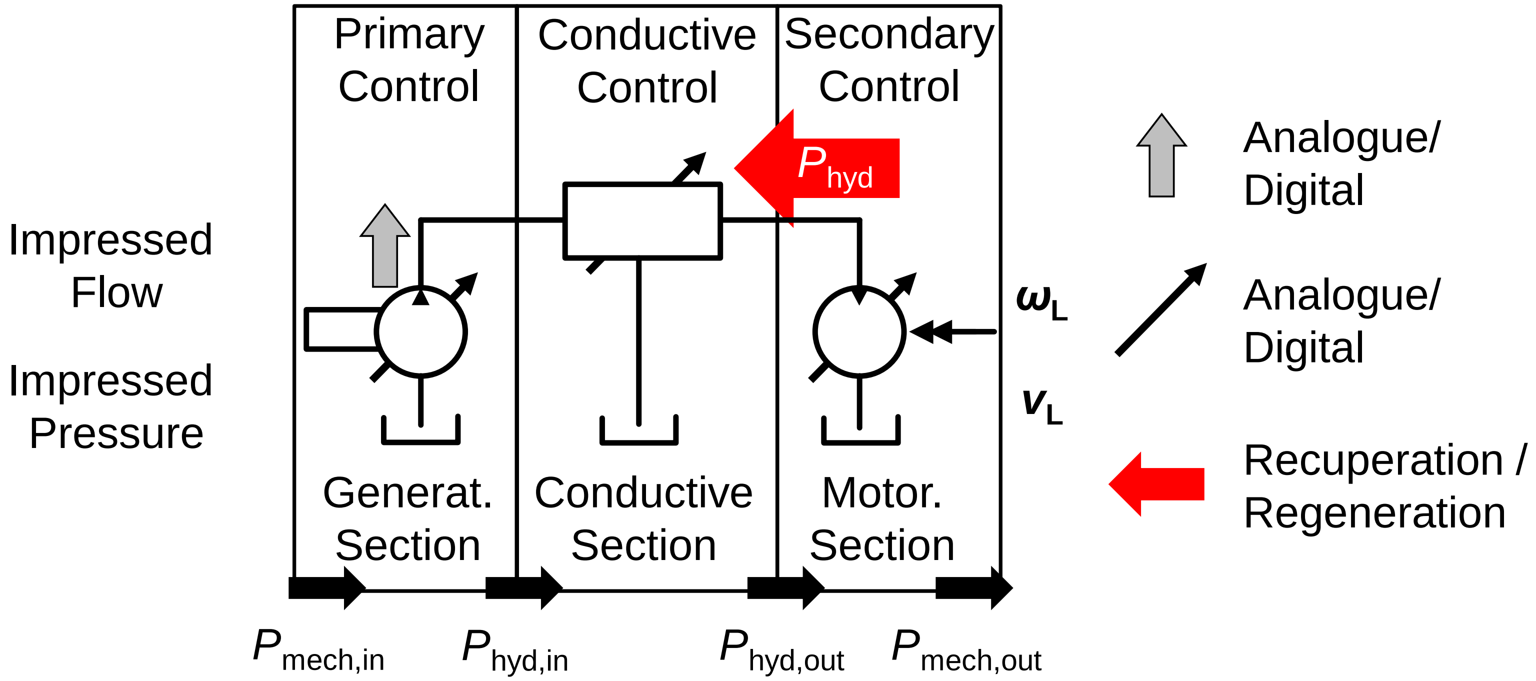
Lecture 9 – Fluid Power Systems

Univ.-Prof. Dr.-Ing. Katharina Schmitz
Winter 2019/2020

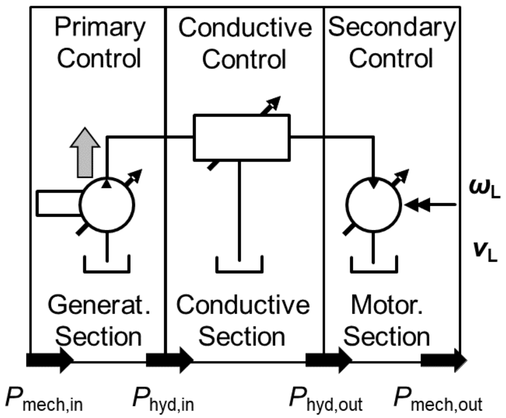
ifas Institute for Fluid Power Drives and Systems
RWTH AACHEN UNIVERSITY

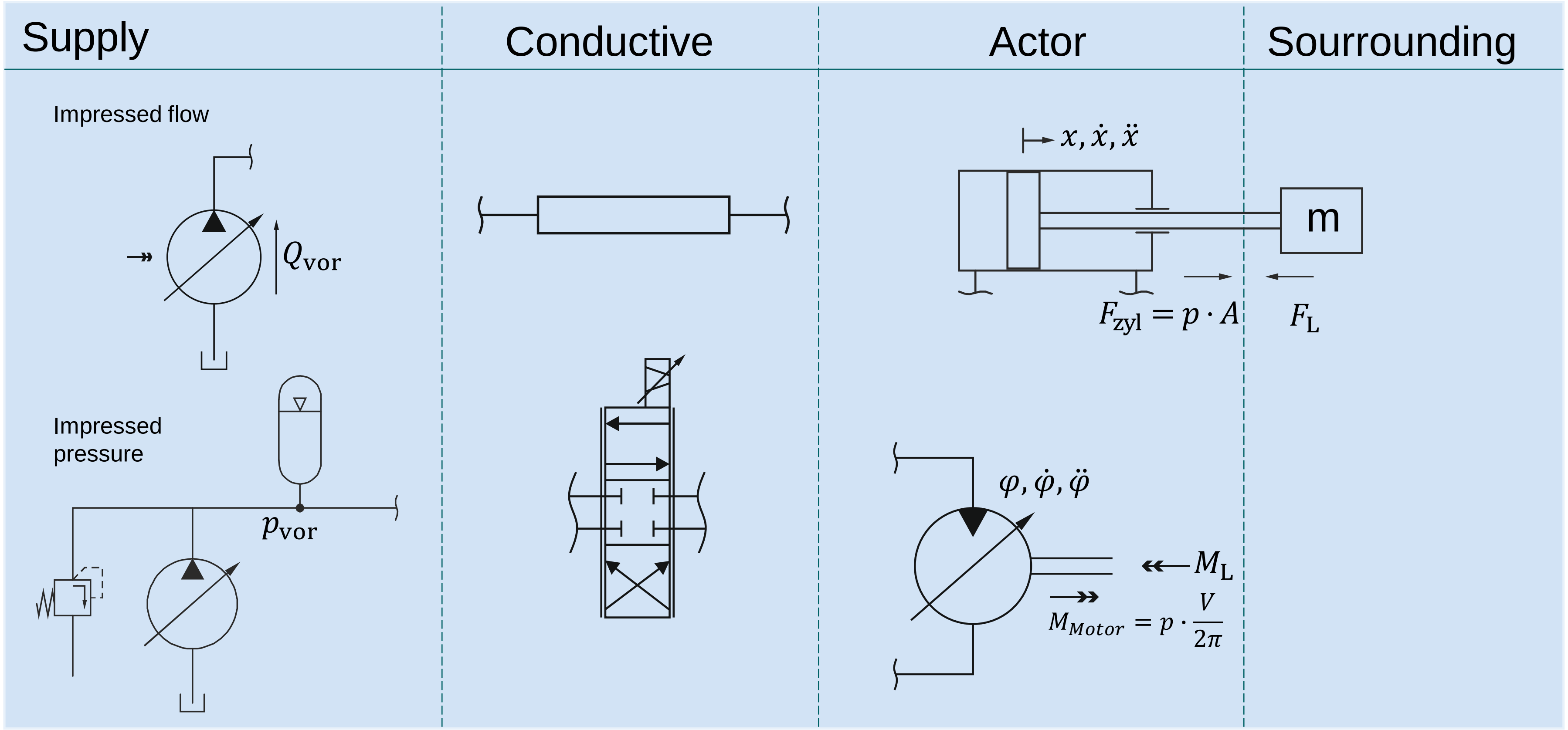
Outline of todays lecture

Structure of hydraulic systems



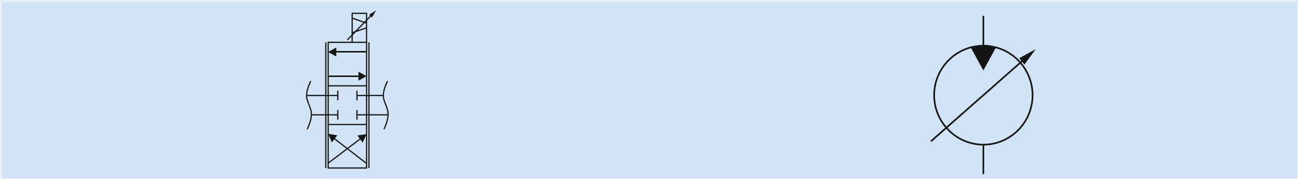
Structure of hydraulic systems





Classification of hydraulic controls

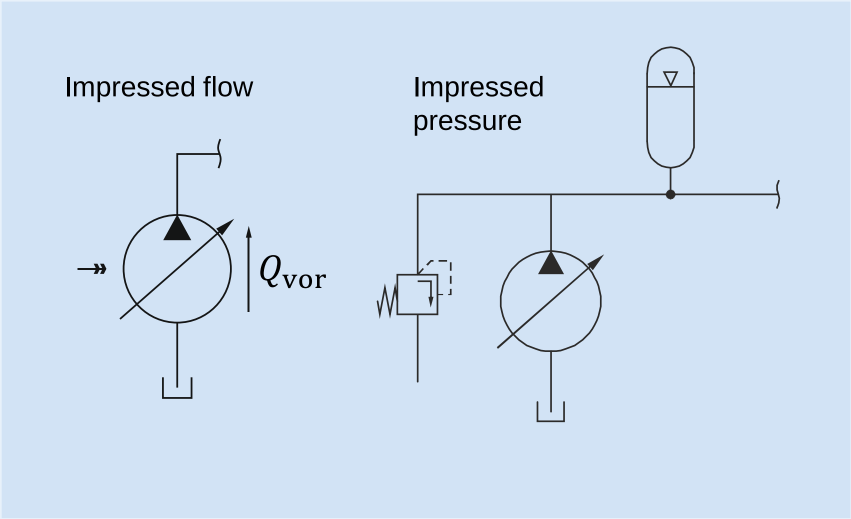
- Classification of systems in 4 quadrans
  - Supply:
    - Impressed flow
    - Impressed pressure
  - Control:
    - Resistance control
    - Displacement control



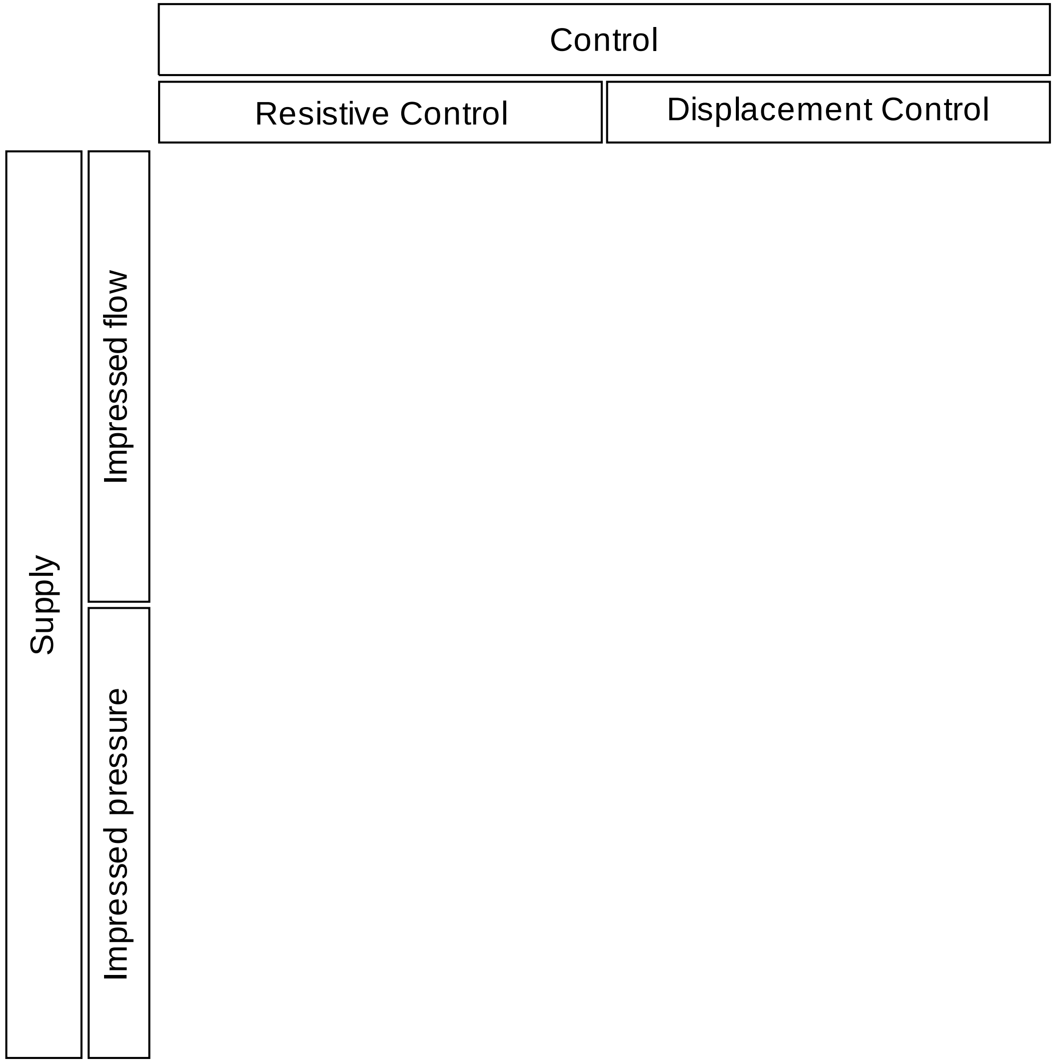
Control

Supply	Resistance	Displacement
Flow	I	III
Pressure	II	IV

4 Quadrans



Classification of common types of hydrauli controls



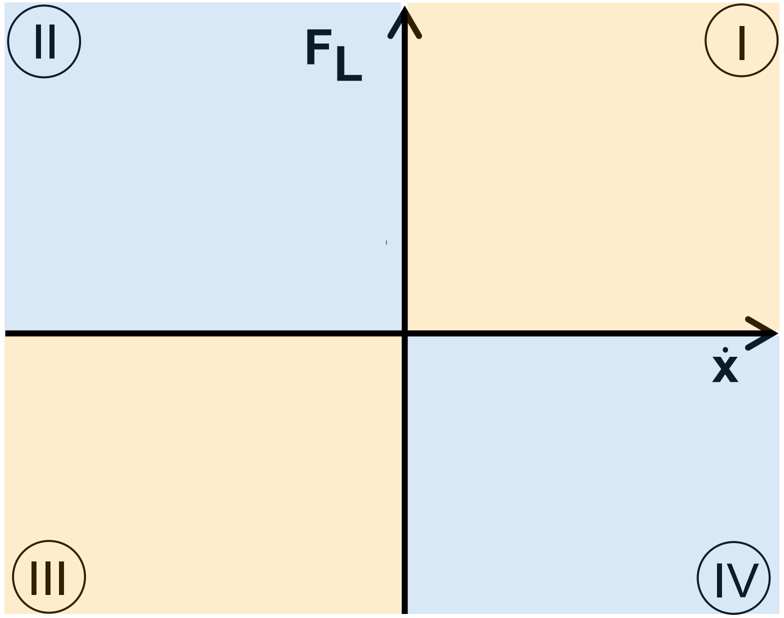
Resistance Control:

- Good dynamics
- Good controllability
- Low investment costs
- High energy losses

Displacement Control:

- Worse dynamics
- High investment costs
- Low energy losses

Load conditions of a hydraulic linear drive

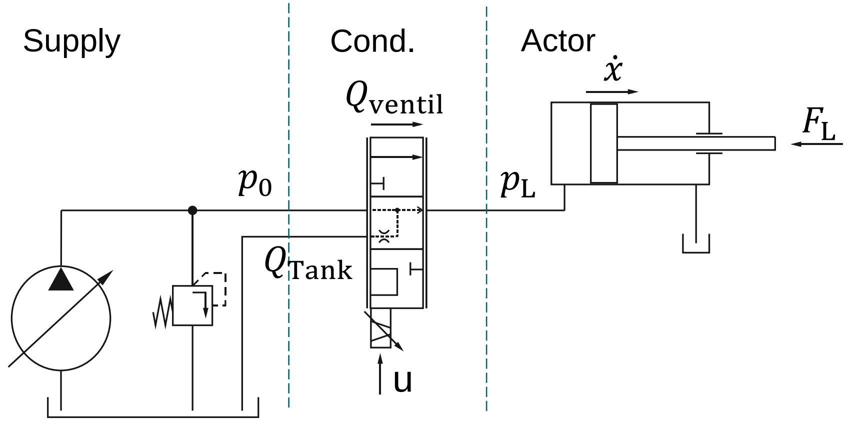


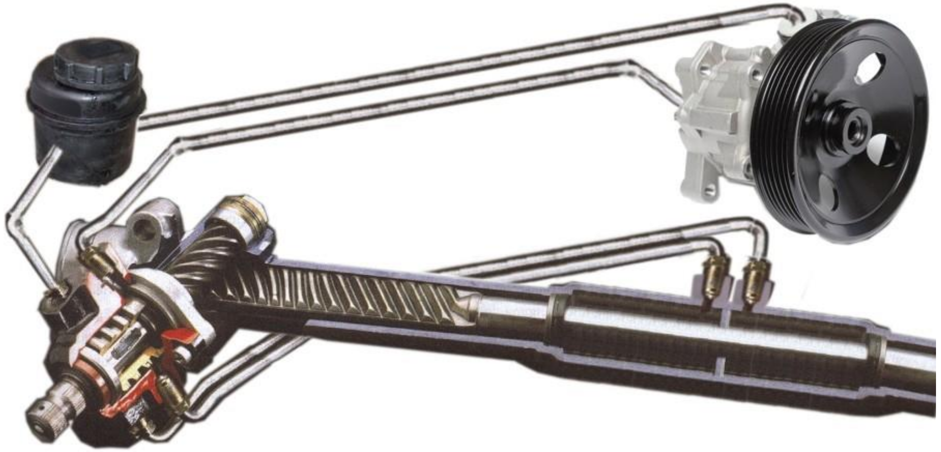
Passive Loads

Active Loads

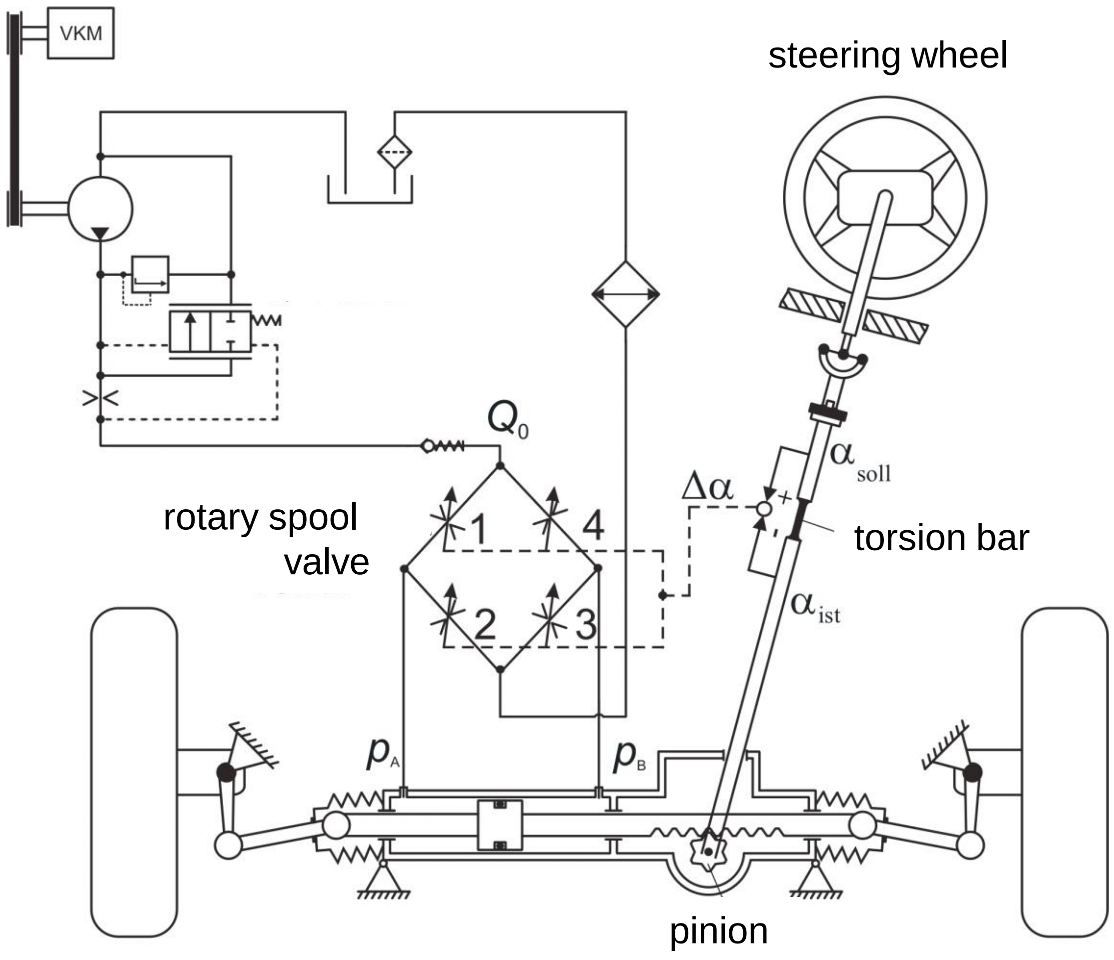
Outline of todays lecture

Example Q I: Power Steering

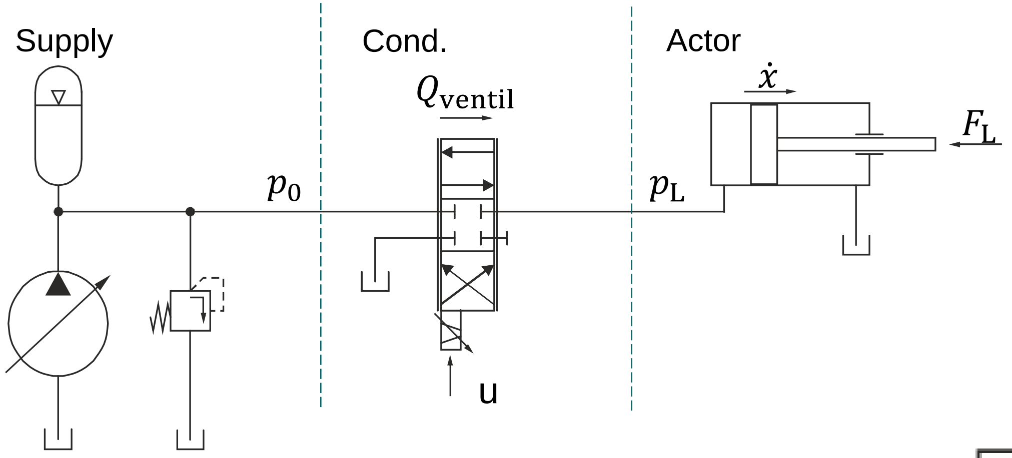


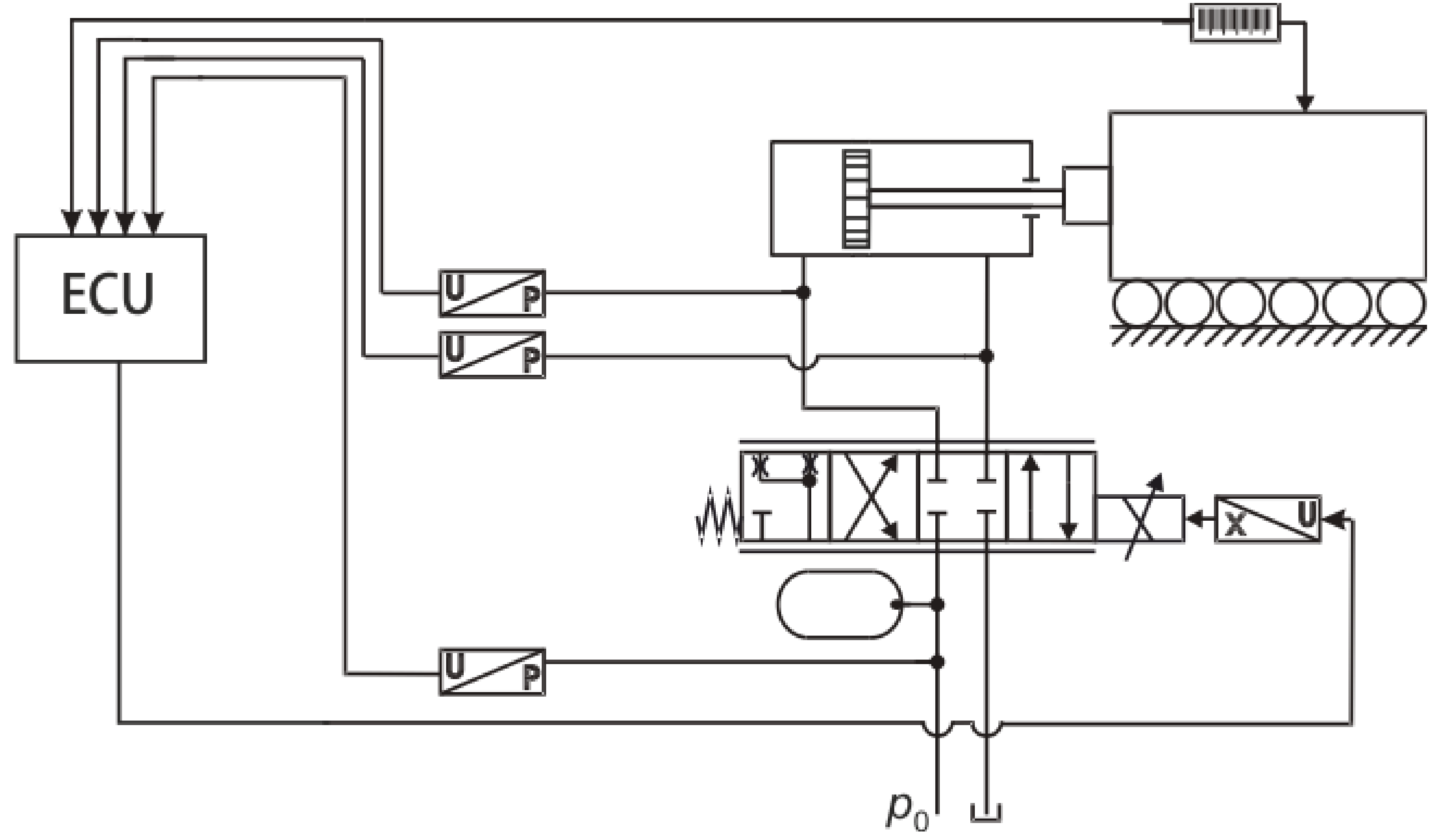


Source: www.kfz-tech.de



Example Q II: Valve controlled linear drive

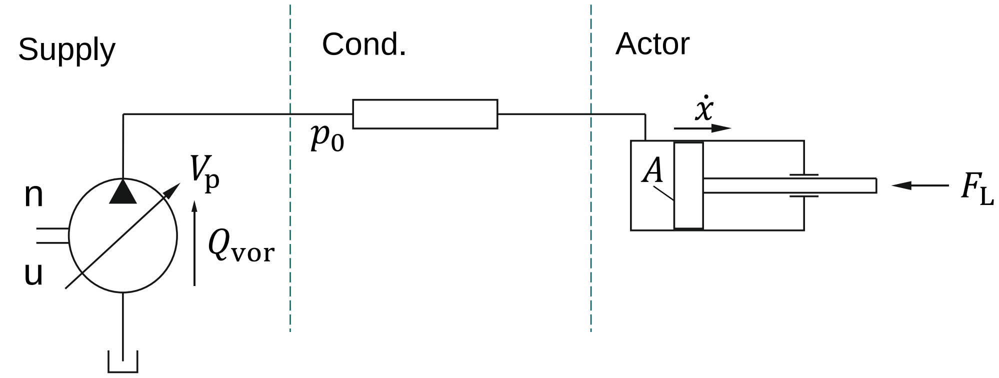


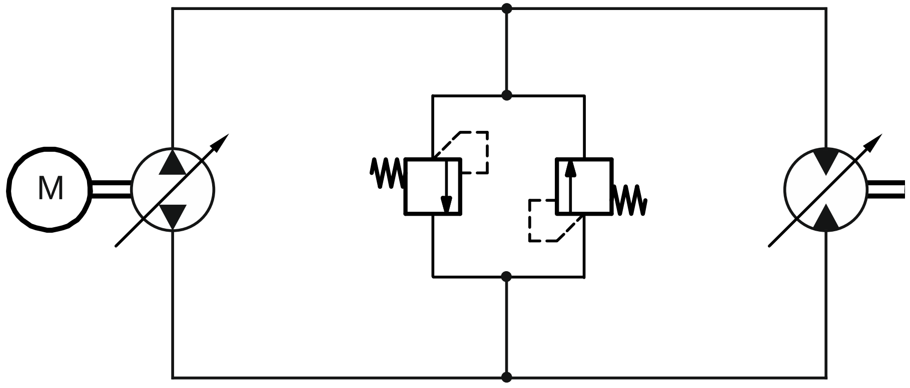


Source: Cat

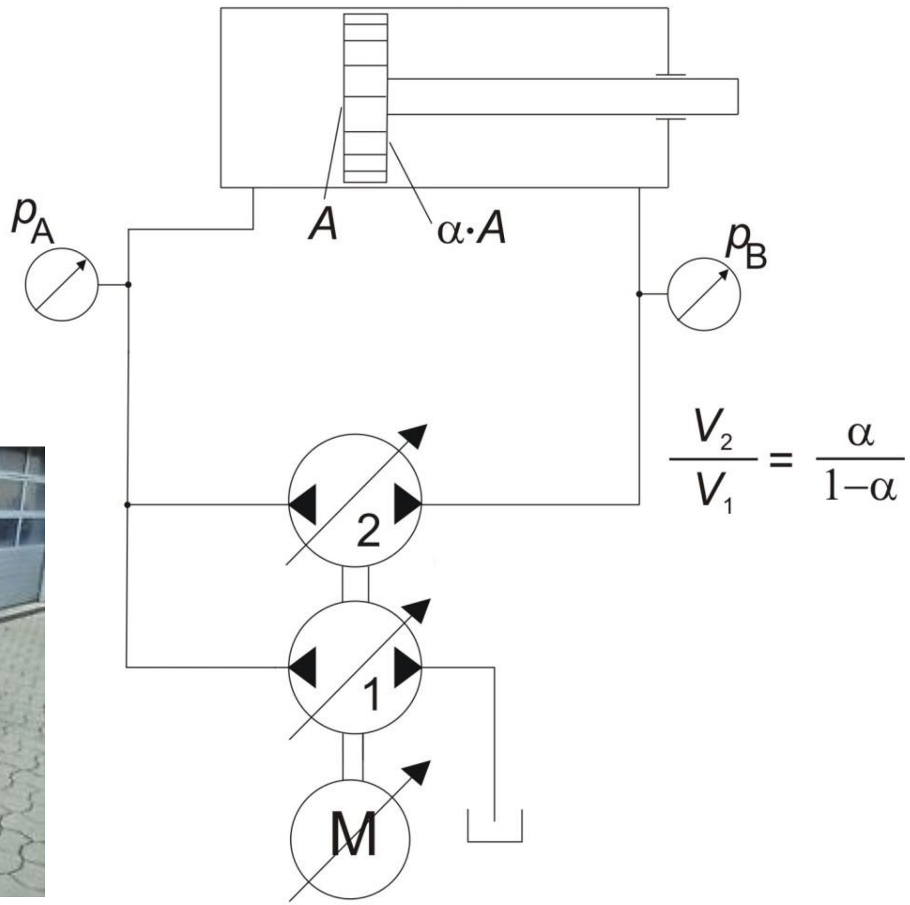
Outline of todays lecture

Example Q III: Displacement control – primary control (hydrostatic transmission)

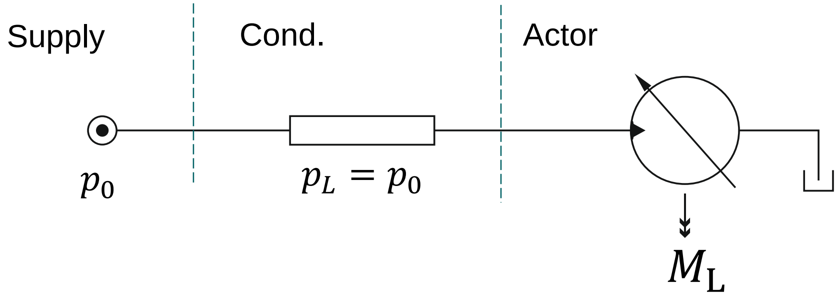


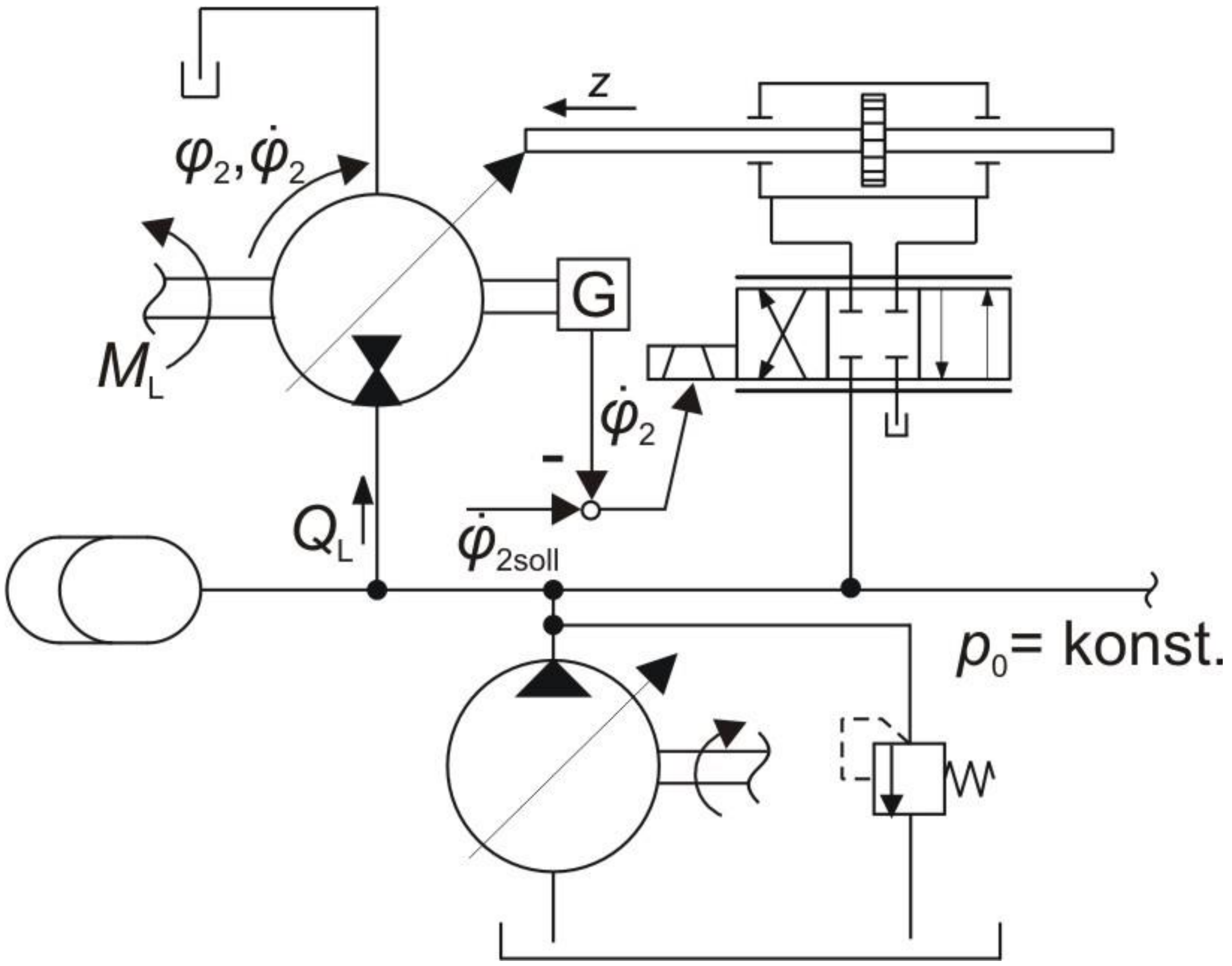


Source: Kubota



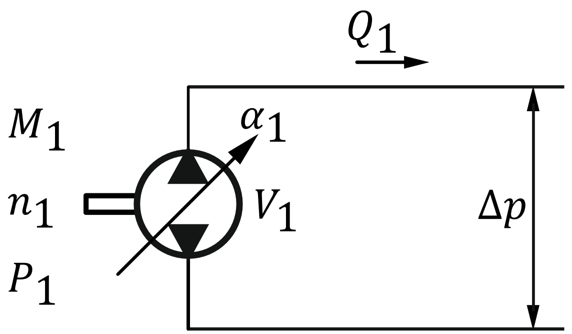
Example Q IV: Impressed pressure + displacement control



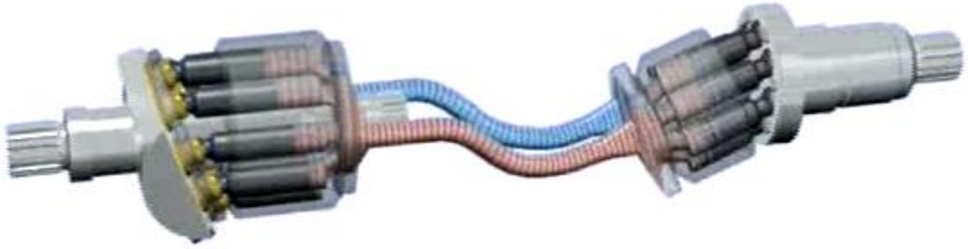


Outline of todays lecture

Transformation features of hydrostatic transmission

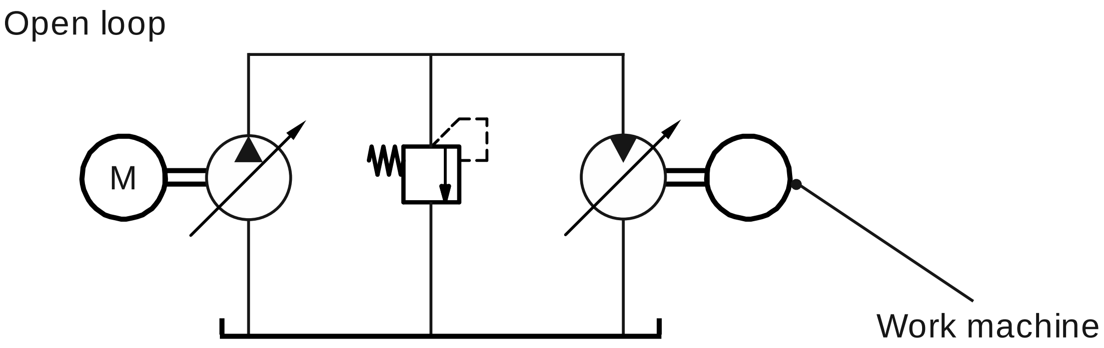


Transformation features of hydrostatic transmission



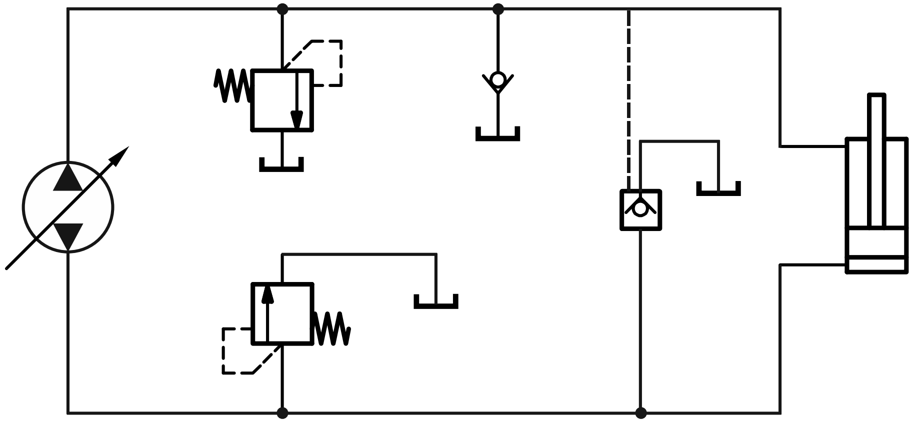
Source: Bosch Rexroth

Methods of interconnection

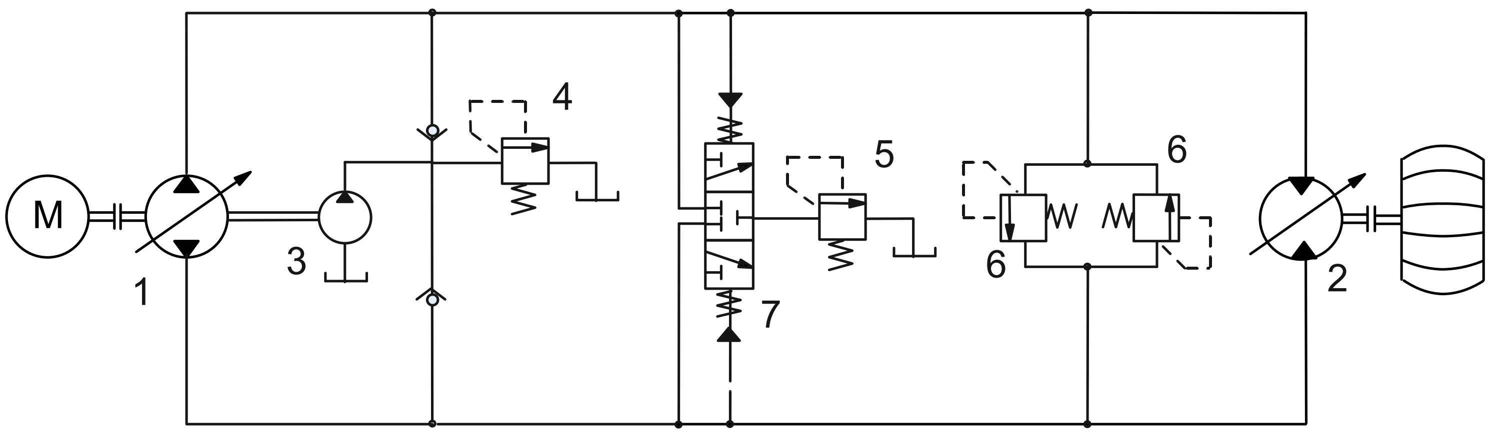


Methods of interconnection

Half open / closed loop



Hydrostatic transmission in a closed circuit

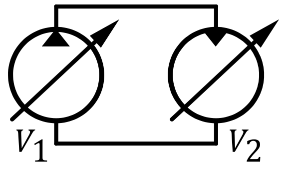


1 Adjustable pump
2 Adjustable motor
3 Feed pump
4 PRV feed circuit

5 PRV flushing circuit
6 PRVs main circuit
7 Flushing valve

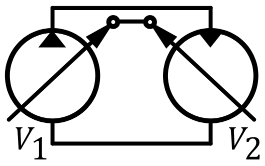
Lossless hydrostatic transmission with separate adjustment

- Starting from standstill with maximum torque
- Speed control via pump and subsequent motor adjustment



$$n_1 = \text{const.}$$
$$V_{1\,max} = V_{2\,max}$$
$$M_{2\,max} = \frac{V_{2\,max}}{2\pi} \cdot \Delta p_{max}$$

Lossless hydrostatic transmission with compound adjustment



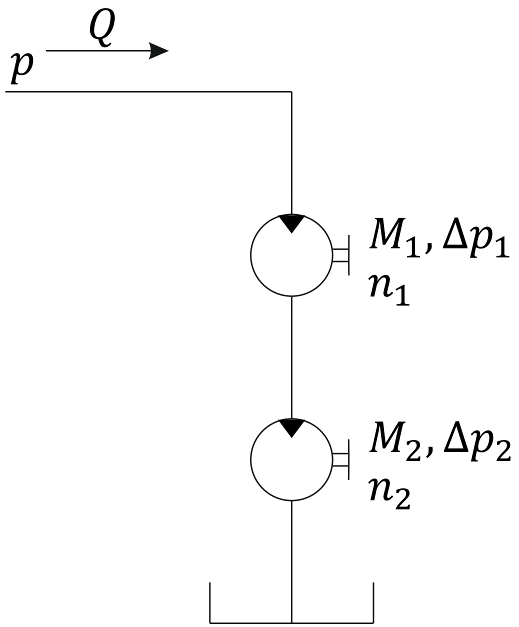
$$n_1 = \text{const.}$$

$$V_{1\,max} = V_{2\,max}$$

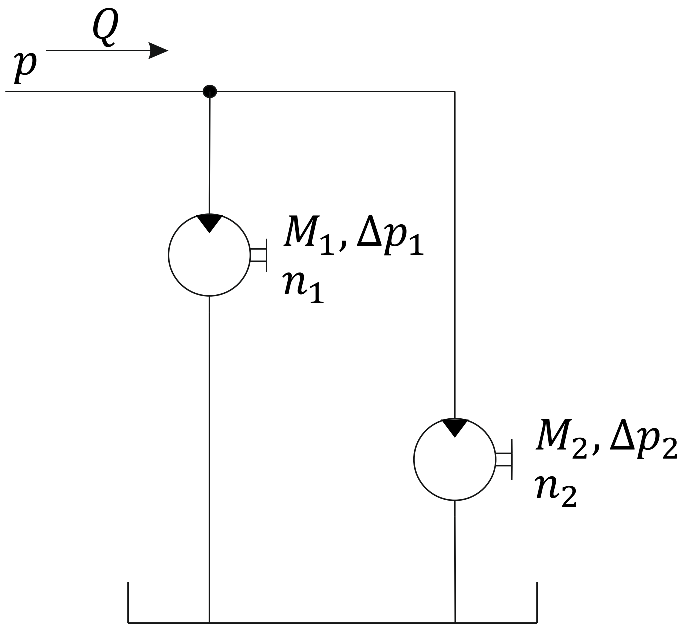
$$M_{2\,max} = \frac{V_{2\,max}}{2\pi} \cdot \Delta p_{max}$$

Serial and parallel motor connection

Serial connection

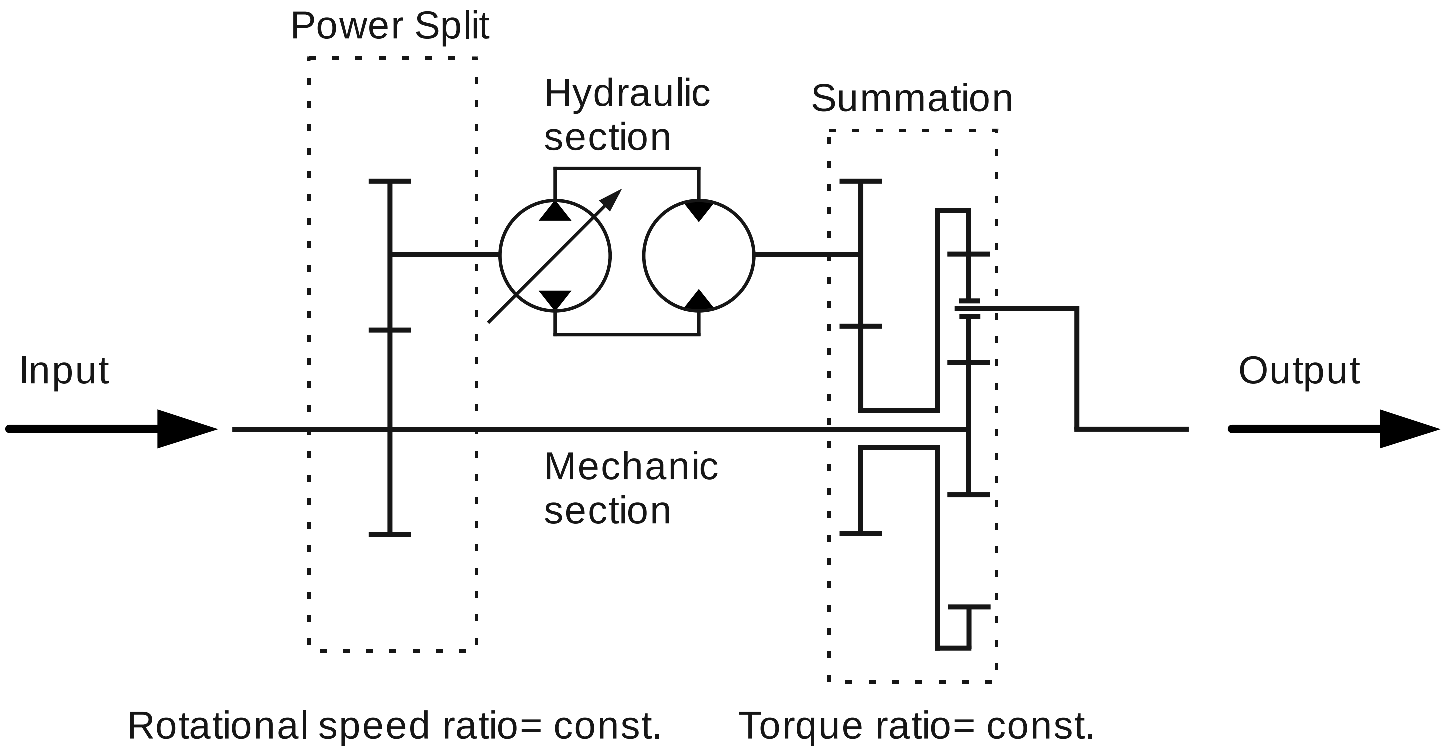


Parallel connection

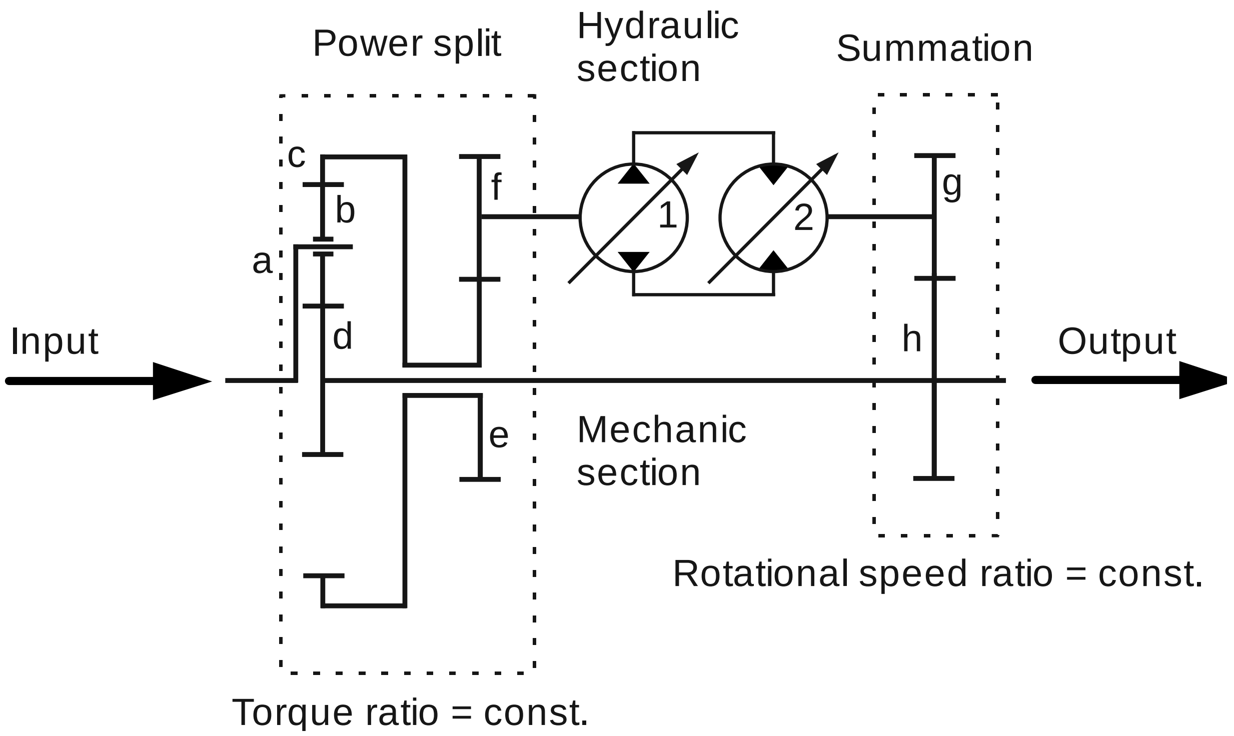


Outline of todays lecture

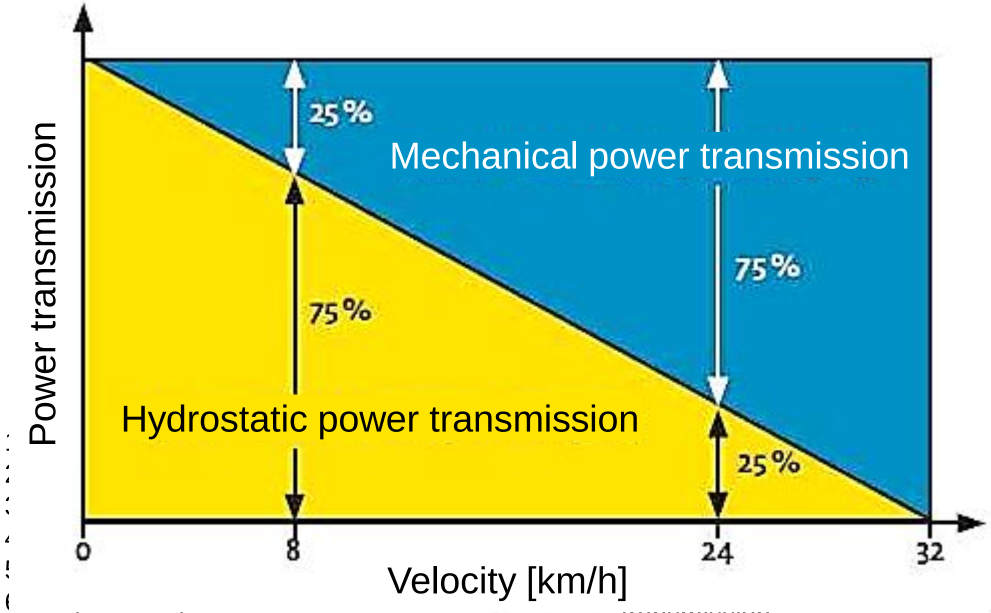
Input-coupled power split transmission



Output-coupled power split transmission



Example: Fendt Vario

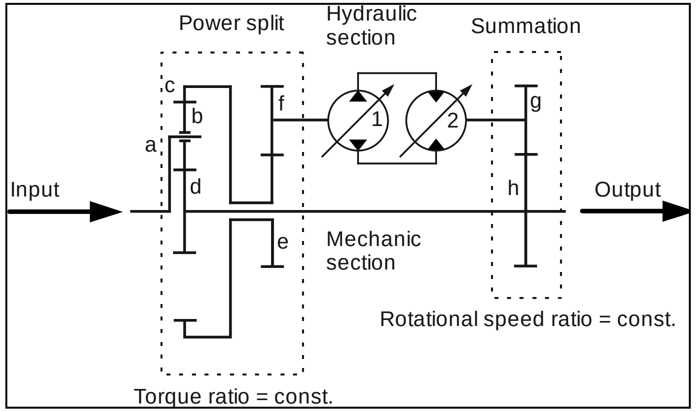


7. Hydr. Motor
8. Summation shaft

transmission
Power take-off
All-wheel drive

Source: Fendt

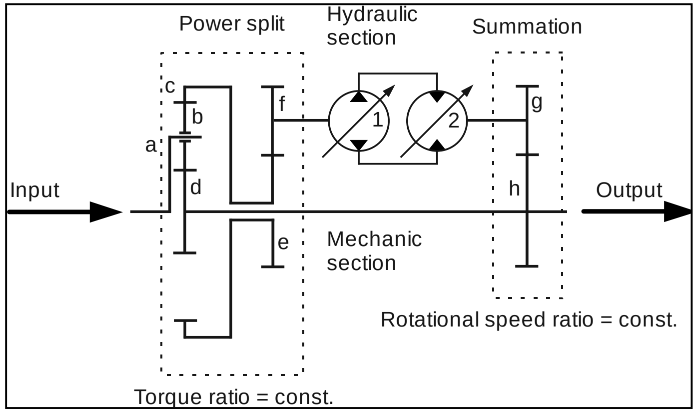
Output-coupled power split transmission



$$Q_1 = \alpha_1^* \, V_1 \, n_e \frac{r_e}{r_f}; \qquad with \qquad \alpha_1^* = \frac{\alpha_1}{\alpha_{1max}}$$

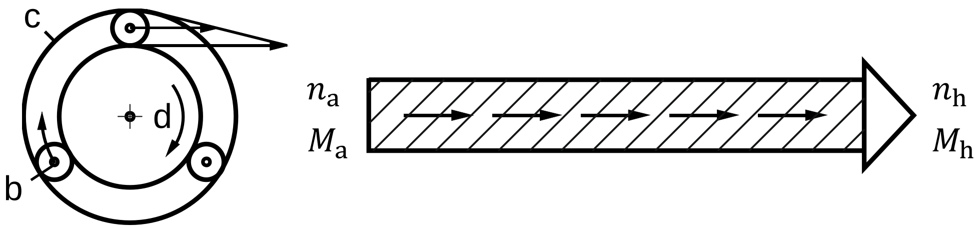
$$Q_2 = \alpha_2^* \, V_2 \, n_\mathrm{h} \frac{r_\mathrm{h}}{r_\mathrm{g}}; \qquad with \qquad \alpha_2^* = \frac{\alpha_2}{\alpha_{2max}}$$

Power flow



Basic ratio

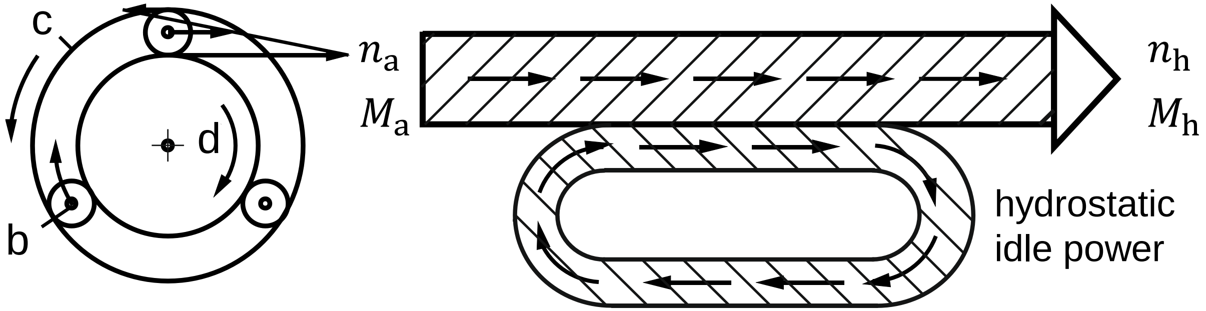
$$n_a = \frac{r_d}{r_c + r_d} n_h$$



Section I

$$n_a < \frac{r_d}{r_c + r_d} n_h$$

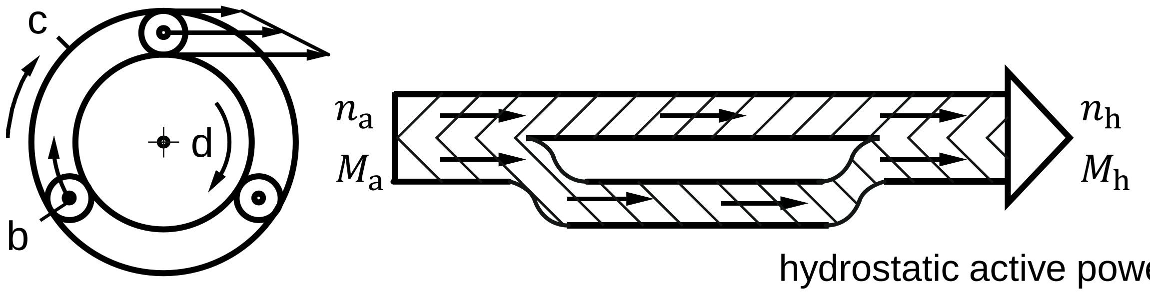
1 – Motor
2 – Pump



Section II

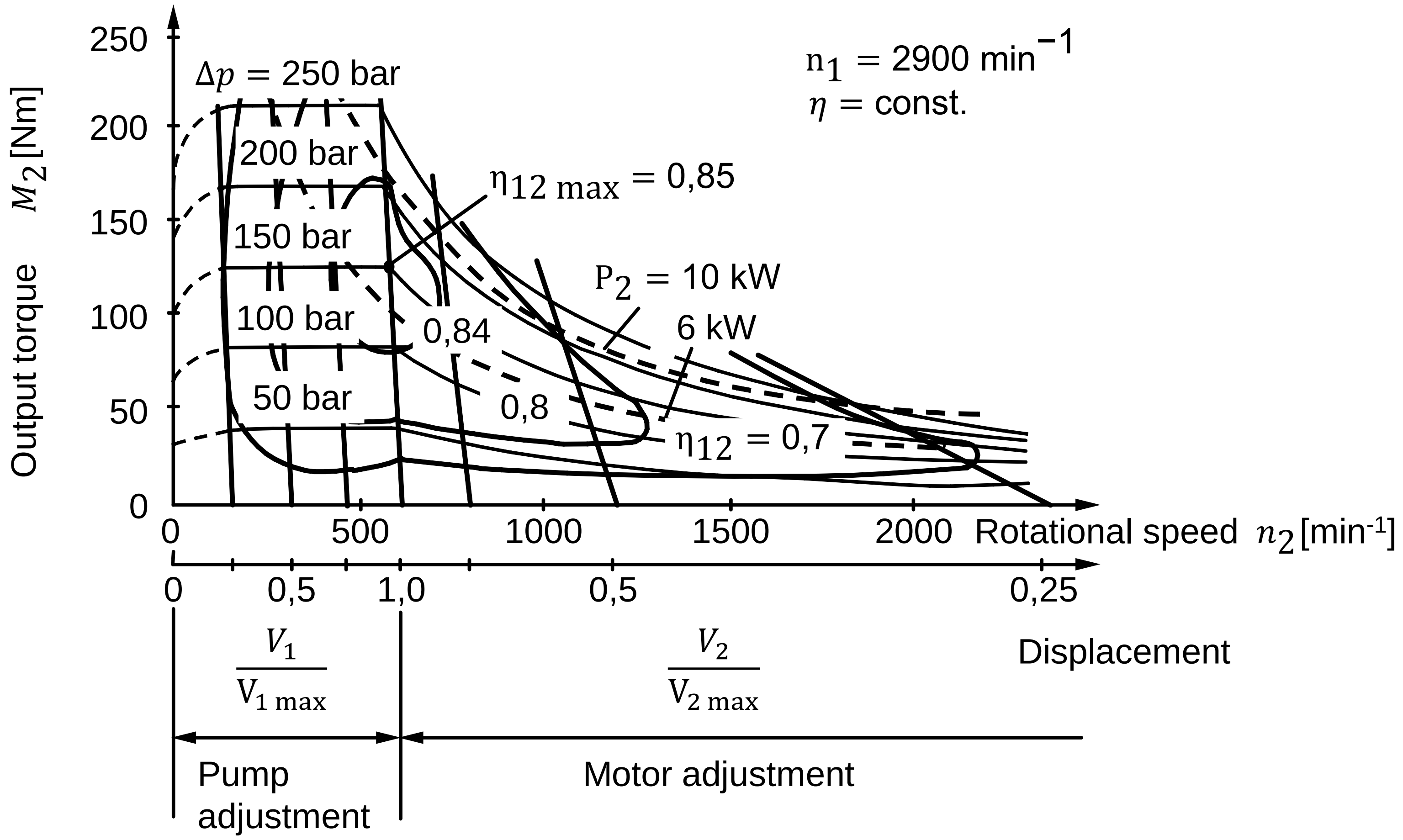
$$n_a > \frac{r_d}{r_c + r_d} n_h$$

1 – Pump
2 – Motor



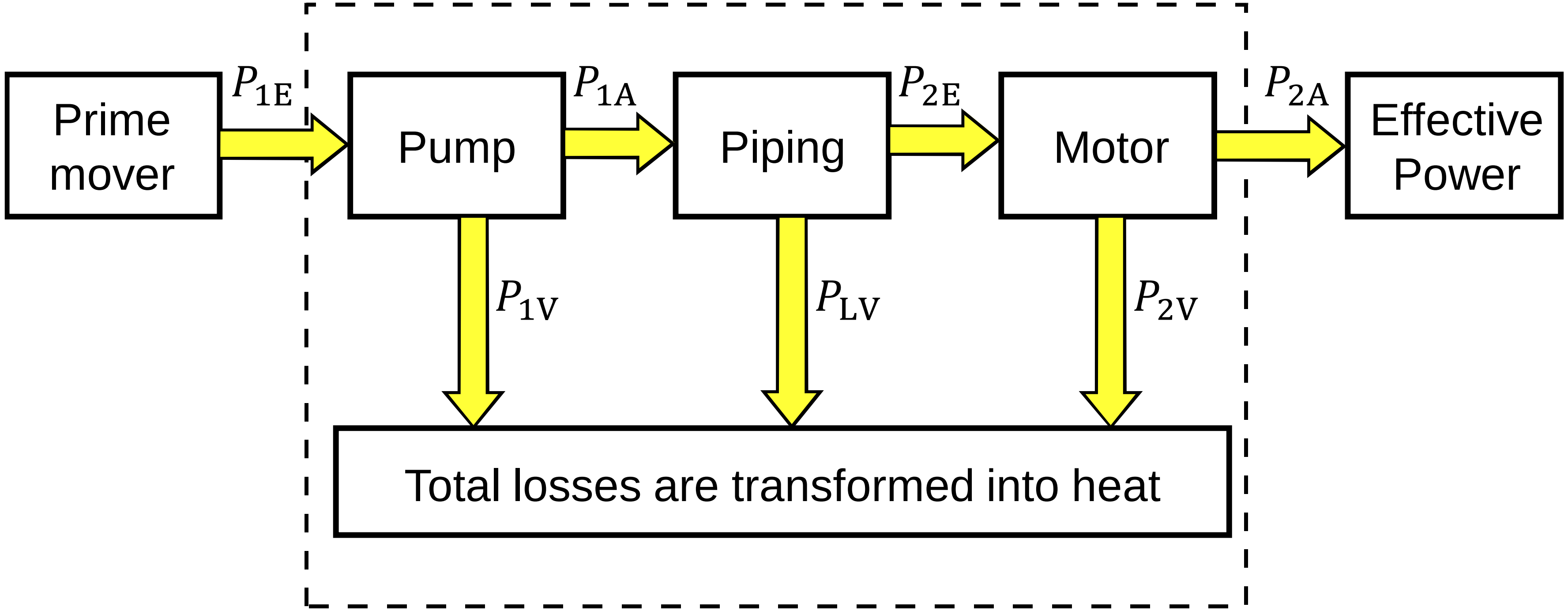
hydrostatic active power

Characteristics of a hydrostatic transmission with separate adjustment

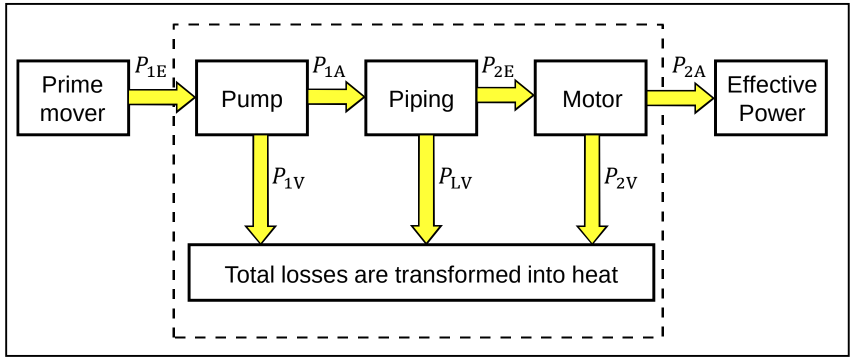


Outline of todays lecture

Losses in a hydraulic system



Losses in a hydraulic system



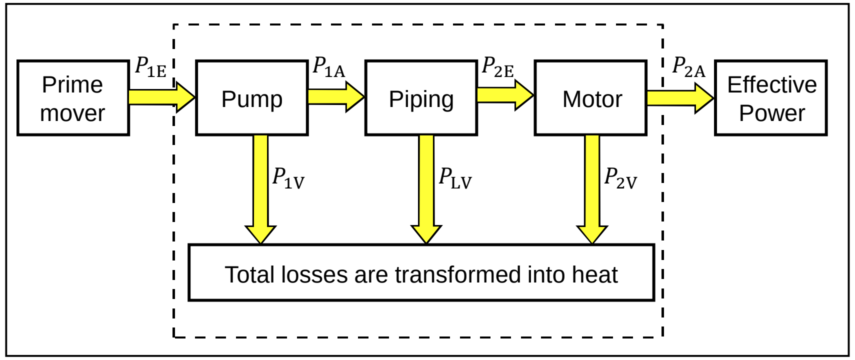
Hydraulic power of a pump: $P_{1A} = \Delta p_1 \cdot Q_{1eff}$

Power losses of a pump: $P_{1V} = \Delta p_1 \cdot Q_{1eff} \cdot (\frac{1}{\eta_{1ges}} - 1)$

Pressure losses in pipings: $\Delta p' = \sum \lambda \cdot \frac{l}{d} \cdot \frac{\rho}{2} \cdot v^2$

Pressure losses in e.g. elbows: $\Delta p'' = \sum \xi \cdot \frac{\rho}{2} \cdot v^2$

Losses in a hydraulic system



Pressure difference at a motor:

$$\Delta p_2 = \Delta p_1 - \Delta p' - \Delta p'' = (1 - b_1) \cdot \Delta p_1$$

(b_1 = Part of pressure losses in the piping)

Flow rate of a motor:

$$Q_{2eff} = (1 - b_2) \cdot Q_{1eff}$$

(b_2 = Part of splitted flow rate)

Losses in the piping:

$$P_{LV} = \Delta p_1 \cdot Q_{1eff} \cdot (1 - (1 - b_1) \cdot (1 - b_2))$$

Losses of the motor:

$$P_{2V} = \Delta p_2 \cdot Q_{2eff} \cdot (1 - \eta_{2ges})$$

$$= \Delta p_1 \cdot Q_{1eff} \cdot (1 - b_1) \cdot (1 - b_2) \cdot (1 - \eta_{2ges})$$

Total power losses:

$$P_{Vges} = P_{1E} - P_{2A} = P_{IV} + P_{LV} + P_{2V}$$

$$= \Delta p_1 \cdot Q_{1eff} \cdot \left[\frac{1}{\eta_{1ges}} - (1 - b_1) \cdot (1 - b_2) \cdot \eta_{2ges}\right]$$

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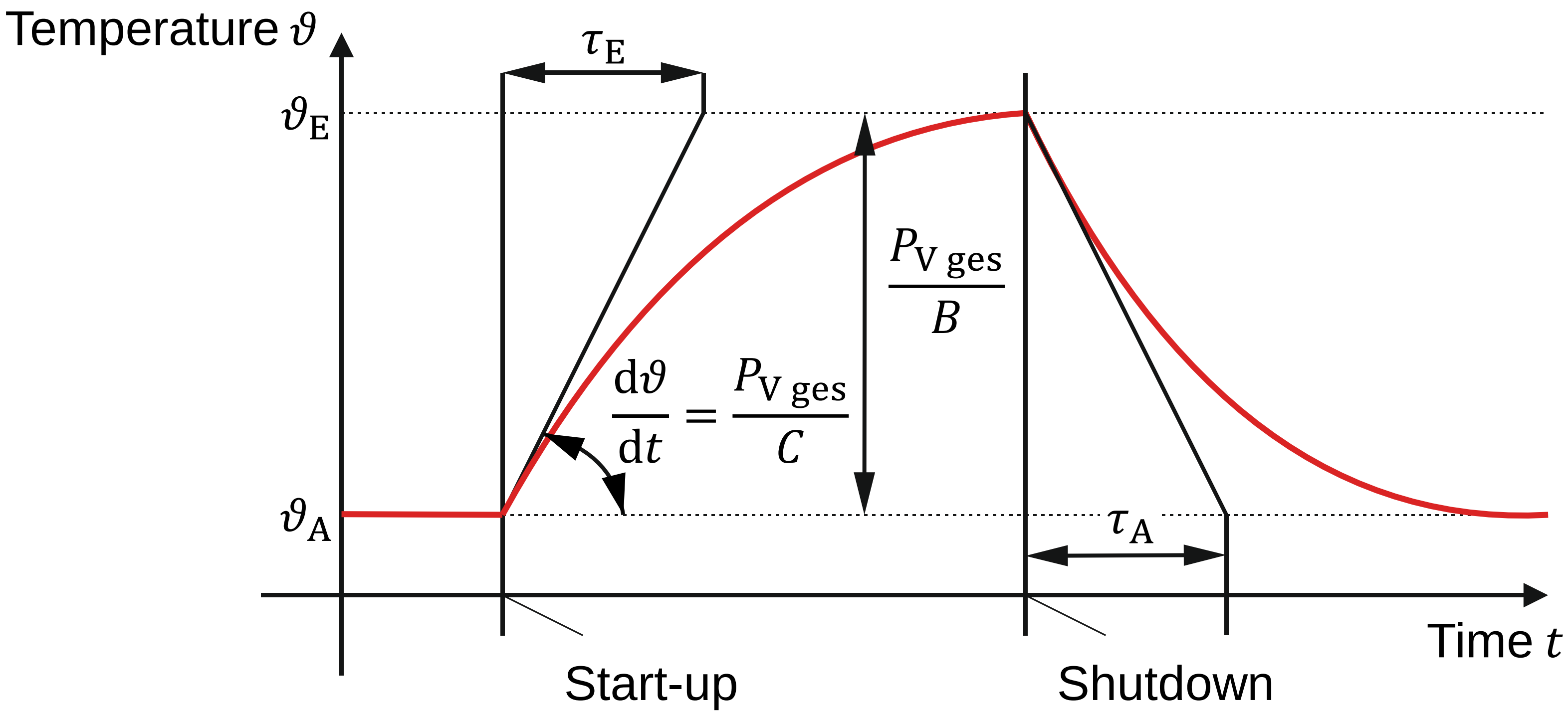
Heating and cooling characteristics of a hydraulic system

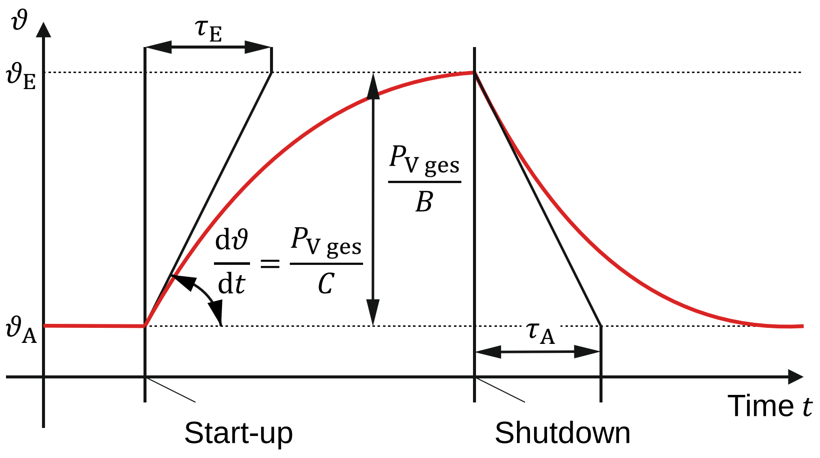


Power losses

Heat emission capacity

Heat storage capacity

Heating and cooling characteristics of a hydraulic system



Heat emission capacity: $B = \sum k_i \cdot A_i = \left[\frac{J}{m^2 sK} m^2\right]$

Heat storage capacity: $C = \sum c_i m_i = \left[\frac{J}{kgK} kg\right]$

Thermal balance: $P_{Vges} dt = C d\theta + (\theta - \theta_A) B dt$

Solution of the differential equation:

$$\theta = \theta_A + \frac{P_{Vges}}{B}\left(1 - e^{-t/\tau}\right) \qquad \text{with:} \qquad \tau = \frac{C}{B}$$

Final temperature ($t \to \infty$):

$$\theta_E = \theta_A + \frac{P_{Vges}}{B}$$

Temperature rise at the beginning of the heating process:

$$\frac{d\vartheta}{dt}(t=0) = \frac{P_{Vges}}{B} \cdot \frac{1}{\tau} = \frac{P_{Vges} \cdot B}{B \cdot C} = \frac{P_{Vges}}{C}$$

Cooler

[Universal Hydraulik]

[Bühler Mess- und Regeltechnik]

	Water cooling	Air cooling
Advantage	▪ low space requirements ▪ low purchasing cost ▪ good controllability ▪ silent operation	▪ low operating costs, ▪ leakage visible immediately ▪ small installation effort
Disadvantage	▪ expensive water ▪ big installation effort ▪ corrosion causes consequential damage for facility and environment	▪ high investment costs ▪ fan noise and draught ▪ higher space requirements ▪ fresh air and used air ducts often required

Outline of todays lecture

Summary

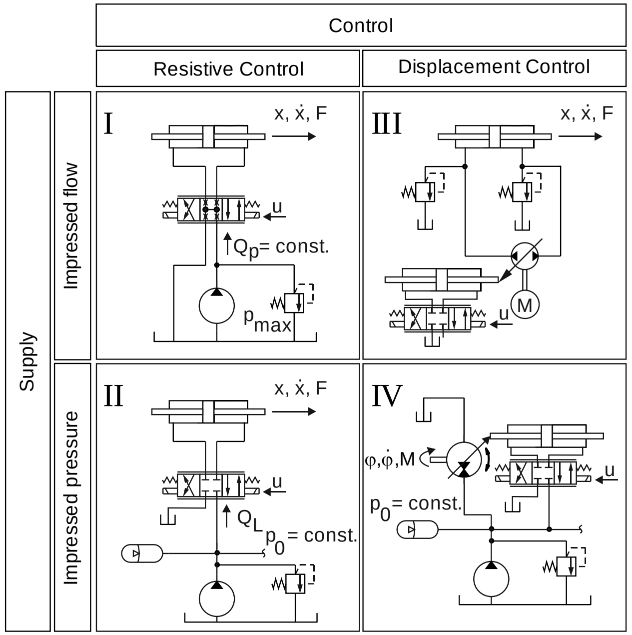
- Which basic types of hydraulic systems exist?
  - Resistance control, displacement control
  - Impressed pressure, impressed volume flow

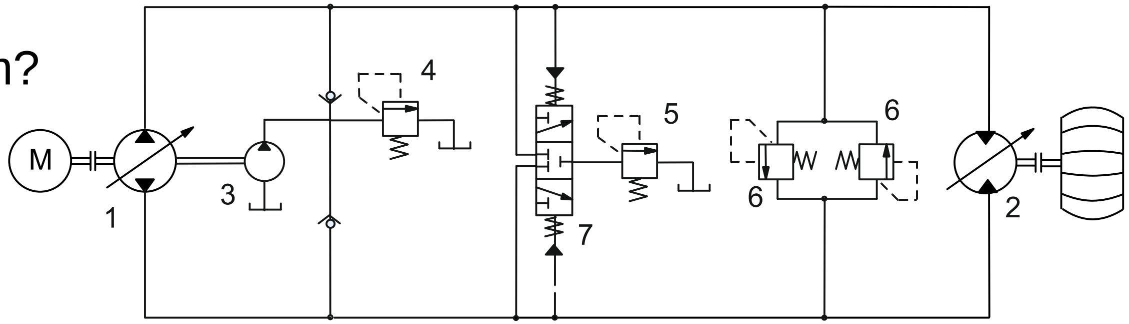
- Which type of control is the most energetically favorable?
  - Positive displacement control, as there are no principle throttle losses

- What are the disadvantages of this type of control?
  - Expensive, slower dynamics

- What does a hydrostatic transmission consist of?
  - Pump, motor, feed pump, feed valve, pressure relief valves

- What influences the final temperature of a hydraulic system?
  - Power loss, heat dissipation capacity, cooling capacity





Thank you for your attention.