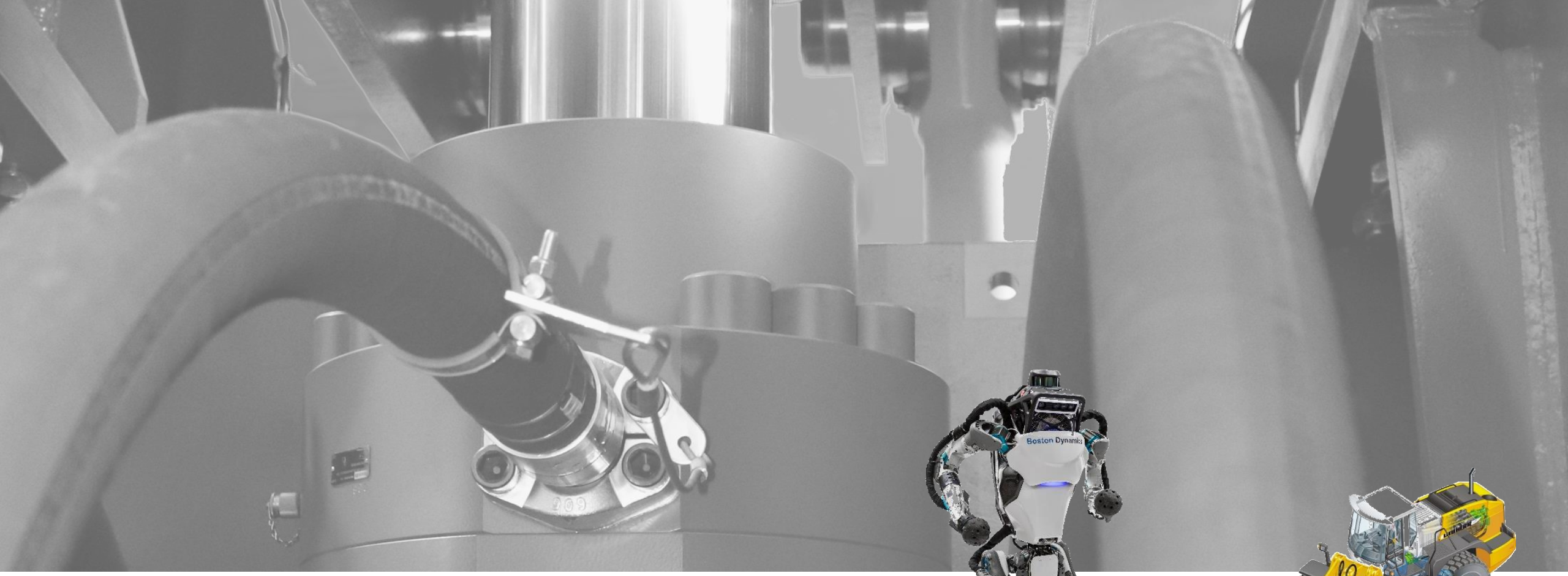


Fundamentals of Fluid Power

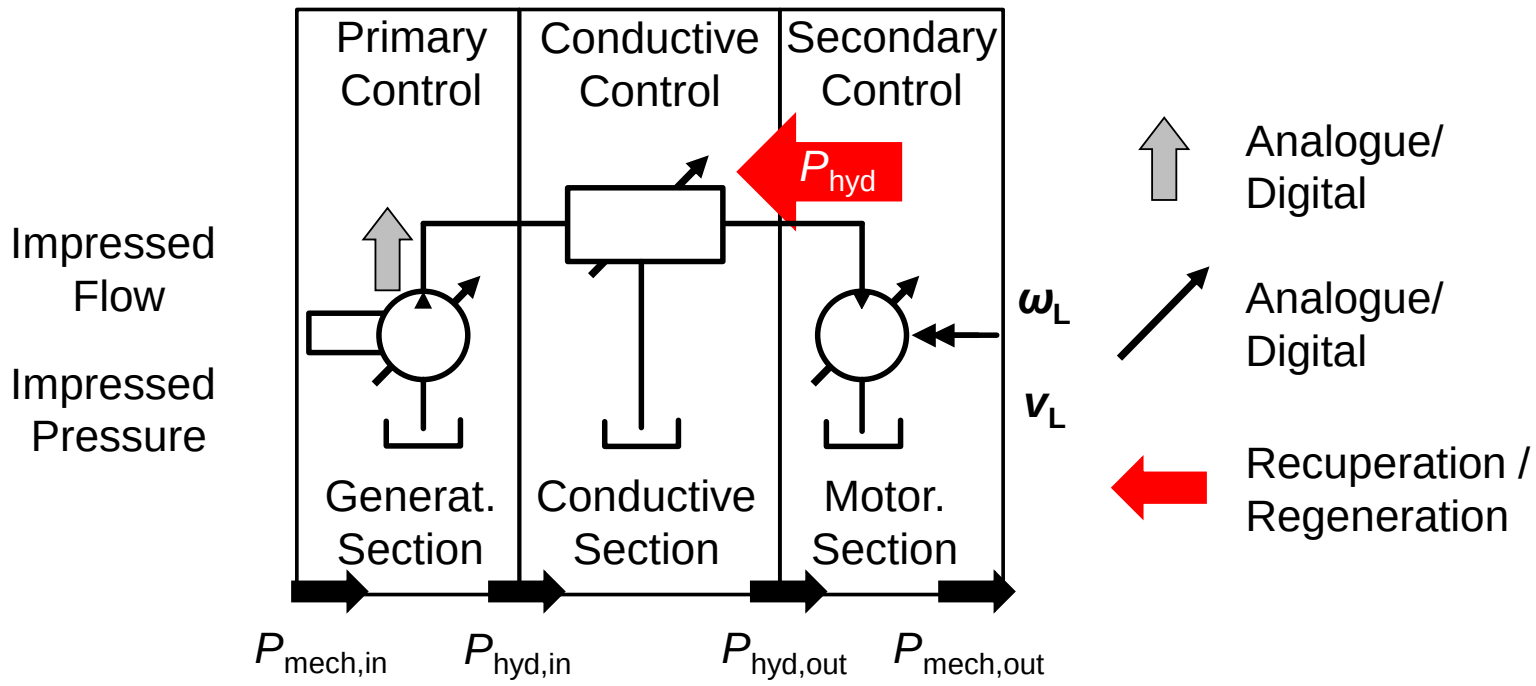
Lecture 10 – Fluid Power Systems

ifas Institute for Fluid Power Drives and Systems | RWTH AACHEN UNIVERSITY

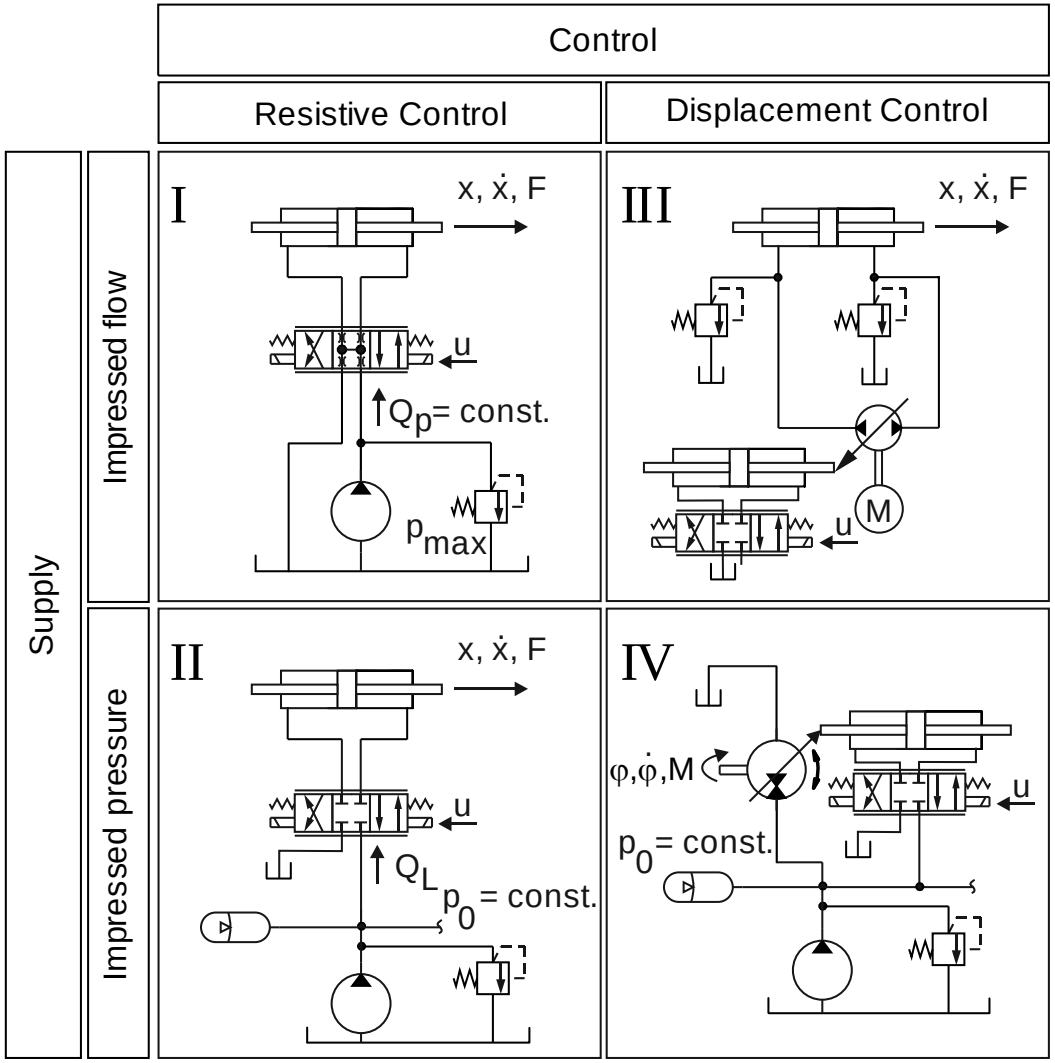
Outline of todays lecture

1. Backflip classification of hydraulic controls
2. Additional classification of hydraulic controls
3. Concepts for energy recovery
4. Exemplary system
5. Practical exercise
6. Summary

Structure of hydraulic systems



Classification of common types of hydrauli controls



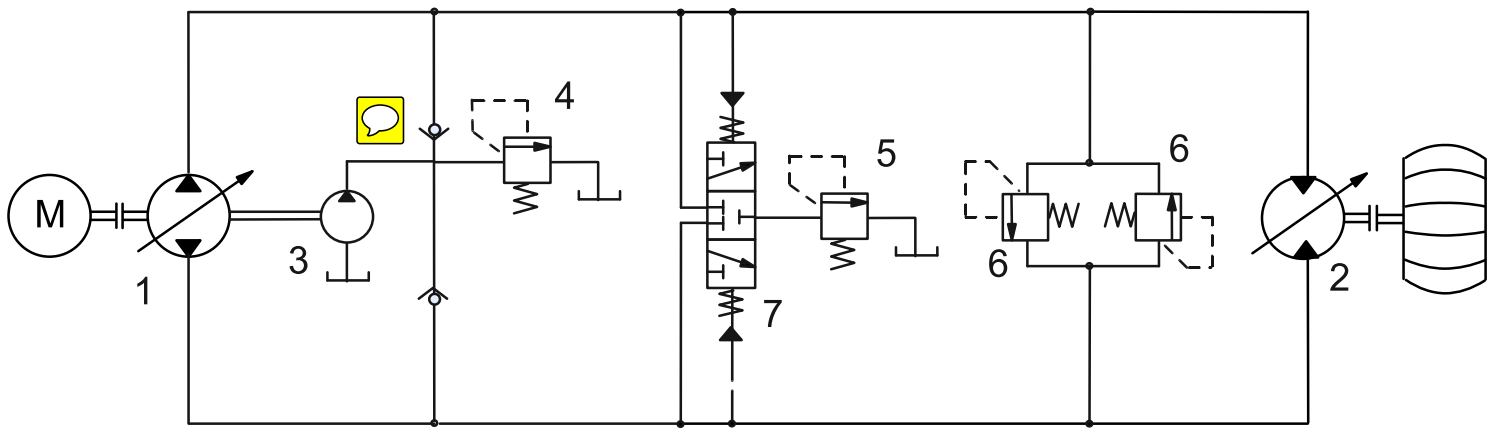
Resistance Control:

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

Displacement Control:

- Worse dynamics
- High investment costs
- Low energy losses

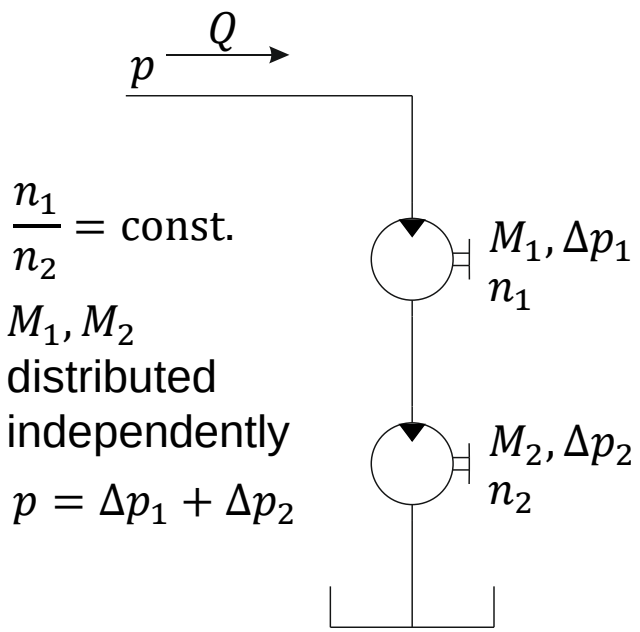
Hydrostatic transmission in a closed circuit



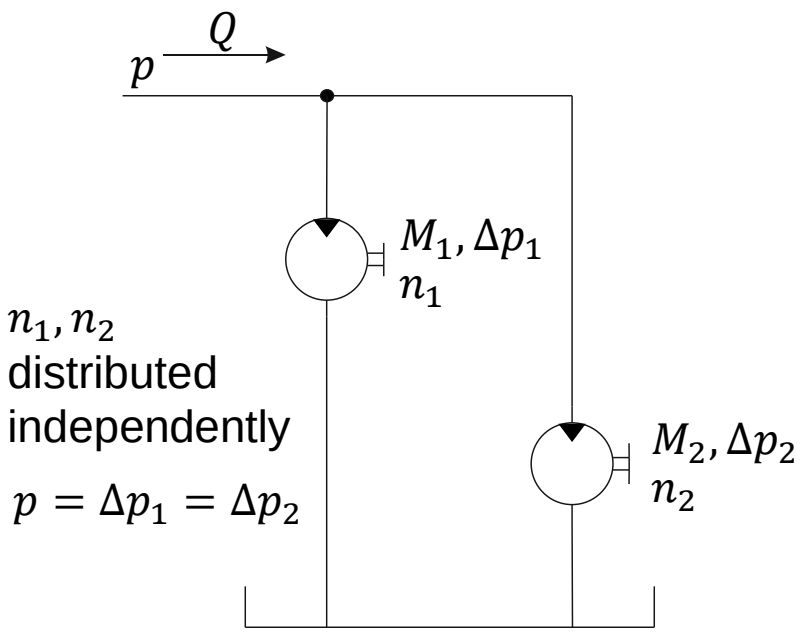
1 Adjustable pump
2 Adjustable motor
3 Feed pump
4 PRV feed circuit
5 PRV flushing circuit
6 PRVs main circuit
7 Flushing valve

Serial and parallel motor connection

Serial connection



Parallel connection



Outline of todays lecture

1 Backflip classification of hydraulic controls

2 Additional classification of hydraulic controls

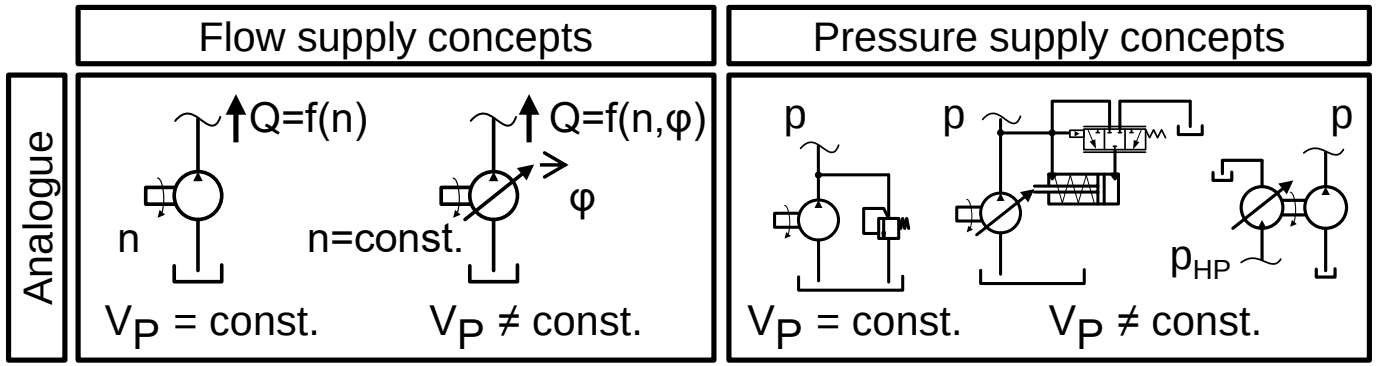
3 Concepts for energy recovery

4 Exemplary system

5 Practical exercise

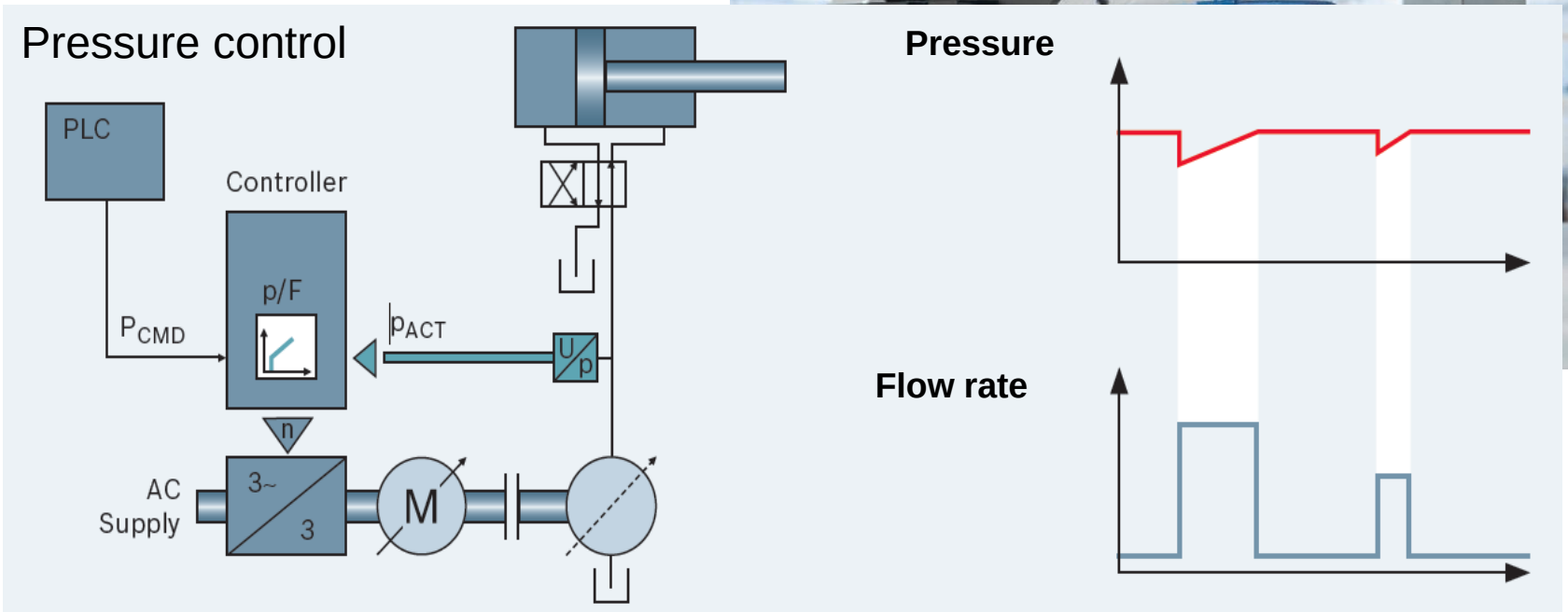
6 Summary

Concepts for supplying hydraulic systems



Example: Variable speed pump drives

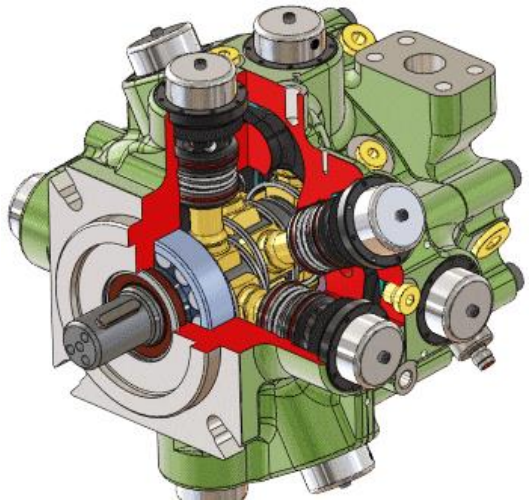
- Control of operating variables by software not by hydraulic-mechanical control units

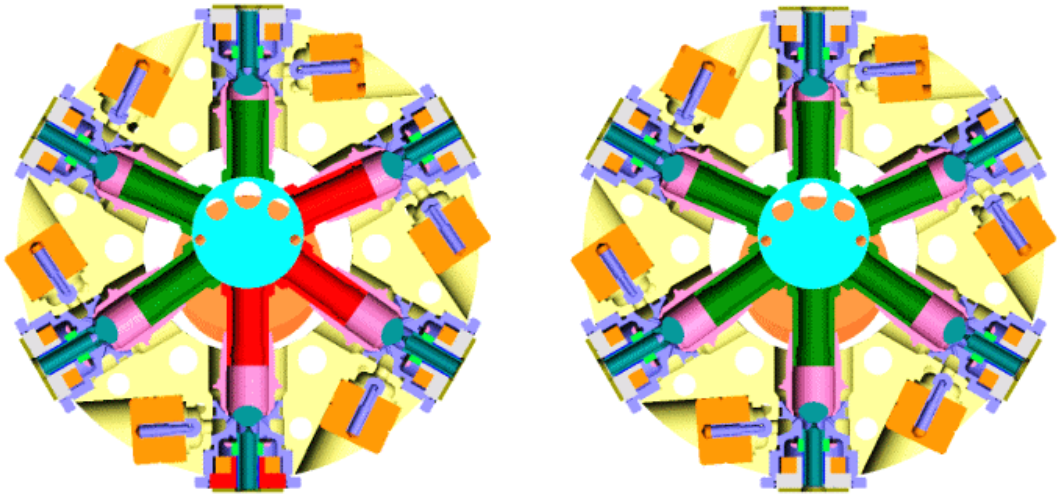


Source: Bosch Rexroth

Example: Artemis Digital Pump

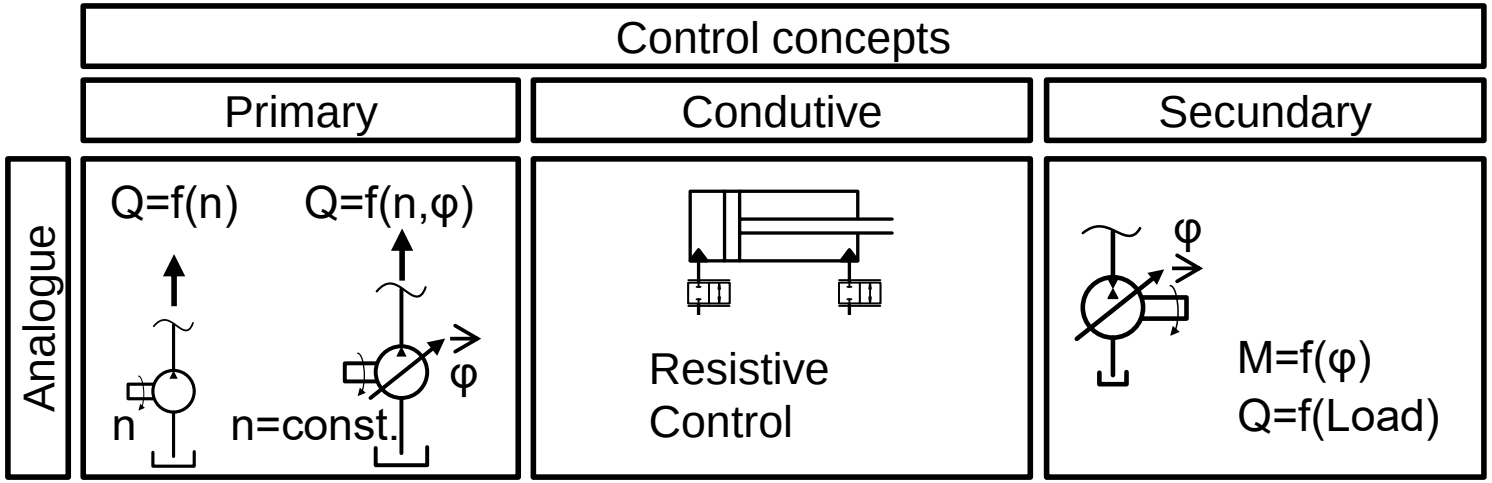
- Internally supported radial piston pump with digitally switchable pistons
- Discrete switchable displacement volumes
- Better efficiency in partial load operation compared to conventional pumps
- Idle mode





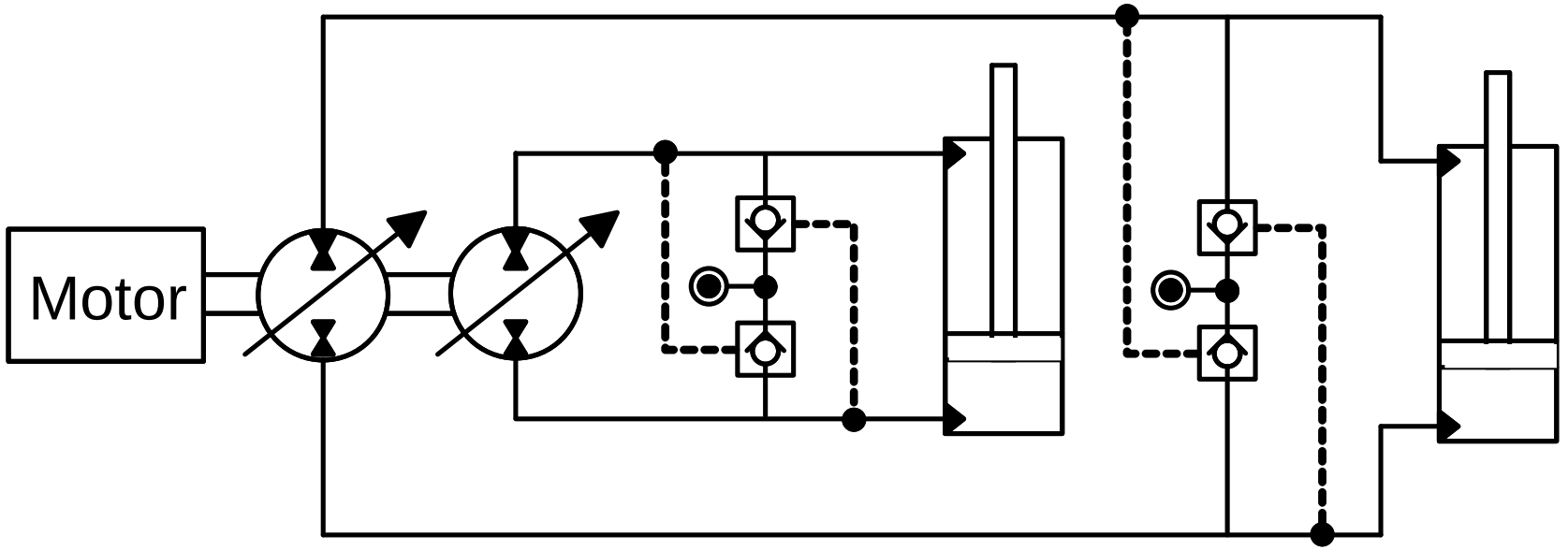
Source: Artemis

Concepts for hydraulic system controls



Example: Displacement controlled differential cylinder

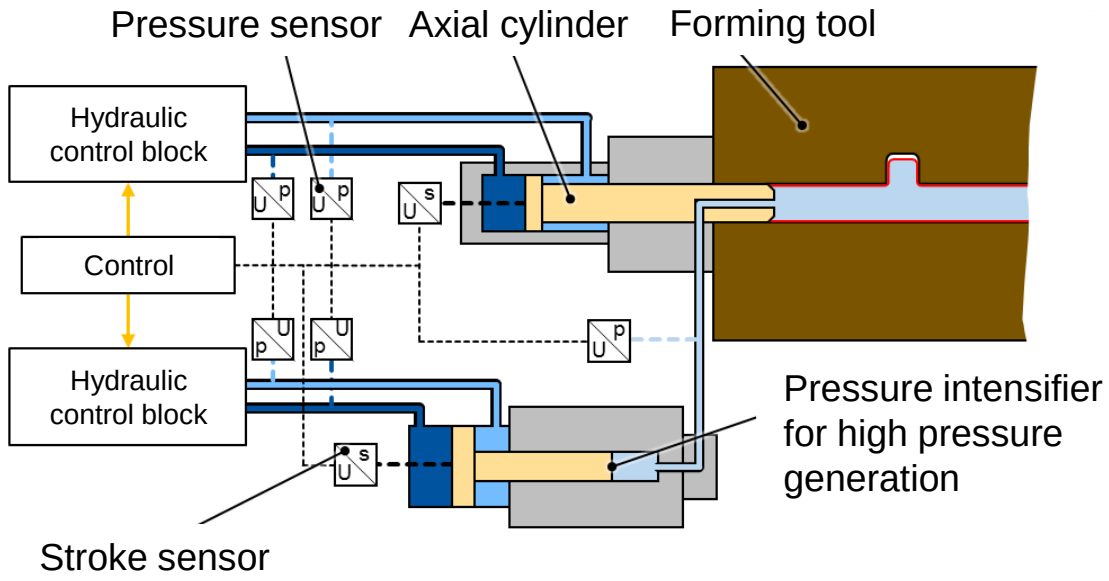
- Control: Primary, analogue



Example: Pressure intensifier in forming processes

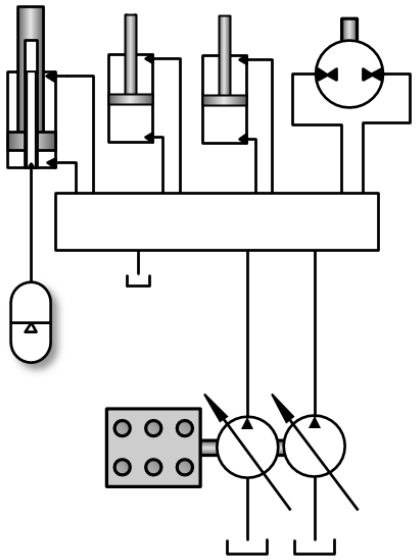
- Control of the pressure during hydroforming

- Use of simple control valves for pressure ranges up to 350 bar to adjust the high pressure up to 2000 bar

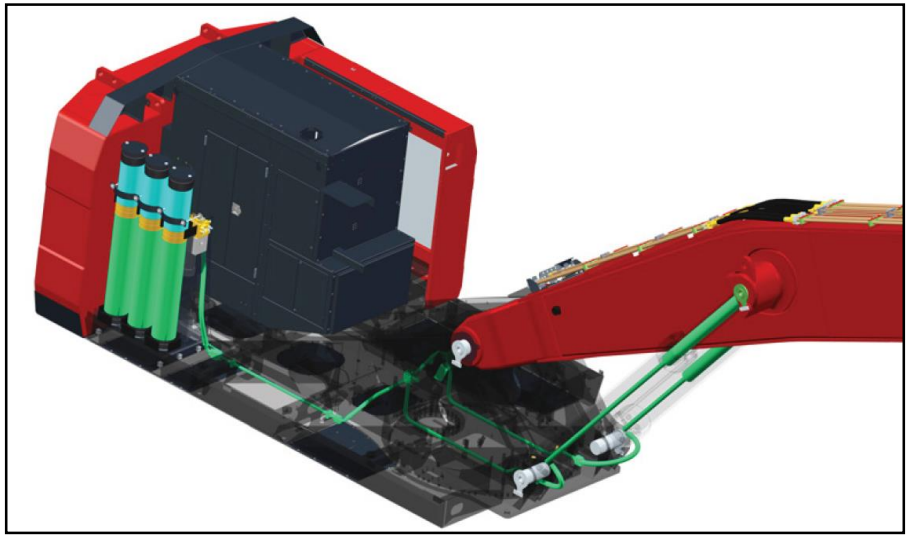


Example: Multi-chamber cylinder

- Mantsinen HybriLift
  - Multi-chamber cylinder for the boom drive
  - Two different areas on the piston side of the cylinder allow energy recovery by increasing the pressure during lowering
  - Fuel savings of 35 %



Source: Mantsinen



Outline of todays lecture

1 Backflip classification of hydraulic controls

2 Additional classification of hydraulic controls

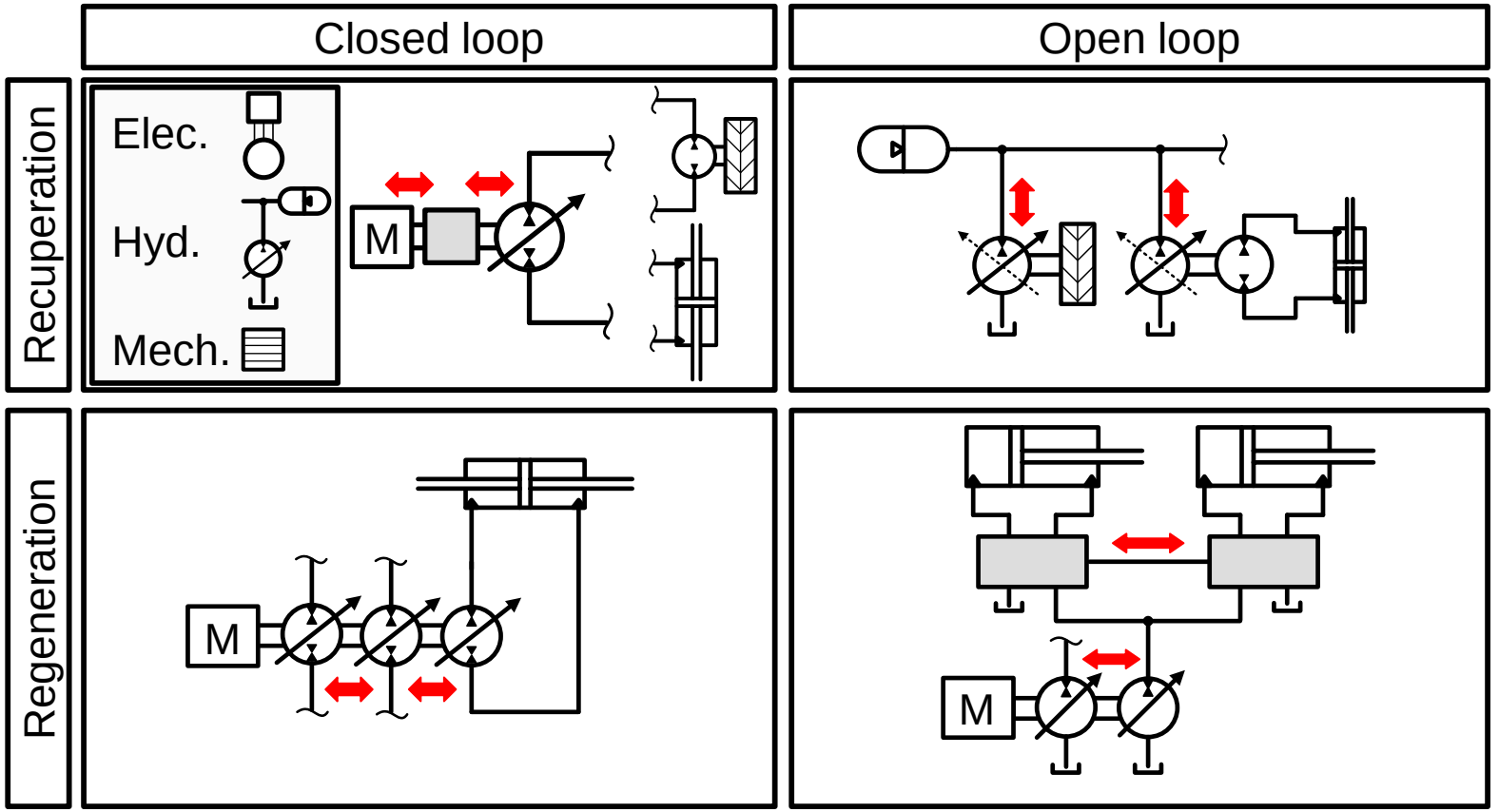
3 Concepts for energy recovery

4 Exemplary system

5 Practical exercise

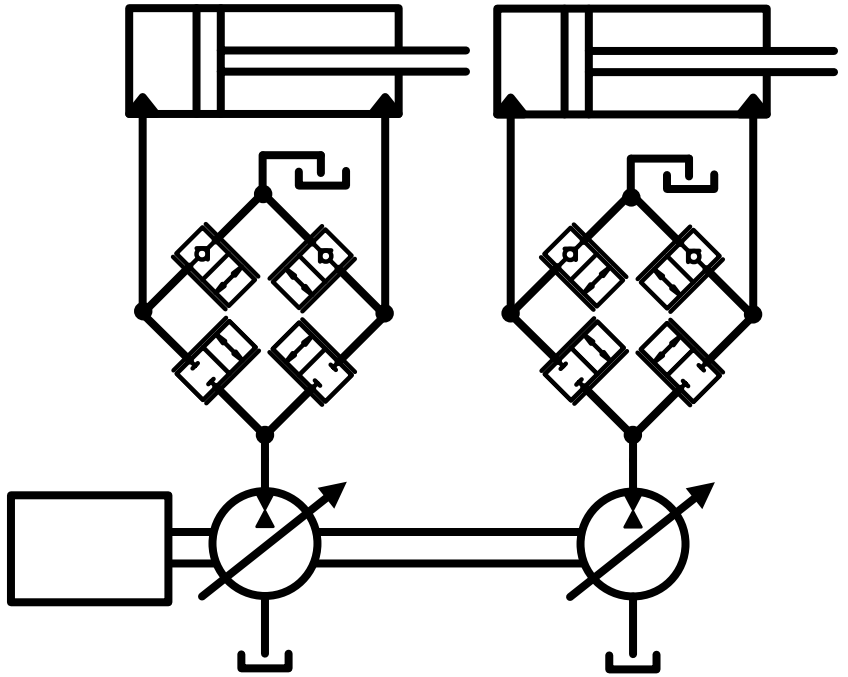
6 Summary

Concepts for energy recovery



Example: Displacement control in open circuit

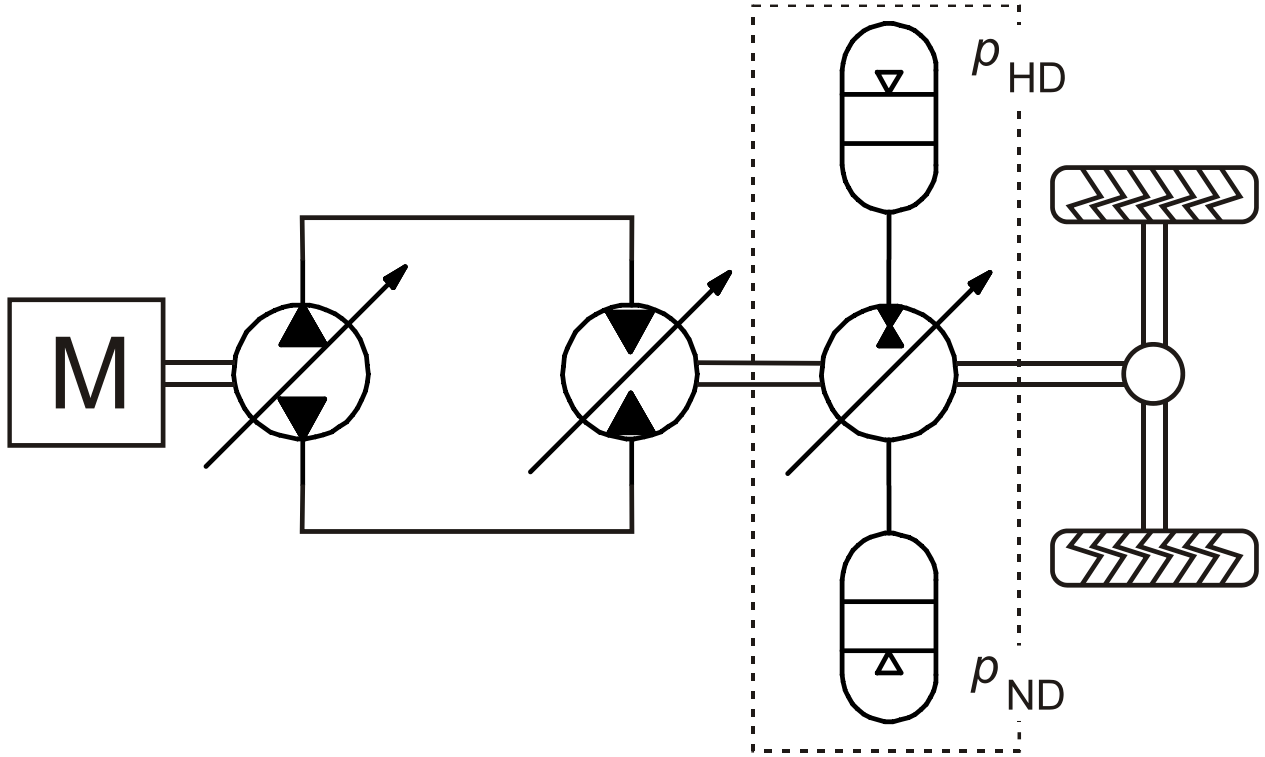
- Displacement control shows poor efficiency in partial load range
- Independent metering enables regeneration circuits (connecting both cylinder chambers)
- Regeneration between the two pumps additionally possible



Source: Heybroek

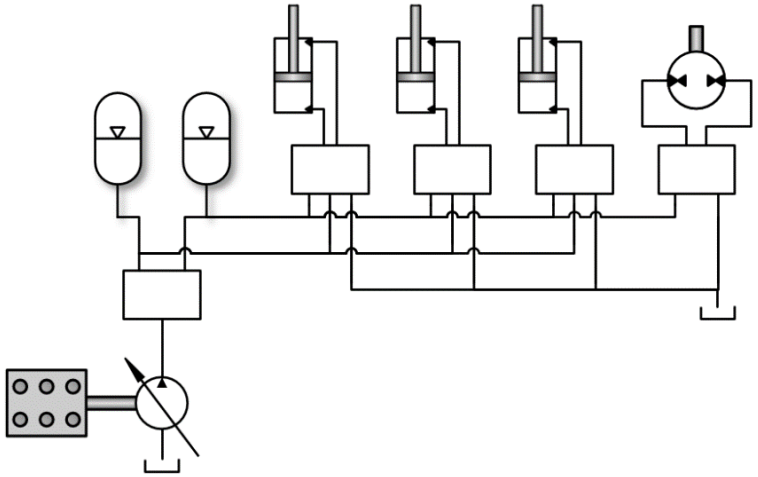
Example: Displacement control in closed circuit

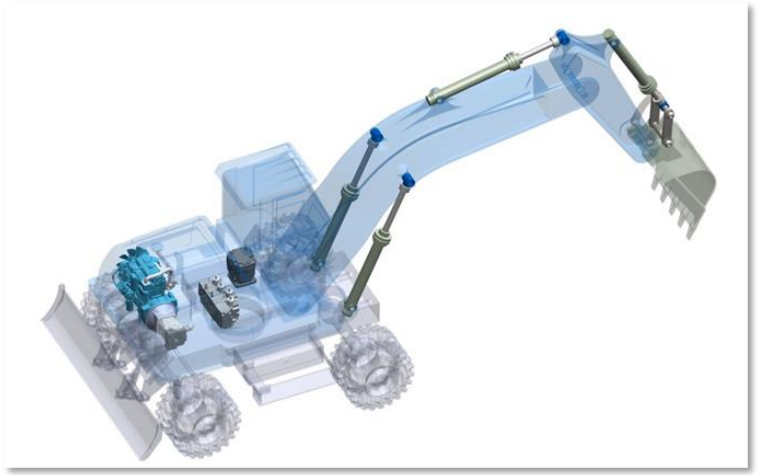
- Hydrostatic drive in a closed circuit
- Braking energy is temporarily stored in the hydraulic accumulator
- Energy is taken from accumulator to accelerate

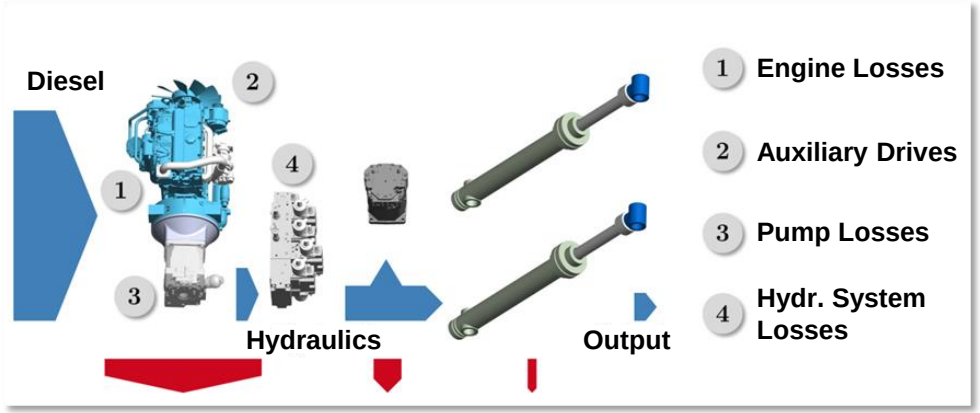


Excursus: STEAM project at ifas

- Focus on relevant loss points in today's machines
- Decoupling of external load and diesel engine load
- Complete development from simulations to prototype

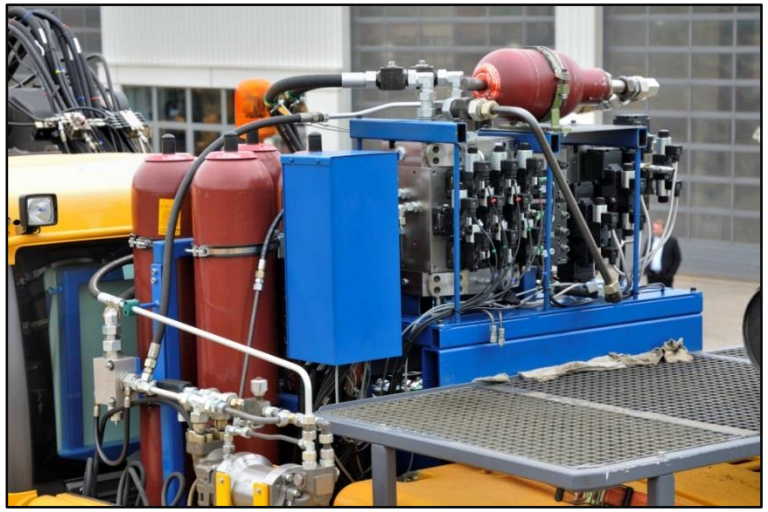






STEAM project: Prototype

- Parallel installation of standard system and the new hybrid system
- Validation on the basis of a 90° truck loading cycle



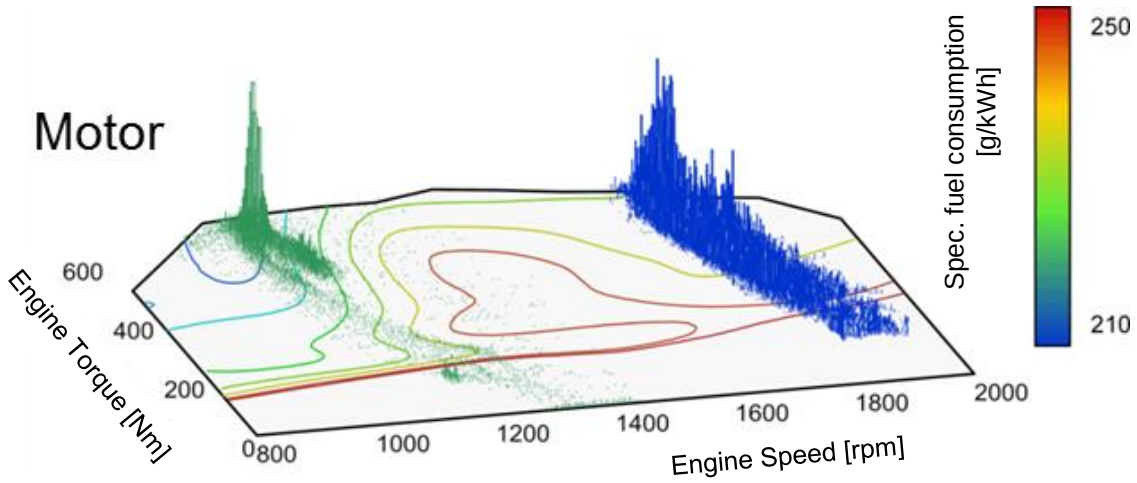
STEAM project: Field test

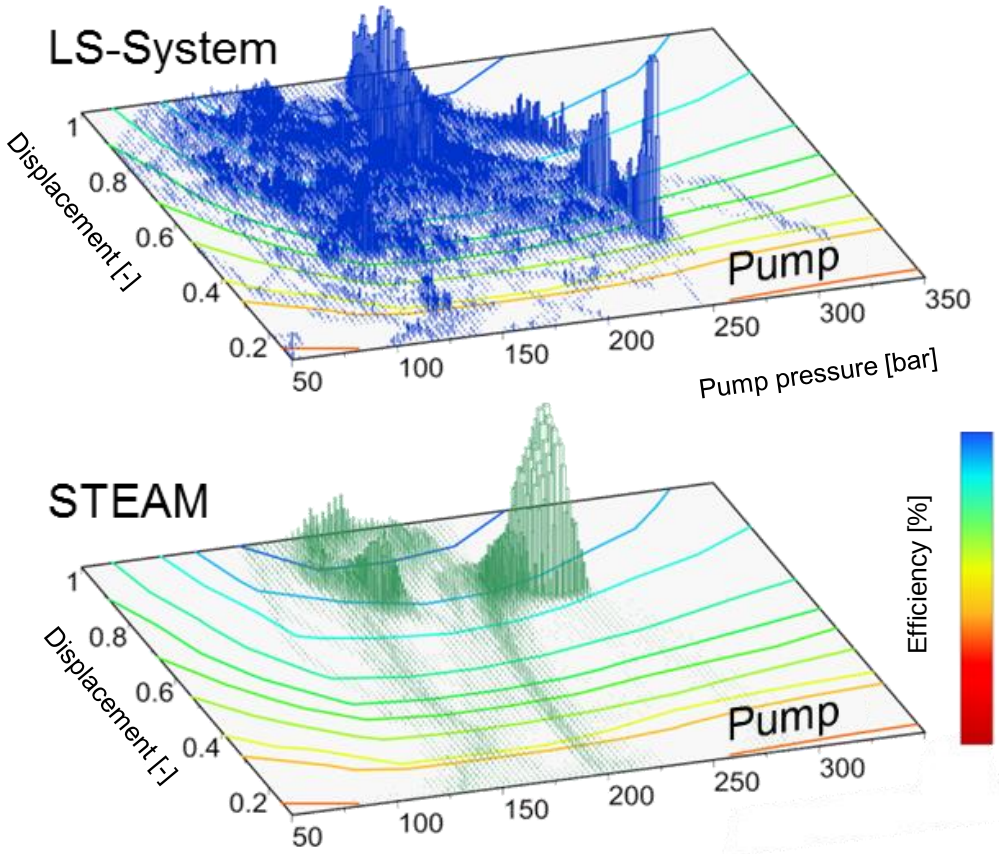
Standard 1800 rpm

STEAM 1200 rpm

STEAM project: Results

- Same productivity as standard system with fuel savings of approx. 27%





Outline of todays lecture

1 Backflip classification of hydraulic controls

2 Additional classification of hydraulic controls

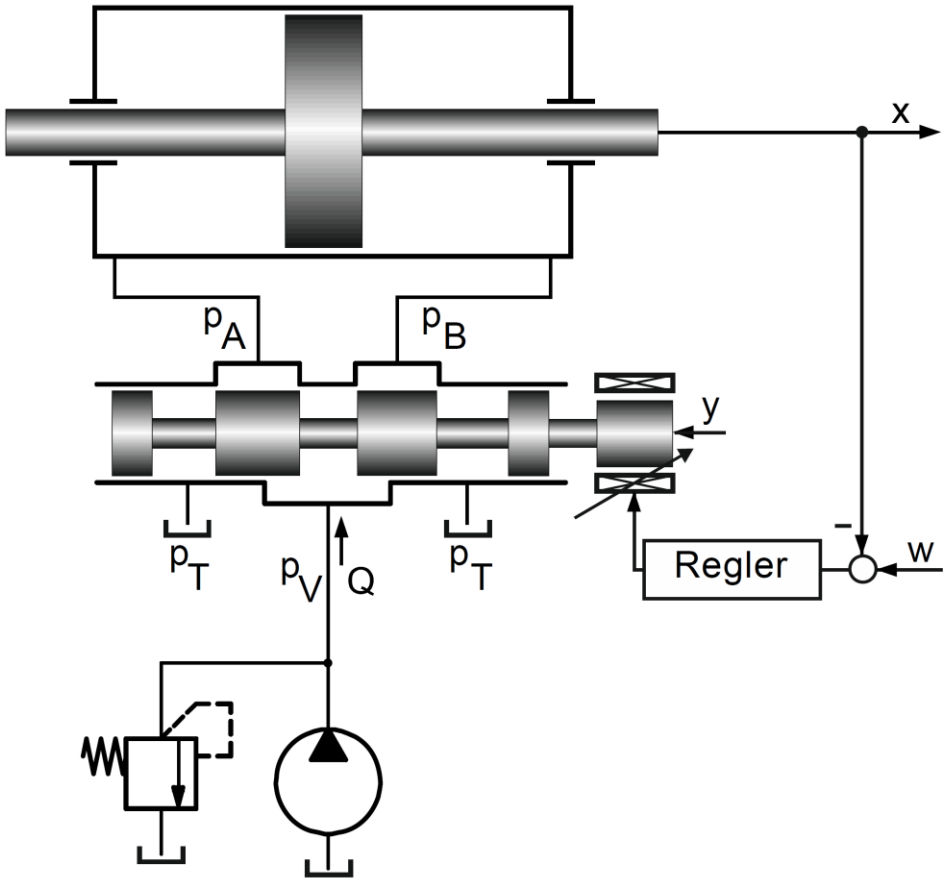
3 Concepts for energy recovery

4 Exemplary system

5 Practical exercise

6 Summary

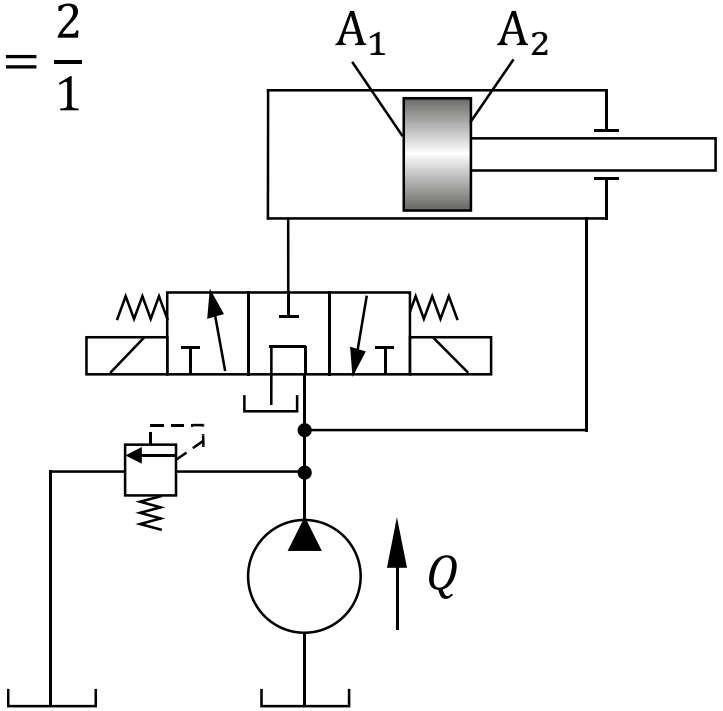
Position control of a cylinder



Velocity control: differential cylinder with equal speeds

- Permanent connection of the rod side to the pump line
- Same speeds at an area ratio of 2:1
- Equal loads in both directions possible

$$\frac{A_1}{A_2} = \frac{2}{1}$$



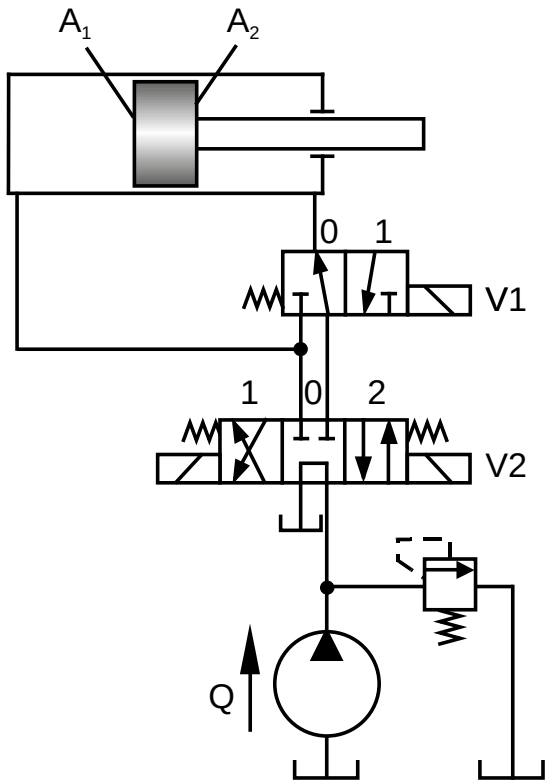
Fast forward circuit – with differential cylinder

- Control of direction of movement or standstill with valve V2
- Fast forward during extension is effected by switching valve V1
- Velocity during extension

$$v = \frac{Q}{A_1}$$

- Fast forward-velocity during extension

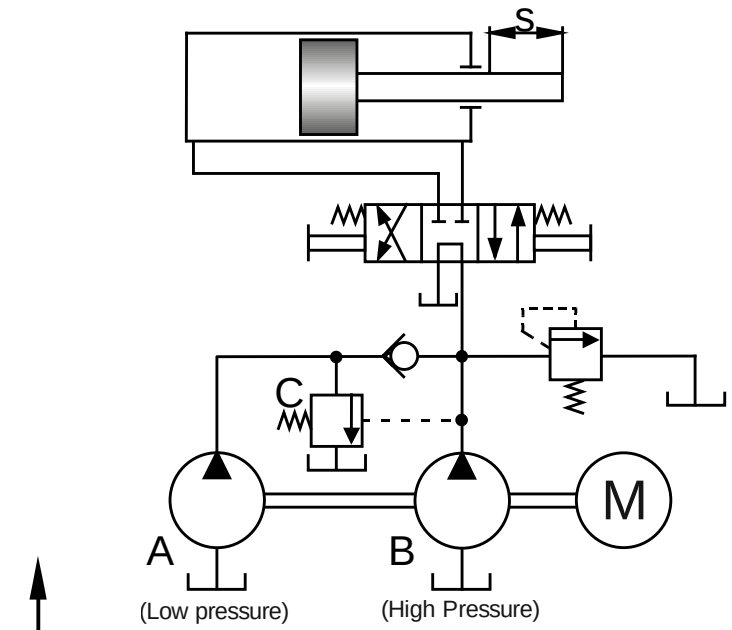
$$v = \frac{Q}{A_1 - A_2}$$



		V1	
		0	1
V2	0	Stop	Stop
	1	Forward	Fast forward
	2	Backward	Float

Fast forward circuit – with low pressure pump

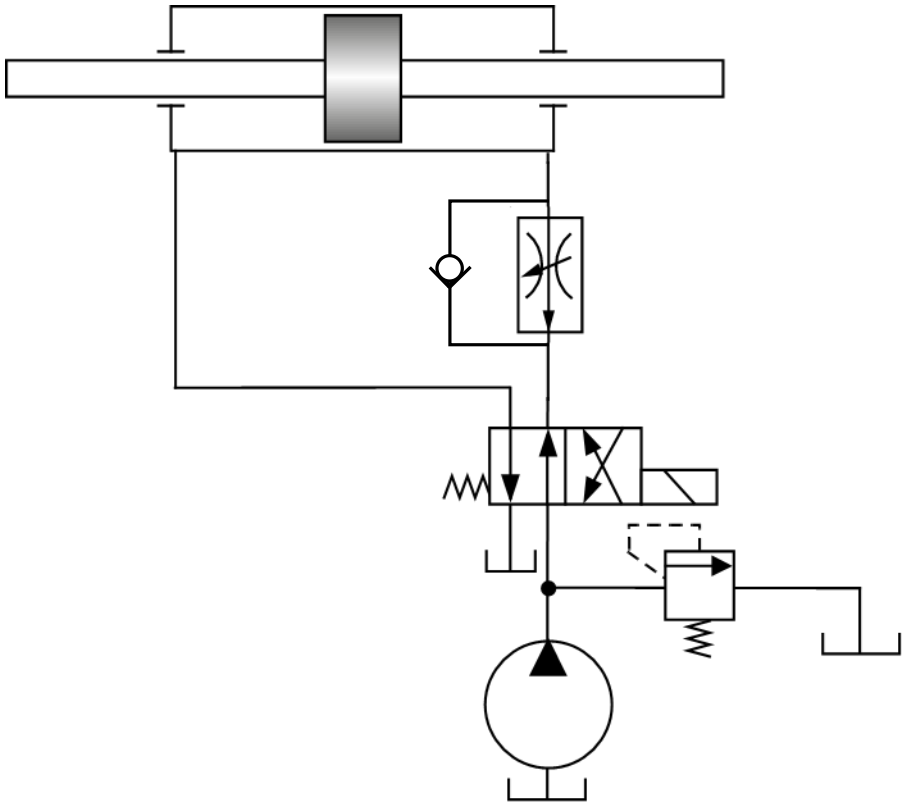
- Parallel connection of a low pressure pump with a high delivery flow, pump A, and a high pressure pump with a low delivery flow, pump B
- In fast forward, pumps A and B both deliver to the cylinder
- When the load increases, valve C is opened and flow of pump A returns into the reservoir



Distance-time diagram

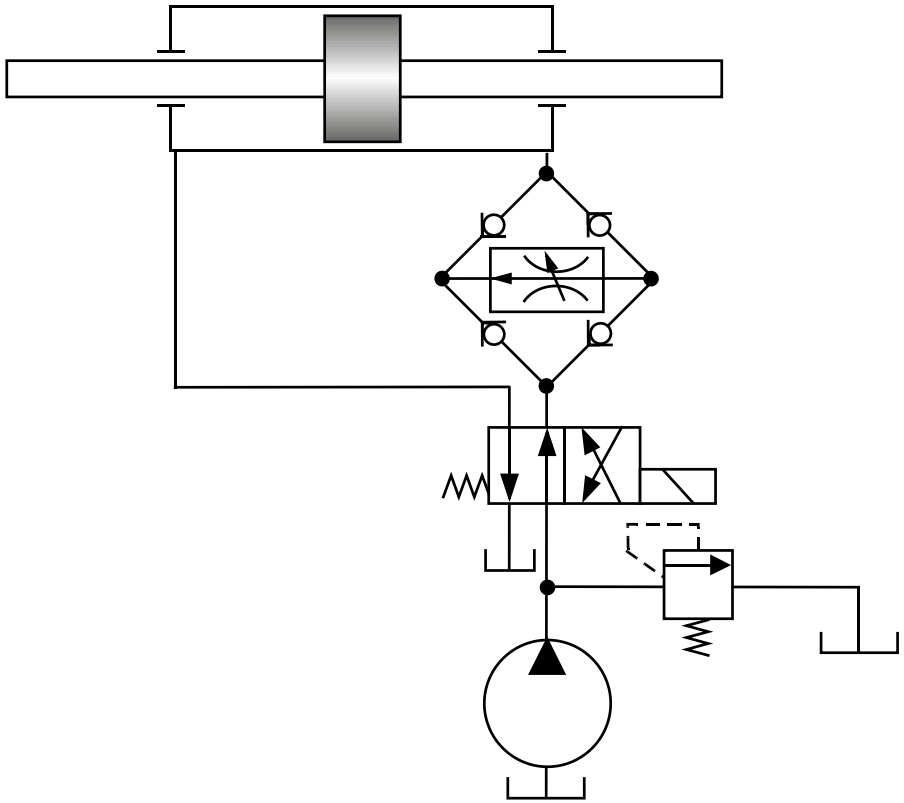
Velocity control – with one flow control valve

- Velocity control of the volume flow from the right cylinder chamber



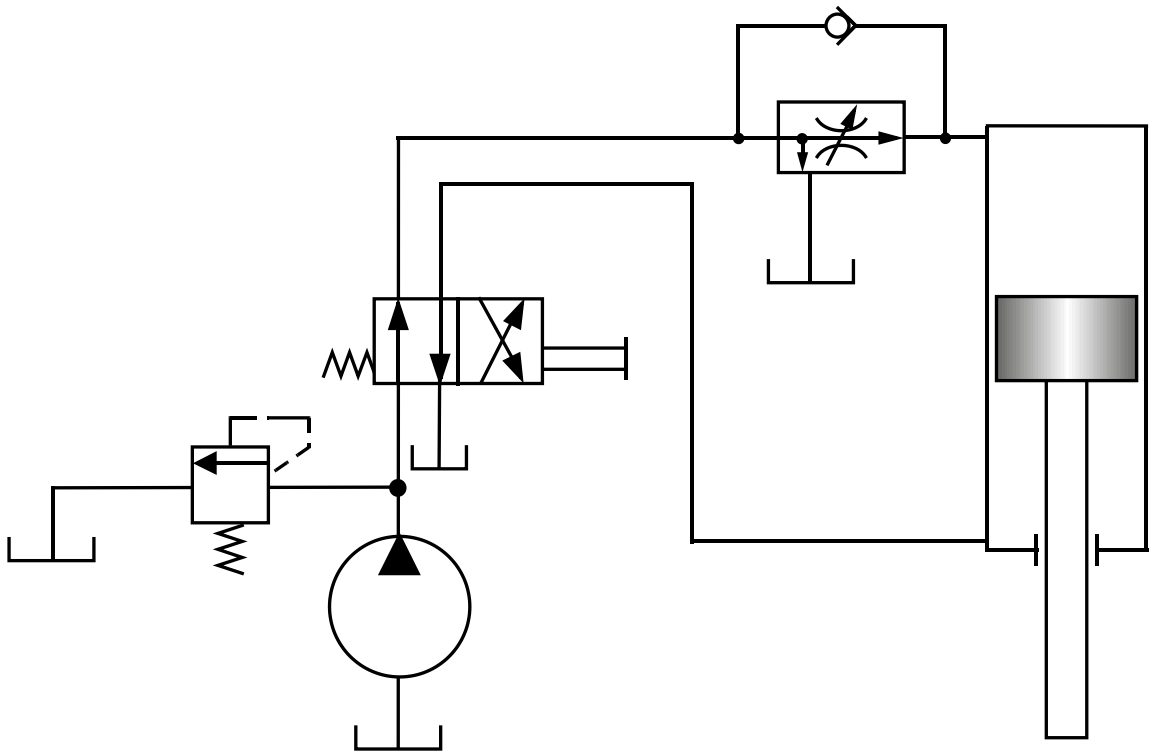
Velocity control – flow control valve in Graetz bridge design

- Velocity control of the volume flow from and to the right cylinder chamber
- Same extension and retraction speeds
- Usability of this circuit depending on the actual loads (risk of cavitation)



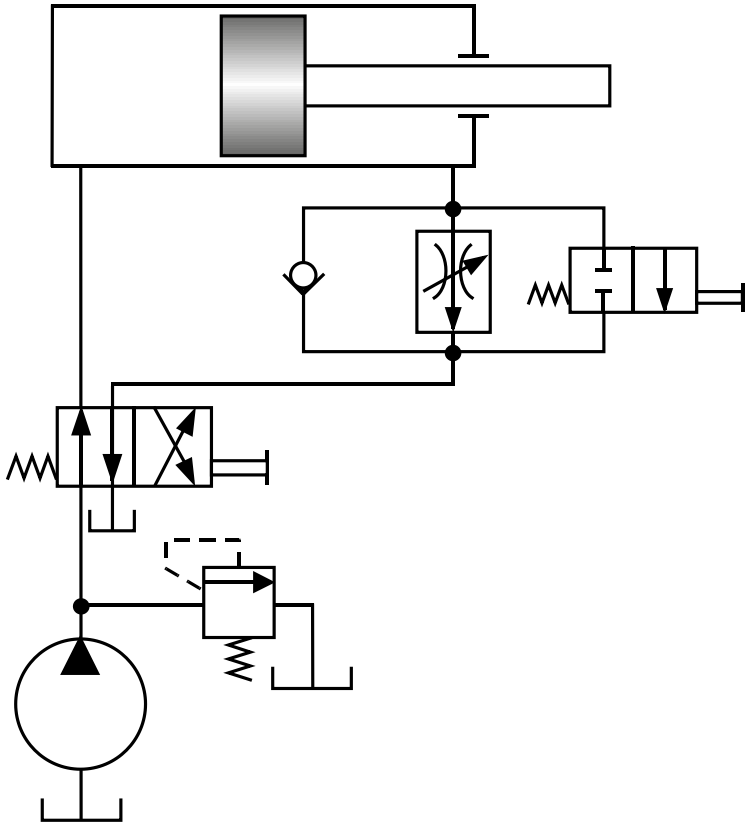
Velocity control – with upstream flow control

- A flow control upstream can take place only when loads are effective in the pressing direction
- When employing a 3-ways pressure compensator, the pressure rises as highly as the load requires



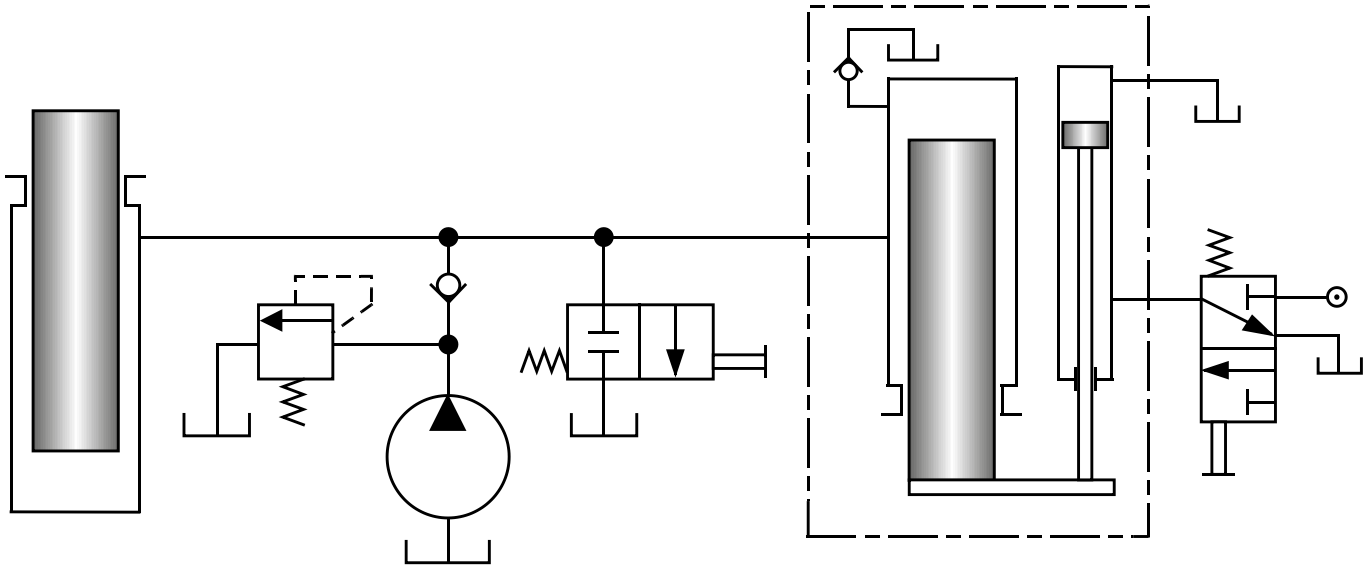
Velocity control – with downstream flow control

- The speed is variable in two steps with the 2/2-directional valve
- Frequent use for drives with active loads, e.g. lifting cylinders for forklift trucks

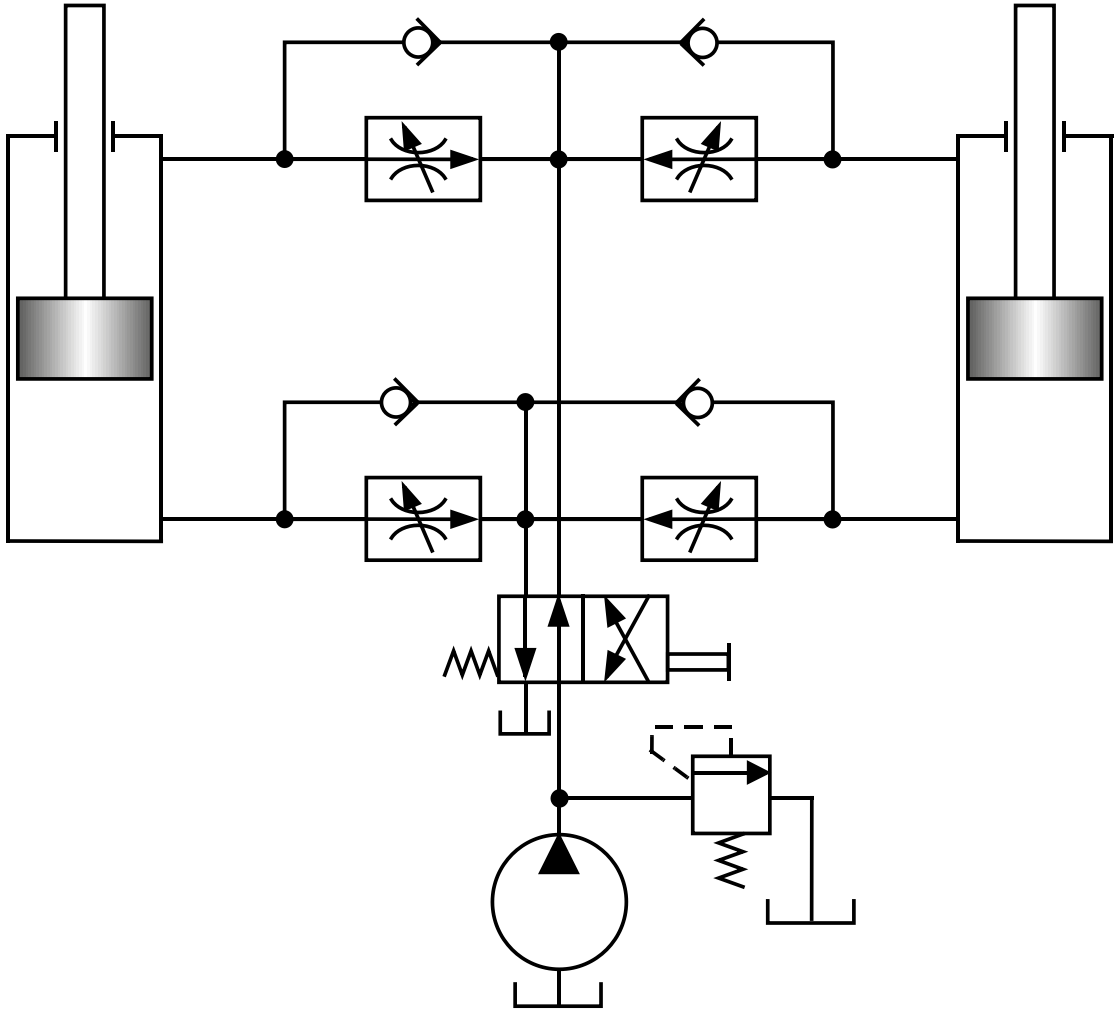


Simple press control

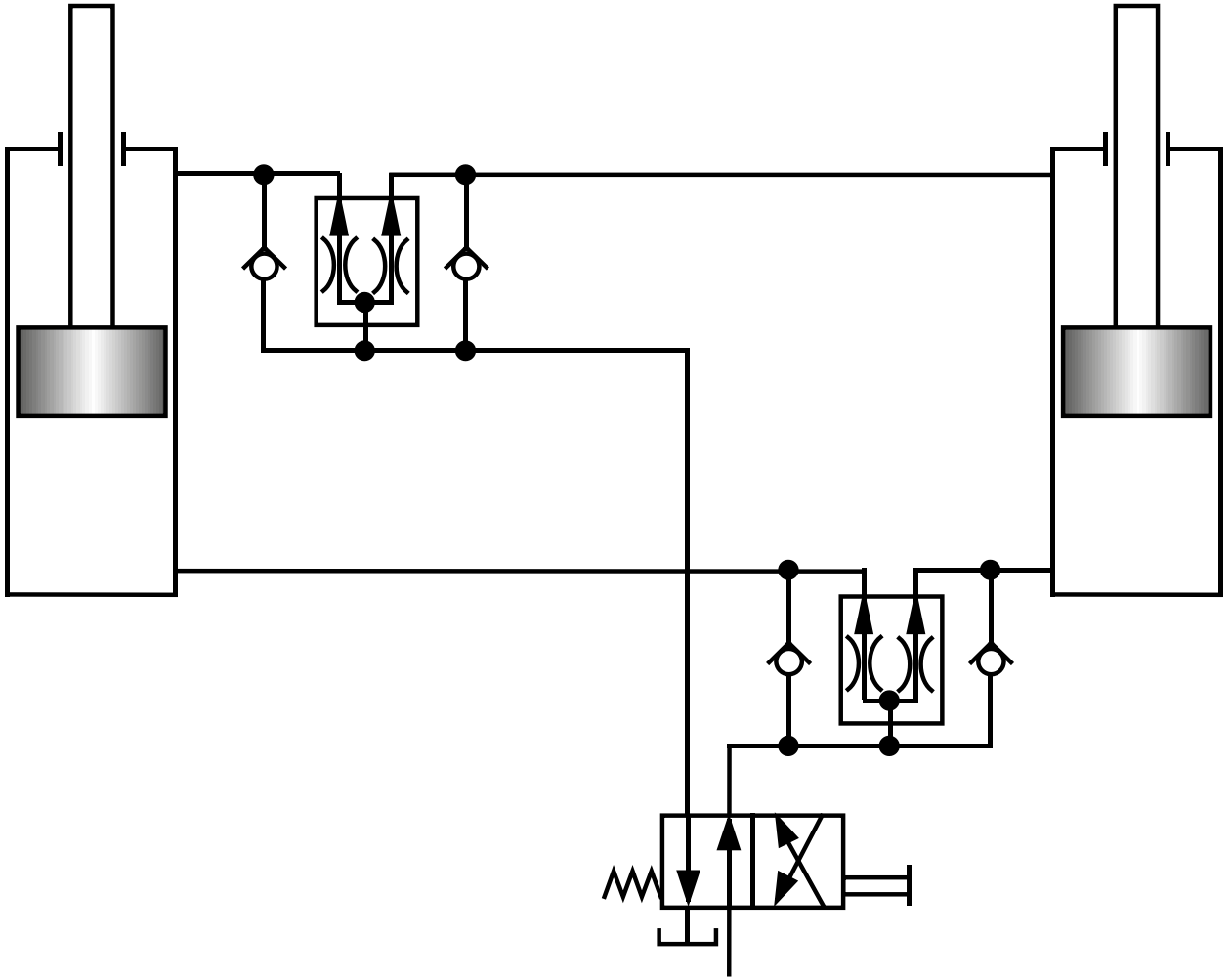
- With the **downstroke press**, the back flow ensues with the piston's own weight
- With the **downstroke press,** however, the press is closed by its own weight.
- The cylinder is filled from a higher vessel by a suction valve. The return trip is performed by a separate pullback cylinder.



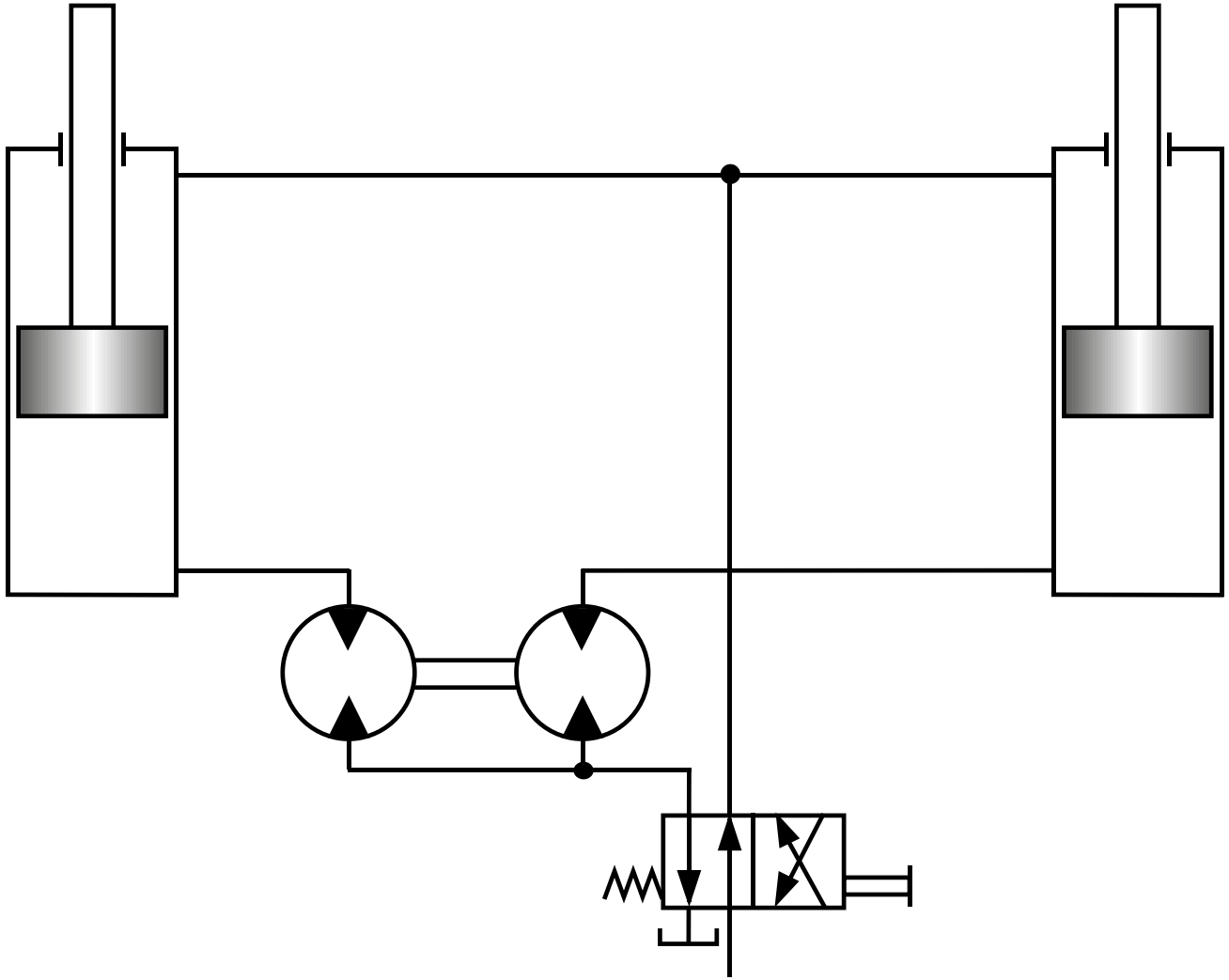
Synchronous run – with flow control valve in return line



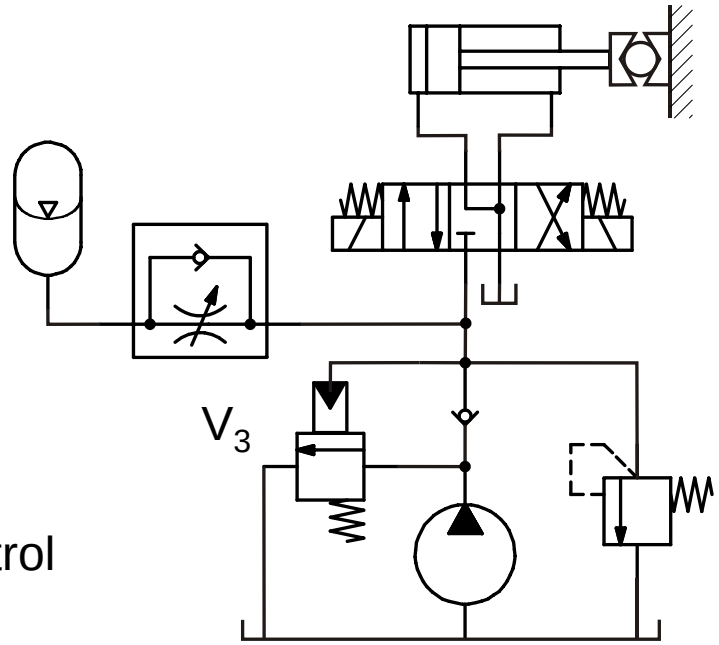
Synchronous run control – with flow divider in feed line

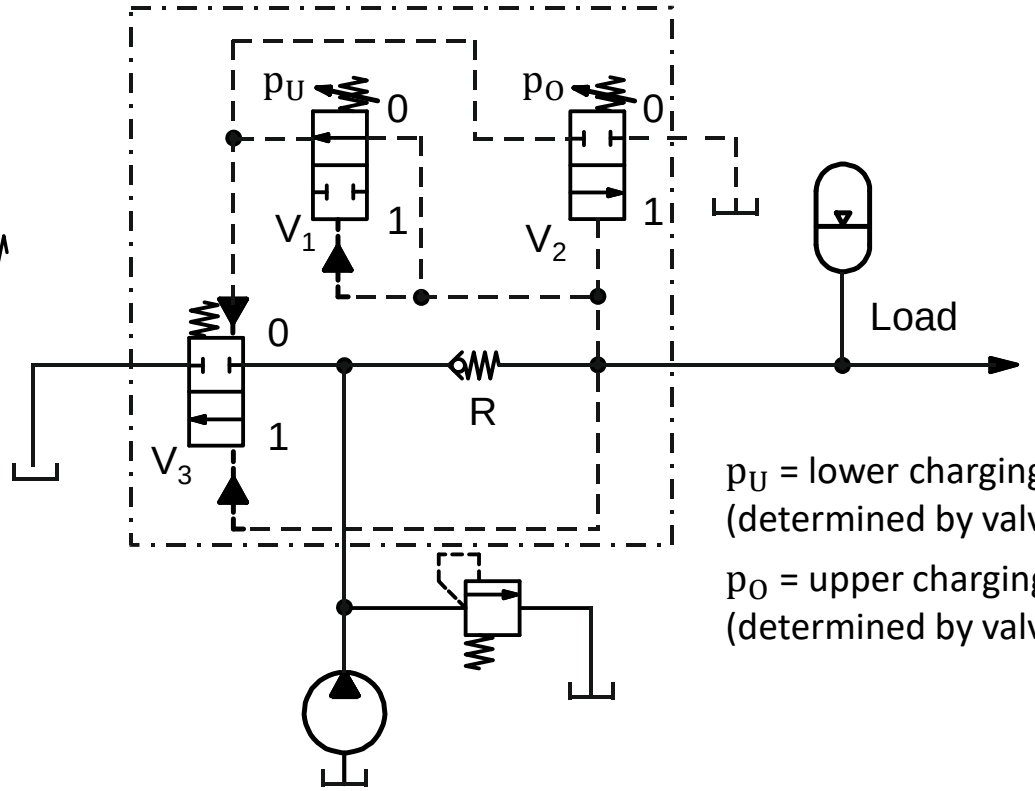


Synchronous run control – with mechanically connected motors



Accumulator Charging Circuit





- Switching two-point control
- Pressure fluctuates between adjustable limits p_U and p_O
- Non-return valve prevents pressure loss due to leakage in the pump

p_U = lower charging pressure (determined by valve V_1)

p_O = upper charging pressure (determined by valve V_2)

Outline of todays lecture

1 Backflip classification of hydraulic controls

2 Additional classification of hydraulic controls

3 Concepts for energy recovery

4 Exemplary system

5 Practical exercise

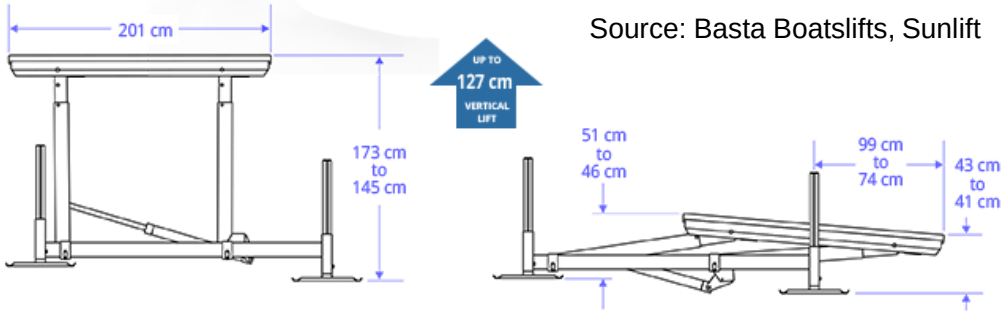
6 Summary

Practical excercise: designing a hydraulic system of a boatlift

- Boundaries:
  - Installation space, weight of the boat, lifting speed

- What to do:
  - calculate the required force of the cylinder
  - set max. system pressure, dimensioning cylinder
  - calculate required cylinder speed
    → pump volume flow
  - select pump
    (utility frequency of electric motor)
  - estimate losses in the system
    → pump pressure level
  - select electric motor
    (max. pressure, max. volume flow)
  - select valves (directional valve, PRV, etc.)
  - dimension the tank
  - cooler ?, filter
  - design circuit diagram & create parts list

Source: Basta Boatslifts, Sunlift



Outline of todays lecture

1 Backflip classification of hydraulic controls

2 Additional classification of hydraulic controls

3 Concepts for energy recovery

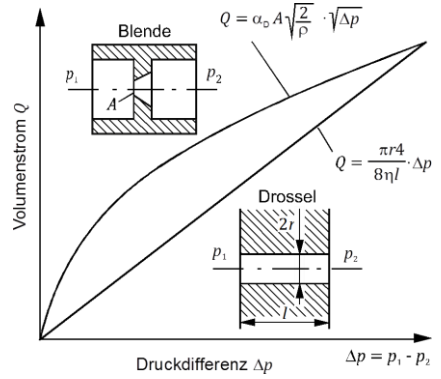
4 Exemplary system

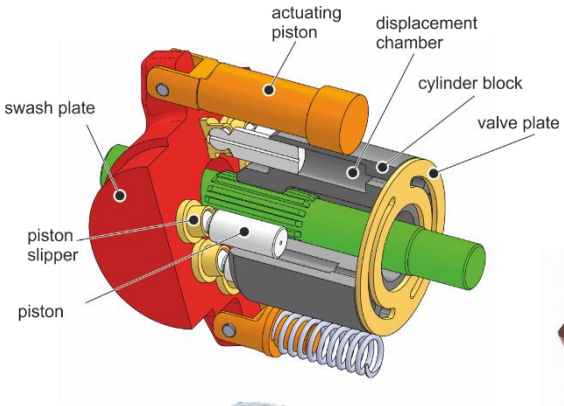
5 Practical exercise

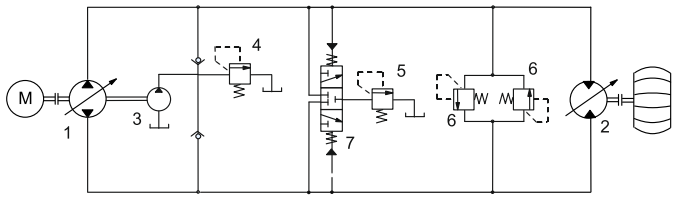
6 Summary

Summary

- Lecture 1: Fundamentals
- Lecture 2: Hydraulics networks
- Lecture 3: Fluids
- Lecture 4/5: Pumps & motors
- Lecture 6/7: Valves
- Lecture 8: Seals, components
- Lecture 9/10: Hydraulic circuits







Thank you for your attention.