



AEROSPACE TECHNOLOGY CONGRESS 2019

SUSTAINABLE AEROSPACE INNOVATION IN A GLOBALISED WORLD

STOCKHOLM WATERFRONT CONGRESS CENTRE, 8-9 OCTOBER 2019

CHALLENGES ON THE DEVELOPMENT OF A DIGITAL HYDRAULIC ACTUATOR FOR PRIMARY FLIGHT CONTROL SURFACES

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- Precise positioning
- High dynamic response
- Jam free solution in case of failures

- Low energy efficiency

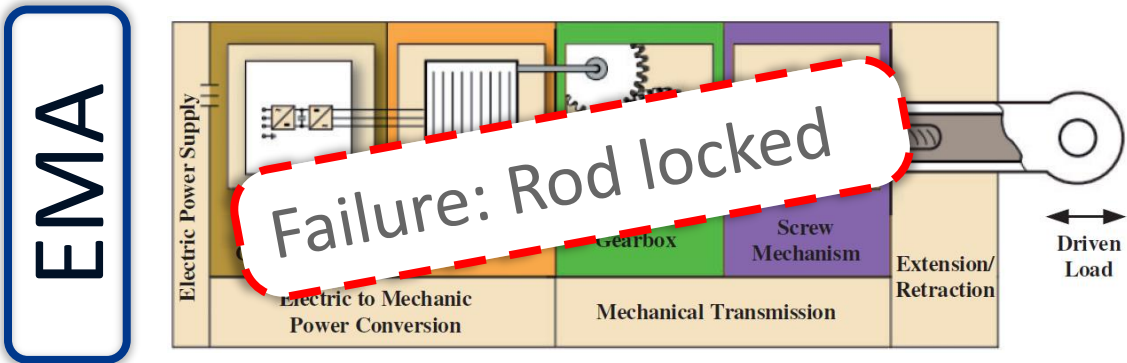


Image Source: QIAO (2017)

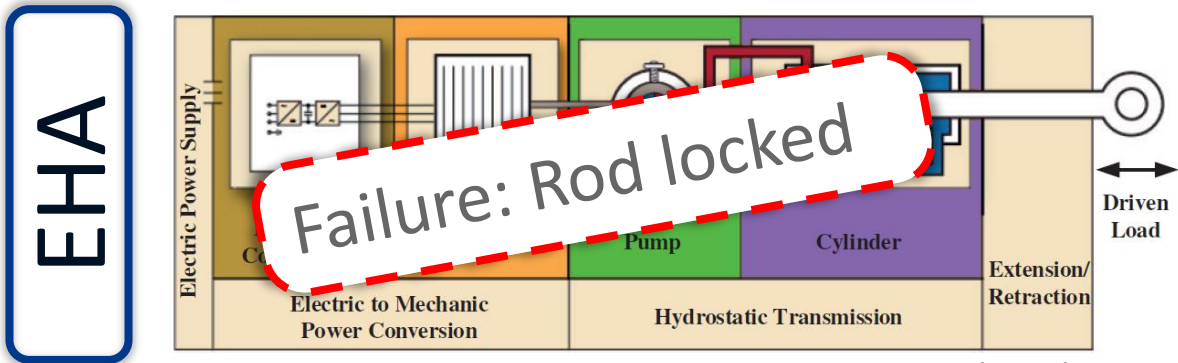
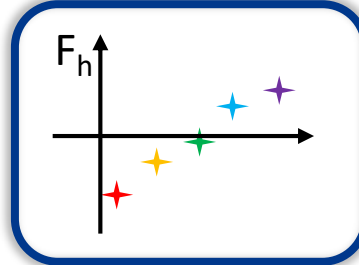
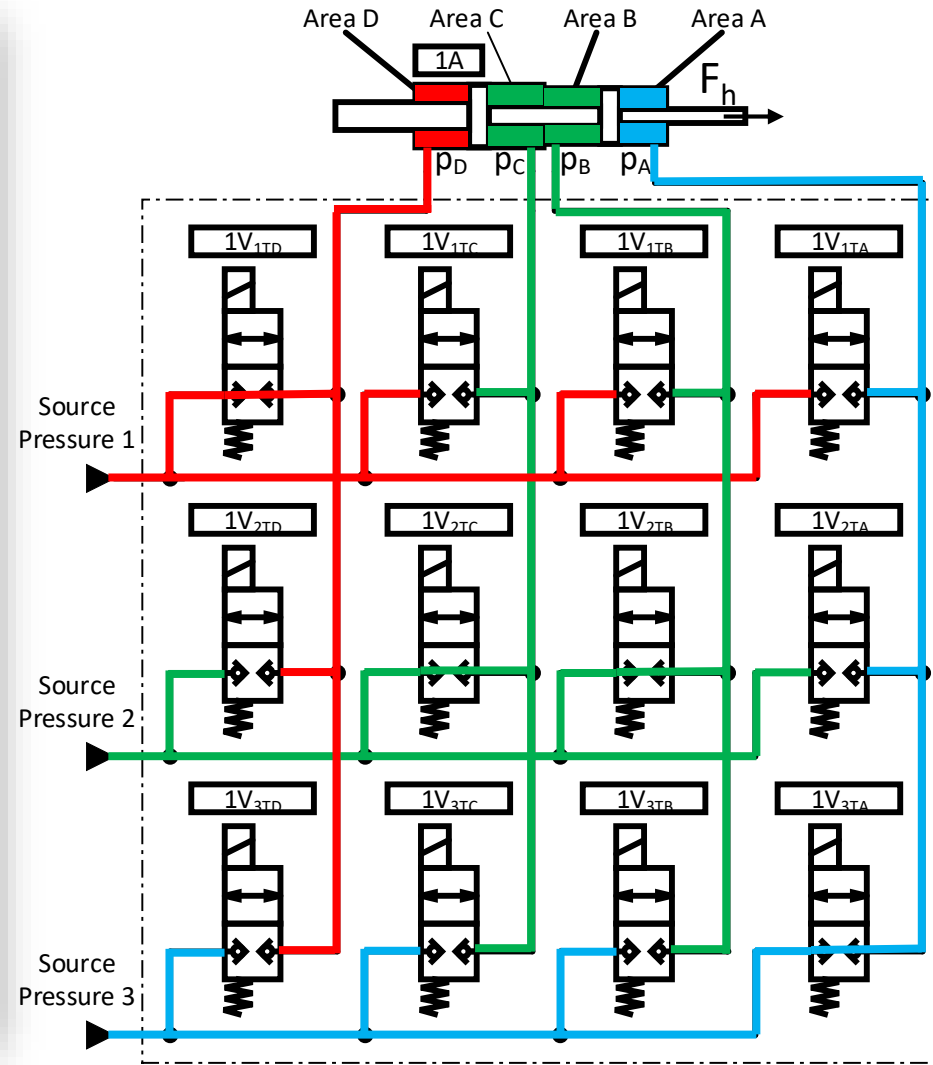


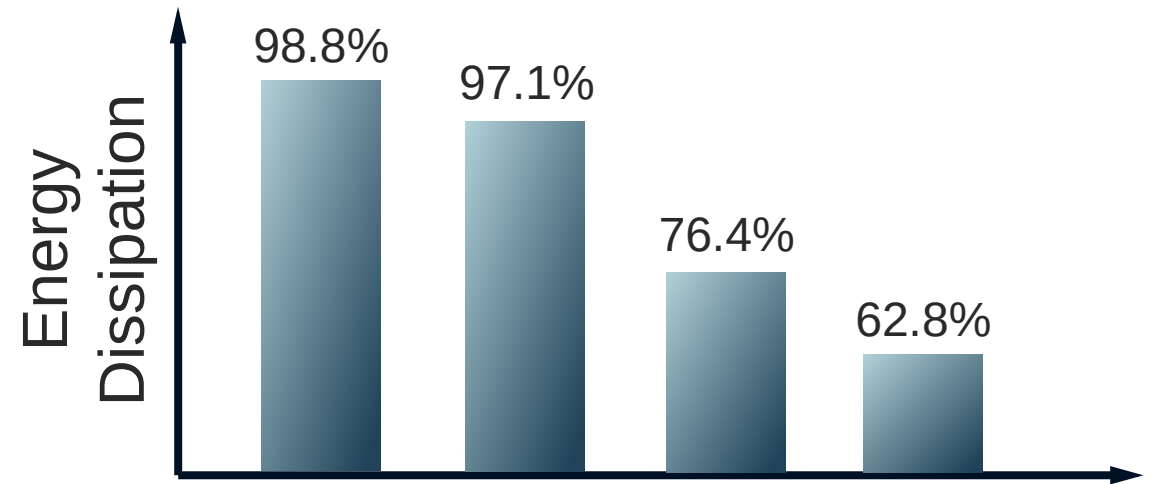
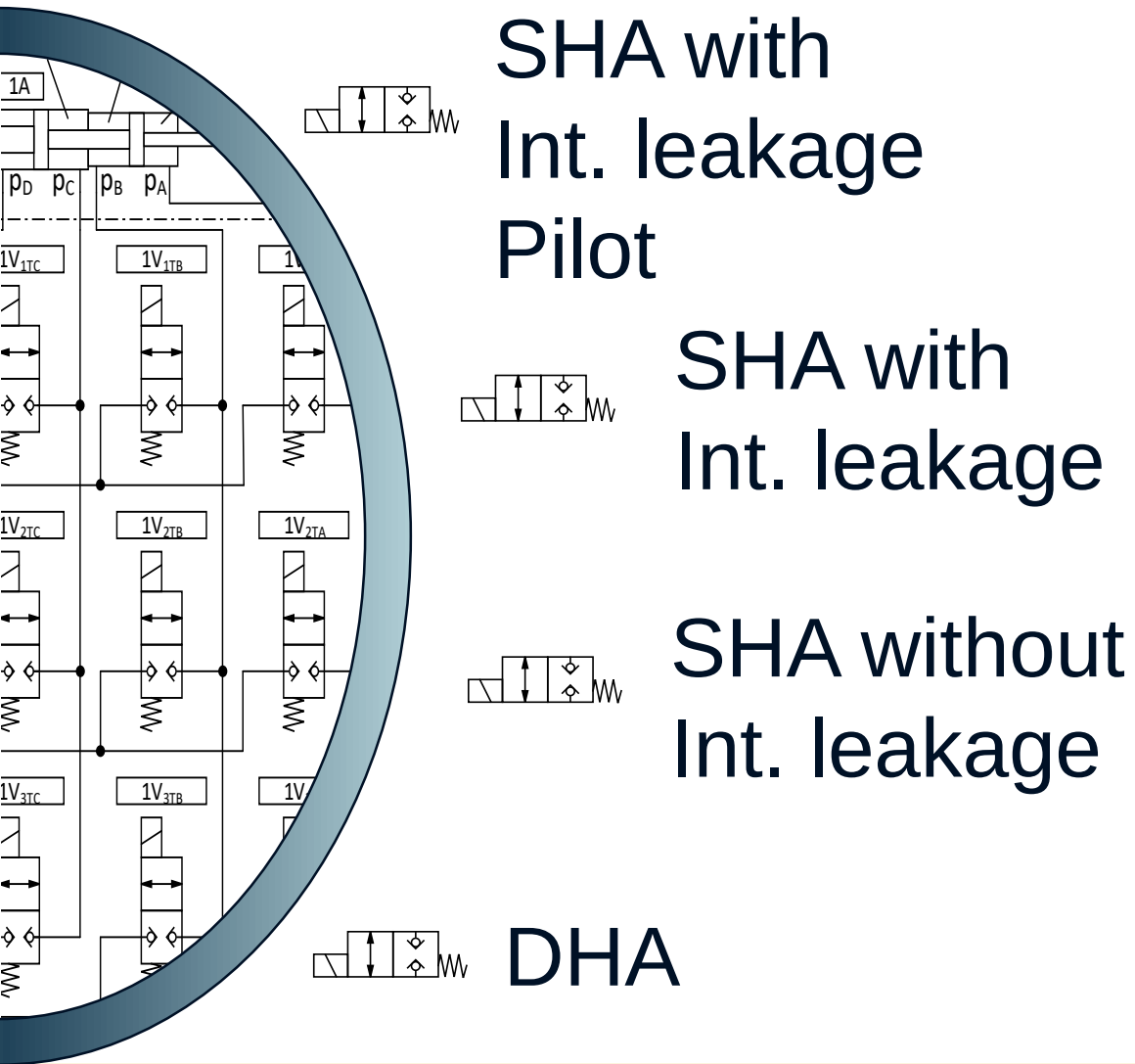
Image Source: QIAO (2017)



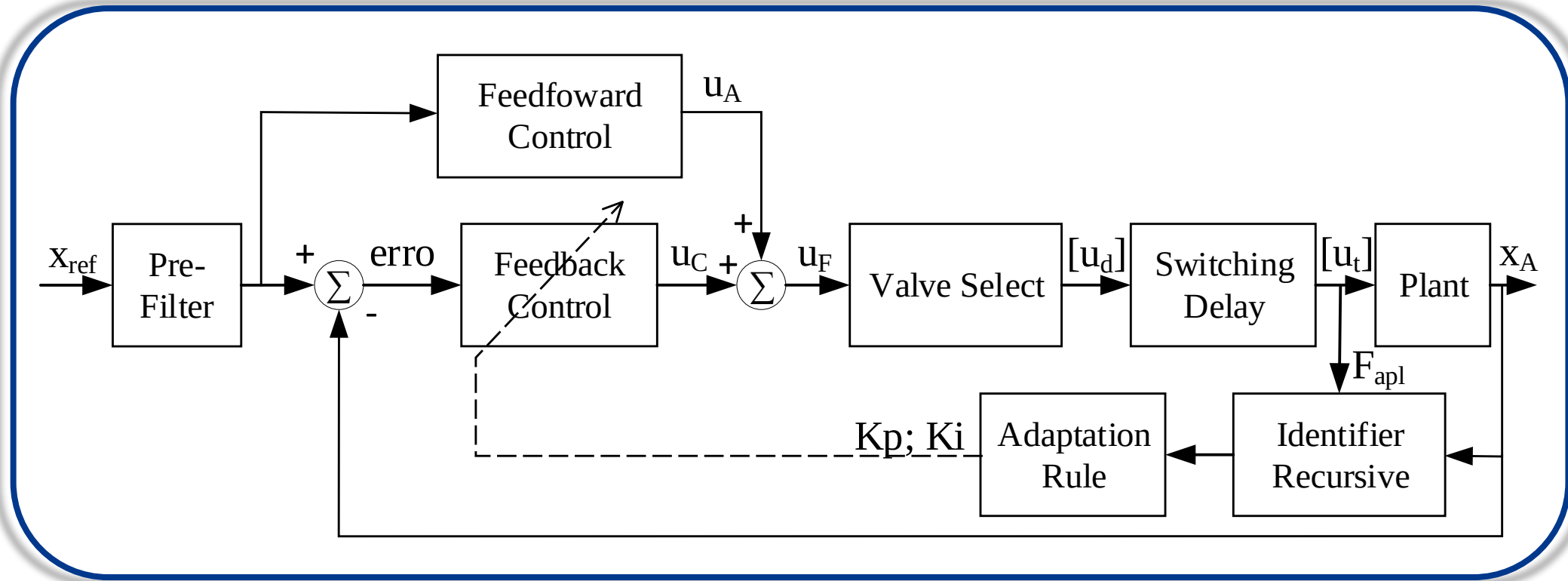
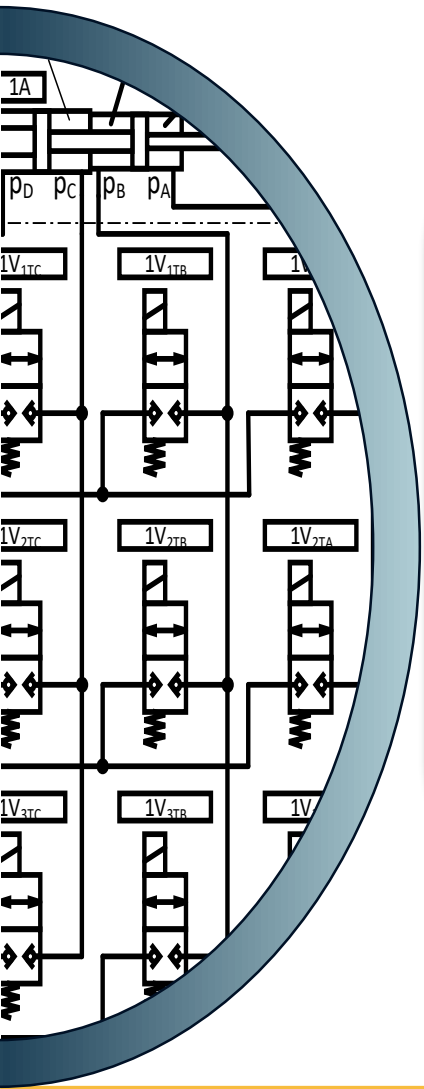
Discrete Force Variation

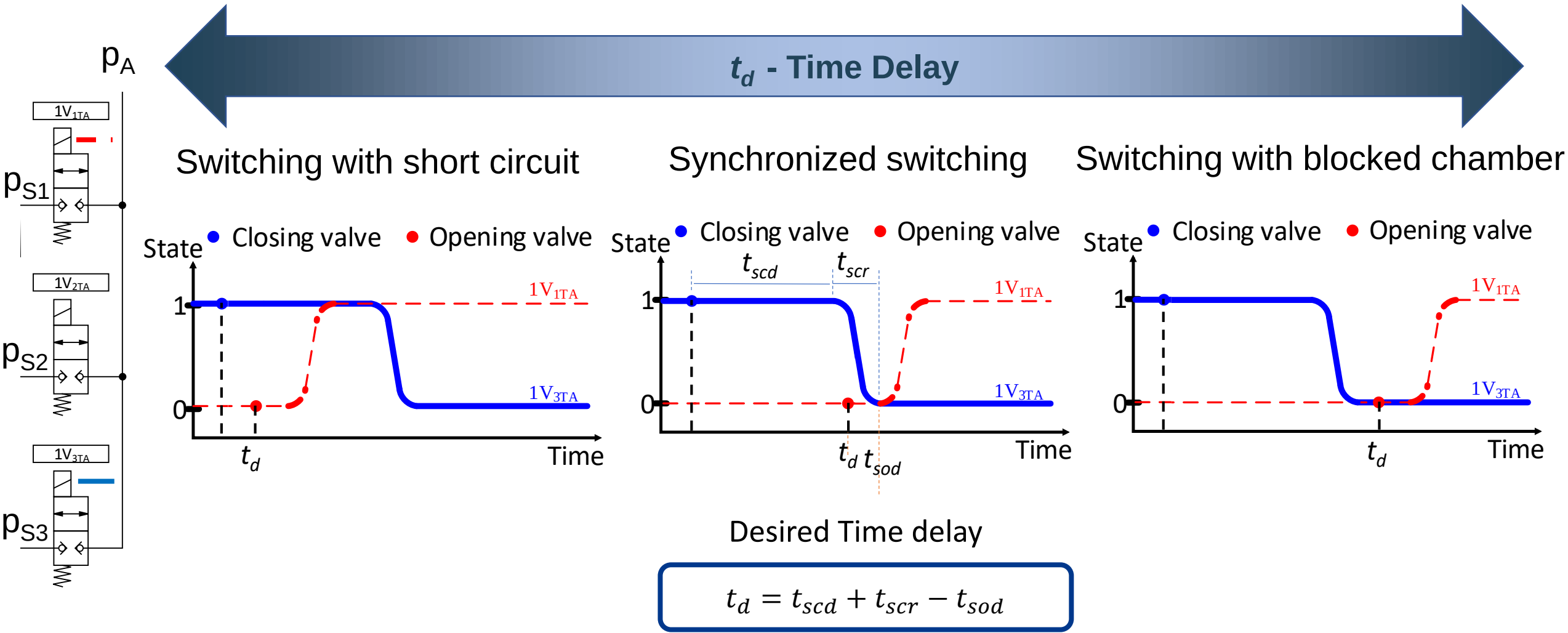
Pressure Shifting

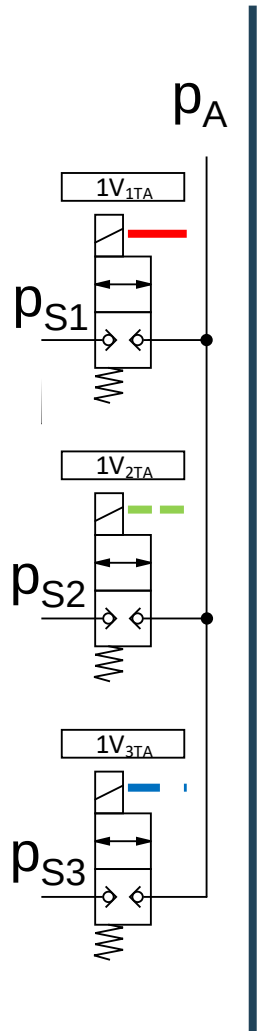
Switching between on/off valves



≈30x more
Useful Energy





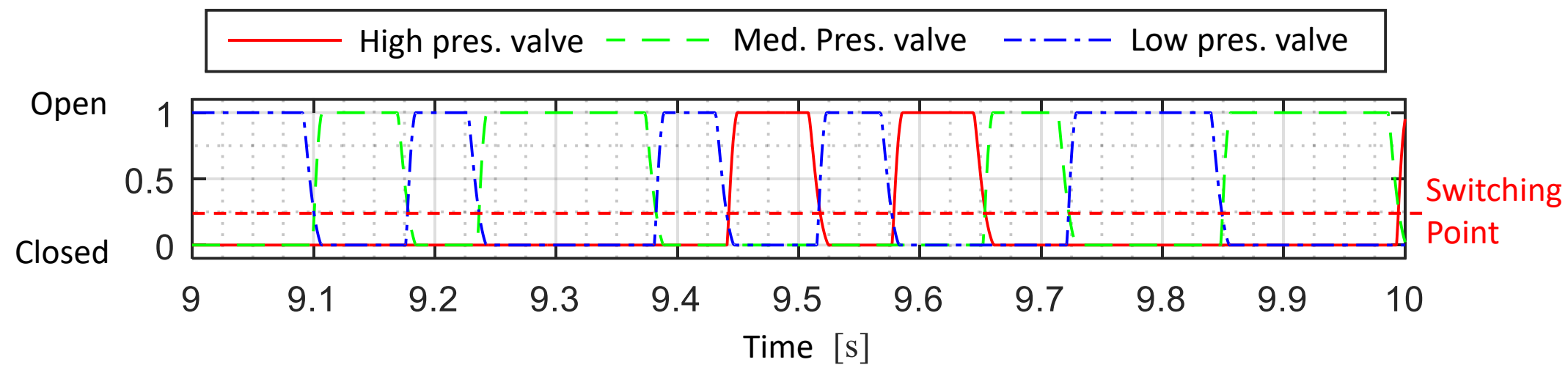


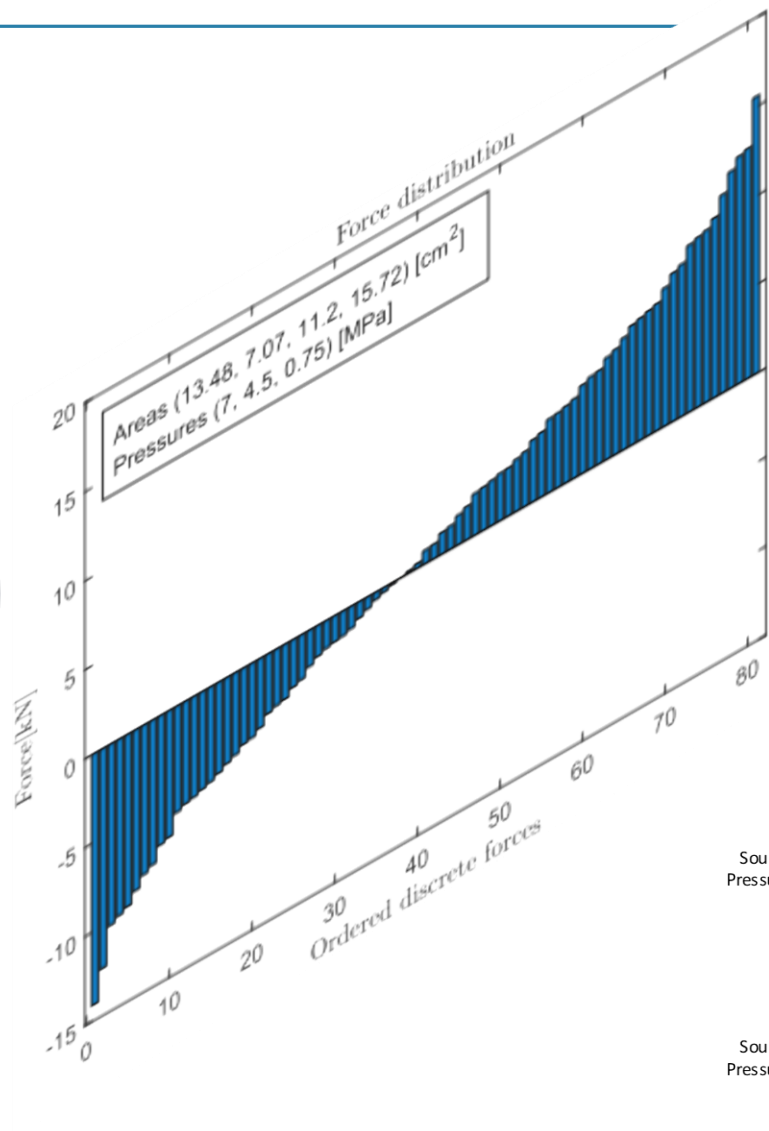
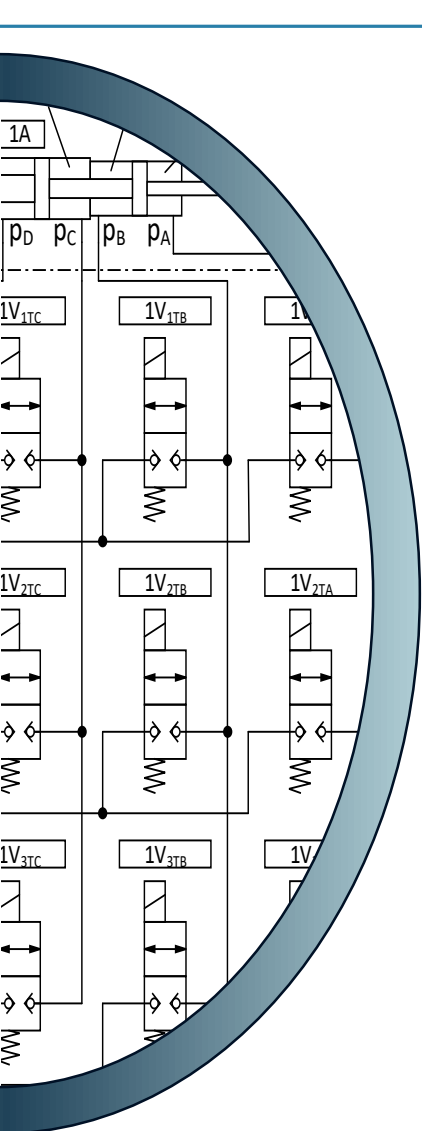
$$t_{ds\ A} = \begin{bmatrix} t_{ds(11)} & t_{ds(12)} & t_{ds(13)} \\ t_{ds(21)} & t_{ds(22)} & t_{ds(23)} \\ t_{ds(31)} & t_{ds(32)} & t_{ds(33)} \end{bmatrix}$$



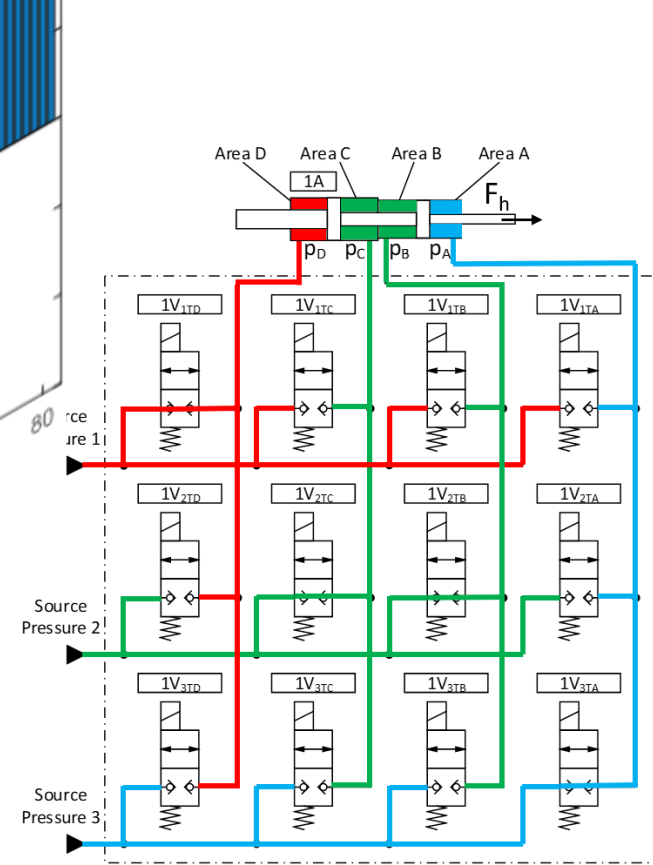
Time Delays [ms]

$$t_{ds\ A} = \begin{bmatrix} 0 & 52 & 50 \\ 52 & 0 & 52 \\ 44 & 44 & 0 \end{bmatrix}$$

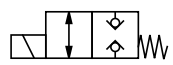
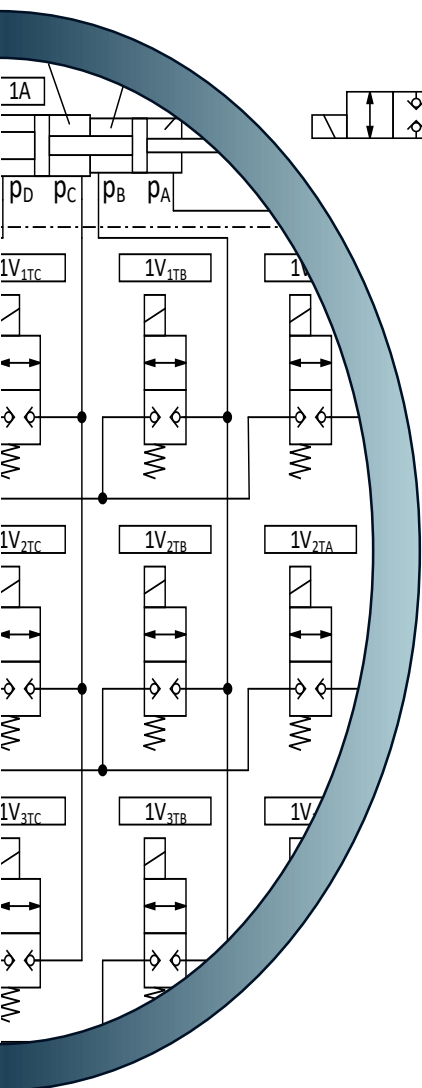




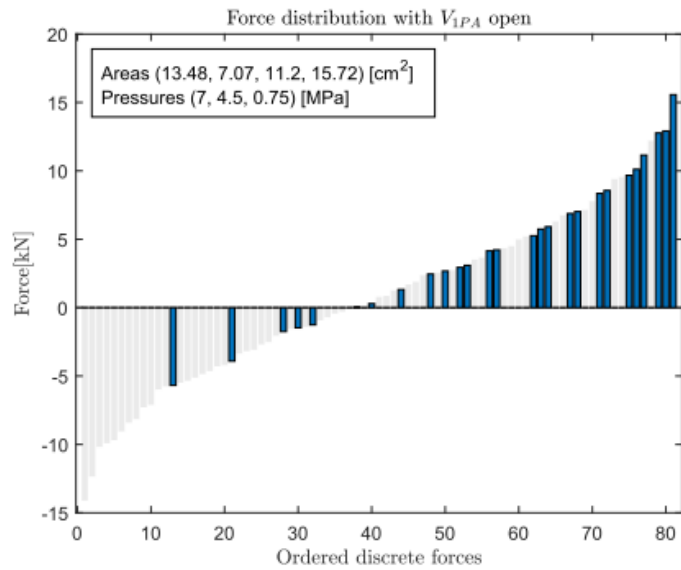
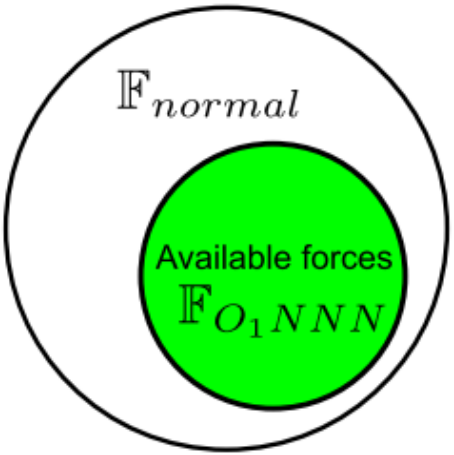
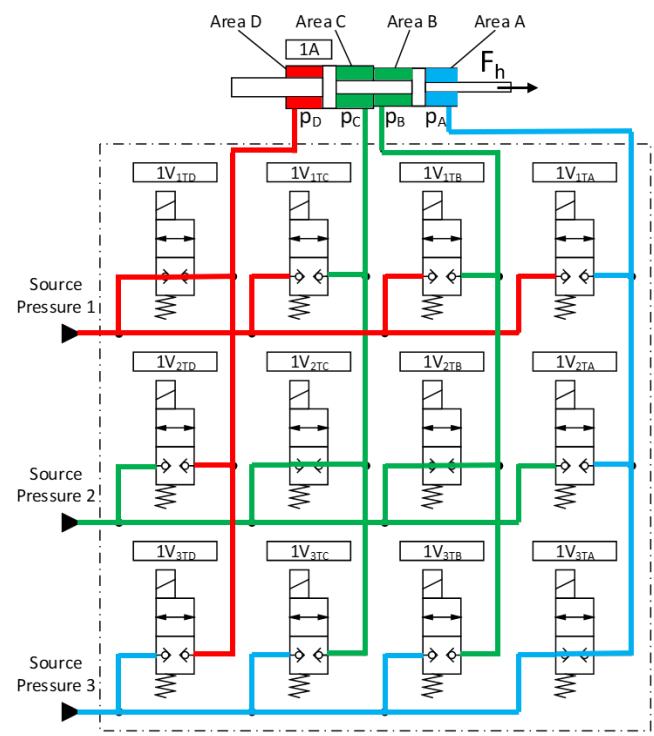
Discrete forces:
function of failure state of valves

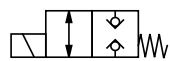


Cylinder chamber:
A B C D
 F
 $Z_i Z_i Z_i Z_i$
 $i = \begin{cases} 1 = \text{High pressure} \\ 2 = \text{Med. pressure} \\ 3 = \text{Low pressure} \end{cases}$
 $Z = \begin{cases} 0 = \text{Open failure} \\ C = \text{Closed failure} \\ N = \text{Normal} \end{cases}$

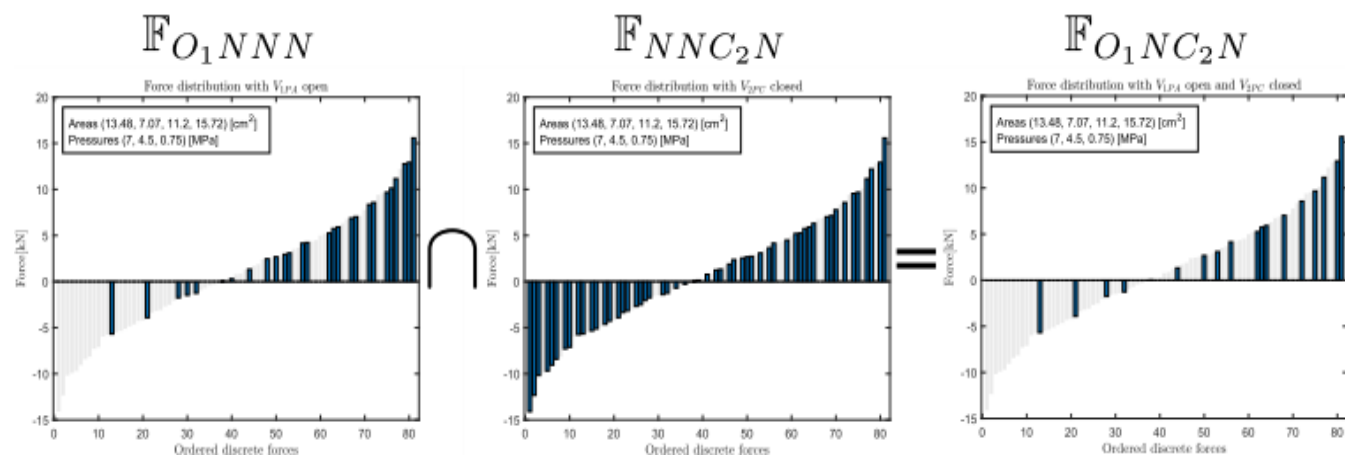
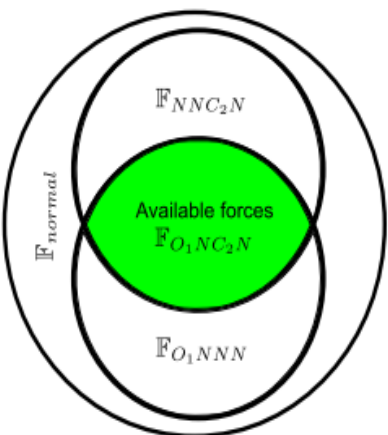
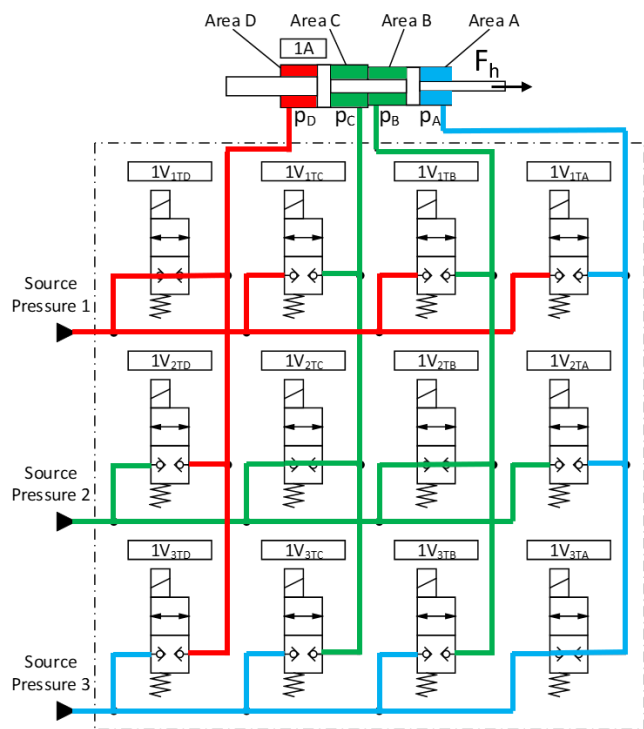
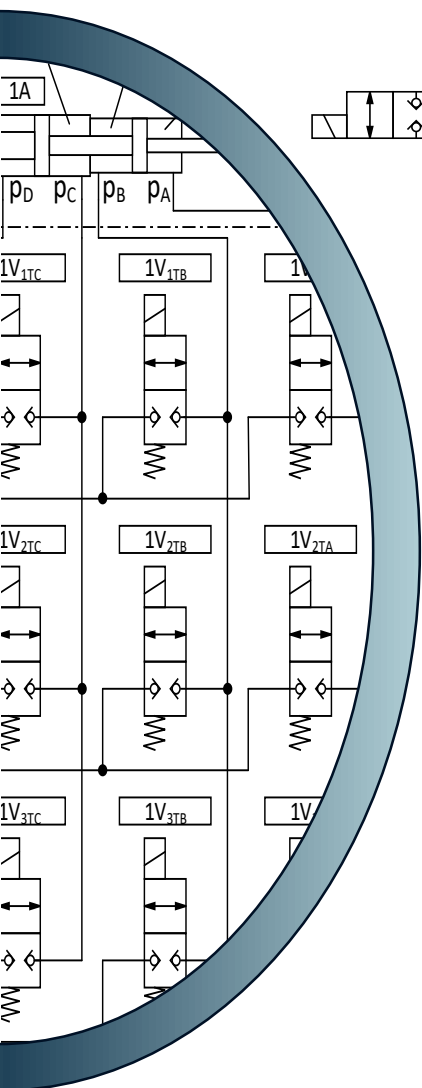


One Failure



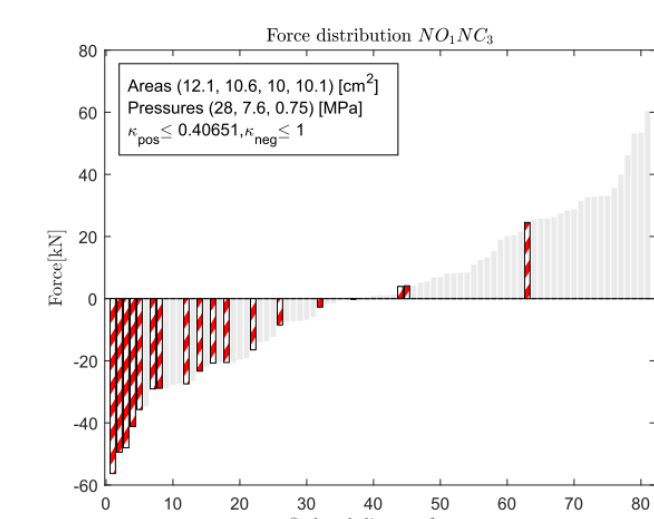
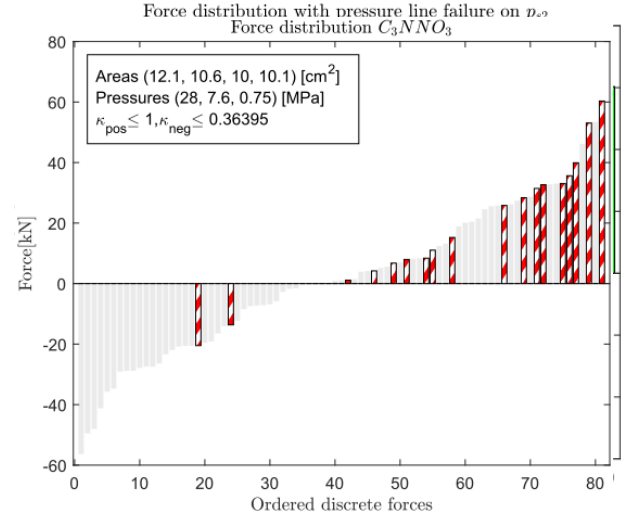
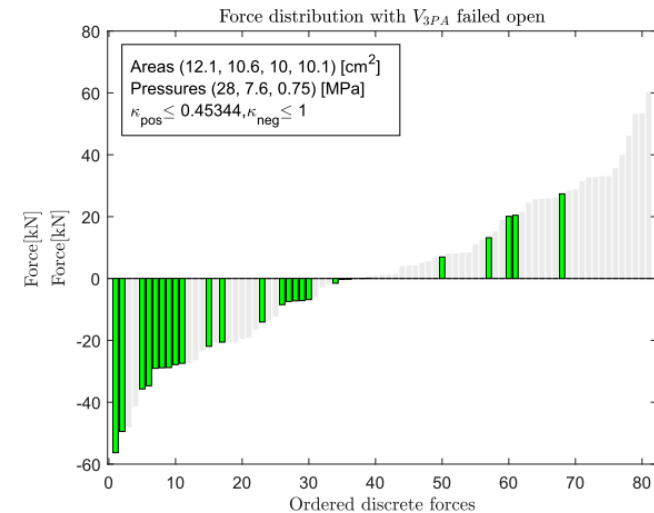
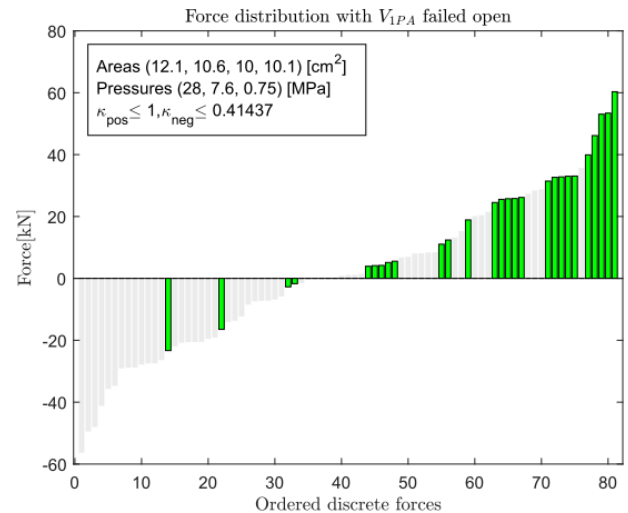
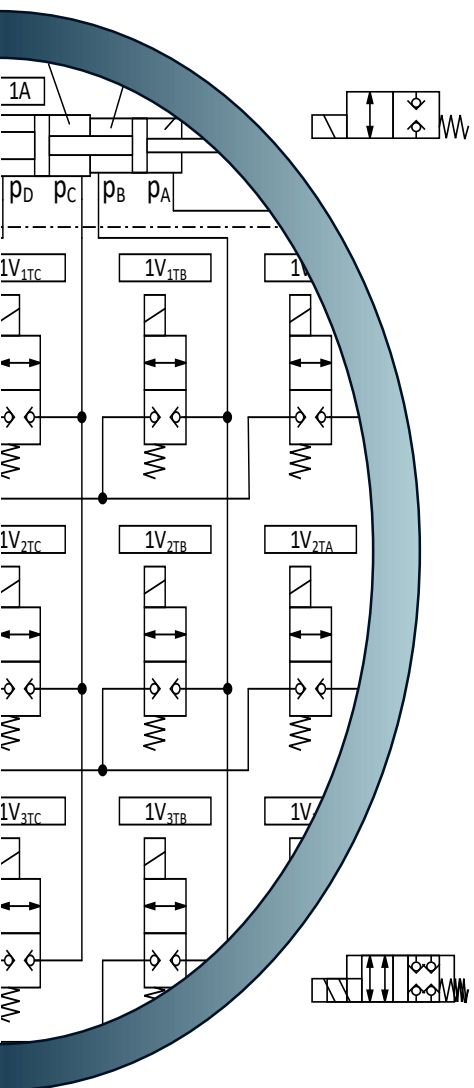


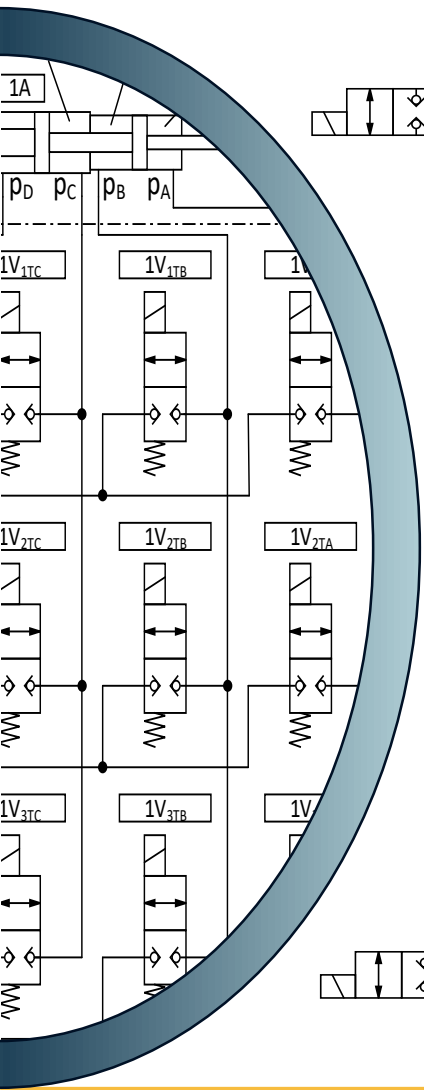
Two or more Failures



Pressure Line Failure

Valve Failure





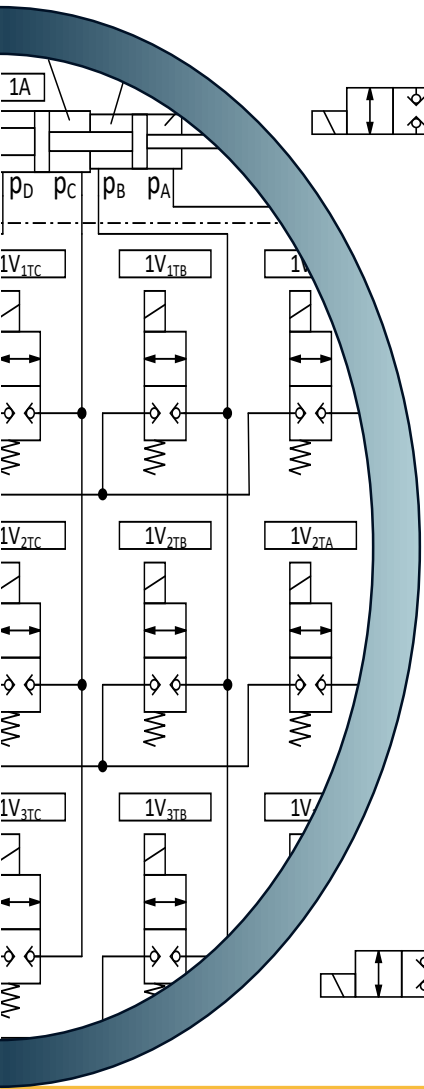
Valve Manifold
Optimized

Variable loading

Optimized
electronic boosters

Interchangeability: Pressure source or Flow source





Cylinder/Manifold: Additive manufacturing or metal casting

Miniaturization of Digital Valves

Control System Optimization

Hybrid alternatives: SHA + DHA





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