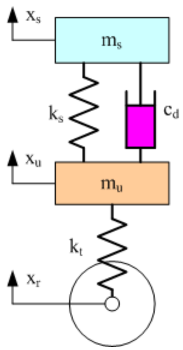
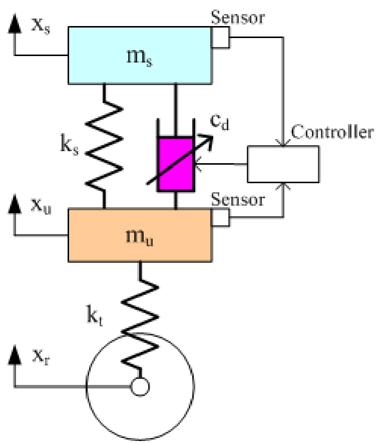
Active Suspensions

Update 20200415

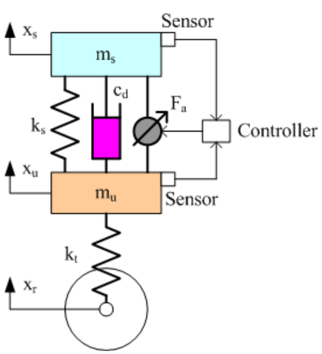
Passive

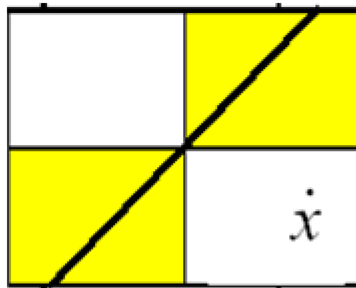
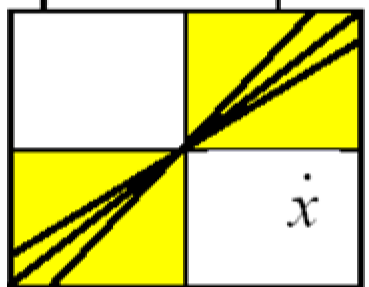


Semi-active



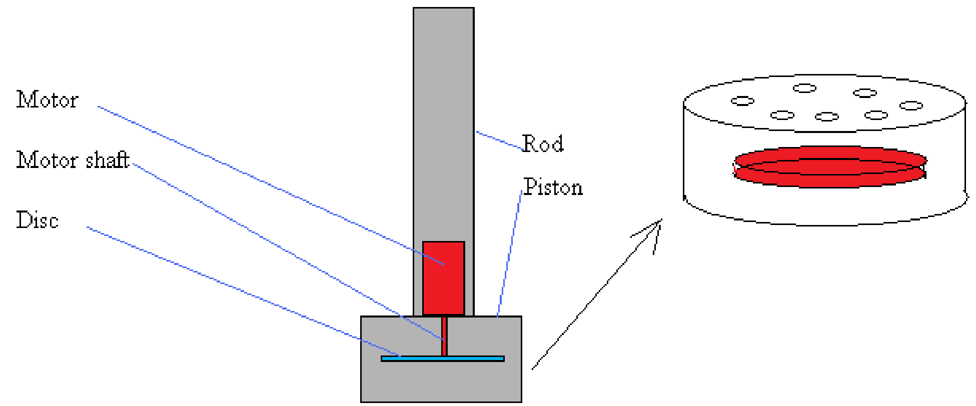
Active

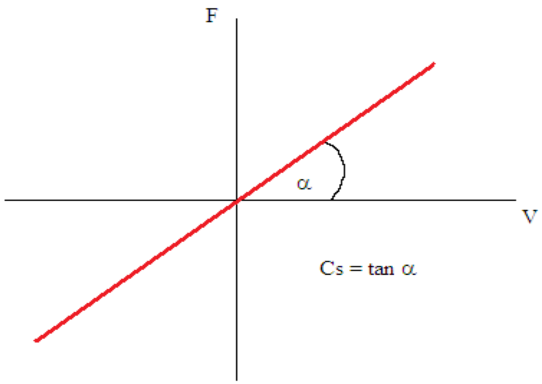


Force characteristic	Energy consumption	Control frequency
		
	low	slower than the bodynatural frequency
	low	larger than the bodynatural frequency
	high	larger than the bodynatural frequency

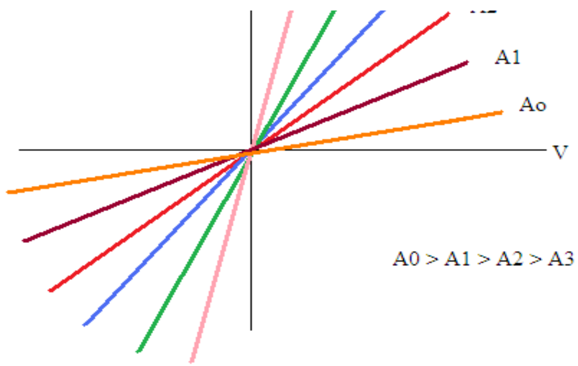
Adaptive/Semi-Active Force – velocity

Orifice based Semi-Active Suspension

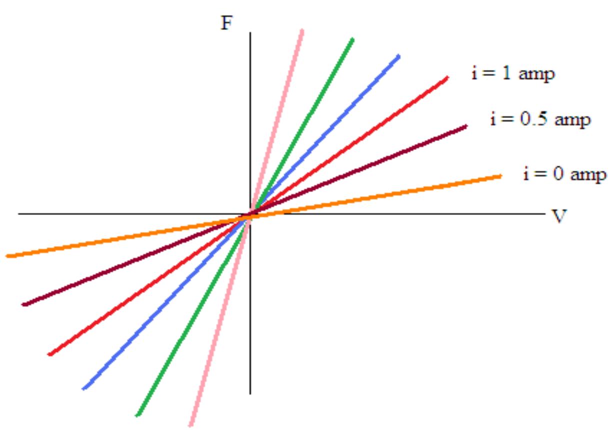




Passive Damper

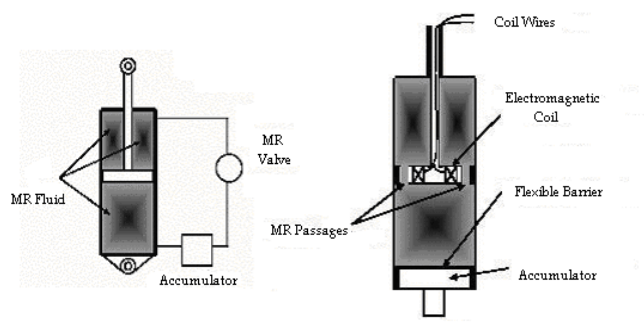


Orifice Based



MR Fluid Based

MR fluid based Semi-Active Suspension



$$F_d = d_p \cdot v_{rel} + d_a \cdot v_a \qquad (1)$$

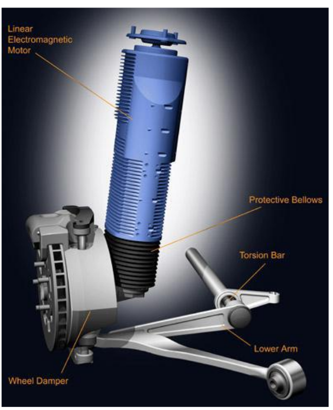
The velocity of the body v_a is determined for each wheel station in the area of the chassis connection. In (1), the coefficients d_a correspond to active Skyhook suspension, d_p is the passive shock absorption and v_{rel} the velocity difference between wheel and body.

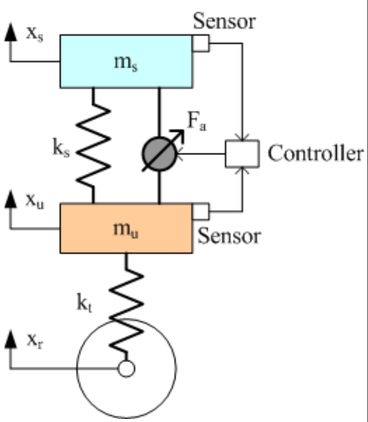
To represent the semiactive Skyhook control, and in contrast to active Skyhook suspension, no external energy is supplied to the system. This corresponds to an adjustable shock absorber; where the characteristic curve is controlled in dependence on the absolute velocity of the body v_a. In the simulation model the resulting absorption is computed as follows:

$$F_d = \begin{cases} d_p \cdot v_{rel} + d_a \cdot v_a & ;\text{ for } v_a \cdot v_{rel} > 0 \qquad (2) \\ d_p \cdot v_{rel} & ;\text{ for } v_a \cdot v_{rel} < 0 \qquad (3) \end{cases}$$

Since Skyhook suspension is only controlled via the body velocity, the effect is unsatisfactory as regards intrinsic wheel frequency and higher frequencies /1/. This is why a frequency-dependent control is required for higher frequencies. For this purpose, an additional conventional shock absorber is used in the simulation.

Electro-mechanical actuator
Bose



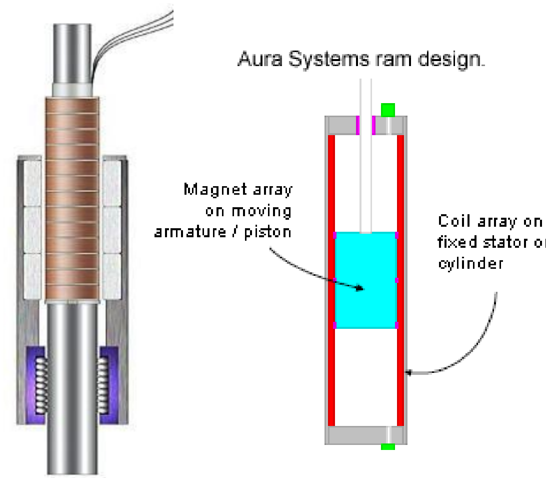


http://www.youtube.com/watch?v=eSi6J-QK1lw&feature=player_embedded
https://www.youtube.com/watch?v=3KPYIaks1UY&feature=player_embedded

Electro-mechanical actuator - Bose

Linear electromagnetic motor (L.E.M.)

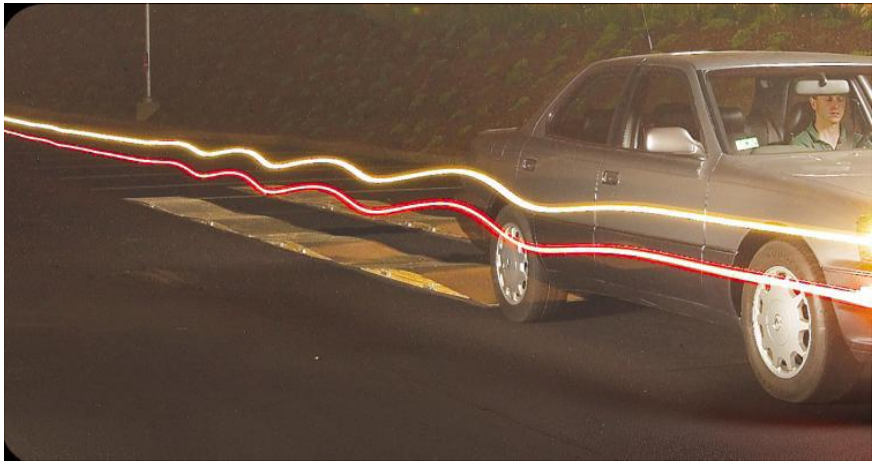
A power amplifier supplies the L.E.M.s.
The amplifier is a regenerative design that uses the compression force to send power back through the amplifier (average power 1.5 kW).



Lorentz-type actuator, in which the applied force is linearly proportional to the current and the magnetic field ($\mathbf{F} = q\mathbf{v} \times \mathbf{B}$).

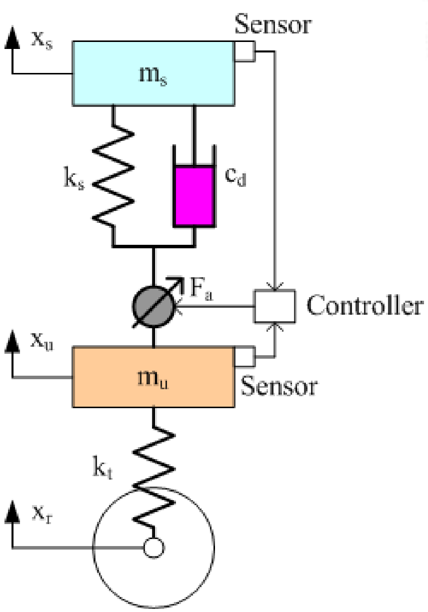
Electro-mechanical actuator - Bose

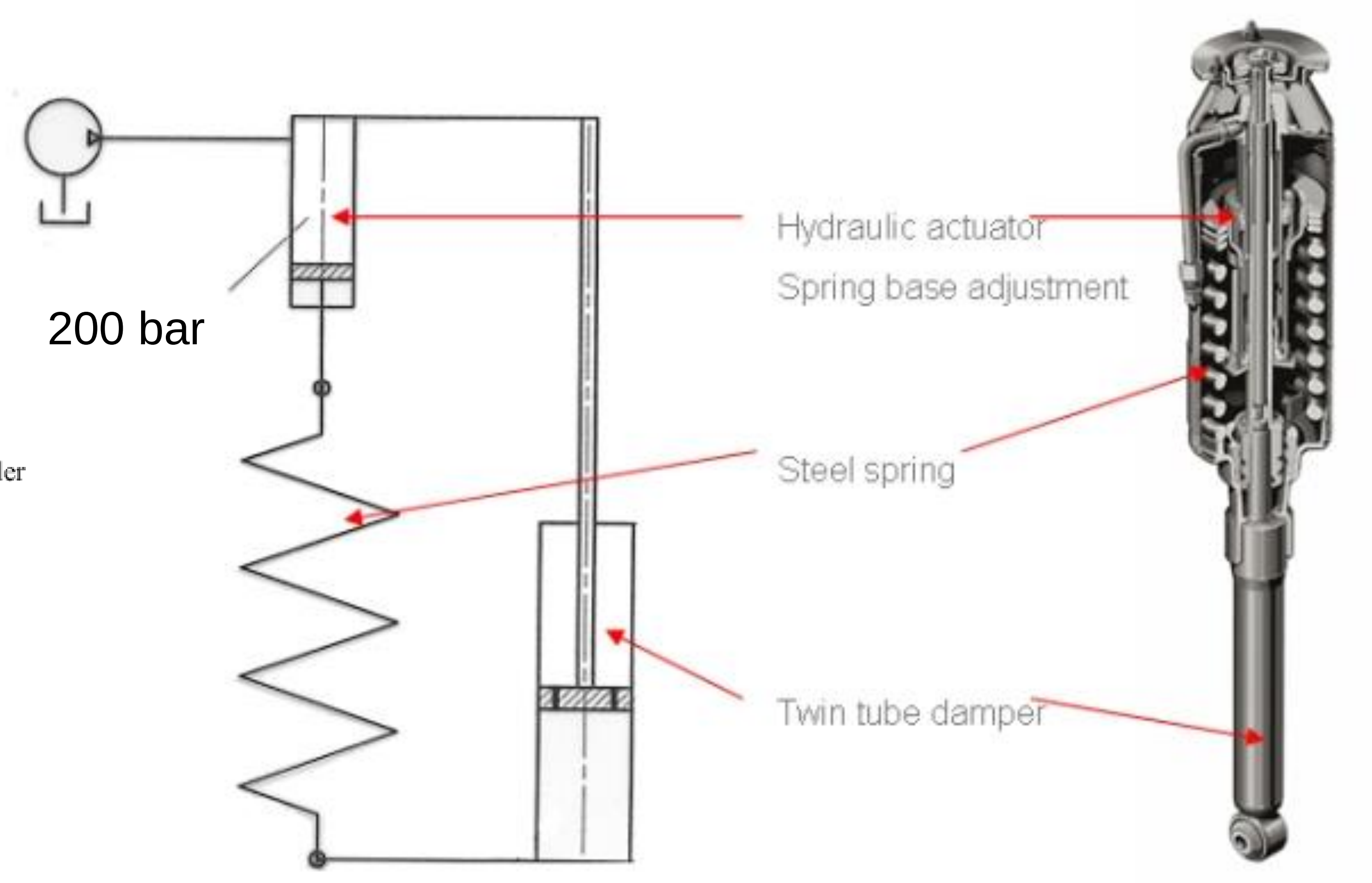
Passive



Sky-hook

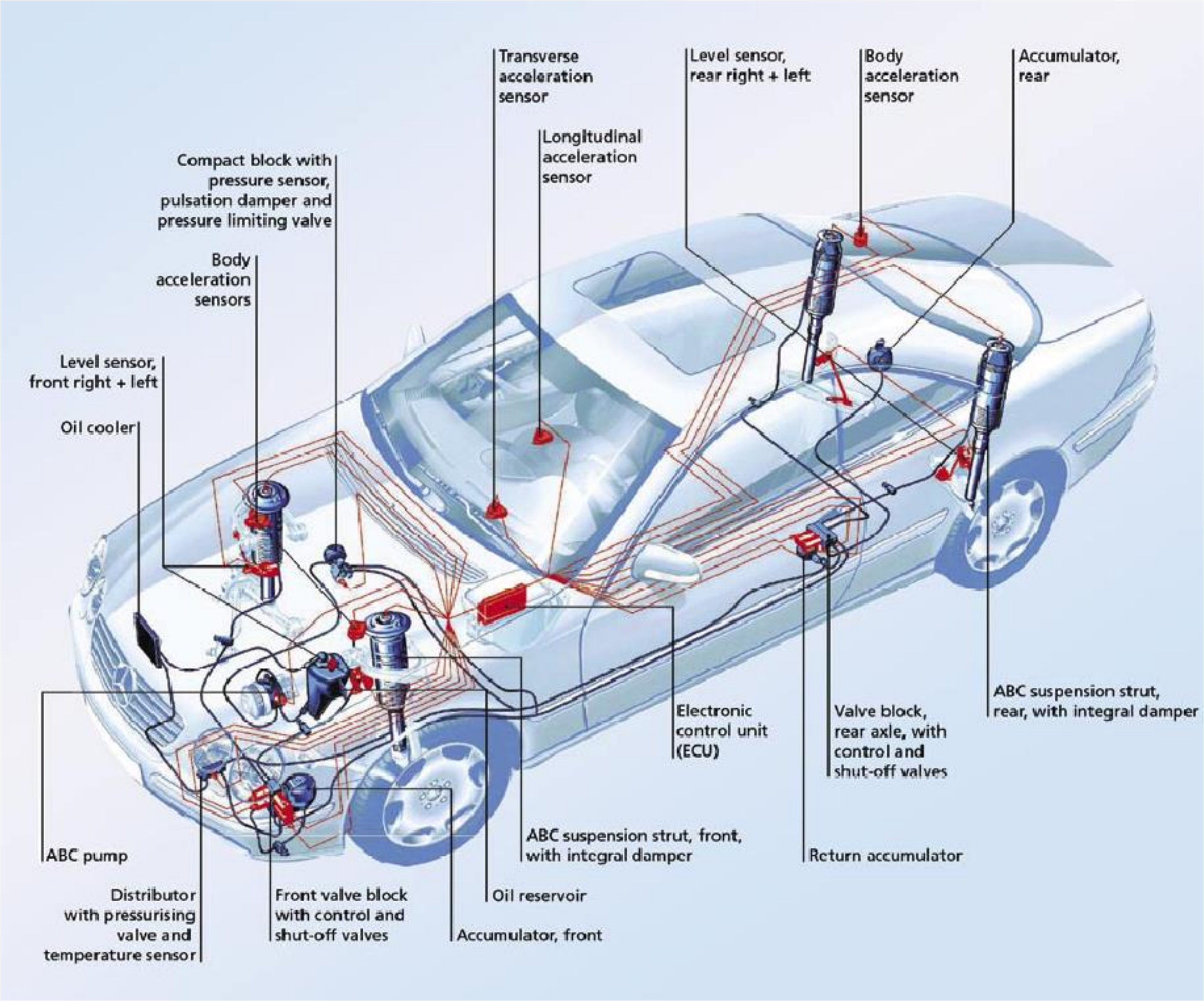
Active Body Control (ABC) – low bandwidth



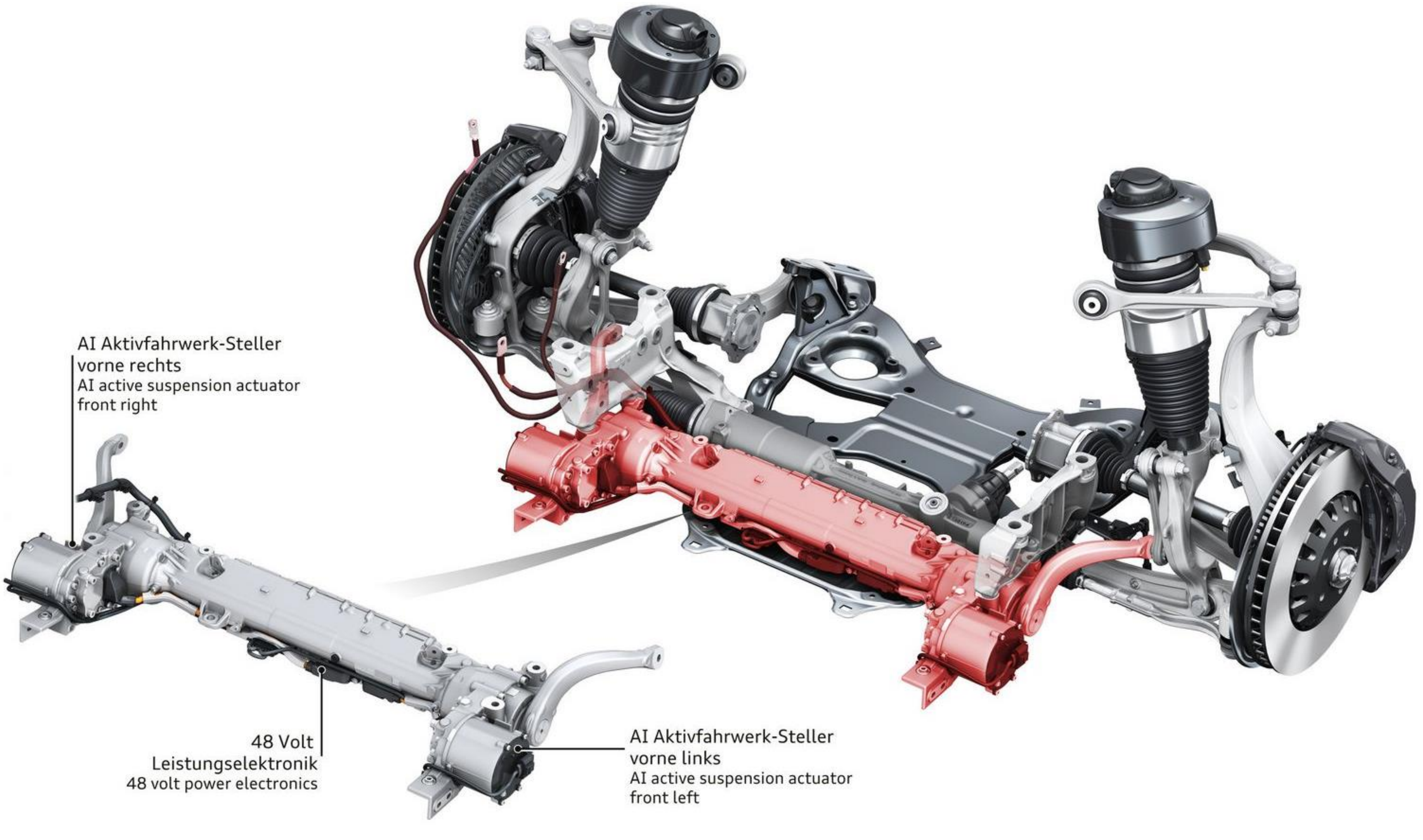


ABC is designed to control body vibrations in the frequency range up to 5 Hz

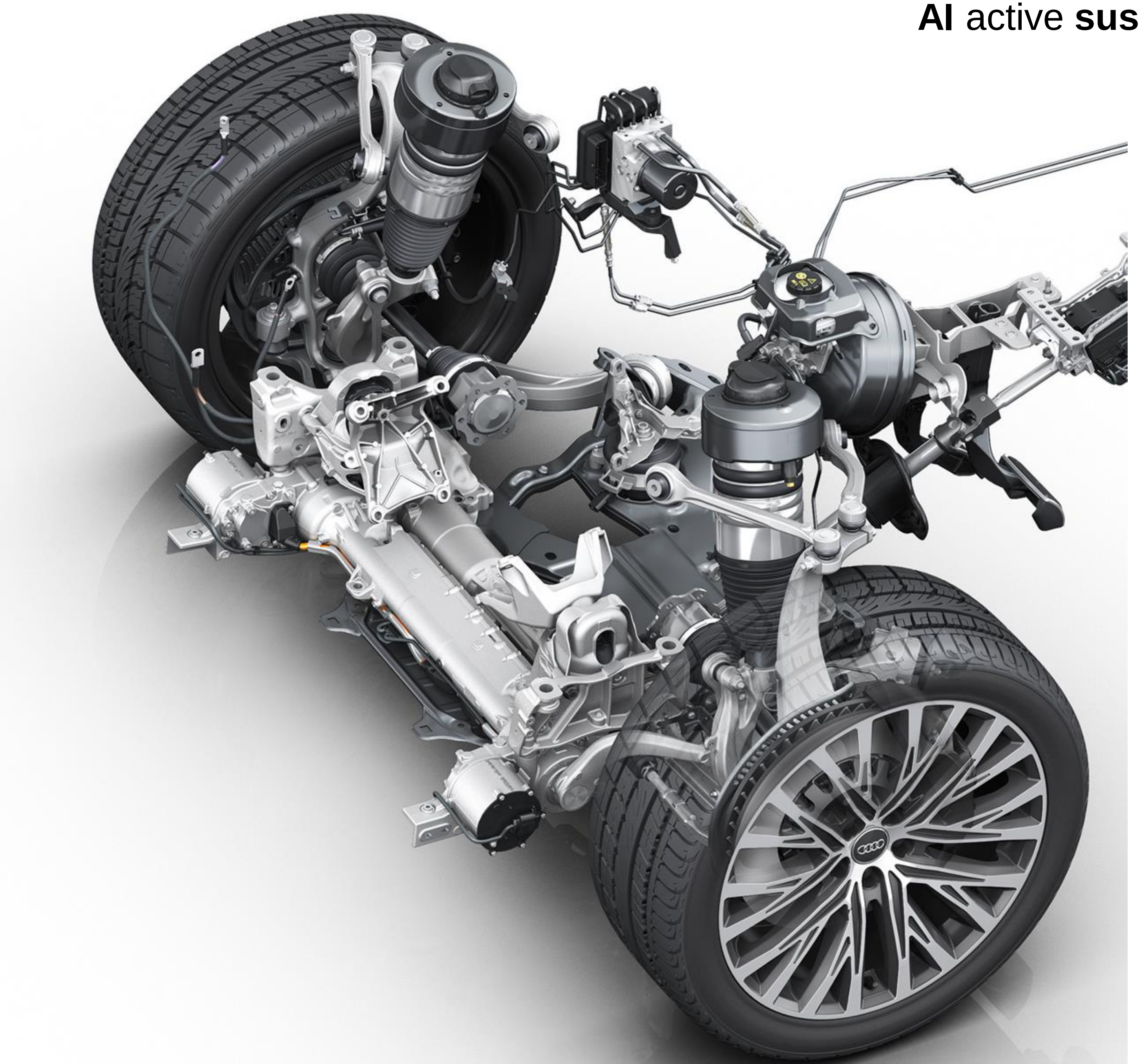
Active Body Control (ABC)



AI active **suspension**



AI active **suspension**

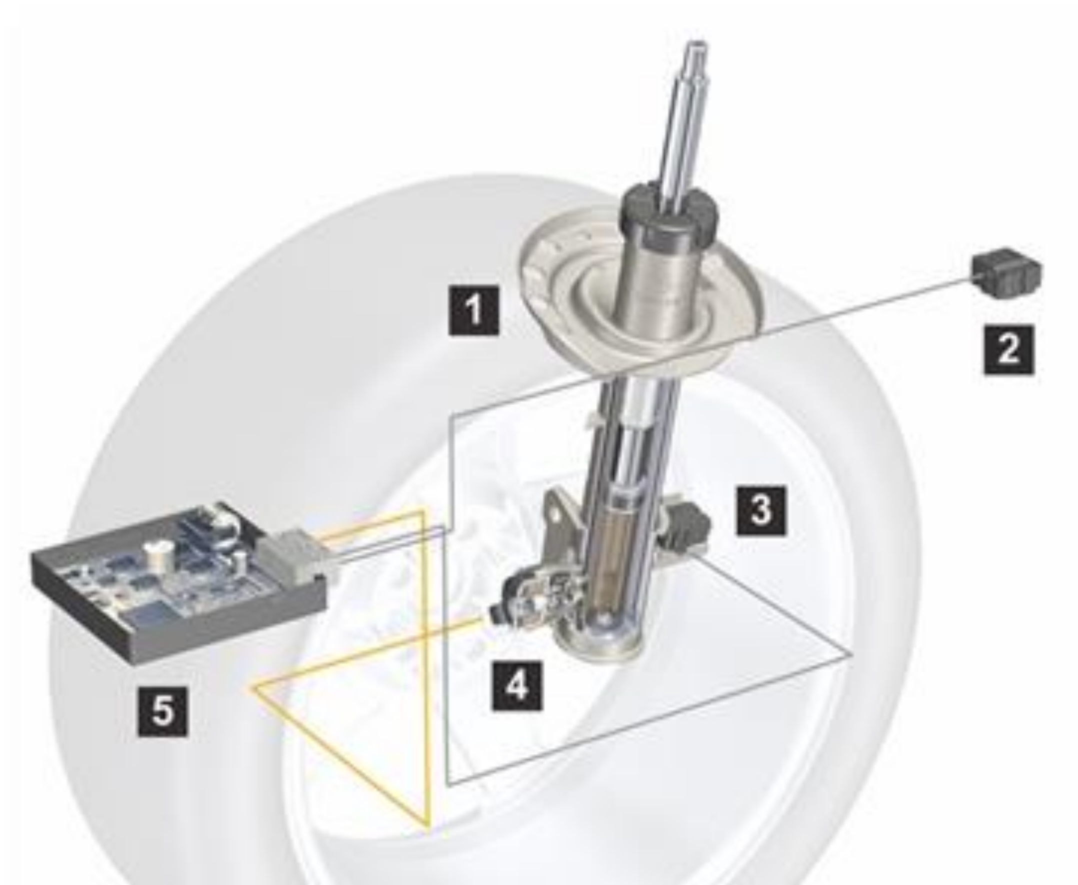


CDC® – Continuous Damping Control (ZF-SACHS)

Damping forces are adjusted for each individual wheel.
Skyhook Strategy steadies the vehicle body.

The CDC® system's control unit calculates the required damping forces every two milliseconds. The heart of the CDC® damper is the proportional valve. Depending on its position, it widens (soft) or narrows (hard) the aperture for oil flow.

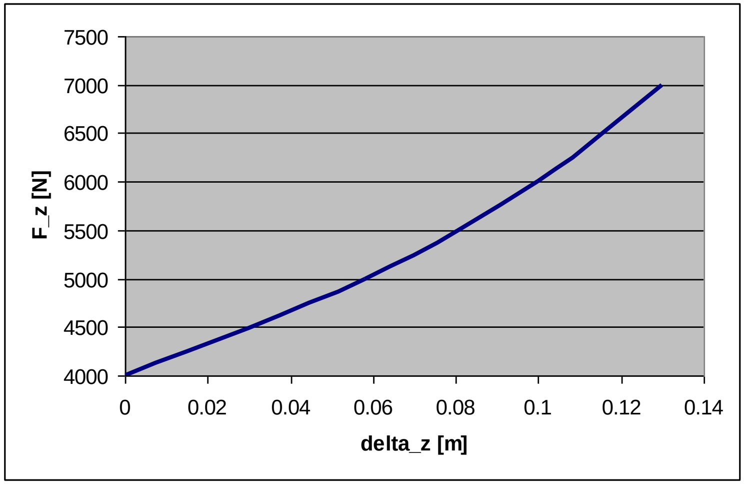
CDC® – Continuous Damping Control (ZF-SACHS)



Design:

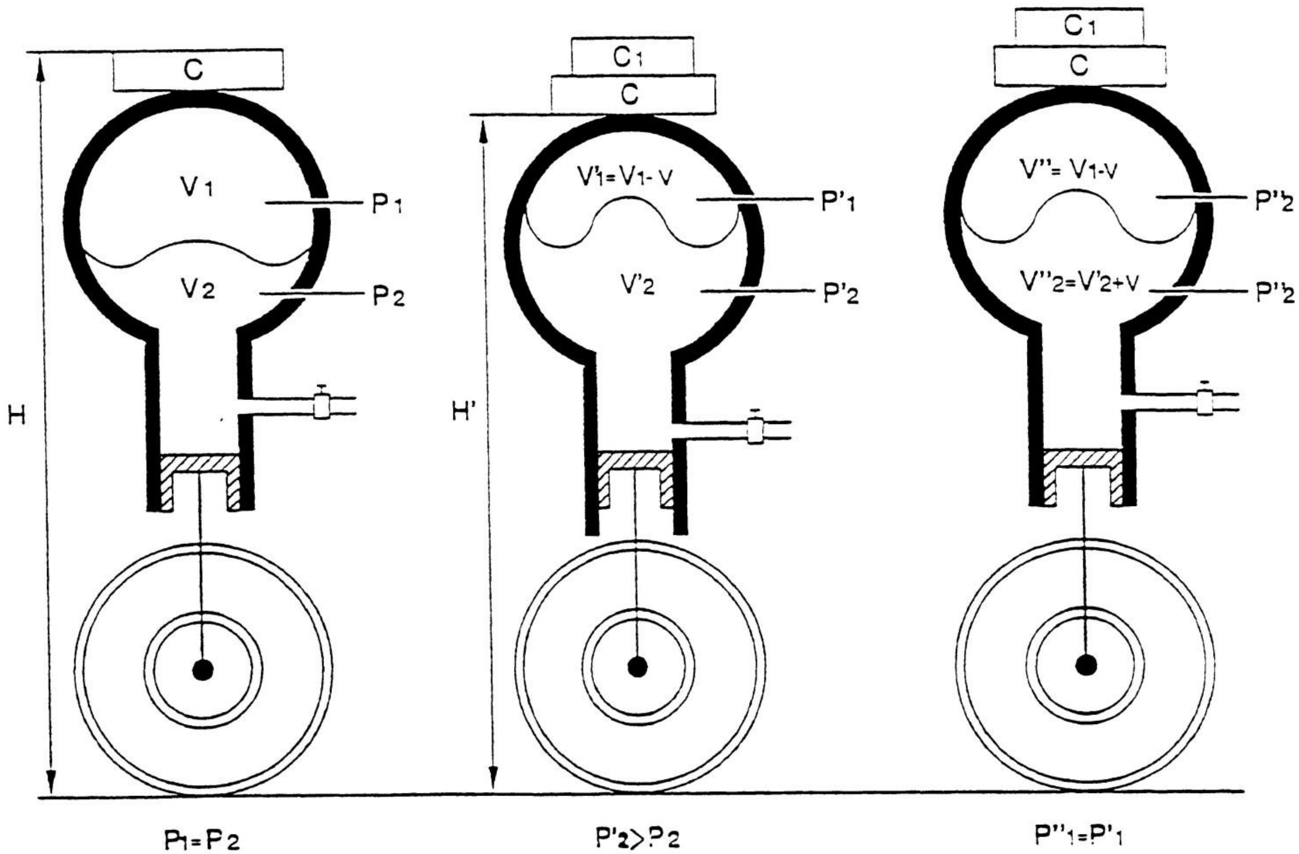
1 CDC damper
2 Body acceleration sensor
3 Wheel acceleration sensor
4 CDC valve
5 ECU

CDC® – Continuous Damping Control (ZF-SACHS)

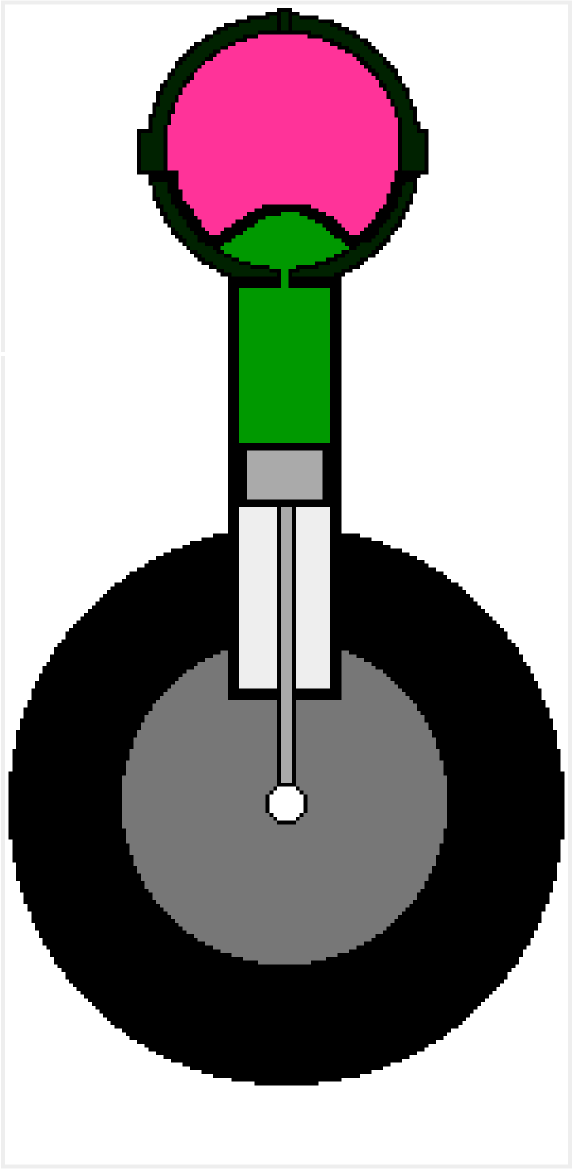


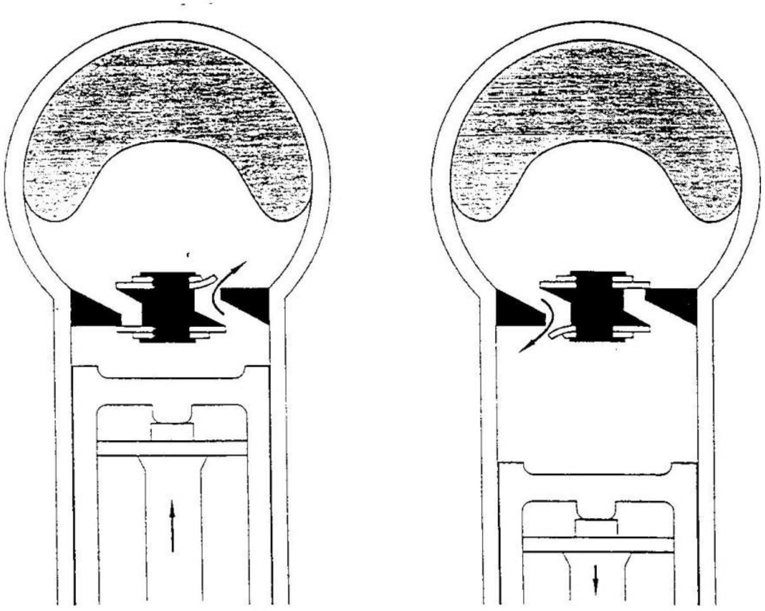
Sospensione Idro-Pneumatica

$$\frac{p}{p_0} = \left(\frac{V_0}{V}\right)^k$$



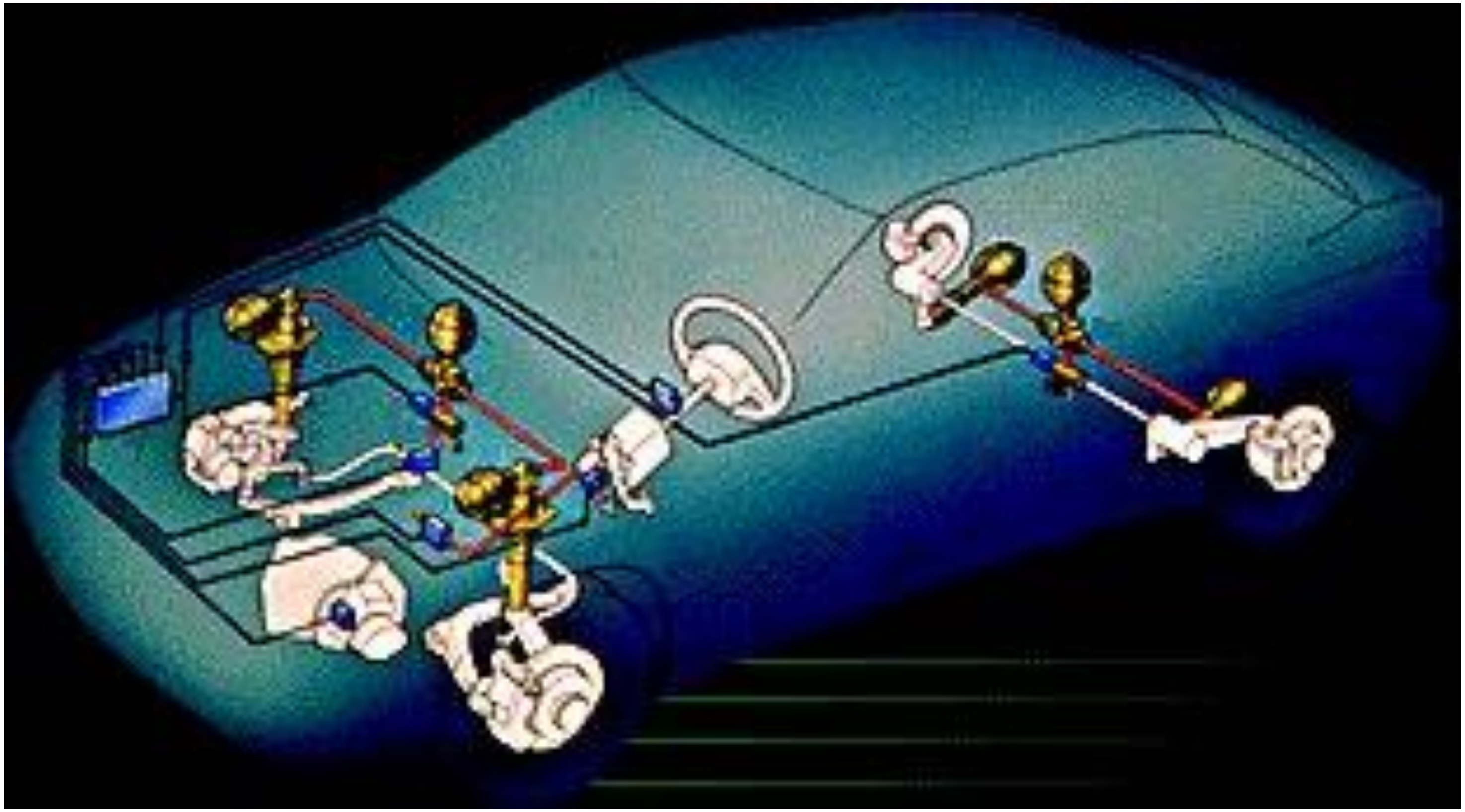
Hydropneumatic suspension





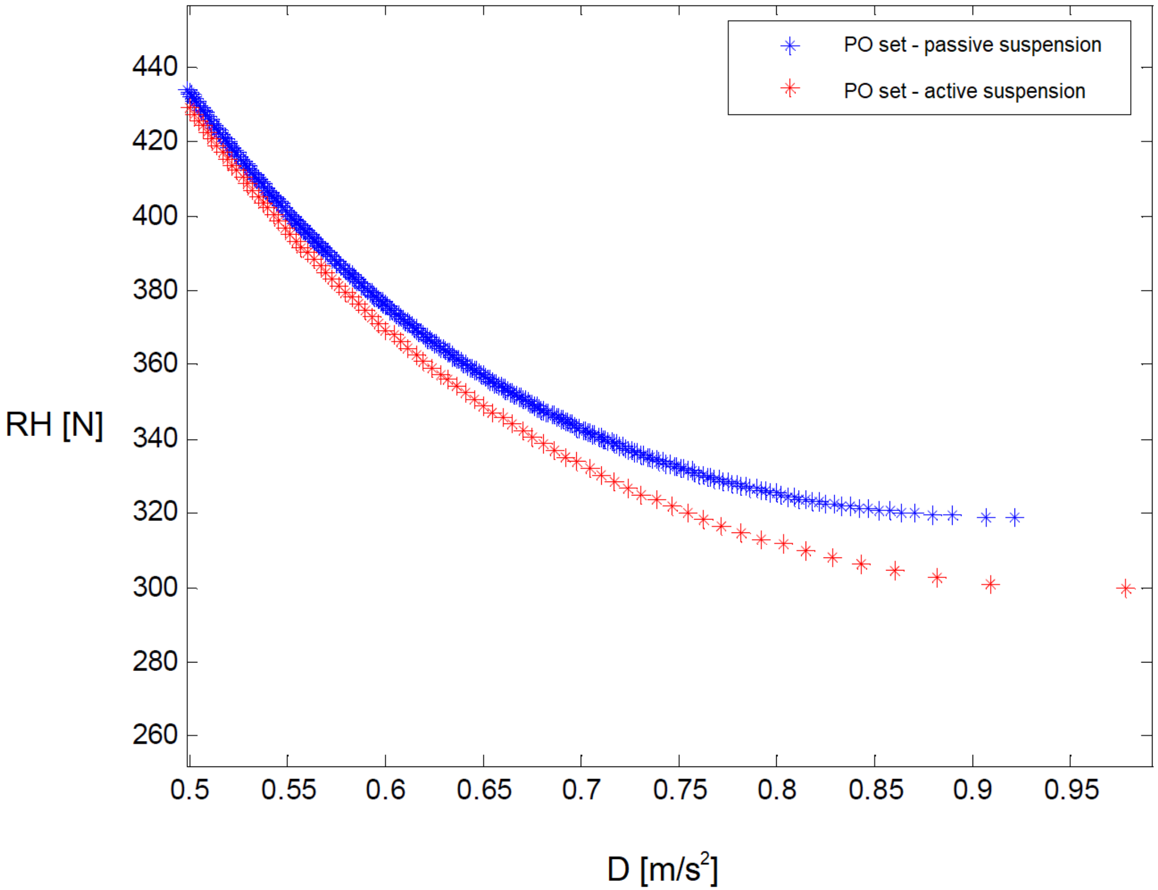
Citroen Hydractiva

Citroen's Hydractive suspension is fast-reacting,
can vary individual axles' spring rate and damping rate (by adding spheres)



Parameters	Passive suspensions	Semi-active suspensions	Hydraulic or pneumatic active suspensions	Electromagnetic active suspensions
Structure	Simplest	Complex	Most complex	Simple
Weight or volume	Lowest	Low	High	Highest
Cost	Lowest	Low	Highest	High
Ride comfort	Bad	Medium	Good	Best
Handling performance	Bad	Medium	Good	Best
Reliability	Highest	High	Medium	High
Dynamic performance	Passive	Passive	Medium	Good
Energy regeneration	No	No	No	Yes
Commercial maturity	Yes	Yes	Yes	No

Study of art of automotive active suspensions, July 2011 DOI: 10.1109/PESA.2011.5982958


PO set - passive suspension
PO set - active suspension
RH [N]
440
420
400
380
360
340
320
300
280
260
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
D [m/s2]