Electronics and Components


# The Synaptic Damping Control System:

## increasing the drivers feeling and perception by means of controlled dampers

**Giordano Greco**
*Magneti Marelli SDC*
*Vehicle control strategies*

Stuttgart, 6 May 2008

# From ‘passive’ to ‘controlled’ suspension

Vehicle suspension systems should guarantee:

Comfort

Safety & handling

Passive suspension

Comfort vehicle

Soft suspension
Low damping suspension

**Suspension tuning**

Sport Vehicle

Rigid suspension
High damping suspension

Controlled suspension

**Adapt its behavior to different running conditions and to driver requests**

# The Synaptic Damping Control system

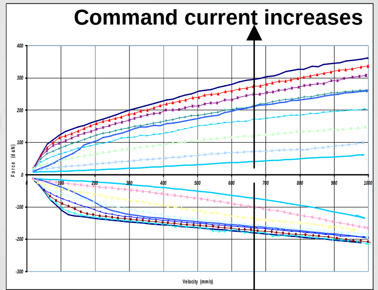
Synaptic Damping Control (SDC) is the continuous damping system by Magneti Marelli suited to control vertical vehicle dynamics and body motions, caused by road surface and by driver inputs (steering wheel, accelerator, brake, gears,..), through controlled shock absorbers.

The system is made up of the following components:

- ❖ 4 Electronically controlled shock absorbers
- ❖ 1 Electronic Control Unit (ECU)
- ❖ 3 Body Accelerometers
- ❖ 2 Front Hub Accelerometers

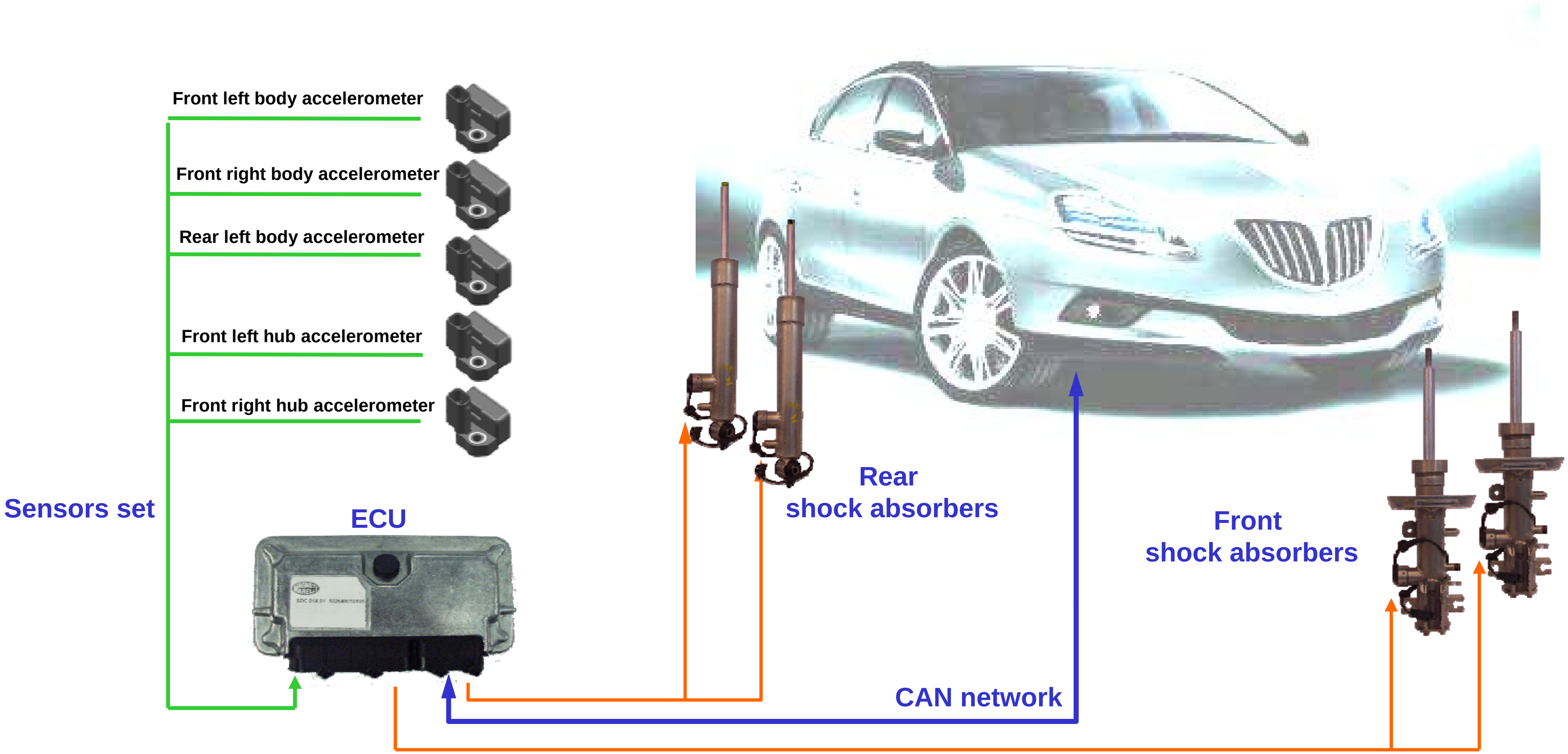
❖ Embedded SW Control strategies

❖ CAN node connection




Electronically controlled shock absorbers include proportional electro-valves which continuously vary their characteristics from a minimum (low command current) to a maximum (high command current) damping curve.

# The Synaptic Damping Control system architecture

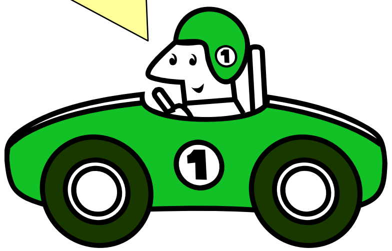



CAN signals from:

- Engine control node;
- Gear-shift control node;
- ABS, EBD, ASR, VDC control node;
- Steering wheel control node;
- Body computer node.

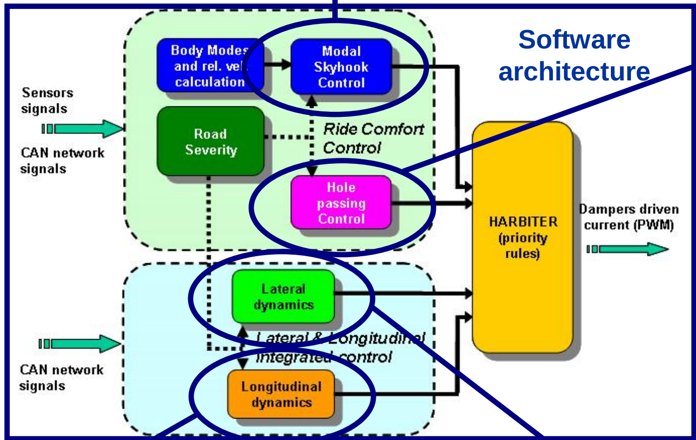
# Vehicle dynamics control functionalities

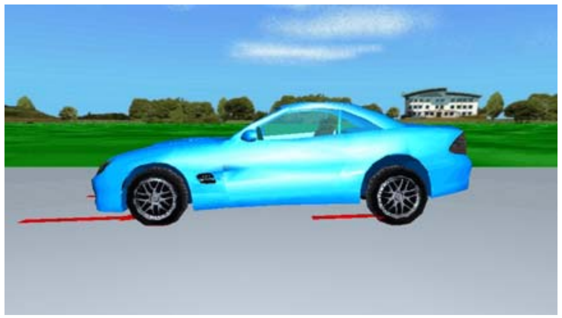
Which functionalities for a controlled shock absorbers system?

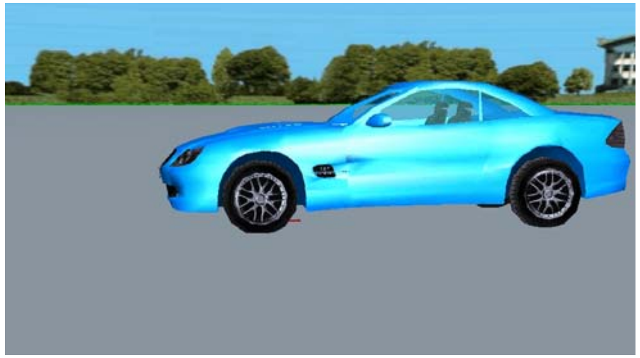


Ride comfort on uneven roads
➢Sky-Hook control

Ride comfort in case of impulsive event
➢Hole/bump management control



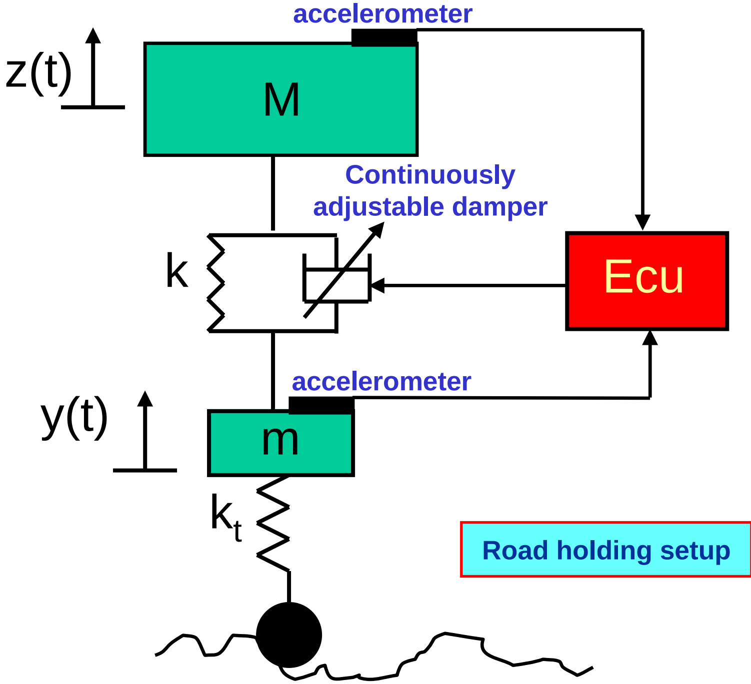


Longitudinal dynamics transients
➢Control of body pitch

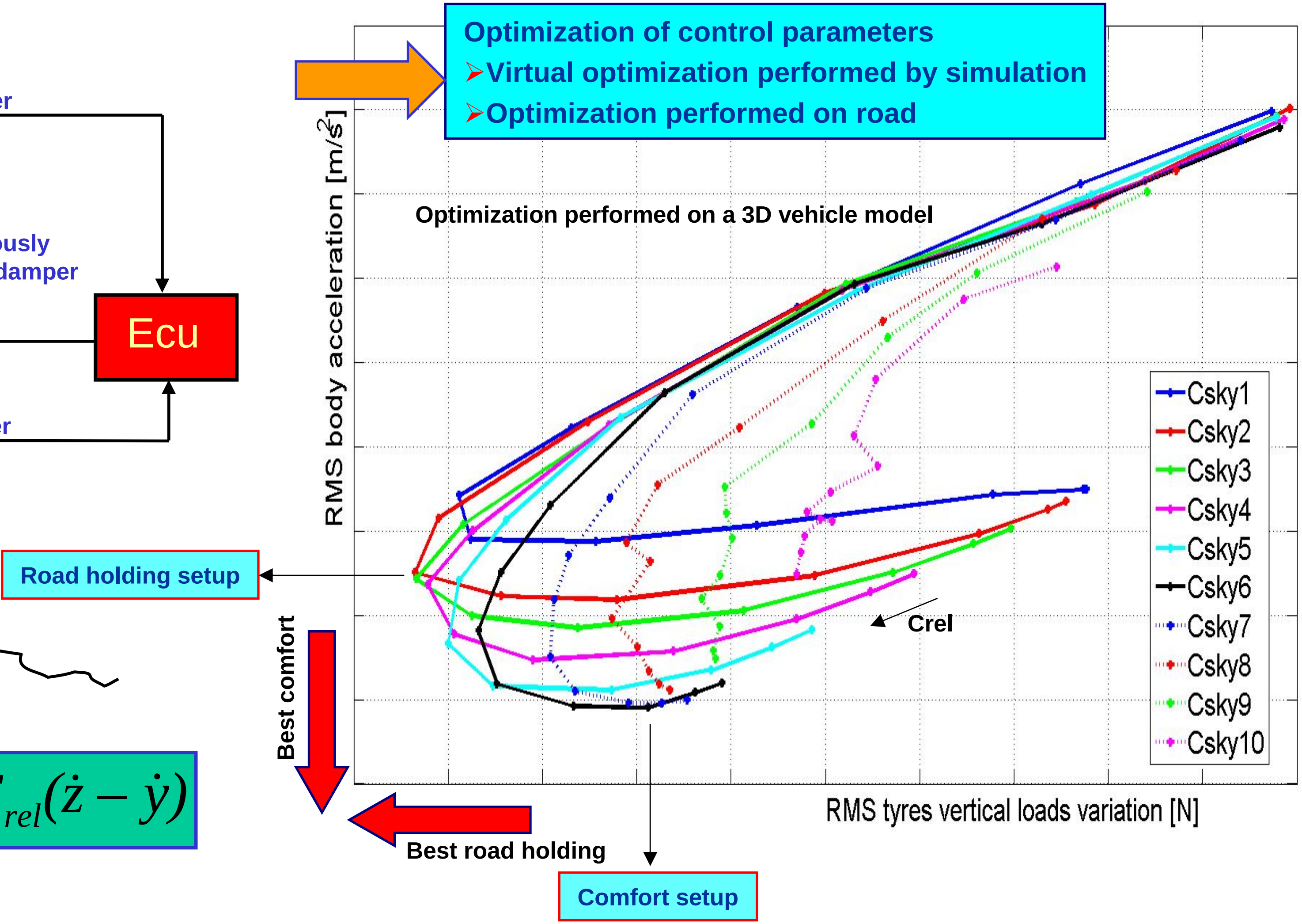
Lateral dynamics transients
➢Control of body roll
➢Control of under-oversteer

# Ride comfort behaviour - modal Sky-Hook control

**<u>Modal Sky-Hook control.</u> Function purpose is to adjust suspension damping level to optimise control of body motion and vibrations caused by road irregularities. The control law is based on the “Sky-Hook” theory.**




$$F_{ref} = C_{sky}\dot{z} + C_{rel}(\dot{z} - \dot{y})$$



# Lateral dynamics control

- The function is deputed to control vehicle behaviour during lateral dynamic transients.

  - ✓**Basic functionality** → damping levels of shock absorbers are set in order to smooth body roll motion.

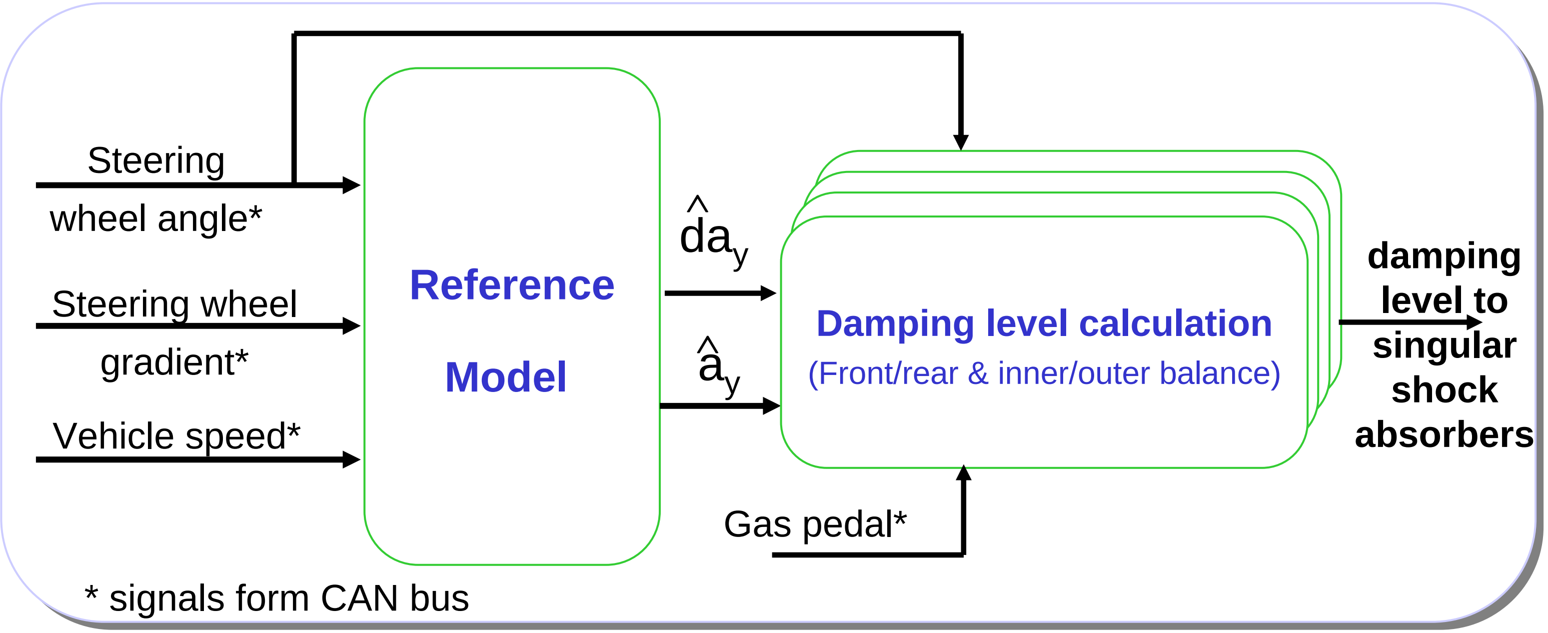
  - ✓**Advanced functionality** → control of the understeer - oversteer behaviour of the vehicle by adjusting the front / rear damping level balance

    - as a function of the actual turn phase (entry, stationary, exit);

    - as a function of the acceleration (throttle-on) or deceleration (throttle-off) requested by the driver.

# Lateral dynamics control – philosophy of the control logic

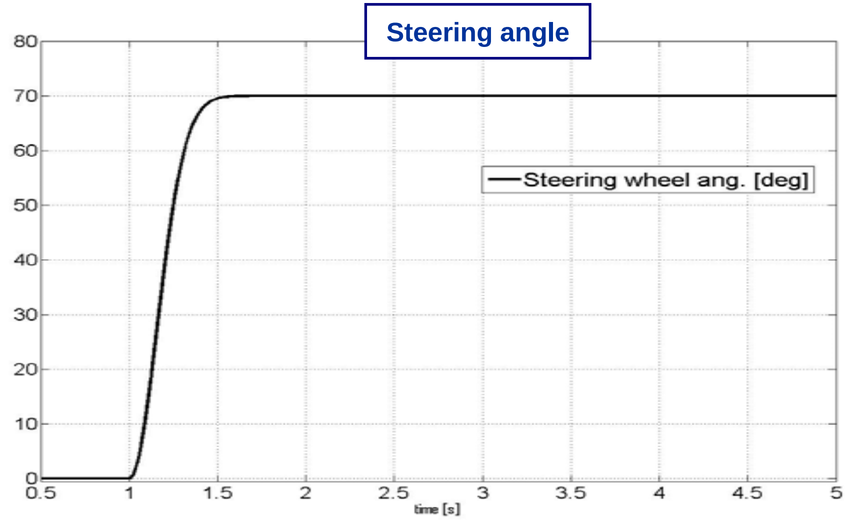
**<u>The basic idea:</u> during lateral dynamics transients the control logic increases damping level of shock absorbers.**

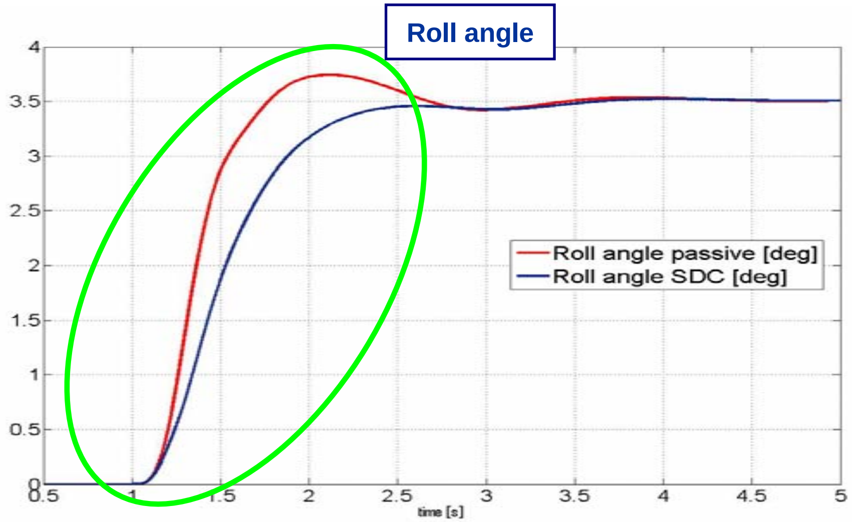


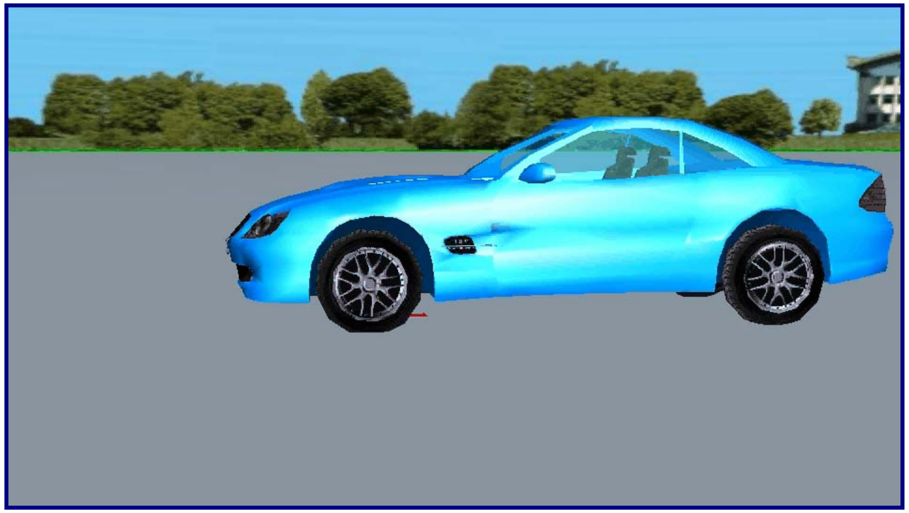

- **The front / rear damping level balance has a strong influence on the understeer / oversteer behaviour.**
- **The SDC control logic adjusts in real time the front / rear damping level balance as a function of**
  - ✓**actual turning phase → steering wheel angle**
  - ✓**acceleration/deceleration request → gas pedal**

# Control of body roll motion

**Steering wheel step input at 100 km/h (simulation results).**

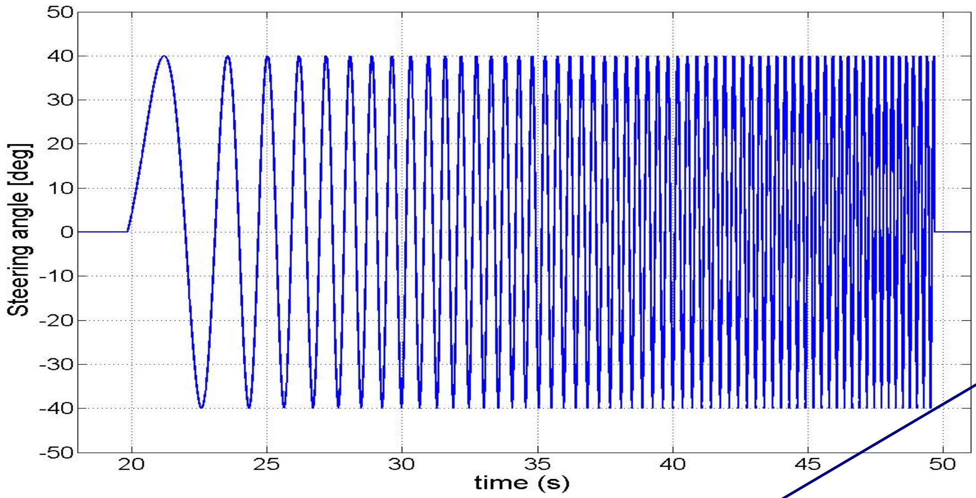


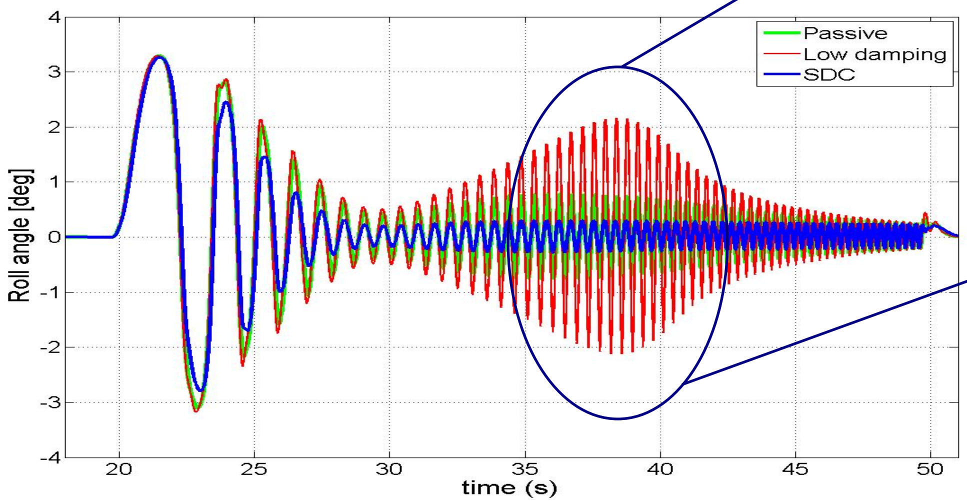



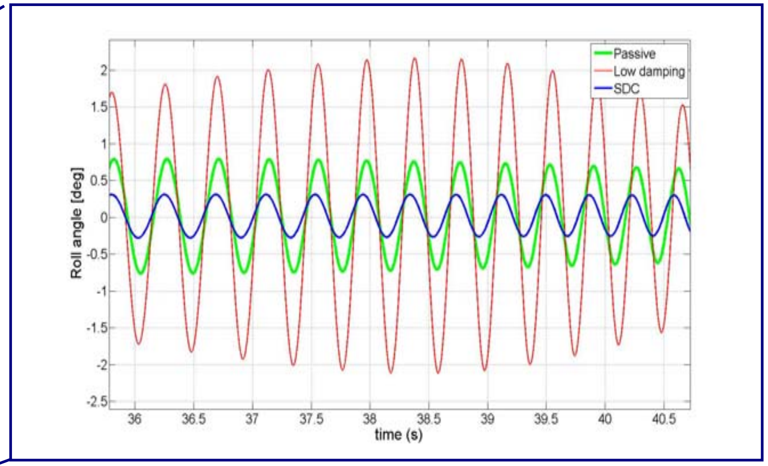
# Control of body roll motion

**Sine sweep at 120 km/h – 40° steering wheel angle (simulation results).**



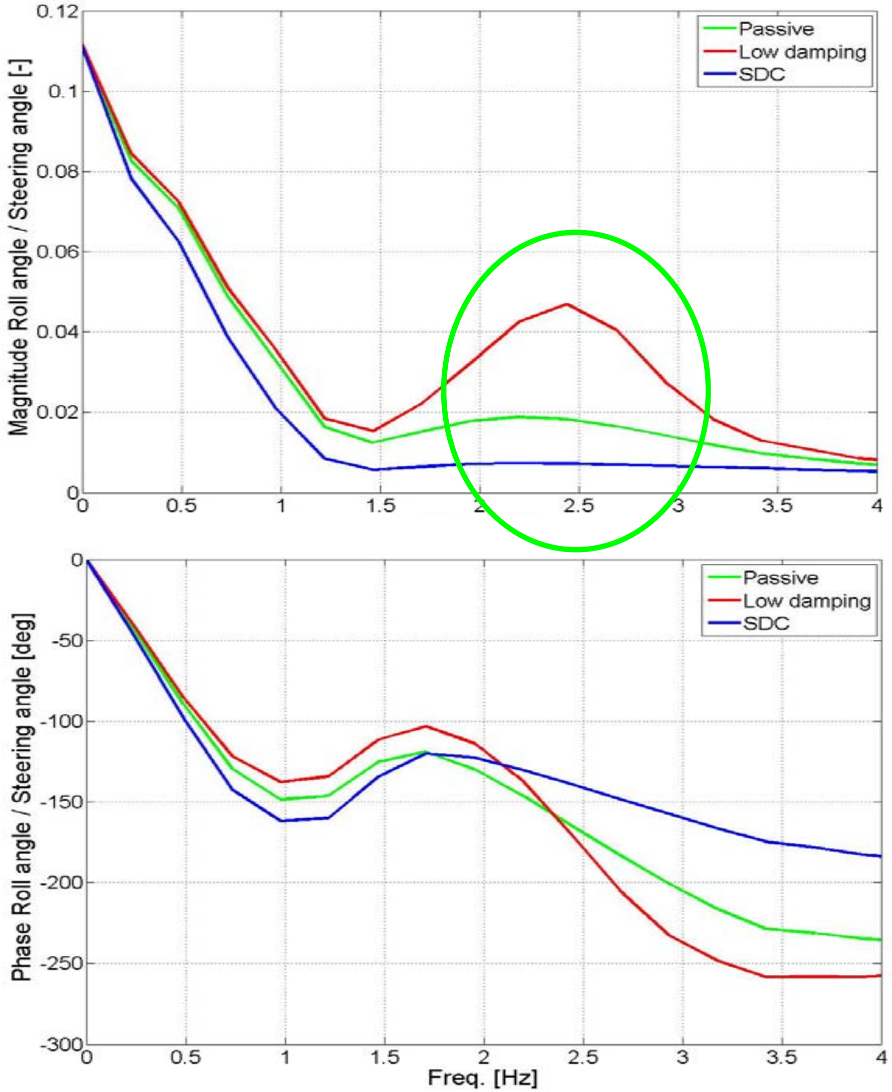

**Zoom**




**Frequency response diagrams**

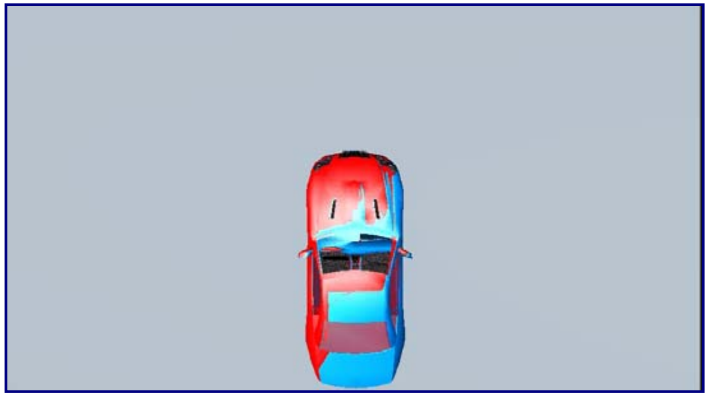
## Control of body roll motion

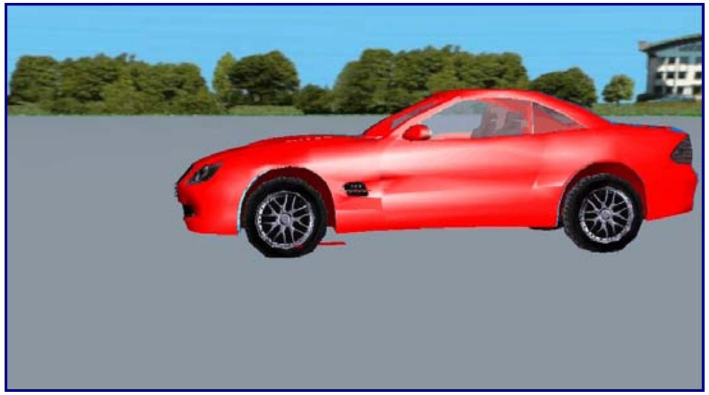
**Sine sweep at 120 km/h – 40° steering wheel angle (simulation results).**

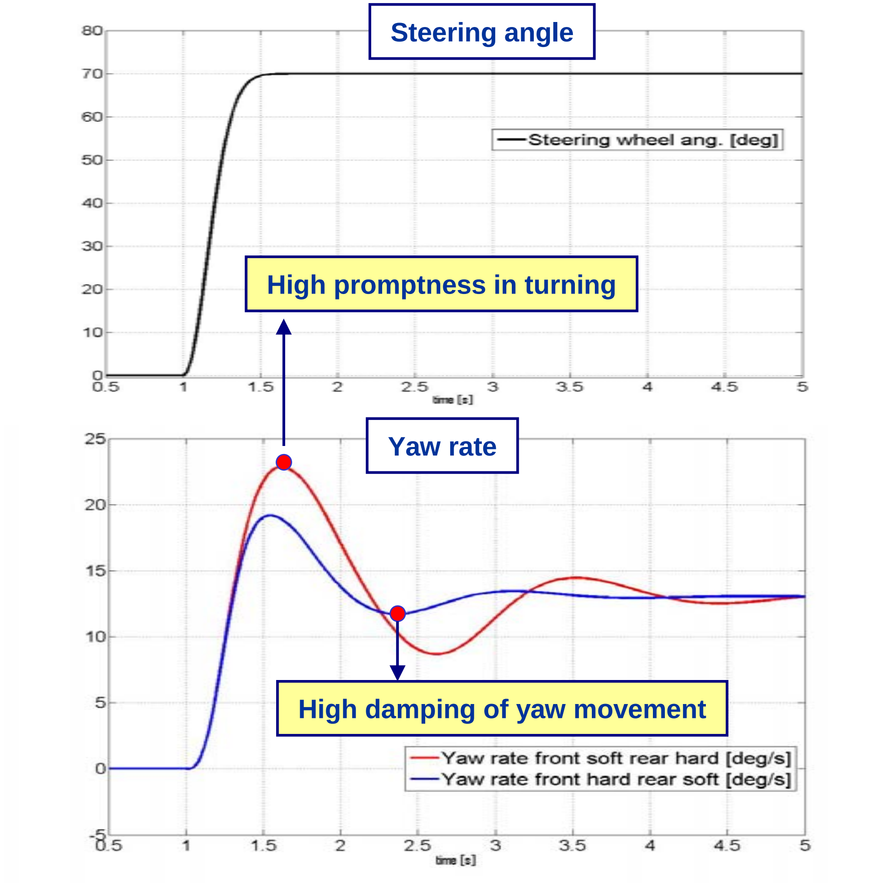


## Introduction to the problem

**Steering wheel step manoeuvre at 100 km/h (simulation results)**



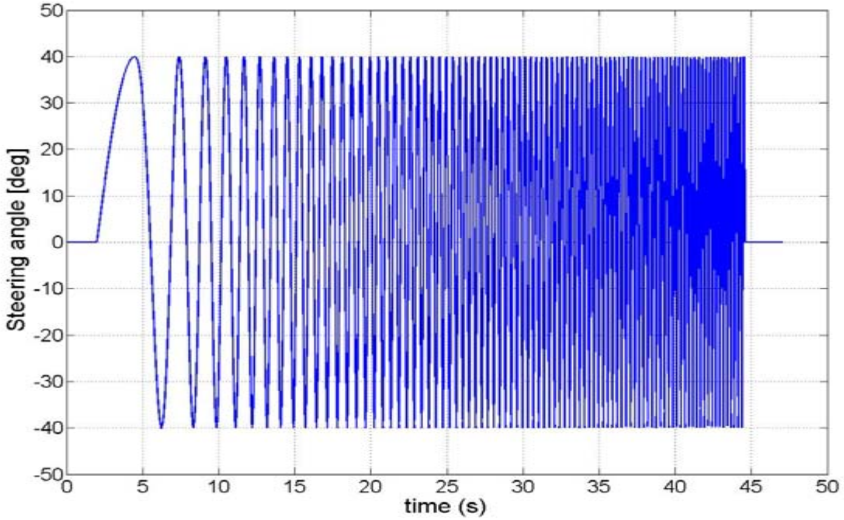


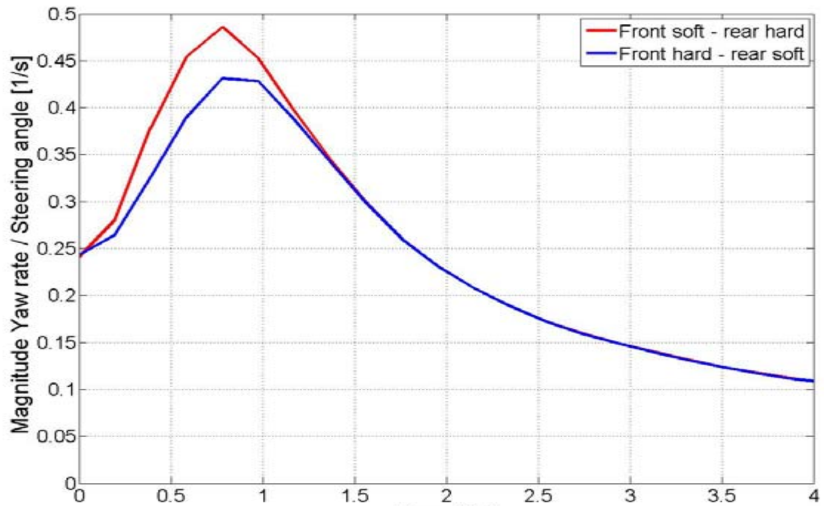


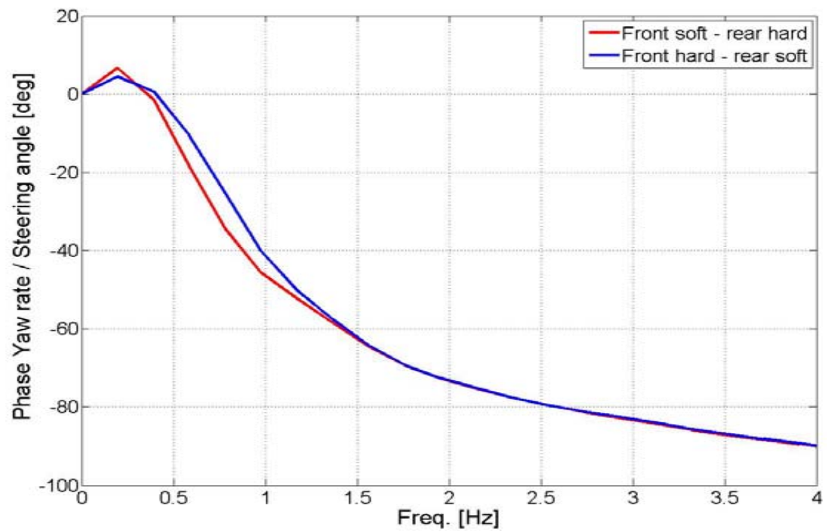

**The front / rear damping level balance has a strong influence on the directional behaviour of vehicles.**

# Control of understeer and oversteer during transient cornering

**Sine sweep at 120 km/h – 40° steering wheel angle (simulation results)**



## Control of understeer and oversteer during transient cornering

- The SDC control philosophy:

  the front / rear damping level balance is adjusted in **real - time** during cornering.

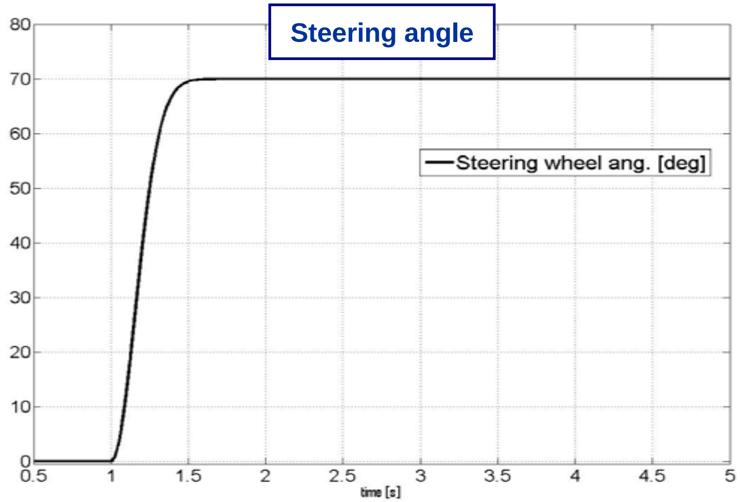
- The logic intervention is **highly tunable**:

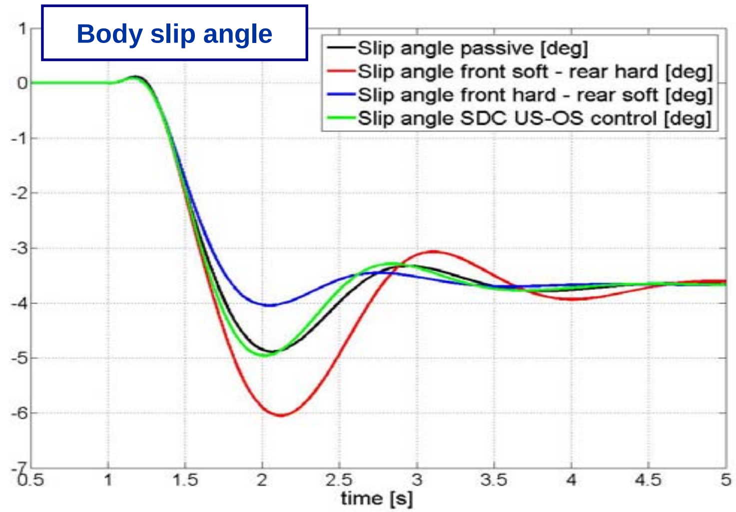
  it is possible to comply to different **drive styles** and different **drivers expectations**.

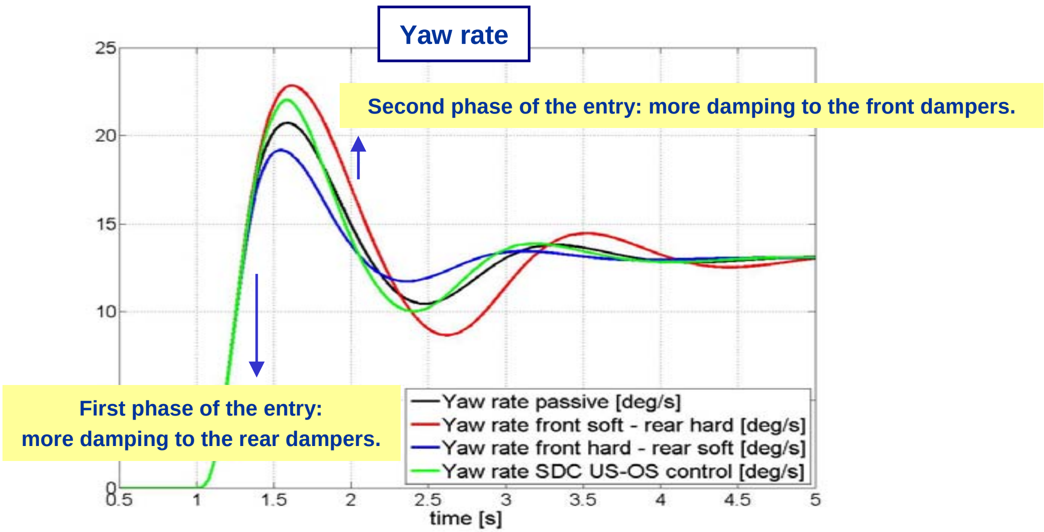
# Control of understeer and oversteer during transient cornering

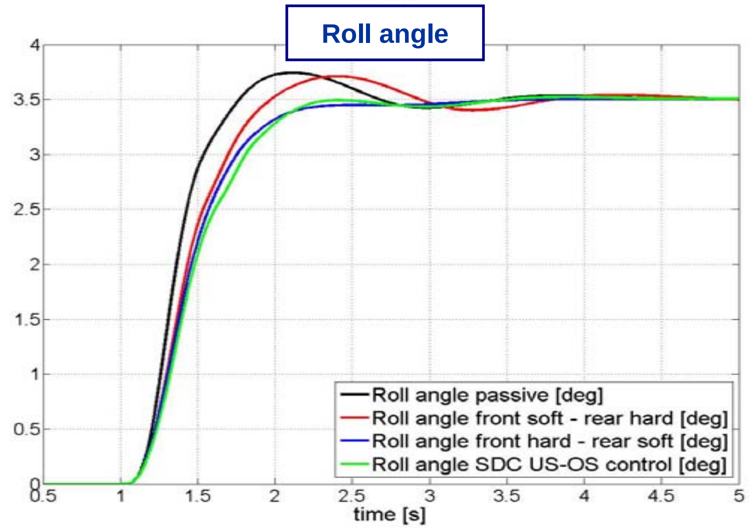
**For instance, a possible goal may be: the higher promptness in turning, with the higher damping of yaw movement:**

**Steering wheel step manoeuvre at 100 km/h (simulation results)**



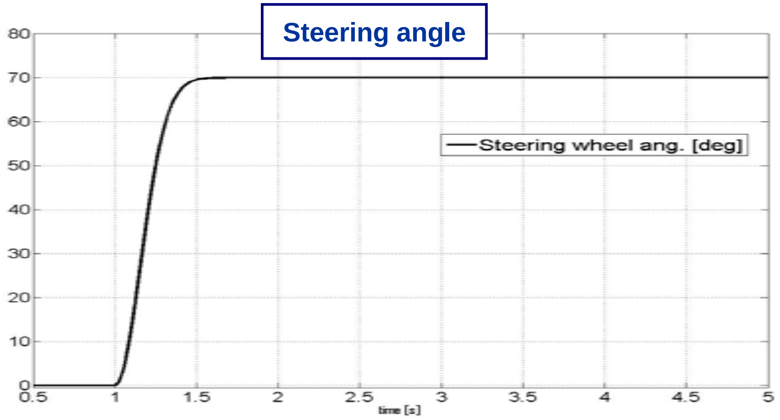



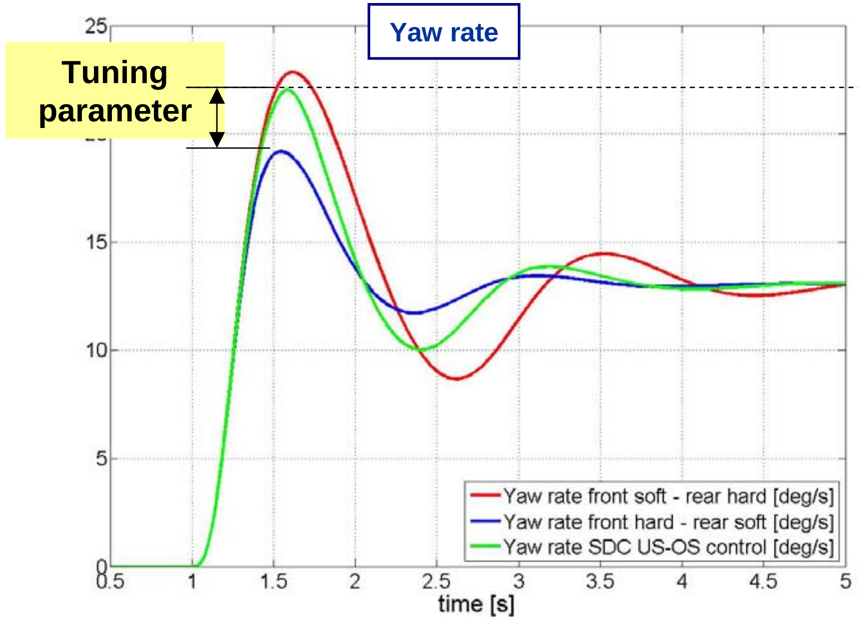



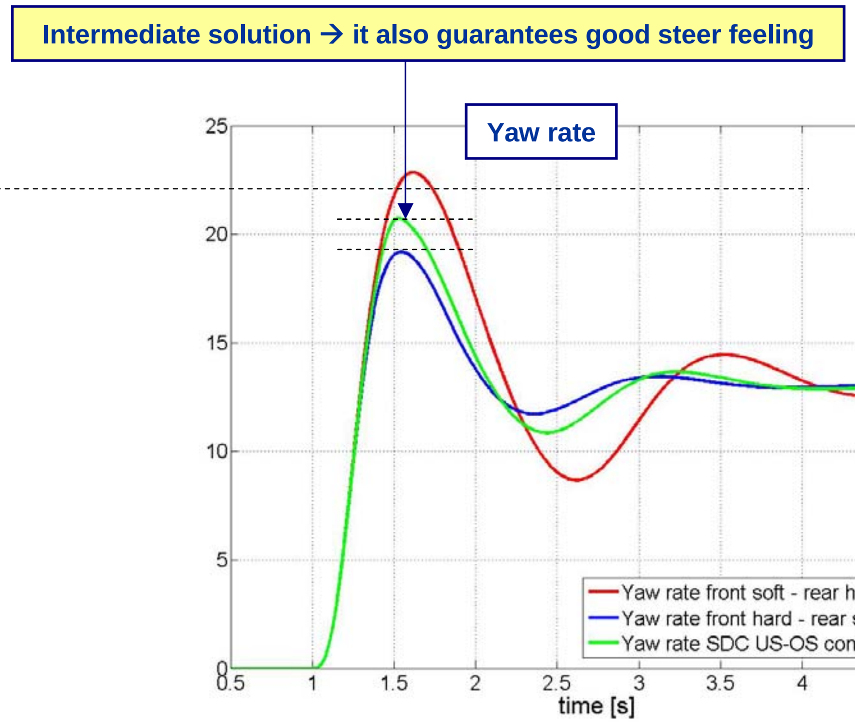
# Control of understeer and oversteer during transient cornering

**SDC offers <u>high tuning possibility</u> → different set up for the logic intervention can be implemented in order to comply to different goals.**




**Theoretical graphs……..**

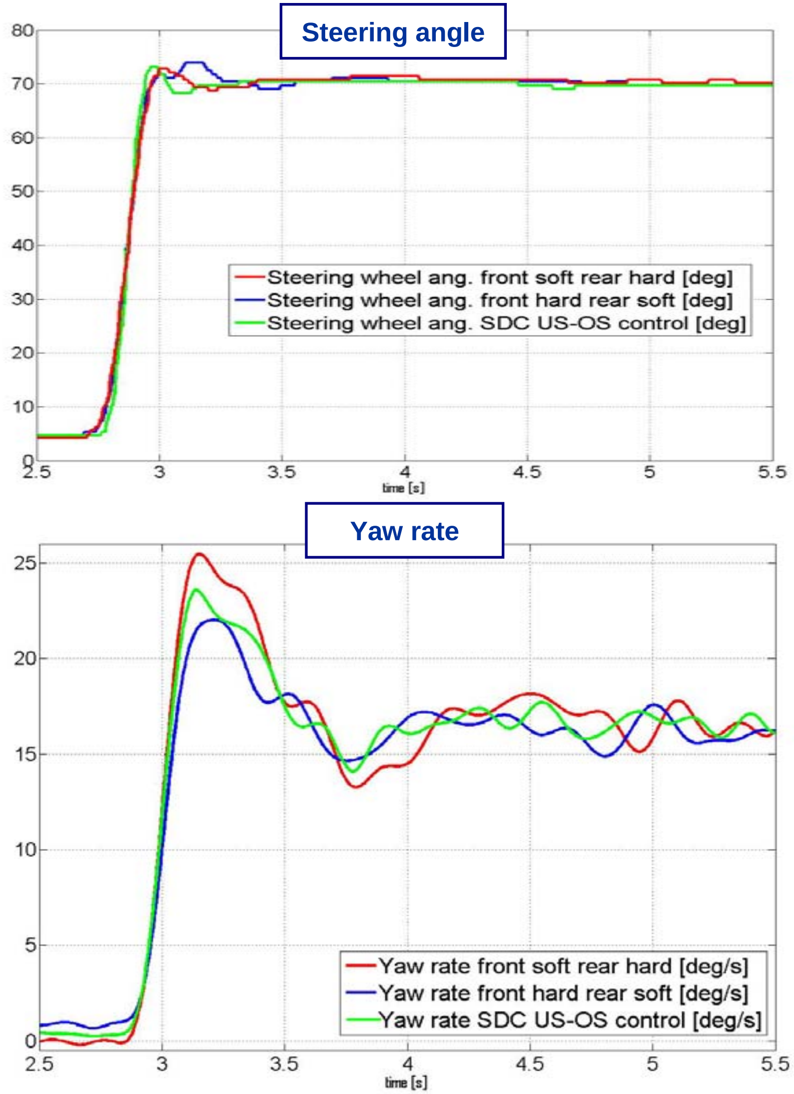


# Control of understeer and oversteer during transient cornering

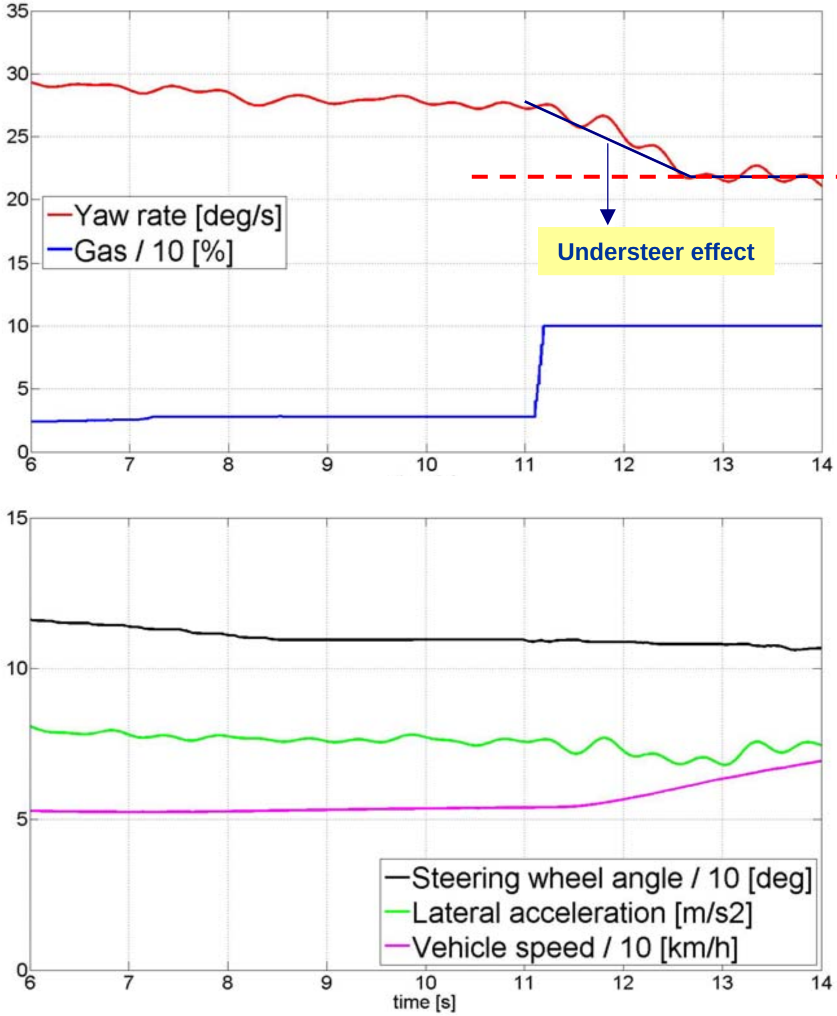
**……..experimental graphs**

**Steering wheel step manoeuvre at 100 km/h (experimental results)**

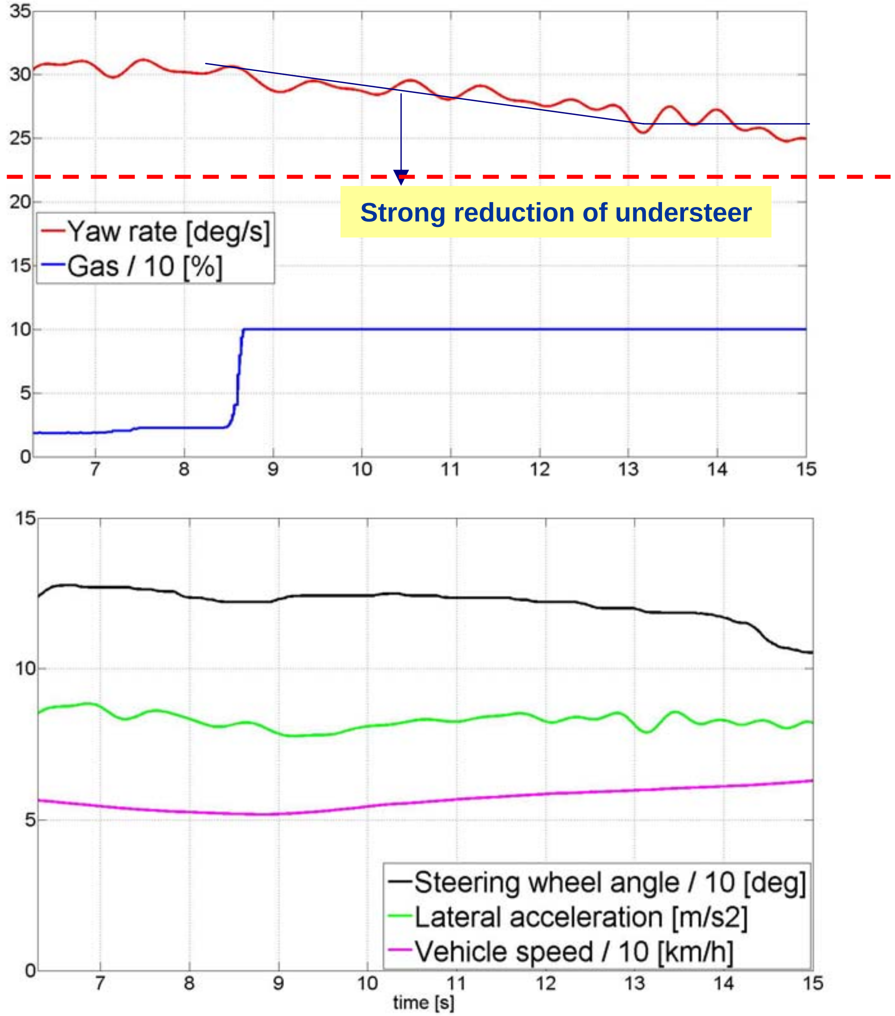


# Control of understeer in throttle-on manoeuvres

**Without understeer control**



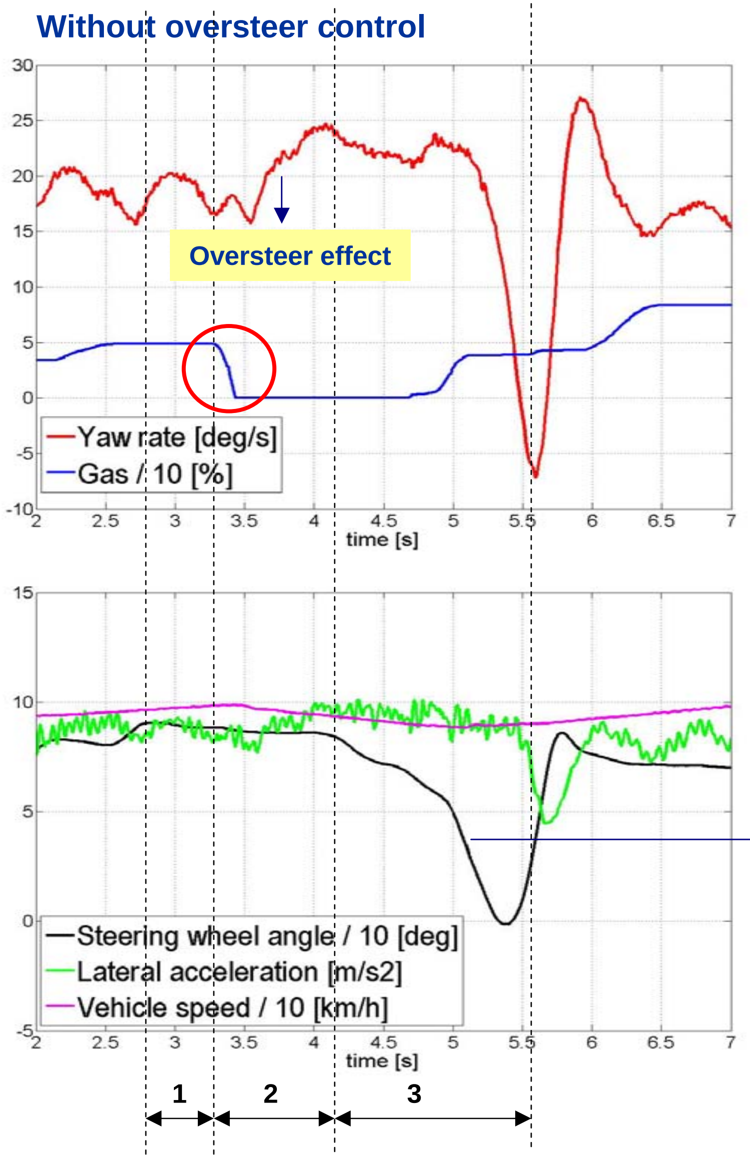

**With understeer control**



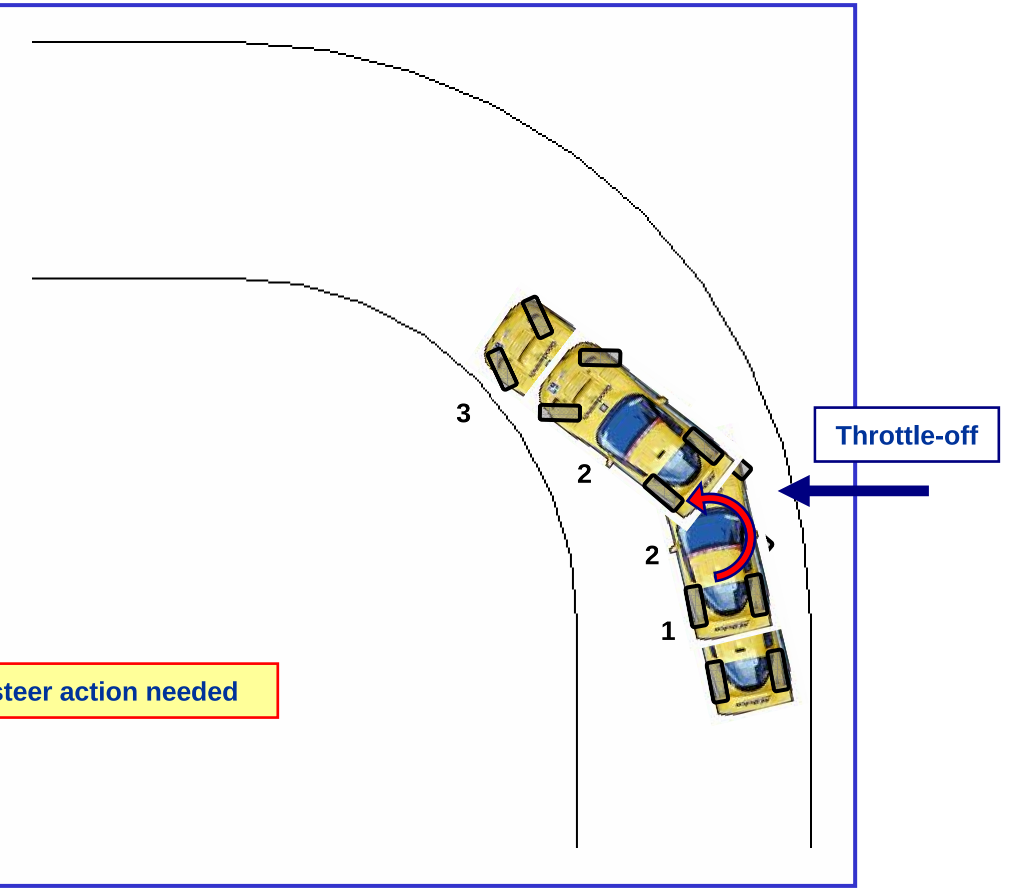

**Experimental results, front-wheel drive car**

# Control of oversteer in throttle-off manoeuvres

Without oversteer control




Counter steer action needed

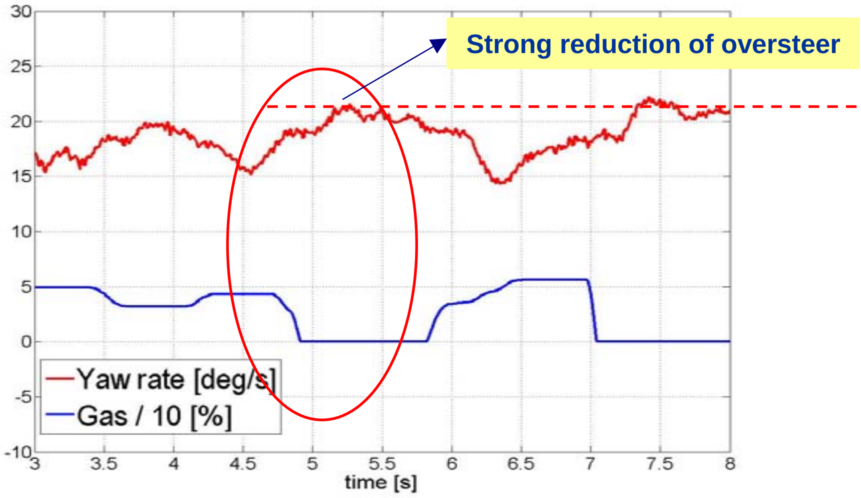


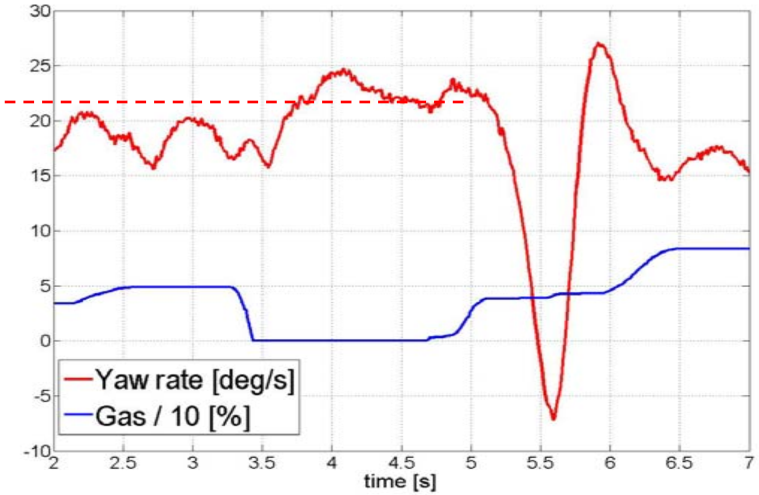

Experimental results

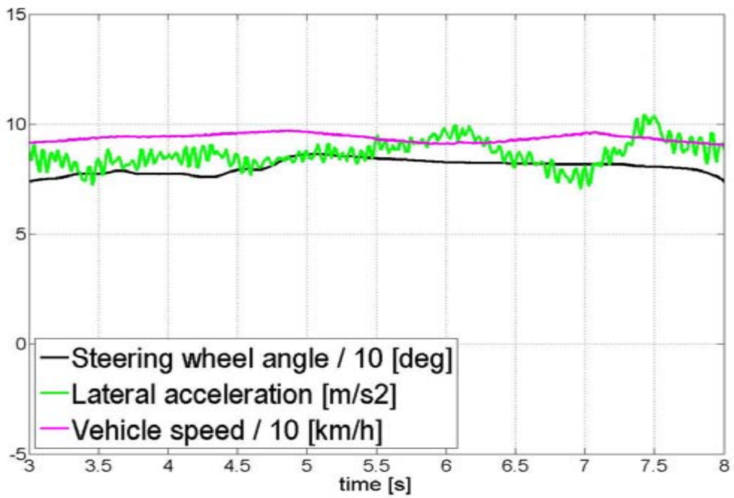
# Control of oversteer in throttle-off manoeuvres

**With oversteer control**

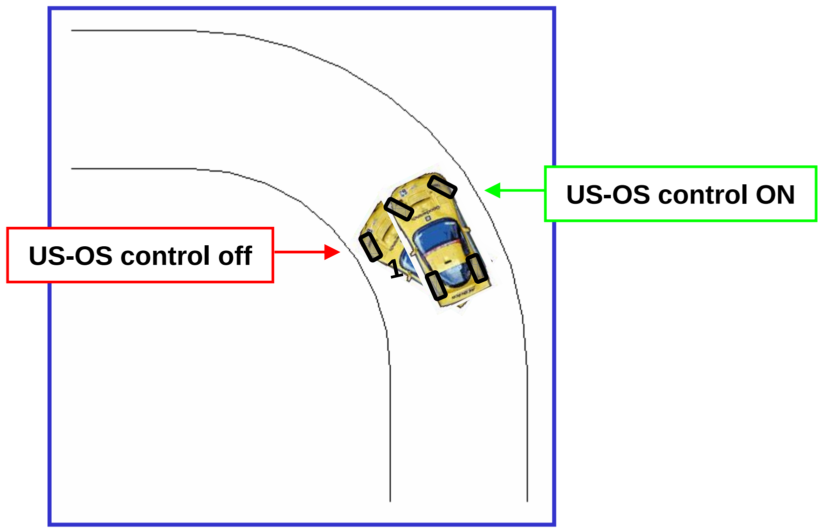
**Without oversteer control**




**Experimental results**



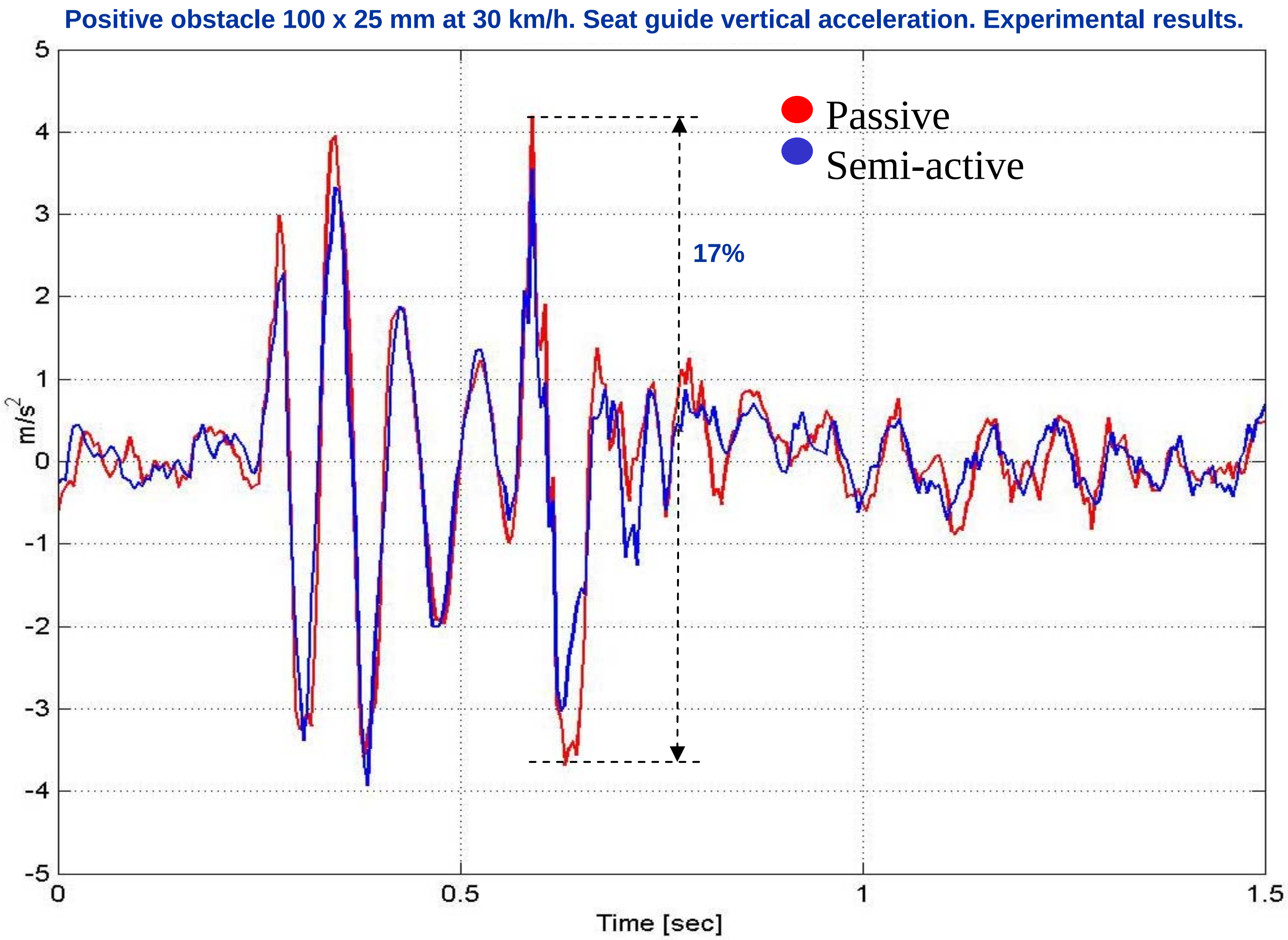
# Hole and bump management

The goal of the hole/bump management module is to optimize **comfort** and **road holding** in case of wheels impact against an obstacle (positive or negative) on the road.

- During **rectilinear path**, the main goal is to optimize **comfort**.
- During **cornering**, the main goal is to optimize **road holding**
  - ✓by reducing hubs vibrations;
  - ✓and so reducing yaw rate disturbances and guaranteeing good trajectory control.
- The SDC hole/bump management module is able to
  - ✓rapidly recognize the presence of the event by monitoring vertical accelerations of front wheels;
  - ✓recognize the sign of the event (hole or bump);
  - ✓act on the rear dampers in a predictive way;
  - ✓differently manage symmetrical and asymmetrical events;
  - ✓differently manage events during rectilinear path and during cornering.

# Hole and bump management during rectilinear path

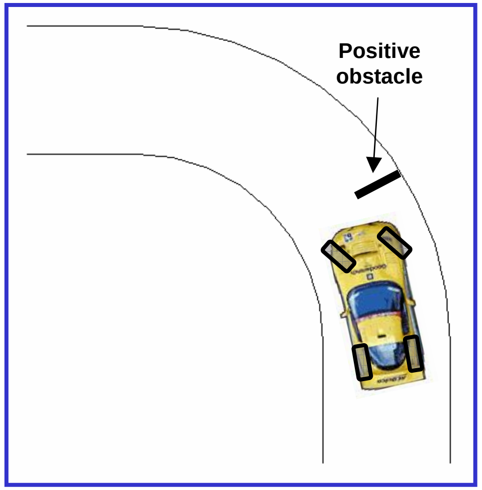
Good comfort → reduction of peak to peak of seat guide vertical acceleration

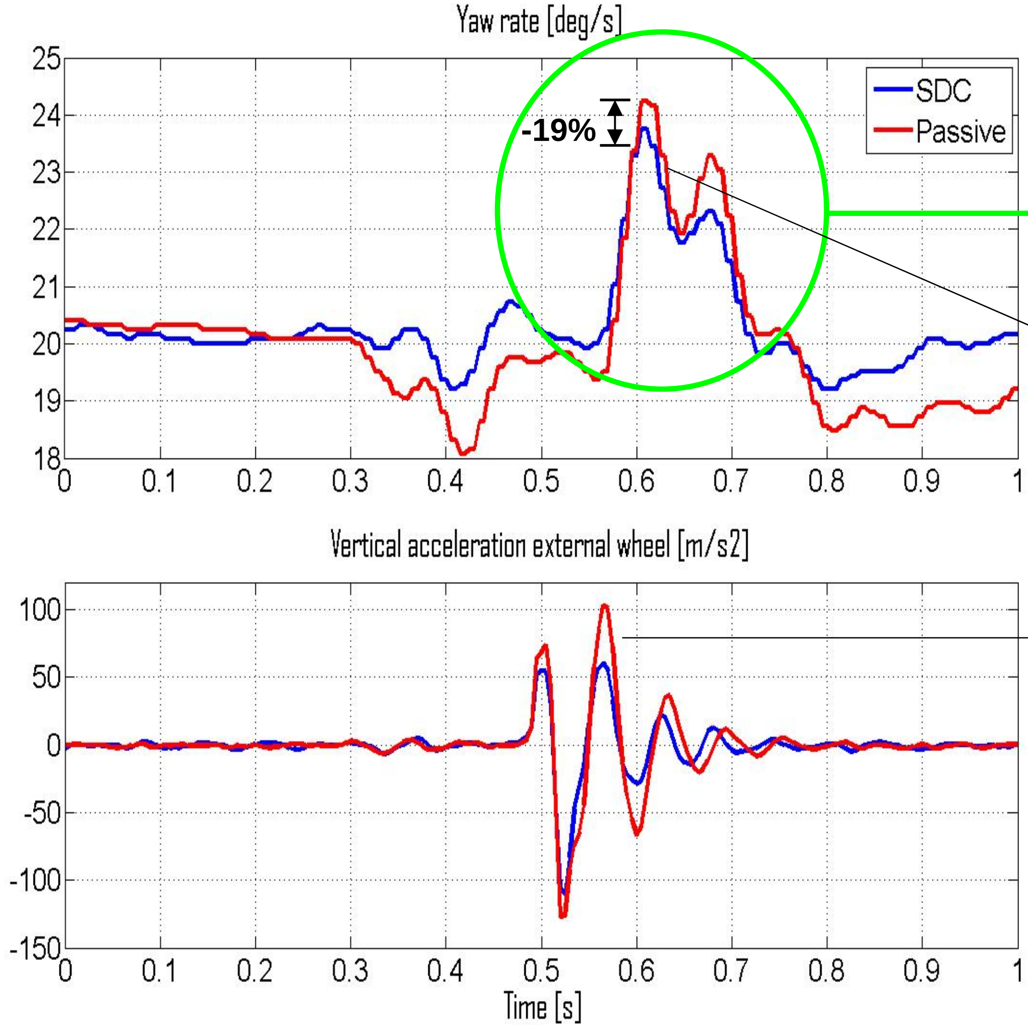


# Hole and bump management during cornering

**Cornering manoeuvre at 40 km/h with 80° steering wheel angle. Positive obstacle on the external wheel. Experimental results.**

**Good trajectory control → reduction of yaw rate disturbances**




**Increment of yaw rate caused by the impact against the rear wheel**

**A strong reduction of the increment of yaw rate is possible with SDC control**

**A strong reduction of hubs vibrations is possible with SDC control**

# Longitudinal dynamics control

- **This function controls body pitch movement caused by longitudinal acceleration jerk induced by driver actions on**

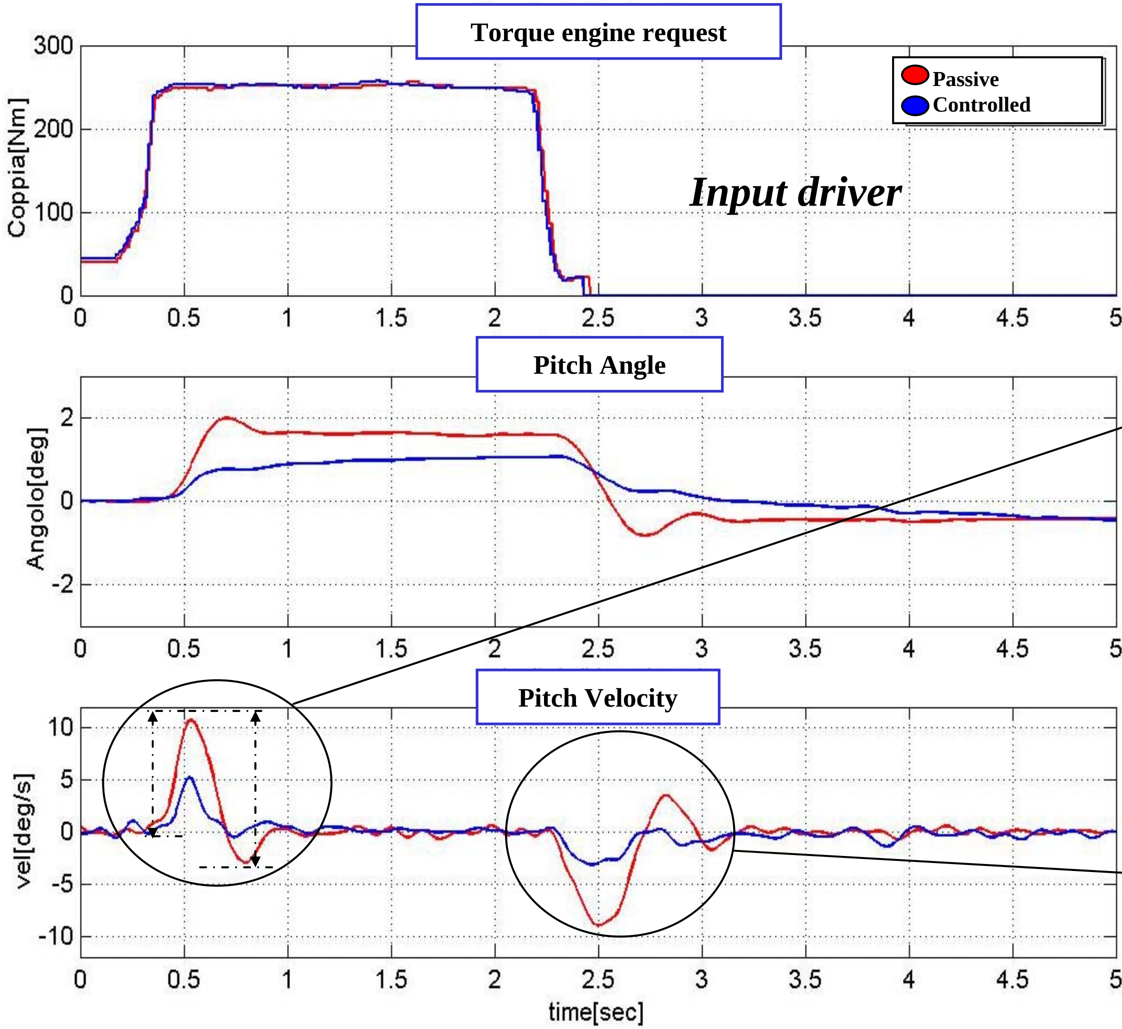
  - ✓ **gas pedal**
  - ✓ **clutch pedal**
  - ✓ **gearbox**
  - ✓ **brake pedal.**

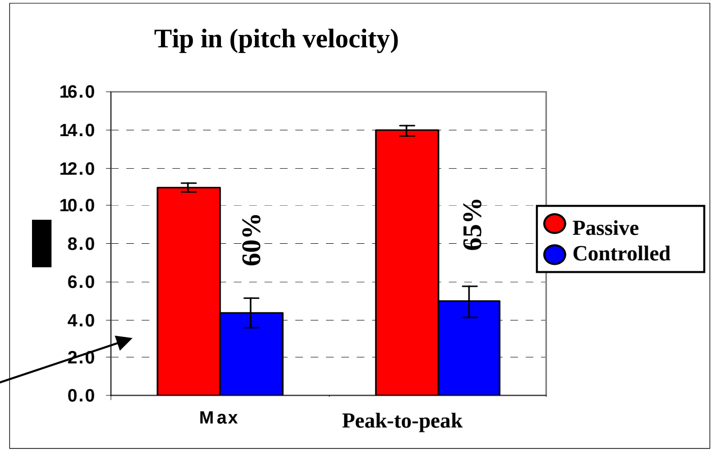
- **Damping levels of shock absorbers are set in order to control dive and squat body motion.**

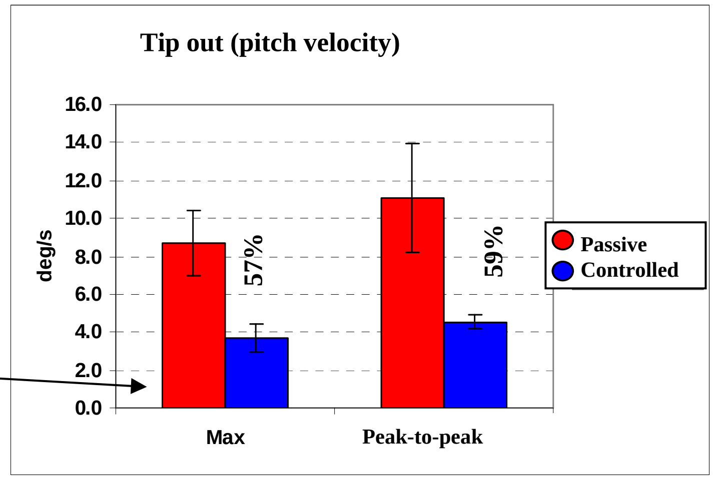
**The basic idea:** **during longitudinal dynamics transients the control logic increases damping levels of shock absorbers.**

# Control of body pitch movement

## Tip in/tip out in **1ª gear** @ 100% gas pedal



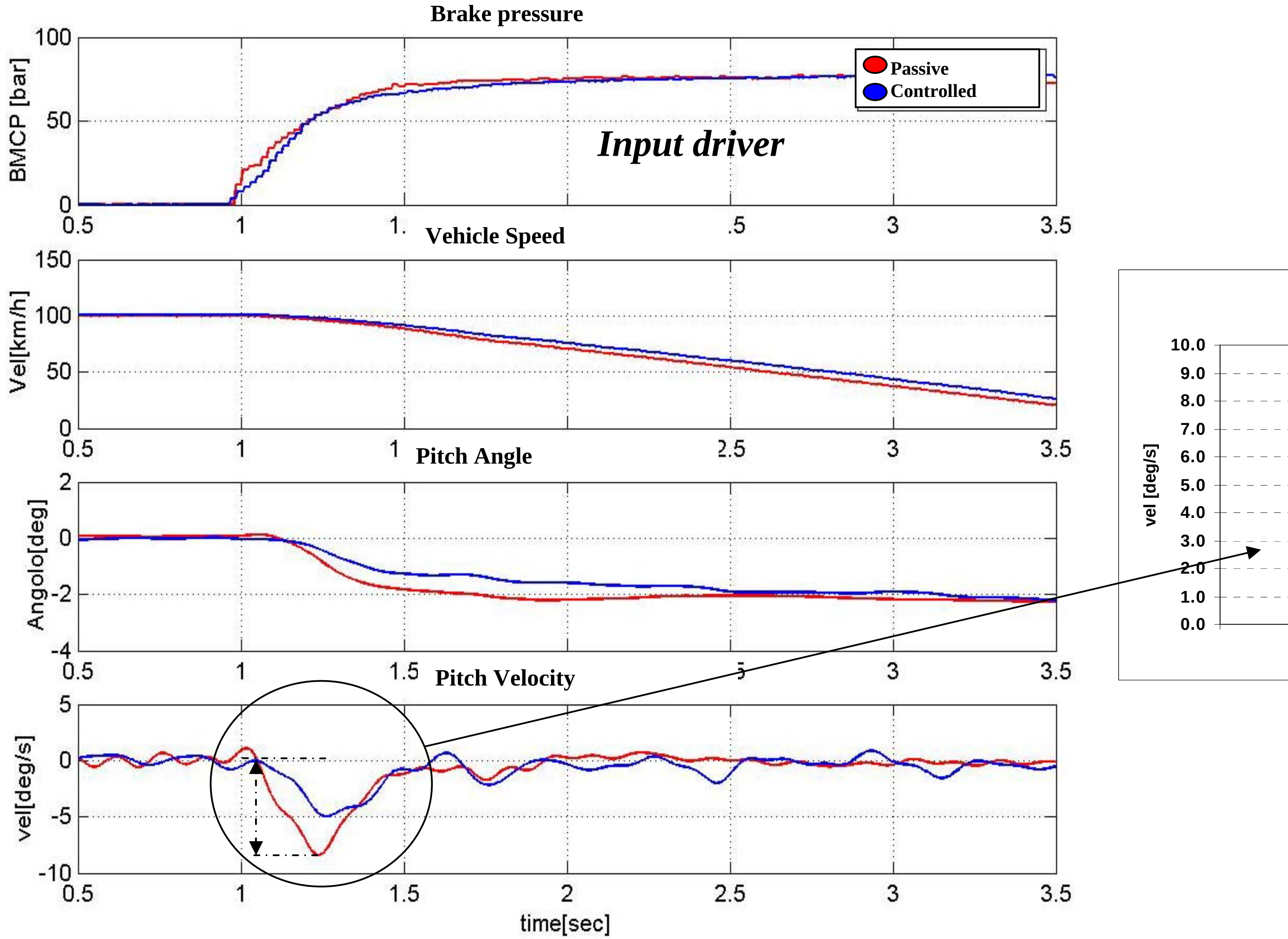



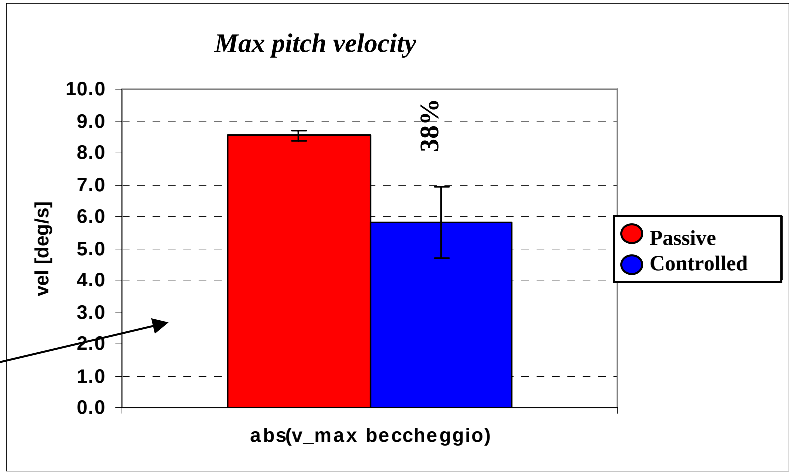




*Average on different tests*

# Control of body pitch movement

## Braking from 100 km/h




*Average on different tests*

# Conclusions

- Control strategies, based on the classical Sky-Hook theory, allow a perceptible improvement of comfort performance in case of controlled dampers.

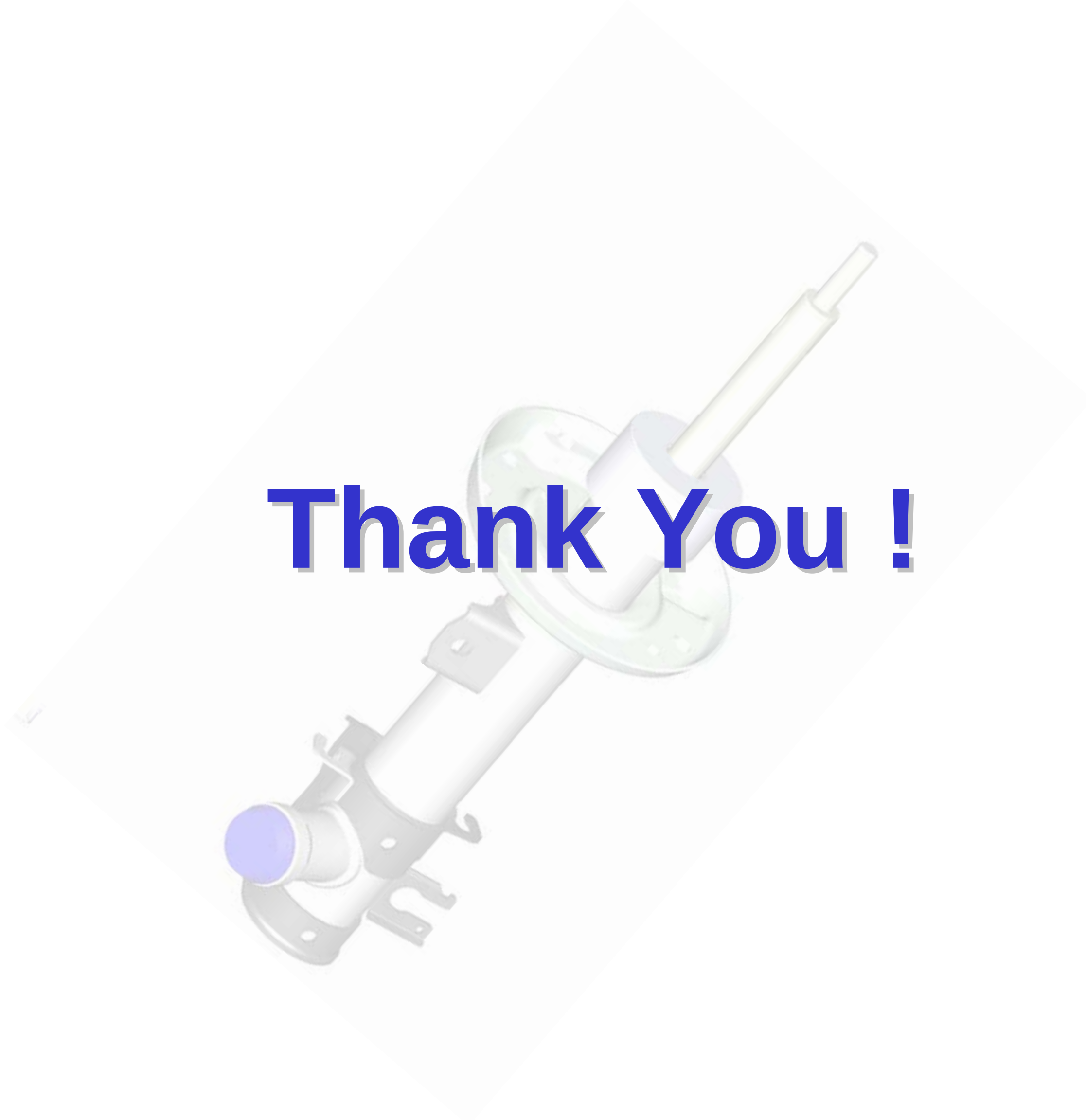
- The ride comfort application represents only a first step in the use of controlled dampers.

- The Synaptic Damping Control strategies are designed in order to increase the drivers feeling and perception.

  - ✓Improvement of handling characteristics of vehicles

    - Control of body roll
    - Control of understeer and oversteer during transient cornering
    - Control of understeer and oversteer caused by throttle-on and throttle-off
    - Minimization of yaw rate disturbances caused by impacts against obstacles during cornering
    - Control of body pitch

  - ✓All these control strategies give the vehicle more stability and allow greater driving pleasure, without compromising vertical comfort.



# Thank You !