

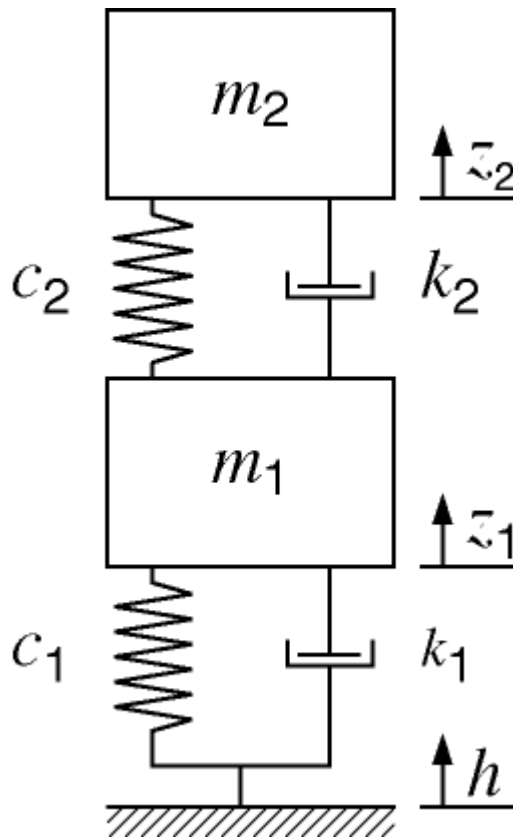
## Vehicle Systems

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# Introduction to vehicle suspension Dampers

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## Last Week - Suspension Ride comfort and frequencies

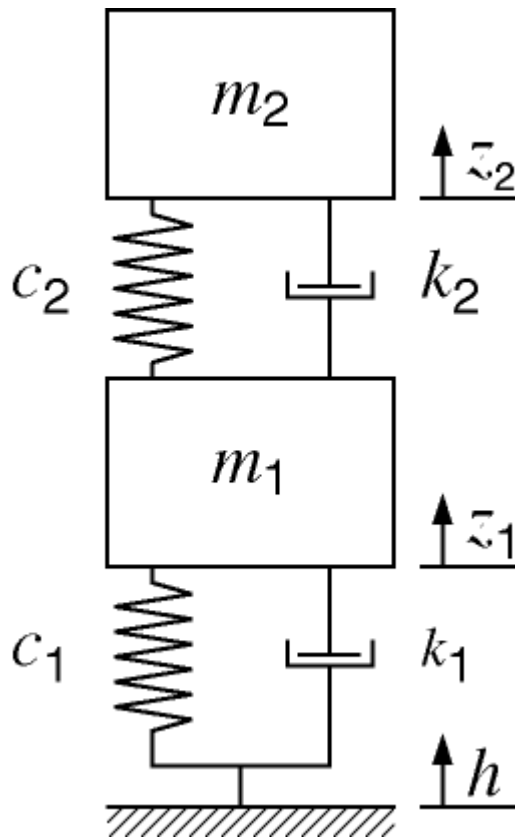


### **Dual-mass model as quarter-vehicle model**

$h$  Excitation amplitude,  
 $z$  Oscillation amplitude,  $c$  Spring  
resistance,  $k$  Damping constants,  
 $m$  Mass.

Subscripts: 1 Tires and axle,  
2 Body.

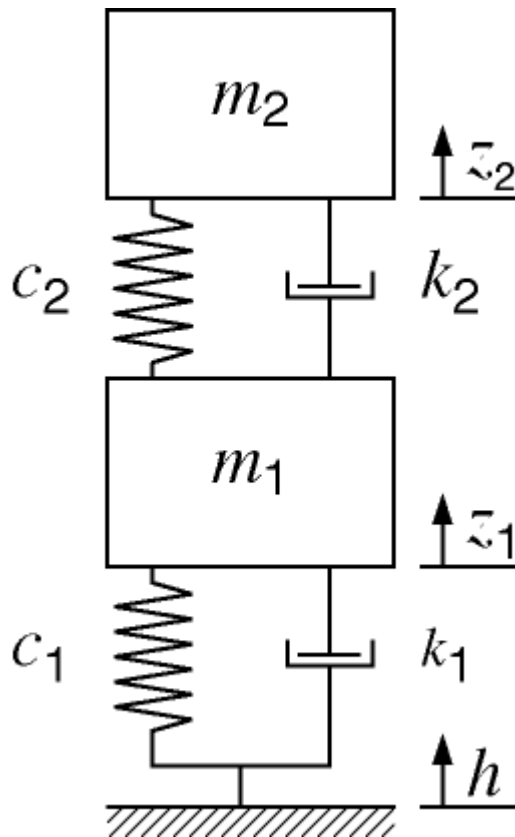
# Suspension Spring Ride Rate RR



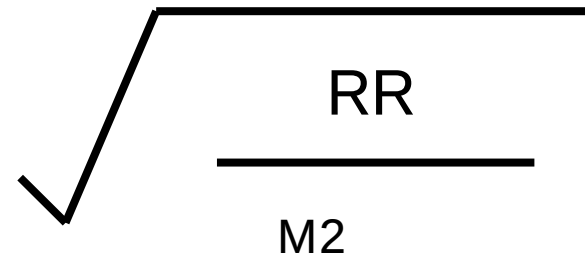
$$RR = \frac{K2 \cdot K1}{K2 + K1}$$

Effective stiffness of tyre and suspension  
Springs in series

# Suspension Spring Bounce natural frequency



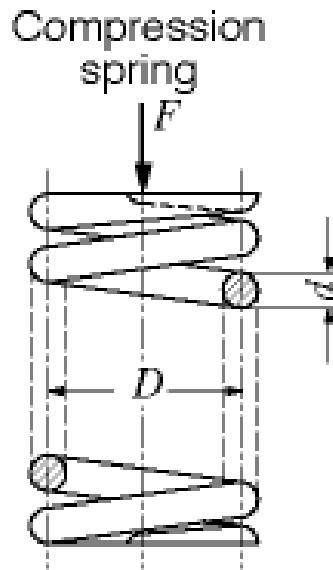
freq = 0.159



Bounce natural frequency

# Suspension

## Spring helical



To increase fatigue life helical springs are shot peened on their surface to induce compressive stresses and minimise any micro cracks that would act as a stress raiser and crack propagation start point

Springs are coated for corrosion and stone chip resistance

Helical springs package well / compact  
Helical springs can be straight wound, Barrel or conical in order to achieve Different characteristics

# Suspension Dampers

- Springs will tend to oscillate about their natural frequency, therefore dampers are used :
- To damp vibration of the vehicle body caused by uneven roads or driving conditions. The damper must maintain low vibration transmissibility to maximise comfort.
- To quickly settle road induced wheel and axle vibration i.e. to provide a constant tyre to road contact and subsequently ensure good traction and braking performance

# Suspension Dampers – damping vibrations

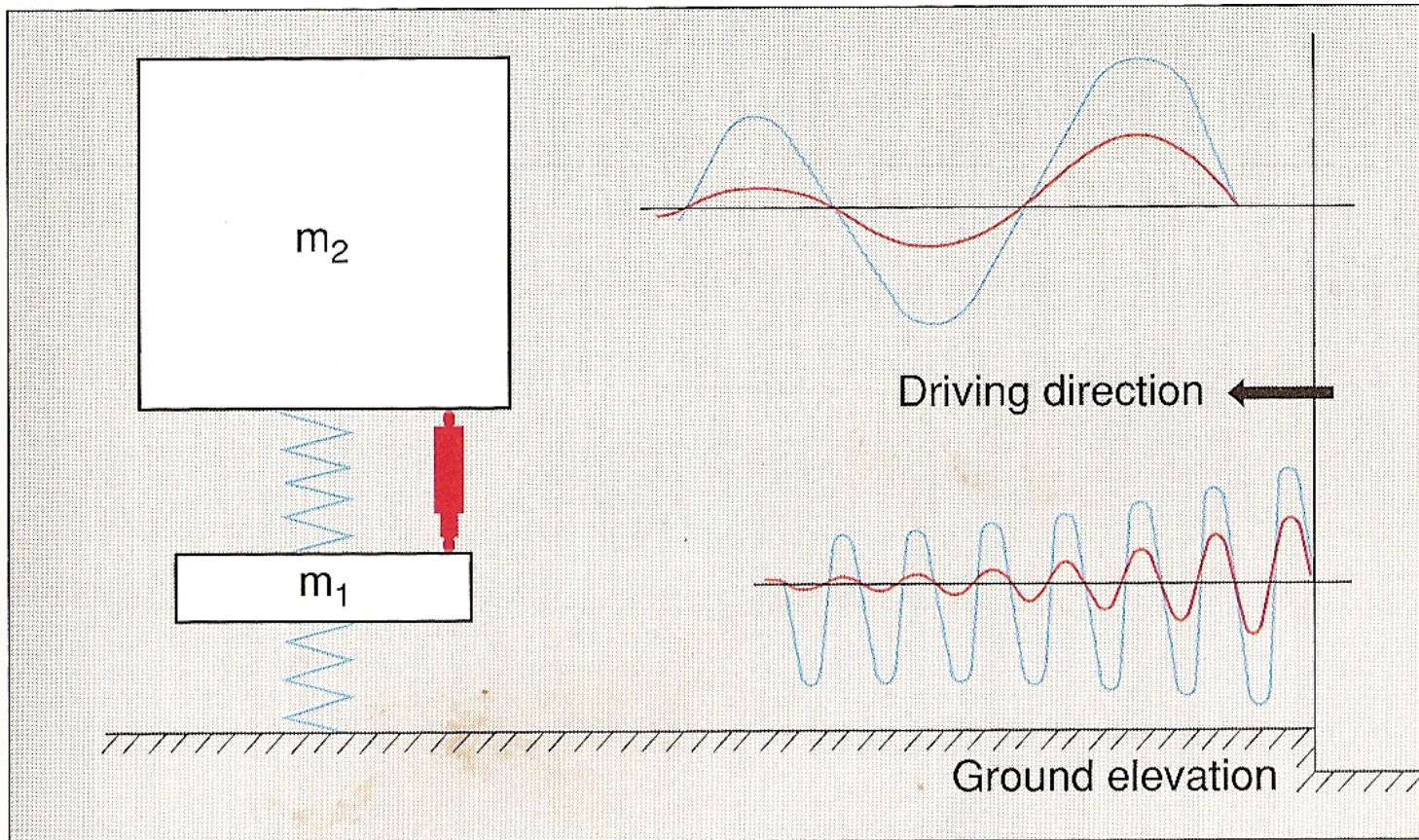


*Fig. 1: Coupled vibrations of chassis and body masses*

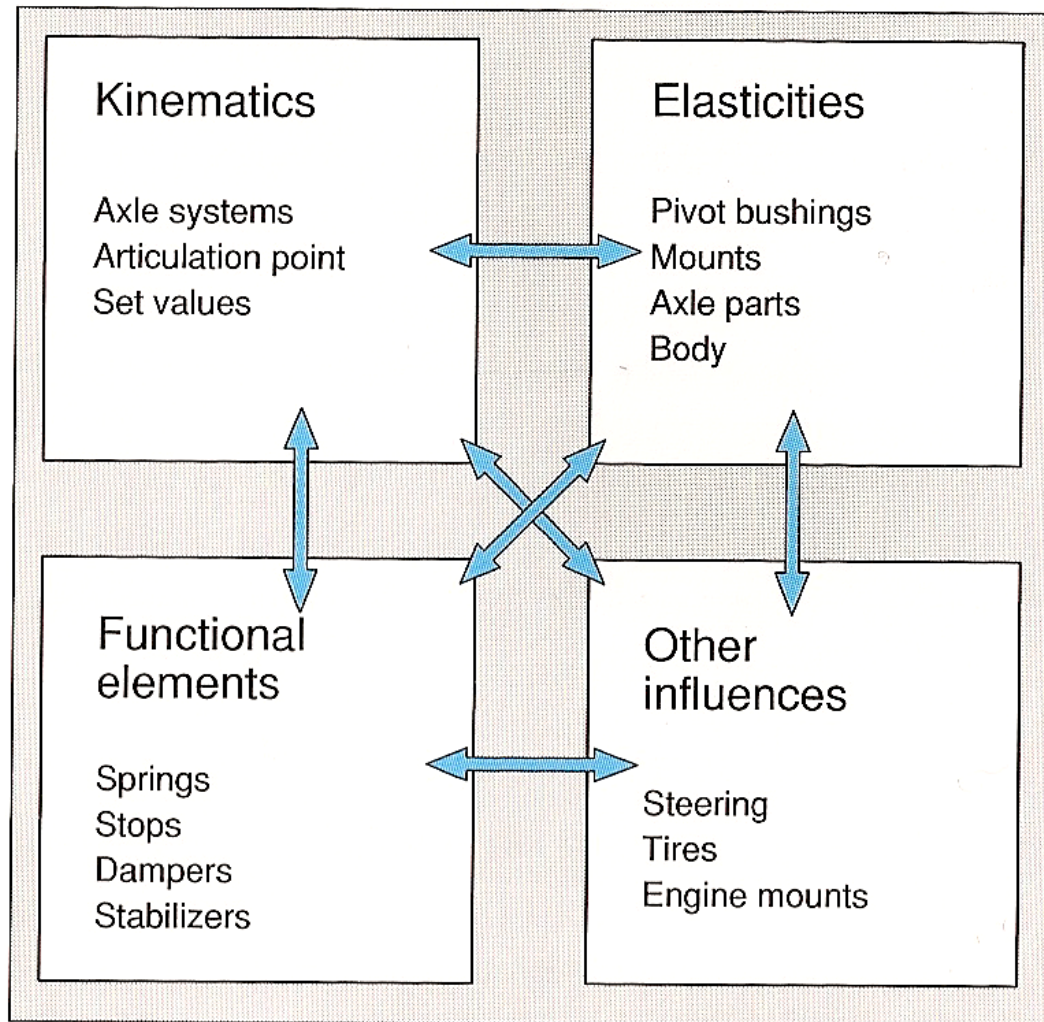
## Old car jump



## Rally car jump

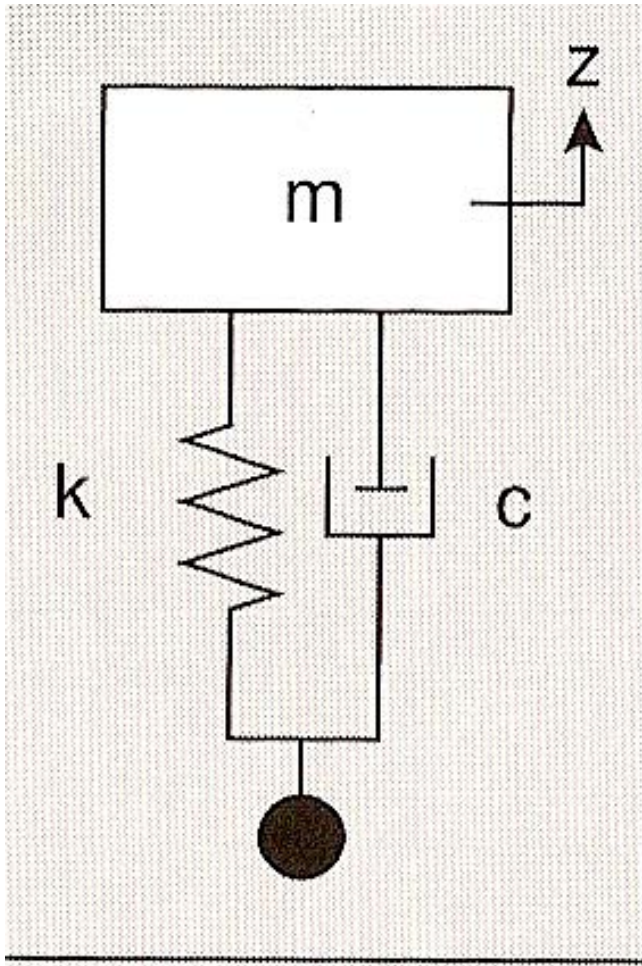


# Suspension Dampers



# Suspension

## Damping ratio

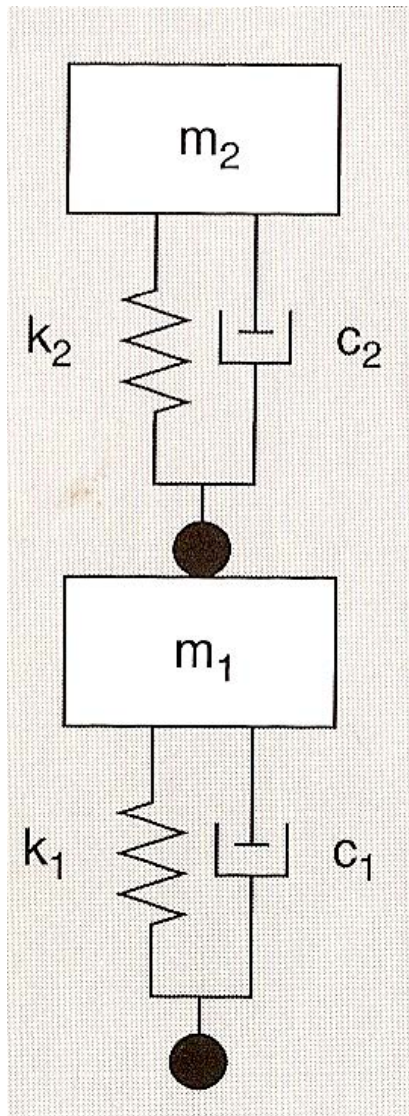


$$D = \frac{c}{2 \cdot \sqrt{k \cdot m}}$$

C= damping coefficient  
units N/m/s

# Suspension

## Damping ratio



$$D_1 = \frac{(c_1 + c_2) \cdot v_1}{2 \cdot (k_1 + k_2)}$$

$$D_{11} = \frac{c_1 \cdot v_1}{2 \cdot (k_1 + k_2)}$$

$c_1$  Wheel damping constant

$k_1$  Wheel spring constant

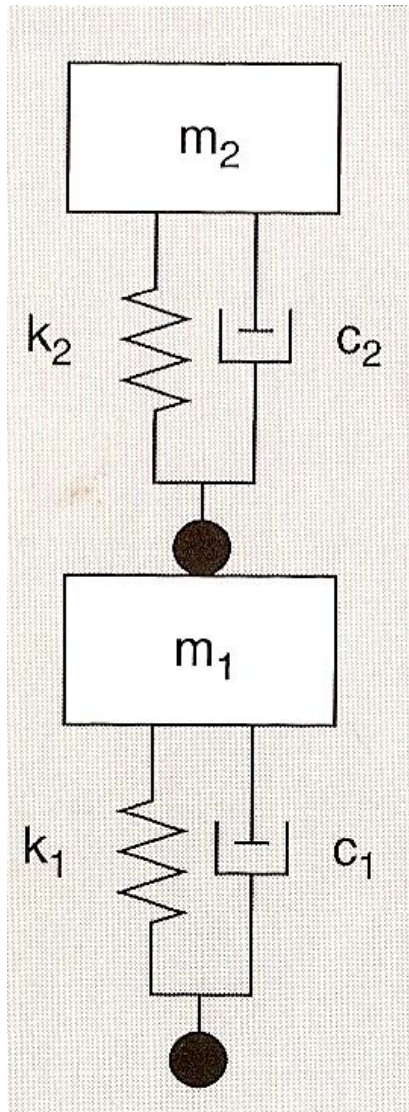
$v_1$  Resonant frequency of axle

$c_2$  Damping constant of shock absorber

$k_2$  Body spring constant

$D_{11}$  Partial damping factor of wheel

# Suspension Damping ratio

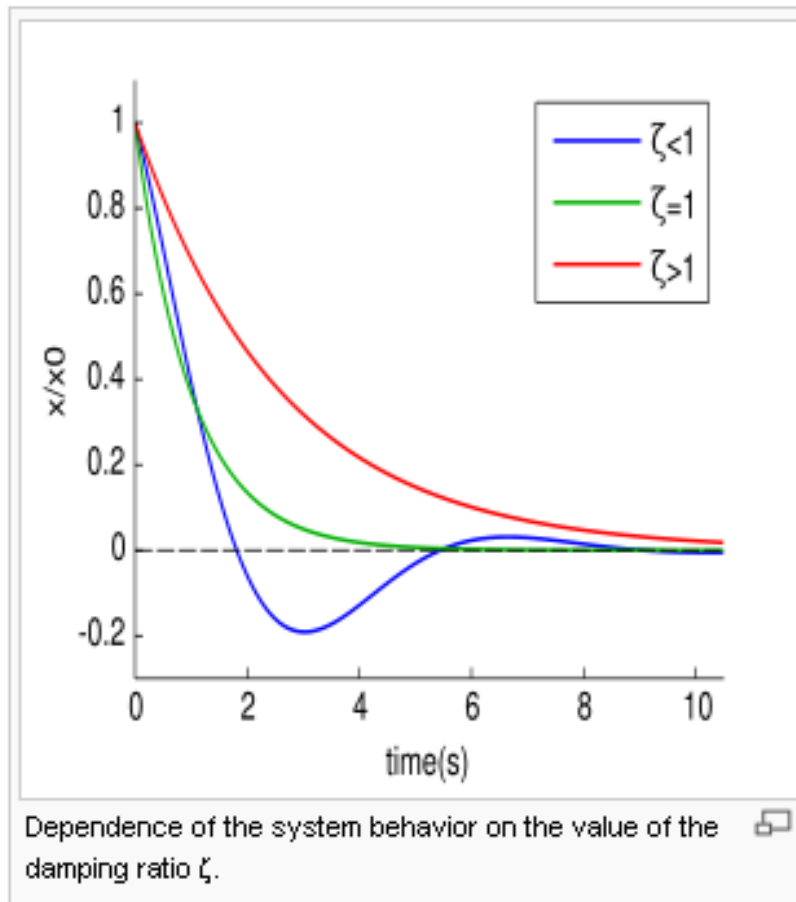


$$D_2 = \frac{c_2 \cdot v_2}{2 \cdot k_2}$$

$v_2$  Resonant frequency of body

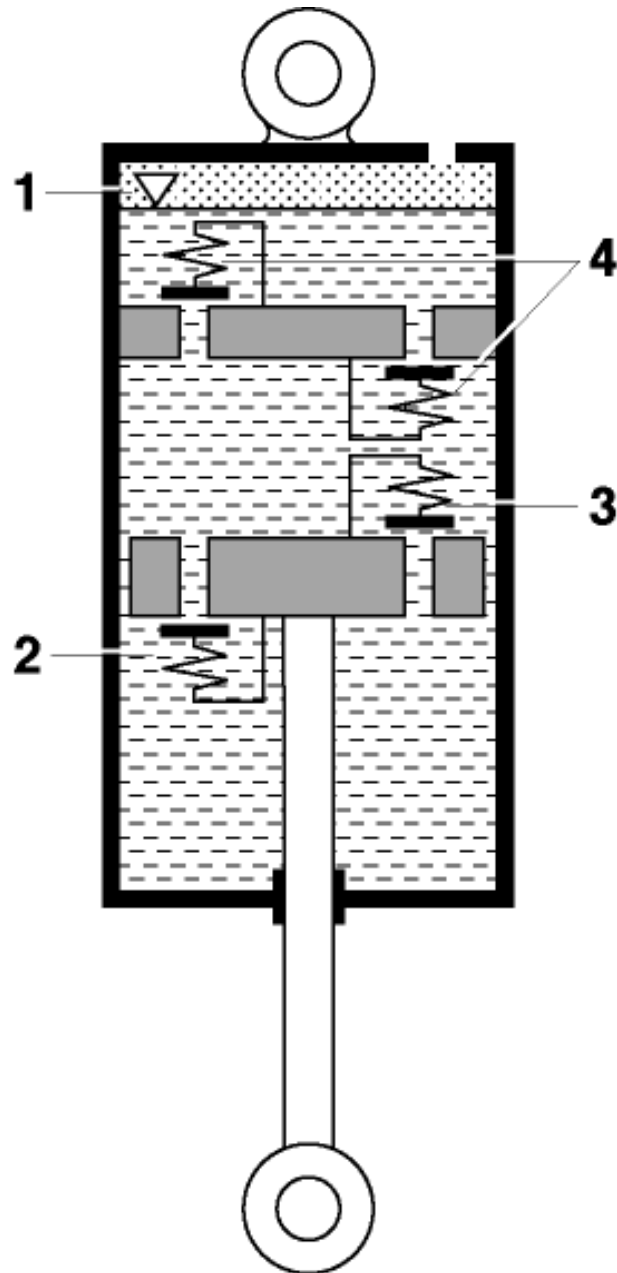
# Suspension

## Damping ratio



$\zeta = 0$  undamped  
 $\zeta < 1$  Underdamped  
 $\zeta = 1$  Critically Damped  
 $\zeta > 1$  Overdamped

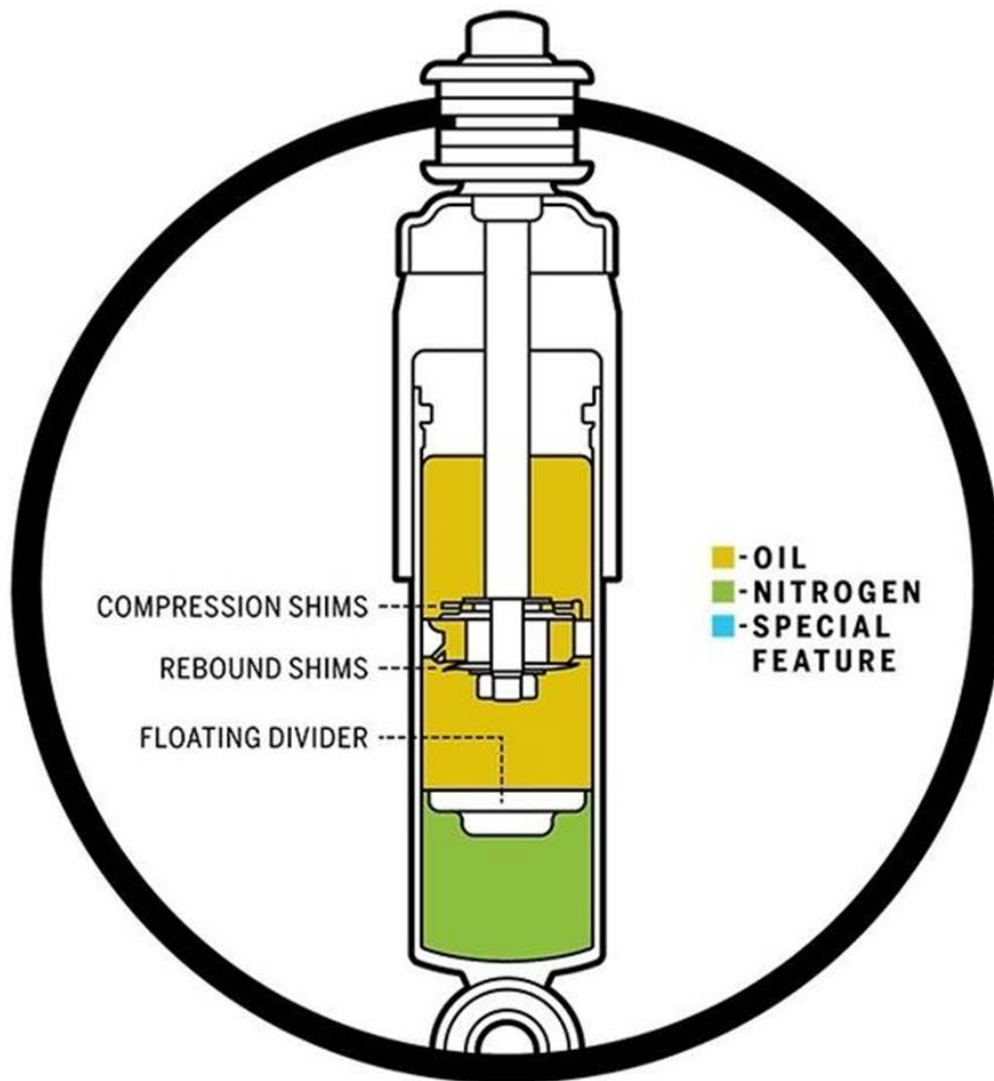
# Damper – Monotube



## Single-tube shock absorber

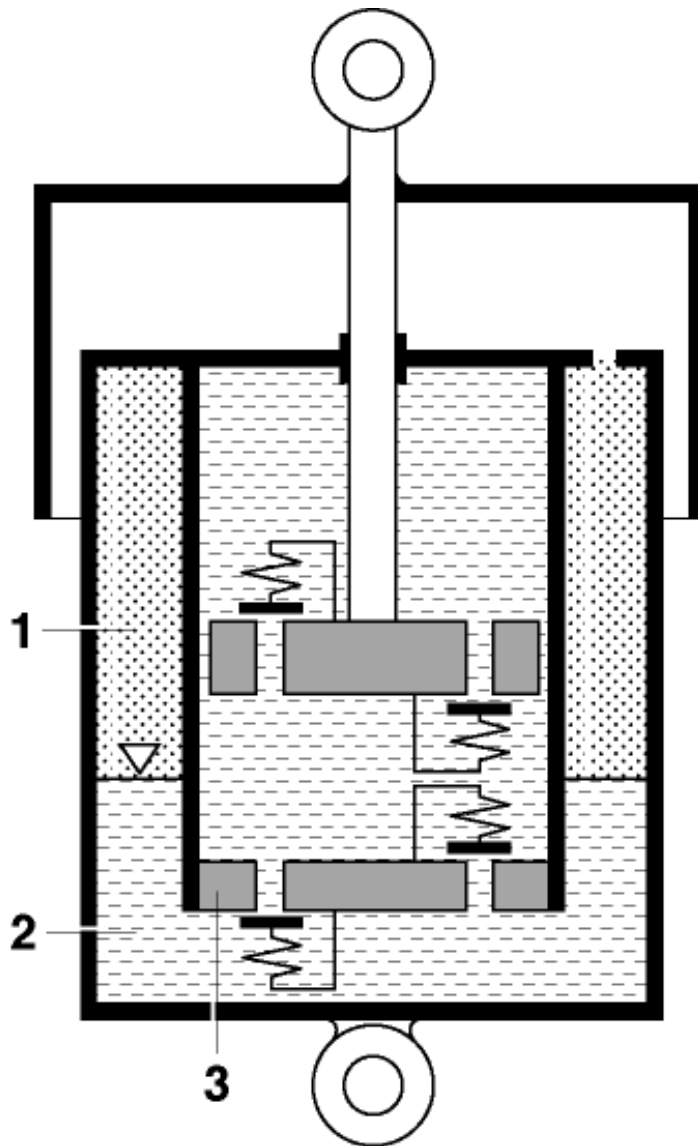
- 1 Atmospheric pressure,
- 2 Valve, soft spring,
- 3 Valve, hard spring,
- 4 Non-return valve.

## Damper – Monotube



- Single Cylinder divided into oil and gas
- Shaft pushes piston to create damping force
- Oil is metered through the shim stack on both bump and rebound movements
- Gas compensates for oil displacement
- Damping force is determined by the shape, size, and number of shims on the piston, the shaft diameter, the cylinder diameter, and gas pressure.

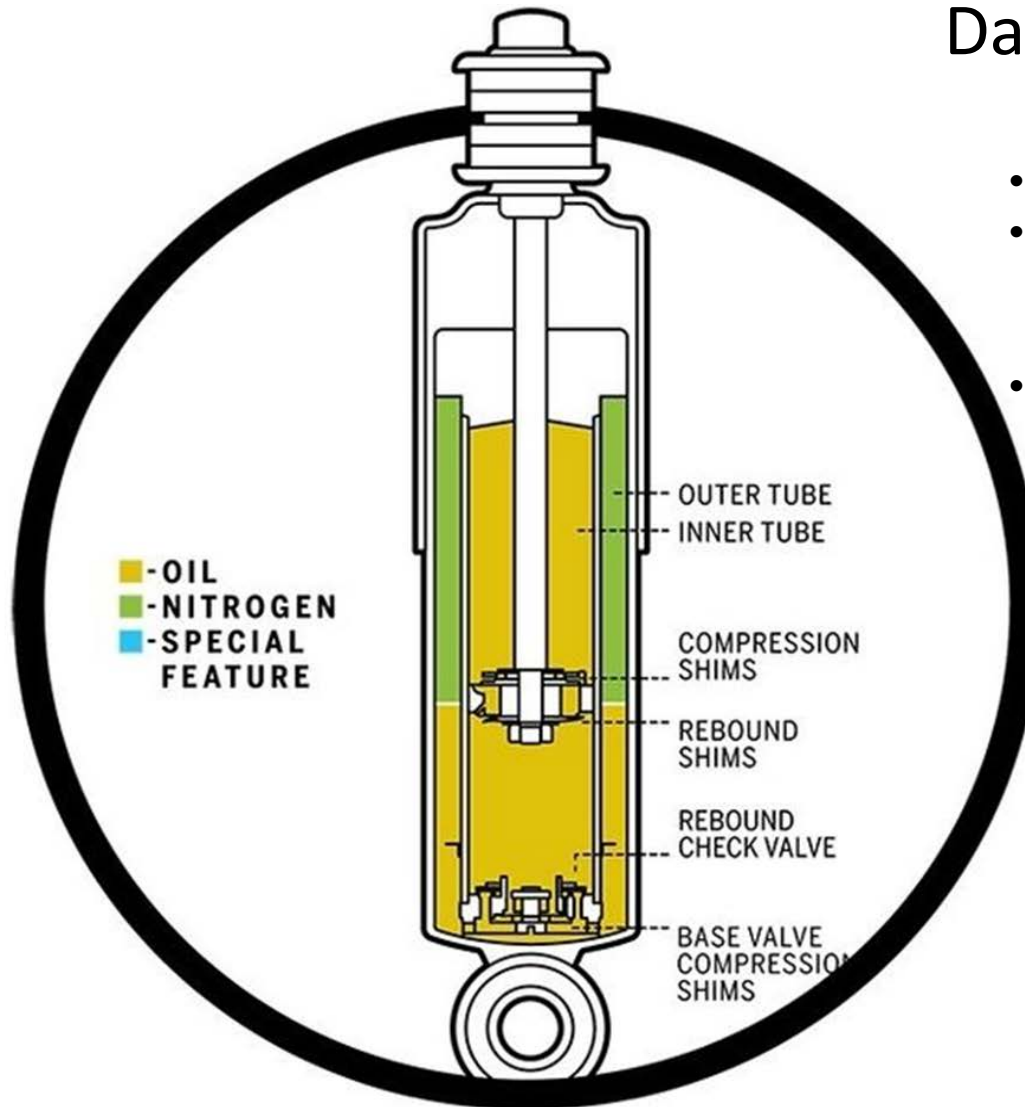
# Suspension Damper – Twin Tube



## **Twin-tube shock absorber**

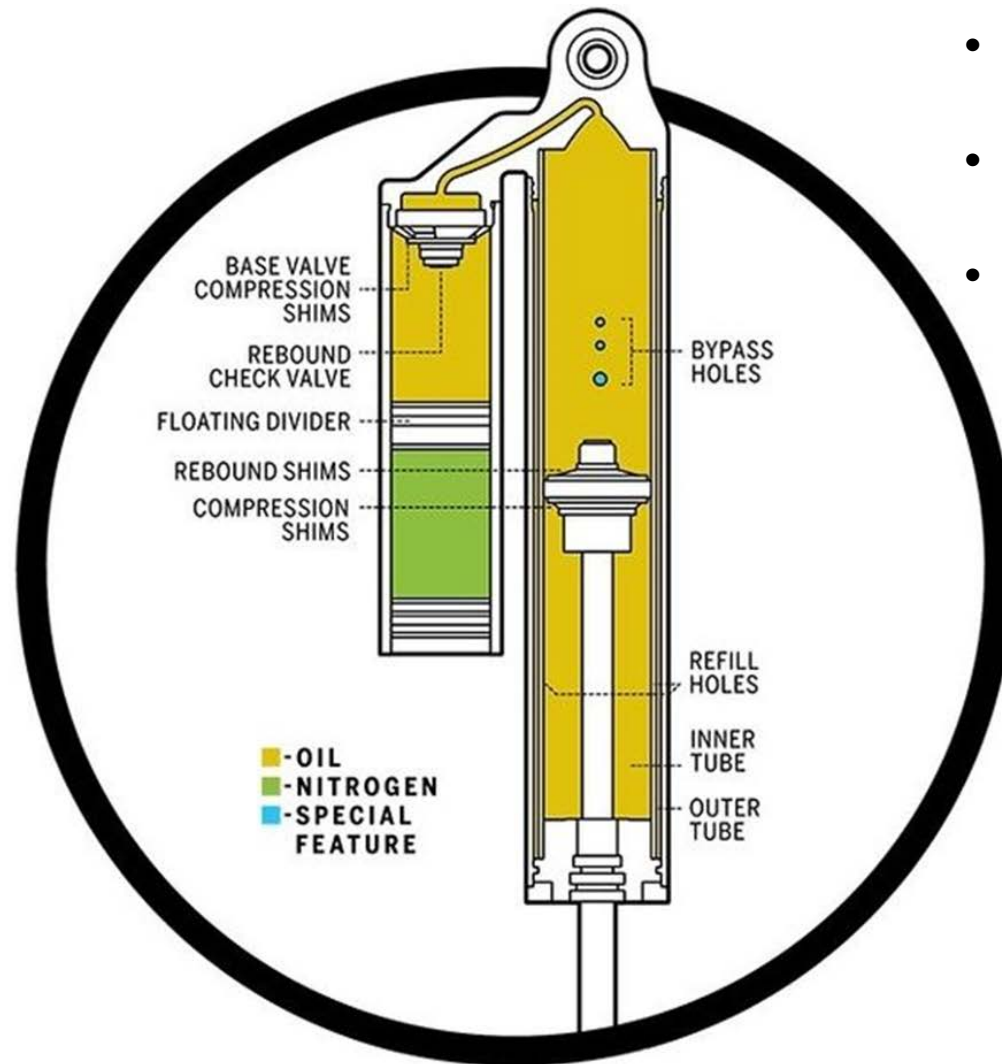
- 1 Atmospheric pressure,
- 2 Reserve chamber,
- 3 Base valve.

# Suspension Damper – Twin Tube



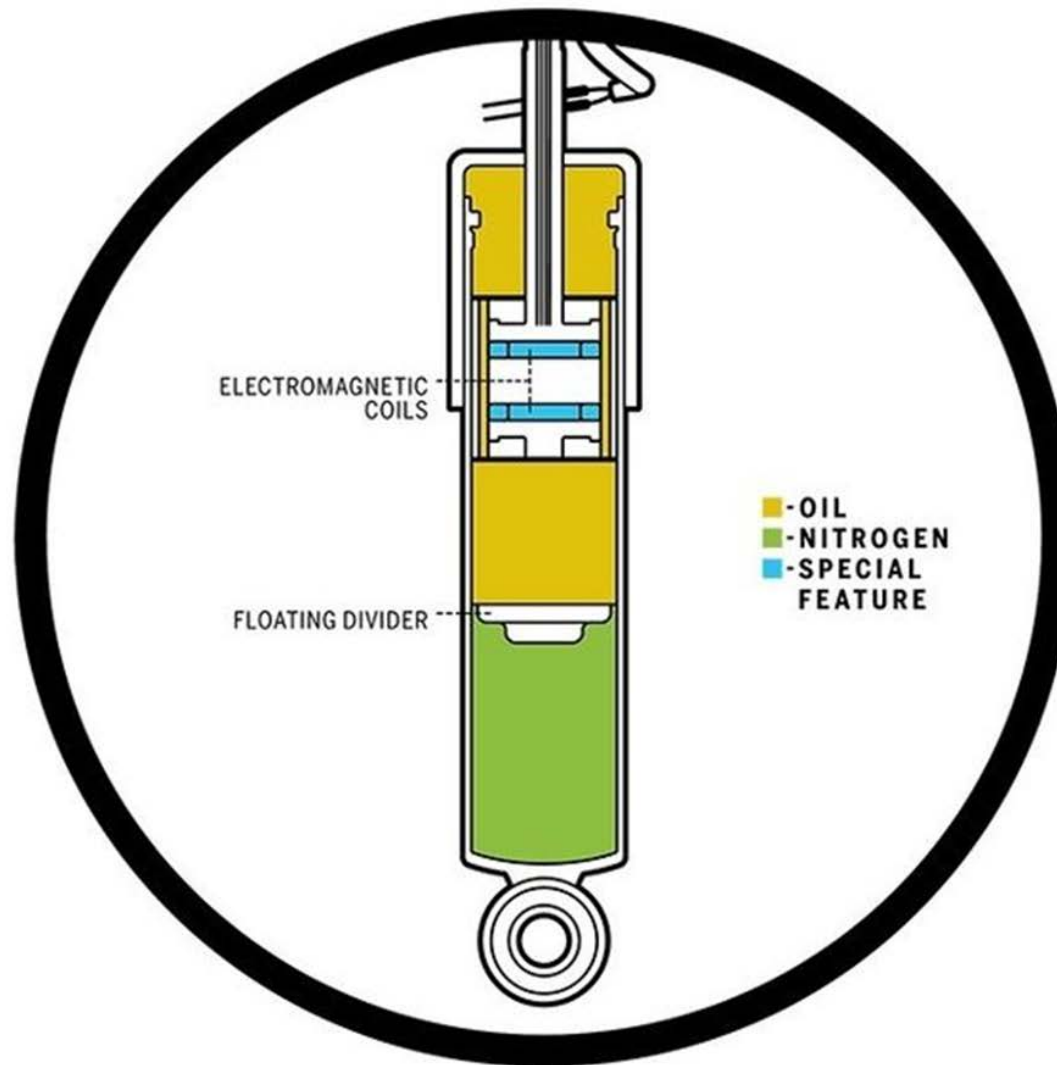
- Inner Tube filled with oil
  - Additional shim stack controls air flow to outer tube during bump
  - Outer Tube works as a reservoir
- Oil flow back during rebound controlled by check valve
- Damping is done by adding or removing shims.

# Damper – Internal Bypass



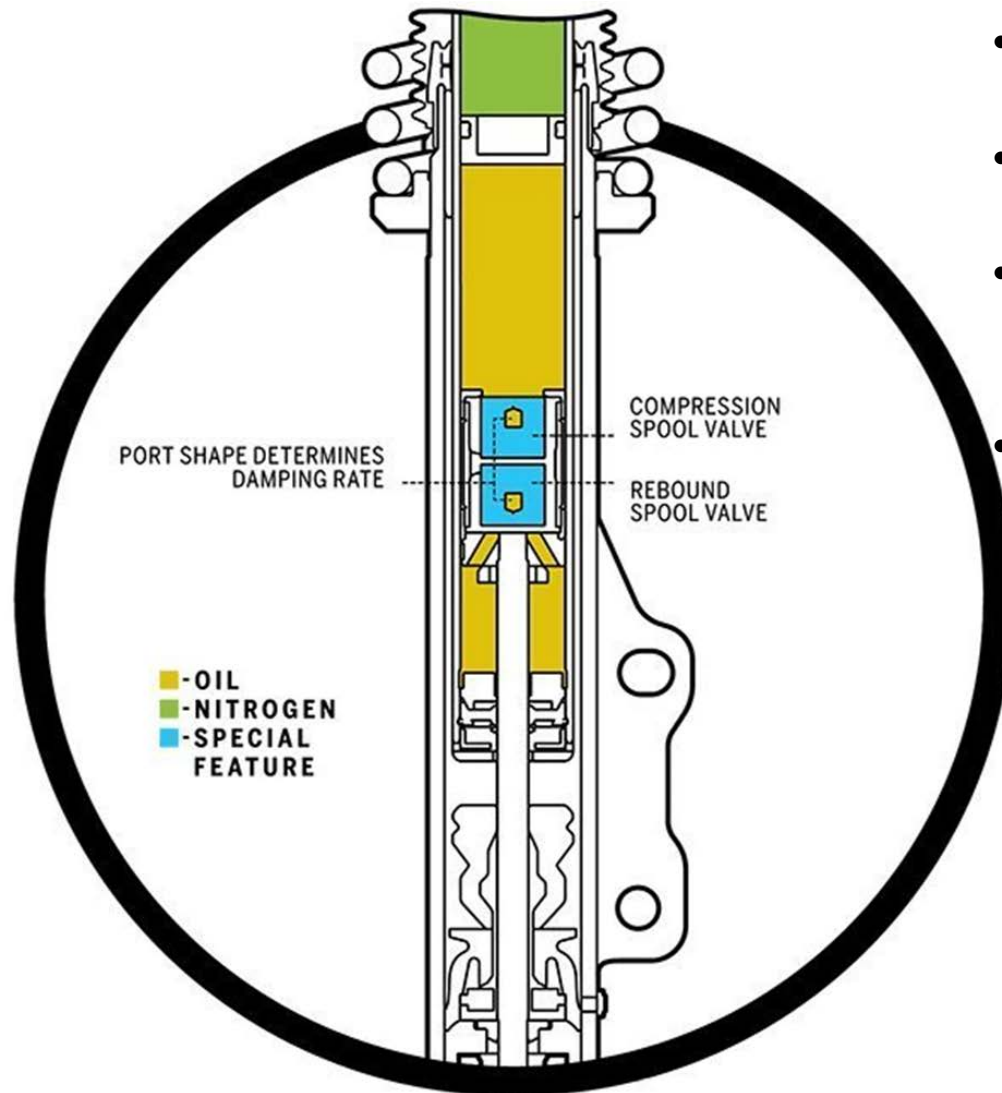
- Multiple circuits allow for fluid to bypass piston
- Allows for most damping force at mid travel
- Fluid “escapes” piston via holes in inner tube  
As piston moves it “opens” larger bypass holes forcing more fluid into stack increasing damping force.

# Damper – Magnetorheological Damper



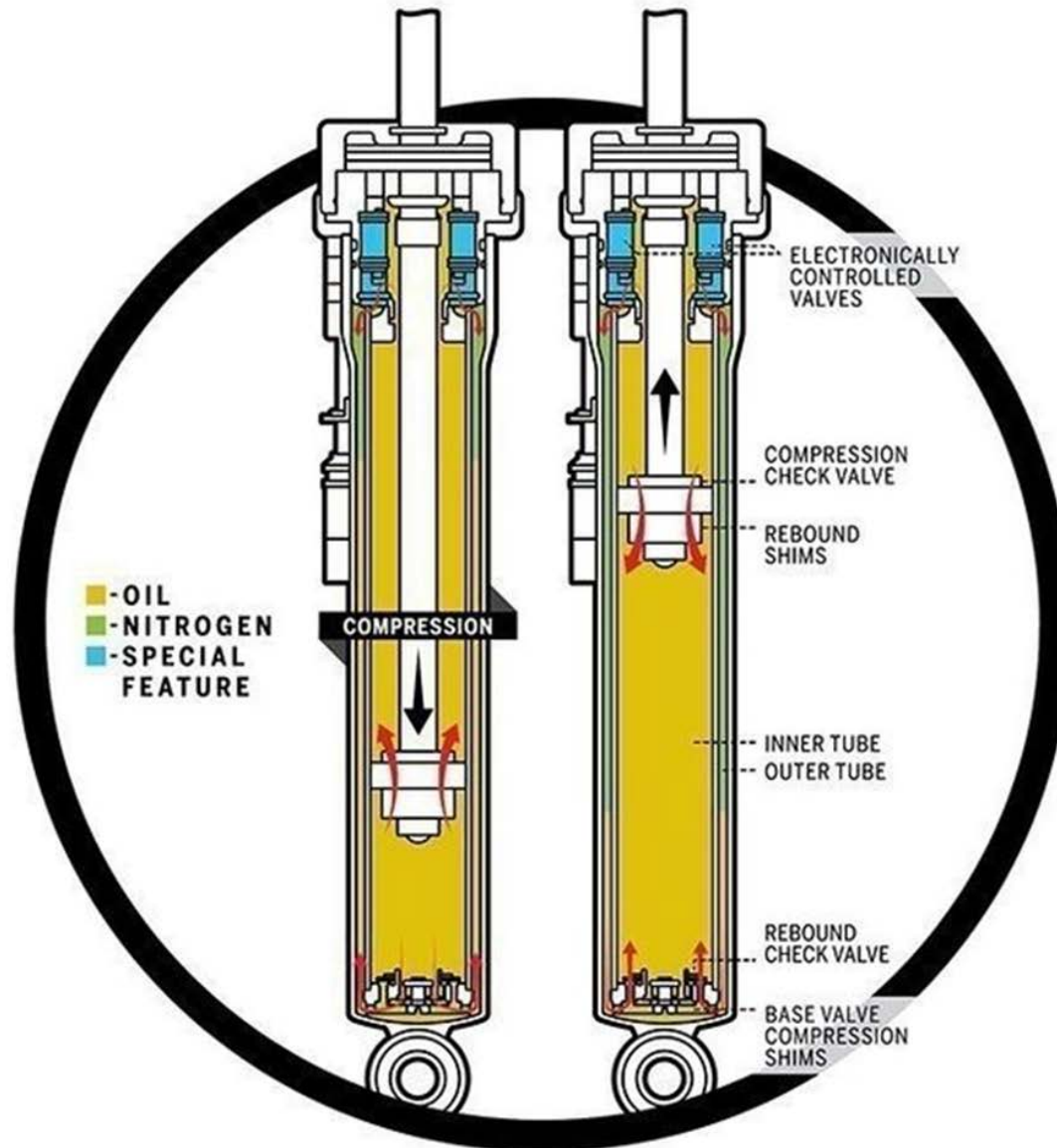
- No valves
- Changes viscosity of oil
- Fluid with iron particles
- Two electromagnets in piston create a field
- This makes fluid more resistant to flow

# Damper – Spool-Valve damper



- Spring loaded disc acting as lid of cylinder
- Allows oil to flow through shaped ports
- Exposed area of port proportional to force applied
- Damping force determined by shape and size of port as well as spring stiffness

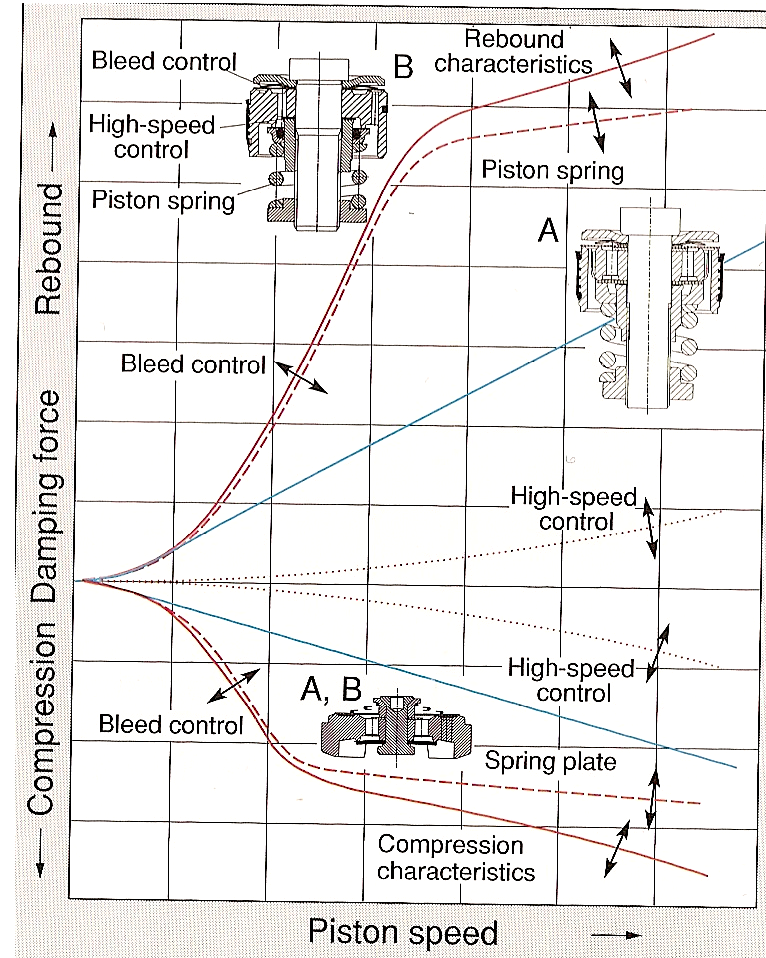
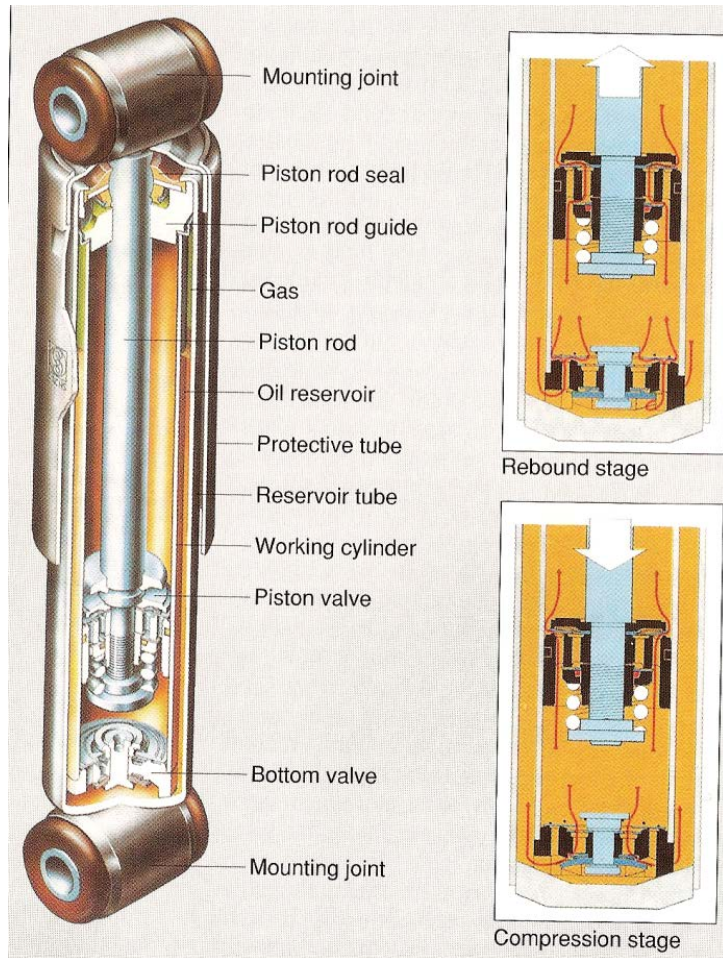
# Damper – Electronically Controlled Damper



Adaptive damper design  
Combines passive shim stack with electronically controlled valves  
Can be applied to both Mono or Twin Tube

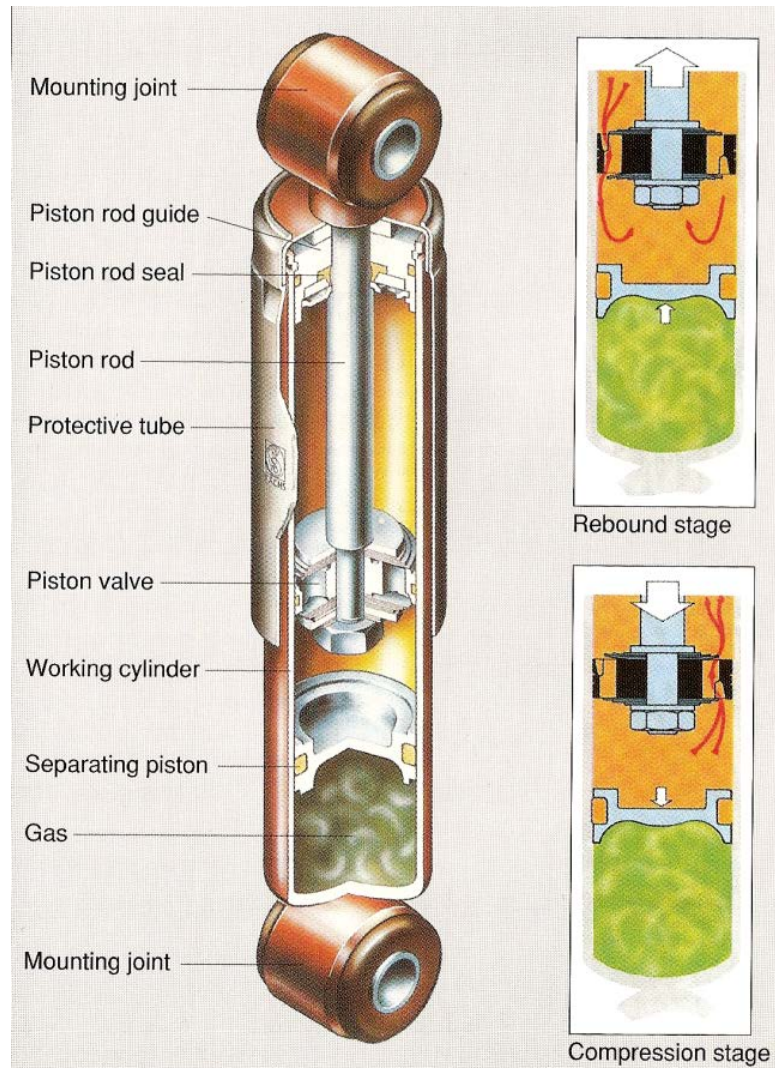
# Suspension

## Ride comfort and frequencies



# Suspension elements

## Monotube damper



Sachs 2000

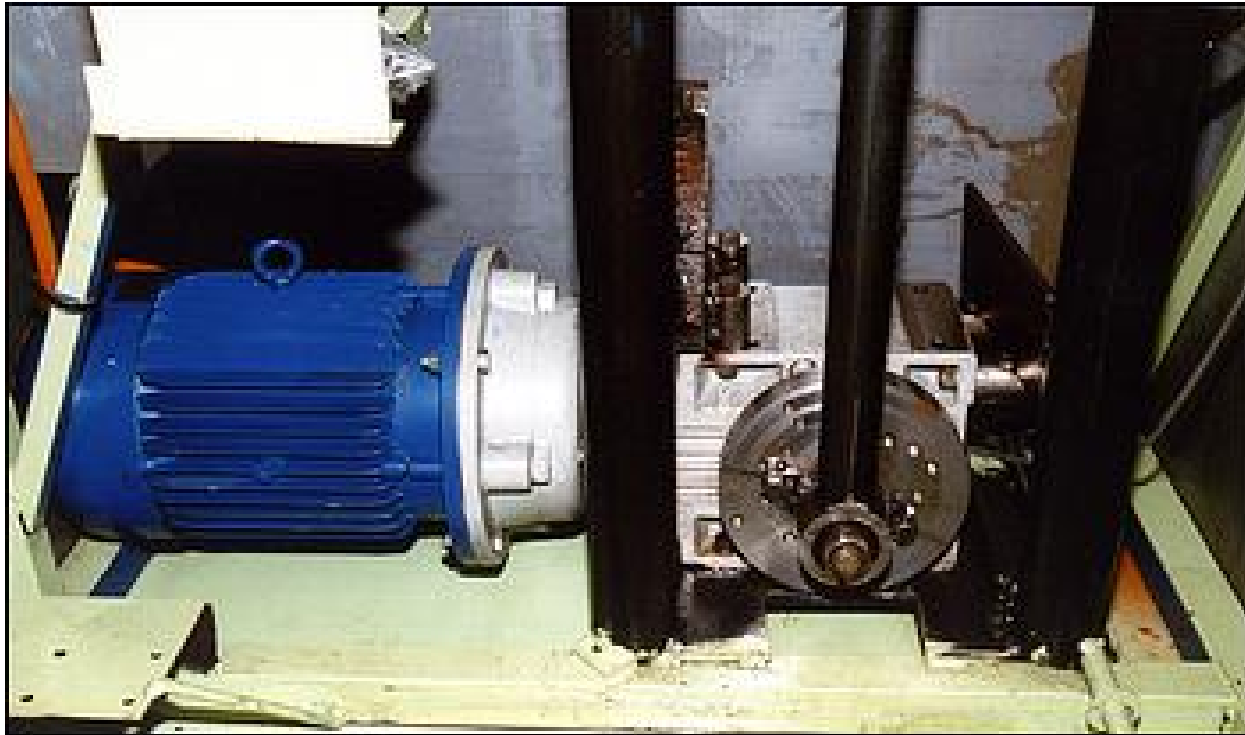
# Koni Dampers



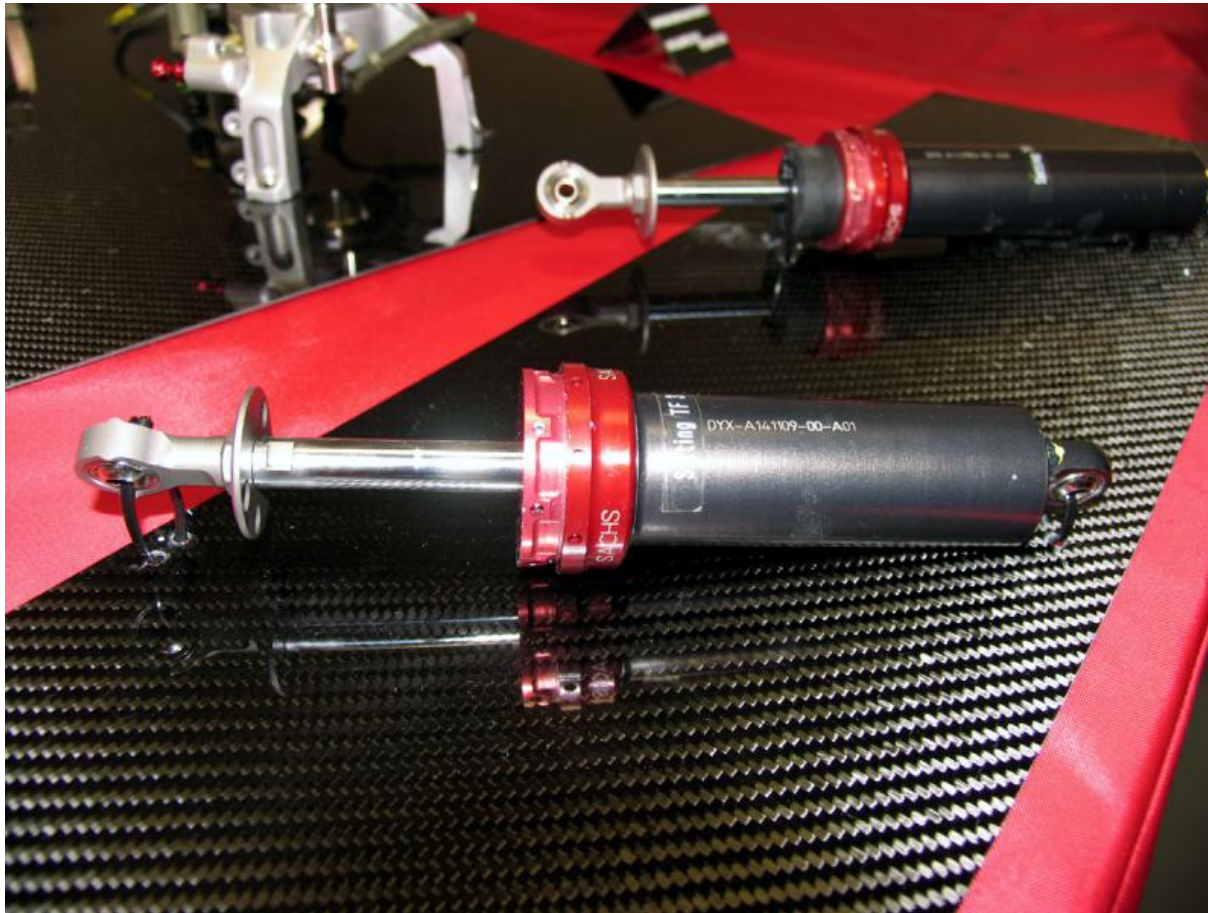
# Damper Dyno



## Damper test machine detail



# Honda F1 Dampers



# Velocity vs Time

## Velocity vs Time Plot

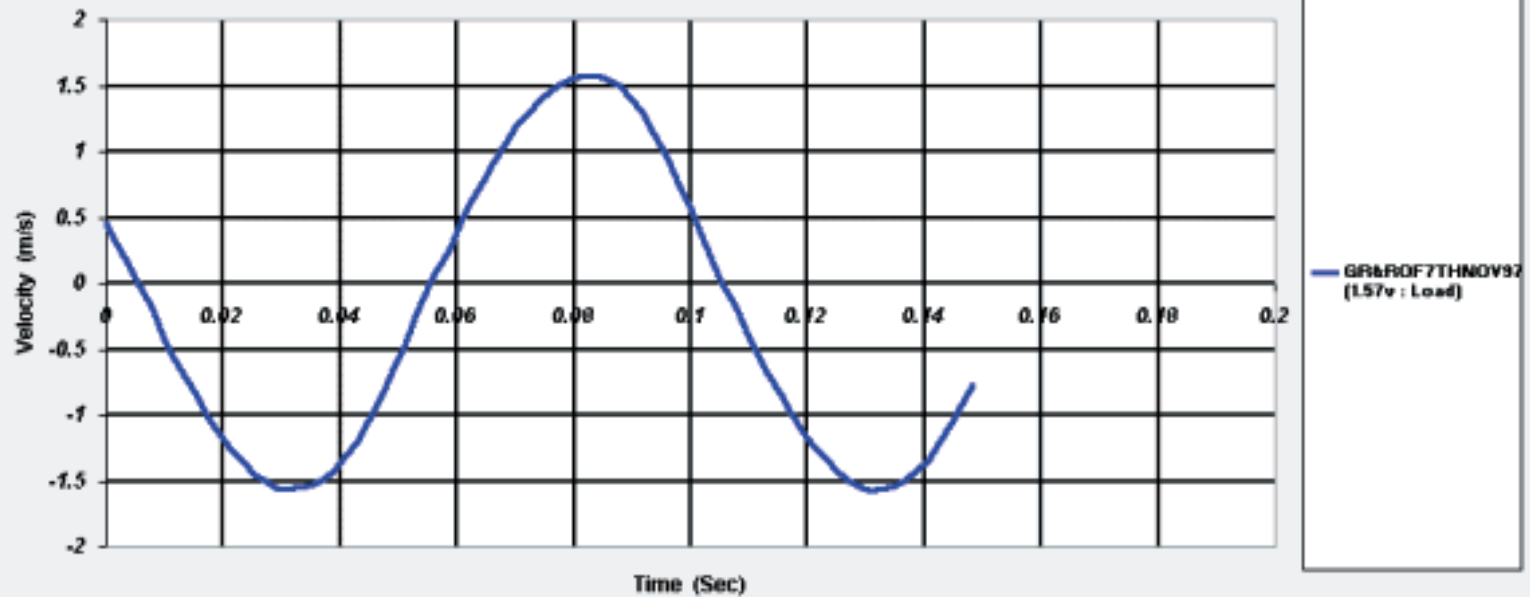
Test File:  
Gabriel

Operator Name: MILIND GAIKWAD  
GABRIEL SHOX NO: 10

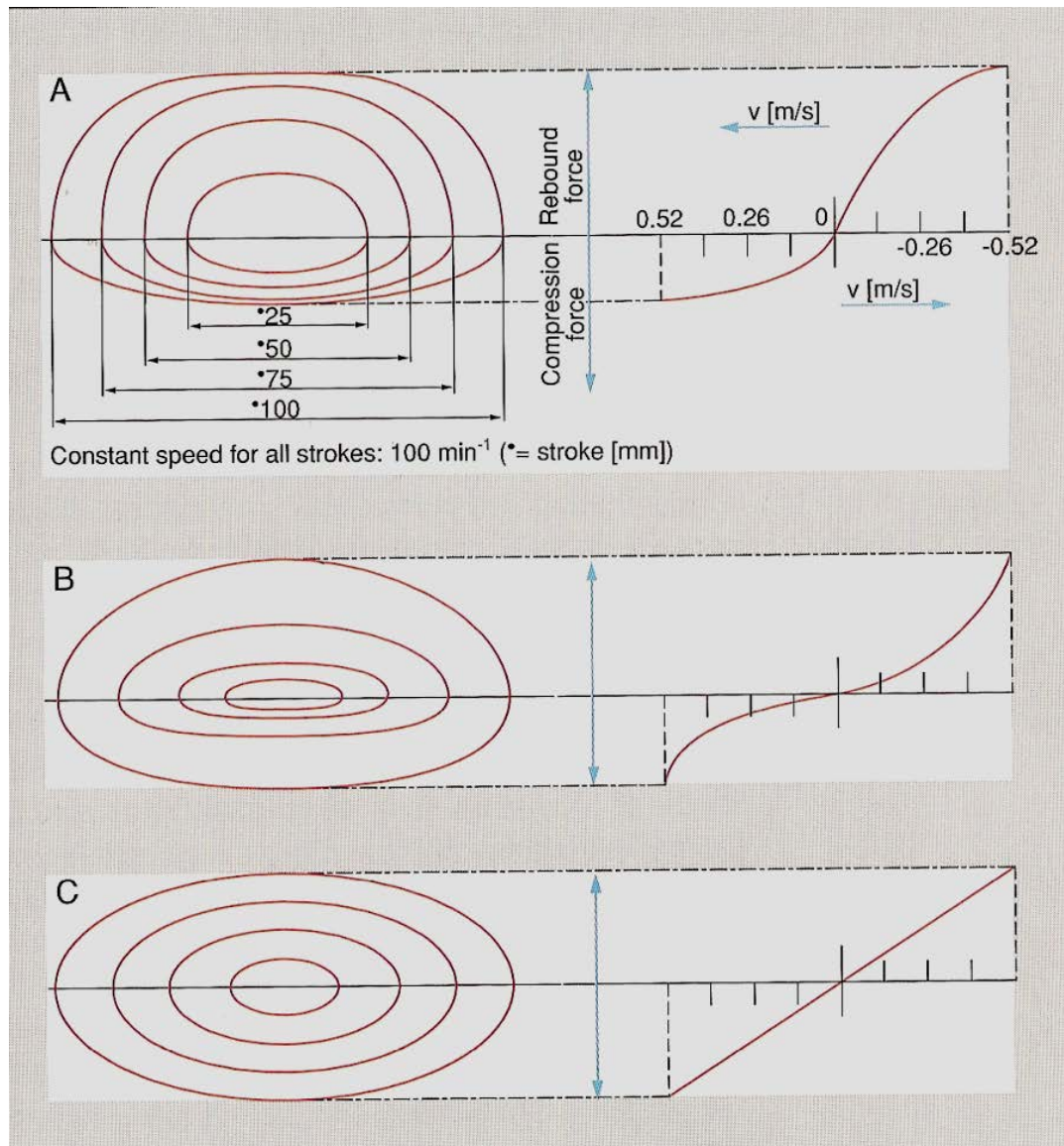
Test Date: 11/7/97 9:40 AM

Report Date: 4/29/98 2:15 PM

Part:  
GR&R TEST ON 4 SHOXS



# Suspension Dampers



A degressive  
B progressive  
C linear

# Force vs Velocity

Force vs Velocity Plot

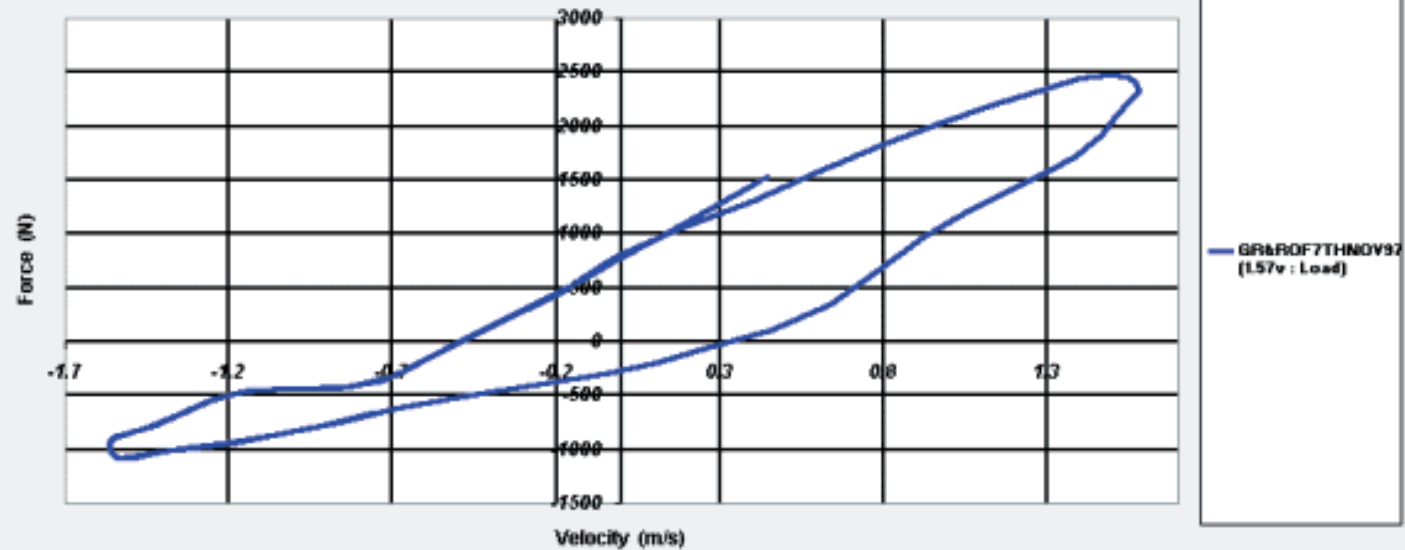
Test File:  
Gabriel

Operator Name: MILIND GAIKWAD  
GABRIEL SHOX NO: 15

Test Date: 11/7/97 9:40 AM

Report Date: 4/29/98 2:15 PM

Part:  
GR&R TEST ON 6 SHOXS



# Force vs Displacement

## Force vs Displacement Plot

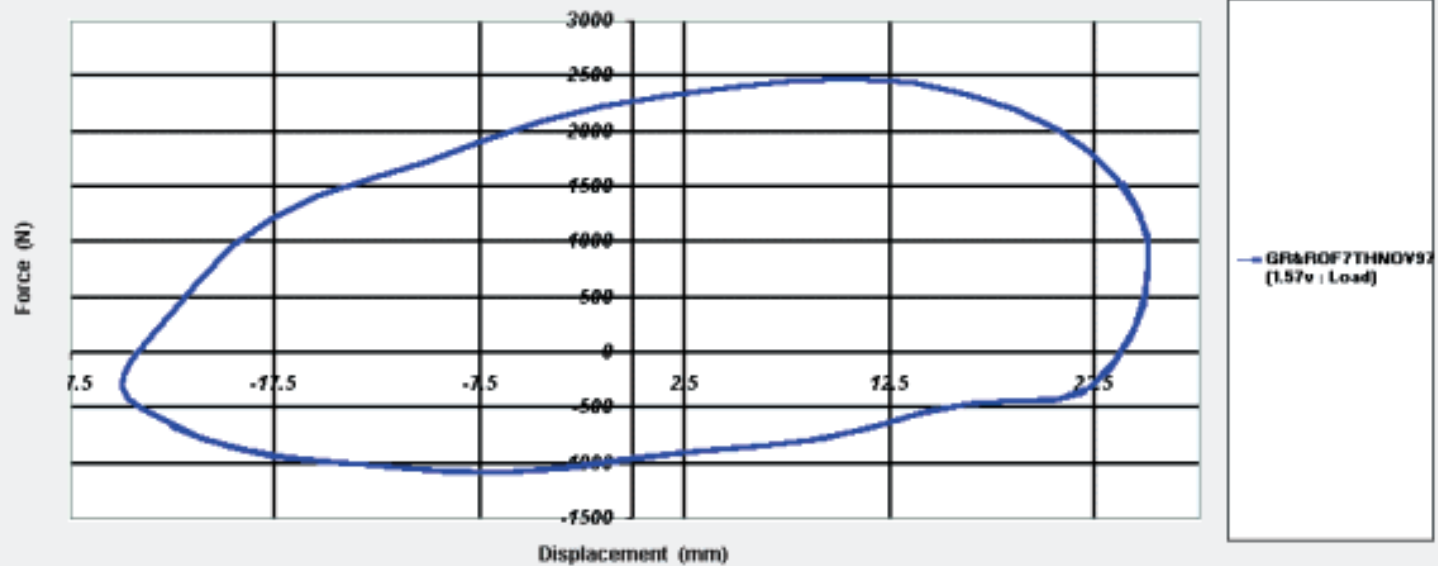
Test File:  
Gabriel

Operator Name: MILIND GAIKWAD  
GABRIEL SNOX NO: 10

Test Date: 11/7/97 9:40 AM

Report Date 4/29/98 2:22 PM

Part:  
GR&R TEST ON 6 SNOXS



# Peak Force vs Peak Velocity

Peak Force vs Peak Velocity Plot

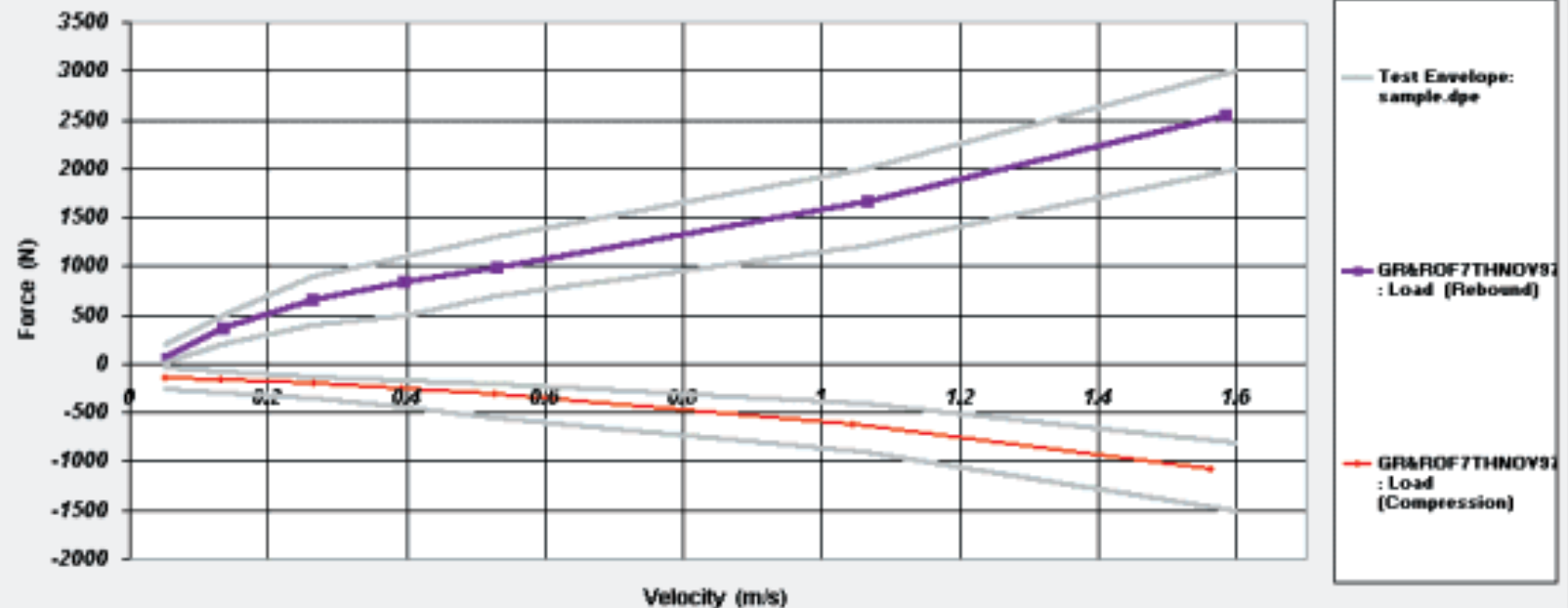
Test File:  
Gabriel

Operator Name: MILIND GAIKVAO  
GABRIEL SHOX NO: 2

Test Date: 10/7/97 9:23 AM

Report Date: 4/29/98 2:23 PM

Part:  
GR&R TEST ON 6 SHOXS





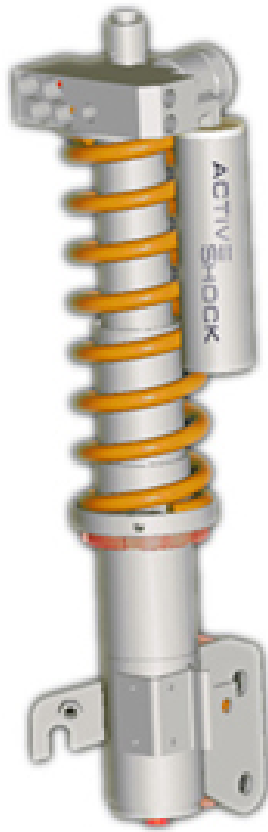
## Koni 2822 Mk2 4 Way adjustable

High speed bump  
High speed rebound

Low speed bump  
Low speed rebound

# Damper – end stops/bump stops



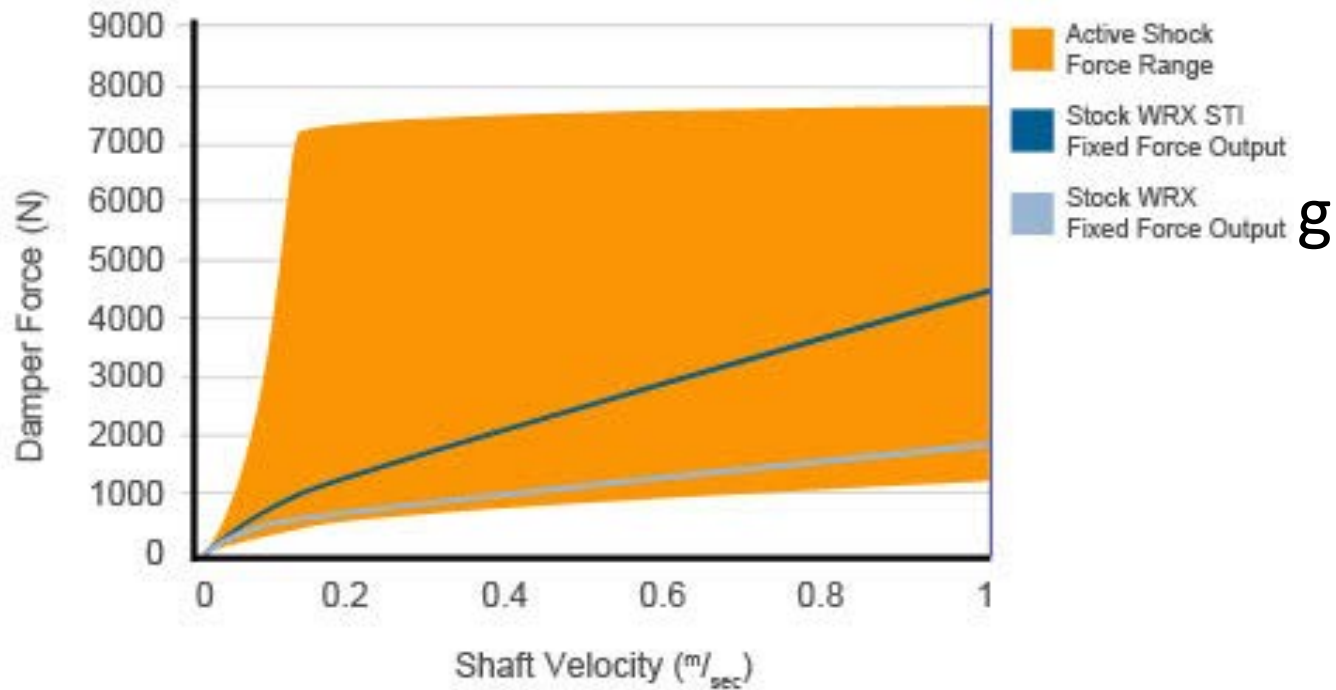


Active Damping

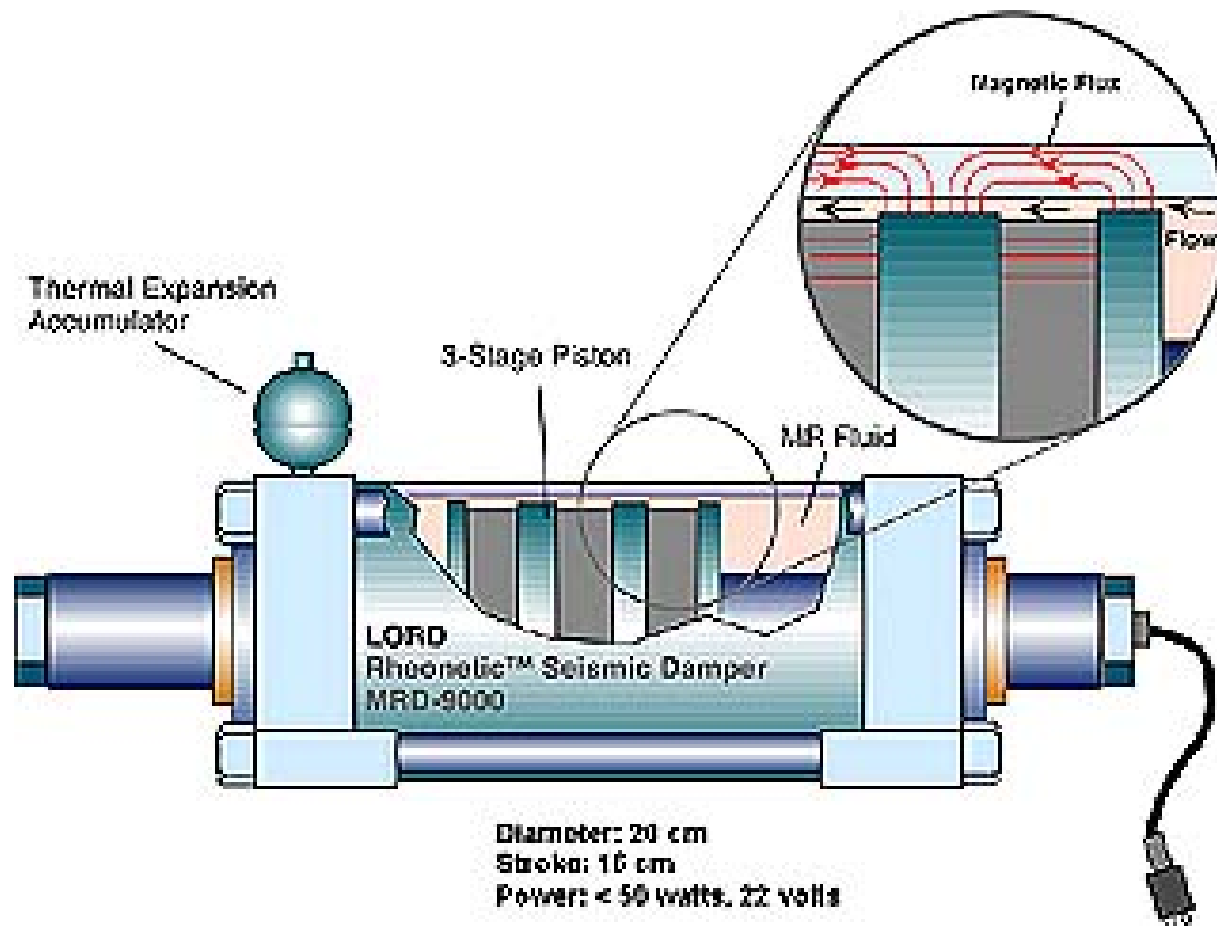
# Active Damping

The damping is controlled with a patented electronically controlled hydraulic valve that changes the damping orifice size in real time. A typical Active Shock damper can provide between 1/2 to 10 times the damping of a standard shock with a full scale step response time of approximately 5 msec. This means that in a typical landing from a jump that lasts 150 msec, the damper valve will be moved to the optimal setting very quickly and will be controlling the vehicle throughout the event. Typical handling maneuvers last 1-2 seconds. This means that the system will update the damping over 1000 times during a single handling event.

### Active Shock Dynamic Range



# Active Damping – Magnetic Rheological fluid





Active Damping  
Dephi -  
Magnaride