

# Mekanik Sistemlerin Bilgisayarla Kontrolü

Dönem Sonu Projesi

## Aktif Süspansiyonun Bilgisayarla Kontrolü

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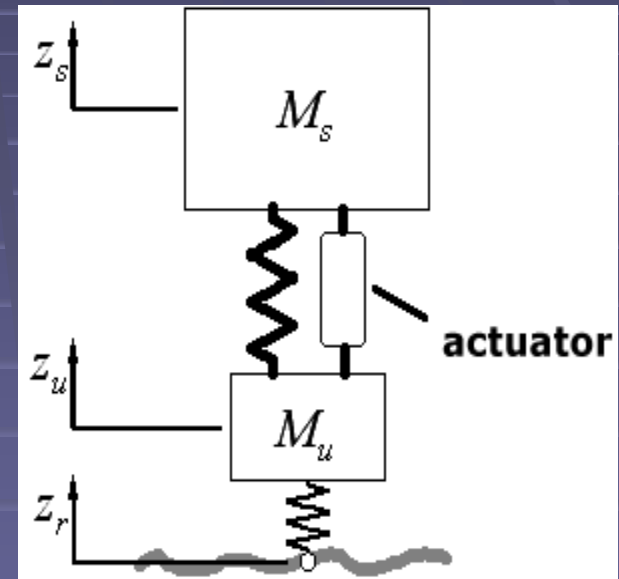
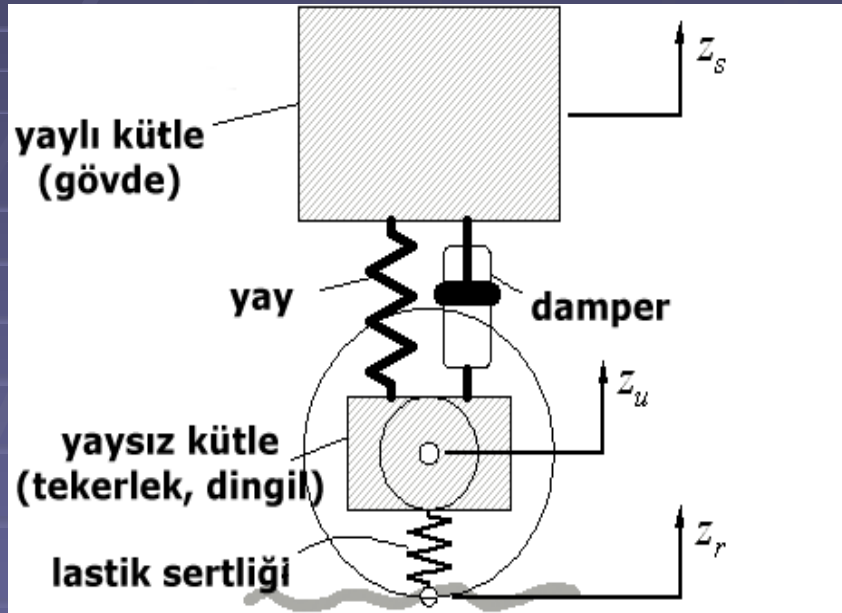
Alper TOZAN - 518041002

# Süspansiyondan Beklenen Özellikler

- Yoldan gelen düzensizlikler ile viraj dönmeleri esnasındaki, kalkış ile duruşlardaki ataletlerden kaynaklanan düzensizliklere karşı gövdeyi korumalıdır.
- Tekerleğin aşırı düşey hareketi lastiğin yola iyi yapışmasını engelleyecek buda yol tutuş özelliğinin kötü olmasına yol açacaktır.
- İyi bir yol tutuş karakterinin sağlanması için, uygun lastik ve yol temasının dört tekerdede sağlanması gerekir.

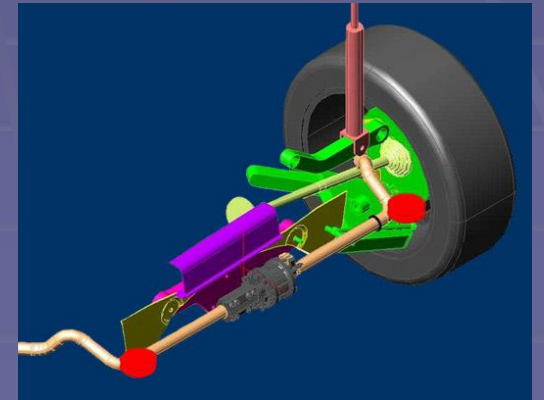
# Aktif Süspansiyon

Aktif süspansiyon sürüş konforu ve yol tutuş arasında uzlaşma sağlar.

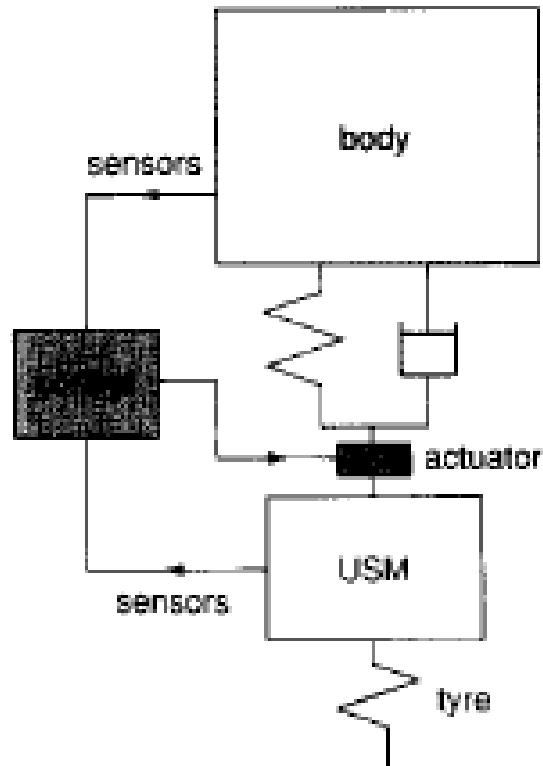


# Aktif Süspansiyonlar

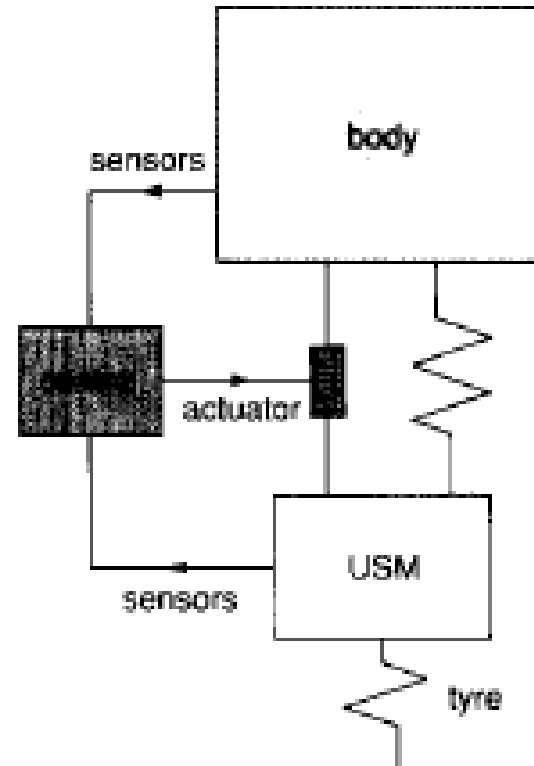
- Adaptif süspansiyonlar: Taşıtın çalışma şartlarındaki değişimlere yavaş cevap verirler. Bunlar yük dengeleme ve açık çevrim kontrollü değişken özelliğe sahip yay ve sönüm elemanları içerirler.
- Yarı-aktif süspansiyonlar: Taşıtın hareketlerinin ölçümüyle gerçekleştirilen kapalı çevrim ile kontrol edilirler ve sadece enerji sönümleyebilirler.
- Düşük bant genişlikli veya yumuşak aktif süspansiyonlar: Aktif eleman yay ve sönüm elemanlarına seri bağlıdır.
- Yüksek bant genişlikli veya sert aktif süspansiyonlar: Aktif eleman yay elemanı ile paralel bağlıdır veya yay elemanın yerine konur.



# Aktif Süspansiyonlar

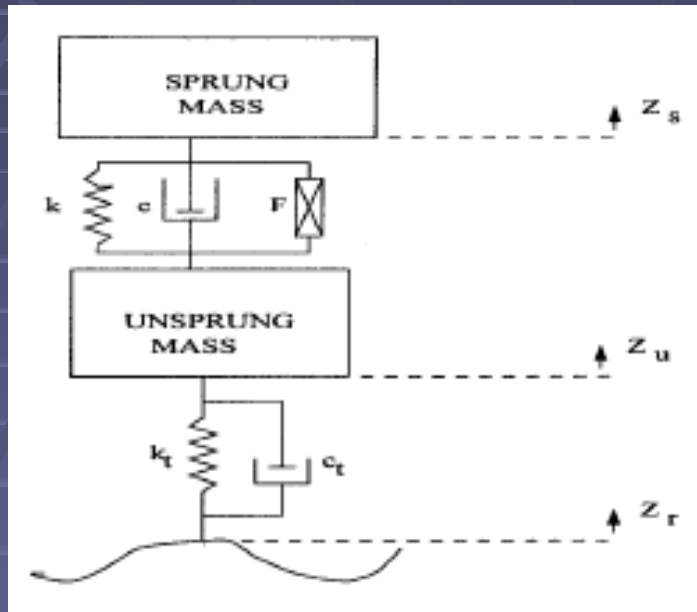


a

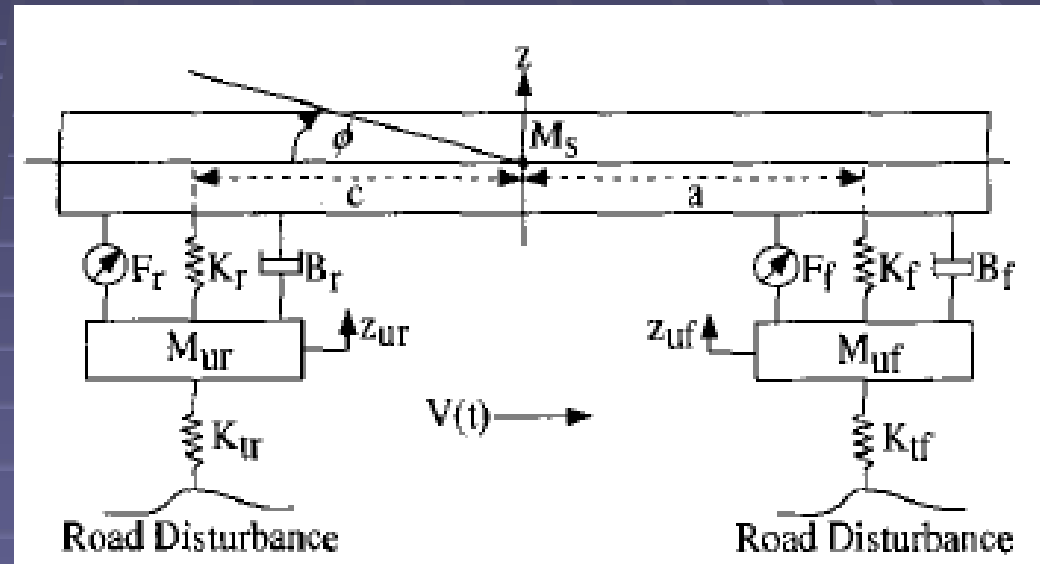


b

# Taşıt Modelleri

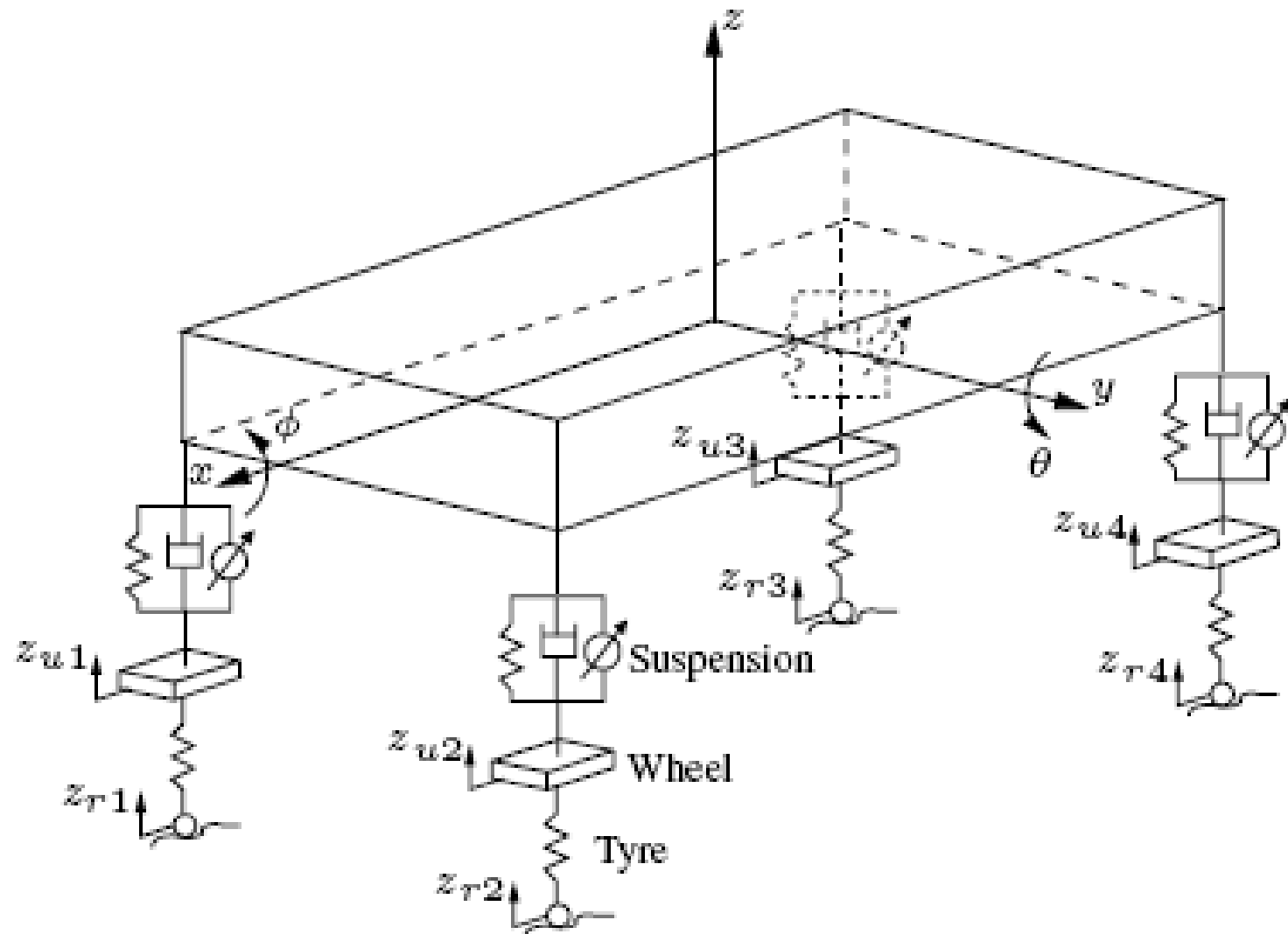


Çeyrek Taşıt Modeli



Yarım Taşıt Modeli

# Tüm Taşıt Modeli



# Tüm Taşıt Dinamik Modeli

Taşıt gövdesinin hareketleri

$$m_s \ddot{z} = -\sum_{i=1}^4 (k_{si} z + c_{si} \dot{z}) + \left( \sum_{i=1}^2 l_f k_{si} - \sum_{i=3}^4 l_r k_{si} \right) \theta + \left( \sum_{i=1}^2 l_f c_{si} - \sum_{i=3}^4 l_r c_{si} \right) \dot{\theta} + \sum_{i=1}^4 (k_{si} z_{ui} + c_{si} \dot{z}_{ui}) + \sum_{i=1}^4 F_i$$

$$I_y \ddot{\phi} = l_f \sum_{i=1}^2 k_{si} z - l_r \sum_{i=3}^4 k_{si} z + l_f \sum_{i=1}^2 c_{si} \dot{z} - l_r \sum_{i=3}^4 c_{si} \dot{z} - l_f^2 \sum_{i=1}^2 k_{si} \theta - l_r^2 \sum_{i=3}^4 k_{si} \theta - l_f^2 \sum_{i=1}^2 c_{si} \dot{\theta} - l_r^2 \sum_{i=3}^4 c_{si} \dot{\theta} - l_f \sum_{i=1}^2 (k_{si} z_{ui} + c_{si} \dot{z}_{ui} + F_i) + l_r \sum_{i=3}^4 (k_{si} z_{ui} + c_{si} \dot{z}_{ui} + F_i)$$

$$I_x \ddot{\phi} = -\omega^2 \sum_{i=1}^4 (k_{si} \phi + c_{si} \dot{\phi}) + \omega \sum_{i=1}^4 ((-1)^i (k_{si} z_{ui} + c_{si} \dot{z}_{ui} + F_i)) + M_r$$

# Tüm Taşıt Dinamik Modeli

Tekerleğin hareketleri

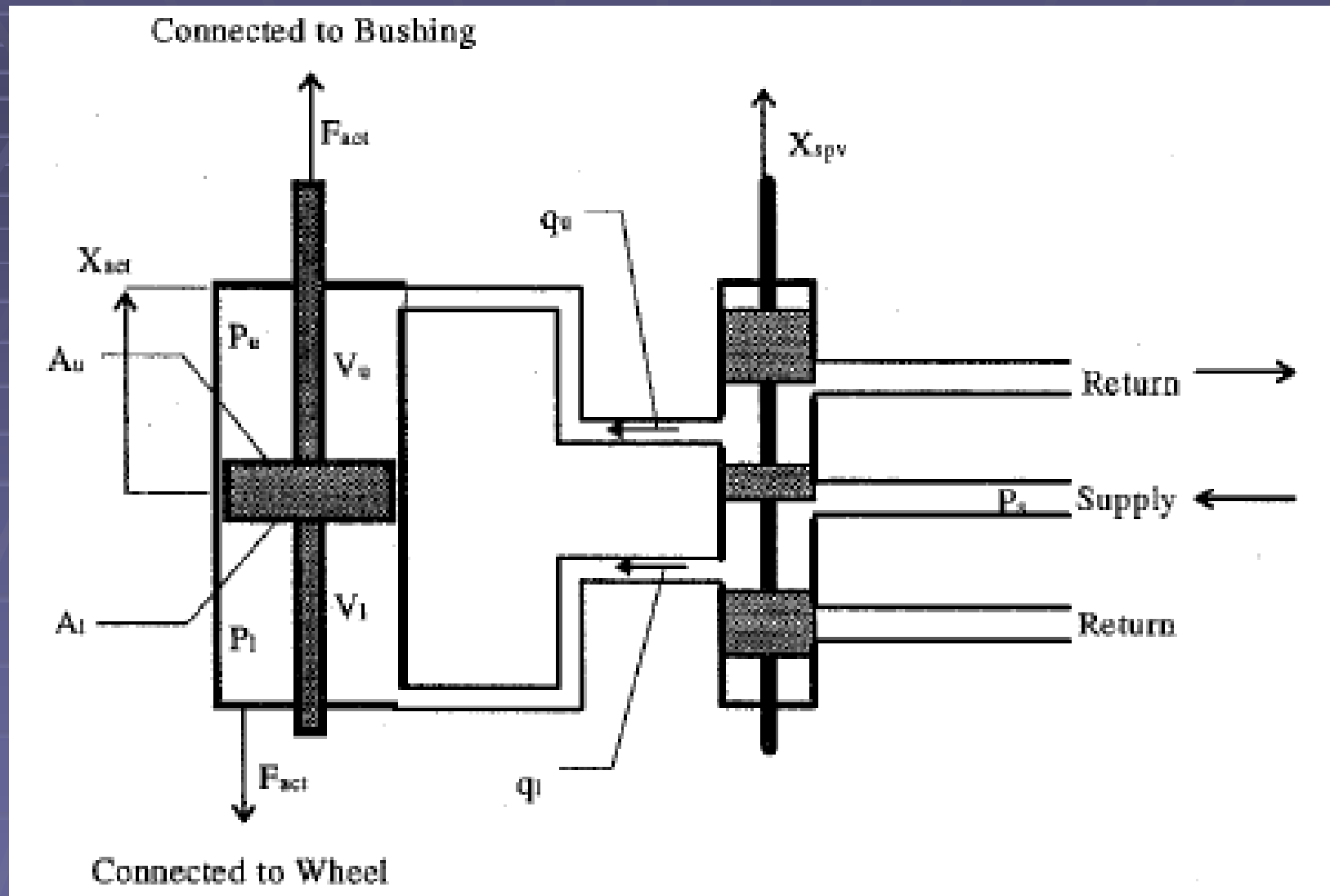
$$m_{u1} \ddot{z}_{u1} = k_{s1} z + c_{s1} \dot{z} - l_f k_{s1} \theta - l_f c_{s1} \dot{\theta} - \omega k_{s1} \phi - \omega c_{s1} \dot{\phi} - (k_{s1} + k_u) z_{u1} - c_{s1} \dot{z}_{u1} + k_u z_{r1} - F_1$$

$$m_{u2} \ddot{z}_{u2} = k_{s2} z + c_{s2} \dot{z} - l_f k_{s2} \theta - l_f c_{s2} \dot{\theta} + \omega k_{s2} \phi + \omega c_{s2} \dot{\phi} - (k_{s2} + k_u) z_{u2} - c_{s2} \dot{z}_{u2} + k_u z_{r2} - F_2$$

$$m_{u3} \ddot{z}_{u3} = k_{s3} z + c_{s3} \dot{z} + l_r k_{s3} \theta + l_r c_{s3} \dot{\theta} - \omega k_{s3} \phi - \omega c_{s3} \dot{\phi} - (k_{s3} + k_u) z_{u3} - c_{s3} \dot{z}_{u3} + k_u z_{r3} - F_3$$

$$m_{u4} \ddot{z}_{u4} = k_{s4} z + c_{s4} \dot{z} + l_r k_{s4} \theta + l_r c_{s4} \dot{\theta} + \omega k_{s4} \phi + \omega c_{s4} \dot{\phi} - (k_{s4} + k_u) z_{u4} - c_{s4} \dot{z}_{u4} + k_u z_{r4} - F_4$$

# Actuator Modeli



# Actuator Modeli

$$q_u = -k_q x_{spv} \sqrt{\Delta P_u} \quad q_l = k_q x_{spv} \sqrt{\Delta P_l}$$

$$\dot{P}_u = \frac{\beta}{V_u} (q_u - A_{act} x_{act} - c_{ip} (P_u - P_l) - c_{ep} P_u)$$

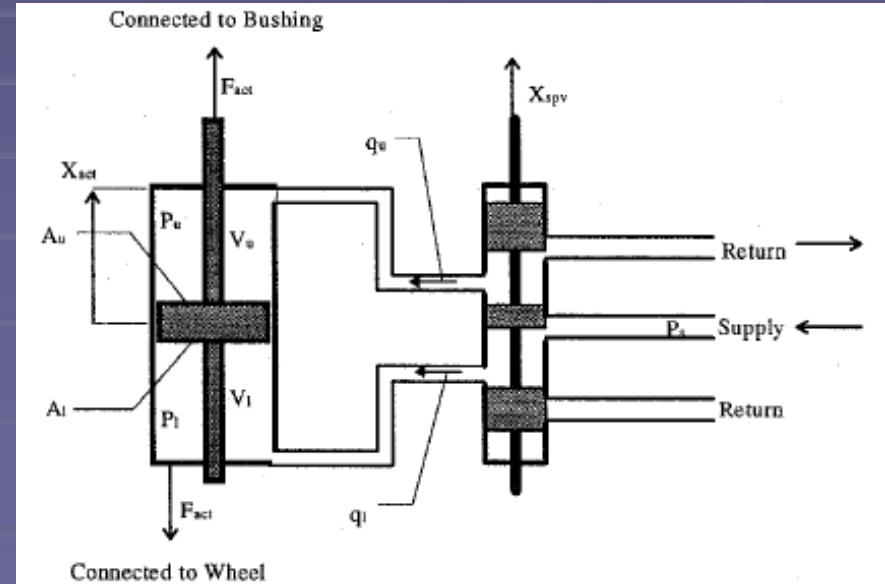
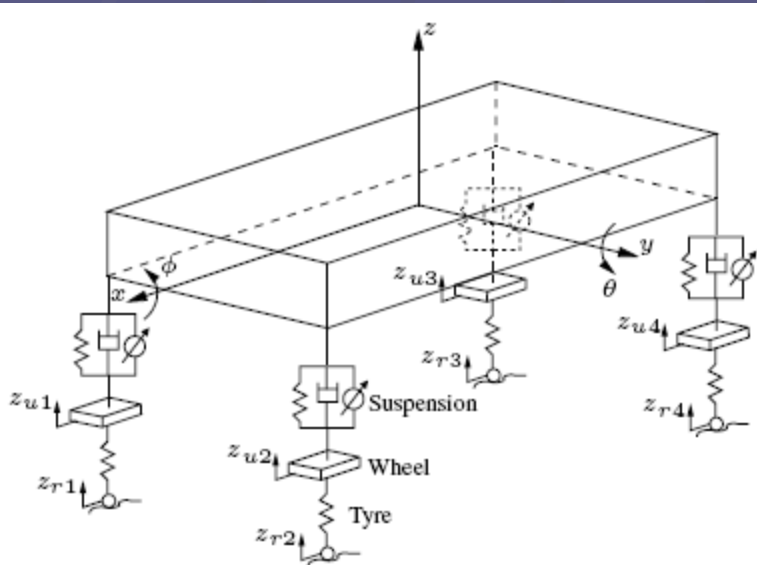
$$\dot{P}_l = \frac{\beta}{V_l} (q_l + A_{act} x_{act} - c_{ip} (P_l - P_u) - c_{ep} P_l)$$

Actuator kuvveti:

$$F_{act} = A P_L - F_f(x_{act}) \quad ; \quad P_L = P_l - P_u$$

# Sensörlerin Belirlenmesi

| Adet | Sensör         | Yeri                               | Ölçüm                                                                       |
|------|----------------|------------------------------------|-----------------------------------------------------------------------------|
| 4    | Load Cell      | Actuatorların üst montaj yerleri   | Actuator kuvveti ( $F_{act}$ )                                              |
| 4    | LVDT           | Yaylı kütle ile yaysız kütle arası | Kütleler arası yerdeğiştirme ( $z_s - z_u$ )                                |
| 4    | Accelerometer  | Her tekerlek göbeğinde             | Dinil düşey ivme ölçümü ( $\ddot{z}_u$ )                                    |
| 1    | Yaw-Pitch-Roll | Taşıtın ağırlık merkezi            | x ve y eksenini etrafında dönmeler (roll,pitch,yaw rate) ( $\theta, \phi$ ) |
| 1    | Accelerometer  | Taşıtın ağırlık merkezi            | z eksenindeki ivmelenmeler ( $\ddot{z}$ )                                   |
| 1    | Basınç Sensörü | Hidrolik actuatora girişte         | Besleme basıncının ölçümü ( $P_s$ )                                         |



# Sensörlerin Seçimi

Load Cell



Honeywell Model 43

Roll-Pitch-Yaw



Microstrain 3DM

LVDT



Applied Measurements Limited  
AML/E serisi

Accelerometer



mikroElektronika

$\pm 2g$  ME1-2 Modeli (Gövde)

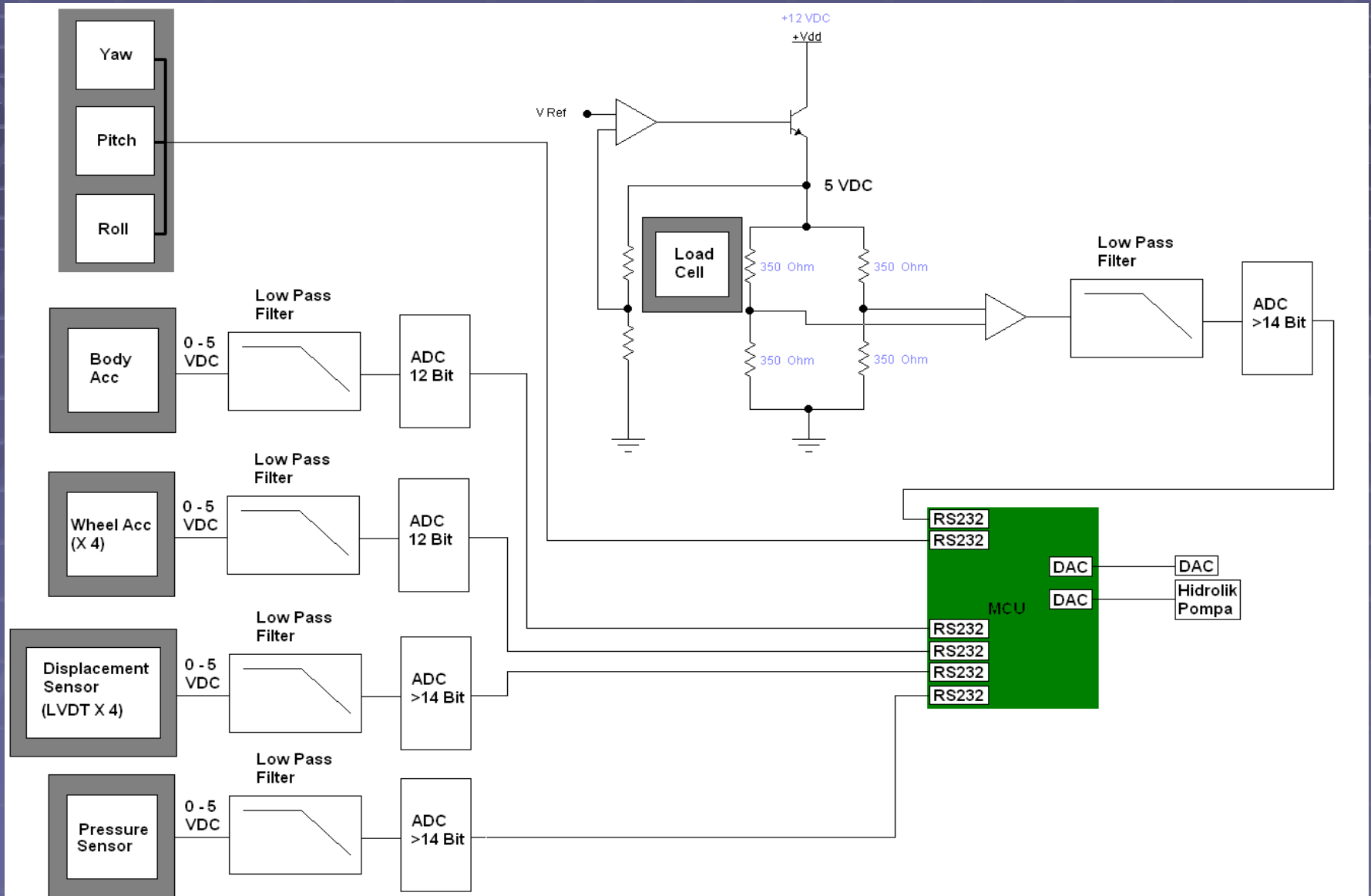
$\pm 10g$  ME1-10 Modeli (Tekerlek)

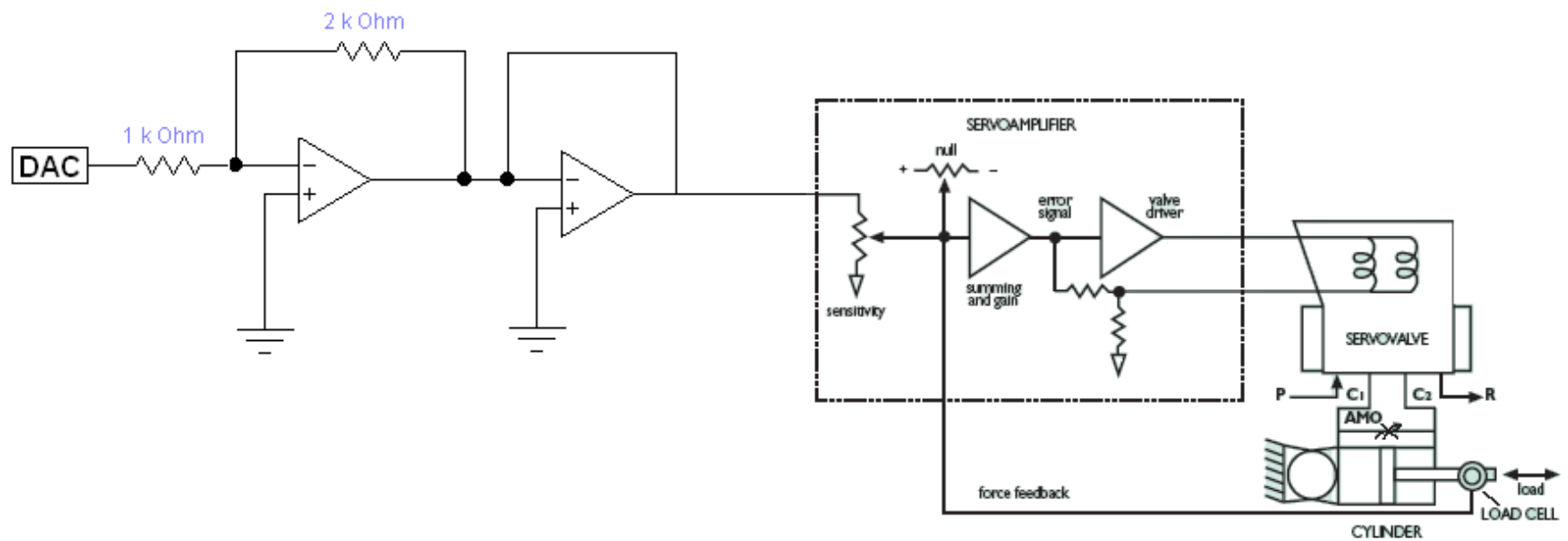
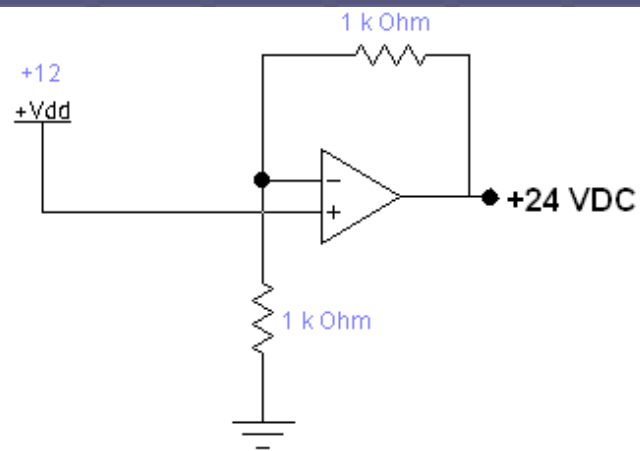
Basınç Sensörü

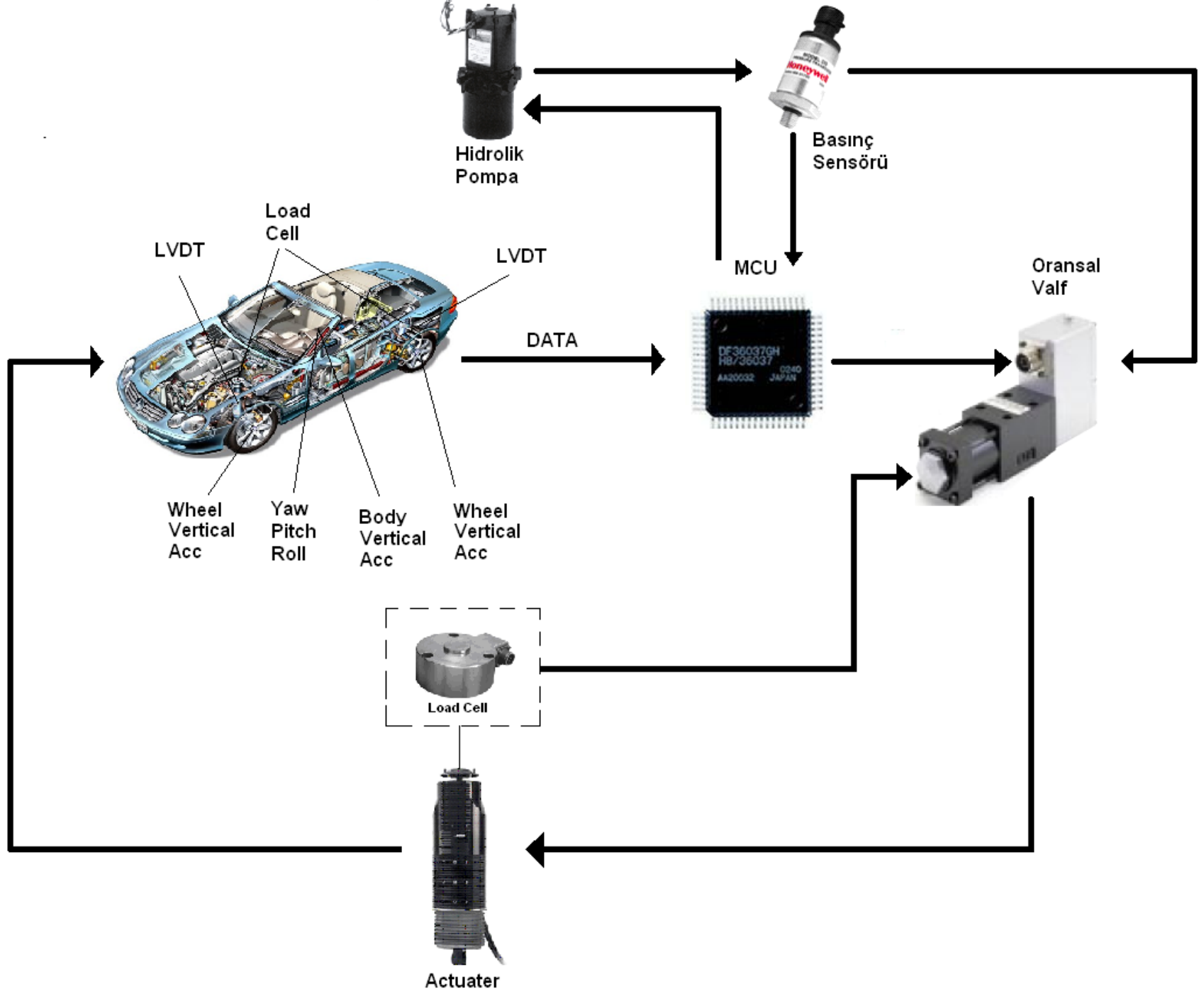


Honeywell DG serisi  
5000psi

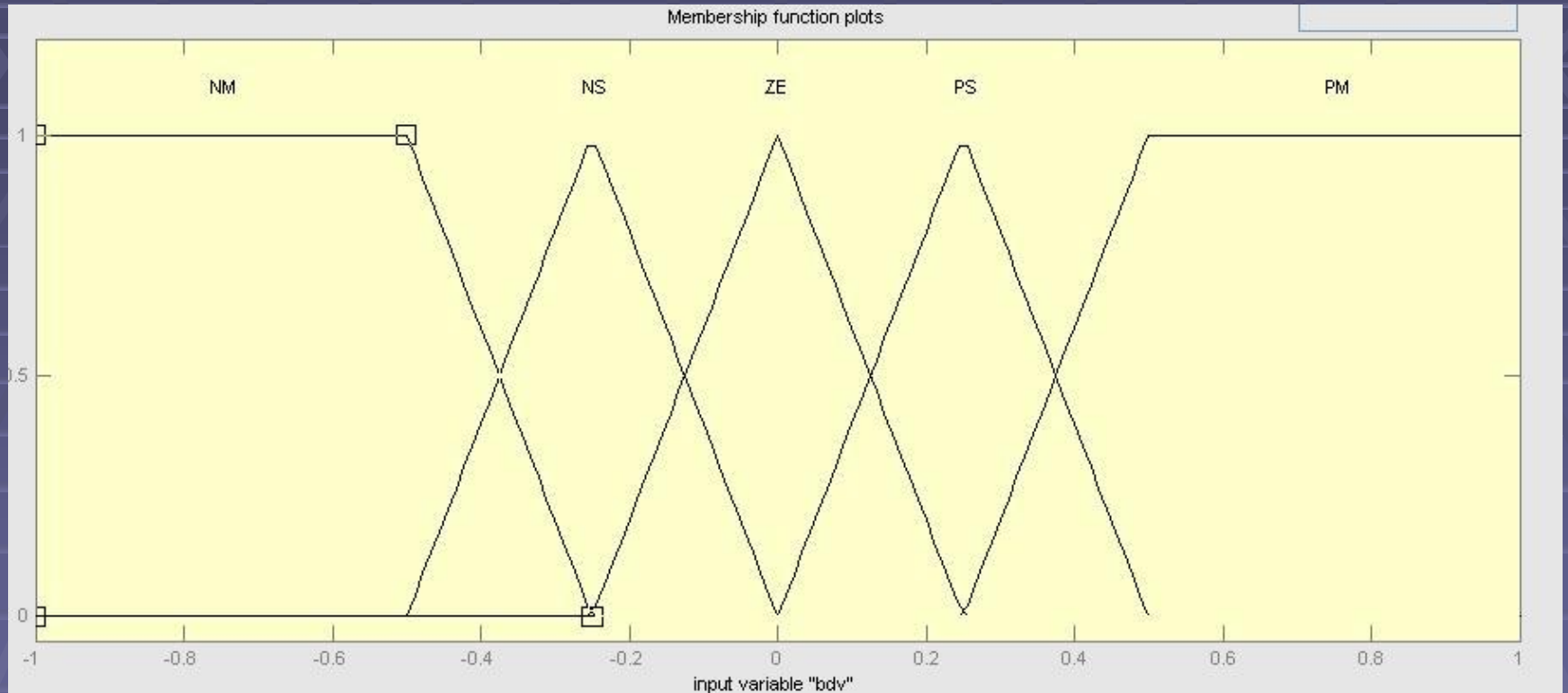
# Arabirim Devreleri





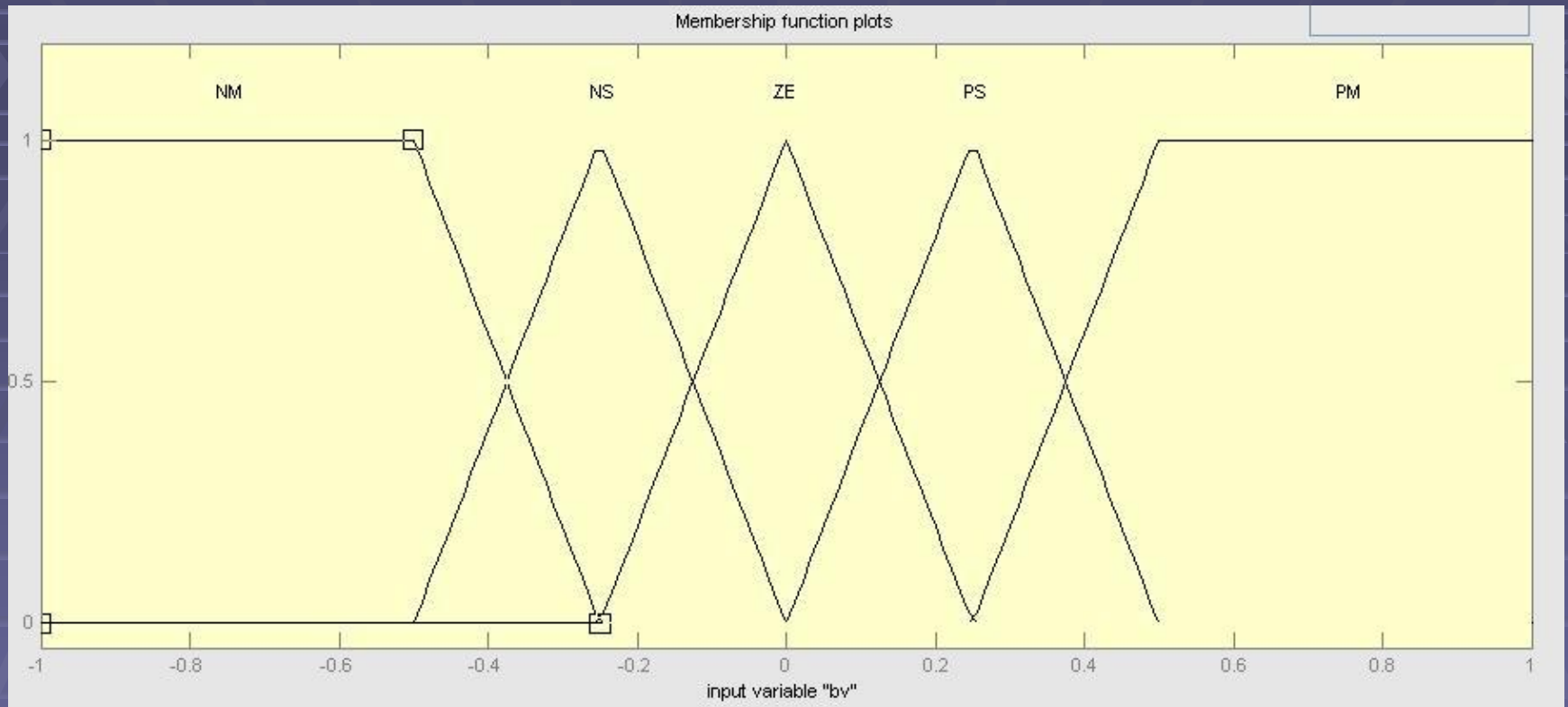


# Fuzzification (Girişler)



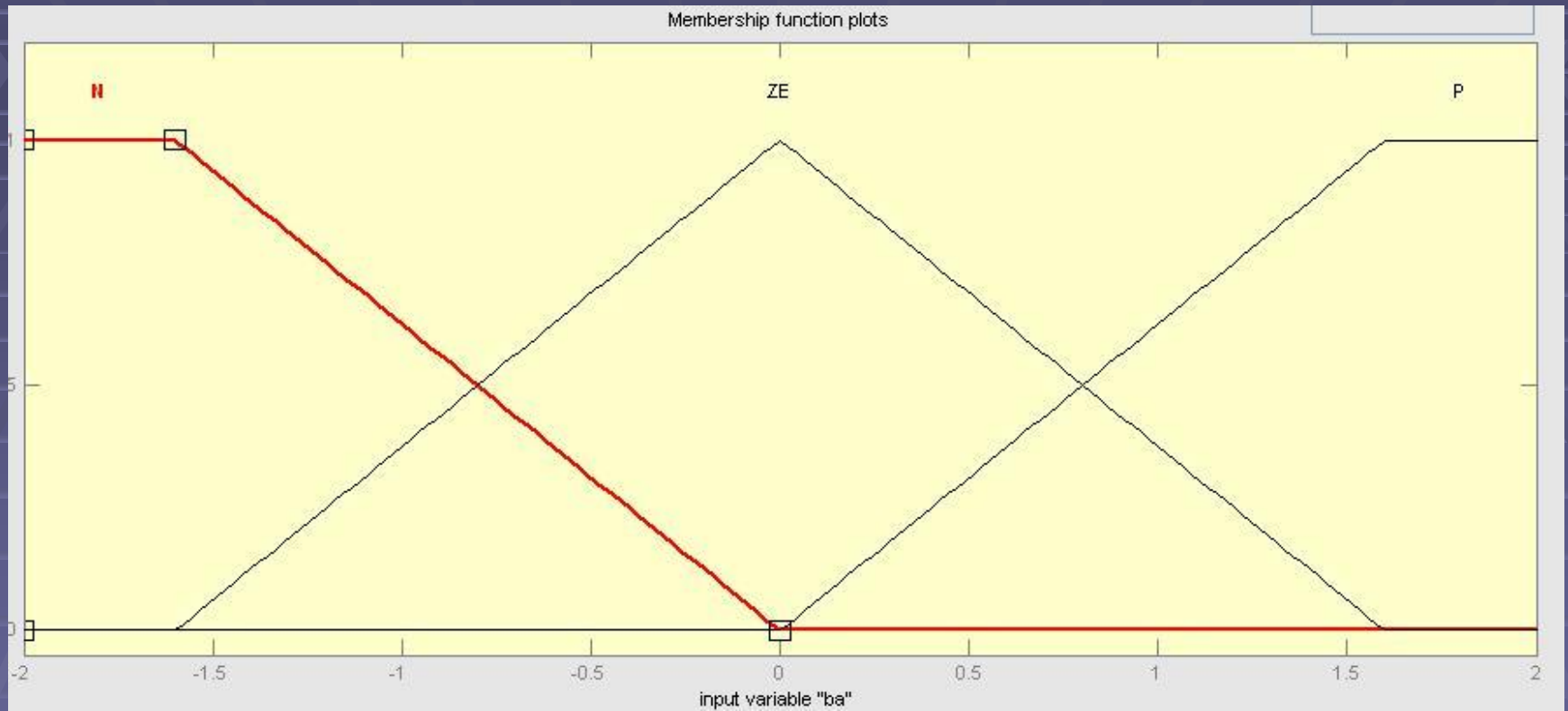
Body Displacement Velocity

# Fuzzification (Girişler)



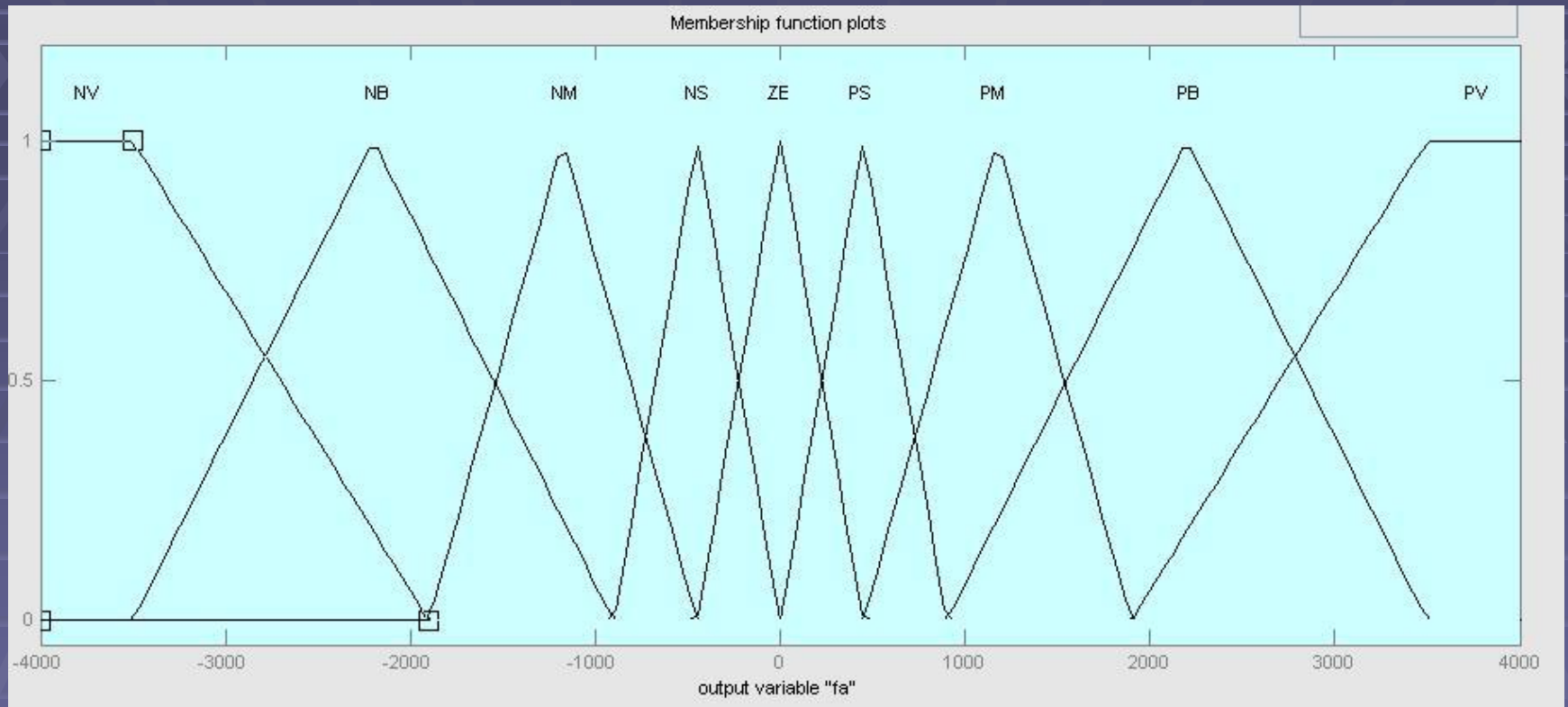
Body Velocity

# Fuzzification (Girişler)



Body Acceleration

# Fuzzification (Çıkış)



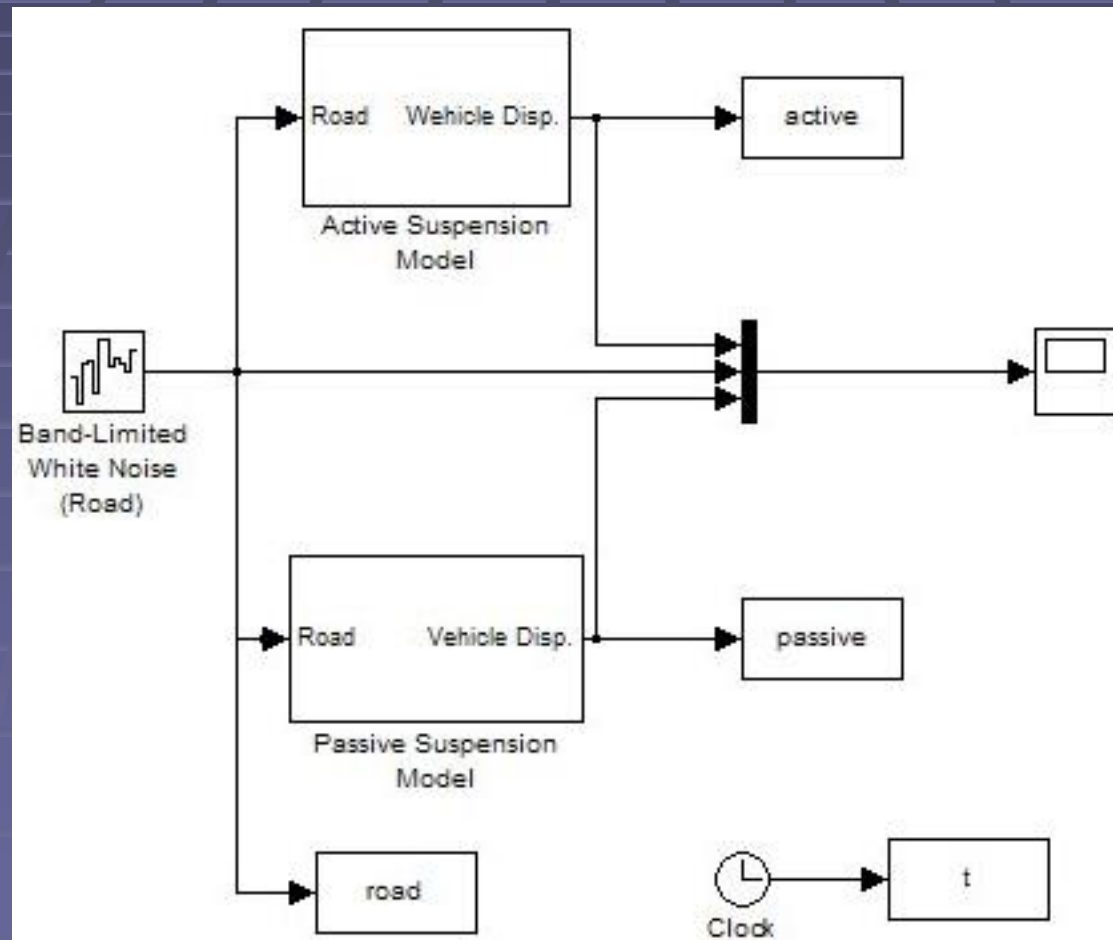
Actuator Force

# Fuzzification

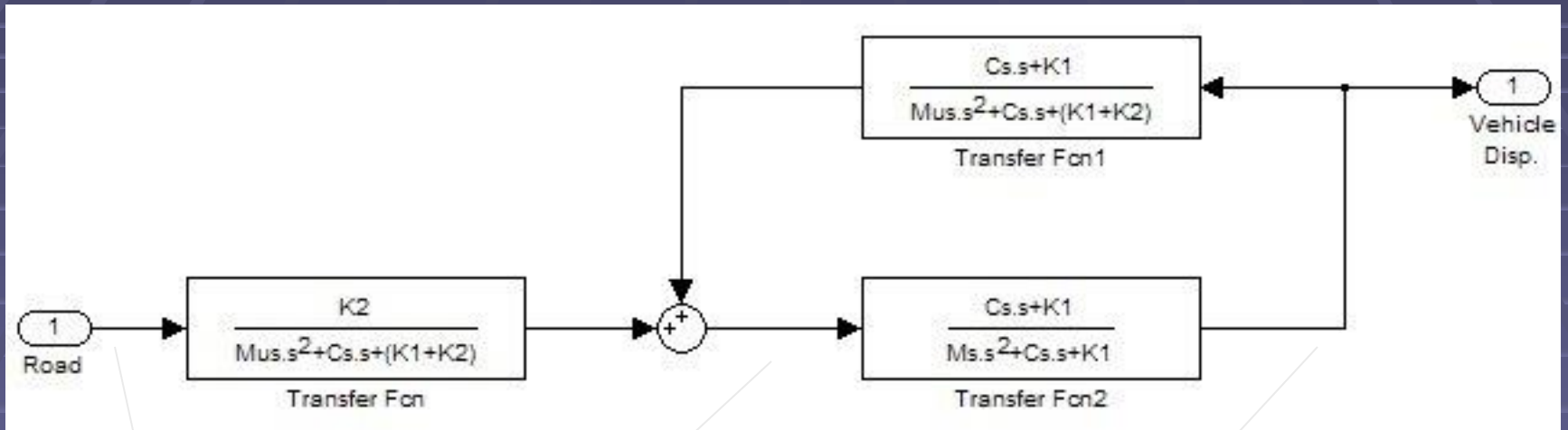
|    |     |                   |
|----|-----|-------------------|
| NV | ... | Negative Very Big |
| NB | ... | Negative Big      |
| NM | ... | Negative Medium   |
| NS | ... | Negative Small    |
| ZE | ... | Zero              |
| PS | ... | Positive Small    |
| PM | ... | Positive Medium   |
| PB | ... | Positive Big      |
| PV | ... | Positive Very Big |

| Body Disp. | Body Deflection V. | Body Acceleration | Actuator Force | Body Disp. | Body Deflection V. | Body Acceleration | Actuator Force |
|------------|--------------------|-------------------|----------------|------------|--------------------|-------------------|----------------|
| PM         | PM                 | ZE                | ZE             | PM         | PM                 | P or N            | NS             |
| PS         | PM                 | ZE                | NS             | PS         | PM                 | P or N            | NM             |
| ZE         | PM                 | ZE                | NM             | ZE         | PM                 | P or N            | NB             |
| NS         | PM                 | ZE                | NM             | NS         | PM                 | P or N            | NB             |
| NM         | PM                 | ZE                | NB             | NM         | PM                 | P or N            | NV             |
| PM         | PS                 | ZE                | ZE             | PM         | PS                 | P or N            | NS             |
| PS         | PS                 | ZE                | NS             | PS         | PS                 | P or N            | NM             |
| ZE         | PS                 | ZE                | NS             | ZE         | PS                 | P or N            | NM             |
| NS         | PS                 | ZE                | NM             | NS         | PS                 | P or N            | NB             |
| NM         | PS                 | ZE                | NM             | NM         | PS                 | P or N            | NB             |
| PM         | ZE                 | ZE                | PS             | PM         | ZE                 | P or N            | PM             |
| PS         | ZE                 | ZE                | ZE             | PS         | ZE                 | P or N            | PS             |
| ZE         | ZE                 | ZE                | ZE             | ZE         | ZE                 | P or A            | ZE             |
| NS         | ZE                 | ZE                | ZE             | NS         | ZE                 | P or N            | NS             |
| NM         | ZE                 | ZE                | NS             | NM         | ZE                 | P or N            | NM             |
| PM         | NS                 | ZE                | PM             | PM         | NS                 | P or N            | PB             |
| PS         | NS                 | ZE                | PM             | PS         | NS                 | P or N            | PB             |
| ZE         | NS                 | ZE                | PS             | ZE         | NS                 | P or N            | PM             |
| NS         | NS                 | ZE                | PS             | NS         | NS                 | P or N            | PM             |
| NM         | NS                 | ZE                | ZE             | NM         | NS                 | P or N            | PS             |
| PM         | NM                 | ZE                | PB             | PM         | NM                 | P or N            | PV             |
| PS         | NM                 | ZE                | PM             | PS         | NM                 | P or N            | PB             |
| ZE         | NM                 | ZE                | PM             | ZE         | NM                 | P or N            | PB             |
| NS         | NM                 | ZE                | PS             | NS         | NM                 | P or N            | PM             |
| NM         | NM                 | ZE                | ZE             | NM         | NM                 | P or N            | PS             |

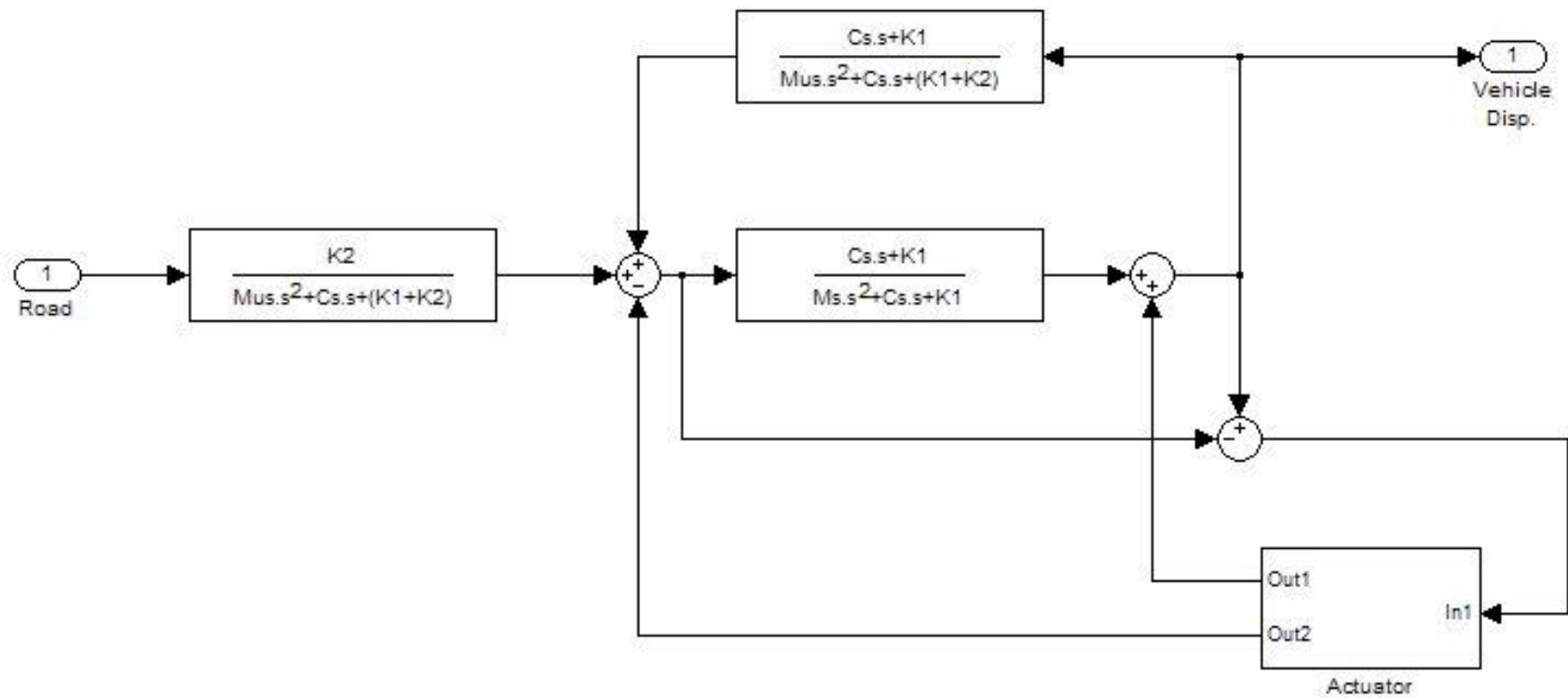
# Simulation of an Active Suspension System



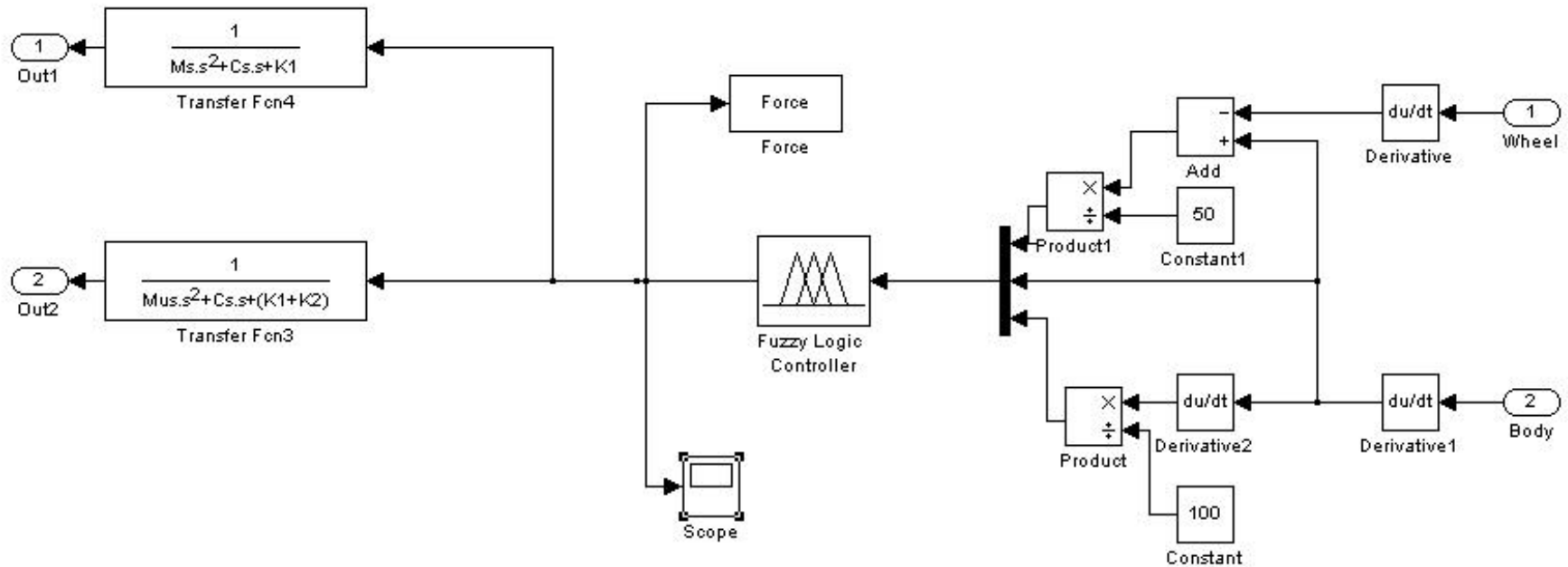
# Passive Suspension Block



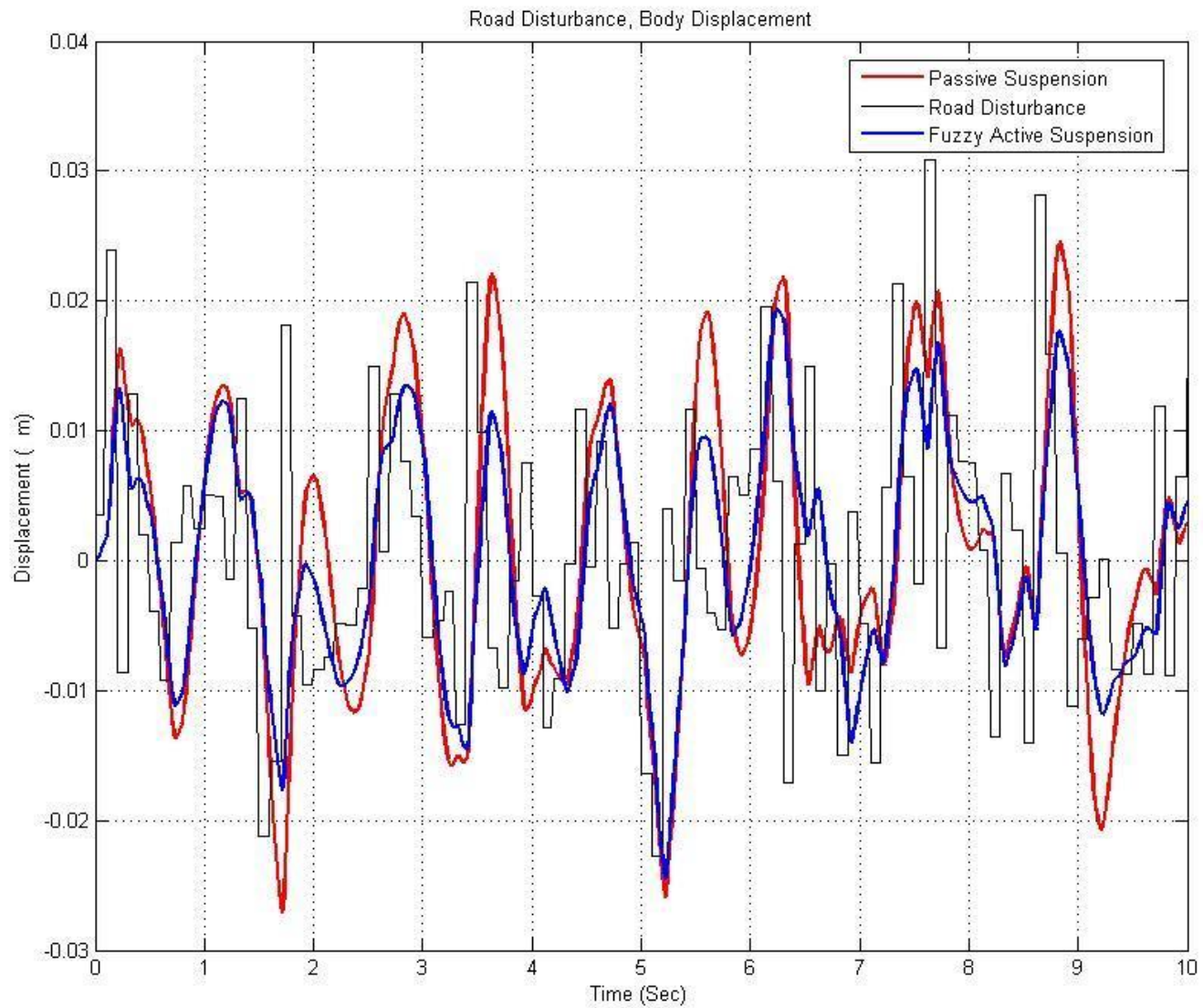
# Active Suspension Block



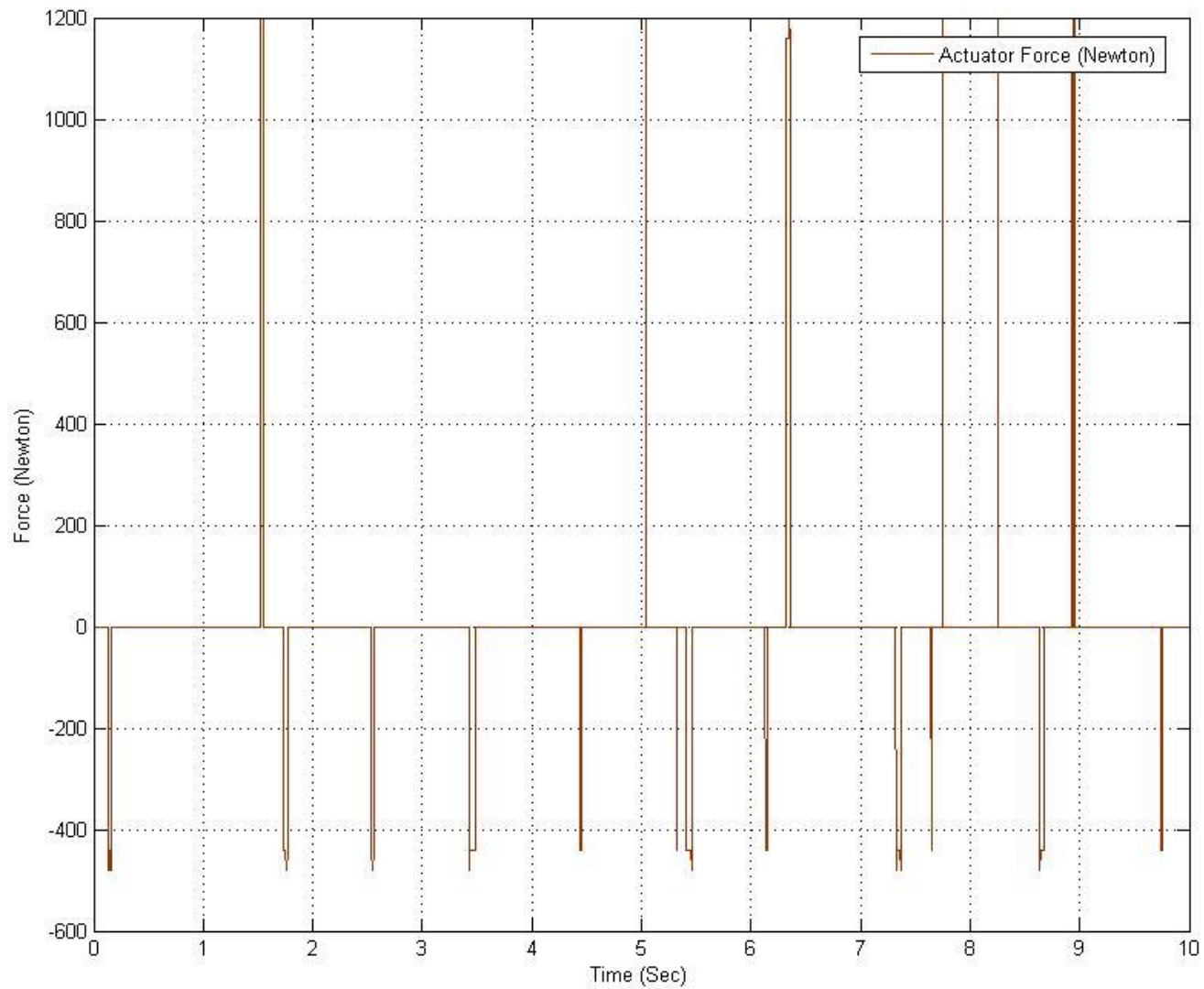
# Fuzzy Controller Block



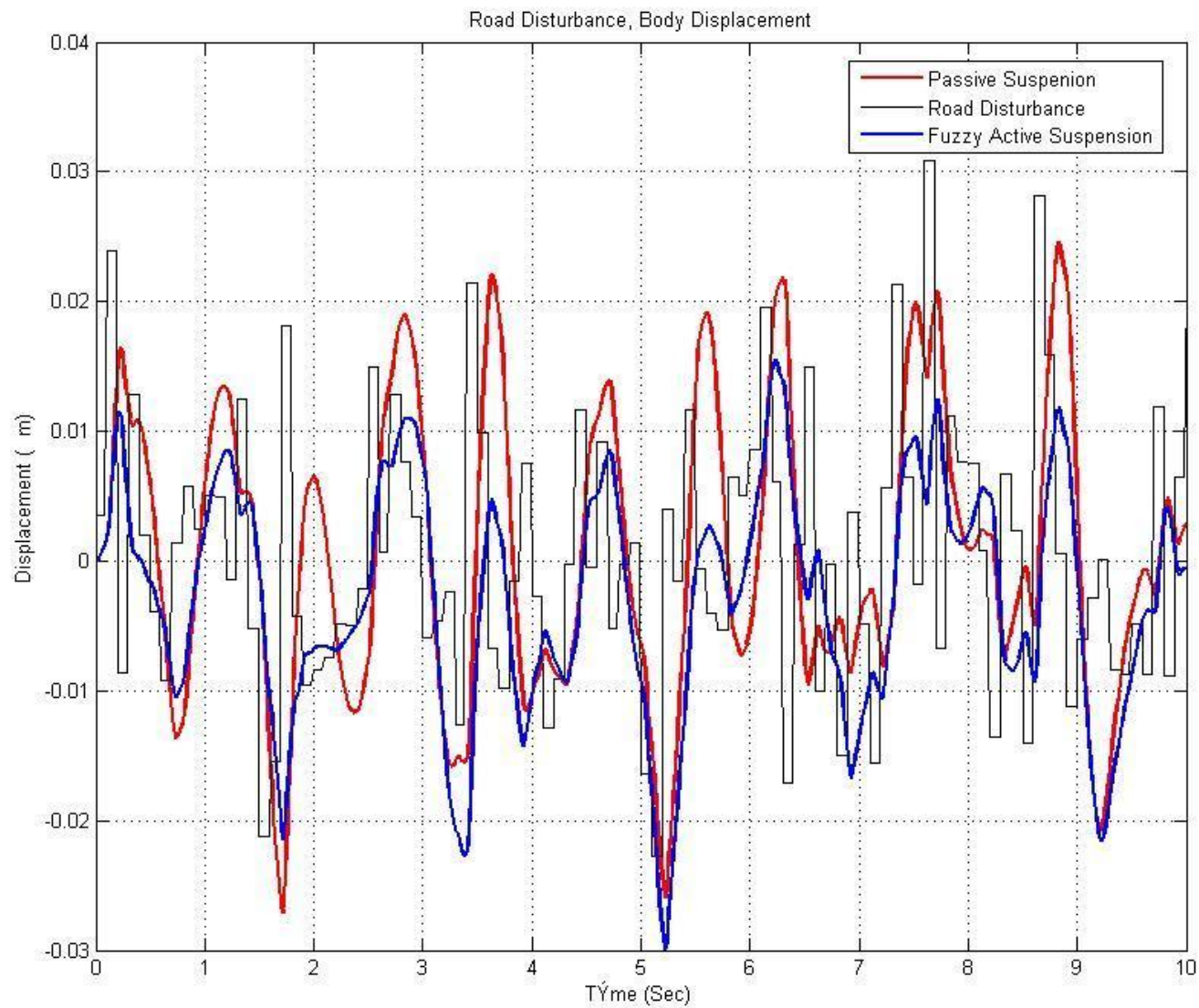
# Result with Mean Of Maximum



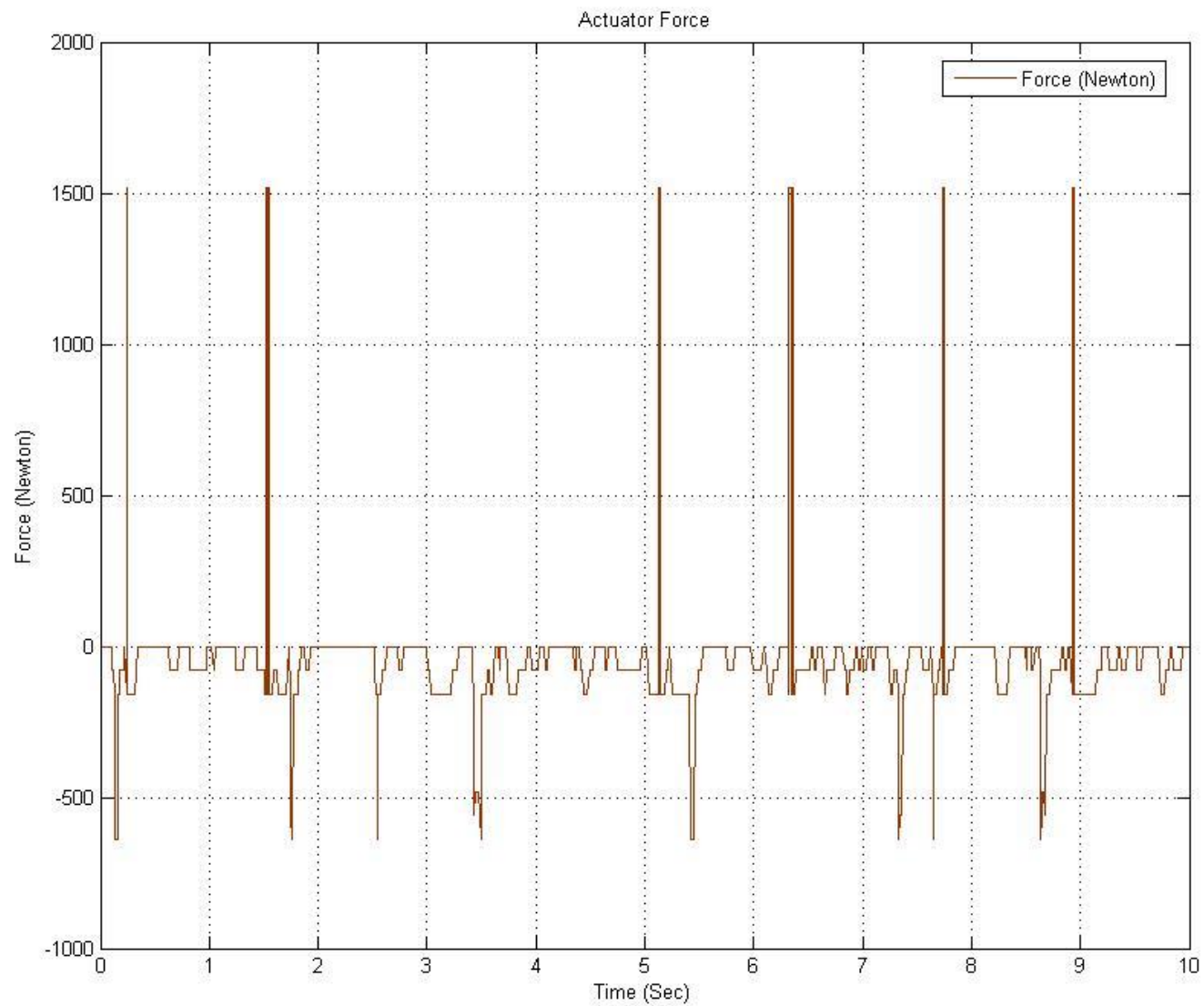
## Result with Mean Of Maximum



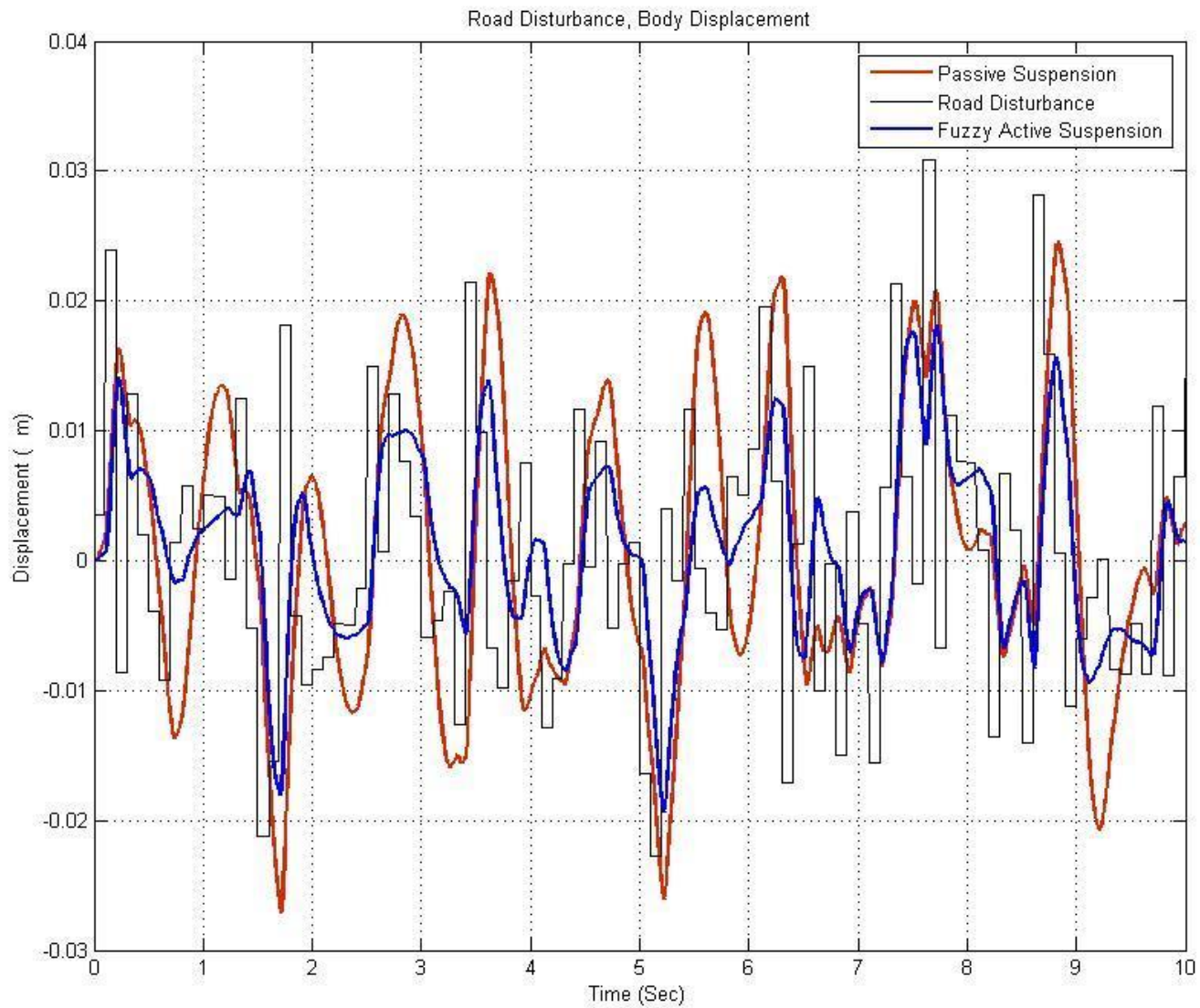
# Result with Smallest Of Maximum



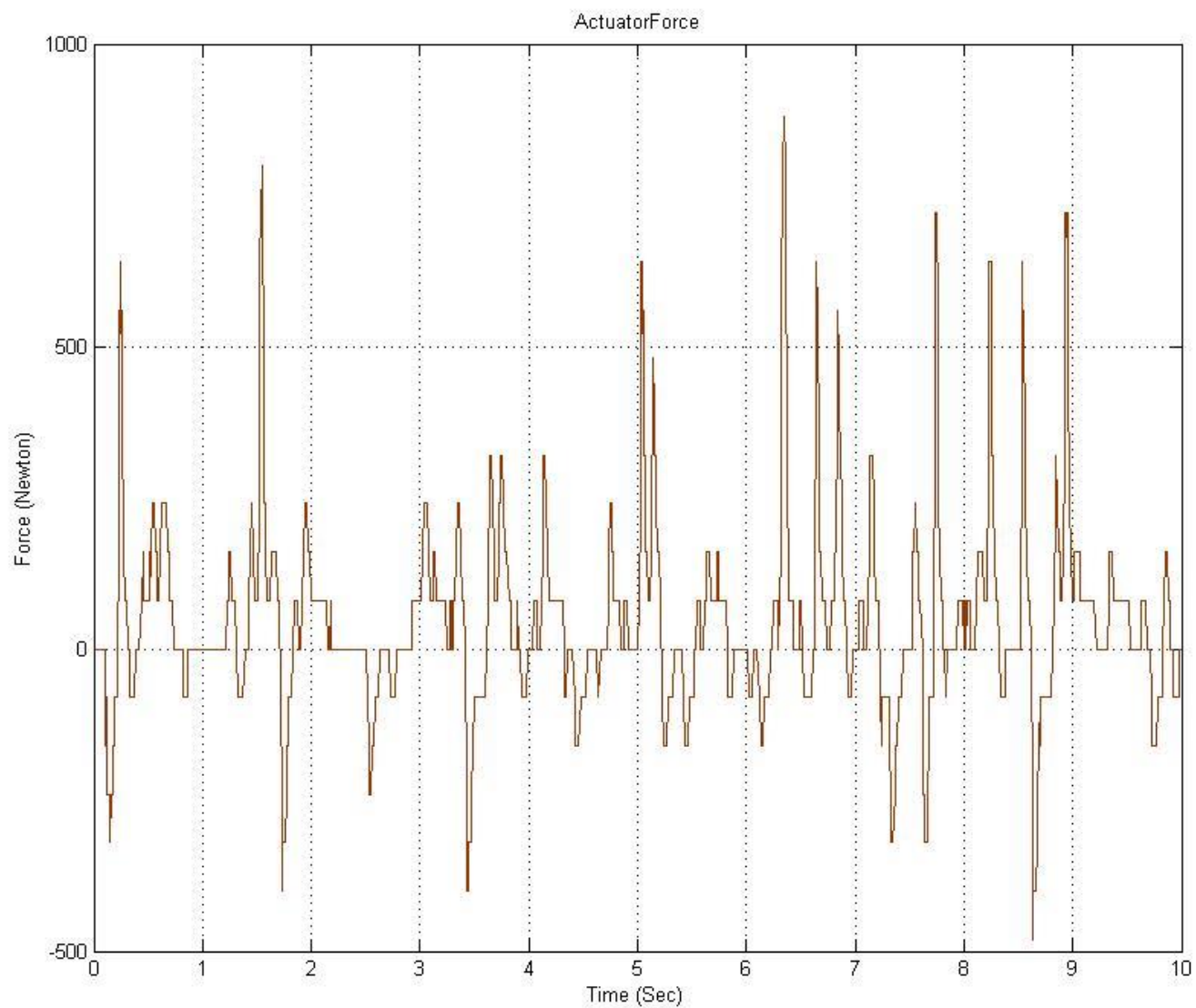
# Result with Smallest Of Maximum



# Result with Bipolar



# Result with Bipolar



# Difference Between Active & Passive Suspension



# Difference Between Active & Passive Suspension

