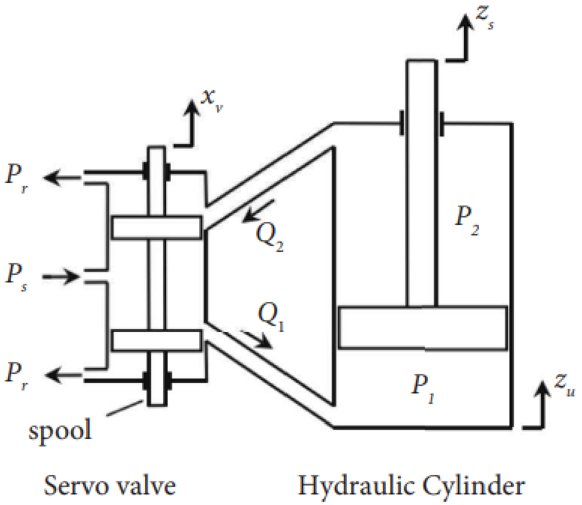
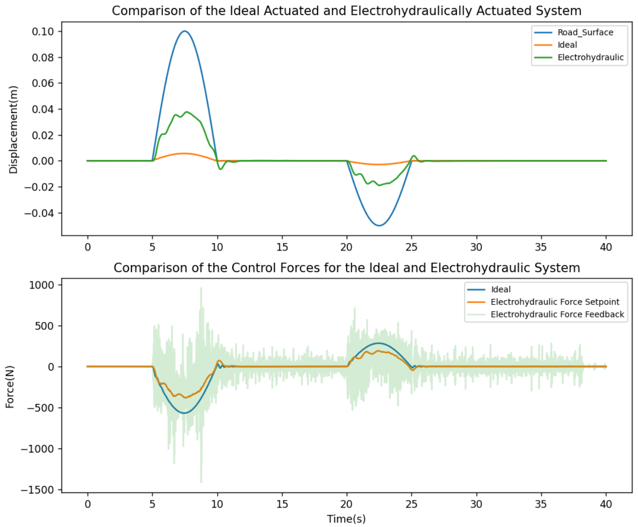




Active Suspension System with a Cascaded controlled Actuator

Boboye Oladosu Okeya (BOO)

This is a continuation of my former post(here) where I modelled an active suspension system with an ideal actuator

A brief operational principle of the actuator is discussed in the next slide

The ElectroHydraulic Actuator

- The actuator's control unit receives the sensor signals.
- The signals are used to adjust the hydraulic pressure within the cylinder.
- The pressure is adjusted by changing the flow to and from the cylinder.
- The flow is adjusted by adjusting the servo valve's displacement
- The valve is displaced by electronically adjusting the spool's position

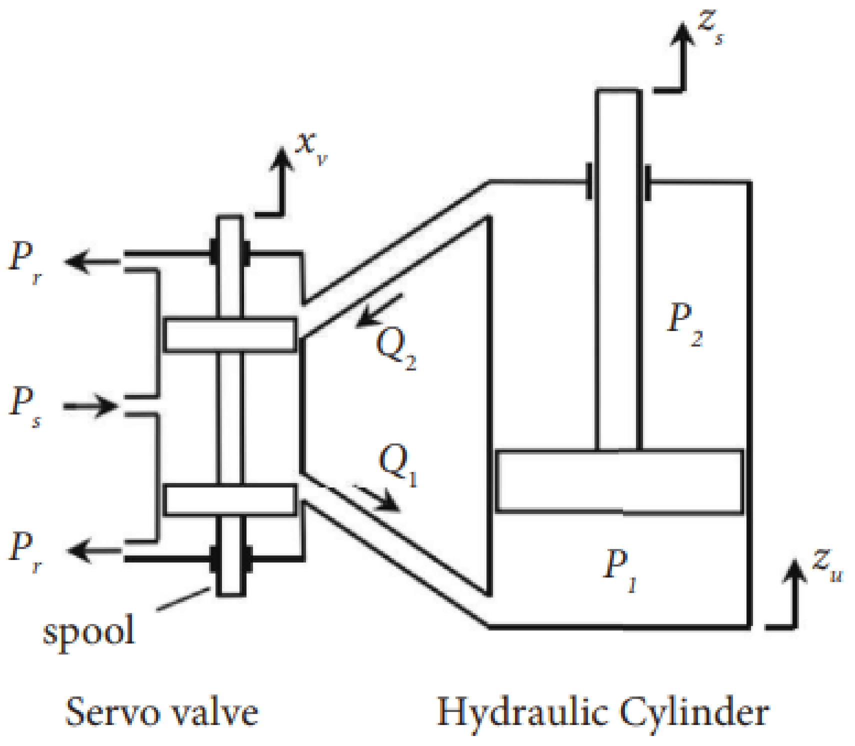


Illustration of the actuator[1]

So, this means that the actuator can regulate the sprung mass displacement as illustrated below

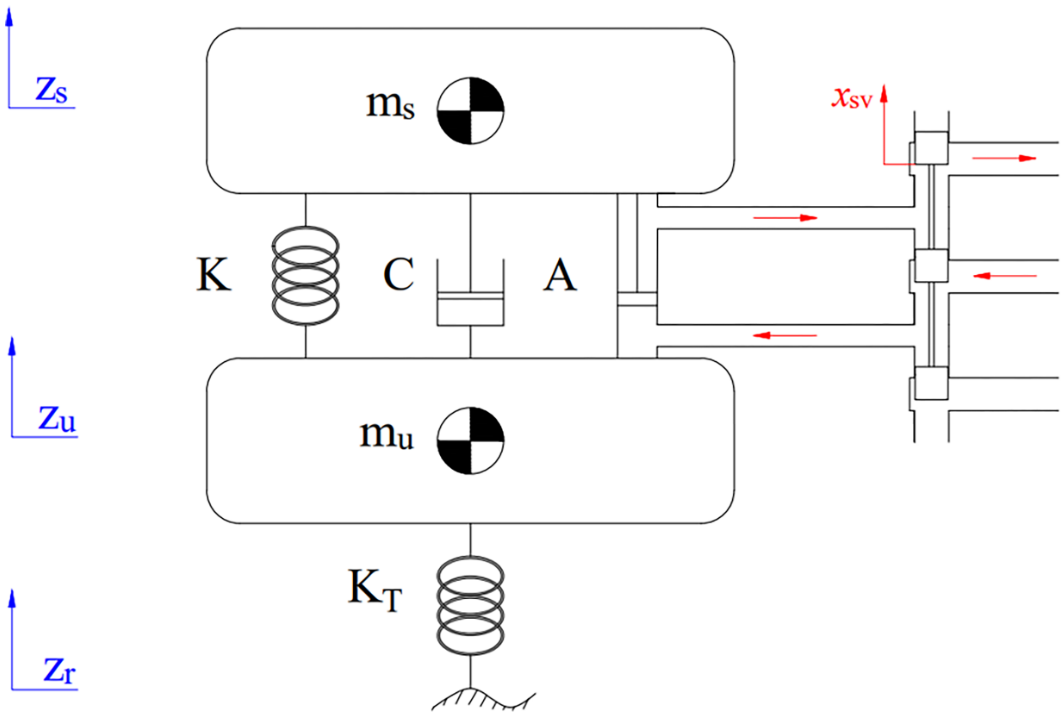


Illustration of actuated active Suspension System [2]

Next, let's write up the actuator's dynamic equation

Dynamic Model of the Electrohydraulic Actuator

Displacement of the servo valve under the influence of an input voltage

$$x_{sv} = \frac{1}{\tau} \int (k_{sv} u(t) - x_{sv})\, dt$$

Flow of hydraulic fluid through the valve

$$Q = \frac{\sigma_3}{\sigma_1} x_{sv} \sqrt{P_s - sgn(x_{sv}) \Delta P}$$

Change in pressure

$$\Delta P = \sigma_1 \int \left(Q - \frac{\sigma_2}{\sigma_1} \Delta P - S_p \dot{x}_s \right) dt$$

The output force generated from the actuator

$$F_A = S_p \Delta P$$

Where, x_{sv} is the servo displacement, τ is the time constant, k_{sv} is the servo valve gain, $u(t)$ is the input voltage, Q is the hydraulic fluid flow rate; $sigma_1$, $sigma_2$, $sigma_3$ are the actuator coefficients; P_s is the supply pressure, ΔP is the change in pressure, S_p is the piston's cross-sectional area.

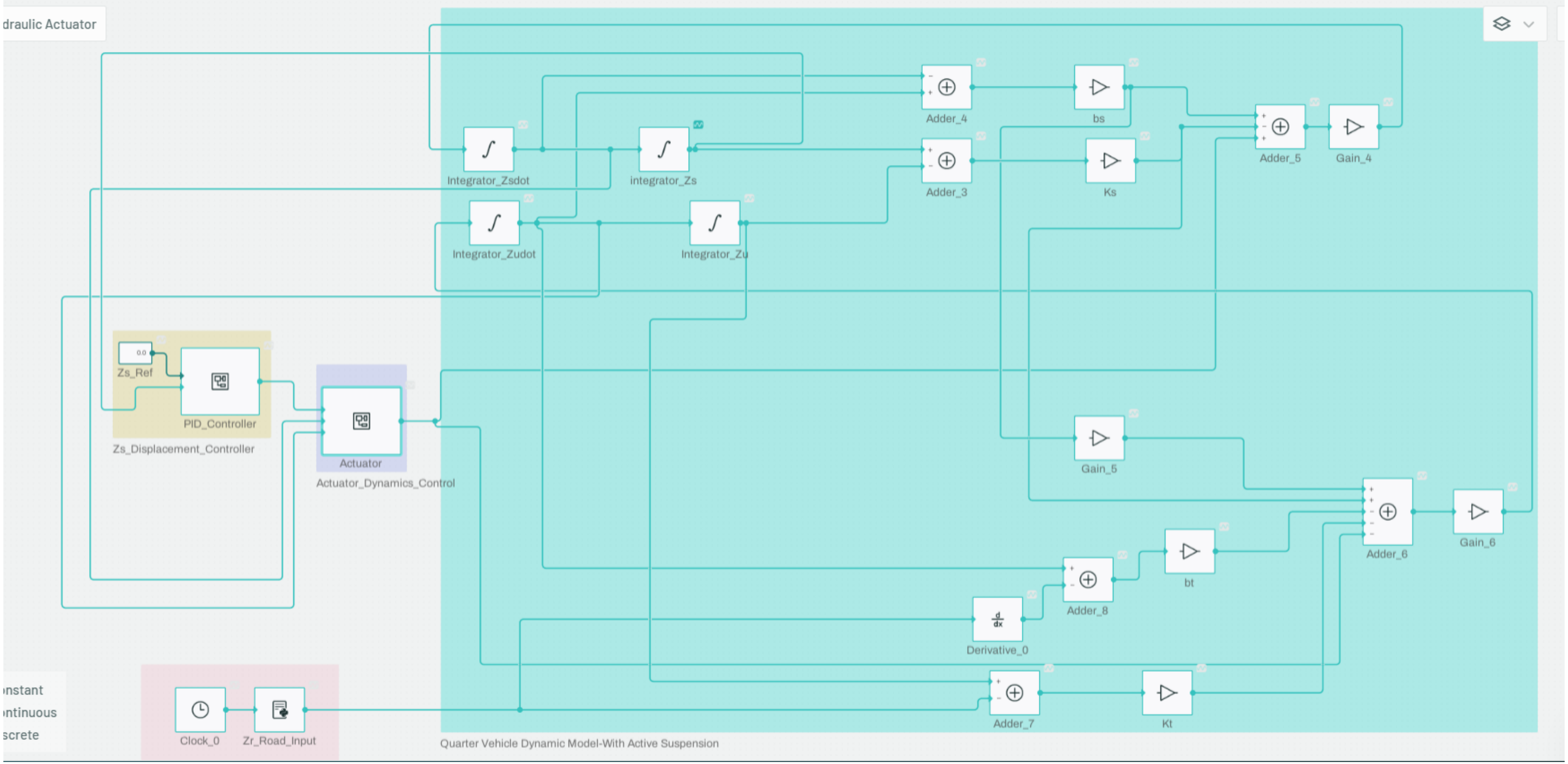
Next, let's incorporate the model into the overall quarter vehicle model using THE COLLIMATOR SIMULATOR!!!.

Simulation Parameters

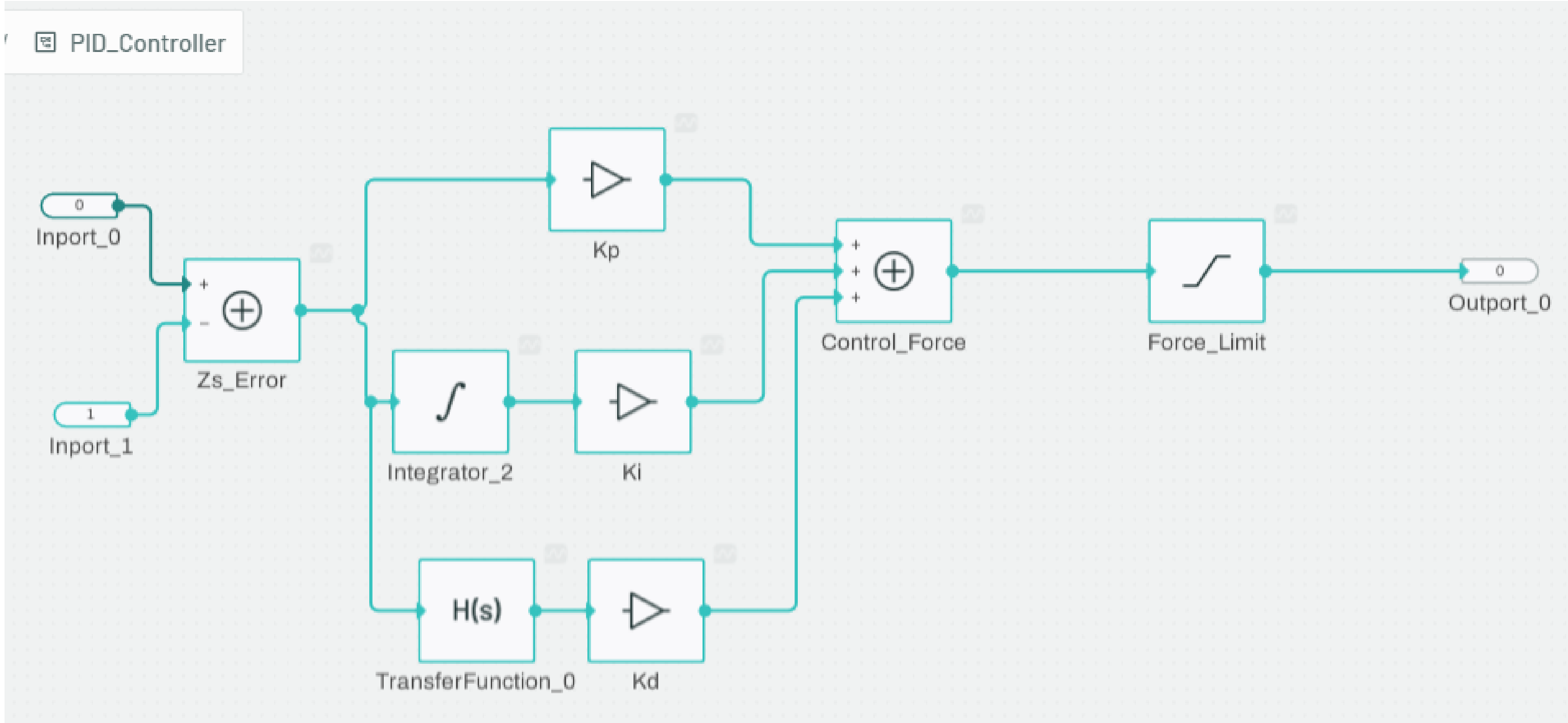
```
#Actuator Parameters
sigma1 = 4.5e13;#N/m^5 actuator coefficient
sigma2 = 1; #s^-1 actuator coefficient
sigma3 = 1.5e9;#N/kg^0.5m^2.5 actuator coefficient
tau = 2.5e-3;#s time constant
Sp = 3.5e-4;#m^2 Piston cross-sectional area
Ps = 1056240;#N/m^2 Supply Pressure
k_sv = 1e-3;#m/V Servo valve gain

#                  ---->Controller parameters for the actuated system<-----
#The PID controller parameters for the Zs Displacement
kp_zs = 1e4; ki_zs = 1e1; kd_zs = 1e3; tau_zs = 1e-3
#Control force saturation limit is between (-Ms*g) to (+Ms*g)

#The outer PID controller parameters for the force produced by the actuator
kp_f = 1e-4; ki_f = 5e-5; kd_f = 1e-5; tau_f = 1e5

#The inner PID controller parameters for the servo displacement of actuator
kp_x = 2e4; ki_x = 2e4; kd_x = 1e3; tau_x = 1e2
#Input voltage limit is -24V to +24V
```

Note: The Actuator parameters are gotten from [3]. The Vehicle Parameters are not shown in the figure above but can be found in the previous post here.

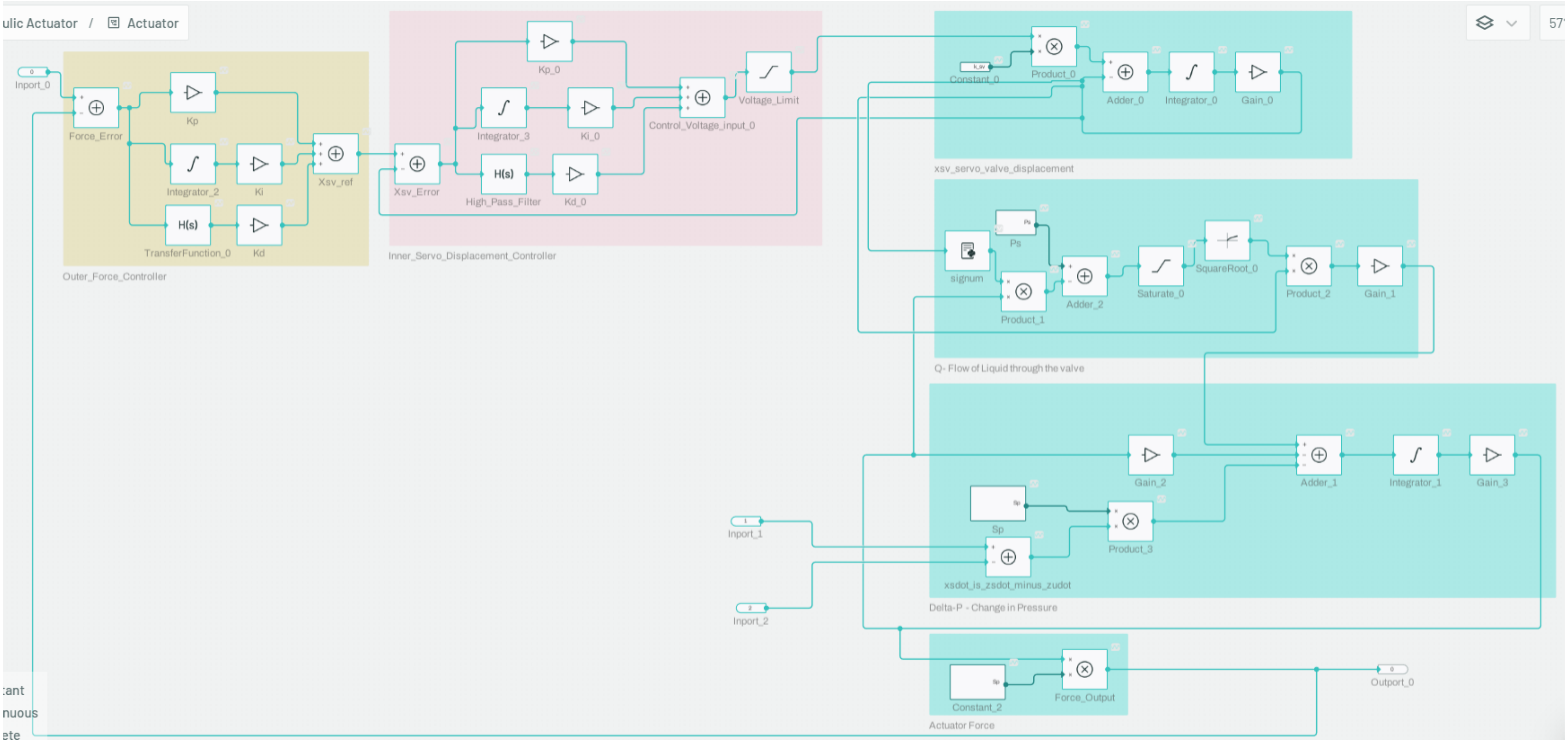
Collimator Model—Overall System view



View of the Sprung Mass Displacement Controller



View of the Actuator Subsystem



Good, let's view our simulation results

Collimator Results

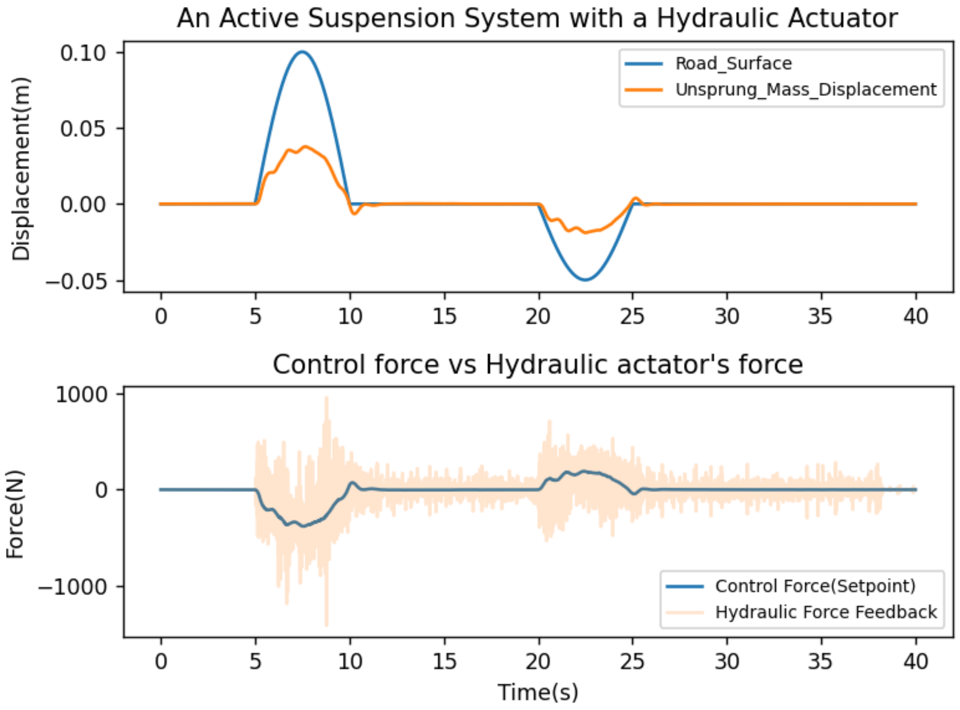


Fig A: The plot shows the displacement and the force response from the actuator subsystem

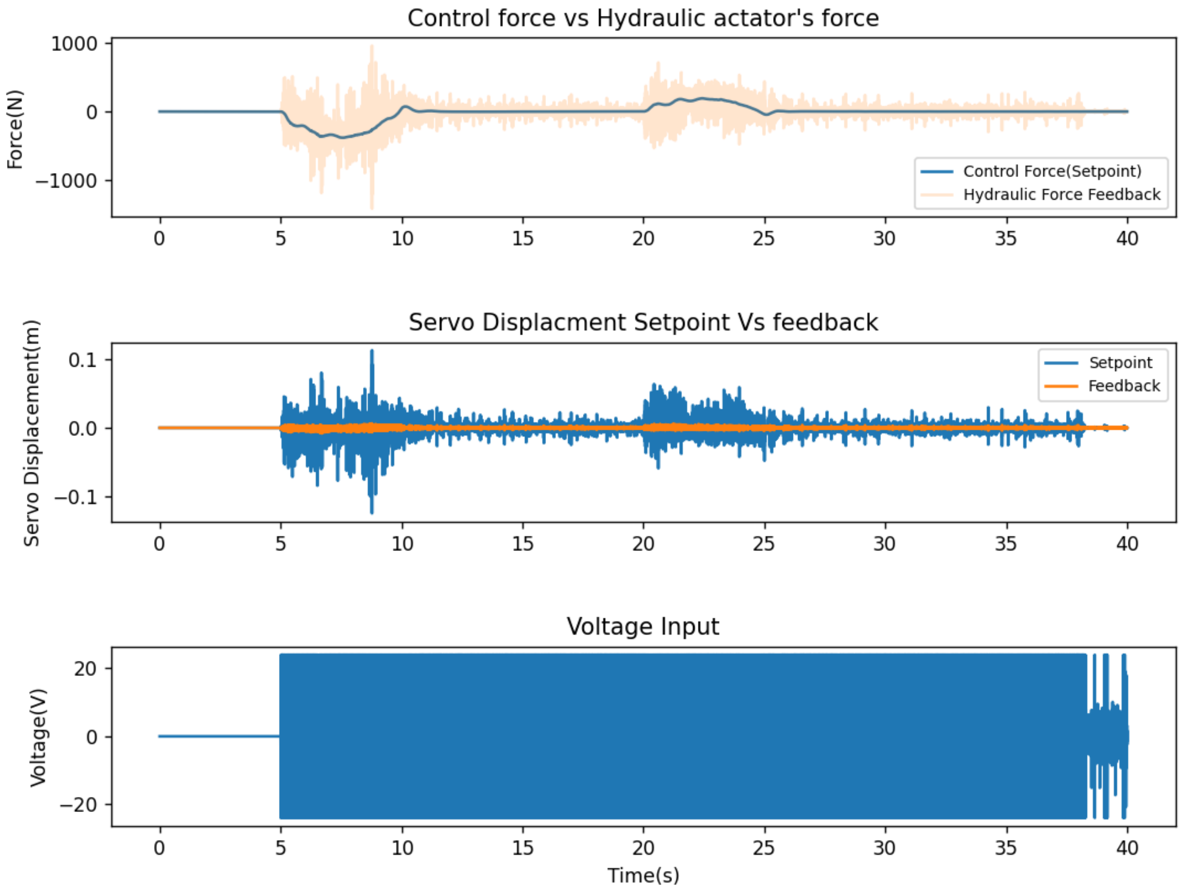


Fig B: The plot shows the internal dynamics of the actuator subsystem(its force response, servo-displacement response, and voltage input)

Collimator Results

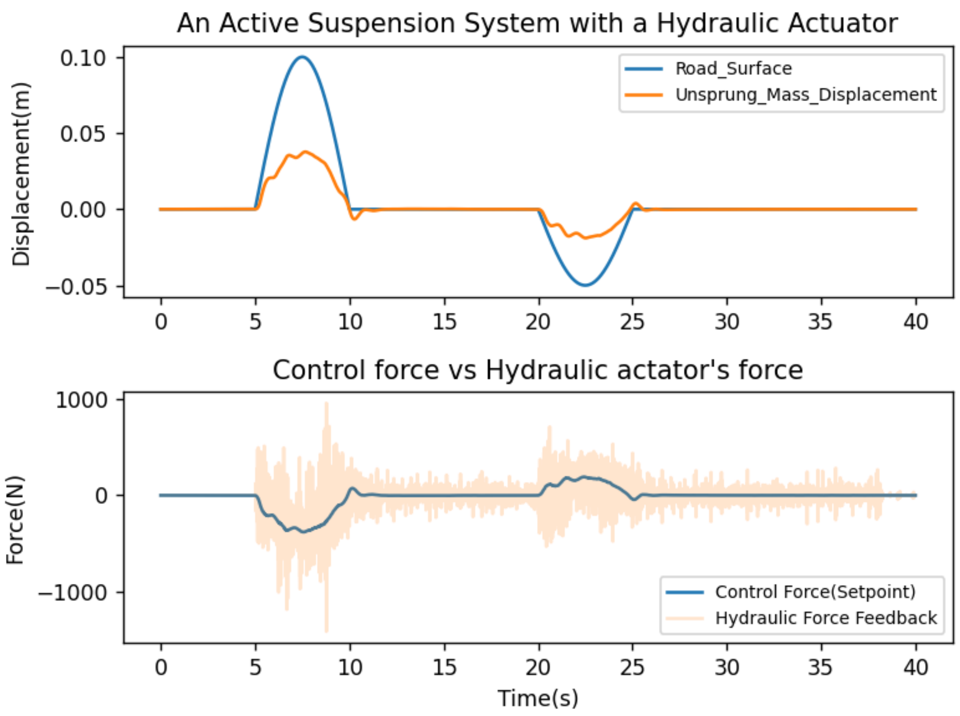


Fig A: The plot shows the displacement and the force response from the actuator subsystem

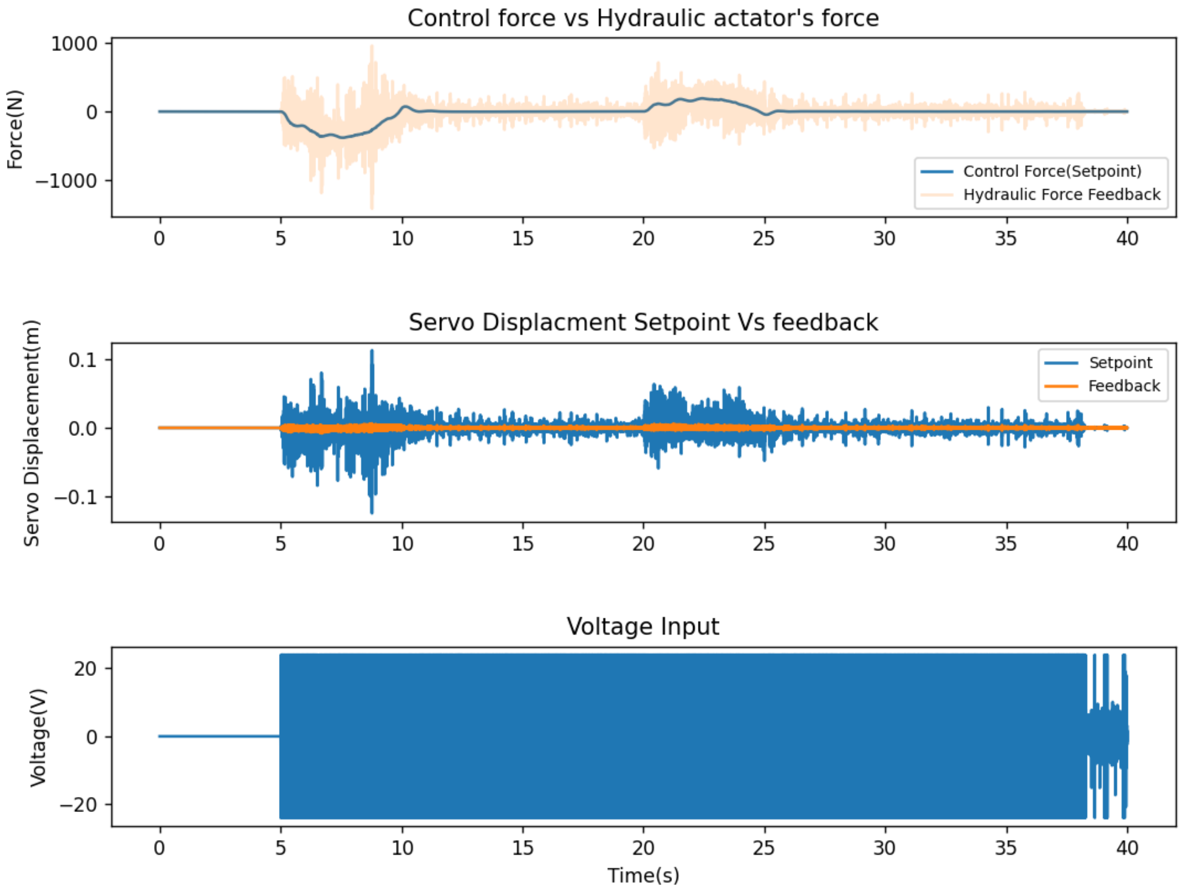


Fig B: The plot shows the internal dynamics of the actuator subsystem(its force response, servo-displacement response, and voltage input)

Discussion of Results

- For a road bump of height 0.1m, the sprung mass max displacement is 0.0404m, and the control force's setpoint is -380N
- For a pothole of depth 0.05m, the sprung mass max displacement is 0.0170, and the control force's setpoint is 230N.
- In contrast, as shown in the figure, the active suspension system with an ideal actuator with a max bump displacement of 0.0056m and control force of -568N
- Likewise, the ideal actuated system has a pothole displacement of 0.00286m and control force of 285N.

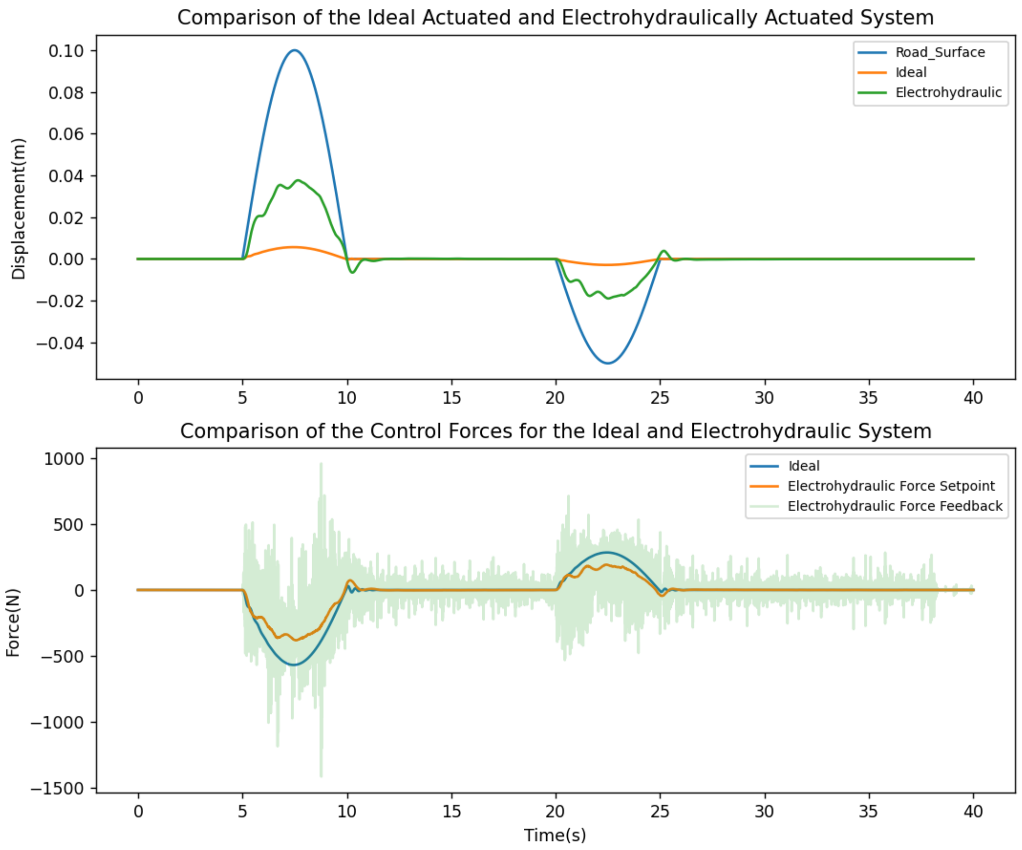


Fig C: Comparison of the performance of between the active suspension system with an ideal actuator and that of an electrohydraulic actuator

So, it is obvious that the electro-hydraulically actuated system has a much larger sprung mass displacement in comparison to the ideally actuated system.

The electro-hydraulically driven system <u>could</u> have a better performance if its controller design is improved.

Presently the controllers are PID controllers, so a next step in this project could be to design a non-linear controller for the actuator subsystem and compare its performance to the PID controller

References

[1] Duc Ngoc Nguyen, Tuan Anh Nguyen, "The Dynamic Model and Control Algorithm for the Active Suspension System", Mathematical Problems in Engineering, vol. 2023, Article ID 2889435, 9 pages, 2023. https://doi.org/10.1155/2023/2889435

[2] https://journals.plos.org/plosone/article/figure?id=10.1371/journal.pone.0278387.g001

[3] Tuan Anh Nguyen, "Improving the Comfort of the Vehicle Based on Using the Active Suspension System Controlled by the Double-Integrated Controller", Shock and Vibration, vol. 2021, Article ID 1426003, 11 pages, 2021. https://doi.org/10.1155/2021/1426003