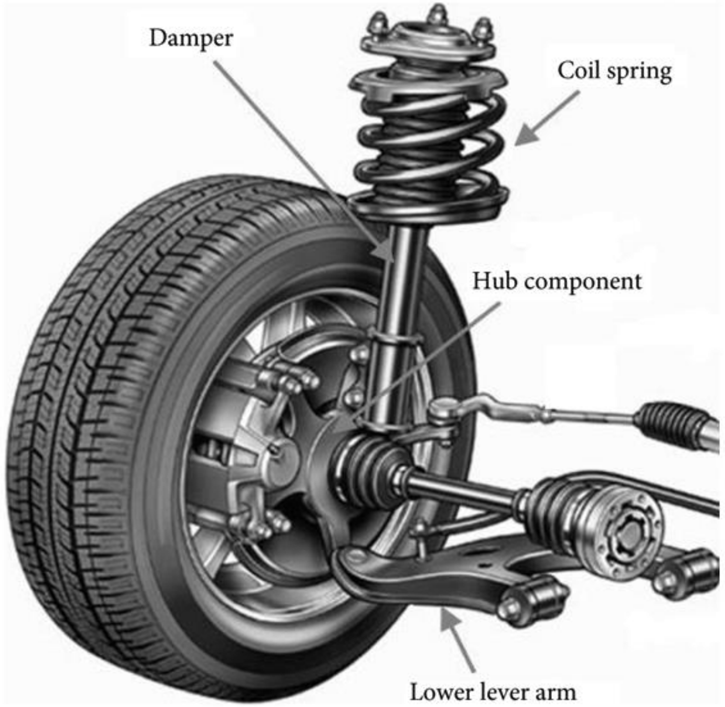


Active Suspension System – Dynamics and Control

Boboye Oladosu Okeya (BOO)

My motivation:

I recently came across a video on linkedin (link here) that shows a proactive ride system—basically an advanced active suspension system.

So, I decided to model a simple version of it

Introduction

A suspension system is designed to dampen vehicle oscillations. There is a wide variety of this technology but the most common are [1][2]:

- Passive: Its components are a damper and a spring.
- Active: Same components as the passive suspension with an extra control component subsystem.
- Semi-active: It has a less complex structure and consumes less energy in comparison to active systems

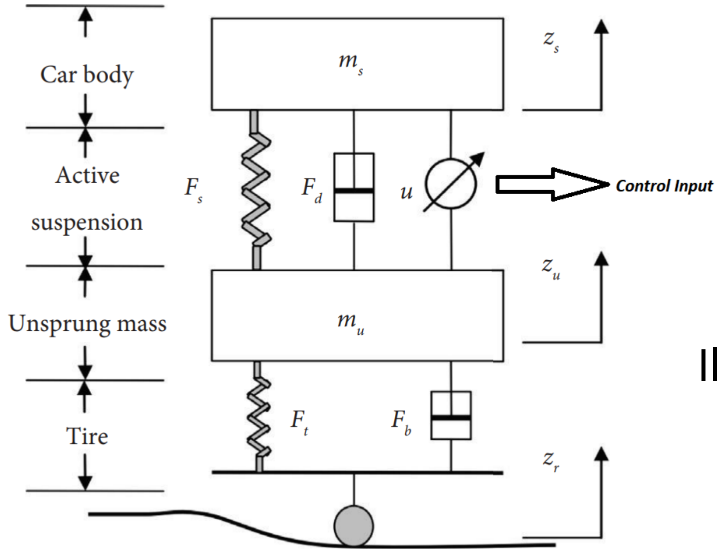


Illustration of An Active Suspension System [2]

Next, let's derive simple models for both systems—Passive and Active—using a quarter vehicle dynamic model

Quarter Vehicle Dynamic Model

Dynamics Equation for the Passive System

$$\ddot{Z}_s = \frac{1}{M_s}\left[b_s(\dot{Z}_u - \dot{Z}_s) - K_s(Z_s - Z_u)\right]$$

$$\ddot{Z}_u = \frac{1}{M_u}\left[b_s(\dot{Z}_s - \dot{Z}_u) + K_s(Z_s - Z_u) - b_t(\dot{Z}_u - \dot{Z}_r) - K_t(Z_u - Z_r)\right]$$

Dynamics Equation for the Active System

$$\ddot{Z}_s = \frac{1}{M_s}\left[b_s(\dot{Z}_u - \dot{Z}_s) - K_s(Z_s - Z_u) + u\right]$$

$$\ddot{Z}_u = \frac{1}{M_u}\left[b_s(\dot{Z}_s - \dot{Z}_u) + K_s(Z_s - Z_u) - b_t(\dot{Z}_u - \dot{Z}_r) - K_t(Z_u - Z_r) - u\right]$$

Where, M_s, M_u, K_s, b_s, K_t,and b_t are the sprung element mass, unsprung element mass, spring stiffness, damper coefficient, tire stiffness, and tire's damping coefficient respectively. u is the control force or control input. Z_s and Z_u are the displacement of the sprung and unsprung mass.

Note:

- The sprung mass of the vehicle includes all systems located above the suspension system
- The unsprung mass includes all systems below the suspension system.

Alright, let's test build this using THE COLIMMATOR!!!.

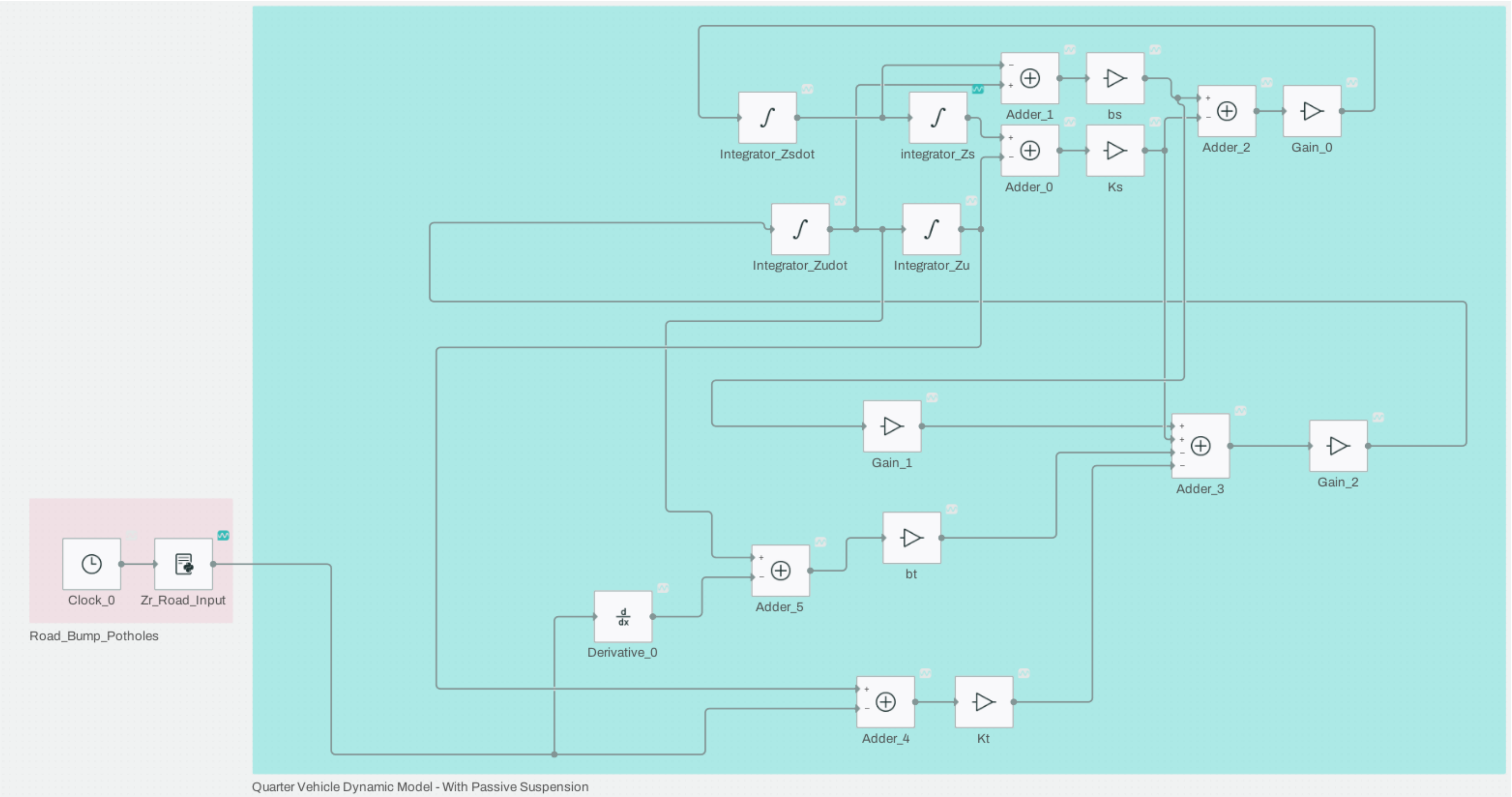
Simulation Parameters

Parameters_Initialization.py

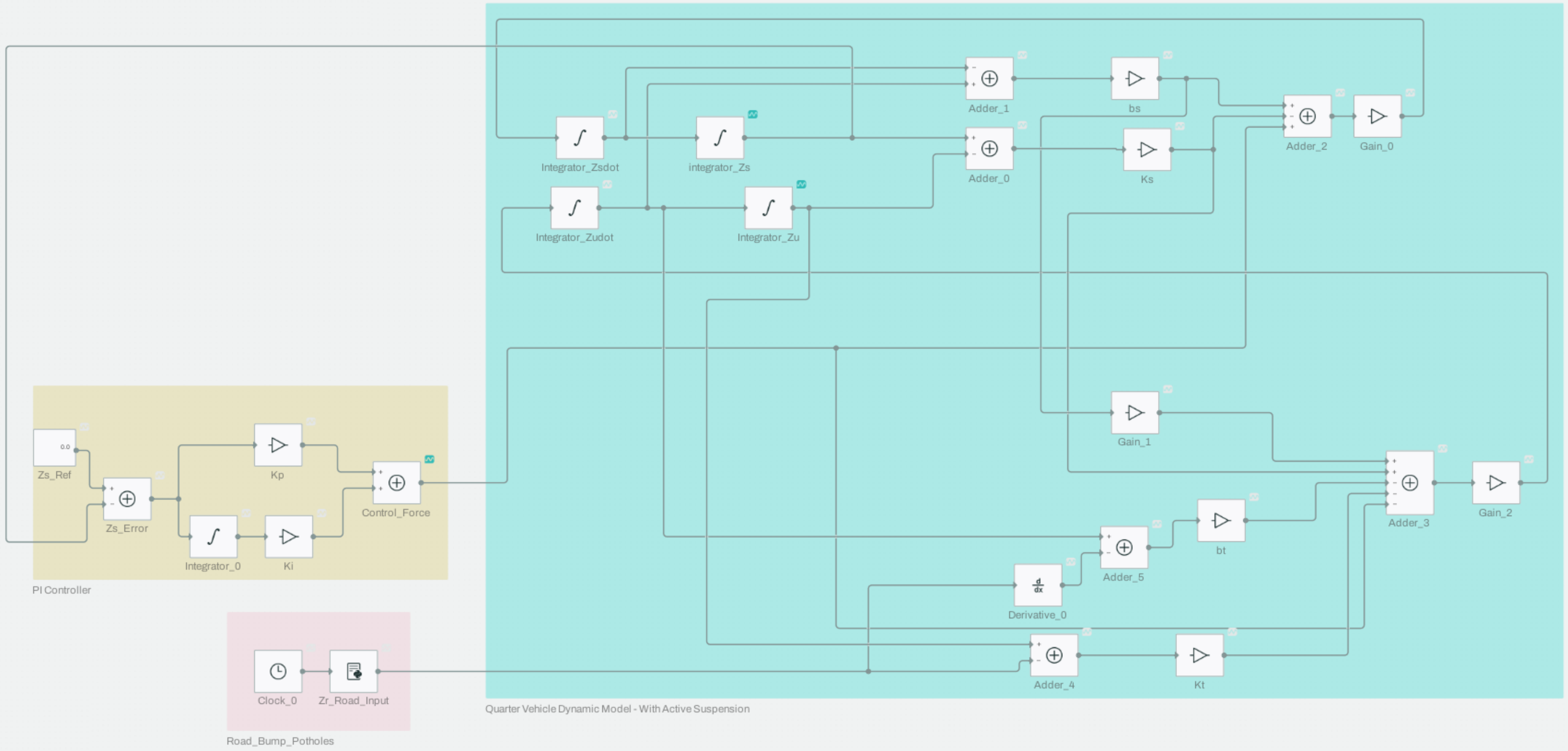
```
#Vehicle's Parameters
Ms = 241.5#kg Sprung Mass
Mu = 41.5;#kg Unsprung Mass
Ks = 6000;#N/m Spring Stiffness
Kt = 14000;#N/m Tire Spring Stiffness
bs = 300;#N.s/m Damper Coefficient
bt = 1500;#N.s/m Tire Damper Coefficient
g = 9.8;#Acceleration due to gravity

#Controller Parameters
kp = 1e5;
ki = 2e2;

```

Vehicle Parameters are gotten from [1]

Collimator Model-Passive Suspension



Collimator Model-Active Suspension

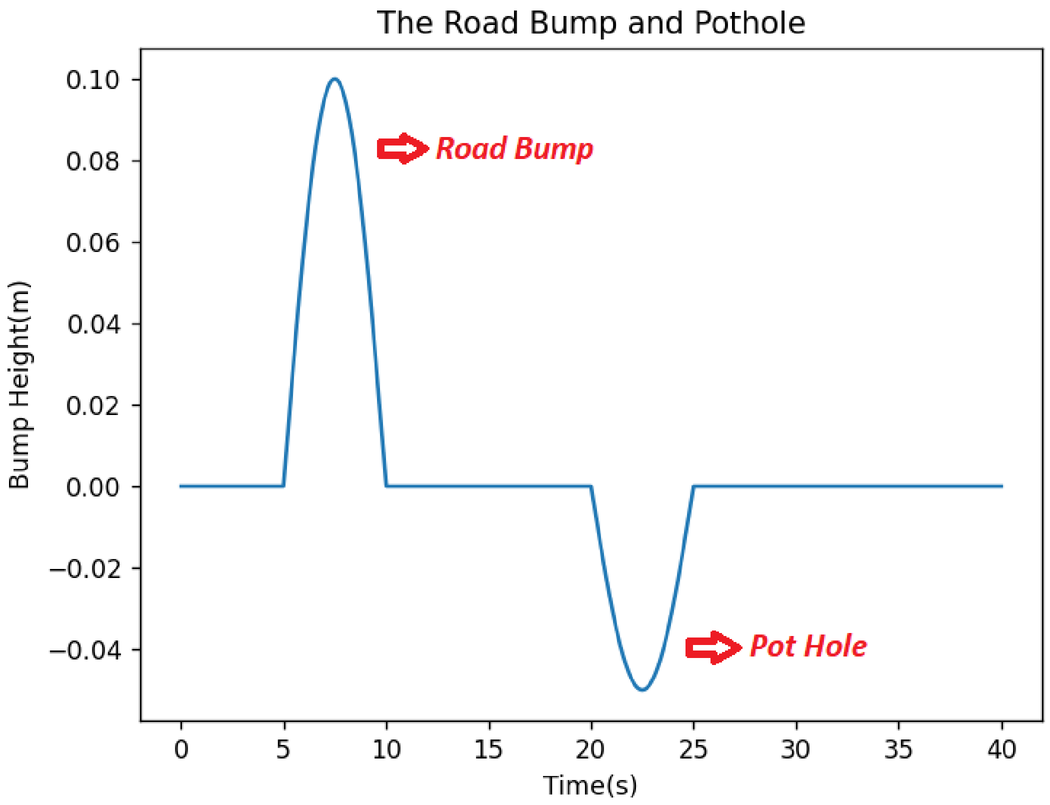


The Road Input Python Code

Active Suspension Control / Zr_Road_Input

Step | Init | Finalize

```python
import numpy as np
#Bump
start_time = 5
end_time = 10
#International standard for speed bump hieght is 8-10cm https://en.wikipedia.org/wiki/Speed_bump
A = 0.1; #the bump_height or wave amplitude in m
#Pothole
start_time2 = 20;
end_time2 = 25;
A2 = -0.05;
init_pos = 0 #This allows for offseting the displacement along the z-axis
def road_surface_generator(in_0,start_time,end_time,start_time2,end_time2,A,A2,init_pos):
    #Bump
    if in_0 < start_time or in_0 >end_time:
        out1 = init_pos
    else:
        out1 = init_pos + (A*np.sin(np.pi*(in_0-start_time)/(end_time-start_time)))
    #Pothole
    if in_0 < start_time2 or in_0 >end_time2:
        out2 = init_pos
    else:
        out2 = init_pos + (A2*np.sin(np.pi*(in_0-start_time2)/(end_time2-start_time2)))
    return out1+out2
out_0 = road_surface_generator(in_0,start_time,end_time,start_time2,end_time2,A,A2,init_pos)
```

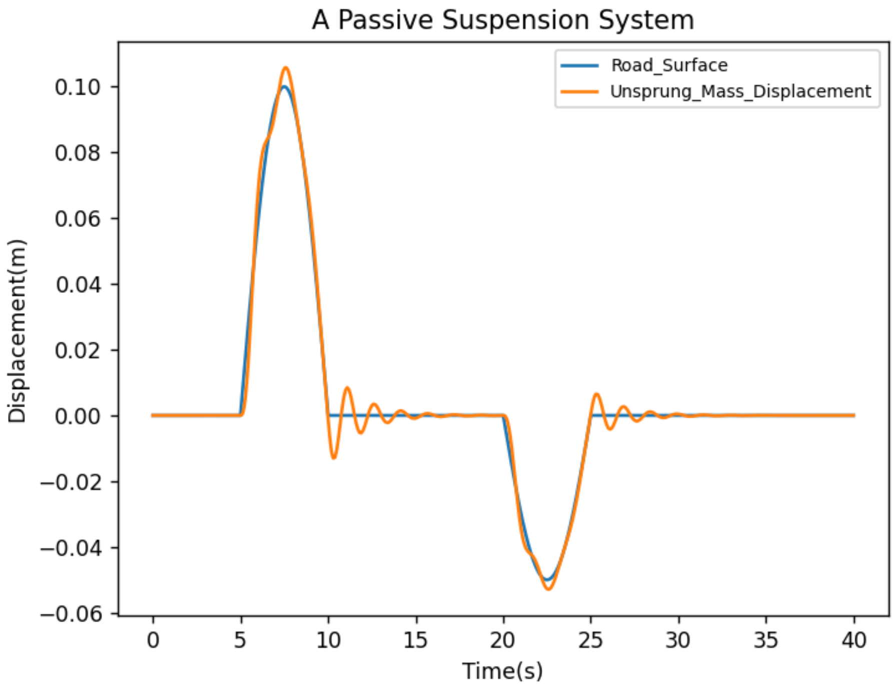


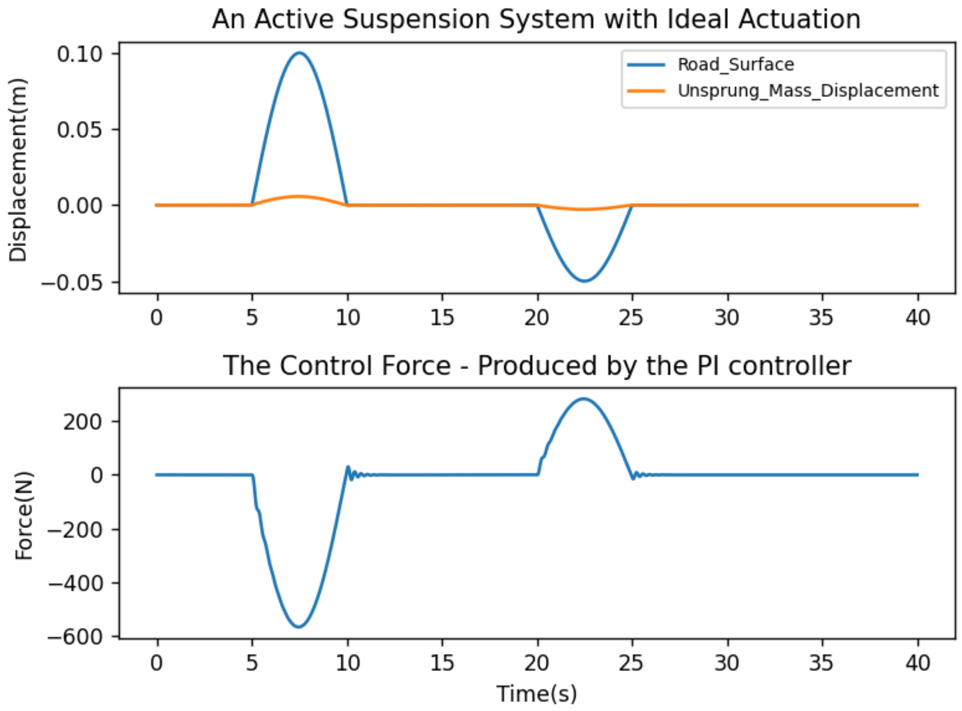
Next, let's run the simulations to view our results

I used a Jupyter Notebook to write a Python script that connects through an API to the Collimator Model.

This allows for easy plotting of the results

Collimator Results





Discussion of Results

- Passive system:
  - For a road bump of height 0.1m, the sprung mass max displacement is 0.1065m
  - For a pothole of depth 0.05m, the sprung mass max displacement is 0.0527m
- Active system:
  - For a road bump of height 0.1m, the sprung mass max displacement is 0.0056m, and the control force is -568N
  - For a pothole of depth 0.05m, the sprung mass max displacement is 0.00286, and the control force is 285N

So, it is obvious that an active suspension system significantly reduces the displacement of a car's sprung mass by generating the force required to counter the effect of changes in the road surface

What's next:

-> Include a non-ideal actuator with its dynamics

-> Design a fast-acting controller for the non-ideal actuator to track the force demanded by the active suspension controller

Let's work together for a greener future

References

[1] S. Kumar, A. Medhavi, R. Kumar, and P.K. Mall, “Modeling, analysis and PID controller implementation on suspension system for quarter vehicle model ”, JMES, vol. 16, no. 2, pp. 8905–8916, Jun. 2022.

[2] 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