MBD Week3 Problem3 Report: Anti-Lock Braking System

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Introduction

Anti-lock braking system, popularly known as ABS is an anti-skid braking system used as safety system on aircraft, cars, motorcycle, trucks, buses and in other land vehicles. ABS operation prevents the wheels from locking up during braking, maintaining tractive contact with the road surface and allowing the driver to have more control over the vehicle, hence ensuring the safety while braking.[2]

This report is about modelling an anti-lock braking system using Simulink[1], demonstrating some Simulink skills on this model and showing various test cases.

Equations

To model the Simulink design for the ABS system, it is important to look into the mathematical equations which represents the system. For this, we need to calculate the slip of the system, which depends on the wheel speed and vehicle speed.

$\omega_v = \frac{V}{R}$ (equals wheel angular speed if there is no slip)

Equation 1:

$\omega_v = \frac{V_v}{R_r}$

$$slip = 1 - \frac{\omega_w}{\omega_V}$$

$\omega_v = vehicle\ speed\ divided\ by\ wheel\ radius$

$V_v = vehicle\ linear\ velocity$

$R_r = wheel\ radius$

$\omega_w = wheel\ angular\ velocity$

From the equation, it is clear that slip is zero if wheel speed and vehicle speed are equal. When the wheel is locked, slip equals one. The desirable value for slip is 0.2, which helps to minimize the stopping distance and hence prevents skidding.

Simulink Model

- Anti-Lock Breaking System

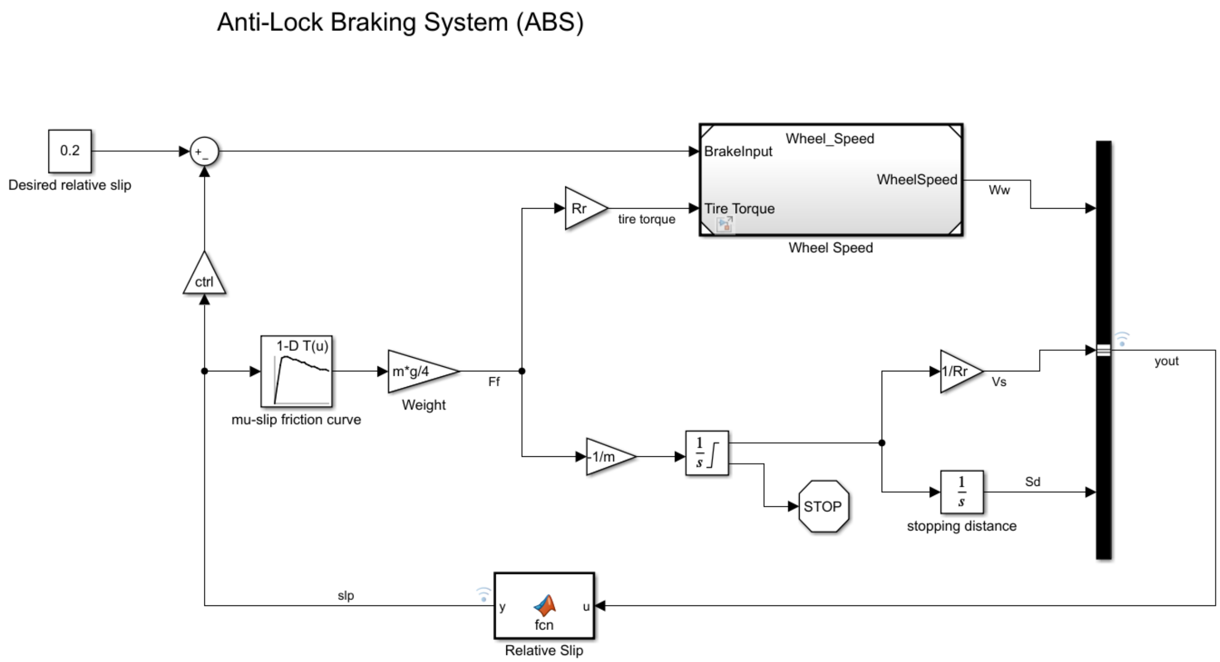

Figure 1: ABS Simulink Model

- Subsystem referenced model – Wheel Speed

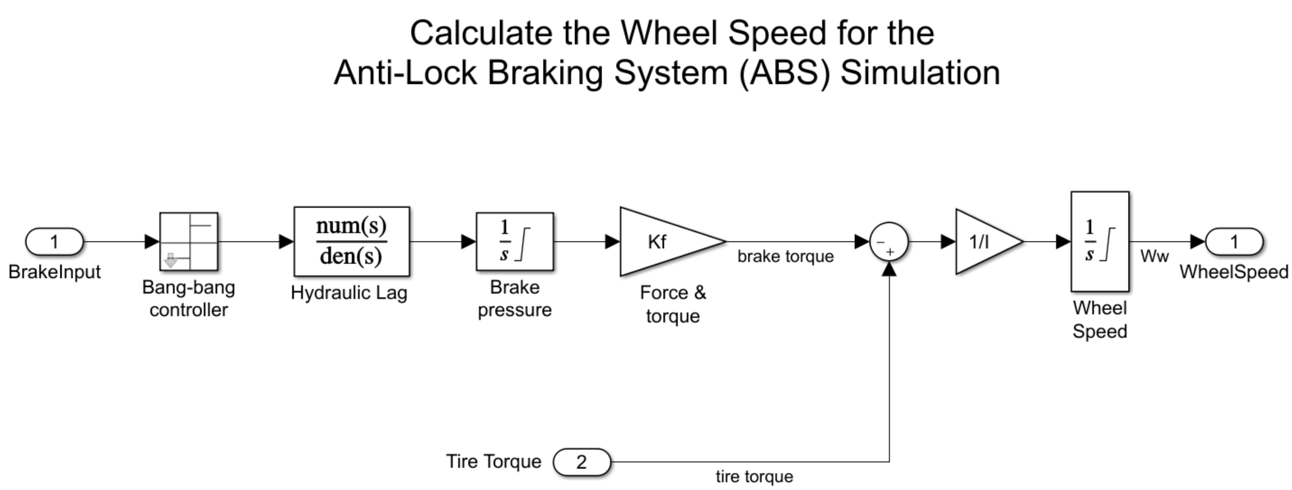

Figure 2: Referenced Model block: Wheel Speed

Skill sets to demonstrate

- Callbacks:

  Callback code is added to initialize the variables at the initialization phase of the model. This can be edited or other callbacks can be included through Property Inspector -> Callbacks. The code entered:

```
I=5;
Kf=1;
Rr=1.25;
TB=0.01;
ctrl=1;
g=32.18;
m=50;
mu=[0 0.4 0.8 0.97 1 0.98 0.96 0.94 0.92 0.9 0.88 0.855 0.83 0.81 0.79 0.77 0.75 0.73 0.72 0.71 0.7];
slip=[0 0.05 0.1 0.15000000000000002 0.2 0.25 0.30000000000000004 0.35000000000000003 0.4 0.45 0.5 0.55 0.6 0.64999999999999991 0.7 0.75 0.8 0.85 0.9 0.95 1];
v0=88;
PBmax=1500;
```

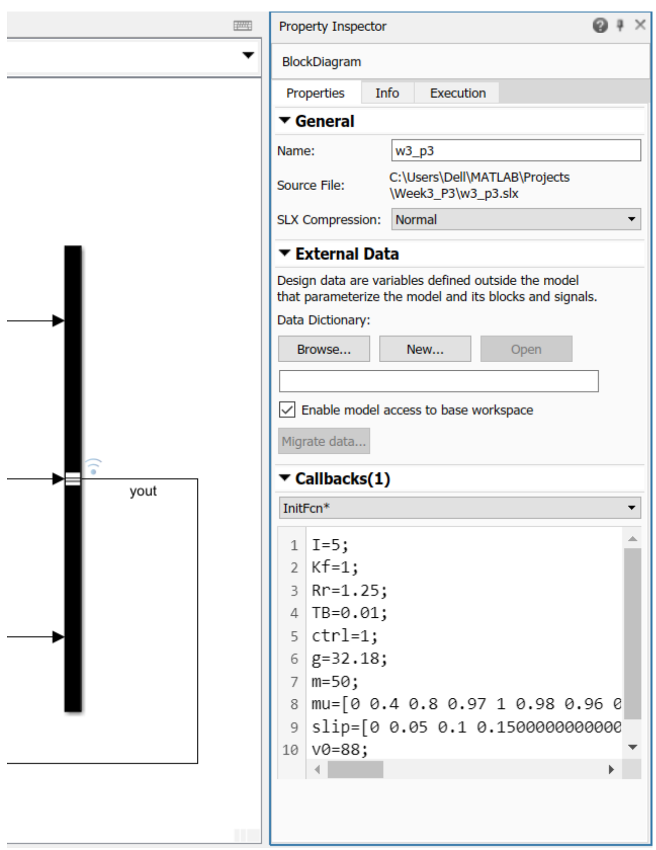

Figure 3: Callback function

- ## Data Inspector:

By enabling data logging, we can view and inspect the signals for each run using data inspector. The data inspector reports are included in this project repository.

Run 1: With ABS

During Run 1, the ctrl gain parameter is set to 1 for ABS mode.

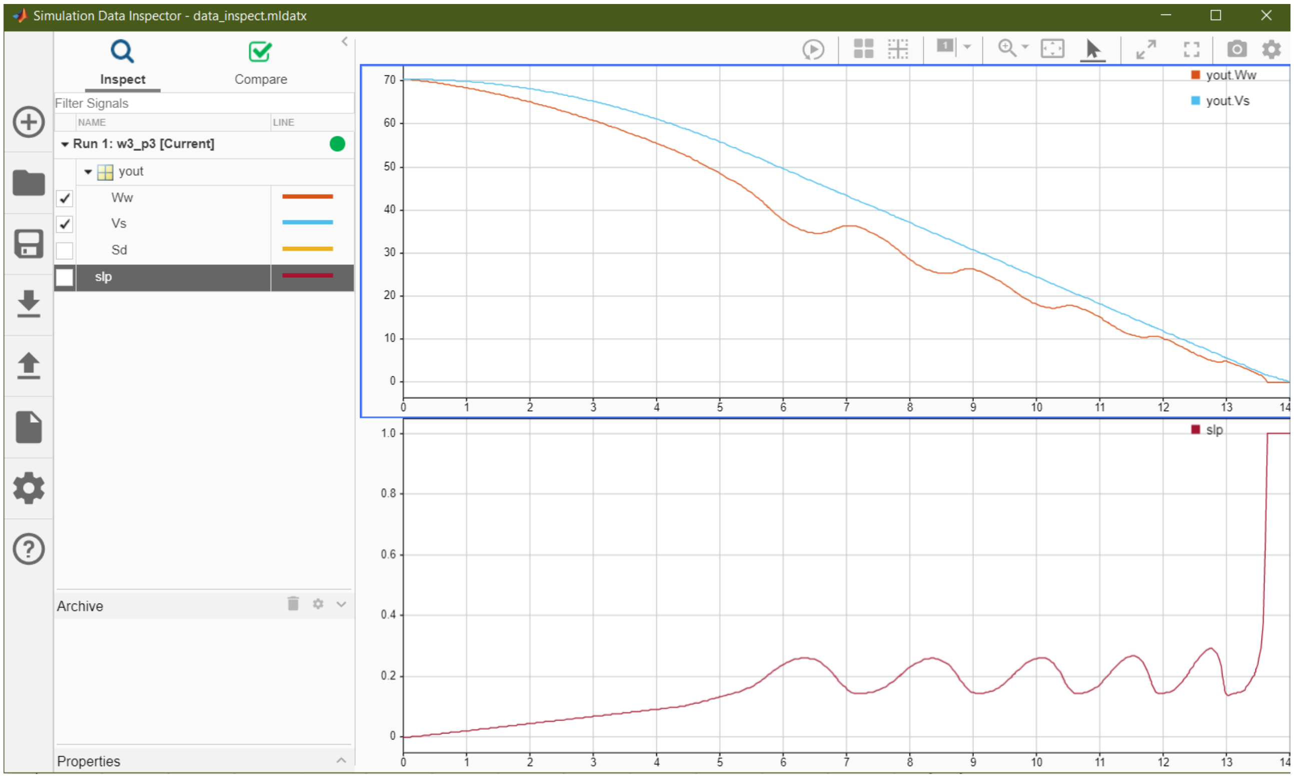

Figure 4: Data Inspector - Run 1: With ABS

Run 2: Without ABS

During Run 2, the ctrl gain parameter is first set to 0. This will disconnect the slip feedback from the controller and causes maximum braking.

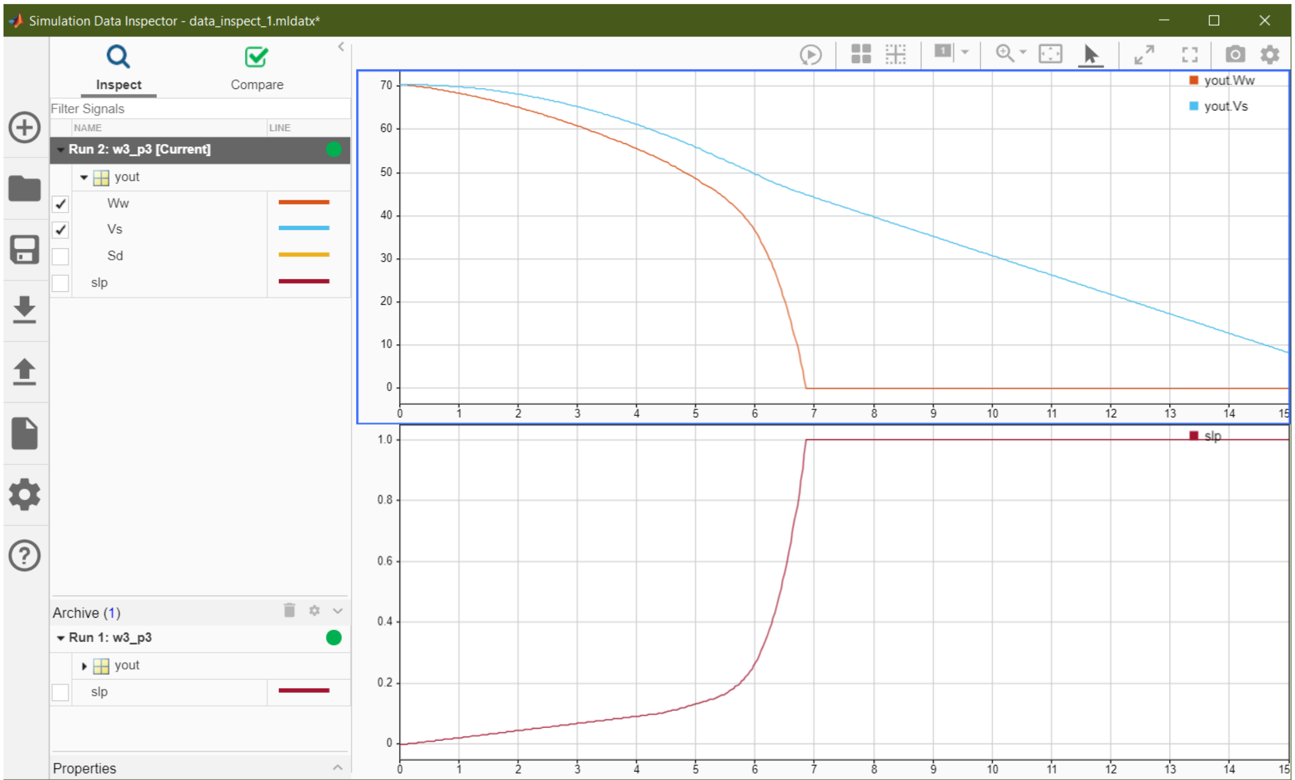

Figure 5: Data Inspector - Run 2: Without ABS

- ## Solver Selection:
  The solver selected for this system is Variable-step type and ode45 for better results.

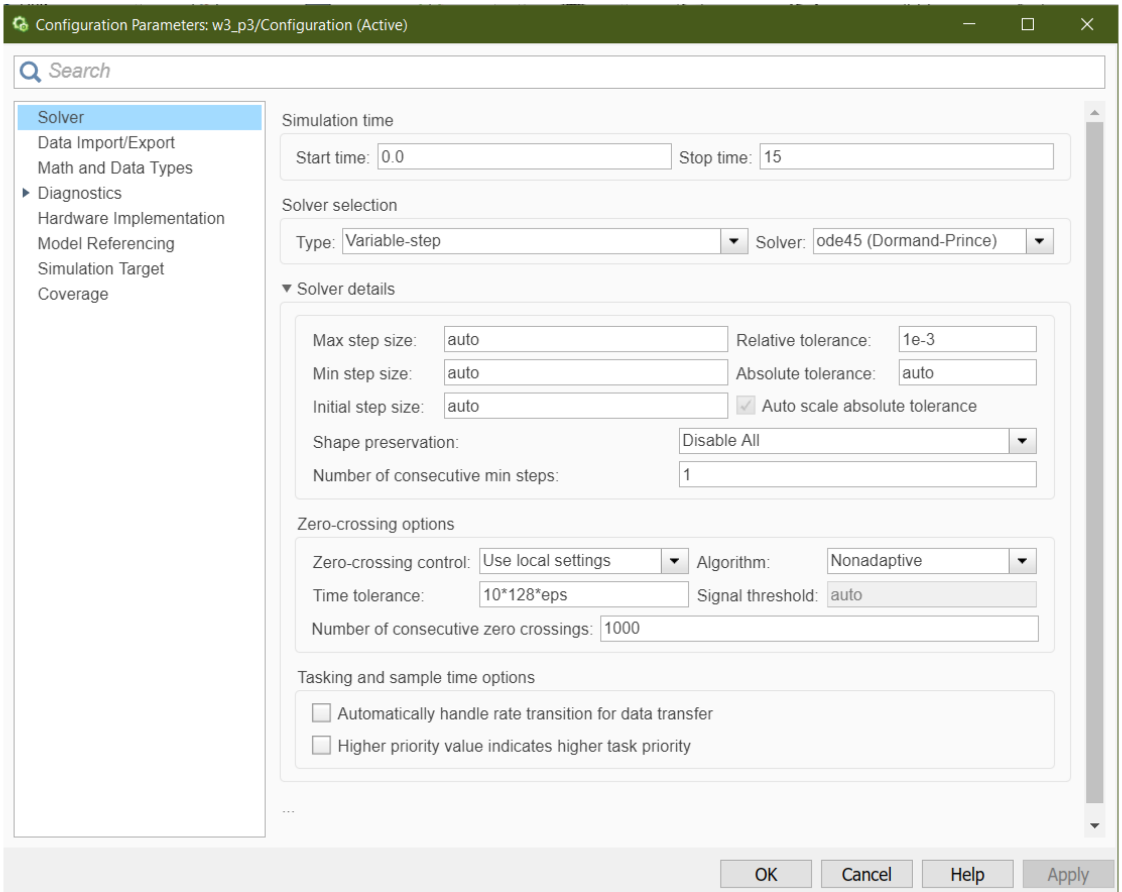

Figure 6: Solver selection

- ## MATLAB Function Block:

  MATLAB Function Block is included in the model to calculate the relative slip output from wheel speed and vehicle speed as input to provide it as feedback.

  Code in the function block:

```
function y = fcn(u)

y = 1.0 - u(1)/(u(2) + (u(2)==0)*eps);
```

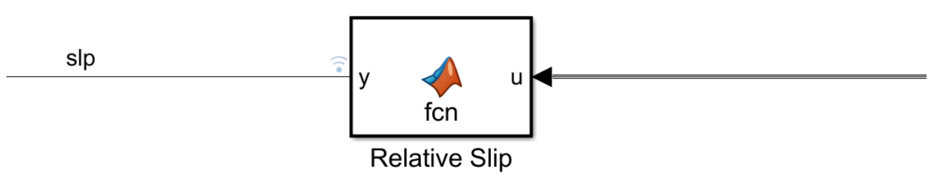

Figure 7: MATLAB Function Block

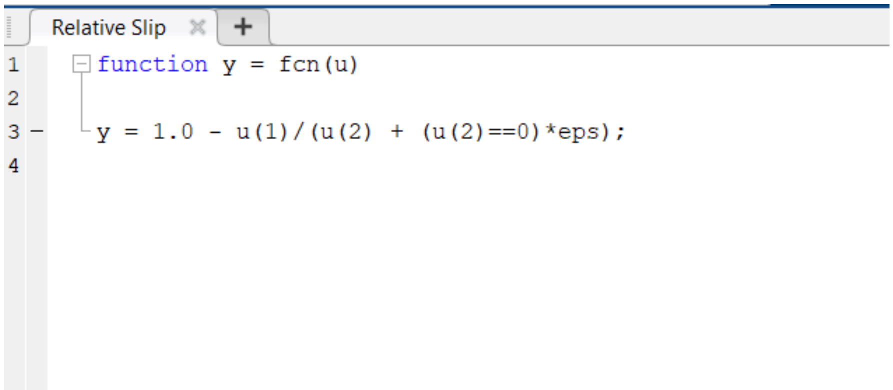

Figure 8: Inside MATLAB Function Block

- ## Look-up Table:

  Look-up Table is included in this model to provide mu-slip friction curve.

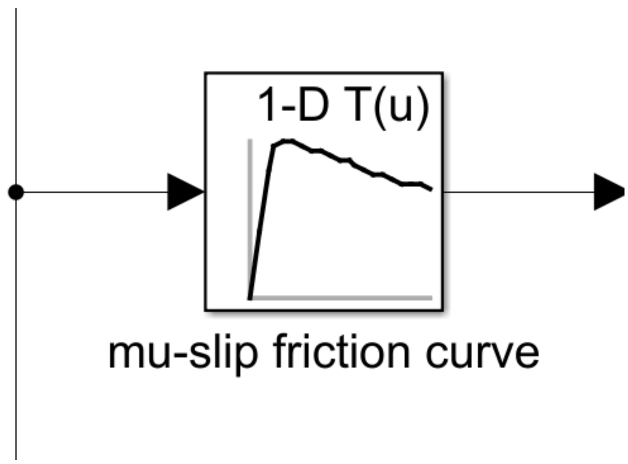

Figure 9: Use of Look-Up Table

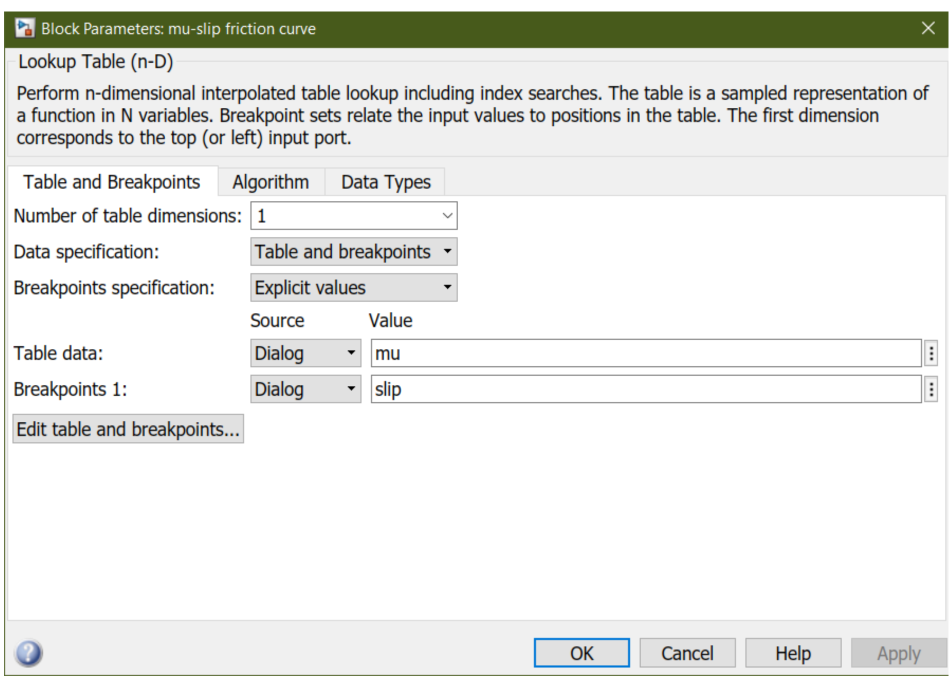

Figure 10: Inside Look-up Table

The values of mu and slip are initialized as arrays in the callback function as:

```
mu=[0 0.4 0.8 0.97 1 0.98 0.96 0.94 0.92 0.9 0.88 0.855 0.83 0.81 0.79 0.77 0.75 0.73
0.72 0.71 0.7];

slip=[0 0.05 0.1 0.15000000000000002 0.2 0.25 0.30000000000000004 0.35000000000000003
0.4 0.45 0.5 0.55 0.6 0.64999999999999991 0.7 0.75 0.8 0.85 0.9 0.95 1];
```

- ## Signal Builder to generate test signals:

  As the desired relative slip is 0.2 for the minimizing braking distance and skidding, changing this will affect the ABS operation.

  Firstly, after adding the signal builder block, three constant signals with time range 0-15 were created. In this, three conditions are verified – slip=0.2, slip=0 and slip=1.

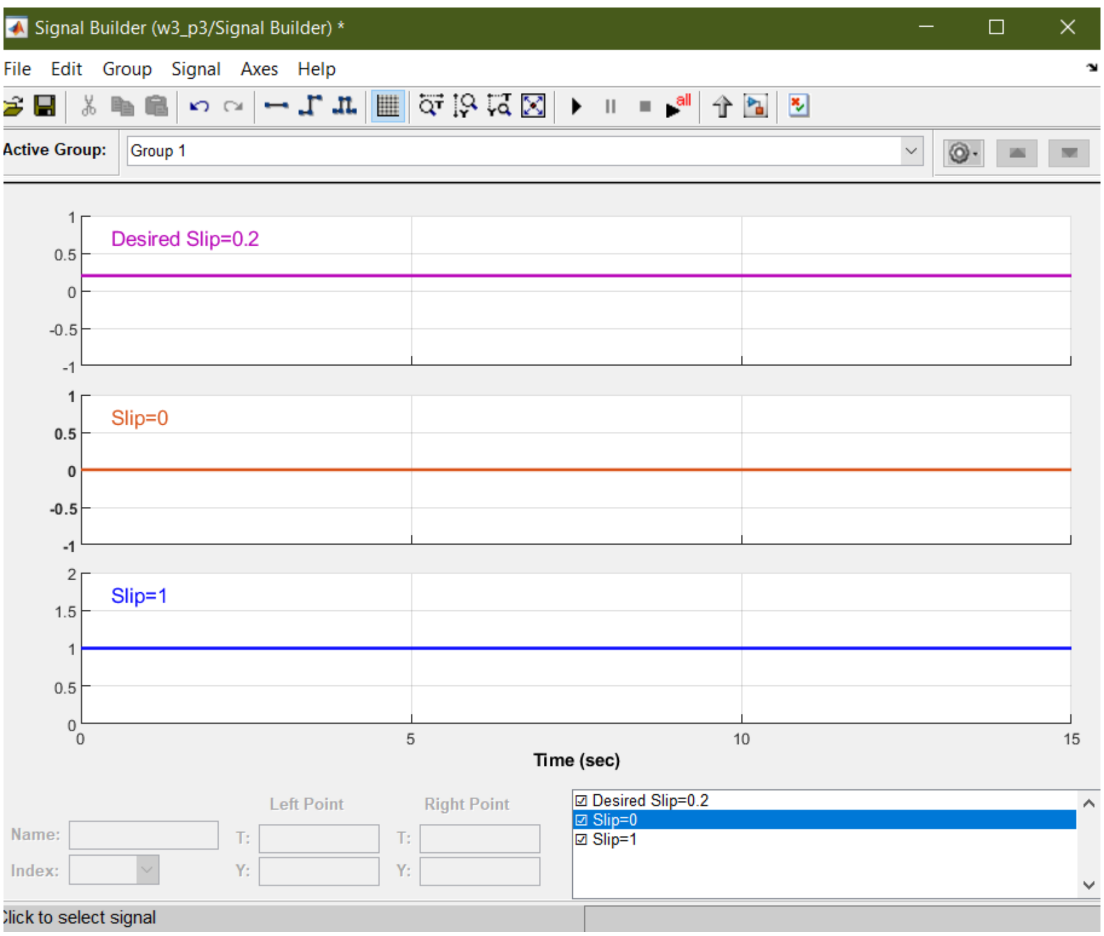

Figure 11: Inside Signal Builder Block

Test Case 1: Desired Slip = 0.2

The desired slip for proper action of ABS is considered to be 0.2, hence the vehicle speed, wheel speed and relative slip is verified through graph in data inspector.

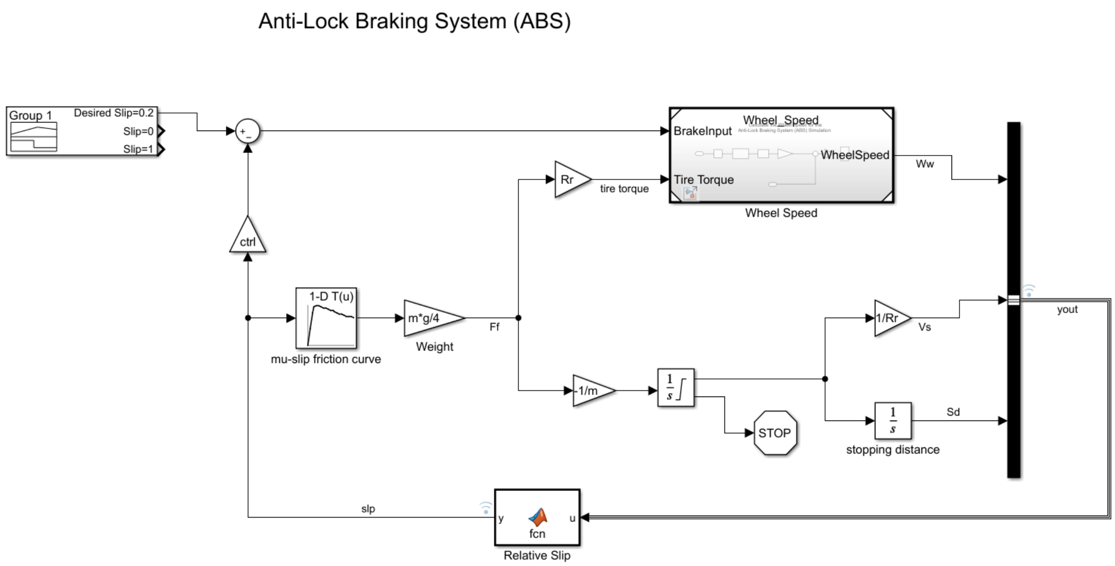

Figure 12: Connections with Signal Builder for Test Case 1

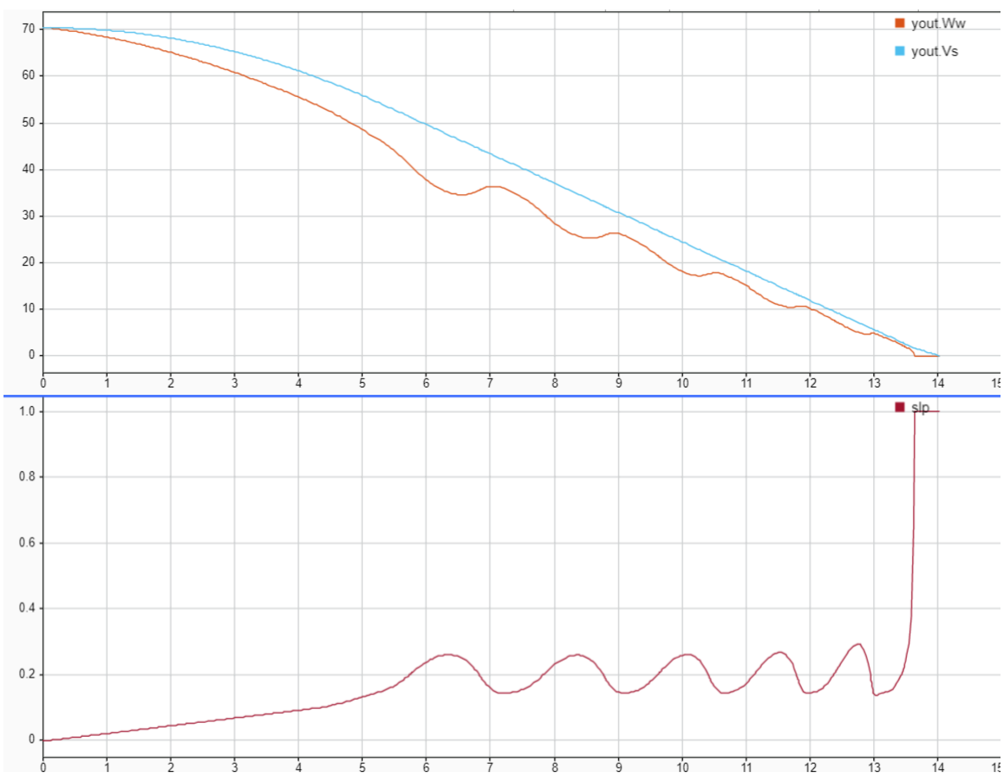

Figure 13: Test Case 1: Desired Slip=0.2

Test Case 2: Slip=0

As analyzed before in Equation 1, slip will be 0 if vehicle speed and wheel speed will be equal. Hence proved in this test case, slip is zero when both vehicle and wheel speeds are 70.

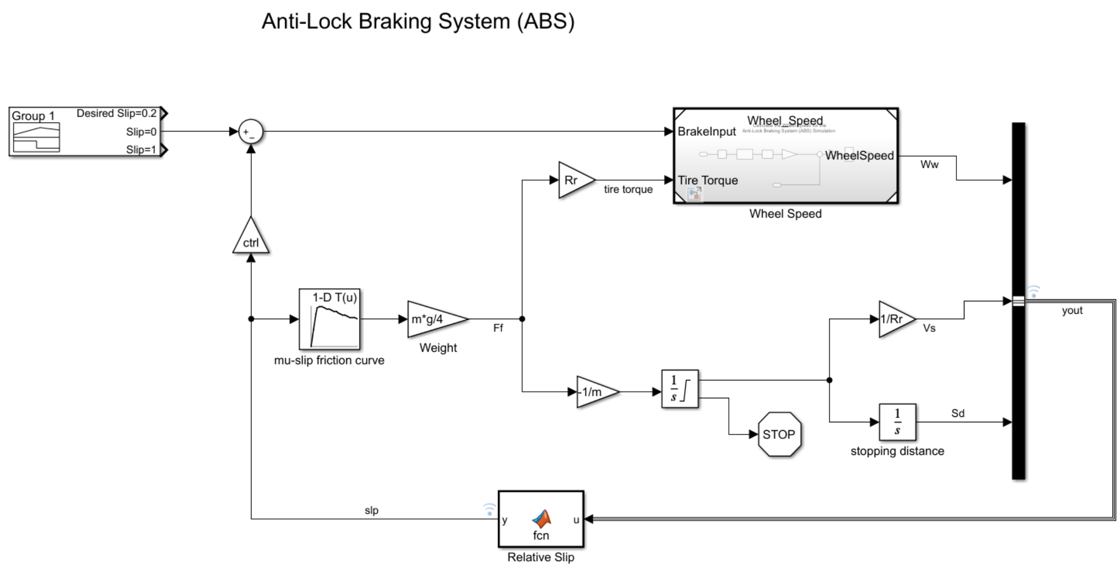

Figure 14: Connections with Signal Builder for Test Case 2

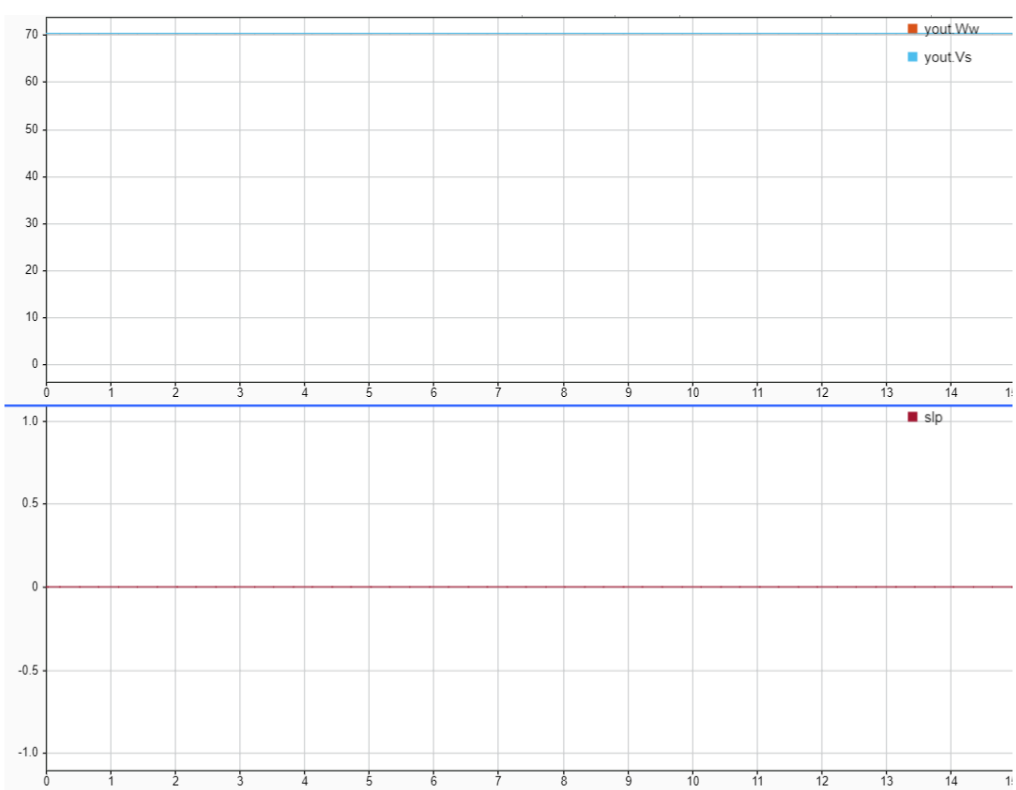

Figure 15: Test Case 2: Slip=0

Test Case 3: Slip=1

As slip equals 1, it is observed that the system is working without ABS, which is undesirable and dangerous as is leading to skidding because of locking of Wheels (Ww reaches to zero while Vehicle is still moving).

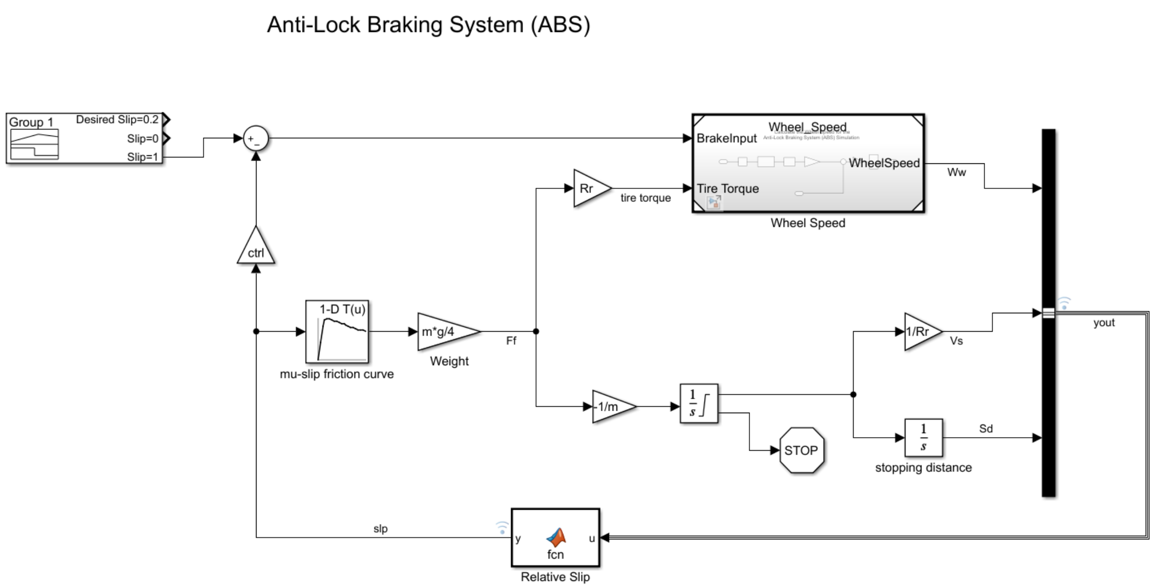

Figure 16: Connections with Signal Builder for Test Case 3

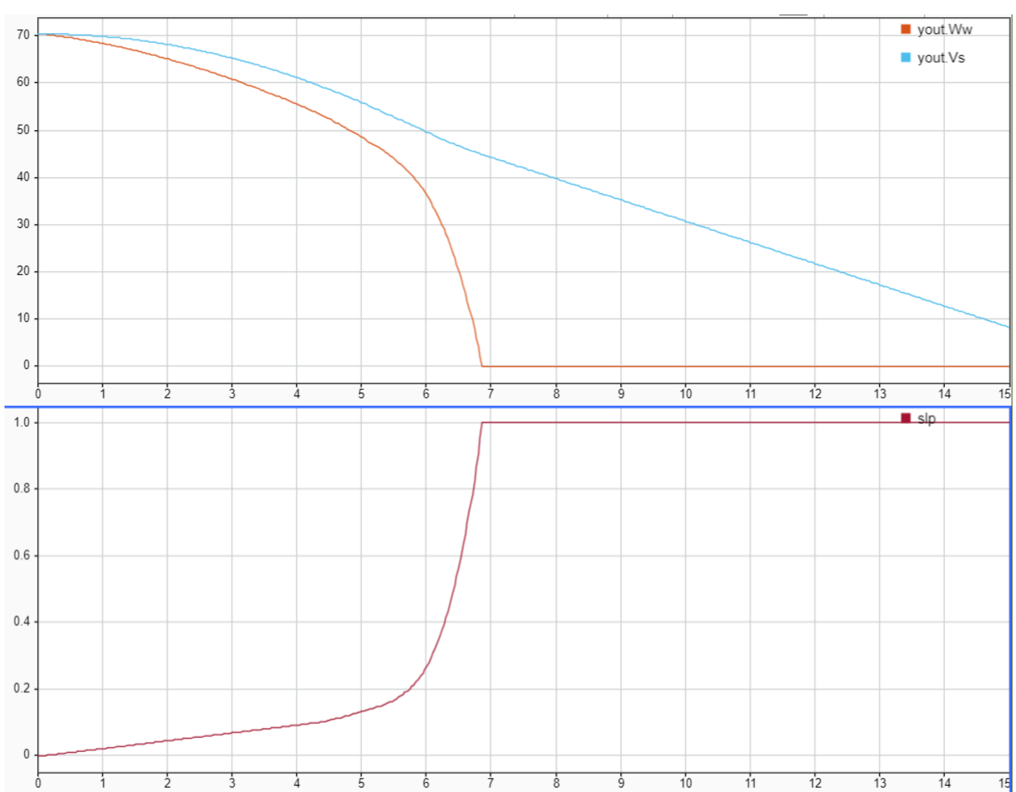

Figure 17: Test Case 3: Slip=1

Conclusion

Through this project, the design of Anti-Lock Braking System was designed. ABS is a safety system installed in a vehicle which prevents the wheels from skidding hence preventing accidents. The desired slip required for proper ABS operation is 0.2.The various test cases were verified through this project as well as various Simulink skills were demonstrated.

References

[1] https://in.mathworks.com/help/simulink/slref/modeling-an-anti-lock-braking-system.html

[2] https://en.wikipedia.org/wiki/Anti-lock_braking_system#Anti-lock_Braking_System_(ABS)