Unique ID: 2005352

Problem statement:
Design complex automotive system of your choice.

Topic: Anti-Lock Braking System

Introduction:

Anti-lock brake systems (ABS) prevent brakes from locking during braking. Under normal braking conditions the driver controls the brakes. However, during severe braking or on slippery roadways, when the driver causes the wheels to approach lockup, the antilock system takes over. ABS modulates the brake line pressure independent of the pedal force, to bring the wheel speed back to the slip level range that is necessary for optimal braking performance. An antilock system consists of wheel speed sensors, a hydraulic modulator, and an electronic control unit. The ABS has a feedback control system that modulates the brake pressure in response to wheel deceleration and wheel angular velocity to prevent the controlled wheel from locking. The system shuts down when the vehicle speed is below a pre-set threshold.

The objectives of antilock systems are threefold:
1. To reduce stopping distances
2. To improve stability
3. To improve steerability during braking.

Mathematical Modelling:

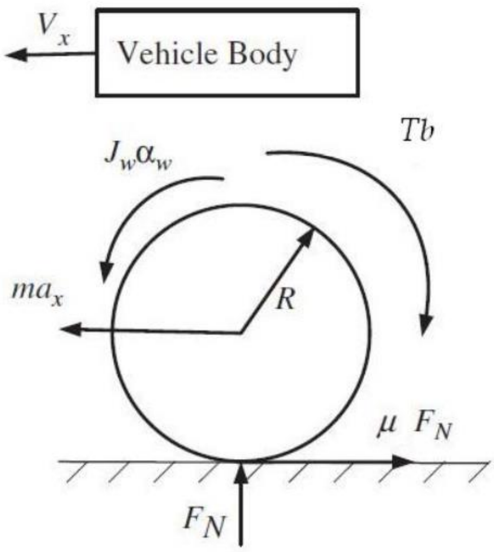

Figure 1: Quarter Vehicle Model

The longitudinal velocity of the vehicle and the rotational speed of the wheel constitute the degrees of freedom for this model. The governing two equations for the motions of the vehicle model are as follows:

For braking force balance in longitudinal direction (vehicle)

$$m\,a_x = -\,\mu\,F_N \quad \Longrightarrow \quad m\frac{d\,V_x}{d\,t} = -\,\mu\,F_N \qquad (1)$$

Summing torque at wheel centre (wheel)

$$J_\omega\,\alpha_\omega = \mu\,R\,F_N - T_b \quad \Longrightarrow \quad J_\omega\,\dot{\omega} = \mu\,R\,F_N - T_b \qquad (2)$$

For convenience a slip ratio is defined according to:

$$\lambda = \frac{V_x - \omega R}{V_x} \qquad (3)$$

Differentiating on both sides with respect to time (t), we get

$$\dot{\lambda} = \frac{\dot{V}_x\,(1-\lambda) - R\,\dot{\omega}}{V_x} \qquad (4)$$

The nomenclature in above equations is presented as follows

V_x = linear velocity of vehicle

a_x = linear acceleration of vehicle

ω = rotational speed of wheel

α_ω = angular acceleration of wheel

Tb = braking torque

μ = friction coefficient

R = radius of tire m = mass of the model

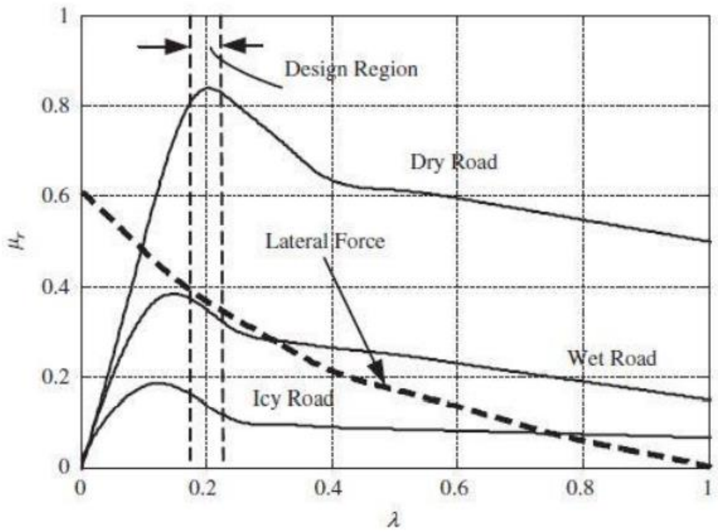

Figure 2: Frictional Coefficient of Road Surface v/s Wheel Slip Ratio

mu	slip
0	0
0.4	0.05
0.8	0.1
0.97	0.15
1.0	0.2
0.98	0.25
0.96	0.3
0.94	0.35
0.92	0.4
0.9	0.45
0.88	0.5
0.855	0.55
0.83	0.6
0.81	0.65
0.79	0.7
0.77	0.75
0.75	0.8
0.73	0.85
0.72	0.9
0.71	0.95
0.7	1.0

Table 1: Contents for lookup table

Modelled system in Simulink using equation 1, 2 and 3 and the look-up table content.

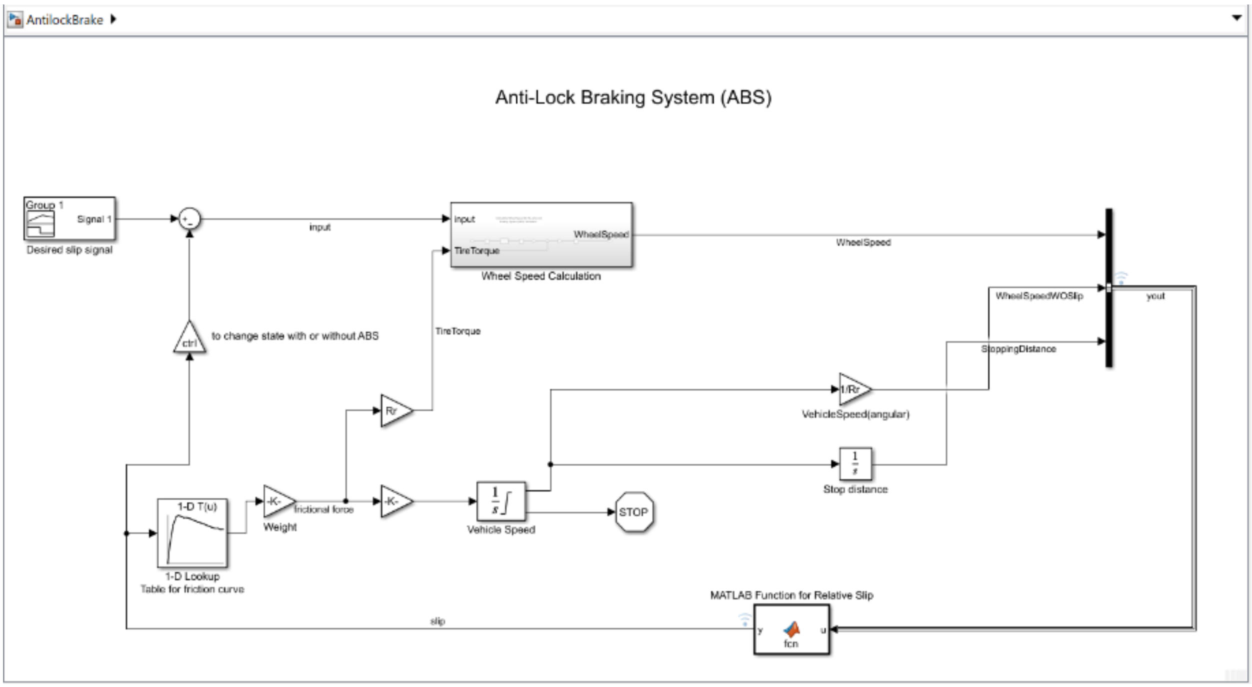

Figure 3: Simulink Model for ABS

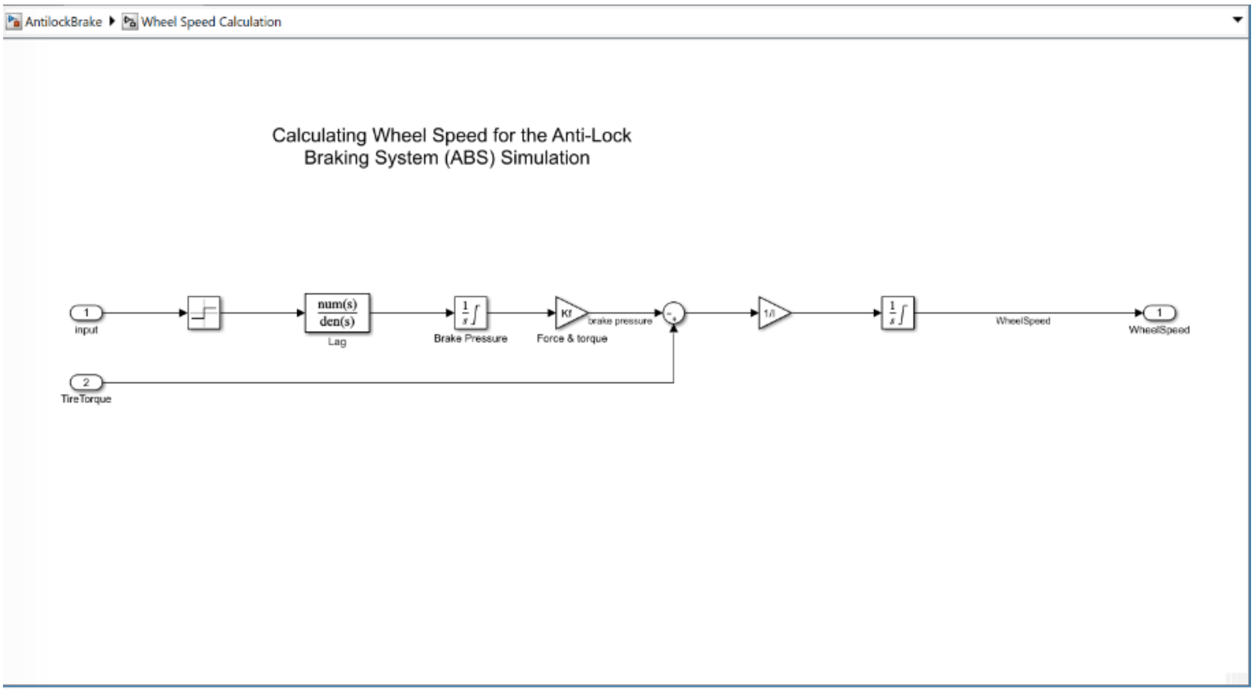

Figure 4: Subsystem for calculating wheel speed

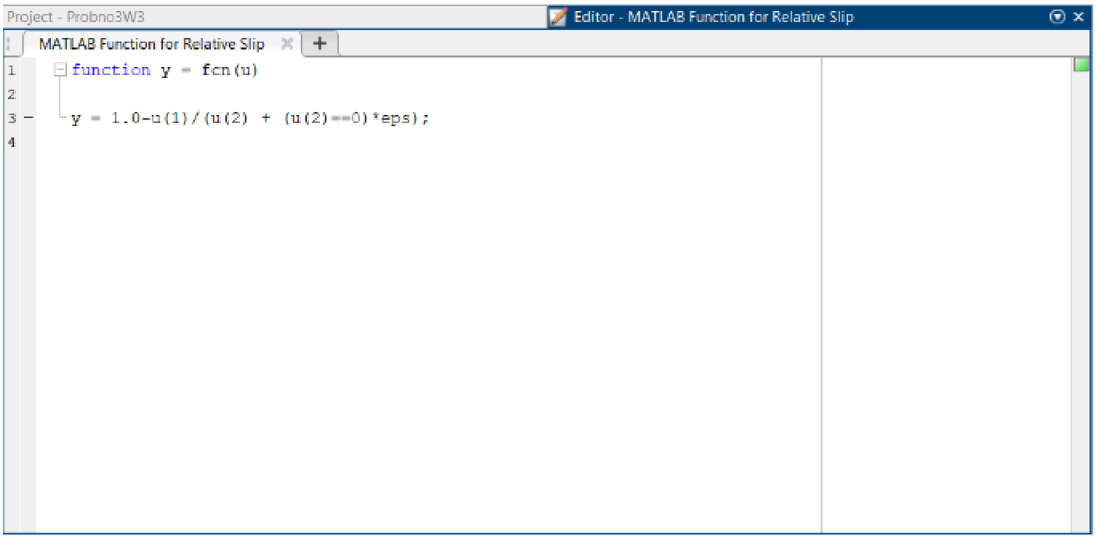

Figure 5: MATLAB Function block statement to Calculate Relative Slip

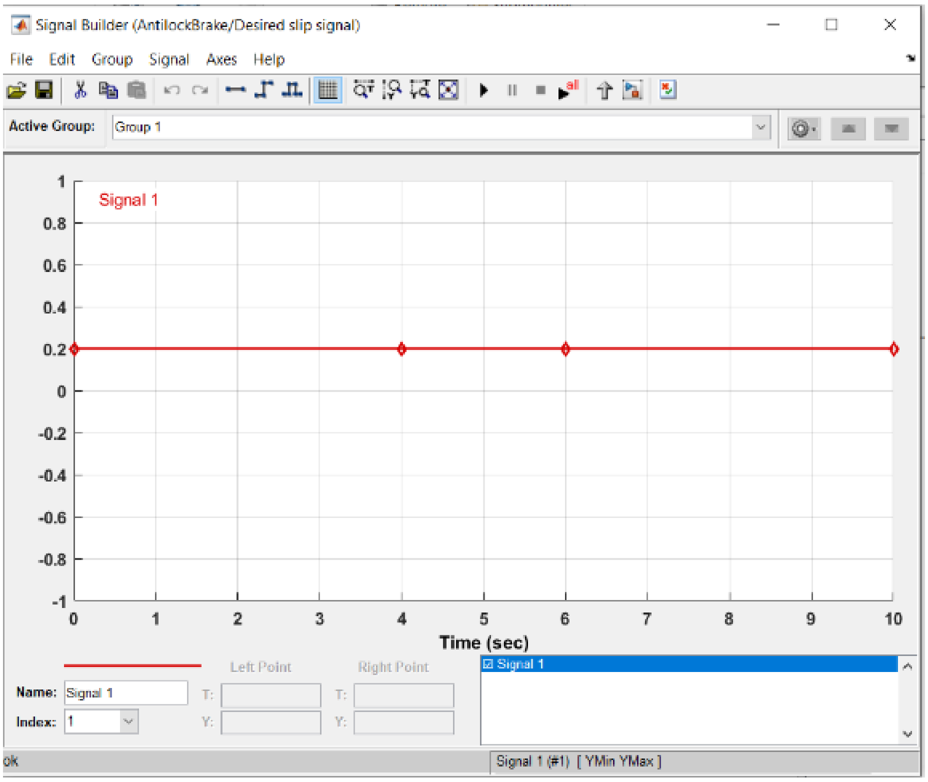

Figure 6: Signal Builder (for desired slip i.e. 0.2)

Input Values in InitFcn Callback:

```
%parameters
g = 32.18;
v0 = 88;
Rr = 15/12;
Kf = 1;
m = 50;
PressureBrakemax = 1500;
TB = 0.01;
I = 5;

slip = (0:0.05:1.0);
mu = [0 0.4 0.8 0.97 1.0 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];
ctrl = 0;
```

Solver Selection Setting:

By default using ode45 and stop field as 40 sec.

Output observed in Data Inspector:

For ctrl = 0→Without ABS

Ctrl = 1→with ABS

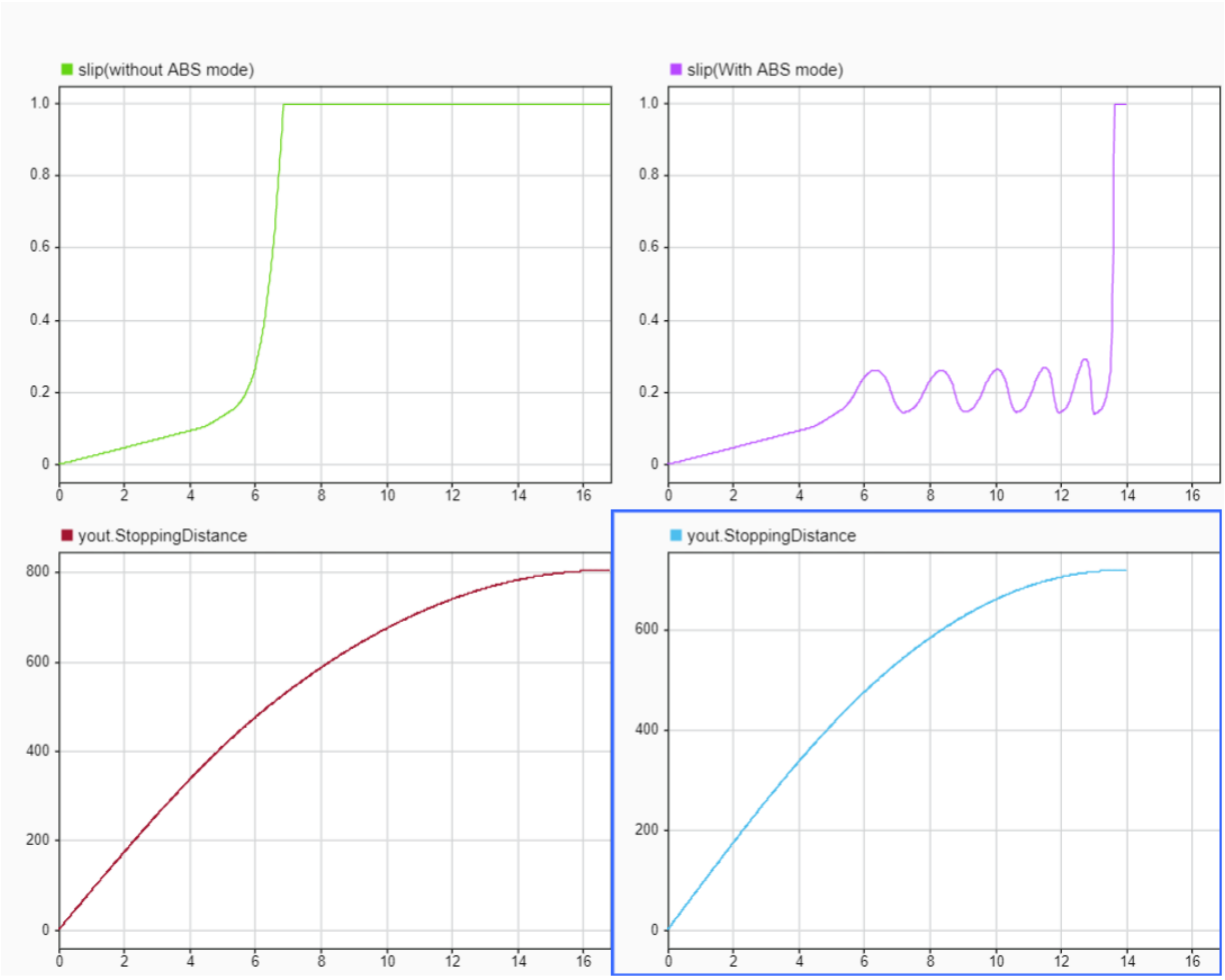

Figure 7: With and without ABS slip and Stopping distance

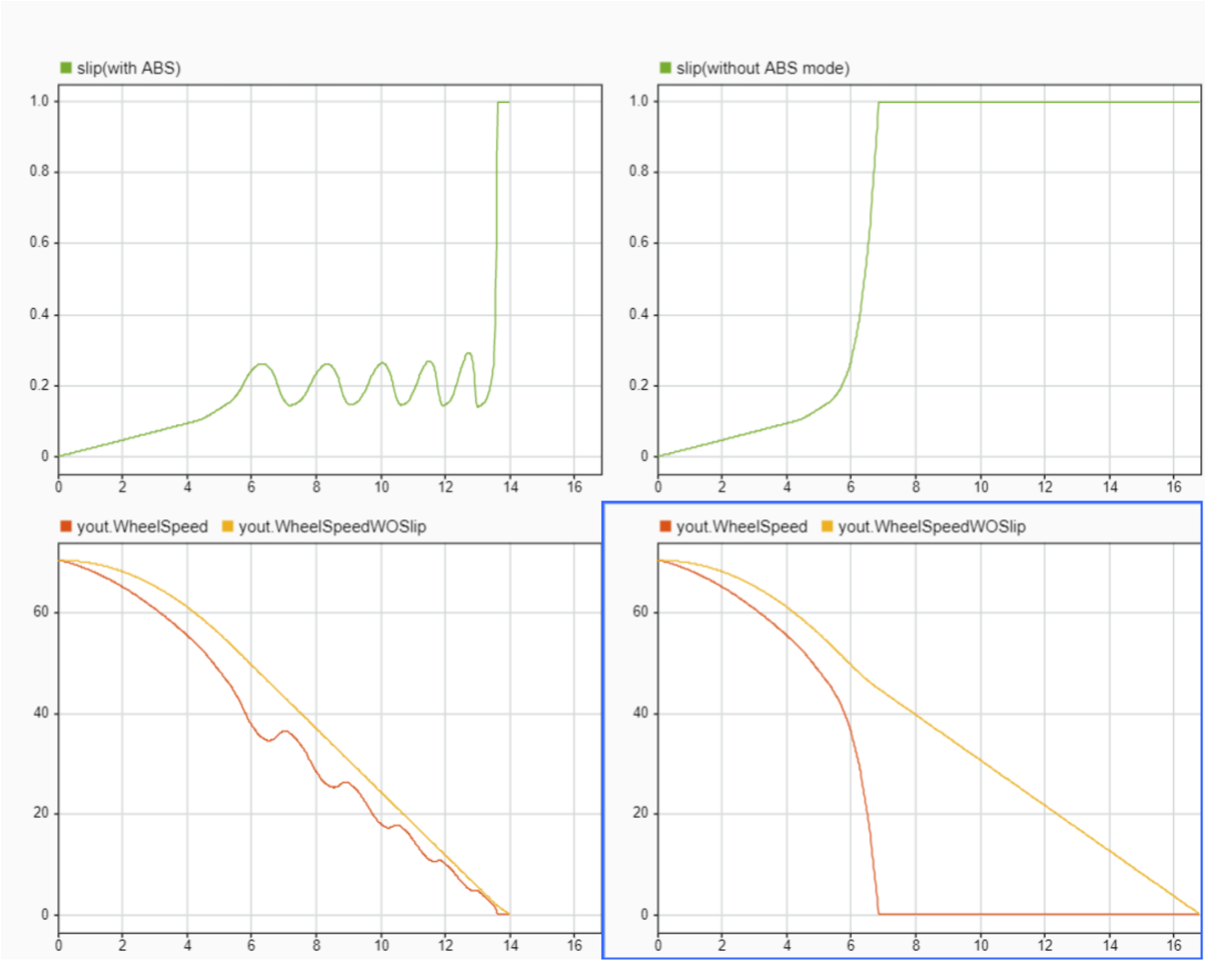

Figure 8: Wheel and Vehicle speed for with and without ABS

Conclusion:

Anti-Lock braking system modelled and response of the system with and without ABS observed. It is seen that with ABS the stopping distance is reduced and stability and steerability improved during braking.

Reference: MathWorks