

**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.

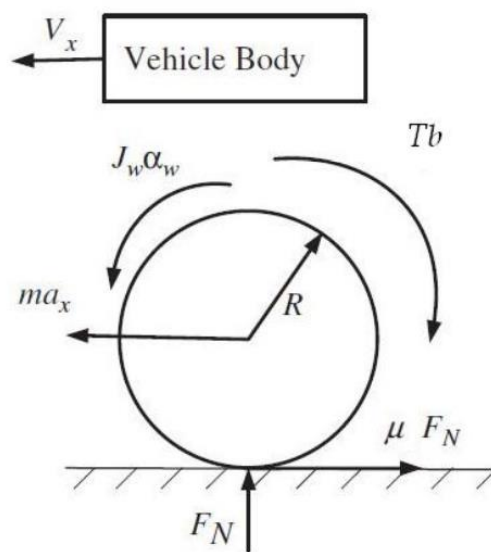
**Mathematical Modelling:**

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)

$$m a_x = -\mu F_N \Rightarrow m \frac{dV_x}{dt} = -\mu F_N \quad (1)$$

Summing torque at wheel centre (wheel)

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

For convenience a slip ratio is defined according to:

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

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

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

The nomenclature in above equations is presented as follows

$V_x$  = linear velocity of vehicle

$a_x$  = linear acceleration of vehicle

$\omega$  = rotational speed of wheel

$\alpha_\omega$  = angular acceleration of wheel

$T_b$  = braking torque

$\mu$  = friction coefficient

$R$  = radius of tire  $m$  = mass of the model

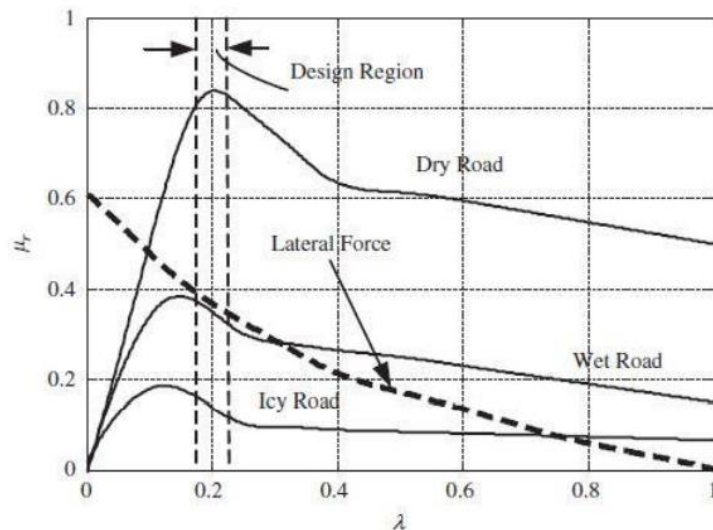


Figure 2: Frictional Coefficient of Road Surface v/s Wheel Slip Ratio



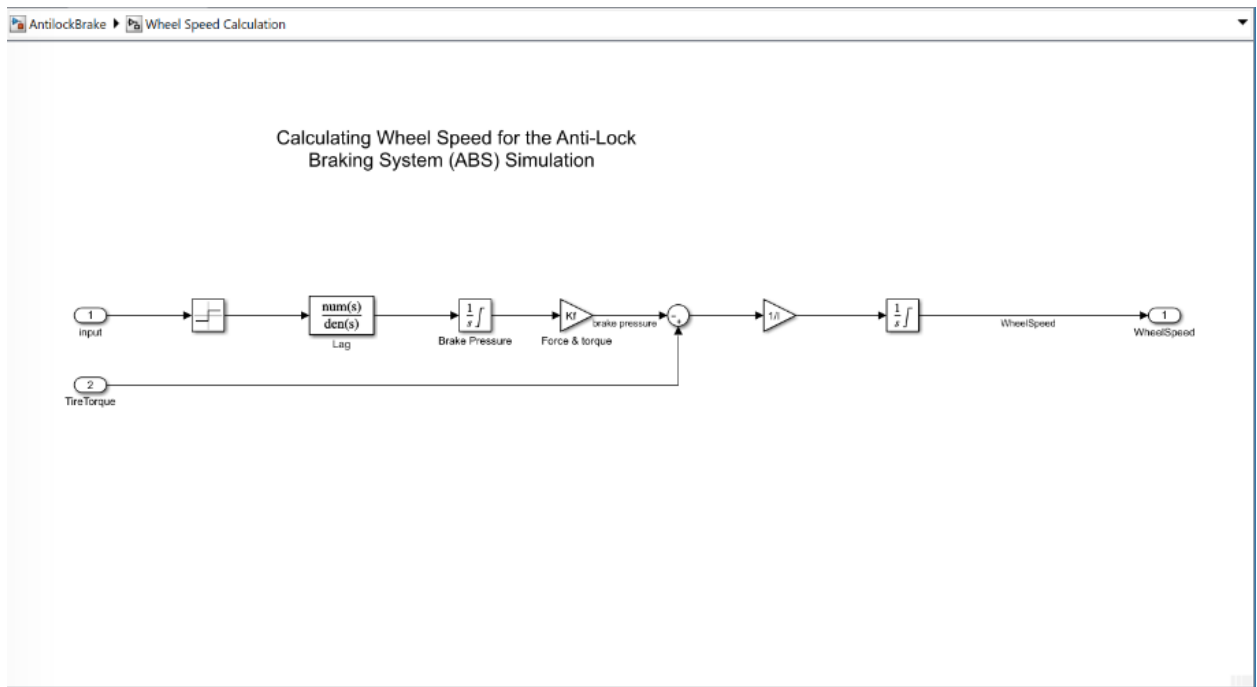


Figure 4: Subsystem for calculating wheel speed

The image shows a MATLAB Function block in the Simulink environment. The function is named "MATLAB Function for Relative Slip" and is defined as follows:

```

function y = fcn(u)
1
2
3   y = 1.0-u(1)/(u(2) + (u(2)==0)*eps);
4

```

The function takes an input vector  $u$  and calculates the relative slip  $y$  using the formula:  $y = 1.0 - u(1) / (u(2) + (u(2) == 0) * \text{eps})$ . The output  $y$  is assigned to the variable  $y$ .

Figure 5: MATLAB Function block statement to Calculate Relative Slip

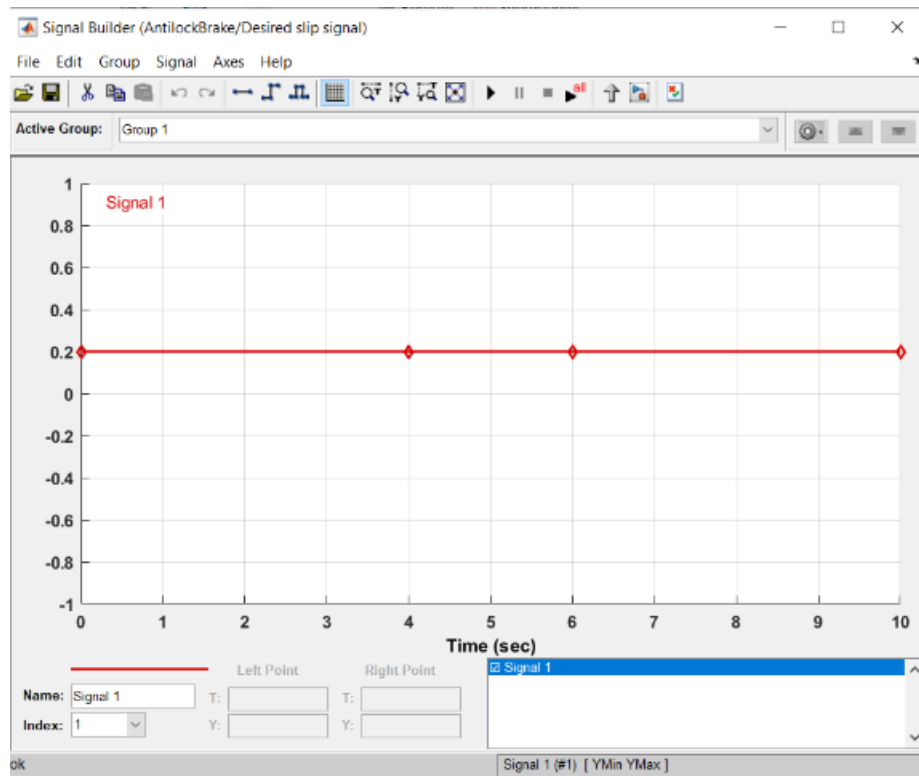


Figure 6: Signal Builder (for desired slip i.e. 0.2)

### 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

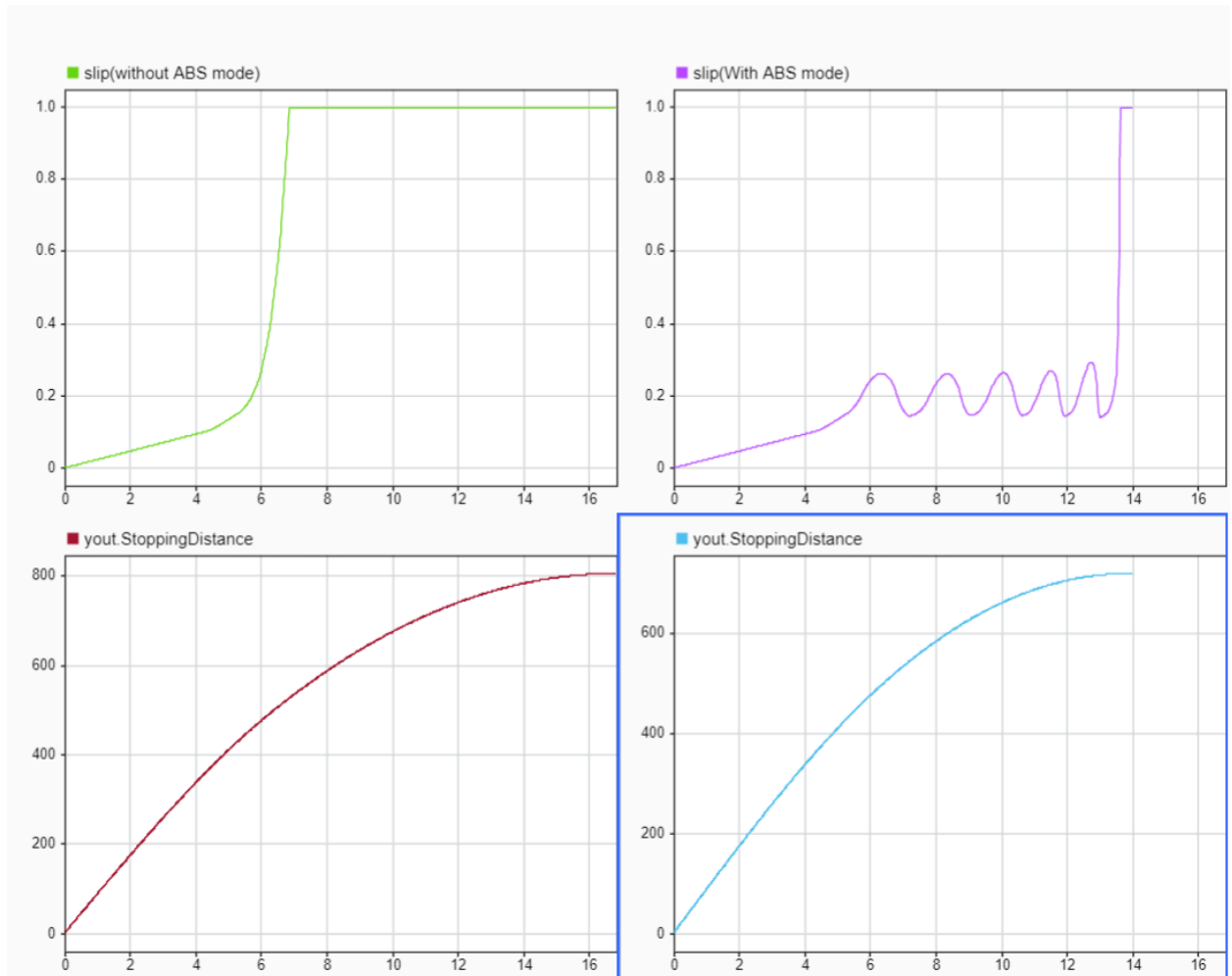


Figure 7: With and without ABS slip and Stopping distance

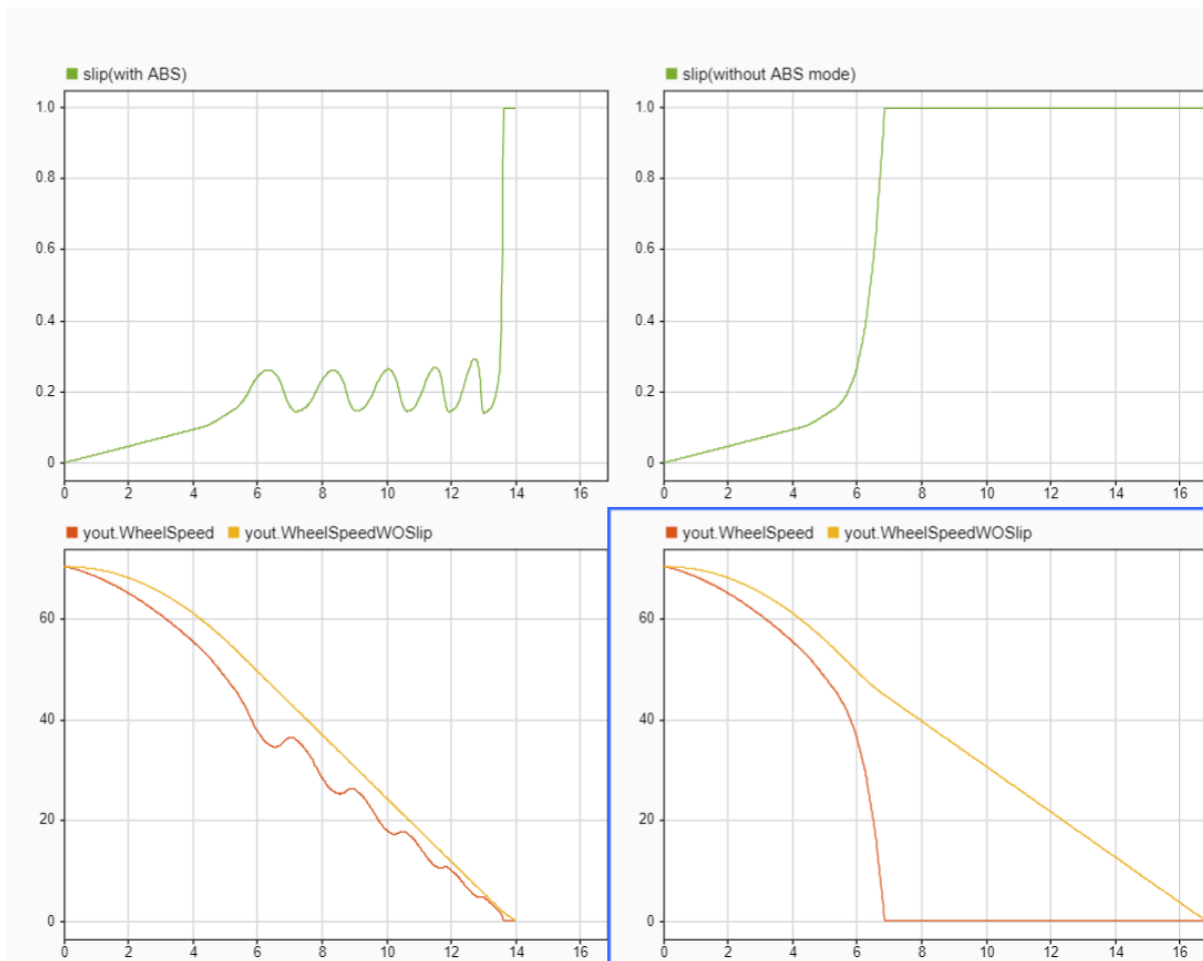


Figure 8: Wheel and Vehicle speed for with and without ABS

### 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.

### Github link:

[https://github.com/BiditaPaul/MBD\\_03\\_ABS.git](https://github.com/BiditaPaul/MBD_03_ABS.git)

Reference: MathWorks