Antilock Braking System

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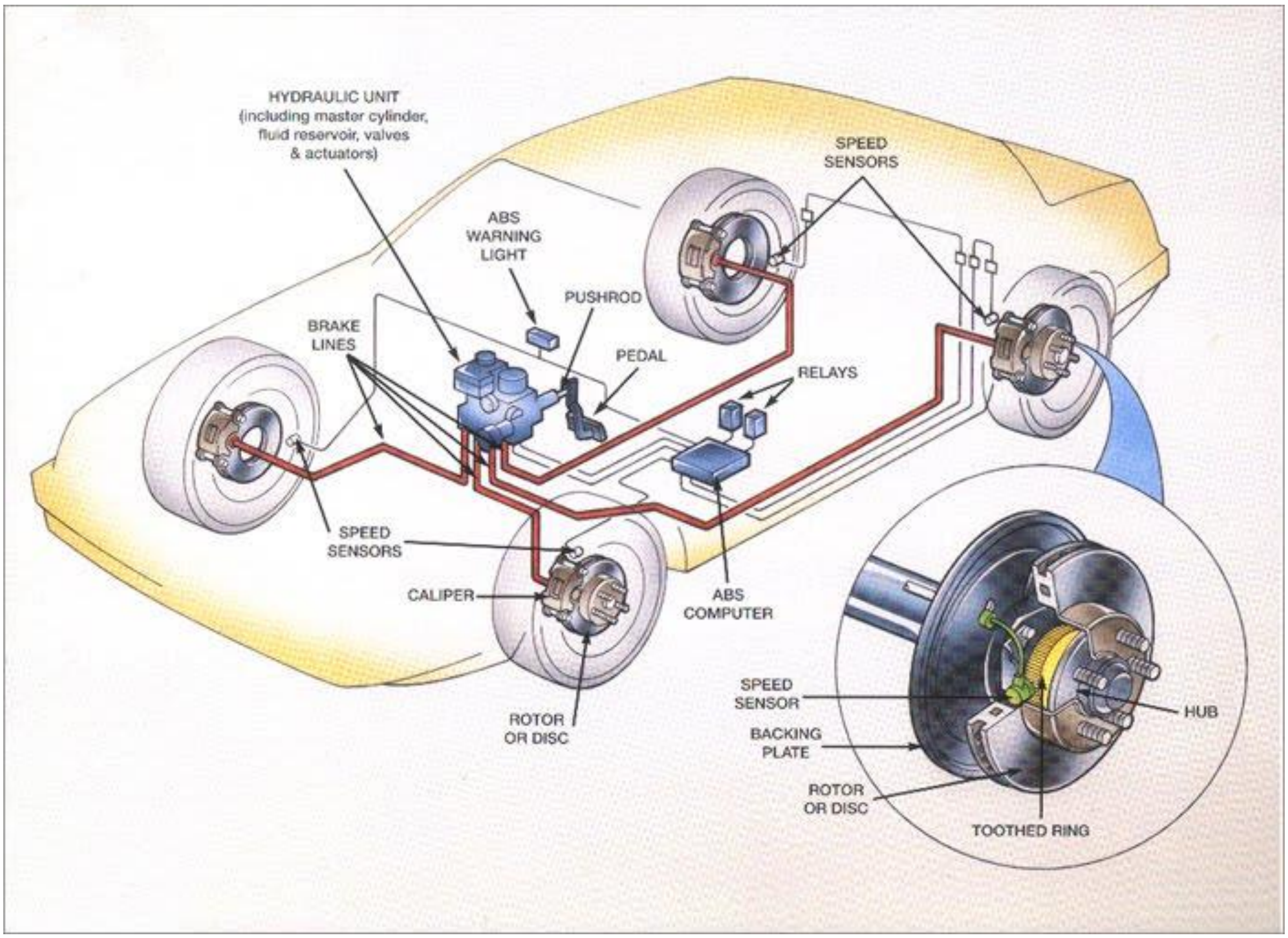
1. Introduction

ABS or an Anti-Lock Braking System is a piece of safety equipment that prevents the wheels of a vehicle from locking up under emergency, panic, or harsh braking conditions. Thanks to the latest safety regulations, nearly all four and two-wheelers nowadays come with an ABS. In case of sudden braking, there is a possibility of an immediate loss of traction between the tyres and the road surface. This can cause tyres to skid. The situation becomes worse when all this happens uncontrollably. In such a case, the vehicle continues to be in motion, and the loss of grip may result in the driver or the rider losing control over the steering of the vehicle. This may, in turn, lead to an accident. That’s where an ABS comes to the rescue!

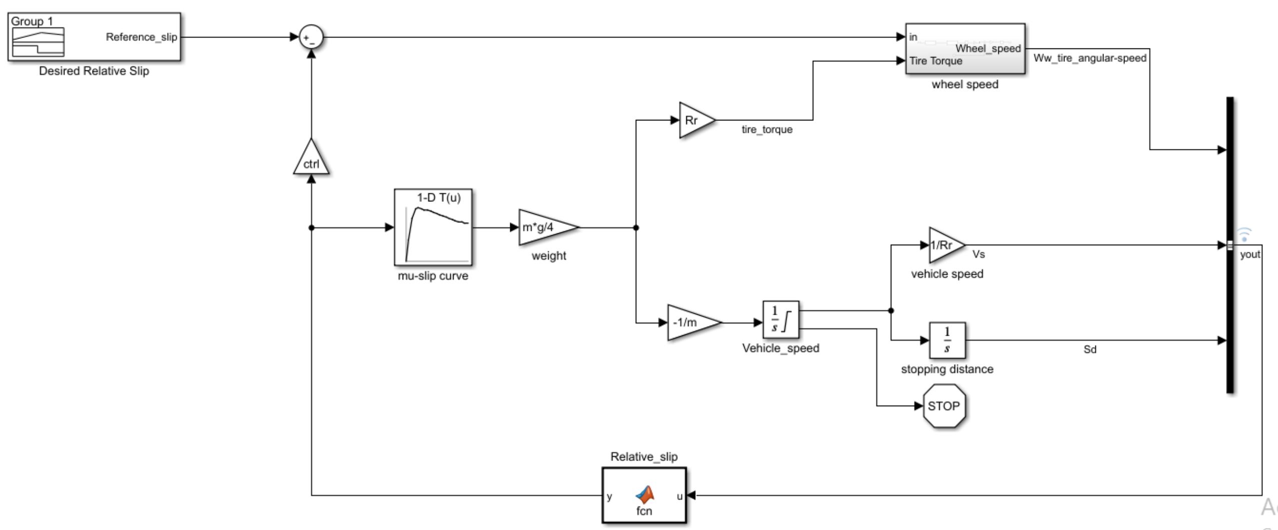


Antilock Braking System

2. Modeling ABS in Simulink

This is a simple model for an Anti-Lock Braking System (ABS). It simulates the dynamic behavior of a vehicle under hard braking conditions. The model represents a single wheel, which may be replicated a number of times to create a model for a multi-wheel vehicle.

In this model, the wheel speed is calculated in a separate model named wheel speed.



3. Analysis and Physics

The wheel rotates with an initial angular speed that corresponds to the vehicle speed before the brakes are applied. We used separate integrators to compute wheel angular speed and vehicle speed. We use two speeds to calculate slip, which is determined by Equation 1. Note that we introduce vehicle speed expressed as an angular velocity.

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

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

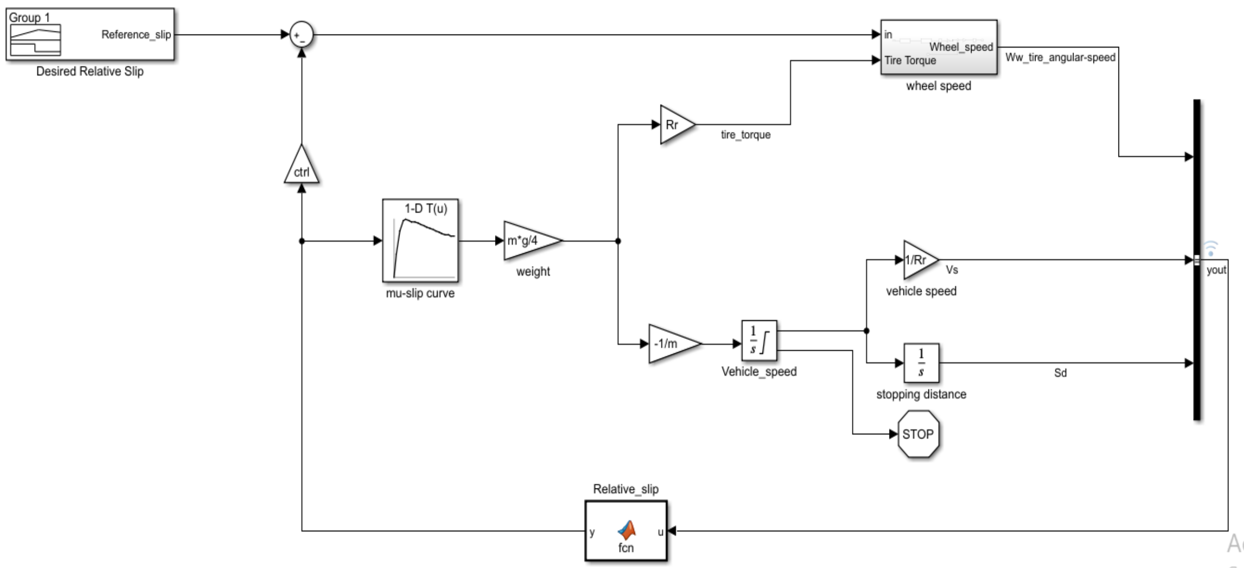
$R_r =$ wheel radius

From these expressions, we see that slip is zero when wheel speed and vehicle speed are equal, and slip equals one when the wheel is locked. A desirable slip value is 0.2, which means that the number of wheel revolutions equals 0.8 times the number of revolutions under non-braking conditions with the same vehicle velocity. This maximizes the adhesion between the tire and road and minimizes the stopping distance with the available friction.

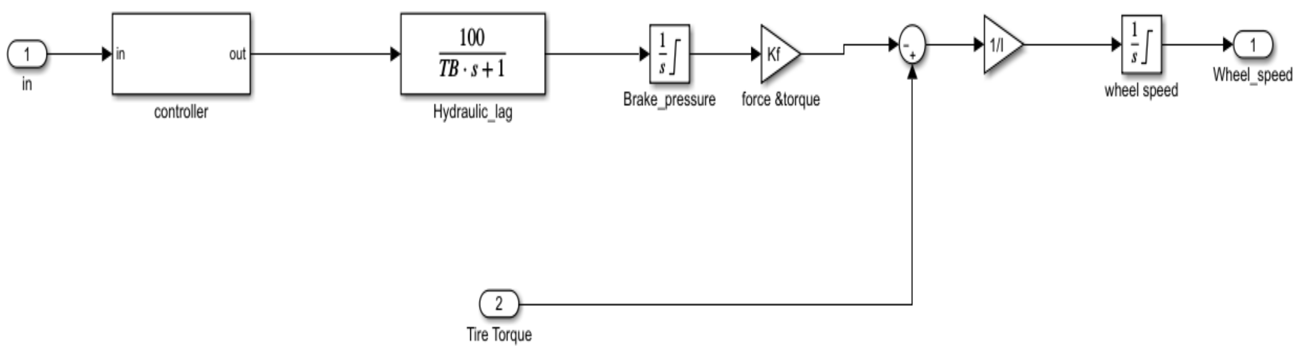
Modeling

The friction coefficient between the tire and the road surface, mu, is an empirical function of slip, known as the mu-slip curve. We created mu-slip curves by passing MATLAB variables into the block diagram using a Simulink lookup table. The model multiplies the friction coefficient, mu, by the weight on the wheel, W, to yield the frictional force, Ff, acting on the circumference of the tire. Ff is divided by the vehicle mass to produce the vehicle deceleration, which the model integrates to obtain vehicle velocity.

In this model, we used an ideal anti-lock braking controller that uses 'bang-bang' control based upon the error between actual slip and desired slip. We set the desired slip to the value of slip at which the mu-slip curve reaches a peak value, this being the optimum value for minimum braking distance.



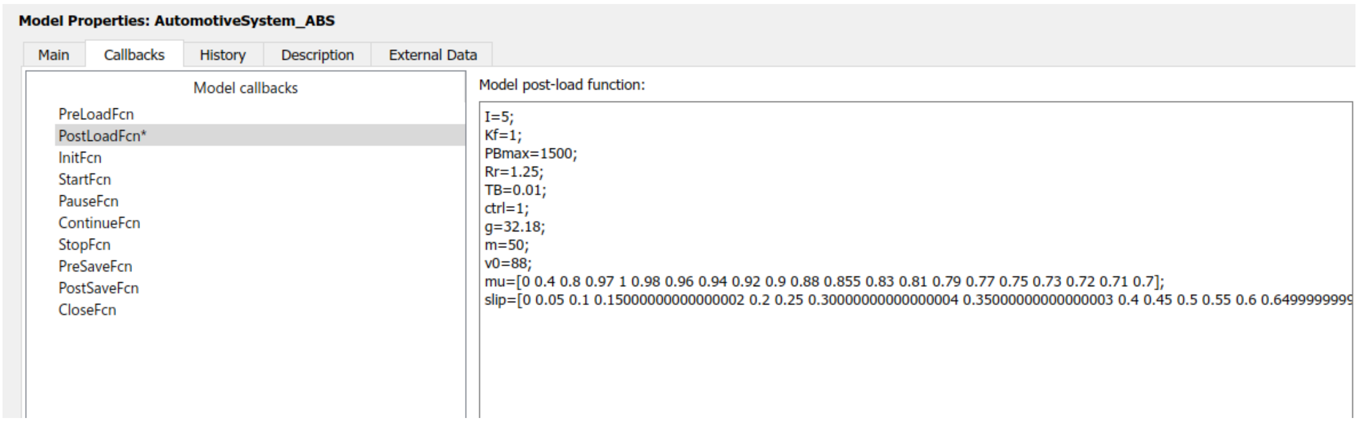
Wheel Speed subsystem:



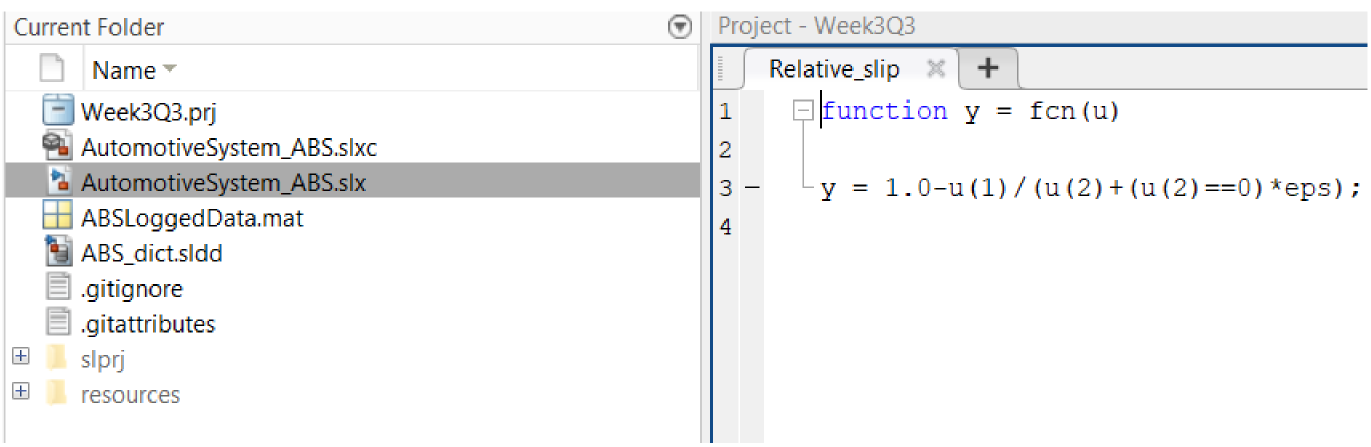
4. Key Factors in model

➢ Callback function:

In this model postload callback function is used.

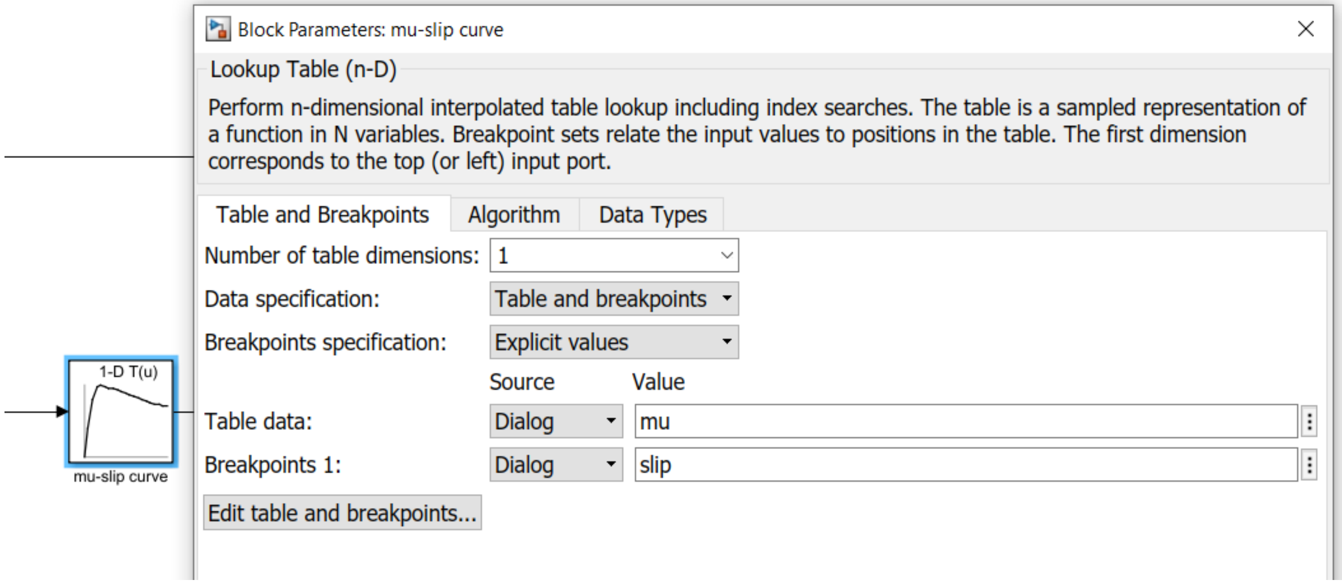


➢ Matlab Function Block:



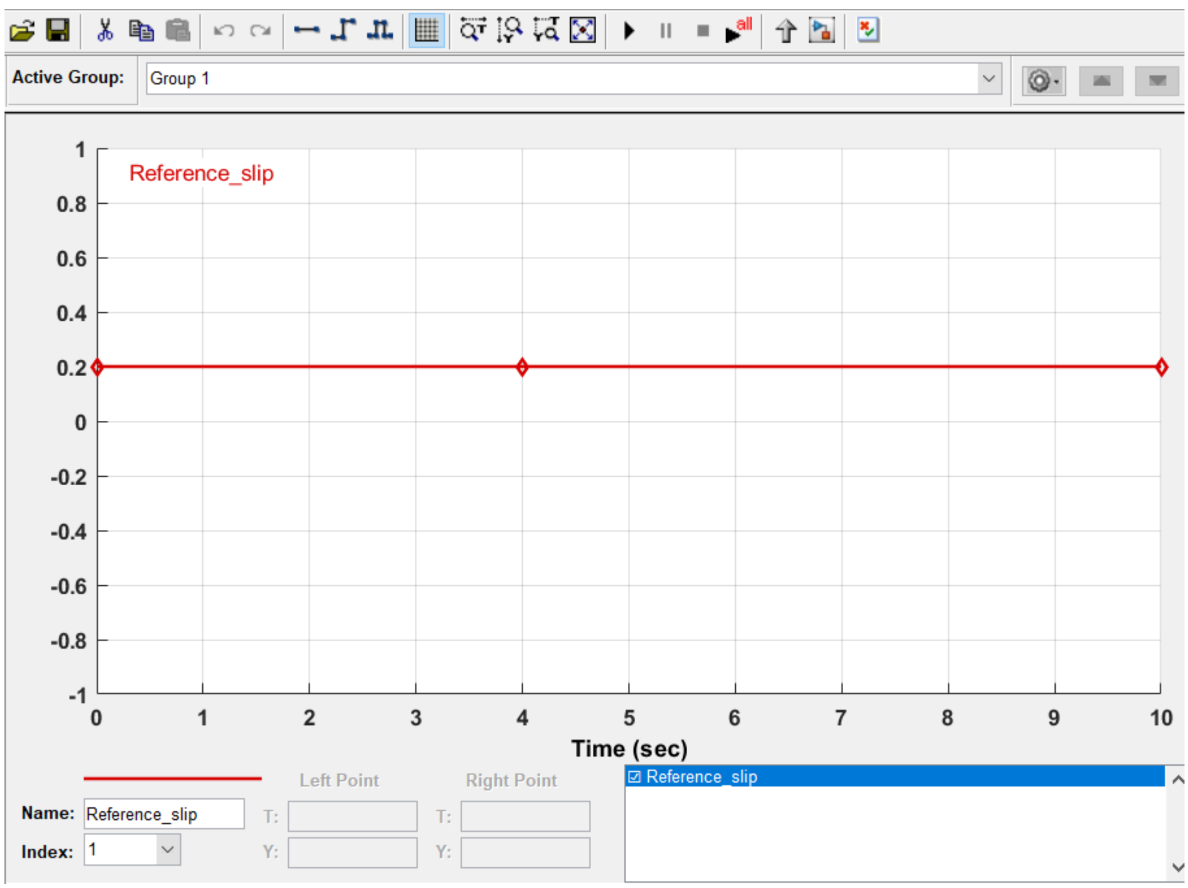
➢ Look-up Table

In this model mu and slip is values are taken into the look-up(1-D) table



➢ Signal Builder

Signal builder is used to generate the desired relative slip which is 0.2



➢ Solver selection

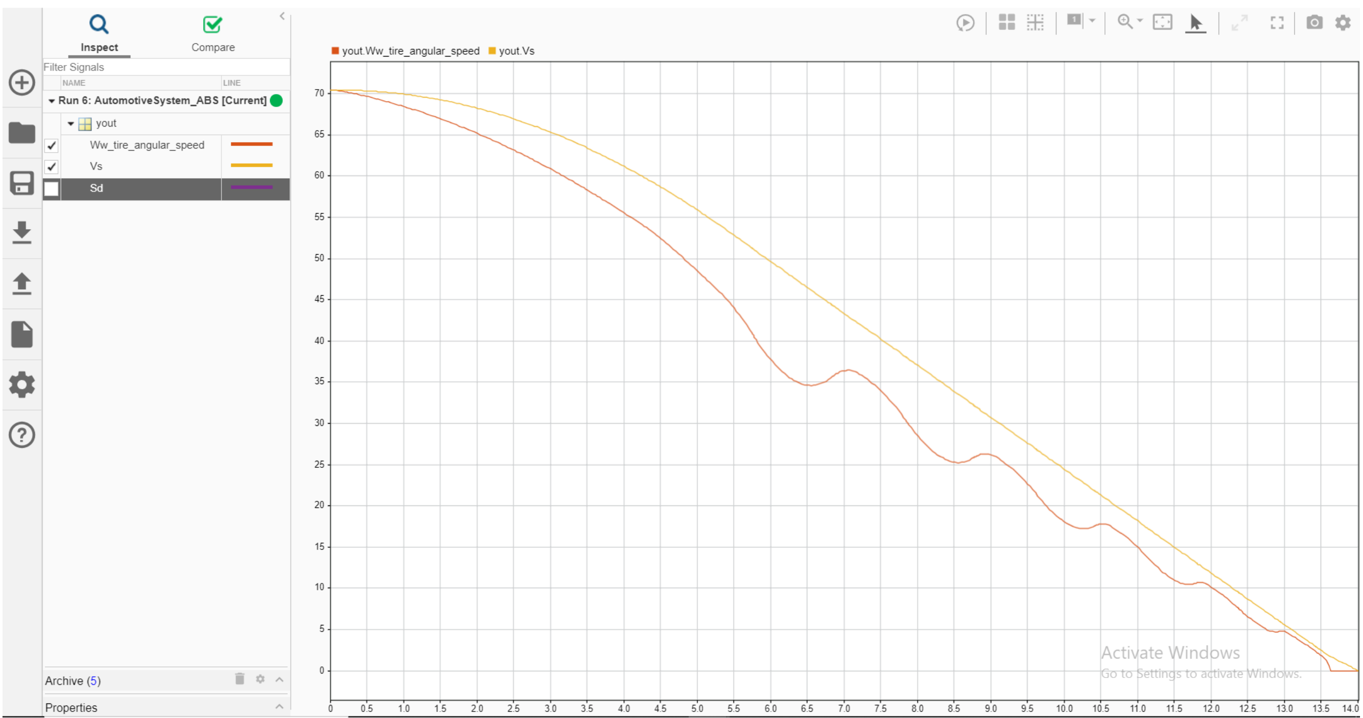
Model uses a variable step solver, so Simulink will track zero-crossings in the model.

Ode45 i.e. Runge-Kutta solver is used as it's accuracy is medium to high.

➢ Data Inspector

The output yout is logged in data inspector.

Graph of vehicle speed and wheel speed



Graph of skidding distance