An anti-lock braking system (ABS) is a safety anti-skid braking system used on aircraft and on land vehicles, such as cars, motorcycles, trucks, and buses. ABS operates by preventing the wheels from locking up during braking, thereby maintaining tractive contact with the road surface and allowing the driver to maintain more control over the vehicle.

This model uses the signal logging feature in Simulink.

In this model, the wheel speed is calculated in a separate mode. This component is then referenced using a Model block. Note that both the top model and the referenced model use a variable step solver, so Simulink will track zero-crossings in the referenced model.

**Equations for Wheel Slip**

The following equations can be used to define the wheel’s slip:

The wheel rotates with an initial angular speed that corresponds to the vehicle speed before the brakes are applied.

Slip=

= vehicle speed divided by wheel radius

= vehicle linear velocity

= wheel radius

= wheel angular velocity

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.

**Wheel Speed Subsystem**

The friction coefficient between the tire and the road surface, mu, is an empirical function of slip, known as the mu-slip curve. Mu-slip curves are created sby 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, an ideal anti-lock braking controller, that uses 'bang-bang' control based upon the error between actual slip and desired slip is used. The desired slip is set to the value of slip at which the mu-slip curve reaches a peak value, this being the optimum value for minimum braking distance.

To control the rate of change of brake pressure, the model subtracts actual slip from the desired slip and feeds this signal into a bang-bang control (+1 or -1, depending on the sign of the error, see Figure 2). This on/off rate passes through a first-order lag that represents the delay associated with the hydraulic lines of the brake system. The model then integrates the filtered rate to yield the actual brake pressure. The resulting signal, multiplied by the piston area and radius with respect to the wheel (Kf), is the brake torque applied to the wheel.

The model multiplies the frictional force on the wheel by the wheel radius (Rr) to give the accelerating torque of the road surface on the wheel. The brake torque is subtracted to give the net torque on the wheel. Dividing the net torque by the wheel rotational inertia, I, yields the wheel acceleration, which is then integrated to provide wheel velocity. In order to keep the wheel speed and vehicle speed positive, limited integrators are used in this model.