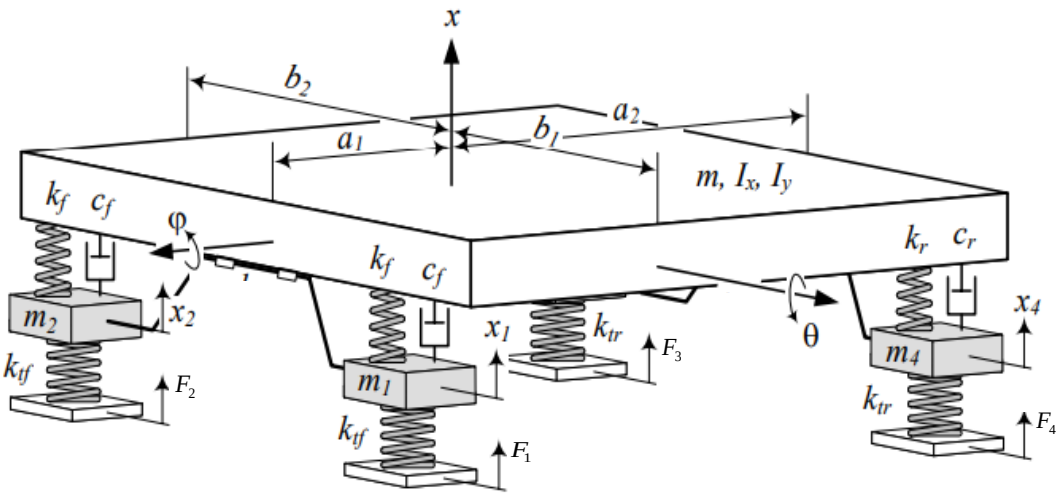
Full Car Model



$$
\begin{aligned}
y_0 &= x \\
\dot{y}_0 &= \dot{x} = y_1 \\
\dot{y}_1 &= \ddot{x} \\
y_2 &= \varphi \\
\dot{y}_2 &= \dot{\varphi} = y_3 \\
\dot{y}_3 &= \ddot{\varphi} \\
y_4 &= \theta \\
\dot{y}_4 &= \dot{\theta} = y_5 \\
\dot{y}_5 &= \ddot{\theta} \\
y_6 &= x_1 \\
\dot{y}_6 &= \dot{x}_1 = y_7 \\
\dot{y}_7 &= \ddot{x}_1
\end{aligned}
\qquad
\begin{aligned}
y_8 &= x_2 \\
\dot{y}_8 &= \dot{x}_2 = y_9 \\
\dot{y}_9 &= \ddot{x}_2 \\
y_{10} &= x_3 \\
\dot{y}_{10} &= \dot{x}_3 = y_{11} \\
\dot{y}_{11} &= \ddot{x}_3 \\
y_{12} &= x_4 \\
\dot{y}_{12} &= \dot{x}_4 = y_{13} \\
\dot{y}_{13} &= \ddot{x}_4
\end{aligned}
$$

$$\dot{y}_0 = y_1$$

$$
\begin{aligned}
m\dot{y}_1 = &-c_f\left(y_1 - y_7 + b_1 y_3 - a_1 y_5\right) - c_f\left(y_1 - y_9 - b_2 y_3 - a_1 y_5\right) \\
&- c_r\left(y_1 - y_{11} - b_1 y_3 + a_2 y_5\right) - c_r\left(y_1 - y_{13} + b_2 y_3 + a_2 y_5\right) \\
&- k_f\left(y_0 - y_6 + b_1 y_2 - a_1 y_4\right) - k_f\left(y_0 - y_8 - b_2 y_2 - a_1 y_4\right) \\
&- k_r\left(y_0 - y_{10} - b_1 y_2 + a_2 y_4\right) - k_r\left(y_0 - y_{12} + b_2 y_2 + a_2 y_4\right)
\end{aligned}
$$

$$\dot{y}_2 = y_3$$

$$I_x\,\dot{y}_3 = -b_1\,c_f\,(y_1 - y_7 + b_1\,y_3 - a_1\,y_5) + b_2\,c_f\,(y_1 - y_9 - b_2\,y_3 - a_1\,y_5)$$
$$+ b_1\,c_r\,(y_1 - y_{11} - b_1\,y_3 + a_2\,y_5) - b_2\,c_r\,(y_1 - y_{13} + b_2\,y_3 + a_2\,y_5)$$
$$- b_1\,k_f\,(y_0 - y_6 + b_1\,y_2 - a_1\,y_4) + b_2 k_f\,(y_0 - y_8 - b_2\,y_2 - a_1\,y_4)$$
$$+ b_1 k_r\,(y_0 - y_{10} - b_1\,y_2 + a_2\,y_4) - b_2\,k_r\,(y_0 - y_{12} + b_2\,y_2 + a_2\,y_4)$$

$$\dot{y}_4 = y_5$$

$$I_y\,\dot{y}_5 = +a_1\,c_f\,(y_1 - y_7 + b_1\,y_3 - a_1\,y_5) + a_1\,c_f\,(y_1 - y_9 - b_2\,y_3 - a_1\,y_5)$$
$$- a_2\,c_r\,(y_1 - y_{11} - b_1\,y_3 + a_2\,y_5) - a_2\,c_r\,(y_1 - y_{13} + b_2\,y_3 + a_2\,y_5)$$
$$+ a_1\,k_f\,(y_0 - y_6 + b_1\,y_2 - a_1\,y_4) + a_1 k_f\,(y_0 - y_8 - b_2\,y_2 - a_1\,y_4)$$
$$- a_2 k_r\,(y_0 - y_{10} - b_1\,y_2 + a_2\,y_4) - a_2\,k_r\,(y_0 - y_{12} + b_2\,y_2 + a_2\,y_4)$$

$$\dot{y}_6 = y_7$$

$$m_f\,\dot{y}_7 = +c_f\,(y_1 - y_7 + b_1\,y_3 - a_1\,y_5) + k_f\,(y_0 - y_6 + b_1\,y_2 - a_1\,y_4)$$
$$- k_{tf}\,(y_6 - F_1)$$

$$\dot{y}_8 = y_9$$

$$m_f\,\dot{y}_9 = +c_f\,(y_1 - y_9 - b_2\,y_3 - a_1\,y_5) + k_f\,(y_0 - y_8 - b_2\,y_2 - a_1\,y_4)$$
$$- k_{tf}\,(y_8 - F_2)$$

$$\dot{y}_{10} = y_{11}$$

$$m_r\,\dot{y}_{11} = +c_r\,(y_1 - y_{11} - b_1\,y_3 + a_2\,y_5) + k_r\,(y_0 - y_{10} - b_1\,y_2 + a_2\,y_4)$$
$$- k_{tr}\,(y_{10} - F_3)$$

$$\dot{y}_{12} = y_{13}$$

$$m_r\,\dot{y}_{13} = +c_r\,(y_1 - y_{13} + b_2\,y_3 + a_2\,y_5) + k_r\,(y_0 - y_{12} + b_2\,y_2 + a_2\,y_4)$$
$$- k_{tr}\,(y_{12} - F_4)$$