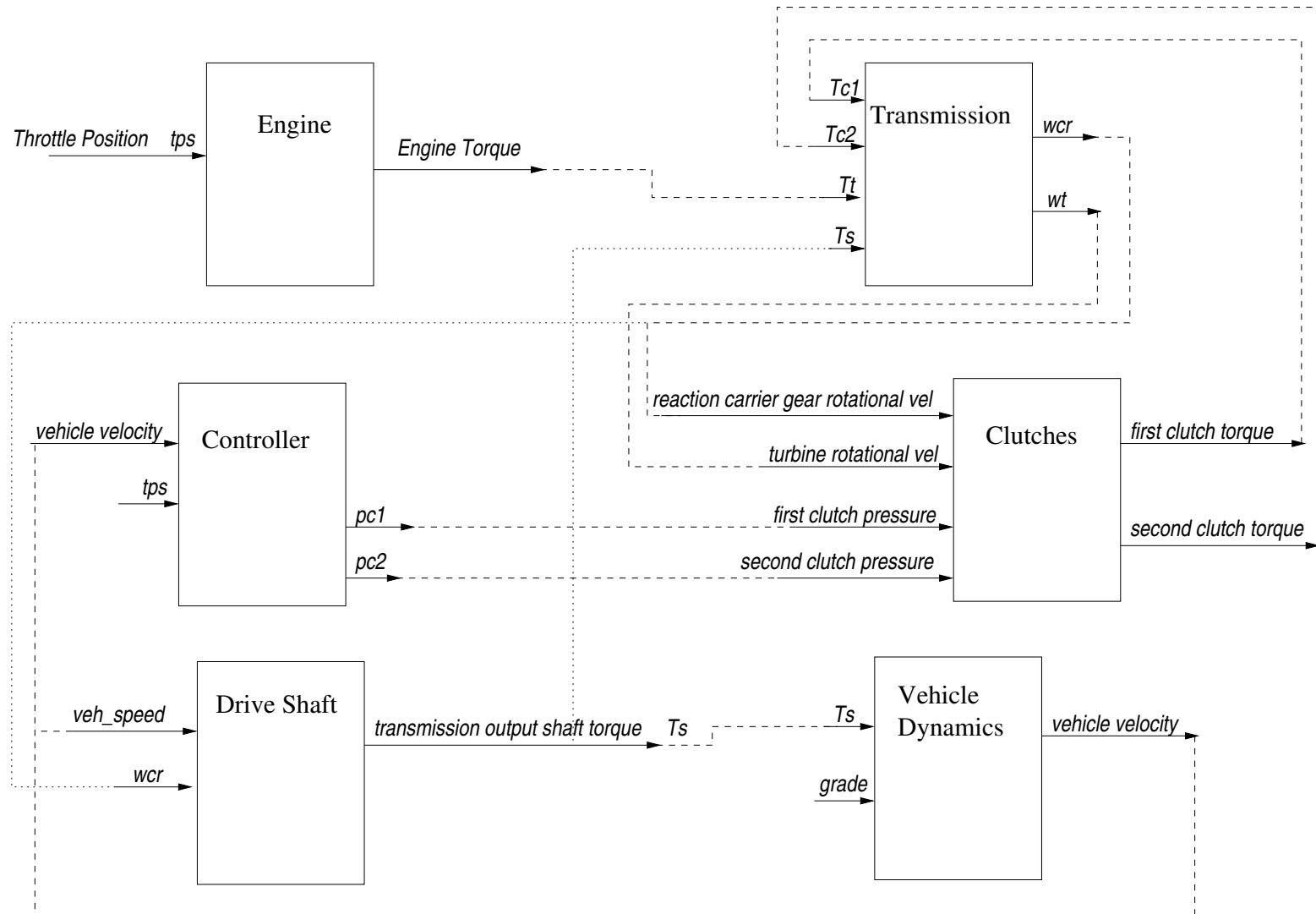


## Powertrain

**Modified version** of the model described in:

- Alongkrit Chutinan and Kenneth R. Butts. Dynamic Analysis of Hybrid System Models for Design Validation. *SmartVehicle baseline report*. In support of the University of California Open Experimental Platform for DARPA-MoBIES. Ford Motor Company.
- Kenneth R. Butts. *SmartVehicle* challenge problems. In <http://vehicle.me.berkeley.edu/mobies/>, 2001

# Powertrain Model



## Powertrain Model

Formal model in both **Matlab** and **HybridSAL**

Matlab model can be used to simulate the powertrain with different choices for **throttle position**  $tps$  and road **grade**

**Verification property:** For a fixed grade in  $[0, 0.1]$  and fixed throttle in  $[0, 100]$ , there is no 2 — 1 — 2 gear change sequence

Matlab can “**verify**” this property for fixed  $tps$  and  $grade$

HybridSAL can be used to analyze it for the **whole range**

## Powertrain Model Facts

The model is described using **20 real variables**

But most are definitions and the system can be formally modeled as a **five dimensional hybrid system**

The continuous dynamics are mostly **linear**, with just one **nonlinearity**

Numerical simulations are sensitive to changes in **step size**, and can be **misleading**

## Powertrain Simulation Plots

Included here are simulation plots generated using the powertrain model for three different scenarios:

In all scenarios, car is moving on a road with constant grade with the throttle at a constant position

**Scenario 1** : tps = 10%, grade = 0

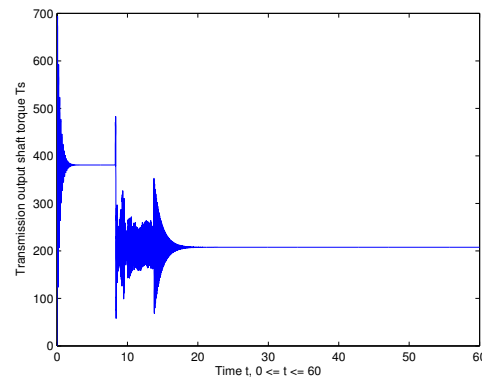
**Scenario 2** : tps = 50%, grade = 0.1 radians

**Scenario 3** : tps = 80%, grade = 0.2 radians

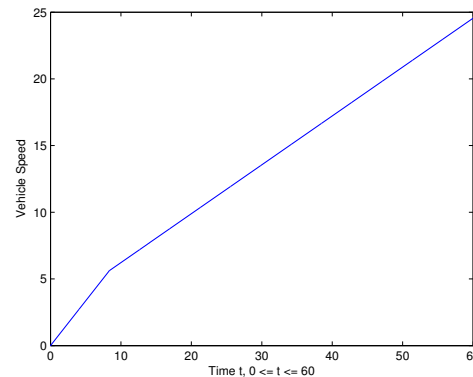
The last scenario is simulated twice: once with step size 0.001s, and then with step size 0.0005s. The first two scenarios are simulated with step size 0.001s.

## Powertrain Simulation Plots: $\text{tps}=10\%$ , $\text{grade}=0$

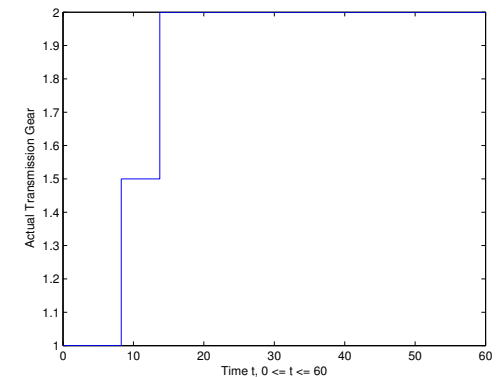
Transmission Torque



Vehicle Speed



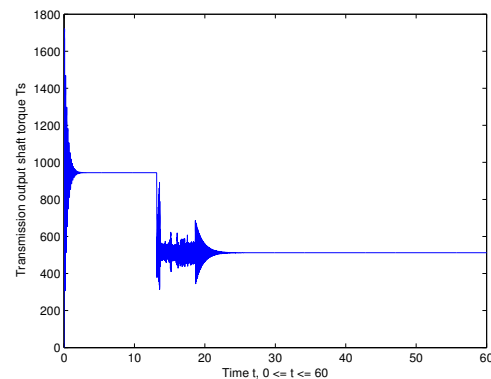
Gear



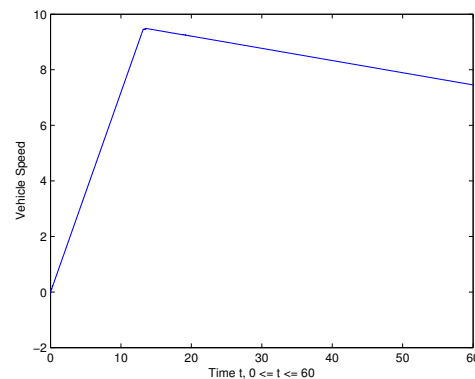
Gear change from 1st to 2nd at around 10s.

## Powertrain Simulation Plots: tps=50%,grade=0.1

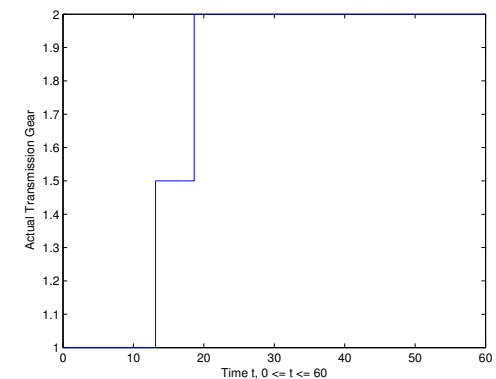
Transmission Torque



Vehicle Speed



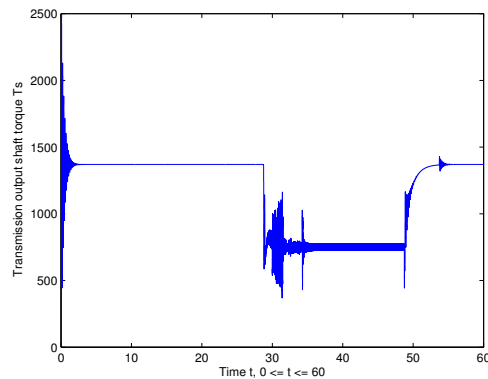
Gear



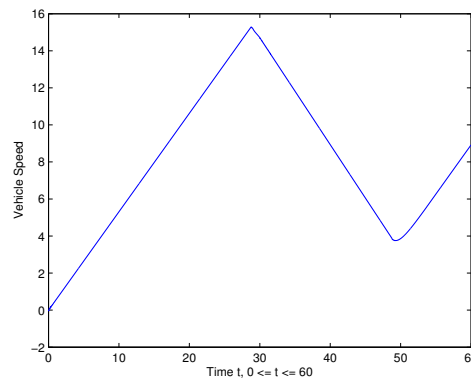
Gear change from 1st to 2nd at around 12s.

## Powertrain Simulation Plots: $\text{tps}=80\%$ , $\text{grade}=0.2$

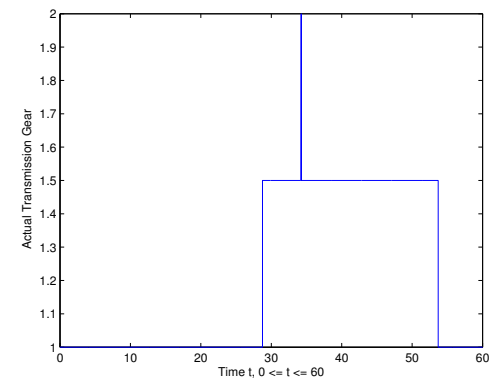
Transmission Torque



Vehicle Speed



Gear

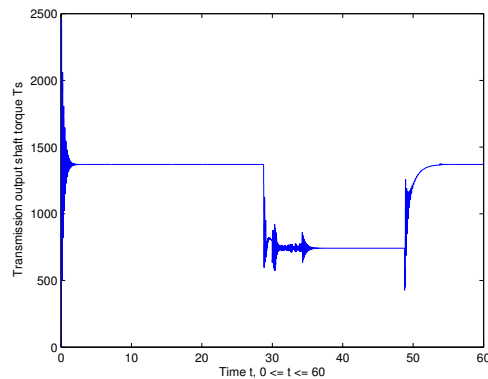


Gear change from 1st to 2nd at around 30s and an (incorrect) elongated back switch to 1st at 40–50s.

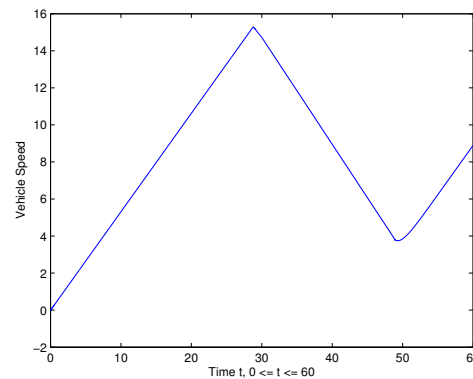


## Powertrain Simulation Plots: $\text{tps}=80\%$ , $\text{grade}=0.2$

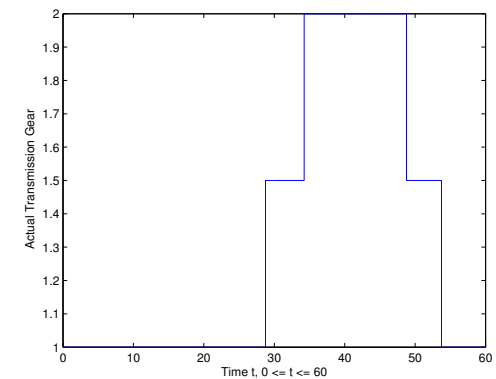
Transmission Torque



Vehicle Speed



Gear



Gear change from 1st to 2nd at around 30s and correctly switching back to 1st at 50+s.