MECH545 - Hybrid Electric Vehicle Propulsion
Project 08 EREV Acceleration Model (Simulink)
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<u>HEV Objective:</u> The purpose of this project is to determine the acceleration performance of the 2017 Audi Q7 with the UMQ motor used in Project 07.

<u>Matlab/Simulink Objectives:</u> In this project you will learn: (a) how to solve a first order differential equation using Simulink, and (b) how to use a ‘Relational Operator’ block to stop the simulation when a specified condition is reached.

<u>Background:</u> The acceleration performance of the baseline vehicle has been tested. A summary of the results is provided in Table 1. The converted vehicle should have performance values similar (or better) than the baseline vehicle.

Table 1 Measured Performance of Baseline Vehicle

Configuration	Combined Power	0-60 mph[1]	35-70 mph[2]	Top Speed
Base Vehicle[3]	300 kW (400 hp)	6.8 s	6.3 s	205 kph (128 mph)

<u>Assignment:</u> Develop a Simulink model for predicting the acceleration performance of an electric vehicle. An outline for your model is provided in Figure 1.

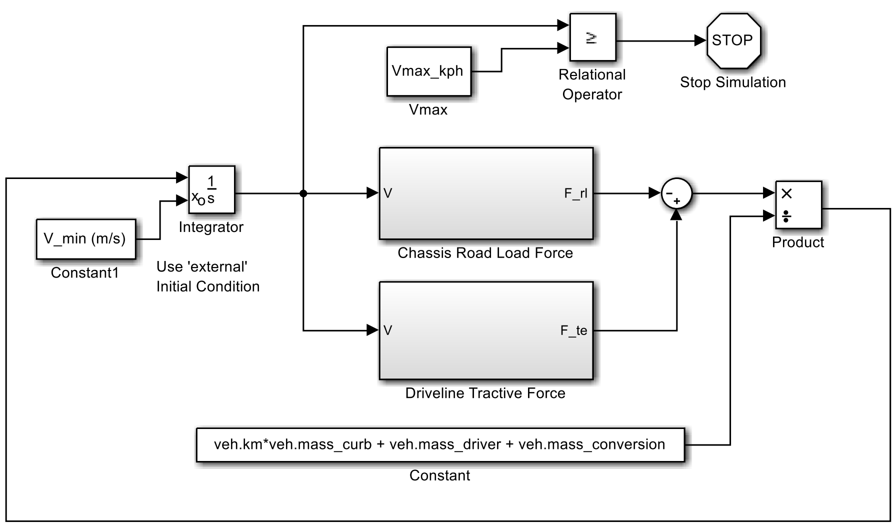

Figure 1 Outline for an EV acceleration model

The ‘Relational Operator’ at the top of the model shown in Figure 1 is used the stop the simulation when a set velocity condition is met; for example, when the vehicle speed reaches 100 kph.

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[1] A measure of overall acceleration performance
[2] A measure of passing performance
[3] http://www.automobile-catlog.com

Recall that this proposed vehicle is equipped with a two-speed transmission and the following parameters have been specified:

Axle Ratio and Efficiency: R_a = 2.29, η_a = 0.95,

First Gear Ratio and Efficiency: $R_{t,1}$ = 5.0, η_t = 0.95,

Second Gear Ratio and Efficiency: $R_{t,2}$ = 2.5, η_t = 0.95,

Inertia Factor: k_m = 1.15,

Tires: r_r = 381 mm, μ_{peak} = 0.95

Vehicle Mass = curb mass + driver mass + 225 kg

Also recall that a lower-cost, single-speed gearbox is also being considered with:

Gear Ratio and Efficiency: $R_{t,1\text{-}spd}$ = 3.5, η_t = 0.95,

Part 1: Determine the effect of the transmission ratio on vehicle performance.

Use your model to complete Table 2. Also provide a plot of a vehicle speed vs. time plot, with all three options on a single plot[4]. Remember that we are using 2 x 100 kW motors.

Table 2 Predicted Performance of Converted Vehicle with Baseline Motor

Configuration	0-100 kph[5]	55-110 kph	Top Speed
$R_{t,1}$ = 5.0, η_t = 0.95			
$R_{t,2}$ = 2.5, η_t = 0.95			
$R_{t,1\text{-spd}}$ = 3.5, η_t = 0.95			

Suggestions for running your model:

- To determine the 0-100 kph time, set the model run time to 30 sec and set Vmin_kph = 0, Vmax_kph = 100.
- To determine the 55-110 kph time, set the model run time to 30 sec and set Vmin_kph = 55, Vmax_kph = 160.
- To determine the top speed, set Vmin_kph = 0, Vmax_kph = 300 and set the model run time to 60 sec.

Or simply run your model for 60 sec and use the data cursor to pick your answer. Note that a smaller time step will help improve the accuracy of your simulation.

Question: What does your analysis indicate about the available powertrain options?

Part 2: Determine the effect of a stronger motor on vehicle performance.

If you've solved Part 1 correctly, you should have noted problems with the proposed baseline motor. The disappointing results should not be surprising given that the original vehicle's rated combined power (300 kW) is greater than the power of the

[4] See handout "Using the Simulation Data Explorer" for a new method to do this.
[5] Note: 55 kph = 35 mph, 110 kph = 75 mph

baseline motors under consideration (2 x 100 kW). To scale up the motor power simply multiply the peak torque values (`mc.trq_max_map`) in the data file by the amount indicated in Table 3. An alternative approach is to multiply the number of motors by a factor; for instance, to make the motors 10% stronger, use number_motors = 2.0*1.10 = 2.2 motors.

Use your model to complete Table 3 using the one-speed transmission with the motor scaling factors indicated. The first option (x 1.25) brings the power of the motor higher (250 kW), but not to the level of the baseline vehicle's engine. The second option (x 1.50) is will bring the total power of the motor to equal the power of the engine (300 kW). Also provide a supporting figure. Comment on your results.

Table 3 Predicted Performance of Converted Vehicle with One-Speed Transmission ($R_{t,1\text{-}spd}$ = 3.5, η_t = 0.95) and Improved Motor

Configuration	0-100 kph	55-110 kph	Top Speed
Baseline Motor			
Baseline Motor x 1.25			
Baseline Motor x 1.50			

Question: What does your analysis indicate about the available powertrain options?

Notes:

- Watch your units!
- You may find that the Simulink Simulation Data Explorer is useful in completing this assignment. See the document *Using the Simulation Data Explorer* which is posted on Blackboard with the Project 08 materials.

<u>MECH-691Students (MECH-545 Students for Extra Credit)</u>

<u>Part 3:</u> Determine the effect of using a two-speed transmission on vehicle performance.

Modify your model to use a two-speed transmission with the shift controller from Project 07. First, calculate your answer based on the base motor power (2 x 100 kW). Second, how much bigger (as a percentage) does the motor need to be to achieve that same 0-100 kph time as the base vehicle

Table 4 Predicted Performance of Converted Vehicle with Two-Speed Transmission

Configuration	0-100 kph	0-160 kph	Top Speed
$R_{t,1\text{-}spd}$ = 3.5 (from above)			
Base motor			
Base motor x [1._____]			

Use your model to complete Table 4. Also provide a supporting figure. Comment on your results. Question: What does your analysis indicate about the available powertrain options?