Candidate Number: 13140

Task 1

Basic Attempt

Test 1.1.1

By looking at the scope of the distance plot of the Simulink model it was found that it takes 1 second before the distance value changes from zero. Using the plot window, the time taken to reach 75 meters was 2.906 seconds. Therefore, it took the car 1.906 seconds for the car to accelerate to 75 meters.

Time of acceleration = 1.906s

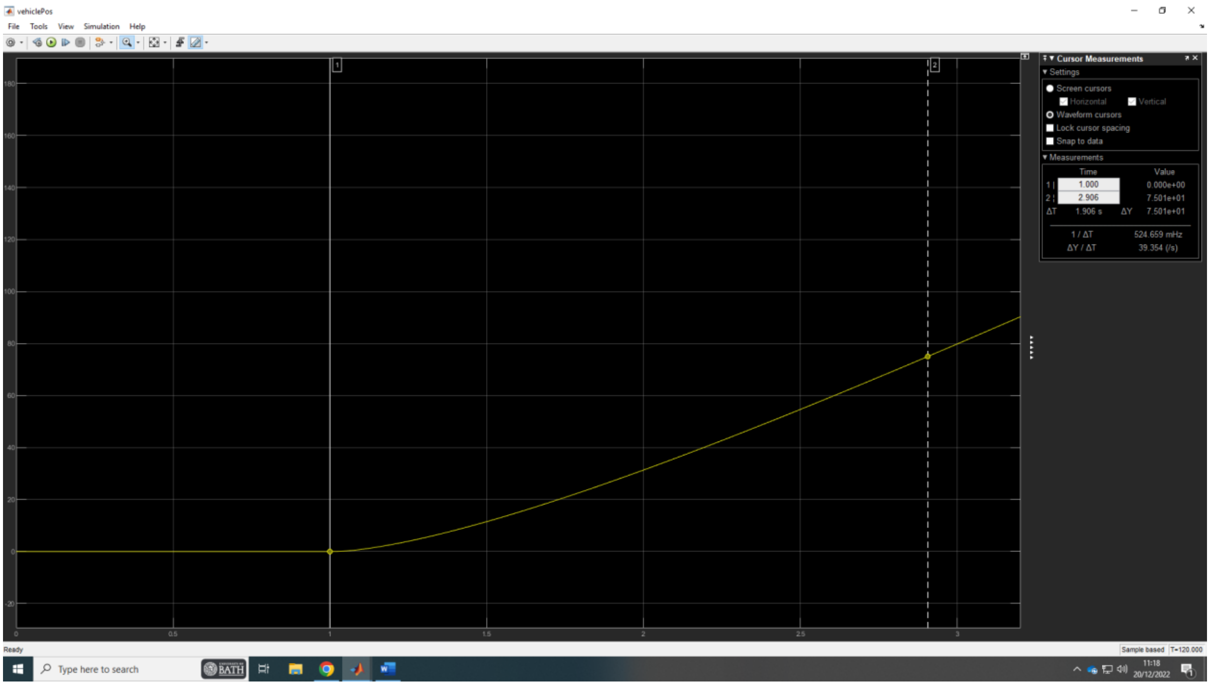

Figure 1: Speed vs Time

Test 1.1.2

By taking the time at which 75 meters was reached the scope for the speed of vehicle was read using this value (2.906 seconds).

Speed at 75 meters = 51.17 m/s

Test 1.2.1

First the length of the track was found as the increments of points given by the speed reduction and point map were multiplied by the sample distance of 5m between points.

Lap time for 1 Lap: 107.70s

Test 1.2.2

The length of the track was multiplied by 5 and the speed reduction was applied similar to test 1.2.1 resulting in a 5 laps for a total of 551.50s.

Lap time for 5 Lap: 551.50s

Task 2

Changes to How the Car Handled at the Corners

Form test 1.2.1 the time taken to complete one lap was 107.7s. This is slightly slower than the fastest Euroformula Open lap time[1] at Silverstone of 107.1s. When reviewing the speed reduction and how this models with the corners it was found that there was unrealistic handling occurring. To adjust for this a measurement of curvature at the corners were taken using Equation 1.

$$Radius = \frac{Point_n + Point_{n+1}}{Angle\ Between\ both\ Points}$$

Equation 1: Radius Calculation for Curvature Operation

To find the greatest possible speed the could reach the formula for centrapetal force was adjusted to account for the problem space producing Equation 2. It is important to note that when the calculated maximum speed around a corner was greater than the maximum achievable speed by the car (during straights) the speed was capped at the maximum achievable speed.

$$Maximum\ Velocity\ Around\ Curves = \sqrt{Frictional\ Force_{tires-track} * Radius * Gravitational\ Acceleration}$$

Equation 2: Maximum Velocity Achievable at Curvature

These calculated curve velocities were applied to the corner XY positions. From this it was still found that handling did not reflect that expected of the driver. The key problem identified was the braking and acceleration values where the theoretical maximum values but does not consider realistic breaking and acceleration times of motors. To better calculate these values, first the 14 curves on the tracks were identified for their intial points and final points. Then the realistic breaking and acceleration values were applied between these values and the maximum realistic velocity was then applied for each point of the cure. For breaking it was decided that the car would be assumed to have a substantial down force with the range of 3g to 5g[2] being the explored space. 3g best represented a breaking response that would be expected of the defined car for the project.

Modified Script Run

This run incorporated the changes to the handling of the car at corners without changing the originally provided model.

Time to accelerate 0-75m: 1.91s

Lap time for 1 Lap: 124.21s

Lap time for 5 Laps: 621.06s

Efficiency of 1 Lap: 13.14 km/kWh

Modified Model

Battery

The battery was modelled to use 125, A123 18650 Lithium[3] Iron Phosphate Cylindrical Cells in series and 8 of these lines in parallel. This configuration gave exactly the upper limits of 450V for the battery packs voltage.

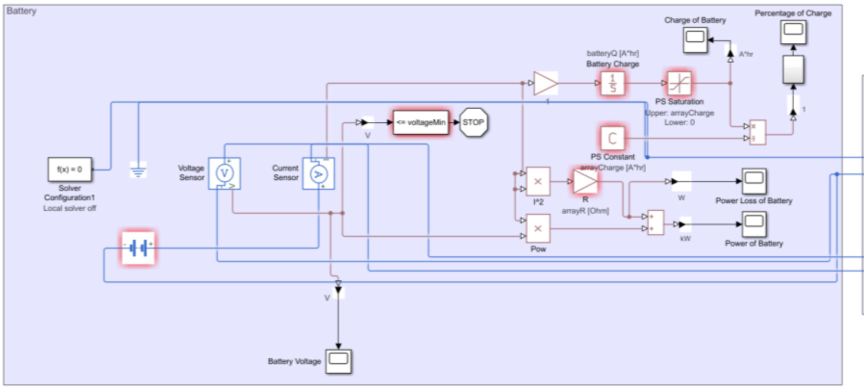

Figure 2: Model of Battery

Gearbox

The gear ratio was iterated through 8 to 15 and found the optimal gear ratio to be 13. At that ratio both the speed after initial acceleration and lap times were at there maximum making it the optimal choice.

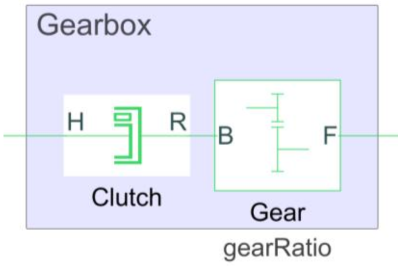

Figure 3: Model of Gearbox

Motor

After research a PMSM motor was decided upon. This was due to there being few viable options for DC. To limit the computation time the simscape system level motor and drive block was used to model entire more and drive. This block includes the control operation for the motor and the inverter but does not factor in the mass therefore a nominal mass of 3kg was added to the total mas for the control unit and inverter. A EMRAX 228[4] combined cooling was chosen due to it best fitting the restraints of 80kW with a continuous power output of 75kW with a high continuous torque of 130Nm making it the ideal motor for the specified application.

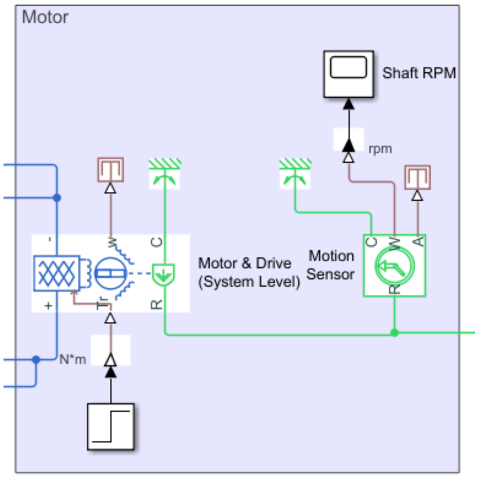

Figure 4: Model of PMSM Motor

Vehicle Body

To better model the vehicles body a longitudinal vehicle block was used with the values of drag coefficient of 0.85 and frontal area of 0.9m taken from the current Bath Formula Student Car. The model was set as a two-wheel drive. The tires used were also set to the current Bath Formula Student Car with a tire rolling drag coefficient of $2*10^6$ and radius of 0.24m. This gave a total mass of 233.2kg.

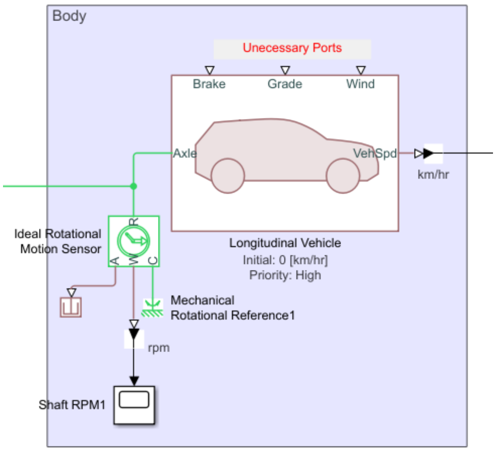

Figure 5: Vehicle Body Model

Modified Script and Modified Model Run

Time to accelerate 0-75m: 2.4677s

Lap time for 1 Lap: 137.74028s

Lap time for 5 Laps: 688.7014s

Efficiency of 1 Lap: 18.1159 km/kWh

[1] https://motorsportstats.com/results/gp3-series/2018/silverstone/stats

[2]https://aip.scitation.org/doi/pdf/10.1063/1.5024107#:~:text=For%20the%20vehicle%20without%20wings,has%20average%20drag%20coefficient%200.56

[3] https://www.altertek.com/products/lithium-ion-pouch-cylindrical-cells/a123-li-ion-cells/a123-18650-lithium-iron-phosphate-cylindrical-cell-2/

[4] https://emrax.com/e-motors/emrax-228/