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ECE 492

Motor Controller + Modeling Simulink Model Memo

5/10/16

Abstract

This report explains how to use the simulink model created by the motor controller modeling team to determine estimated static case motor RPM and in the dynamic case both power supply current and motor RPM based on data collected from the motor throughout the spring 2016 semester.

System Description

Based on the data collected and analyzed in the Static characterization report and Dynamic characterization report, simulink models were created using the coefficients found after extensive data analysis.

Static Characterization Model

The Simulink model in **Figure 1** below uses constant inputs of current and torque to determine the steady state speed of the motor. Note: the torque input only accepts values in Nm not lb-ft.

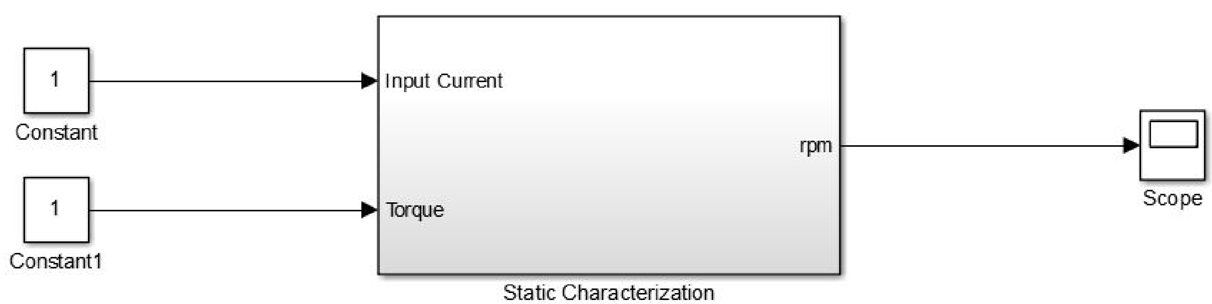


Figure 1

If modification of this model were necessary the base equation to use for this would be:

$$T_L = K_T i - fw$$

Rearranging this equation in order to solve for motor RPM yields the following:

$$w = \frac{K_T i}{f} - \frac{T_L}{f}$$

However, it was found in the static characterization report for this project[1] that the value for f is actually linearly proportional to torque. The final equation from that report is given below:

$$w = \frac{768.75i}{T_L} - 178.57$$

In **Figure 2**, the simulink model which implements this equation is shown.

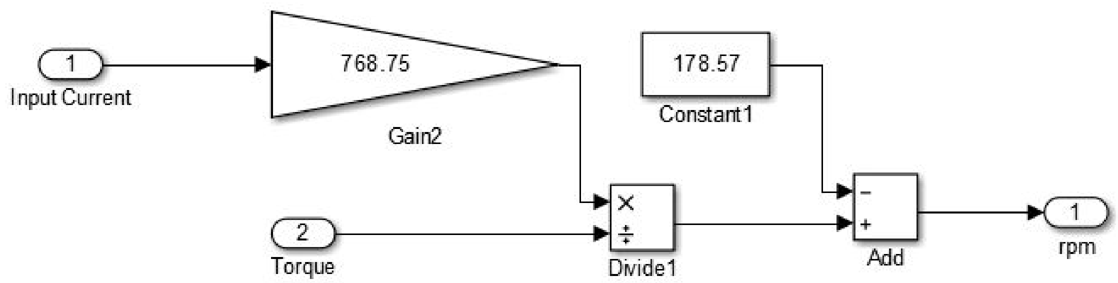


Figure 2

Static Model Verification

PS Current	Torque(N-m)	Motor RPM	Model RPM	Difference (RPM)
19.8	7.46	1631	1821	190
57.1	15.86	2496	2589	93
81.1	25.76	2250	2242	-8
36.3	14.32	1718	1770	52
65.9	18.15	2597	2612	15
44.7	18.29	1703	1700	-3
163.2	29.83	4110	4027	-83
149	33.78	3295	3212	-83

As expected the values fall in the +/-200 RPM tolerance noted in the static characterization report.

Dynamic Characterization Model

The first simulation model which can be seen below in **Figure 3** is used to determine power supply current drawn using given torque and RPM inputs. This equation was derived in the team's dynamic characterization report [2] and can be seen below:

$$i = \frac{T_L(w+178.56+.006(\frac{dw}{dt}))}{768.75}$$

In order to obtain results which simulate real parameters of the car, signals for motor torque and RPM are built and passed in. This model can be extended in the future in order to model a fully integrated car on a track at parametrized speed and torque values by simply varying the torque and RPM signals which are passed in. The signals built in **Figures 4 and 5** are the motor speed and load torque data which were obtained from the the first experiment listed in this project's dynamic characterization report[2]. To utilize the acceleration block different data sets representing different test conditions need to be generated.

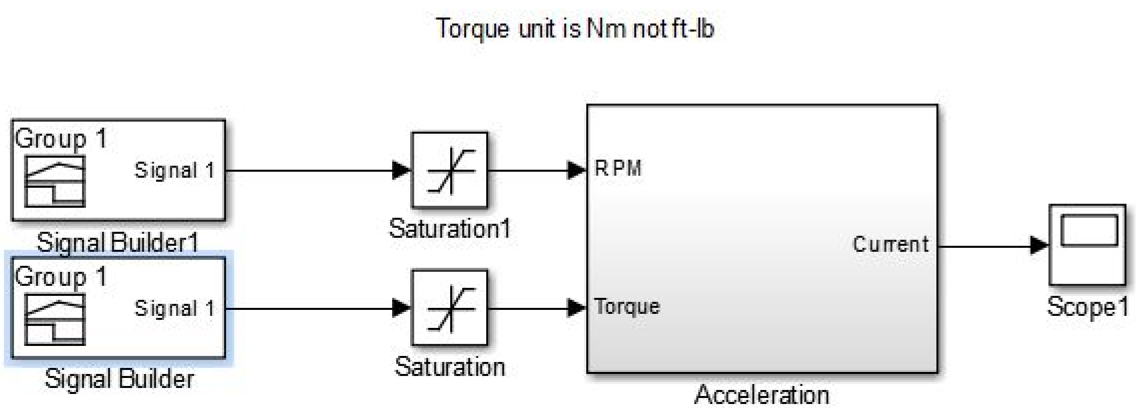


Figure 3

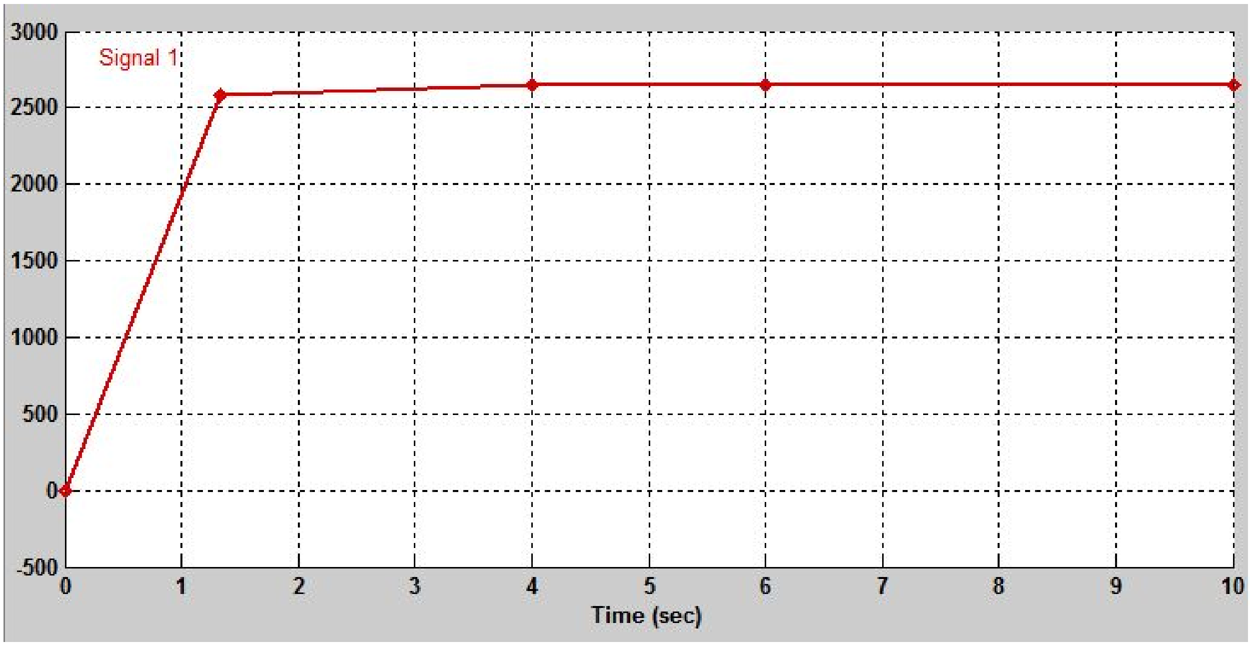


Figure 4 - Collected Data for Motor RPM vs Time (s)

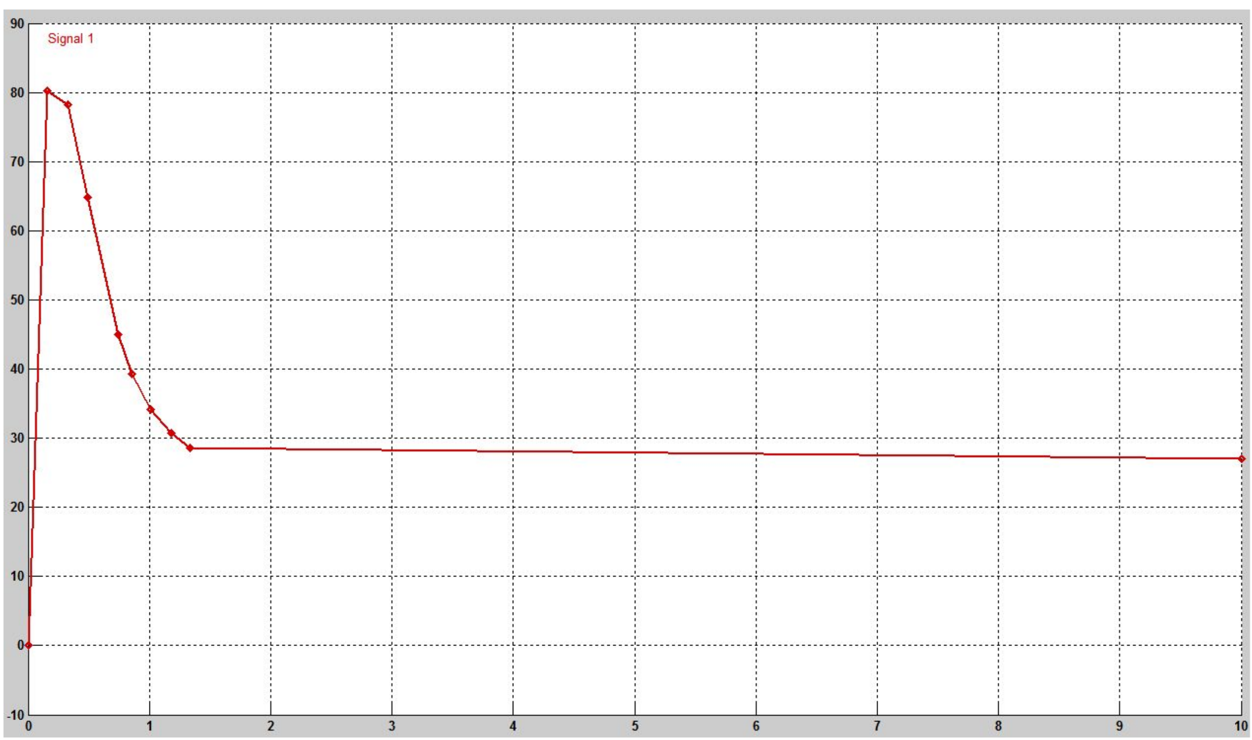


Figure 5 - Collected Data for Motor Torque (N-m) vs Time (s)

The model in **Figure 6** will allow you modify the dynamic characteristics of the motor. Modification should only occur if the same analysis process is practiced as outlined in the Dynamic Characterization report[2] .

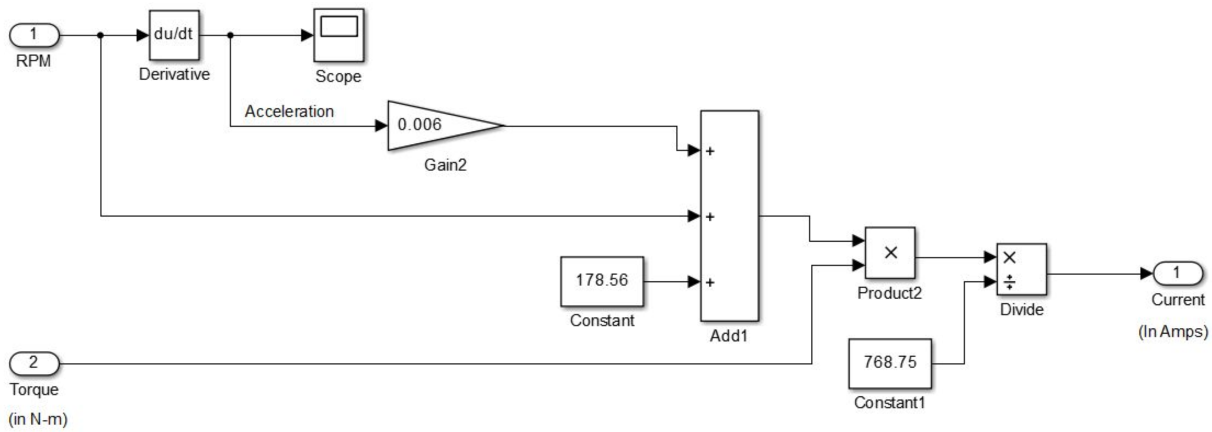


Figure 6

We found in simulating the simulink model that having a non linear model for J led to an unstable transient response. This caused us to determine J to be the average of all J's found in the dynamic characterization report[2]. With the matching torque and RPM data as inputs, our new model using the average J value was more accurate as seen in **Figure 7**.

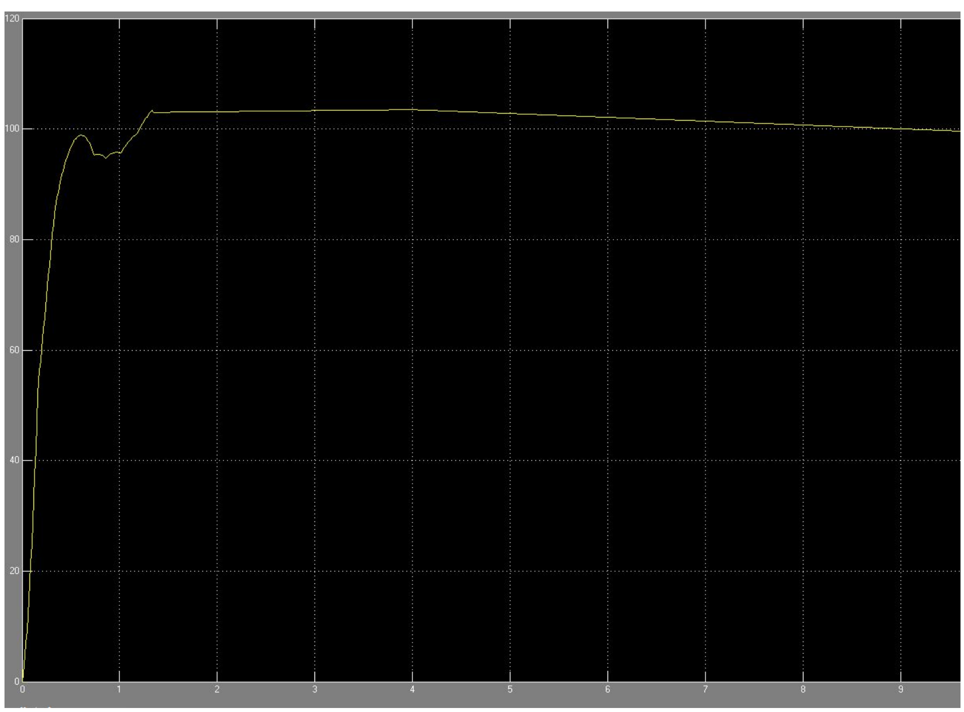
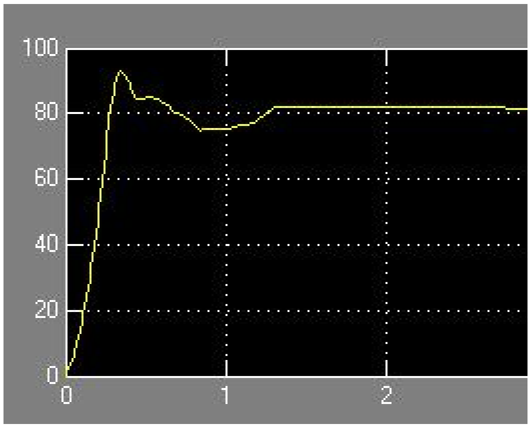


Figure 7- Power Supply Current (A) vs Time (s)

The current settles at ~1.31s at ~102A which coincides with the test results in the conclusion section of the dynamic characterization report. The graphs below are at settings Throttle 30% Load 80%.



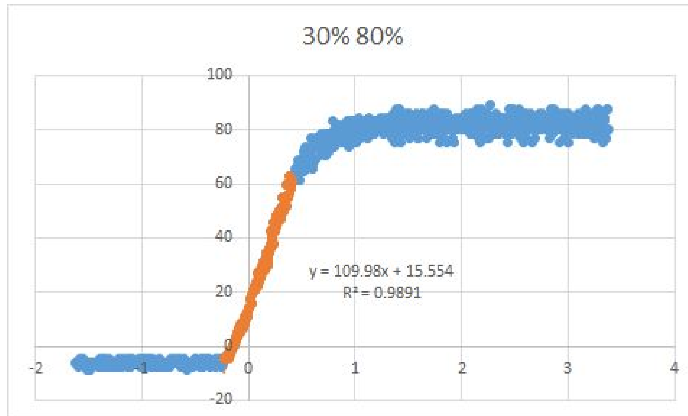


Figure 8 (Current vs Time)

Comparing the rise times (time it takes to reach 90% of the final steady state power supply current) of the simulation against the rise times calculated from the collected data, the percent difference between simulated and measured values is never greater than 10%. Therefore, the Simulink model can be deemed valid. Below are test cases simulated the same way as described previously.

Case Tested (Throttle, load)	Rise Time Simulated (s)	Rise Time Measured (s)	Difference (%)
30%, 80%	0.86	0.8	7.50
30%, 90%	0.8	0.74	8.10
30%, 100%	0.72	0.79	8.86
25%, 100%	1.31	1.22	6.55
25%, 90%	0.88	0.9	2.22
25%, 80%	0.69	0.76	9.21
25%, 70%	0.55	0.53	3.77

25%, 60%	0.35	0.32	9.37

Based on the above simulations the model is acceptably accurate for predicting results, but there are some improvements that could be made to the acceleration coefficient *J* which would further improve performance. As seen in J value vs Motor Acceleration graph below from the team's dynamic characterization report [2], a linear relationship has been identified between the best possible value for J and the motor's rate of acceleration. Simply implementing this slope into the current Simulink model causes an unstable transient response, so a better implementation would be to store these J values in a lookup table which would be selected based on motor acceleration.

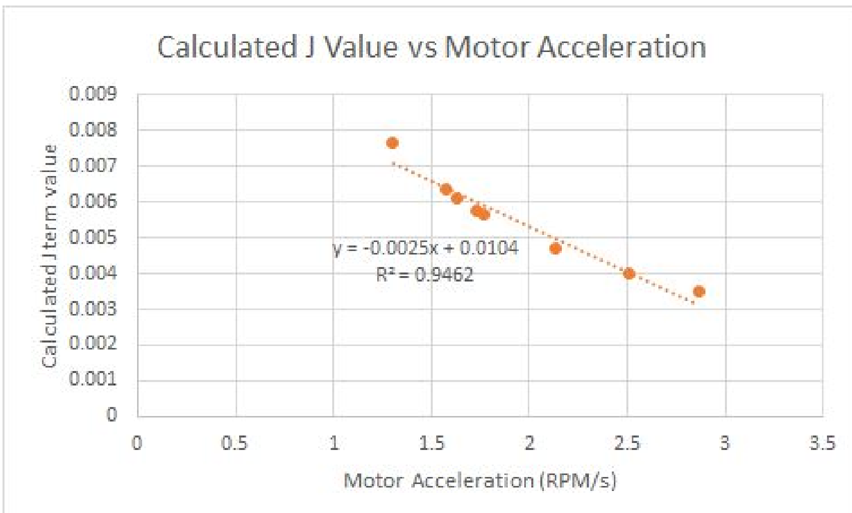


Figure 9

One additional Simulink model has been generated based on the following equation from the team's dynamic characterization report [2] which can be used to predict motor RPM from simulated torque and power supply current inputs.

$$w = -.006(\frac{dw}{dt}) + \frac{768.75i}{T_L} - 178.56$$

The block diagram for this model can be seen below in **Figure 10.** It is simply a rearrangement of the equation used in the above-tested model, so no further validation is required. This model exists in order to facilitate the prediction of car speed given a known power supply current draw and expected values for torque. One important note to make is that this simulation requires a starting time just slightly greater than zero because of the issues with calculating a derivative in feedback at time zero.

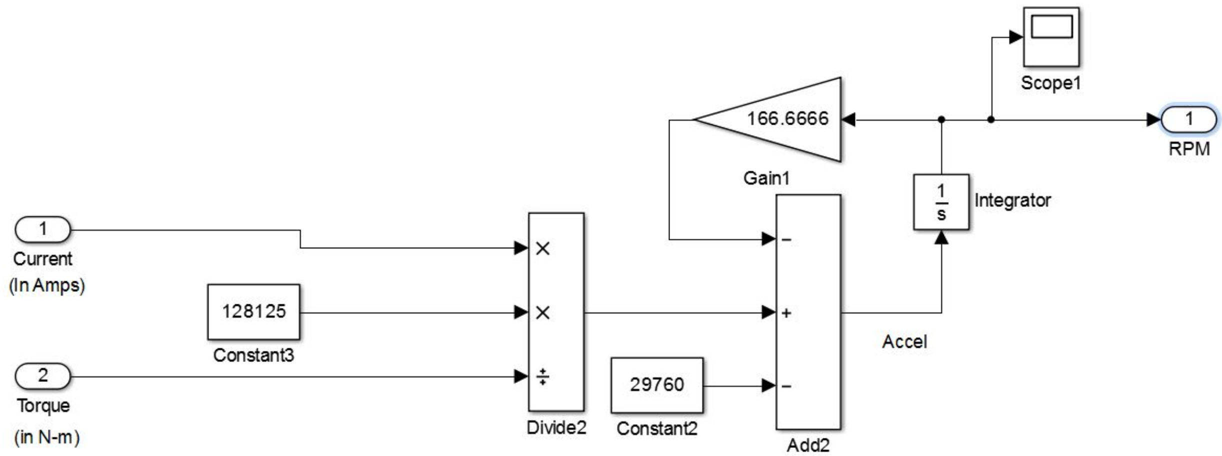

166.6666
Scope1
1
RPM
Gain1
1
s
Integrator
1
Current
(In Amps)
128125
Constant3
Accel
2
Torque
(in N-m)
29760
Divide2
Constant2
Add2

Figure 10

References

1. https://sites.lafayette.edu/ece492-sp16/files/2016/05/Static_Characterization-1.pdf
2. https://sites.lafayette.edu/ece492-sp16/files/2016/05/Dynamic_Characterization.pdf