UNIVERSITY OF VICTORIA

Department of Electrical and Computer Engineering

ELEC 360 – Control Systems I

Laboratory

Experiment no.:	1
Title:	Modeling and Identification of a DC Motor
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1.0 Summary

The lab “Modelling and Identification of a DC Motor” lab uses the QICii software to examine the properties of a DC motor in use. With the tools available, the experimenters will gain an understanding of the properties associated with the motor by using multiple equations to explore the results in more detail. With the results, the experimenters will be able to derive optimal conditions for motor function.

2.0 Introduction

The objective of this laboratory project is to develop an understanding of modeling a DC motor using the Quanser’s DC Motor Control Trainer (DCMCT). The model developed in this experiment will be used for control design in experiments 2 and 3.

3.0 Answers to the Pre-laboratory Assignments

4.4 table	Values
T_e	7.74 x 10^-5
J_l	2.09 x 10^-5
J_{eq}	2.21 x 10^-5
w_{max}	298.8
i_{m_max}	1.42
T_{max}	0.071
a	10.8
b	214.3
k	19.9
τ	0.0929

4.0 Experimental Results

4.1 Section 5.2.1

1) Set the input voltage amplitude to zero and vary the offset voltage and observe the result (do this for 3 different trials). Then, fix the offset to 5V and vary the input voltage amplitude and observe the result (do this for 3 different trials). What is the difference between varying these two parameters?

Offset Voltage	Observation
1.0	Very little oscillation of the measured input, wheel moves slowly
2.0	Very little oscillation measured input, wheel moves faster
5.0	Very little oscillation measured input, wheel moves very quickly

Amplitude	Observation
1.0	Speed changes slightly every interval based on frequency
2.0	speed changes more drastically
5.0	extreme speed change ranging from 0 to ~150

2) Determine the maximum velocity and compare with calculations from 4.2.1.

   The measured maximum speed = 80 rad/s
   Calcuated Maximum speed = 298.8 rad/s

   Hence, the measured speed is much lower than the calculated speed from 4.2.1.

4.2 Section 5.2.2

Sample #	**u_m[V]**	**Offset measured in current i_{bias} [A]**
0	0	-0.023

Sample #	**u_m[V]**	**Measured Current i_{m_max} [A]**	**Corrected for Bias i_m [A]**	**Resistance R_m [Ω]**
1	-5	-0.280	-0.257	19.455252918
2	-2	-0.103	-0.08	25
3	1	0.013	0.036	27.777777778
4	2	0.070	0.093	21.5
5	5	0.230	0.253	19.76
Average Resistance R_{avg} [Ω]				**22.70**

4.3 Section 5.2.3

Sample #	u_m[V]	Measured Speed ω_m [rad/s]	k_m [V * s/rad]
1	5	78	0.064102564
2	2	29	0.068965517
3	1	13	0.076923077
4	-2	-27	0.074074074
5	-5	-78	0.064102564
Average back-emf constant $k_{m\ avg}$ [V * s/rad]			**0.069633559**

4.4 Section 5.2.4

J_{eq} = 2.21 x 10^-5 kg*m^2
R_m = 22.70 Ω
K_m = 0.069633559 V * s/rad

$G(s) = (1/k_m)/(sJ_{eq}R_m/k_m^2 + 1)$

$G(s) = K / \tau s+1$

k=14.36

τ = 0.103462018 s

4.5 Section 5.3.1

Determine the parameters K and of the model defined in (13) (see fig. 1.4) and compare them with the model obtained by in the pre-laboratory questions

Step 1

Set :

- K = 10
- τ = 0
- A = 2 V
- Offset = 3 V
- freq = 0.4 Hz

Step 2

deltaY = 80.6 - 14.0 = **65.4**
deltaU = 4 - 0 = **4**

The measured value, K = deltaY / deltaU = 65.4/4 = **16.35**
The calculated value, K from the pre-lab : **19.9**

Hence, the measured value is less than the calculated value from the pre-lab.

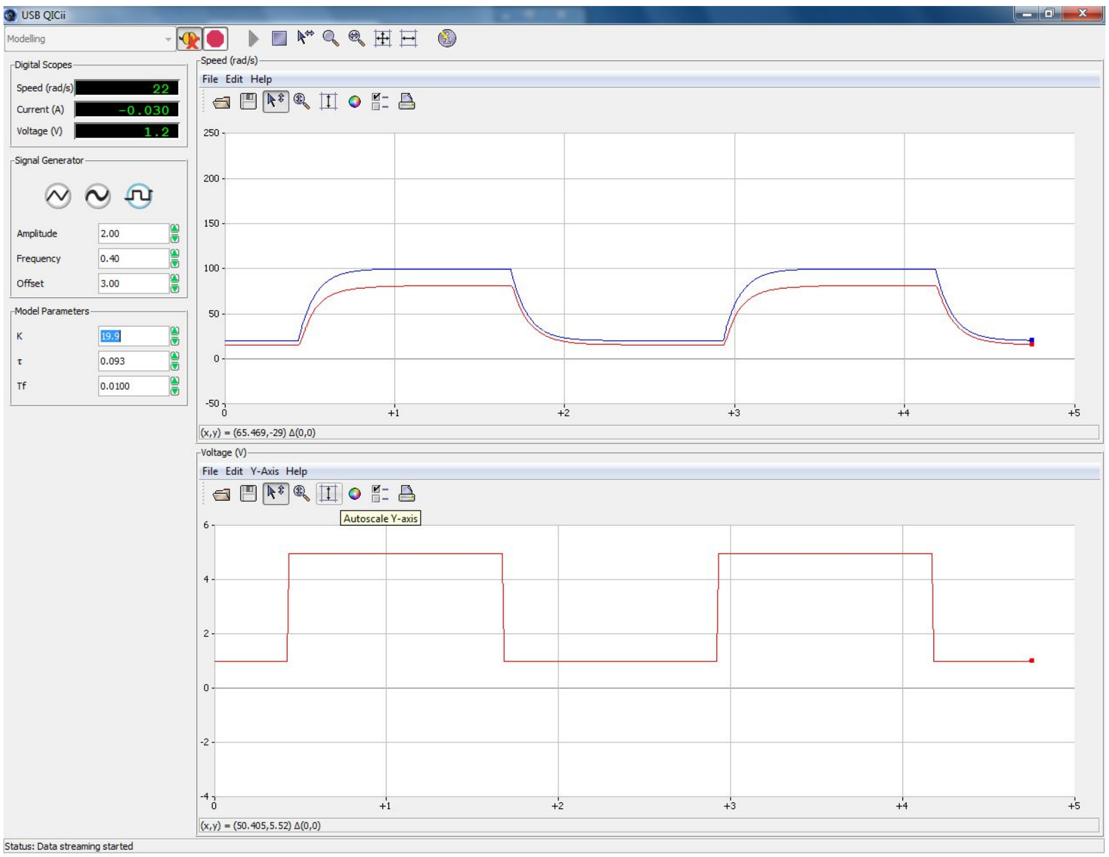
The measured value, τ = 6.64 - 6.528 = **0.112s**
The calculated value, τ from the pre-lab : **0.0929s**

Hence, the measured value of the time constant is greater than the calculated value of time constant from the pre-lab.

4.6 Section 5.4

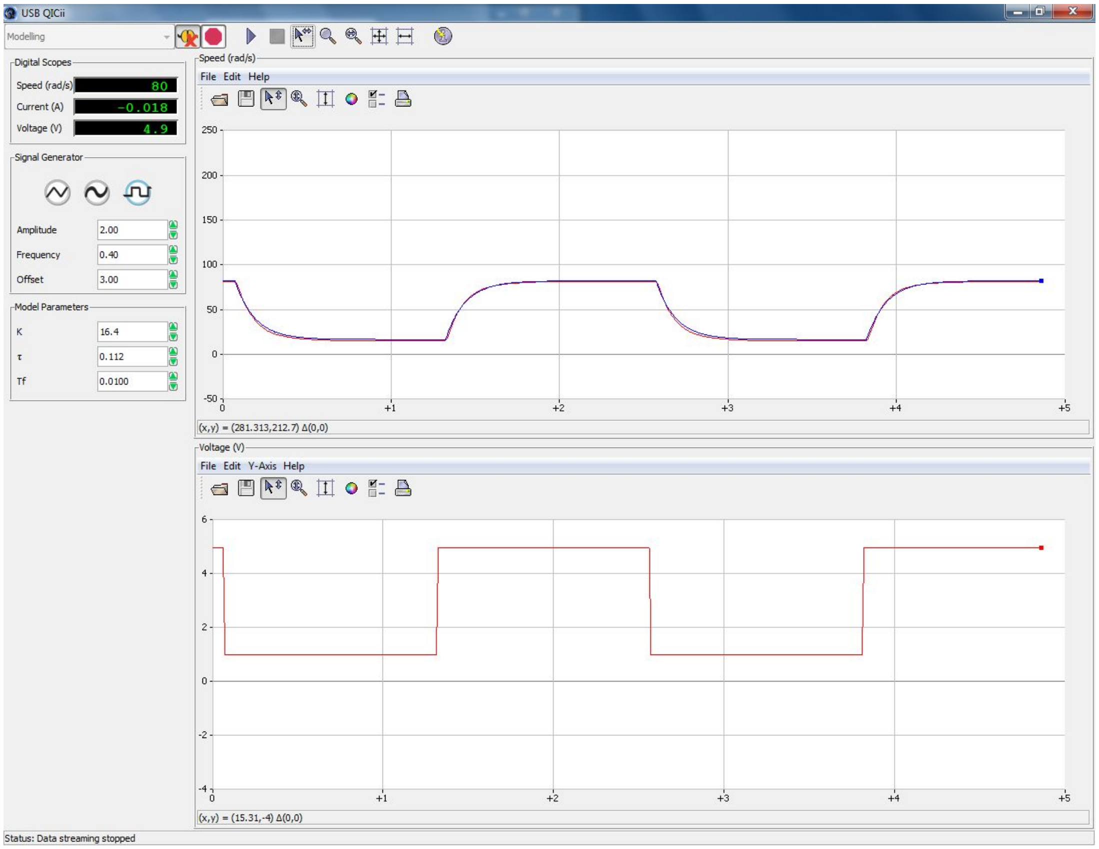
Step 1

- K = 19.9
- τ = 0.0929



Step 2

- K = 16.35
- τ = 0.112



Step 3

- When we adjust K:
  - The change in the input mirrors the changes in the speed, but becomes more drastic as K increases
- When we adjust τ:
  - τ seems to be a percentage of the impulse that is used to adjust the input arc on voltage jump

Step 4

best fit:

- K = 16.0
- τ = 0.101

5.0 Discussion

Several comparisons between a calculated outcome and the experimental outcomes have been observed during the experiment. When the voltage amplitude was set to zero and the offset voltage was varied for 3 different trials, it can be seen that the larger the offset voltage, the faster the wheel moves. When the offset was fixed to 5V and the amplitude was varied, it was found that the larger the amplitude, a greater variation in the speed change was observed.

While the maximum speed calculated was 298.8 rad/s, the measured maximum speed is 80 rad/s. The lower value of measured velocity is because of the energy loss in the system due to other sources such as friction and heat.

The calculated open-loop steady-state gain, K, is 19.9, whereas the measured K is 14.36. The variation is due to the measured motor torque constant, K_m (0.069 v*s/rad) being greater than the theoretical value of K_m (0.0502 V*s/rad); K = 1/ K_m, the measured value of K is lower than the calculated value of K.

The calculated open-loop time constant, τ is 0.0929 s, whereas the measured τ is 0.10342018 s. The variation in τ is due to the measure average motor armature resistance, R_m (22.70 Ω), being greater than the theoretical value of R_m (10.6 Ω). Since $\tau = sJ_{eq}R_m/k_m^2$, a higher value of the measured average resistance, R_m, will give higher value of open-loop time constant.

For the bump-test, the measured value of open-loop steady-state gain, K, is 16.35, whereas the calculated value of K is 19.9. The measured value of K is also lower than the calculated value of K because the value of ∆Y/∆U is low. The bump-test results complement the results from above. The calculated open-loop time constant, τ, is 0.0929 s, whereas the measured value of τ is 0.112s. Hence, the measured value of the time constant is greater than the calculated value of the time constant.

From the model validation, the changes in the input value of K mirrors the changes in the speed, but the change becomes more drastic as the value of K increases. When we adjust the input value of τ , it changes the input arc on the voltage jump.By adjusting the values of K and τ , it has been found from the experiment that the best fit for the model input is when K = 16.0 and τ = 0.101.

The entire experiment has been carried out with the input voltage being above 0.4V, where the coulomb friction in the motor is still dominant. Hence, the the motors can turn for a voltage input above 0.4V which is required for overcoming the friction. Moreover, the experiment has been carried out with the input voltage being under 15V where the saturation of the motor amplifier occurs.

6.0 Conclusions

The voltage offset and the amplitude of the voltage has been altered during the experiment and it has been found that the higher the offset voltage, the faster is the movement of the wheel, and the larger the amplitude, the more drastic change in speed. The maximum measured speed is less than the calculated value of the maximum speed which is due to the friction in the motor. The measured value of the open-loop steady-state gain is lower than the calculated value in both static relations and the bump-tests. The measured value of the open-loop time constant is greater than the calculated value in both the static relations and the bump-test. From the model validation, it can be seen that the changes in the input value of the open-loop steady-state gain mirrors the changes in the speed and how drastic the change is; the changes in the open-loop time constant input represents the steepness of the arc formed during the voltage jumps. It has been found from the experiment that the best fit for the model input is when K = 16.0 and τ = 0.101.

During the experiment, the input voltage was always greater than the voltage where the friction is dominant, and always below the voltage where the saturation of the motor amplifier occurs. Hence, the linear model developed in the experiment represents an acceptable approximation of the behaviour of the real systems.