LAB 5: MODELING THE DC MOTOR

5.1. Start-Up Procedure.

(1) Your TA will power up the DCMCT motor unit.
(2) Download the Labview zip file. Unzip the file and place all of the contents in a folder on the desktop. Then, open the Lab_5_DC_Motor.exe file. Once Labview opens, you will see the motor begin to move. Set the Offset and the Signal Amplitude to 0V.

5.2. Effects of Voltage Inputs.

(1) We apply a torque to the rotor by applying the voltage to the motor. The motor voltage is set by the signal generator, where it has a voltage offset and an oscillation amplitude. Keep in mind that although the motor maximum input voltage is 15 V, the Offset numeric input is limited to 5 V. You can change the applied voltage by entering the desired value in the Offset (V) box.
(2) Start with the offset voltage to 0V. Very slowly increase the voltage until the motor starts to move. You will notice that the tachometer signal (plotted in the "Motor Speed Plot") may have a small offset value, we can ignore this small error for most of the lab. **RECORD** the voltage when the motor begins to move. Repeat the test with negative voltages. **HYPOTHESIZE** as to why the motor does not actually move at an infinitesimal voltage.
(3) Now, sweep the voltage gently over the full signal range (from 0V to 5V and then 0V to -5V) and observe the steady-state current and velocity. You can read the actual motor current (amps) and velocity (rad/s) from the digital display. **RECORD** what happens to the variables as you change the offset.
(4) Set the offset voltage to 5V. **RECORD** the output velocity. Assuming a linear relationship between voltage input and velocity, **EXTRAPOLATE** the value you would expect at 15V and **RECORD** this value.

5.3. Estimating the Motor Resistance.

(1) Set the generated signal amplitude to zero. You will vary the offset voltage and **RECORD** the current in the table in the worksheet. See the table for the values for the offset voltage. For each measurement <u>hold the motor shaft stationary</u> by grasping the inertial load to stall the motor. Note that for 0 Volts you will measure a current, I_{bias}, that is possibly non-zero. This is an offset in the measurement which you need to subtract from subsequent measurements in order to obtain the correct current. Note also that the current value shown in the digital display is filtered and you must wait for the value to settle before recording it. Only record the values for which you can hold the motor still.
(2) For each iteration above, **CALCULATE** the motor resistance $R_m(i)$ and obtain an average value for it, R_{avg} and record your calculations in the table. **EXPLAIN** the procedure you used to estimate the resistance R_m.

(3) **COMPARE** the estimated value for R_m (i.e. R_{m_avg}) with the specified value given in Pre-Lab table specifying the parameters. **CALCULATE** the relative error: $(R_{m\_ave} - R_m)/R_m$ for a couple of the above resistance values.

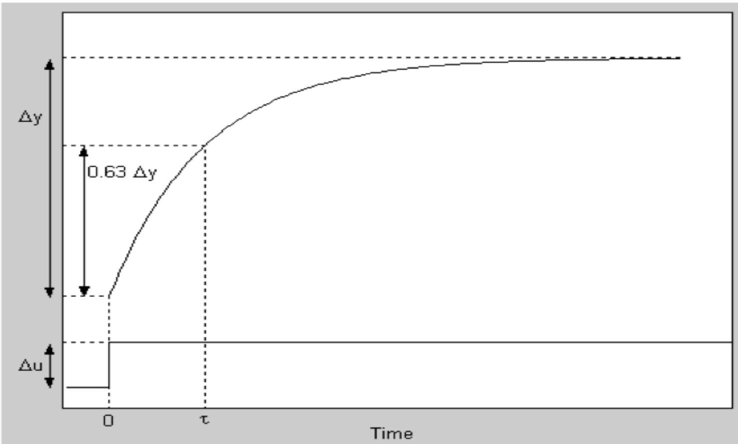
5.4. **Estimating the Motor Torque Constant.**

(1) With the motor free to spin, apply the same procedure as above and fill in the corresponding table. You can read a value for the motor angular speed (rad/s) from the digital display. Wait a few seconds after you enter a new voltage value as the displayed speed values are low-pass filtered. Both the current and speed measurement may have an offset which you will need to account for.
(2) For each iteration above, **CALCULATE** the motor back-EMF constant for each measurement iteration and then calculate an average for the 10 measurements. You can find the necessary relationships to solve for k_m in the Pre-Lab. You should use the value of R_{ave} that you found in the previous section. **EXPLAIN** the procedure you used to estimate the k_m.
(3) **COMPARE** the estimated value for k_m (i.e. k_{m_avg}) with the specified value given in the pre-lab table, **CALCULATE** the relative error for a couple of samples, and **DISCUSS** your results.

5.5. **Obtaining the Motor Transfer Function and Measurement Noise.**

(1) From the above static estimates, R_{m_avg} and k_{m_avg}, **OBTAIN** a numerical expression for the motor open-loop transfer function, as discussed in the Pre-Lab. Be sure to **IDENTIFY** the estimated open-loop steady-state gain and time constant. **COMPARE** with the open-loop transfer function that was theoretically obtained in the Pre-Lab.
(2) Determine the measurement noise for speed control by running the motor with a constant voltage and observing the fluctuations in the velocity. Set the voltage offset at 2V, voltage amplitude at 0V, and run the system for 2 seconds. Look at the time trace of the velocity and zoom in on the y axis to observe the fluctuations. **PRINT** out the screenshot of the velocity, label it 5.5.2 (2V), and attach it to the end of your report.
(3) Set the offset voltage at 4V, **PRINT** out the screenshot, label it 5.5.3 (4V), and attach it to your report.
(4) Observe the fluctuations in the above two plots. **EXPLAIN** how the fluctuations in the time traces do or do not reflect a bearings noise source.

5.6. **The Bump-Test.** The bump-test is a simple test based on a step response for a stable system. It is carried out in the following way. A constant input is chosen. A stable system will then reach an equilibrium. A bumptest is illustrated in the following figure:



As discussed in the Pre-Lab, An estimate of the steady-state gain, K, is then given by $K = \Delta y/\Delta u$ and the settling time τ is approximately given by the time the output has reached 63% of its total change. With these two values, the open loop transfer function can be estimated.

(1) Apply a step input with a Signal Amplitude of 2V, Frequency 0.4 Hz (enter in the appropriate Signal Period), and and Offset of 3V.
(2) Step voltages are applied to the motor from the signal generator with a period that is so long that the system well reaches steady-state at each step. The motor should run at the corresponding constant speeds.
(3) **PRINT** a screenshot of the angular velocity, ω_m, as a function of time, where the time spans 5 seconds. Label the plot 5.6.5 and attach it to the end of the report.
(4) Looking at one rise response, **OBTAIN** the parameters K and τ from one step response and compare them with the model obtained by first principles. Then **WRITE** the transfer function from voltage V_m to angular velocity ω_m.
(5) **CALCULATE** and average the K and τ parameters for all of the rise and fall responses in the 5 second window and **DISCUSS** the reliability of this parameter estimation.

5.7. **Model Validation.** A simple form of model validation can be done because the software Modeling contains a first-order simulation, whose model is driven by the actual open-loop motor voltage. This model is running in parallel with the motor which can be used for model fitting. The simulation parameters K and τ can be adjusted VI. The output of the model is displayed together with the actual motor speed. You can explore this in the following procedure.

(1) Change the simulation parameters K and τ to what you obtained from the bump test. Keep the same parameters for the input as you did in the bump test.
(2) Observe how closely the simulation model fits the experimental results for various inputs.
(3) Try to improve the simulated response match by adjusting the simulation parameters K and τ on-the-fly until you have a good fit. This procedure is called model fitting.
(4) **PRINT** a screenshot of you best fit simulation and experimental velocities over a time range of 5 seconds and label the plot 5.7.4. Attach the plot to the end of this report.

(5) Change the amplitude from 2 V to 1V while keeping the same offset and observe how well your simulation model follows the experimental results. Do not change your K and τ values. **PRINT** a screenshot and label the plot 5.7.5.
(6) In this lab you used 3 methods for obtaining the K and τ values for this experiment. **FILL** in the table to summarize your findings.
(7) **DISCUSS** how closely the theoretical estimations, the static estimations, and the bump-test estimations match the model fitting results from this section and also the benefits and drawbacks of each method.