LAB 6: SPEED CONTROL USING P-I CONTROL

6.1. 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, within one of the subfolders you will find the exe file. Open it.
(3) Once the system powers on, you will notice that the motor does not move with both $k_p = 0$ and $k_i = 0$. To check to make sure the program is working properly, provide a small value for k_p to make sure the motor responds.
(4) This lab will use several methods, as described in the Prelab, in order to obtain a zero steady state error, no overshoot, and a 2% settling time, $T_s \leq 0.25$.
(5) Please note that when we discuss voltage saturation, the largest voltage that the motor can receive is ±15V, so any control voltage that is larger than 15V will be cut off at 15V.

6.2. Pure Proportional Control.

(1) The reference signal is set to a square wave. When you change the reference signal level ensure that the control signal does not saturate. If it does, you will see the green indicator turn red. Also, it may be useful to adjust the offset of the slider gain so that the sign of the velocity does not change. In this way you will avoid the effects of Coulomb friction. For the reference signal, set the amplitude to 25 (rad/s), the frequency to 0.6 (Hz), the offset to 50 (rad/s). You will likely want to vary the frequency from 0.1 to 1, depending on the time scale of the dynamics. The frequency is only a suggestion; adjust it so that it is long enough between jumps that you observe a steady state behavior.
(2) The simulated transfer function should have values close to what you had for lab #5: $K \approx 18$ and $\tau \approx 0.085$. Also, the filter, which eliminates unwanted noise is at $t_c = 0.03$.
(3) In this section we are interested in only proportional control so set the integral gain to zero and the set point (b_{sp}) to 1.
(4) Start the $k_p = 0.01$ and incrementally increase the proportional gain by $0.01 Vs/rad$ until you start seeing a second order response for the tachometer (hint: look for the overshoot phenomena). **DESCRIBE** in words what generally happens to the overshoot and the steady state error (aka "Speed Error") as you keep increasing k_p. Also, **DISCUSS** how well the simulated response corresponds to the actual response. In order to zoom, note that you will need to stop the simulation.
(5) From the Prelab, **CALCULATE** the expected k_{pc}^{theory}. Then, looking at the DC motor, **FIND** the k_{pc} that appears to give a critically damped solution, labeling it k_{pc}^{actual}. **CALCULATE** the relative error between the two k_{pc} values.
(6) Continue increasing the proportional gain until the system goes unstable. **RECORD** the value of the k_p at the critical instability, k_{pu}, and **RECORD** the corresponding period of oscillation

of the instability, T_u, and **DESCRIBE** what happens to the voltage control. (Use the zoom feature on the graph to calculate T_u.)

(7) **PRINT** out the screenshot of the speed as a function of time at $k_p = k_{pc}^{actual}$, label it 6.2.3a, and attach it to your report. **PRINT** another screenshot this time for $k_p = k_{pu}$, label it 6.2.3b, and attach it to your report.

6.3. **Pure Integral Control.**

(1) Now, set the proportional gain to zero. Sweep the proportional gain from $0Vs/rad$ to $2.5Vs/rad$. **DESCRIBE** in words what generally happens to the overshoot and the steady state error as you increase k_i. Also, **DISCUSS** how well the simulated response corresponds to the actual response.

(2) From the Prelab, **CALCULATE** the expected k_{ic}^{theory}. Then, looking at the DC motor, **FIND** the k_{ic} that appears to give a critically damped solution, labeling it k_{ic}^{actual}. **CALCULATE** the relative error between the two k_{ic} values.

(3) **PRINT** out the screenshot of the speed as a function of time at $k_i = k_{ic}^{actual} Vs/rad$, label it 6.3.3a, and attach it to your report.

(4) With $k_i = k_{ic}^{actual}$, **CALCULATE** the theoretical settling time from the Prelab and compare it with the actual settling time.

6.4. **Proportional and Integral Control, $b_{sp} = 0$.**

(1) In this case, we must rely on the analysis for getting an estimate. From the Prelab, **CALCULATE** the gain coefficients k_i and k_p that are predicted to produce critical damping and a $T_s = 0.25$.

(2) Use the estimated gain coefficients to run the experiment. **PRINT** out the screenshot of the response, labeling it 6.4.2, and attach it to the end of the report.

(3) **COMPARE** the estimated settling time with the actual settling time and how well the prediction produced a critical damping case.

(4) Staying close to the predicted values, manually tune the gain coefficients and attempt to achieve a better response. **COMPARE** these manually tuned parameters with the predicted parameters and **MEASURE** the improvement in the settling time for the manually tuned case, if there is any.

6.5. **Proportional and Integral Control, $b_{sp} = 1$.**

(1) Using the Prelab and results from the pure proportional section, **CALCULATE** the proportional and integral gain parameters as suggested by the ZN method. Be sure to use the formulas: $k_p = 0.4 * k_{pu}$ and corresponding $k_i = 0.5 * k_{pu}/T_u$.

(2) Set the gain parameters to the ZN values, run the experiment, and **PRINT** the screenshot, label it 6.5.2, and attach it to the end of your report.

(3) From your plot, **MEASURE** the overshoot (you may not have any) and the settling time. Be sure to **COMMENT** on whether your system had a saturation in the control response.

(4) **COMPARE** the estimated coefficients and then **DISCUSS** the the similarities and differences in their responses.

6.6. **Effect of the set point weighting parameter.** This last section is to explore the qualitative effects of the set point parameter.

(1) Set the gains as you did in Section 6.4.4, except for the set point weighting factor, b_{sp}. Vary the parameter b_{sp} from 0 to 1 and **RECORD** your observations about what happens as the set point weighting factor is increased.
(2) For the k_p and k_i, from Section 6.4.4, find the b_{sp} that obtains a faster settling time and yet has no overshoot. **RECORD** the settling time you obtained.
(3) **COMMENT** on how each method performed according to the specifications with regards to steady state error, overshoot, and 2% settling time.