UNIVERSITY OF VICTORIA

Department of Electrical and Computer Engineering

ELEC 360 – Control Systems I

Laboratory

Experiment no.:	2
Title:	Speed Control using a DC Motor
Date of Experiment:	2016.03.08
Report Submitted on:	2016.03.XX
	(should be within one week from the date of the experiment)
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1.0 Summary

The lab “Speed Control Using a DC Motor” uses the QICii software to further examine the speed properties of a DC motor. With the tools available, the experimenters will gain an understanding of Proportional and Integral control as it applies to speed control applications. They will also gain an understanding of the design of PI controllers and the response of a PI controlled system when it is affected by a disturbance. With the results, the experimenters will be able to determine approximate ideal values to maintain a stable system with the fastest recovery time.

2.0 Introduction

The objective of this lab project is to develop an understanding of Proportional and Integral controls and applied to a speed control application. In particular, the qualitative properties of proportional and integral action, design of PI controllers for given specification and response of a PI controlled system to load disturbances have been explored in the lab.

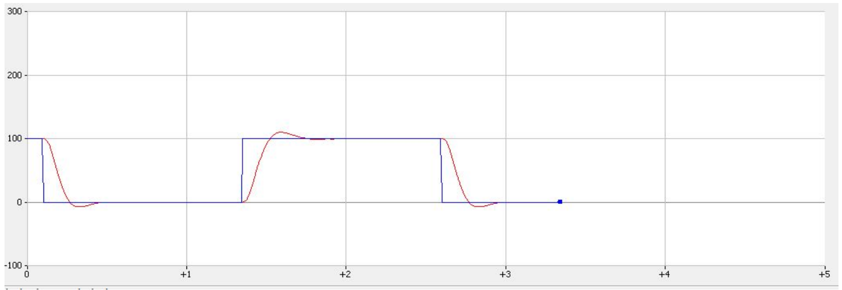
3.0 Answers to the Pre-laboratory Assignments

Description	***Symbol***	***Value***	***Units***
Open-loop steady-state gain t	k	19.9	rad/(V*s)
Open-loop time constant	τ	0.0929	s
PI Controller Design			
Given Damping Ratio	ζ	1	
Given Undamped Natural Frequency	w_n	16	
Proportional Gain	k_p	0.0995	(V*s)/rad
Integral Gain	k_i	1.195	V/rad
Closed Loop Poles			
2% Settling Time	T_s	-16	s
Output at Steady-State using PI control	$w_{ss\ PI}$	0.25	rad
Response To Load Disturbances			
Steady-State Velocity, P control	$w_{ss\ P}$	non_zero	rad
Steady-State Velocity, I control	$w_{ss\ I}$	0	rad

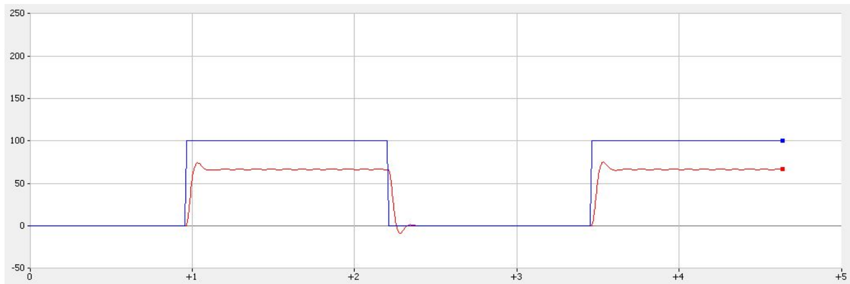
4.0 Experimental Results

4.1 Section 5.1.1

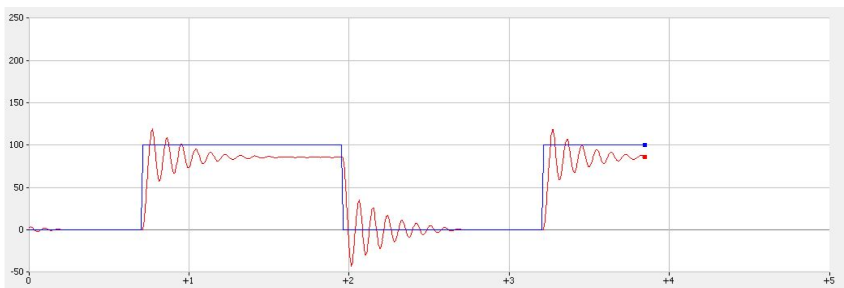
1. At the beginning, the signal looks like:



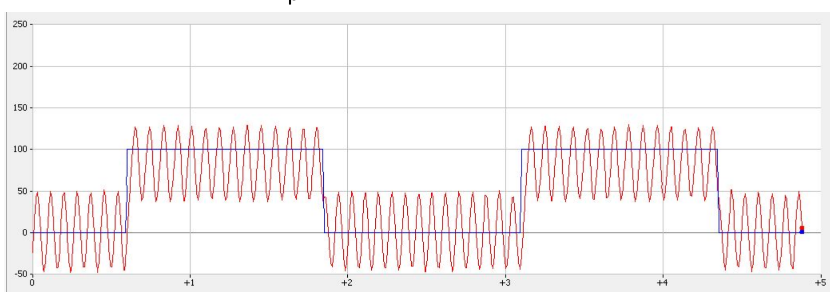
2. For the value of K_p of 0.1:



For the value of K_p of 0.3:



And for the value of K_p of 0.5:

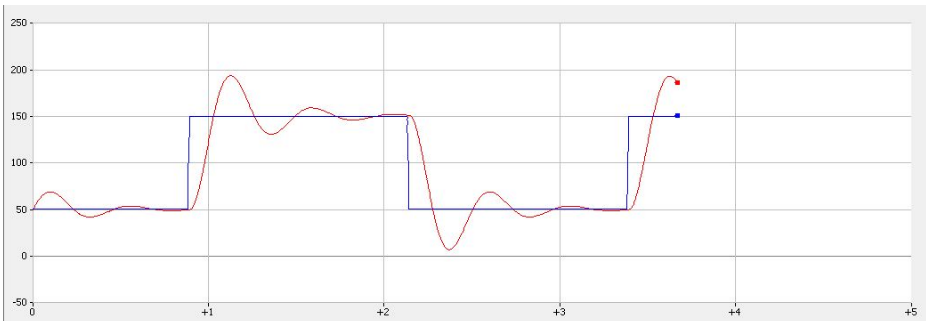


We notice that as K_p increases, the system becomes increasingly unstable until it reaches a breakpoint in stability and never reaches a stable state.

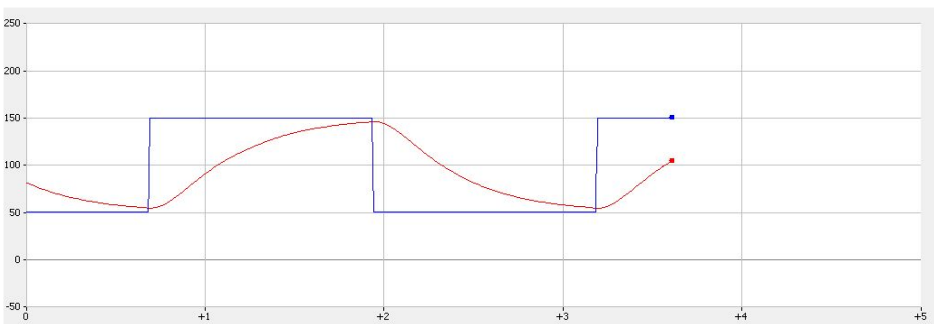
4.2 Section 5.1.2

1) Values are set.
2) Gain changed. It seems that the overshoot become higher with the increase of K_i.

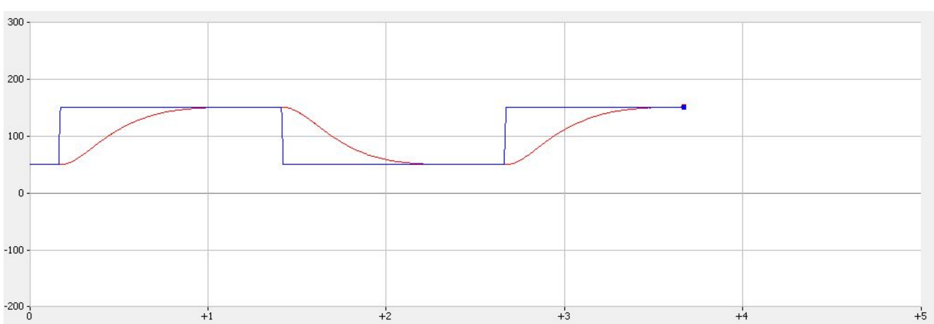
Value of 0.9 K_i:



Value of 0.1 K_i:



3) Value of 0.16 K_i was found to be the fastest response with no overshoot:

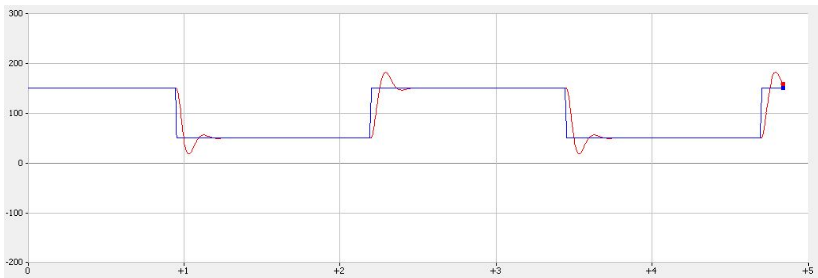


4) From 4.2, the equation obtained represents that with increase in Ki, the system becomes more damped. The above figures show the same.

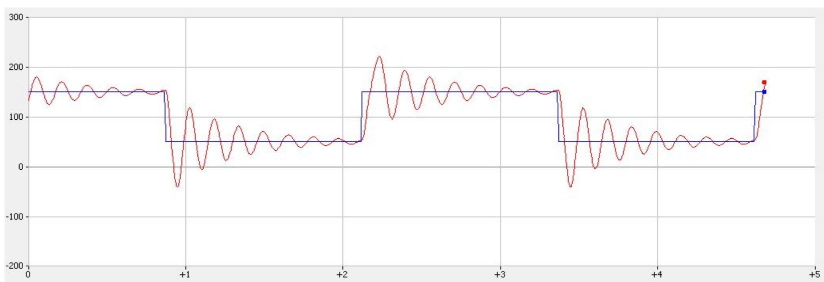
4.3 Section 5.1.3

1) Parameters Set
2) As the value of K_i increases, the overshoot size and quantity increases significantly, and the stability of the system decreases.

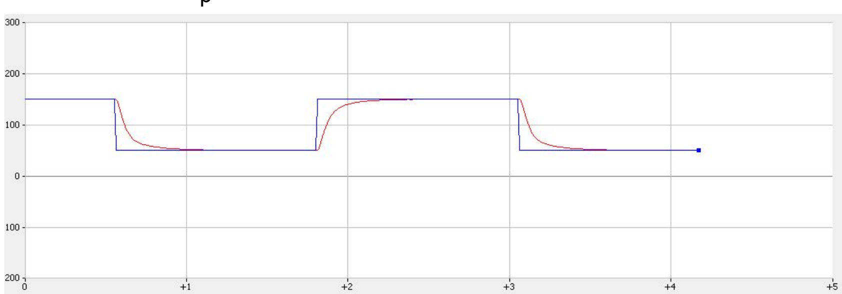
The Value of K_i at 2.0:



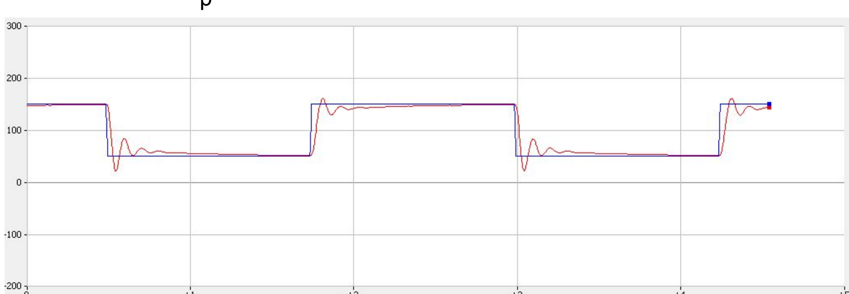
The Value of K_i at 5.0:



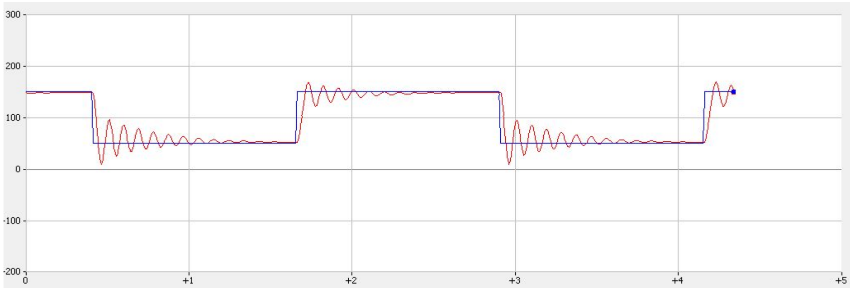
3) The Value of K_p at 0.05:



The Value of K_p at 0.2:



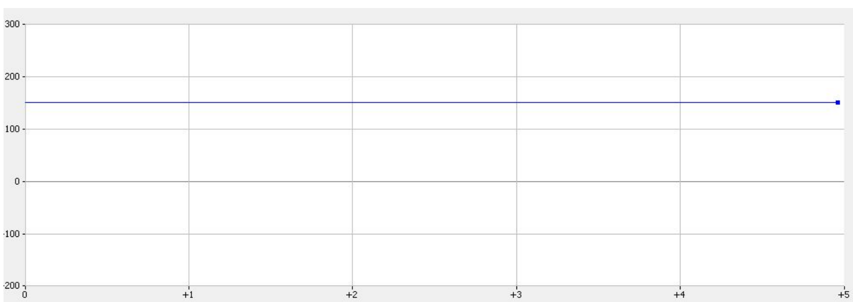
The Value of K_p at 0.3:



5) The bsp for the pre-lab was 1 and the experimental value given is also 1. The results shown above comply with the formula obtained from section 4.3.

4.4 Section 5.2

1) Constant speed of 150 rad/s

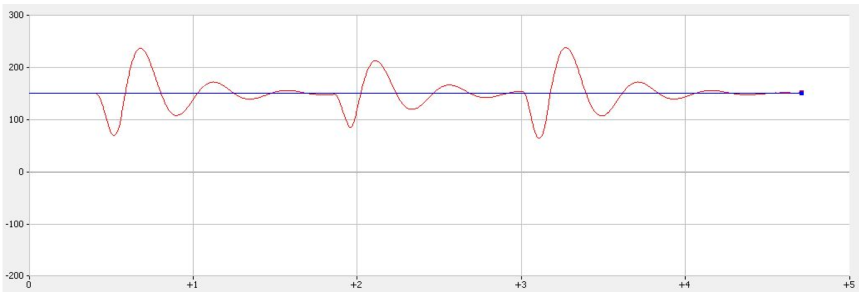


2) With kp = 0.2 V.s/rad and applying pressure with finger

With kp = 0.3 and applying pressure with finger

as K_p value increases, recovery time becomes longer!

3) The recovery time is very long and the offset from disturbance is an immediate spike.



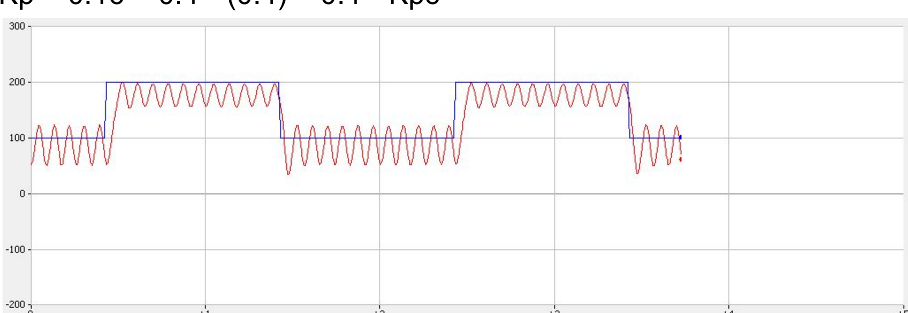
4) The system output take longer to recover to the stable state with increase in the value of the kp, and for the value of ki set to 1.0 V.s/rad, the recovery time for the offset from the disturbance is significantly longer than before.

4.5 Section 5.3

1)

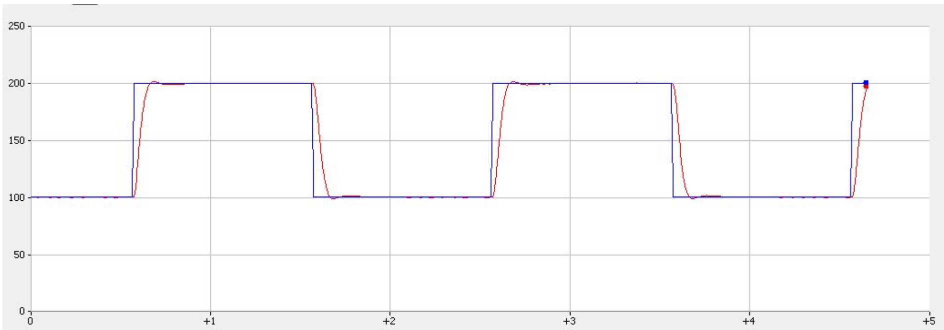
Description	***Symbol***	***In-Lab Result***	***Units***
Properties of PI Control			
Critical Proportional Gain	k_{pc}	0.4	(V*s)/rad
Critical period for k_{pc}	T_{pc}	0.087	s
Ziegler-Nichols design			
Proportional Gain	k_p	0.16	(V*s)/rad
Integral Gain	k_i	0.0174	(V*s)/rad

2) Kpc = 0.4
Kp = 0.16 = 0.4 * (0.4) = 0.4 * Kpc



Tpc = 6.864 - 6.777 = 0.087 = tau

3) Kp = 0.08   Ki = 0.9



4) The Kp value of the Ziegler-Nichols is the exact same as the ideal K_i value obtained from section 5.1.2 Step 3. The Kp value from the Ziegler-Nichols is smaller than the average of the values measured from sections 5.1.1 and sections 5.1.3.

5.0 Discussion

The system output take longer to recover to the stable state with increase in the value of the kp, and for the value of ki set to 1.0 V.s/rad, the recovery time for the offset from the disturbance is significantly longer than before

Several comparisons between a calculated outcome and the experimental outcomes have been observed during the experiment. When bsp was set to 1 and the proportional gain to 0.04 V.s/rad in the beginning, and it was increased by incremental steps of 0.1 V.s/rad, it has been noticed that as K_p increases, the system becomes increasingly unstable until it reaches a breakpoint in stability and never reaches a stable state.

When the the proportional gain was set to zero and the integral gain was set to 0.4 V/rad at the beginning and the integral gain was altered with steps of about 0.5 V/rad, keeping the proportional gain at zero, since the bsp value was set to 1 for both the cases, the results shown in the diagrams comply with the formula obtained from section 4.3.

For the closed-loop system's response to disturbance observation, the the integral gain was set to zero , proportional gain to 0.2 V*s/rad and the value was increased and external force was applied. The same was done with setting the proportional gain to zero and increasing the integral gain from 0.1 V*s/rad to different values. The results were observed and it has been obsereved that the system output take longer to recover to the stable state with increase in the value of the kp, and for the value of ki set to 1.0 V.s/rad, the recovery time for the offset from the disturbance is significantly longer than before.

For the performance for the closed-loop system with manually tuned PI controller, the values were set according to the description ;the Kp value of the Ziegler-Nichols is the exact same as the ideal K_i value obtained from section 5.1.2 Step 3. The Kp value from the Ziegler-Nichols is smaller than the average of the values measured from sections 5.1.1 and sections 5.1.3. The values has been recorded and the calculations has been shown.

6.0 Conclusions

The goal of this experiment was to attain a stable system that was able to recover from disturbances. It was found that by varying the K_p and the K_i values, the stability of the system would change. The higher the K value, the less stable the system was, although if the K value was too low, then the system would not recover fast enough. The ideal K_i value obtained from section 5.1.2 is 0.16 (V*s)/rad, and the same value was received from section 5.3 for the Kp value. We notice that as K_p increases, the system becomes increasingly unstable until it reaches a breakpoint in stability and never reaches a stable state. With an increase in Ki, the system becomes more damped. The bsp for the pre-lab and the experimental value given were both equal to 1.

Through the adjustment of these gain values, the recovery state of the system was able to be drastically altered. By finding the ideal gain for a given system, its optimal performance can be achieved.