UNIVERSITY OF VICTORIA

Department of Electrical and Computer Engineering
ELEC 360 – Control Systems I

Laboratory

Experiment no.:	3
Title:	Position Control Using a DC Motor
Date of Experiment:	2016.03.22
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1.0 Summary

The lab Position Control Using a DC Motor uses the QICii software to further examine the speed and position properties of a DC motor. With the tools available, the experimenters will gain an understanding of Proportional and Integral control as it applies to the position of the motor. They will also gain an understanding of the the design of controllers for specifications on the set-point response, and the tracking of triangular signals. With the results, the experimenters will be able to determine the steady state error using a PD controller.

2.0 Introduction

The objective of this lab project is to develop and understanding of Proportional and Integral controls that are applied to changes in position of a DC motor. In particular, the qualitative properties of proportional and derivative action in regards to settling and peak times to achieve a steady stable state when modifying the position of a DC motor.

3.0 Answers to the Pre-laboratory Assignments

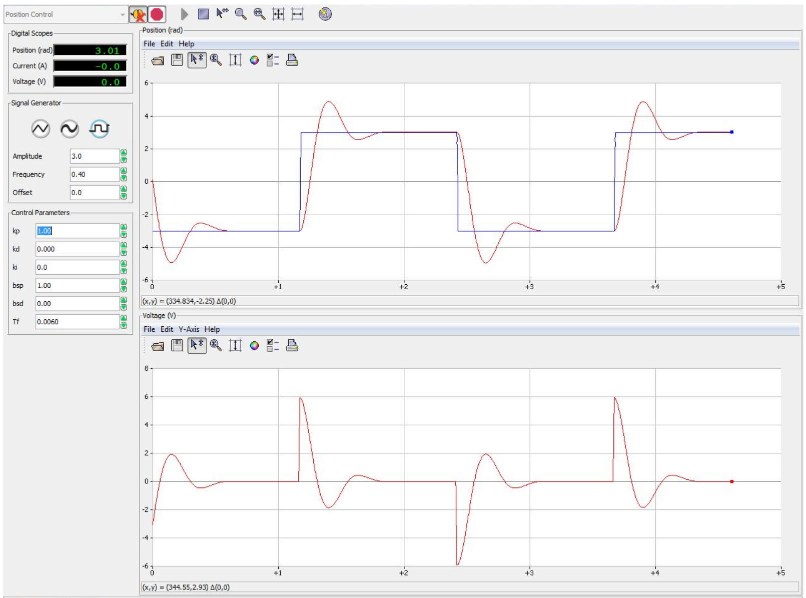
Description	***Symbol***	***Value***	***Units***
Open-loop steady-state gain t	k	19.9	rad/(V*s)
Open-loop time constant	τ	0.0929	s
PI Controller Design			
Proportional Gain	k_p	1.62	V/rad
Derivative Gain	k_d	0.0366	V*s/rad
Set-Point Weight On Derivative Part	b_{sd}	0	
Desired Damping Ratio	ζ	0.5	
Desired Undamped Natural Frequency	ω_n	18.6	rad/s
Given Maximum Percentage Overshoot	PO	16.3	%
Given 2% Settling Time	T_s	0.43	s
Desired Peak Time	t_p	0.195	s
Steady-State Value of Position using PD	$\theta_{ss\ PD}$	r_0	rad
Tracking Triangular Signals			
Steady State Error using PD control	$e_{ss\ PD}$	1.72	rad

4.0 Experimental Results

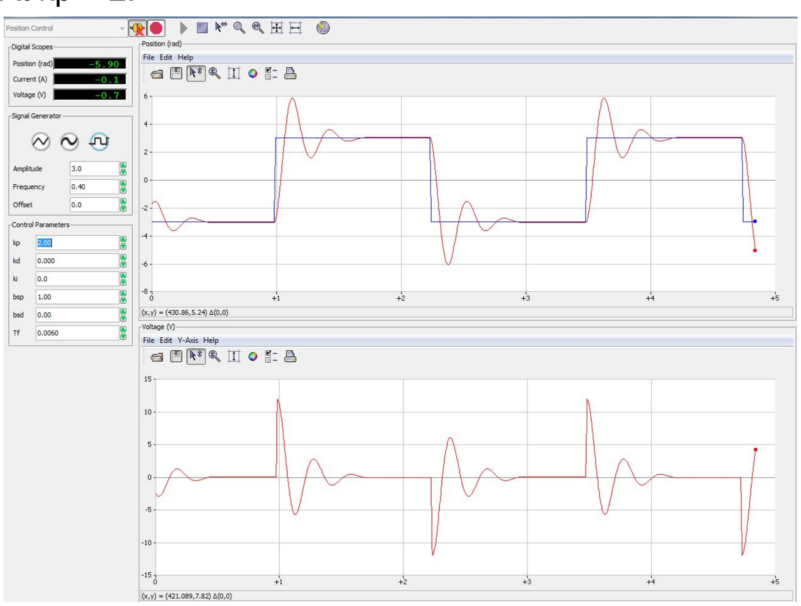
Lab Section 4.2

STEP2

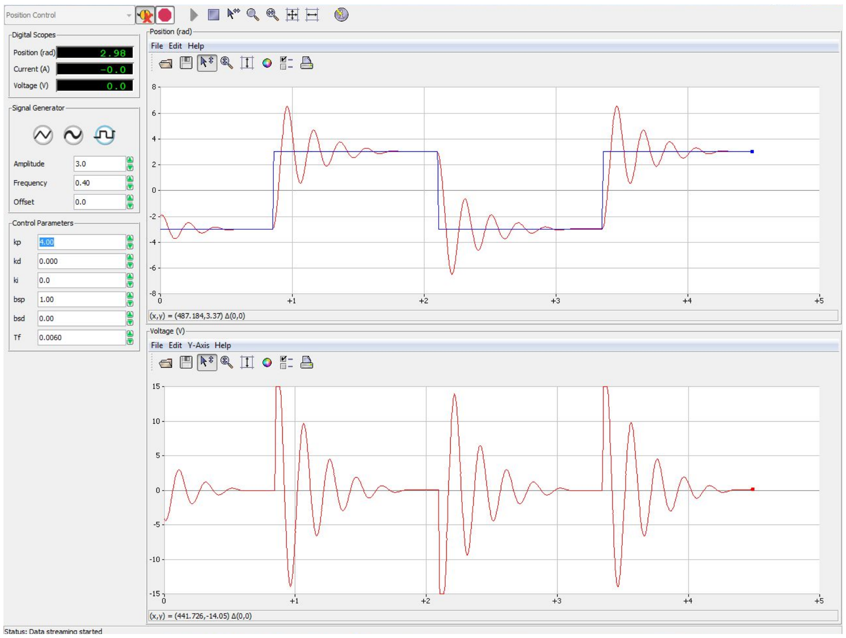
At kp = 1:



At kp = 2:



At kp = 4:



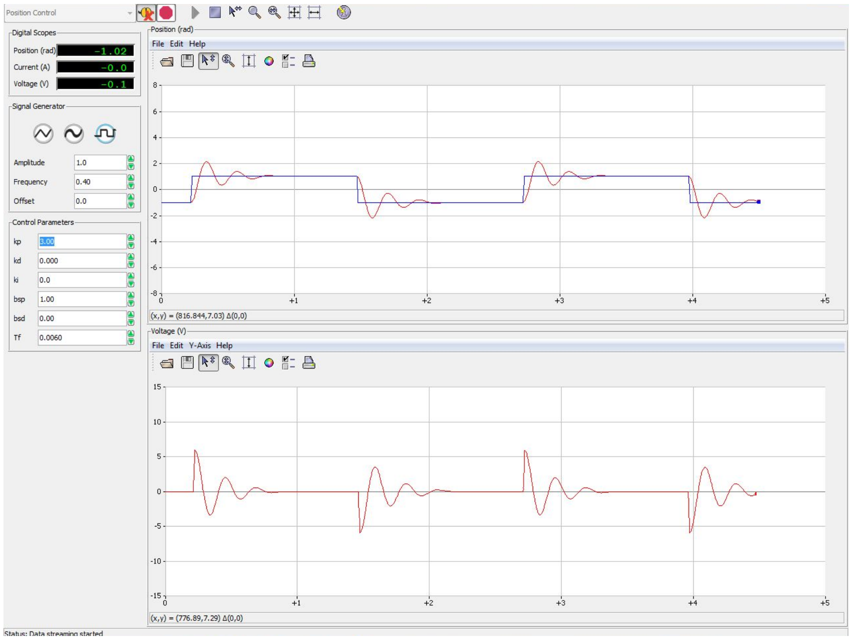
It can be seen that with increase in Kp value, the overshoot becomes higher and the oscilations stay longer.

STEP3

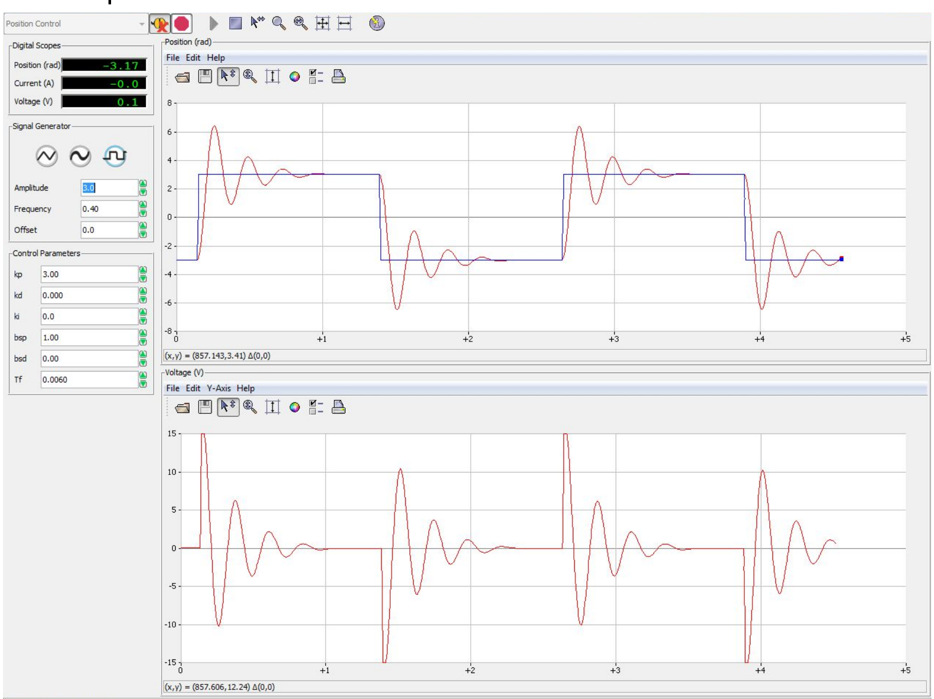
With increase in the kp value, the overshoot becomes higher and and the oscillation stays longer.

STEP4

With amplitude= 1:



With amplitude = 3:

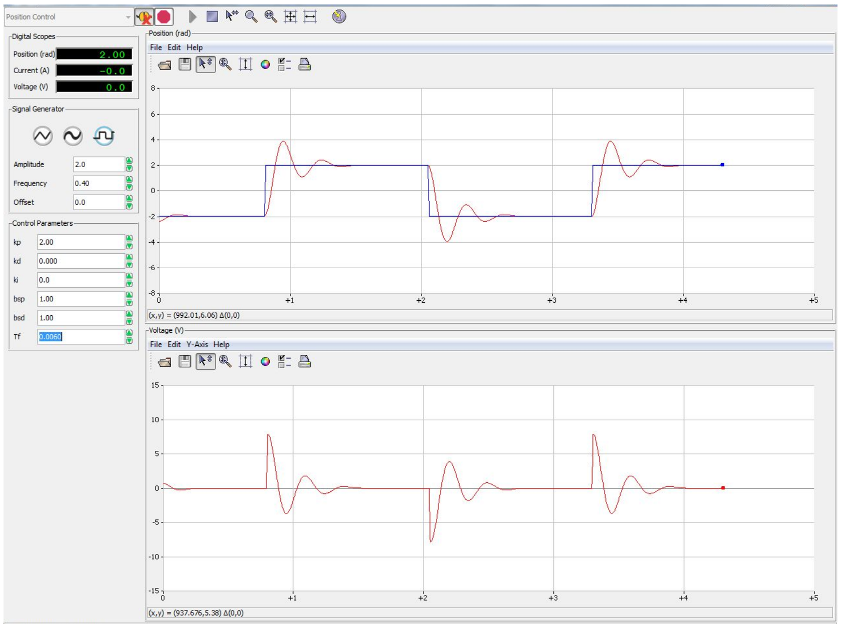


The peaks of the overshoots are higher with higher amplitude. The signal saturates at amplitude 15.

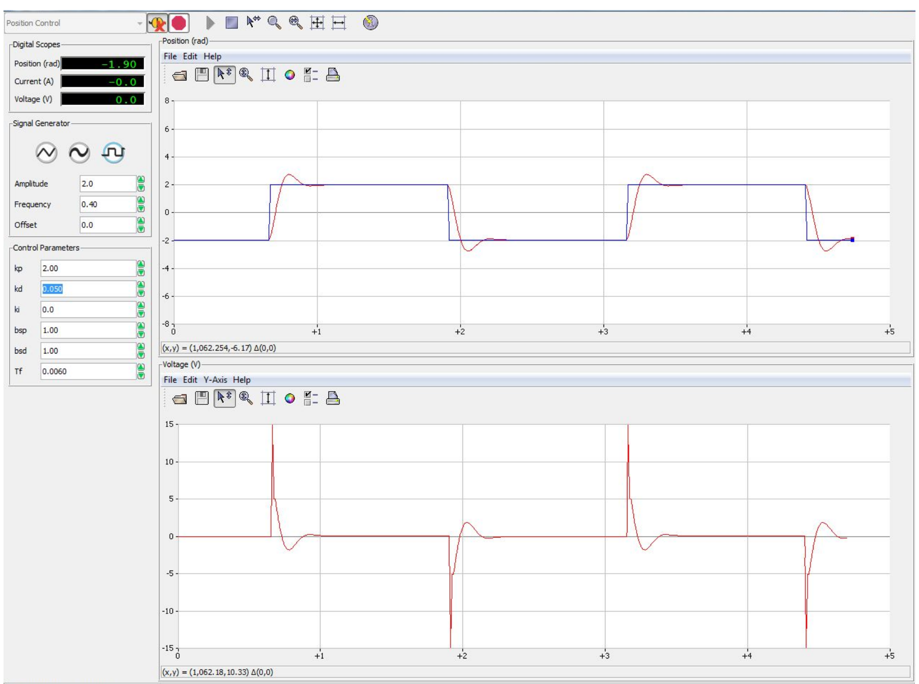
Lab Section 4.3

STEP2

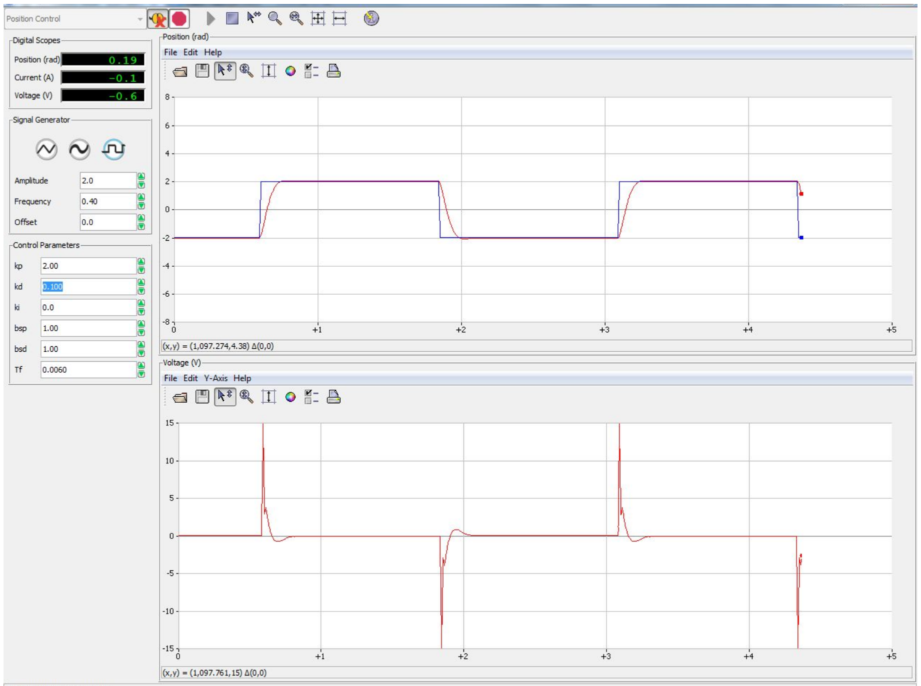
For kd= 0:



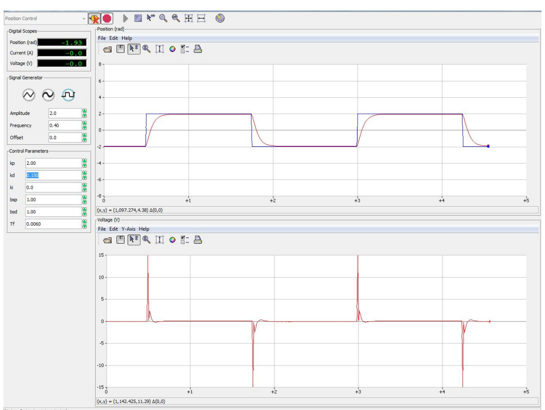
For kd = 0.05:



For kd = 0.1:

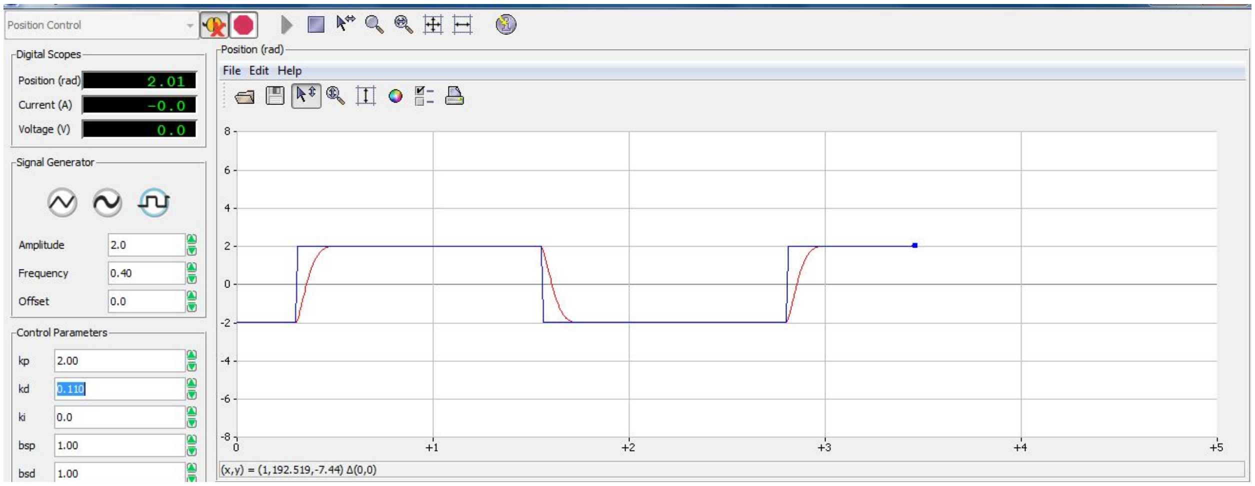


For kd = 0.15:



Observation: The overshoot decreases with increase of kd.

STEP3



The kd value is 0.11

Settling time:

Point 1 = 6.159

Point 2 = 6.324

Settle = 6.324 -6.159 = 0.165 seconds

Compare to Ts of 0.195, difference is 0.03

Lab Section 4.4

STEP2

Is PO <18%?

Calculate overshoot:

Point1 = 4.43

Point2 = 6.11

Overshoot = (6.03-4.43)/9 = 0.177777778

Overshoot is not greater than 18%

Calculate Ts

Point1 = 56.011

Point2 = 56.459

Settling time =56.459 - 56.011 = 0.448

Compare to Ts of 0.43, difference is 0.018

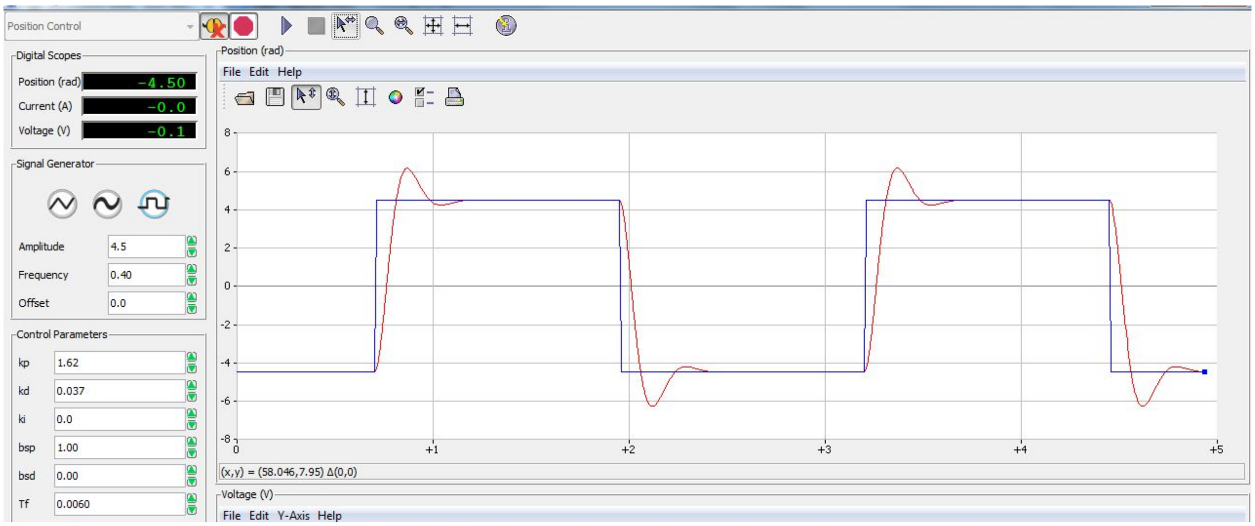
Calculate Tp

Point1 = 56.011

Point2 = 56.181

Peak time = 56.181 - 56.011 = 0.170

Yes, the system's actual response meets the desired requirement. The measured settling time, Ts is within the 0.018s difference between the calculated value. The measured Tp is within 0.17s within the calculated value.



Lab Section 4.5

STEP2

Slope of r0

rise/run

Rise:

Point1 = 15.8

Point2 = -9.9

Rise = 15.8 - -9.9 = 25.7

Run:

Point1 = 118.459

Point2 = 117.651

Run = 118.459 - 117.651 = 0.808

Slope = 25.7/0.808 = 31.806930693

Compared to a given value of 32, the measured value is well within the range.

STEP3

Tracking error:

Point1 = 17.6

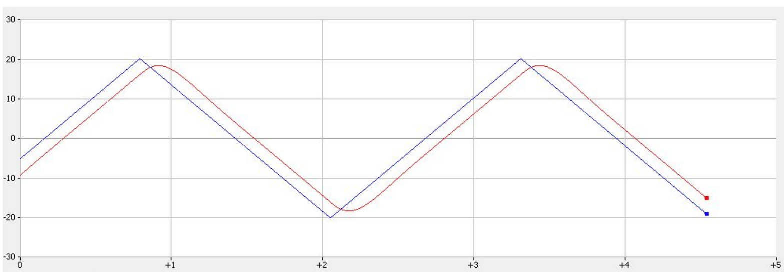
Point2 = 15.8

Error = 17.6-15.8 = 1.8

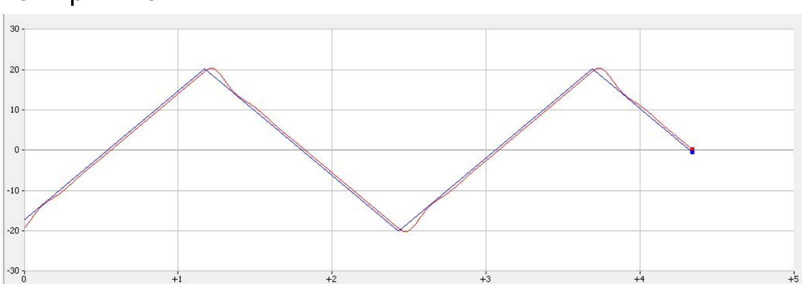
Compared to given value of 1.72, the measured value is higher, but well within the range.

STEP4

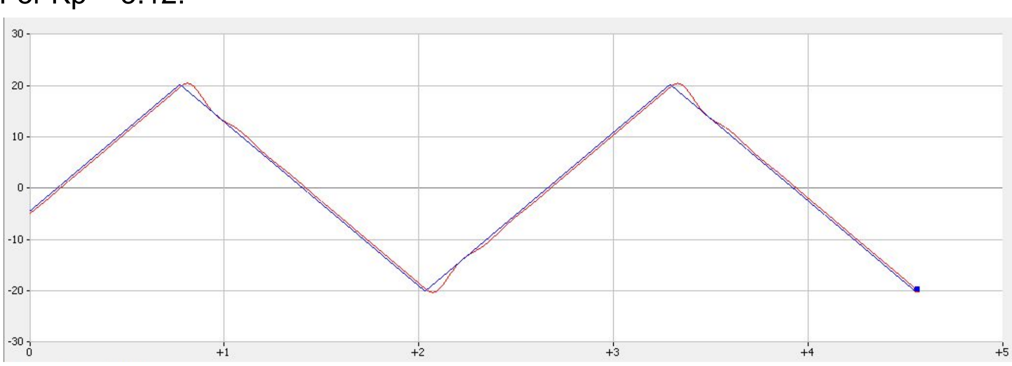
For Kp = 0.62:



For Kp = 2.62:



For Kp = 3.12:



As Kp increases, the tracking error decreases up to a point which it then becomes unstable.

5.0 Discussion

The proportional control, closed loop system for proportional controllers with different gains has been observed. The kp values were set to 1,2 and 4 V/rad consecutively. I has been observed that with increase in the Kp value, the overshoots in the system became higher and the oscillations after the overshoot stayed longer till it came back to a stable state again. The observations has been repeated again by changing the amplitude of the reference signal. It has been observed that the control signal saturates at 15V of reference signal amplitude.

The proportional derivative control section focused on exploring the combination of proportional and derivative control on the signals. The derivative gain has been incremented at a step of 0.05V.s/rad to investigate the closed-loop system for PD controllers with different derivative gains. It has been observed that the overshoot decreases with the increase in the value of derivative gain, Kd. The lowest value of the derivative gain, Kd which gives a step response without overshoot has been found to be 0.11 V.s/rad. The settling time for this particular value is 0.165 seconds.

The PD controller design to given specifications included verification for PD controller desing to given specifications. The experimental result has shown that the system's actual response meets the desired requirement. The measured settling time, Ts is within the 0.018s difference between the calculated value. The measured Tp is within 0.17s within the calculated value.

For tracking triangular signals, the measured slope is 31.8. Compared to the calculated value in the pre-lab section which is 32, the values are well within the ranges of each other. The tracking error is 1.8, and the calculated error is 1.72. The values are close to each other; Hence, the experiment has been a success.

6.0 Conclusions

The goal of this experiment was to attain a stable system with a steady error constant when the position of the DC motor was changed. It was found that by varying the Kp value of the system, the overshoot became higher and there were prolonged oscillations. The peaks of the Kp overshoot increased in height as the amplitude of the system increased. The signal was found to be saturated at an amplitude of 15. As the Kd increases, the overshoot of the system decreases. The measured settling time Ts and the measured Tp are well within acceptable values. For triangular signals, the tracking error decreased up to a point in which it becomes extremely unstable and the error increases dramatically.