University of Bristol

Faculty of Engineering

Sensors, Signals and Control

# Part 2: Elevation Axis– Theory and Simulation with Control Requirements

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*7th April 2017*

# 1 P-I-D analysis

This report introduces the effects of proportional, derivative and integral terms for a typical PID controller. The effect of varying gain is assessed using time-domain and root locus results. For a closed loop classical PID controller, the basic aim is to reduce tracking error between the control input and the observed output. In an engineering context, it is desirable to have a sharp response to user input and correctly tuned PIDs will achieve this. The responses highlighted in this report are in relation to the Quanser behaviour observed in Control Coursework Part 1.

## 1.1 Proportional Feedback Controller

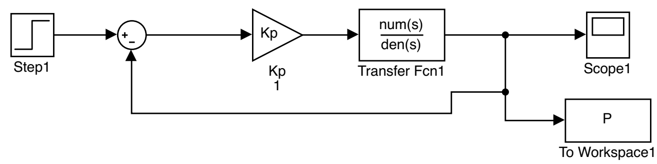


*Figure 1: Caption Text*

Proportional control uses the `Present' state of the plant to error correct. The correction applied is proportional to the deviation from the desired state of the plant. This implies a highly oscillatory system response, as the present error doesn't take into account the past or future but rather the instantaneous state of the plant. The effect of varying proportional gain (Kp) was observed through the simulation built in REFERENCE. This simulation was executed in an iterative loop with varying Kp from 0 to 0.1 in increments of 0.01. REFERENCE shows the time domain response of increasing Kp. When Kp = 0, a flat line is observed as there is no signal passing through the plant. With increasing proportional gain, the correction factor becomes larger and as seen by the increased amplitude for higher Kp gains. The `stepinfo()' function shows that increasing Kp -- reduces rise time and steady state error whilst increasing overshoot.

The root locus plot in REFERENCE allows observation of s-domain features with varying proportional gain. For pure variation in proportional gain, the (stable) poles are restricted to the same distance from the imaginary axis. In addition, increasing Kp moves the poles away from the real axis in both directions. This implies increased natural frequency with increased Kp and decreased damping ratio. This verifies the observation noted in the time domain plot, as increased natural frequency will lead to greater oscillatory behaviour and decreased damping ratio increases the overshoot.

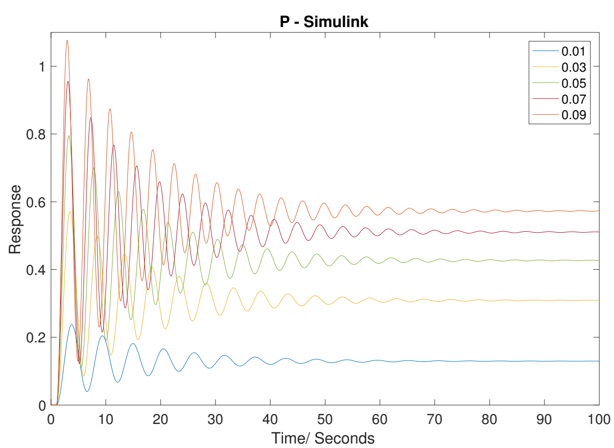


*Figure 2*

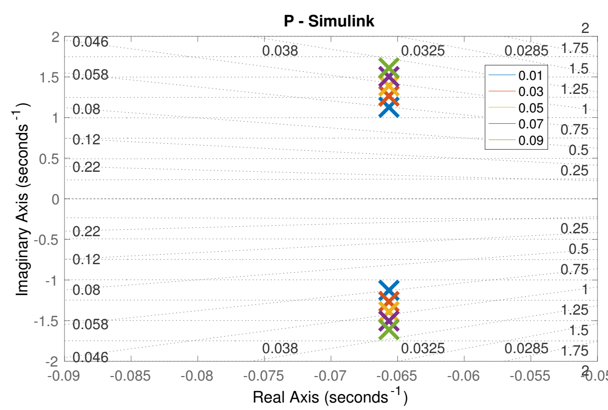


*Figure 3*

## 1.2 Derivative Feedback Controller

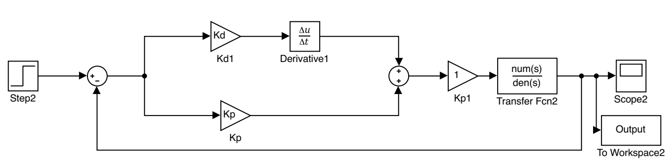


*Figure 4: Caption Text*

Derivative control utilises the expected `Future' state of the system to pre-emptively produce an error correct signal. This correction is proportional to the rate of change of the system state at a point in time. The system calculates the state of the plant in the future based on rate of change conditions correctly and accounts for that by anticipating the response. For this reason a large damping effect is expected for increasing derivative gain (Kd). The simulation in REFERENCE was implemented to observe two things -- first the effect of purely varying derivative gain with constant proportional gain, and second the effect of varying both gains by the same amount -- this was controlled using the additional gain block after the controller. The gain/s in both REFERENCE and REFERENCE was incremented from 0 to 1 in increments of 0.05.

As expected, the time domain responses show that increasing Kd has a greater damping effect on oscillations. There is a reduction in overshoot and increase in rise time. For a Kd = 0 , large oscillations are observed and decrease with increasing gain. For larger gain values of 0.6 and above there is high damping with the response settling to a steady level quickly. Increasing both Kd and Kp by the same amount shows reduction in rise time, overshoot and steady state error. PD control appears more effective.

The root locus S-domain metrics show that as Kd is increased the poles are shifted more negatively in the real axis. The semi-circular shape represents the line of equal proportional gain and points represent varying Kd at that Kp level. As Kd increases the angle between the imaginary axis increases -- this implies poles closer to the real axis, ie higher Kd corresponding poles have greater damping; natural frequency is reduced (and hence less oscillatory behaviour).

### 1.3 Integral Action

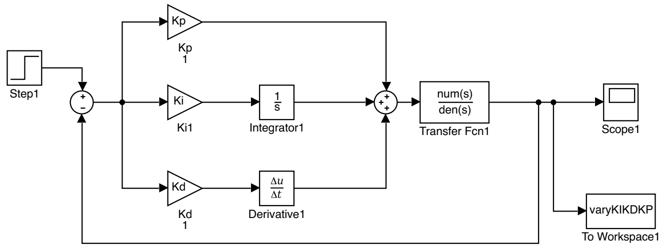


*Figure 5: Caption Text*

Integral control utilises the `Past' state of the system to produce an error-correcting signal. The integral term looks at the period and how far the measured variable is from the desired state in time. This controller sums the complete error in history up to current time state. For this reason the integral control will eliminates offset and leads to zero steady state error. REFERENCE shows the variation of pure Ki with constant Kp and Kd. REFERENCE shows the variation of all three gains Kd, Ki and Kp by the same magnitude -- this was implemented using a gain-scaling block after the controller. The time domain plots confirm the zero steady state error as the oscillations level to desired response level.

0 there is steady state error that exists in the system, but as integral gain increases the steady state error is completely eliminated. The preferred controller is PID.

## 2 PID Design to Achieve Control Requirements

### 2.1 Open Loop Transfer Function PID Controller

### 2.2 Tuned Quanser Controller