MMAN3200 – 2020.T1

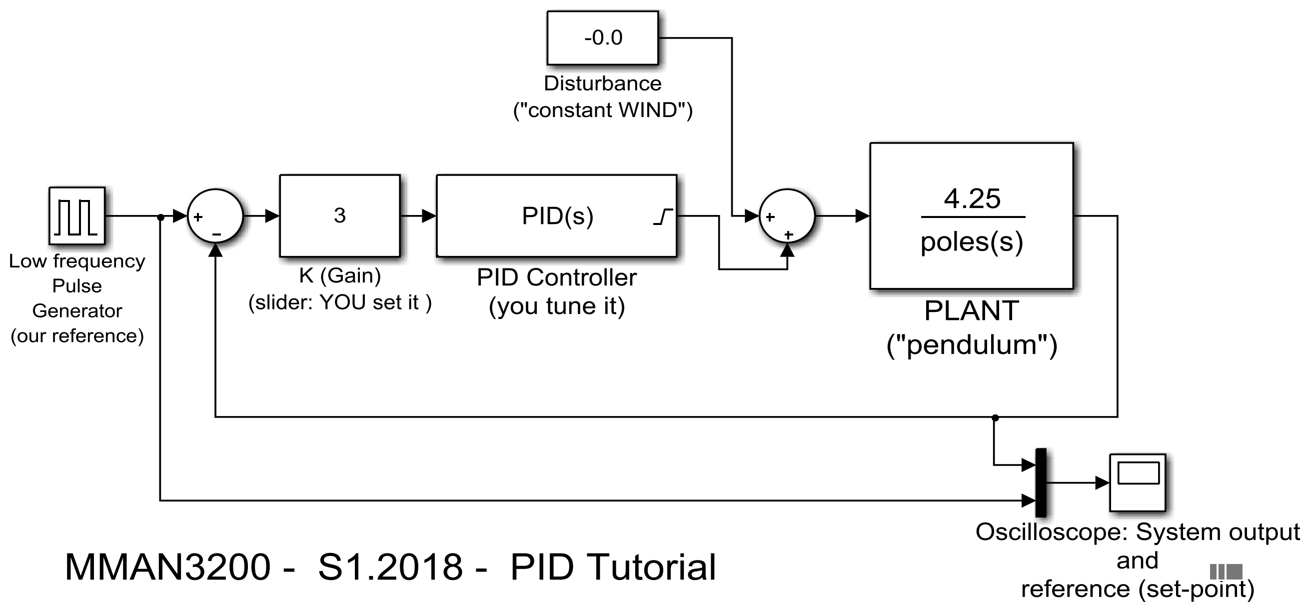
Tutorial and lab work for topic "PID"

In this task we will study the application of the P, PD and PID controllers for controlling a given plant. The plant has a dynamics which is similar to that of a pendulum; it is modeled as a SISO LTI second order system, having two poles which are complex conjugate (those are located at s={ -0.5+j2, -0.5-j2 }). The system is controlled as indicated in Figure 1. The controller has the PID structure; however, by properly setting it, we can cover all the usual approaches such as proportional controller, PD, PI and full PID versions.

Given a Matlab/Simulink program, named "MMAN3200_2020_PID_PlantPendulum.mdl", which is provided with this document, you are expected to use it to verify the capabilities of the PID controller, for treating the case of a system, whose dynamics is similar to that of a pendulum.

The controller is a PID module; in addition, we have a multiplicative gain "K". For that reason, we recommend the parameters of the PID to be kept normalized, i.e. Kp=1 and the rest (Ki and Kd) being expressed relative to Kp=1. In that way, we can have an easier interpretation of the results, based on the root locus analysis.

In addition, we expose the plant to certain external perturbation (disturbance); which is similar to the case of "wind" constantly pushing the structure of a big machinery, consequently introducing a driving force. For simplifying the model, we simply added it to the actuator that feeding the plant.



This task involves an analytical part and an experiment part (in simulation).

The analytical part can be solved during the tutorial time, in which the tutors may help the students. The experimental part is intended to be solved by the students (individually or in groups), working at home or in the computer laboratory, using Matlab/Simulink.

Analytical part

A1) Consider the CLTF for the cases in which the controller is implemented by a proportional controller of gain K=2 in one case, and gain K=10 in the second case. Assume that there is no external disturbance.

A1.1) For each case, obtain the steady-state error which happens for a reference signal being a unit step.

A1.2) Sketch the root locus that is associated to this plant and this type of controller (for all positive values of the gain K).

A1.3) Based on what you see from the root locus, explain why, for the case of the higher gain (K=10), the response should present more oscillations than the response associated to the gain K=2.

A2) Repeat what you did in (1), now considering that the controller is a PD (Proportional + derivative), having a TF expressed by $C(s) = K \cdot (1 + s/z)$, with a zero predefined at s=-5. The only parameter that you can adjust is the gain ***K*** of the controller.

A2.1) Sketch (an approximated) the root locus, associated to this controller and the plant.

A2.2) For certain sufficiently high gain K, would you expect a close loop transient response better than that of the proportional controller? (base you answer on the approximated root locus obtained in A2.1.)

A2.3) Give an estimate of the steady-state error, for a unity step input function, considering a gain K=10 (and z=5).

A3) Consider the case in which the controller is implemented by a PID.
Show (analytically) that the steady-state error is negligible, for the case in which the input is a unit step. Assume that the gain Ki is Ki>0.

Simulation part

All the required simulations, in this section, are intended to be performed using the provided Simulink program ("MMAN3200_2020_PID_PlantPendulum.mdl")

B1) Simulate the case in which the disturbance is negligible (e.g. = 0). Assume that the controller is a proportional controller (Ki=Kd=0; Kp=1).

B1.1) Try a low gain K (e.g. K=2.); B1.2) Try a higher gain (e.g. K=10.)

B1.3) Briefly, explain the observed behavior by interpreting the root locus (you should have sketched it in section A, to explain what you see in the time responses observed in B1.1 and B1.2)
E.g. why for one of the experimented gains, its response seems to present more oscillations than that of the other case?
Are the observed steady-state errors consistent with the results that you obtained in section A?

B2) Set the constant disturbance to a value = -0.4. Try the simulation again, for both proportional controllers used in (1). What happens with the Steady-state error? Why is that happening? Give your interpretation.

B3) Repeat what you did in (1), but adding a derivative component, e.g. setting Kd=0.4, still keeping Ki=0 (and Kp=1).

B3.1) What happens with the oscillation we observed in (B1)?

B3.2) Do you appreciate some performance aspect, which may still be unsatisfactory?

B4) Keep the settings defined in (3), except the value of Ki (which was Ki=0). Consider using the integral component of the PID, try Ki=0.5 or similar setting.
Describe what happens in terms of the performance of the system (transient response and Steady-state error), when the output "tries" to copy the input.

B5) Finally, include the constant disturbance (=-0.4)

B5.1) Run the system having the full PID controller (using the settings which were used in (B4))
B5.2) Run the system for the case in which Ki=0, as you used in (B3).
Give your opinion, about the obtained results.

If you have doubts about how to use the Matlab/Simulink program, you may watch a video-demo from file "MMAN3200_PID2.mp4"

During the tutorial time, the tutors can help in solving the analytical components of the problems (e.g. for sketching the root locus, for evaluating the steady-state error based on Final Value Theorem.) In addition, they can help in interpreting the results you may have obtained in your simulations.

Questions? Ask via the Forum, in Moodle; or via email the lecturer: j.guivant@unsw.edu.au

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