How-To Document Control Related Experiments

Purpose of this document

This document supports the exercise entitled ”Automatic Temperature Regulator” related to the course I3GFV offered at the School of Engineering at Aarhus University. The purpose of the document is to illustrate good-practice when documenting control related experiments to the students. Furthermore, the student should obtain some insights into WHY this type of documentation is suitable.

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Background

In the exercise “Automatic Temperature Regulator” the student is asked to implement and test different control tunings for a temperature control system. In particular, the student is asked to evaluate performance of the system when commanding steps to the reference. That is, when the system is commanded to go from one temperature to another. He student is then required to DOCUMENT and comment the results. The question is then: “what to illustrate in the journal?” and “what to comment?”. The answer to these two questions should be more obvious when having read the following argument:

When evaluating the performance of a control system it is important that the system is exposed to similar conditions (if comparing different settings). This means that surrounding conditions and initial conditions should be comparable. Otherwise, it is not possible to associate a change in behaviour to the tuning – it could just as well be an effect of different initial conditions. Furthermore, it is important that the final stable condition is identified. If a steady and stable behaviour has not been reached before the experiment has been terminated the final state is actually not known (it can only be assumed).

What to Document

The data presented to the reader of a journal should document the initial conditions, the transient phase, and the final stable phase. To document this the following good-practice can be used:

- <u>Initial conditions should be similar</u>, which for this exercise means
    - The temperature should be steady and independent of the ambient temperature. This can be achieved by setting the reference slightly above the ambient temperature such that the actuator (the heating element) is always active.
    - Controller must be in steady state (meaning that both integral, proportional and differential part[1] of the controller are steady. They do not need be at the same value for all experiments, but they should be constant!
- <u>Full transient behaviour should be visible</u>, which for this exercise means
    - The behaviour of all changing parameters should be included. That means, from the step is imposed until all variables have converged to a steady value. Good variables to include here are: Temperature, Reference, Control signal, proportional part, integral part, and differential part (if the differential part of the controller is used).
- <u>Steady-state conditions </u>, which for this exercise means

- o The behaviour of all changing parameters should be stable. That means, all variables are converged to a steady value. Good variables to include here are: Temperature, Reference, Control signal, proportional part, integral part, and differential part[1] (if the differential part of the controller is used).

Good-practice Example

Imagine an experiment typical for the exercise where a new tuning (set of parameters for the PID controller) has been implemented in the PsOC code. The code is compiled and downloaded to the PSoC and the code starts executing, bringing the temperature from the ambient temperature of 25°C to the reference temperature of 30°C. Here the systems stays for a while to make sure that all variables are constant. When the system is considered to be steady, the reference is increased to 40°C. The controller now increases the power of the heating element until the temperature reaches 40°C. To ensure a final steady performance is reached, the experiment is continued for a while before terminated. A good-practice documentation of this experiment is illustrated in Figure 1 and Figure 2.

From this documentation it can be seen that the system was steady before the stem was applied (all temperatures and control variables are constant in the time interval [2500s ; 3000s]. The control performance can be evaluated form the time interval [3000 s to 3600s]. Observe that not only can the ability to control the temperature be observed. It can also be observed HOW the controller achieves the performance from looking at behaviour the different components of the controller. Finally, it is clear that the temperature actually reaches the target temperature when observing the time interval [3600 s to 4200s]. Furthermore, it is seen that the controller has also converged (no changes in any of the controller contributions).

Good-practive documentation

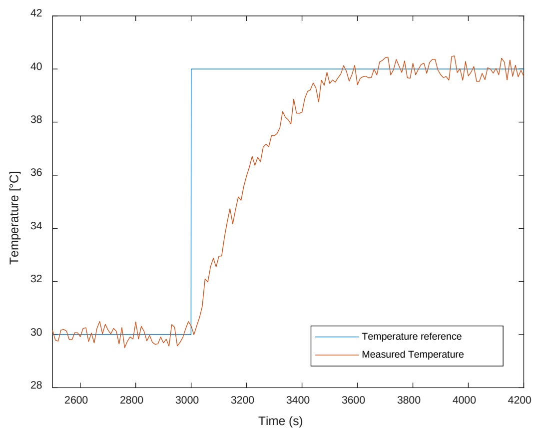

Figure 1: Good practice documentation of reference and measured temperature. Initially conditions are seen in the time interval [2500 ;3000], transient performance is seen in the time interval [3000;~3600], and the final steady performance is seen in the interval [~3600; 3200].

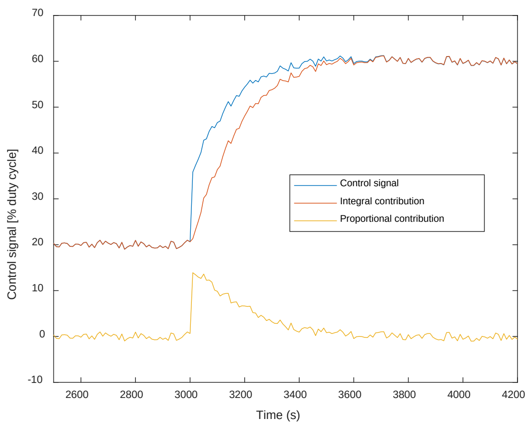

Figure 2: Good practice documentation of control behavior. Initially conditions are seen in the time interval [2500 ;3000], transient performance is seen in the time interval [3000;~3600], and the final steady performance is seen in the interval [~3600; 3200].

[1] Note that the differential part can be quite noisy, so a completely steady behavior cannot always be achieved. Changes related to system changes should be steady but high-frequency noise is acceptable in steady operation.