Homework 6 – PID Switching

YI CHEN

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Overview

PID switching algorithm

System setup in Simulink

Controller design

System response

System response in comparison to fixed controller

Summary

Reference

Professor’s note: Step responses don't show much in adaptation. It is preferable to use square wave as an input so you can see the adaptation progress. You can open the period enough so that the response reaches a steady state.

→ Works were done after the presentation to redesign the controller set as well as using a pulse train to analyze the system

Switching Algorithm

Algorithm proposed from the paper on Unfalsified Adaptive Control:

Algorithm 1: The switching algorithm, which is copied directly from the literature of unfalsified adaptive control e.g. [12], [13], is as follows:

Step 1. Let ε be a small positive constant, τ be the current time (initialized to $\tau = 0$), $\Delta\tau$ be the time increment, and $\tilde{C} \in \boldsymbol{C}$ be the controller in the feedback loop of Fig. 2;

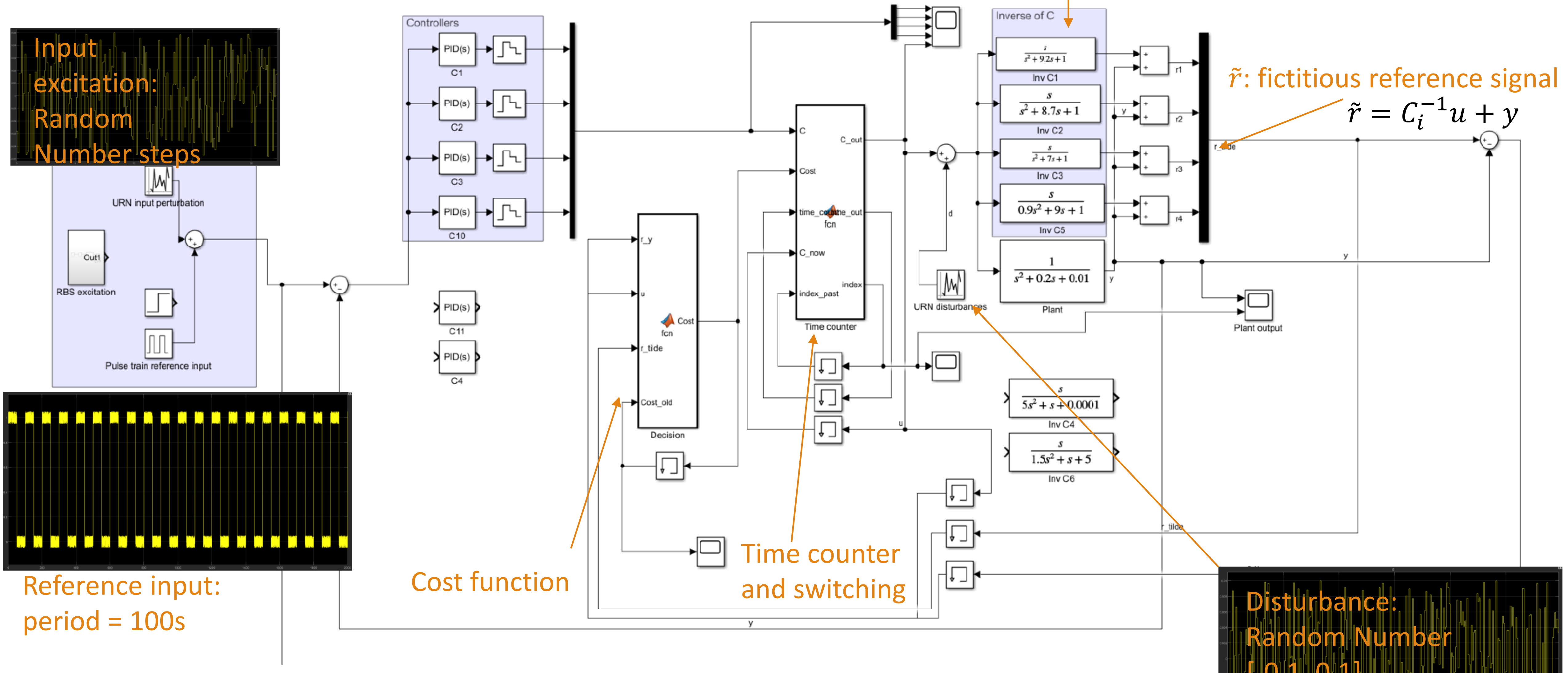
Step 2. $\tau \leftarrow \tau + \Delta\tau$;

Step 3. If $V(\tilde{C}, u, y, \tau) > \min_{C_i \in \boldsymbol{C}} V(C_i, u, y, \tau) + \varepsilon$, then $\tilde{C} \leftarrow \arg\min_{C_i \in \boldsymbol{C}} V(C_i, u, y, \tau)$;

Step 4. Go to Step 2.

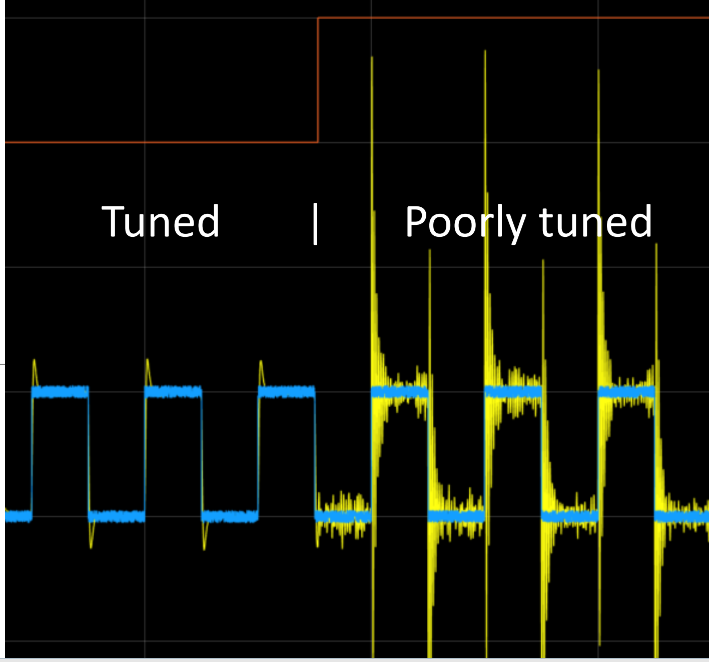
System Setup

Objective: design a good tracking controller to the reference input for plant 1



In this case we are using the proposed forward-path unfalsified adaptive controller setup.

PID controllers



Numerical design parameters:

- % Overshoot: 15%
- Rise time: 1.15

Controller 3 and 4 are designed using PID tuner

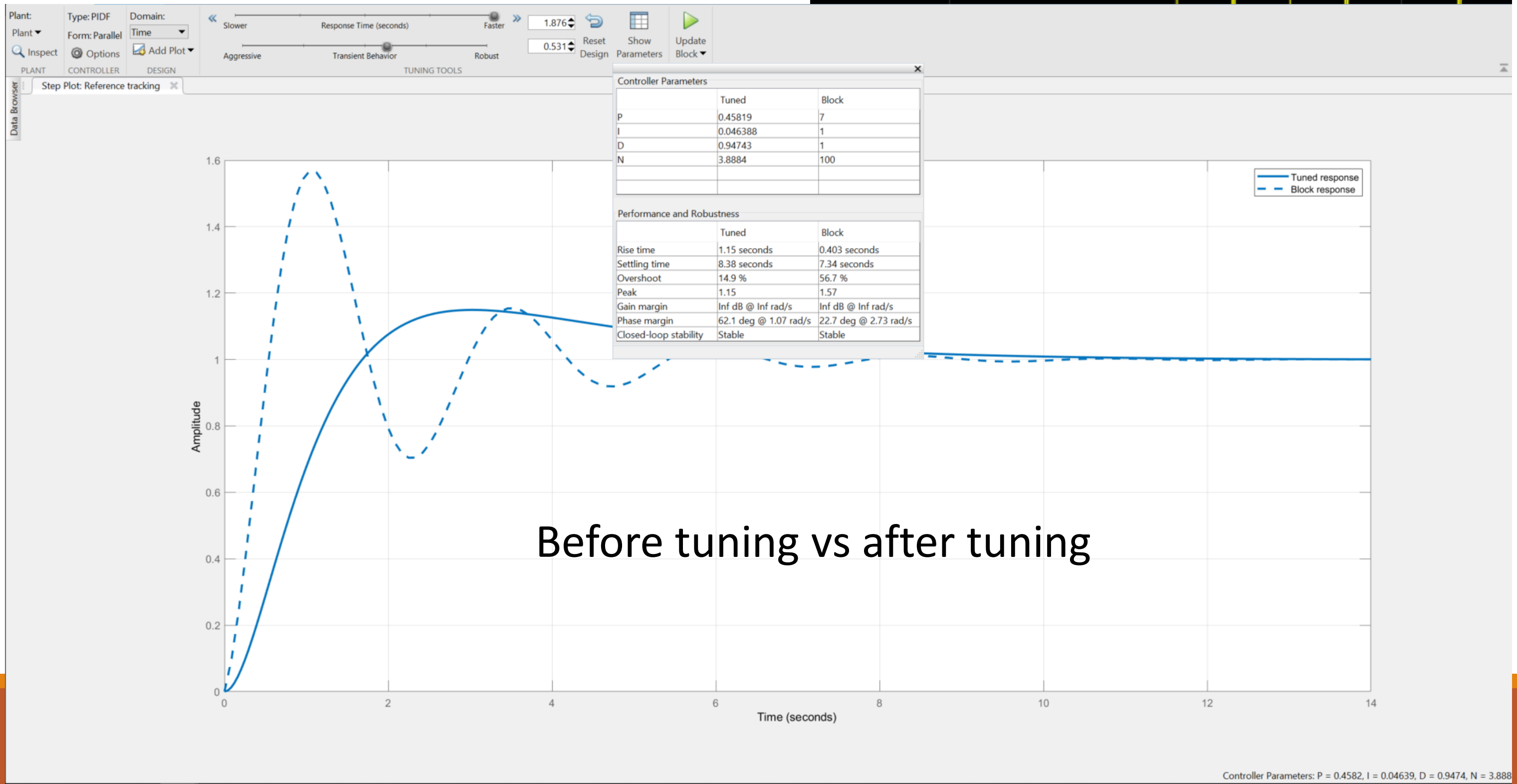
Controller 1 and 2 are poorly tuned with trial and error

C1: [kp ki kd] = [10 1 1]

C2: [kp ki kd] = [9 1 0.9]

C3: [kp ki kd] = [0.45 0.046 0.947]

C4: [kp ki kd] = [0.5 0.05 0.9]

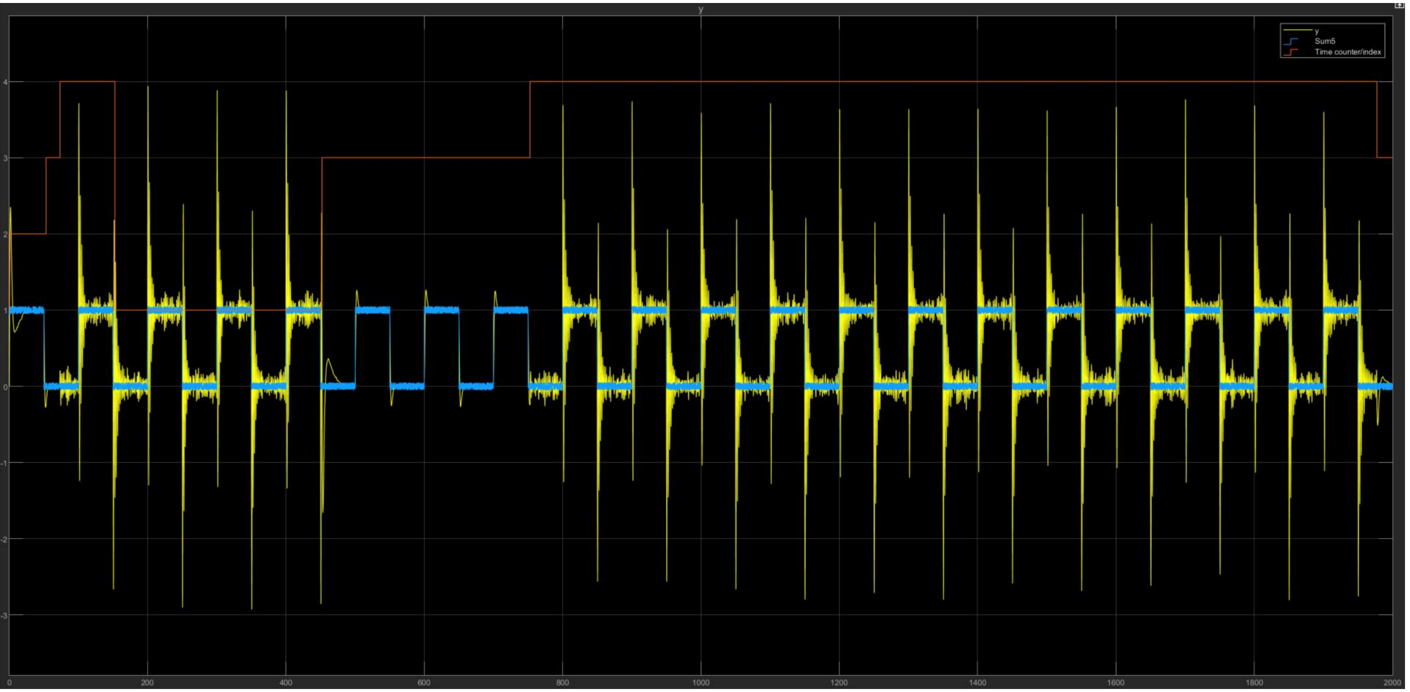


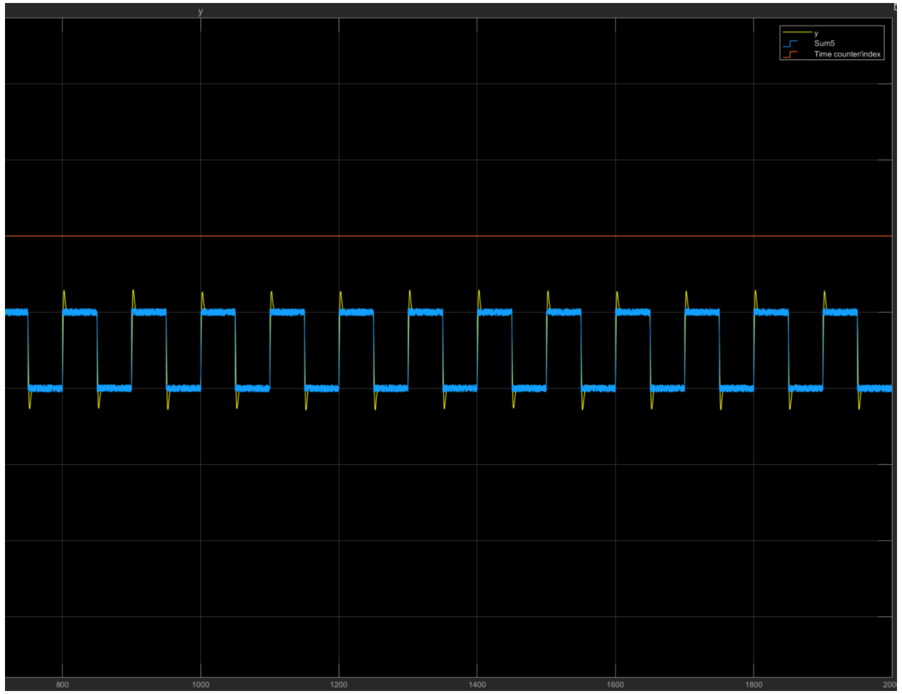
Cost function comparison

Two cost functions proposed in different papers were tested for the use in our plant.

$$V(C,u,y,t) = max \frac{1}{\|r\|_{L_2[0,t]}} \sqrt{\|W_1(y-r)\|^2_{L_2[0,t]} + \|W_2 u\|^2_{L_2[0,t]}}$$

$$V(C_i,u,y,t) = \max_{\tau \in [0,t]} \frac{\|u\|_\tau^2 + \|\tilde{r}_i - y\|_\tau^2}{\|\tilde{r}_i\|_\tau^2 + \alpha}$$





Cost function on the right better reflected our definition desired controller

Effect of Dwell time on system response

Here we investigate the effect of dwell time on the transient response of the system, as discussed in the paper.

Higher disturbance ([-0.1, 0.1]) were introduced to encourage switching.

Similar number of switches trend to the one proposed in the paper.

Dwell-Time	0.1	1	3	6	10
Number of switches	2	1	1	1	1

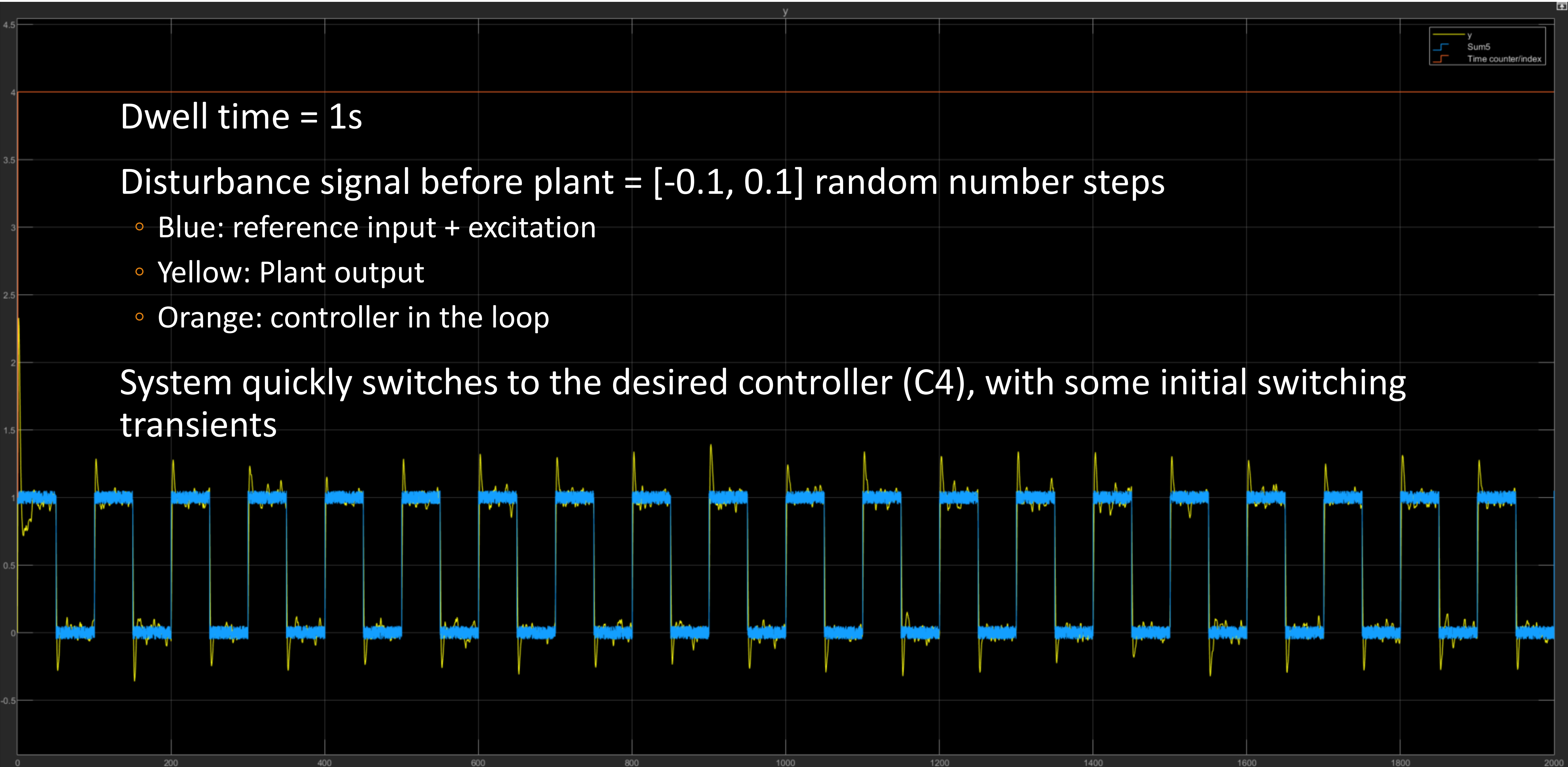
Final Design - System response

Dwell time = 1s

Disturbance signal before plant = [-0.1, 0.1] random number steps

- Blue: reference input + excitation
- Yellow: Plant output
- Orange: controller in the loop

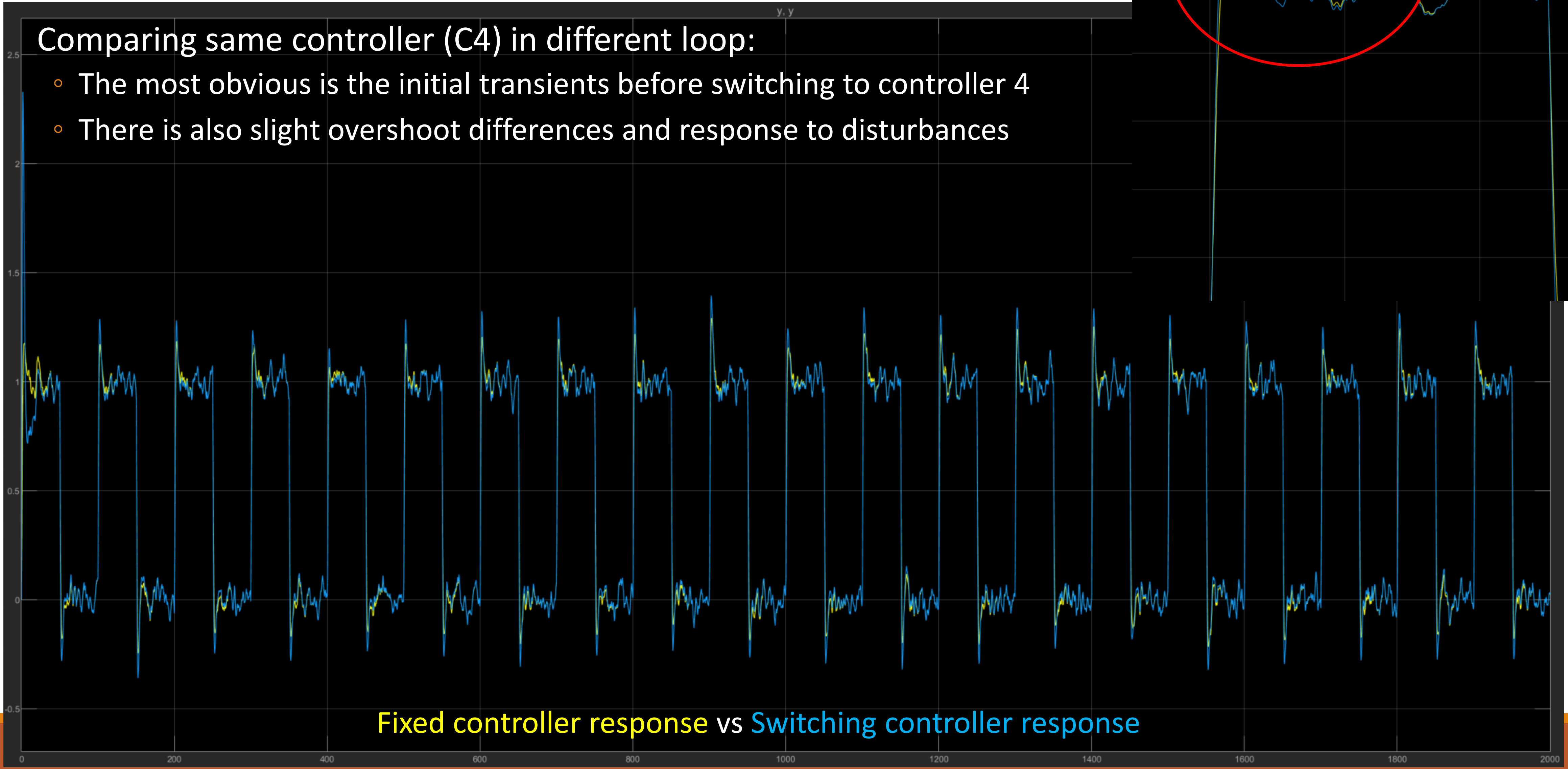
System quickly switches to the desired controller (C4), with some initial switching transients



System Response:
Comparison with fixed controller

Comparing same controller (C4) in different loop:

- The most obvious is the initial transients before switching to controller 4
- There is also slight overshoot differences and response to disturbances



Fixed controller response vs Switching controller response

Summary

Benefit of the switching mechanism as shown would be combining different PID characteristics for better transient and steady-state performance

We attempted to introduce some input perturbation to the plant, but the controller outputs are too different in steady state to have an effect.

Implementing larger number of controllers might give us insight to potential improvement with more switching between controllers that are better at different scenario.

Reference

[1] Unfalsified Adaptive Control - A new Controller Implementation

[2] The Unfalsified Control Concept and Learning