UNIVERSITY OF PADOVA

Control Engineering Laboratory

First Laboratory Challenge

SECOND SHIFT (Friday 10:30) GROUP NAME: F.1

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1 Challenge Description

The challenge requires the design of a control system for the QUANSER SRV-02 MOTOR (real or black-box model) capable of asymptotic tracking of step references with an overshoot $M_p \leq 10\%$ for a 70° reference signal. The goal is to optimize the raise time t_r to be as small as possible. For the sake of comparability with other groups, the design was carried out on the black-box model.

2 Control Strategy

To match all the performance specifications mentioned above, a *robust state-space controller with an added integrator anti-windup mechanism* is used. The robust state-space controller alone ensures perfect step-tracking with a low raise time, while the additional anti-windup action is added to limit the overshoot of the response below 10%.

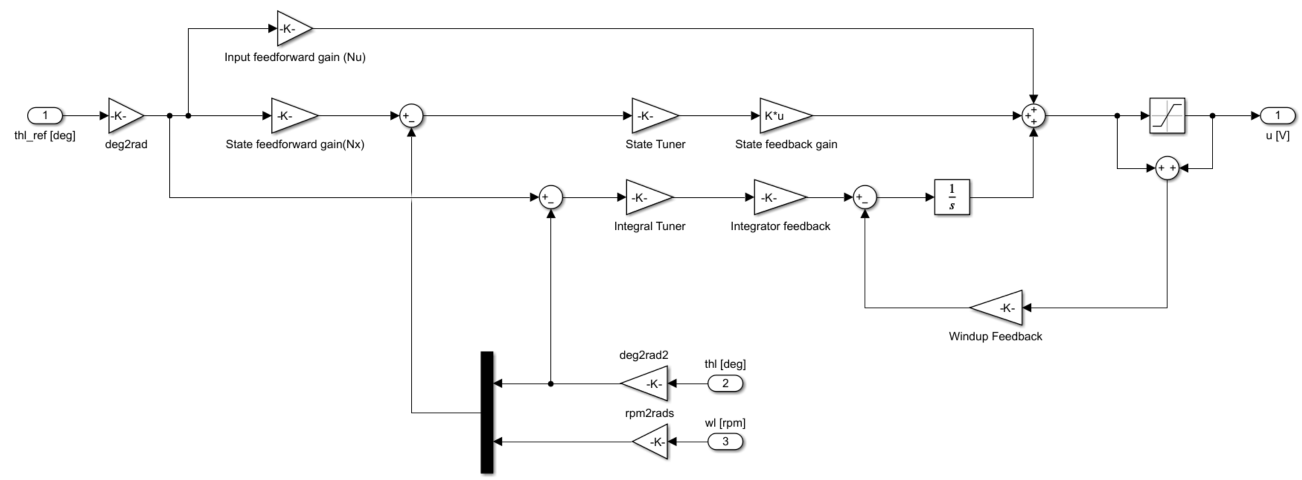

Figure 1: Robust state-space controller with additional anti-windup mechanism.

To minimize the rise time t_r, a set of custom gains (manually tuned) is added in addition to the state- and integrator feedback gains that are calculated via the MATLAB function `acker()`. These gains are as follows:

1. State Tuner: In the form of a vector gain ($\mathbb{R}^{1\times 2}$) to balance the contributions from ϑ_l (degrees) and ω_l (rpm).

2. Integral Tuner: To manipulate the integral action from the robust design.

The entire design can be examined in detail in Figure 1. The calculation of all feedback gains used in the robust state-space design, was carried out based on the pole allocation method for the reduced, augmented state-space model, with the following closed loop poles:

$$\lambda_{c,\{1,2\}} = 2\sigma \pm j\omega_d, \quad \lambda_{c,3} = 3\sigma$$

The anti-windup and tuner gains were chosen iteratively. The final set of all gains is listed in Table 1.

Gains	**Values**
Input feedforward gain (N_u)	0
State feedforward gain (N_x)	$\begin{bmatrix} 1 & 0 \end{bmatrix}^T$
State Feedback	$\begin{bmatrix} 43.649 & 0.66259 \end{bmatrix}$
Integrator Feedback	859.45
Windup Feedback	13.667
State Tuner	$\begin{bmatrix} 2 & 0.5 \end{bmatrix}$
Integral Tuner	1.26

Table 1: Complete set of gains

2.1 Results

The described controller, together with the black-box model, was implemented in Simulink. The plot of the response is shown in Figure 2, and the response data was logged to MATLAB for analysis. The `stepinfo()` function was used to verify the results for the overshoot and raise time. The following values were archived:

$$M_p = 9.54\%, \qquad t_r = 0.0314\ s$$

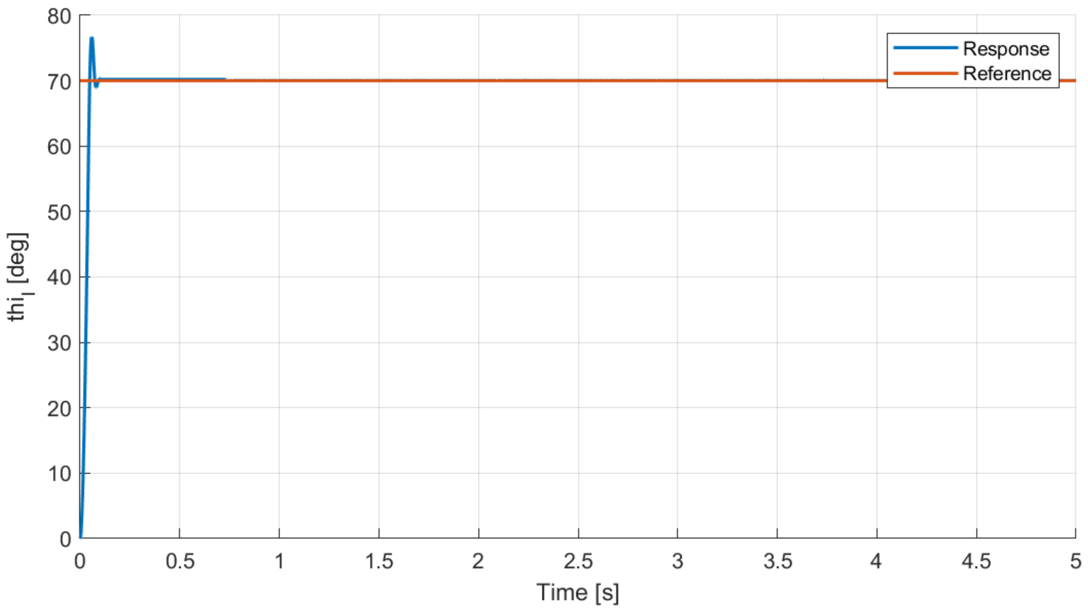

Figure 2: Response for 70° step reference.

In addition to the signal of the angular displacement of the load, the controller output voltage was also recorded. Figure 3 shows the output voltage over the first 0.1 s of the simulation. It can be seen, that the voltage is saturated, and thus maximal, until roughly 0.04 s. This means that the motor torque and, therefore, the load acceleration are also maximal during this period. Since the raise time is reached before the saturation of the voltage ends, it must be minimal. The simulations behind this challenge can be viewed here.

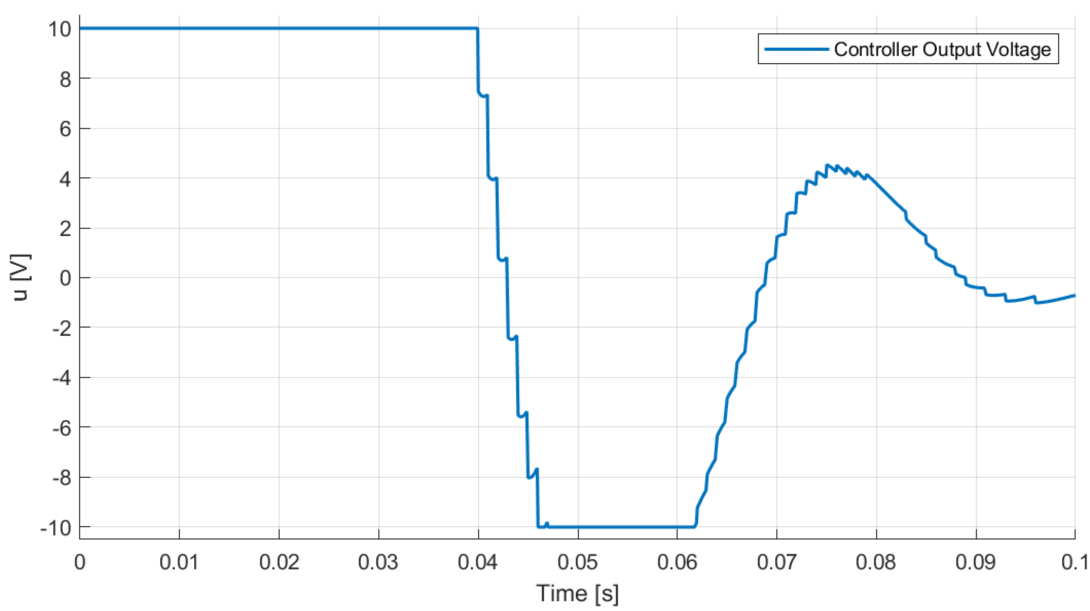

Figure 3: Controller output voltage in the transient period.