3 Constructing a standard performance compensator using a plant model

A plant model is used to construct a compensator. There is considerable delay in the plant which must be properly managed without overshoot or oscillation. The resulting closed-loop system is simulated and compared to the original uncompensated Step Response.

We start with already having the plant model from which we will construct a standard performance compensator. The uncompensated Step Response is slow but acceptable. There is, however, a considerable amount of system delay from control effort to plant response.

Our task is to replicate the uncompensated performance of the plant in a closed-loop system while properly managing delay, and without overshoot or oscillation.

Let’s take a moment to clarify terminology and understand system construction arrangements.

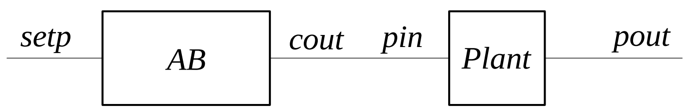

Figure 1 (AB compensator)

Figure 1 shows a compensator AB (Adjustment Block) followed by a Plant model. The purpose of this arrangement is to shape plant input and output using simulation to confirm system design goals are met, such as overshoot, oscillation, plant input remaining within bounds, plant input sequence, plant output sequence, shape of step response, and so on. This arrangement is normally part of the design workflow but is a trivial step in this example. This compensator is not deployed in a real physical system.

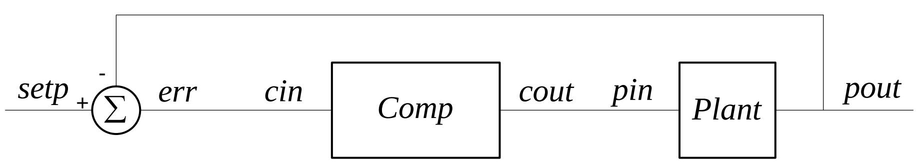

Figure 2 (closed loop compensator)

Figure 2 shows a closed loop compensator (with integrator included) followed by a Plant model. When we are satisfied with system performance using the AB compensator shown in figure 1 above (as determined by system simulation), the closed loop compensator is directly computed from the AB block. In simulation, the same setpoint (aka reference) sequence applied in figure 1 or figure 2 will produce the identical plant output sequence $pout$. This arrangement is deployed in a real physical system.

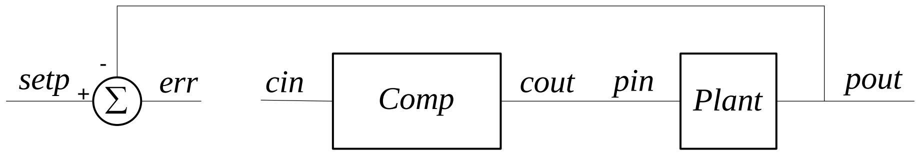

Figure 3 (closed loop compensator operating open loop)

Figure 3 shows the closed loop compensator open at the compensator input cin. In all other respects, this is the same arrangement that is shown in figure 2 (the compensator and plant is identical). The purpose of this arrangement is to obtain a bode plot of open loop system operation with the frequency sweep applied directly to the compensator input cin, and system response observed at the plant output $pout$ using either the plant model or the real physical plant. From the bode plot, the general appearance of the response, the crossover frequency f_x, the gain margin, and the phase margin can all be observed. Alternate methods, such as a frequency response analyzer can also be used, as appropriate.

“Impulse Response” is terminology used in the context of continuous-time systems, whereas “Unit Response” is terminology used in the context of discrete-time systems. In every situation in which “Impulse Response” is used in the context of discussing discrete-time systems, it is intended to convey the meaning of “Unit Response.”

Figure 4

Figure 4 shows the plant’s Step Response. The delay from control effort to plant response is very noticeable.

Let’s compute the Impulse Response:

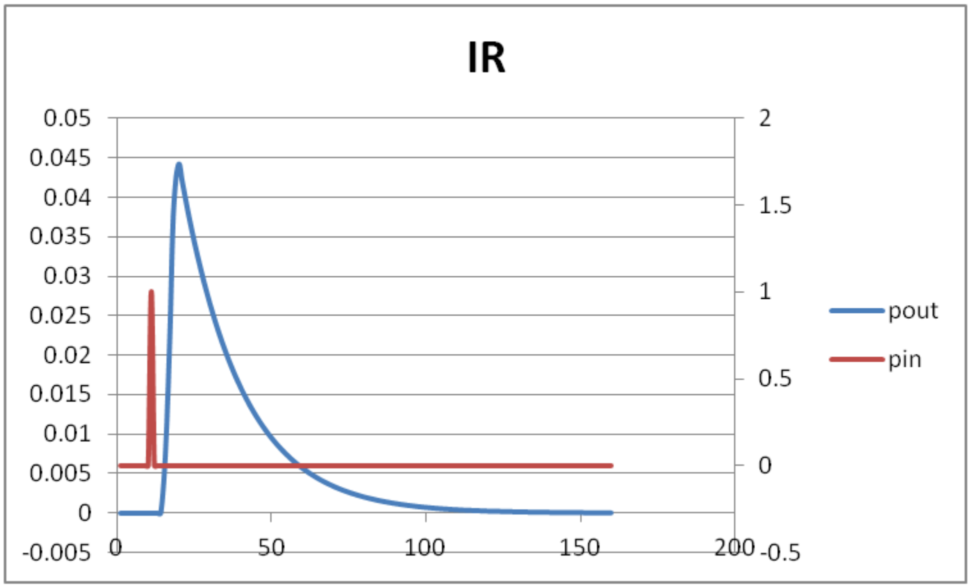

Figure 5

Figure 5 shows the system delay that was evident in Figure 4.

The goal of this method is to implement a closed-loop system that is equivalent to the uncompensated Step Response of the plant. Let’s check that now.

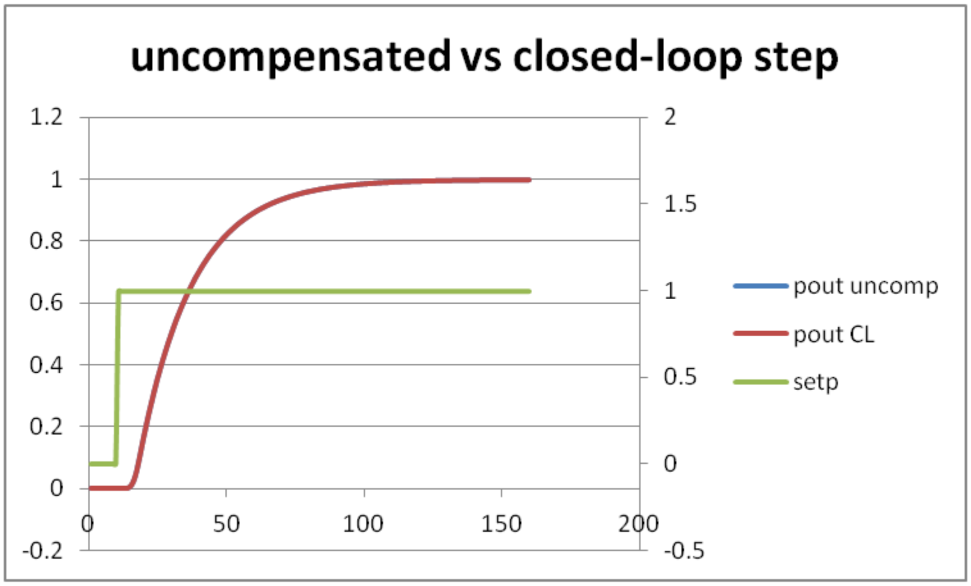

Figure 6

Figure 6 shows the setpoint as a step input to both the uncompensated and closed-loop implementations. The closed-loop response *exactly* overlays the uncompensated response, so that only one line appears visible.

Let’s compare performance with a different setpoint sequence:

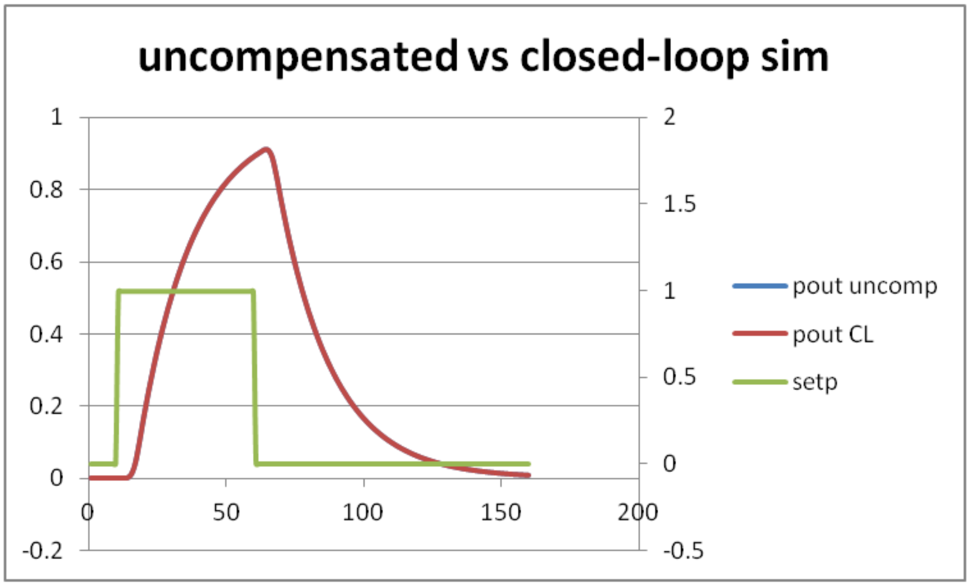

Figure 7

The simulation in figure 7 shows both the uncompensated and closed-loop response to the new setpoint sequence to be identical.

Summary:

This method of compensator construction starts with a derived plant model already in hand, and acceptable uncompensated plant Step Response performance. Using the plant model, we are able to exactly replicate the uncompensated plant behavior in a closed-loop system, while properly managing plant delay. There is no overshoot or oscillation.

This example is similar to "Constructing a compensator directly from in-system Step Response data without a plant model." Similarities include:

- The same plant is used in both examples
- The same system performance is achieved in both examples
- System offset is removed in both examples
- System delay is properly managed in both examples

Differences include:

- A plant model is derived from in-system measured plant Step Response
- System drift is removed in the plant model
- Noise in the Impulse Response is reduced
- Noise in simulation is reduced
- Runtime computational requirements are dramatically reduced