7 Constructing a compensator that generates a specified plant output sequence

A plant model is used to construct a compensator that produces a specified plant output sequence. The resulting closed-loop system is simulated.

We start with already having the plant model from which we will construct a compensator that produces a specified plant input sequence. The plant that is used in this example is simple, reasonably fast, and has no delay from control effort to plant output.

Given a specific desired plant output sequence, our task is to construct a compensator that produces the desired plant output sequence in a closed-loop system. This problem can be framed as solving a different problem, that is, what is the plant input sequence that generates the desired plant output sequence?

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

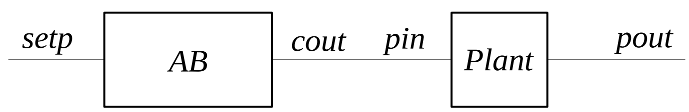

Figure 1 (AB compensator)

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 compensator is not deployed in a real physical system.

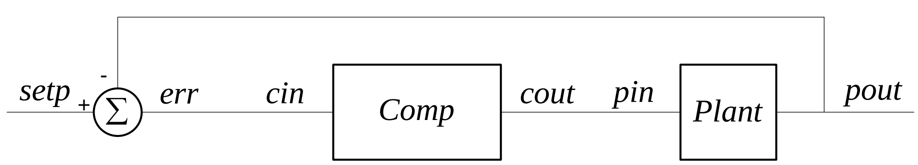

Figure 2 (closed loop compensator)

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.

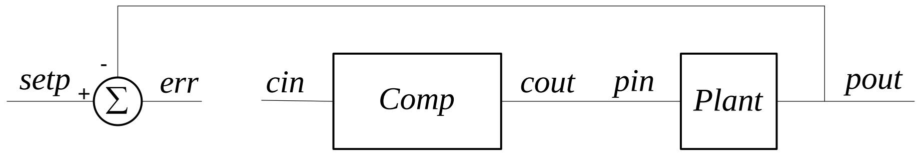

Figure 3 (closed loop compensator operating open loop)

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.

Let's start with the plant model Step Response:

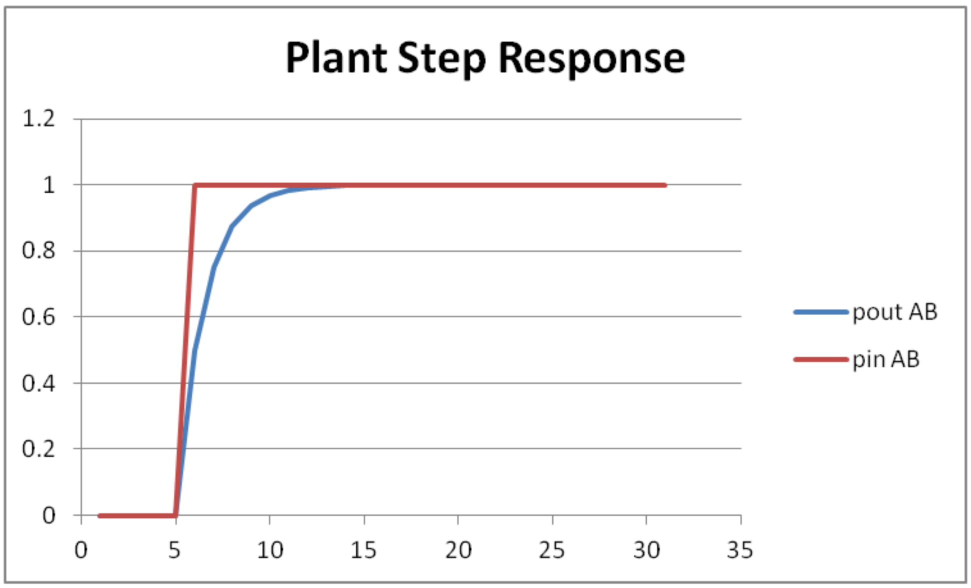

Figure 4

Figure 4 shows the plant's Step Response. The plant is simple, reasonably fast, and there is no delay from control effort to plant response.

System performance is typically evaluated using Adjustment Block simulations, where candidate compensators are proposed and observed. This is typically an iterative process, as we experiment with system parameters and refine system design goals. When we are satisfied with the AB system performance, the AB system is converted to a closed-loop equivalent system. Simulation can be used to confirm identical performance as compared to the open-loop AB system. This example illustrates this workflow. We have a plant model and we will be asking three questions:

1. What happens when the plant output is a step?
2. What happens when the plant output is a linear ramp?
3. What happens when the plant output is a smooth curve?

The third question may be particularly interesting for system designers that are controlling a mechanical system in which acceleration and jerk must be managed.

We have already seen the answer to the first question in Figure 4 above. We will answer the remaining questions now.

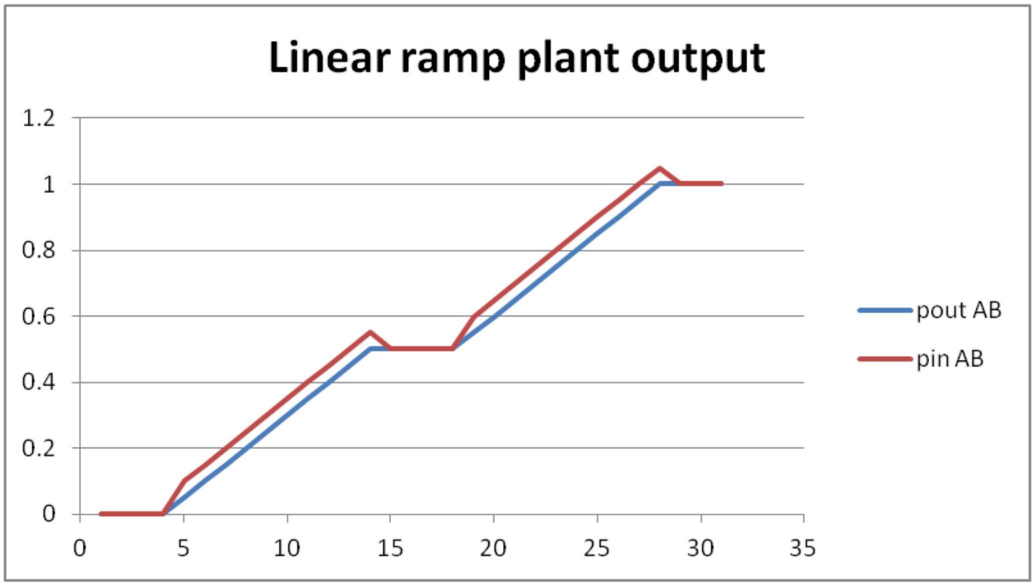

Figure 5

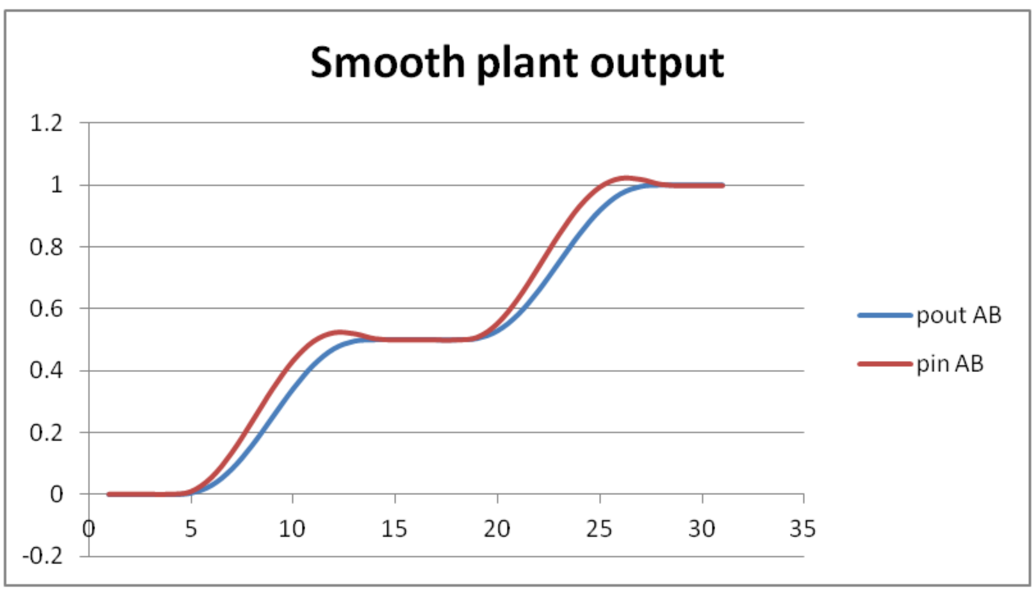

Figure 6

After deciding on implementing the smooth plant output, the open-loop AB system is converted to the equivalent closed-loop system, simulated, and compared to the AB system as a final confirmation of correct implementation.

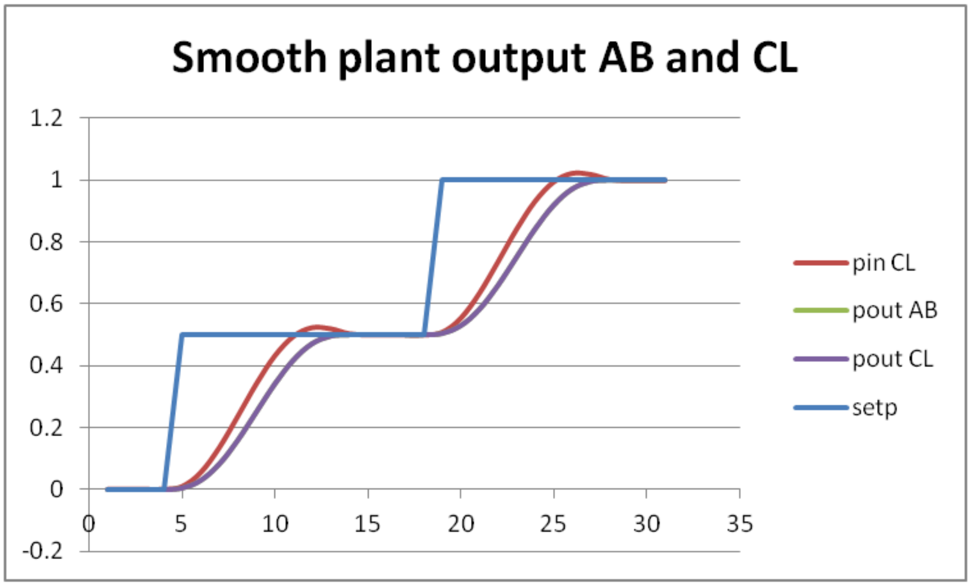

Figure 7

Figure 7 shows the setpoint as a step input to the system, and the compensator generates the desired smooth plant output sequence in the closed-loop simulation. We also see that the closed-loop plant output exactly overlays the open-loop AB plant output as expected, confirming correct implementation of the closed-loop compensator.

Summary:

This method of compensator construction is particularly useful in situations where the output sequence of the plant is important.

It should be noted that generating arbitrary plant output sequences is somewhat computationally expensive at run-time, when implemented directly in the compensator. For example, for the sequences shown above, in which the length of the ramp sequence and smooth sequence was 10 steps, 22 coefficients are required. Fewer coefficients are required for shorter length sequences.

It is not strictly necessary to implement arbitrary plant output sequences directly in the compensator. Equivalent plant output sequences can be achieved by appropriately manipulating the system setpoint sequence, in which case, many fewer coefficients would be required in the compensator.

Not all plants are candidates for this method. For example, for plants with delay from control effort to response, no amount of control effort will produce a change at the plant output for the first few cycles.