8 Power supply design example part 1 (Implementation)

A plant model for a digital power supply is used to construct a compensator with maximum (fastest) performance. There is no overshoot or oscillation. System performance is adjusted as desired, a closed-loop compensator is constructed, and the resulting closed-loop system is simulated and compared to the desired system.

This example is based upon a digital power supply seminar in which the plant is already known.

Our task is to shape system performance so that the system is on-setpoint quickly, without overshoot or oscillation, while keeping the control effort within the input range of the plant. After we are satisfied with the performance of the shaped system, we construct the compensator that replicates that performance in a closed-loop system.

The maximum performance (Active Compensation™) compensator is an active design that is given limits on the plant input range and performs run-time computations to assure that these limits are enforced. The compensator may continuously drive (or overdrive) the plant input to the limit for an extended number of cycles, as determined by run-time computations.

This is akin to applying full-throttle for an extended period of time, then after some number of cycles, adjust the throttle as the system approaches setpoint. This is all done while remaining within the prescribed input bounds of the plant and is enforced by run-time computation.

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

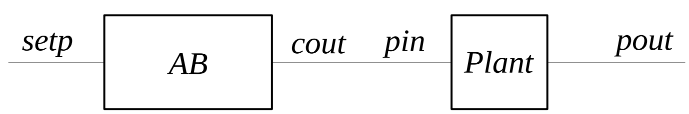

Figure 1 (AB compensator)

Figure 1 shows a compensator AB (Adjustment Block) followed by a Plant model without feedback. 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.

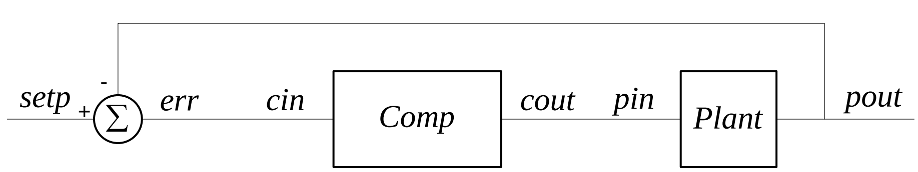

Figure 2 (closed loop compensator)

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 constructed directly 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.

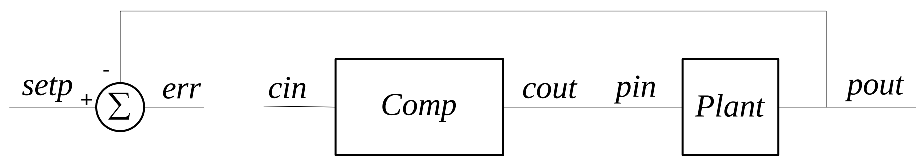

Figure 3 (closed loop compensator operating open loop)

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 are 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. The bode plot is discussed in a future paper.

"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 the terminology "Impulse Response" is used in the context of discussing discrete-time systems, it is intended to convey the meaning of "Unit Response."

The system used in the seminar was

$$G_p(s) = \frac{3.8968*10^{-5}s + 11.139}{7.5091*10^{-10}s^2 + 1.8337*10^{-5}s + 1}$$

and the proposed compensator was

$$G_c(s) = 1.60974*10^{-5} * \frac{s^2 + 1.34540*10^4 s + 4.04259*10^8}{s}$$

In this example, we are normalizing the plant to be $0 \le pout \le 1$ and restricting the range of the plant input to be $0 \le pin \le 1$. Let's start with the original (normalized) plant model:

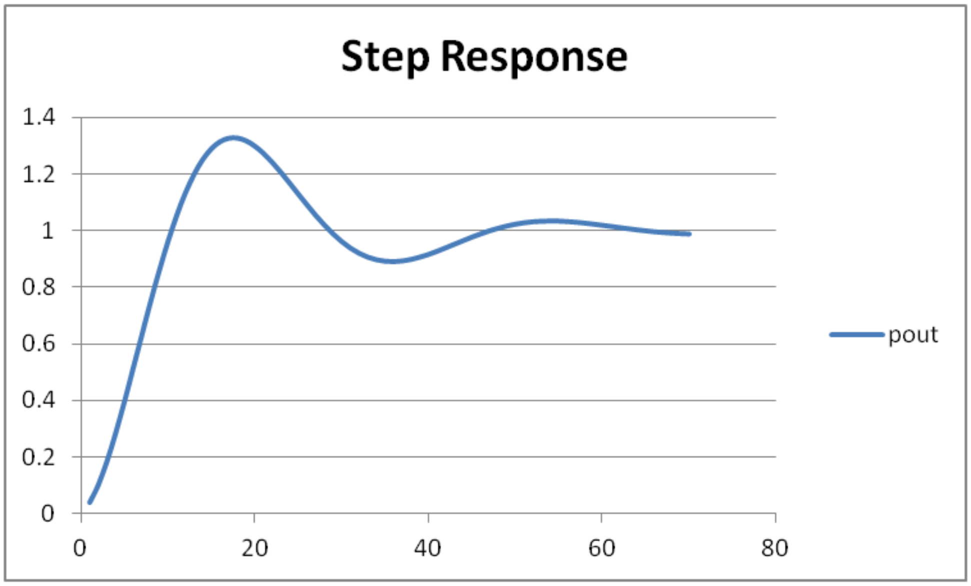

Figure 4

Figure 4 shows the plant's Step Response. There is oscillation and 33% overshoot.

Let's compute the Impulse Response:

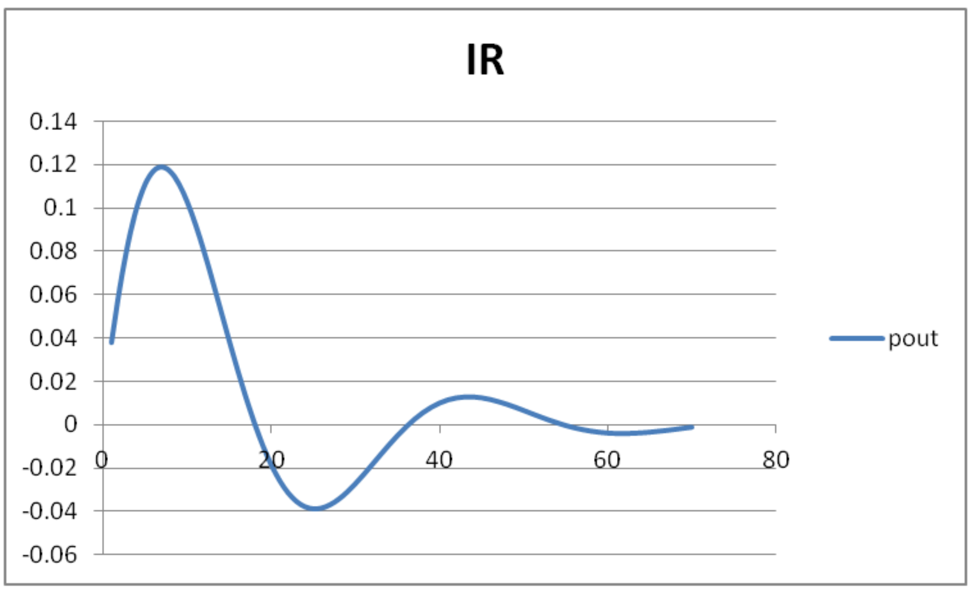

Figure 5

Run-time computations assure that commanded control effort at the plant input is always within bounds.

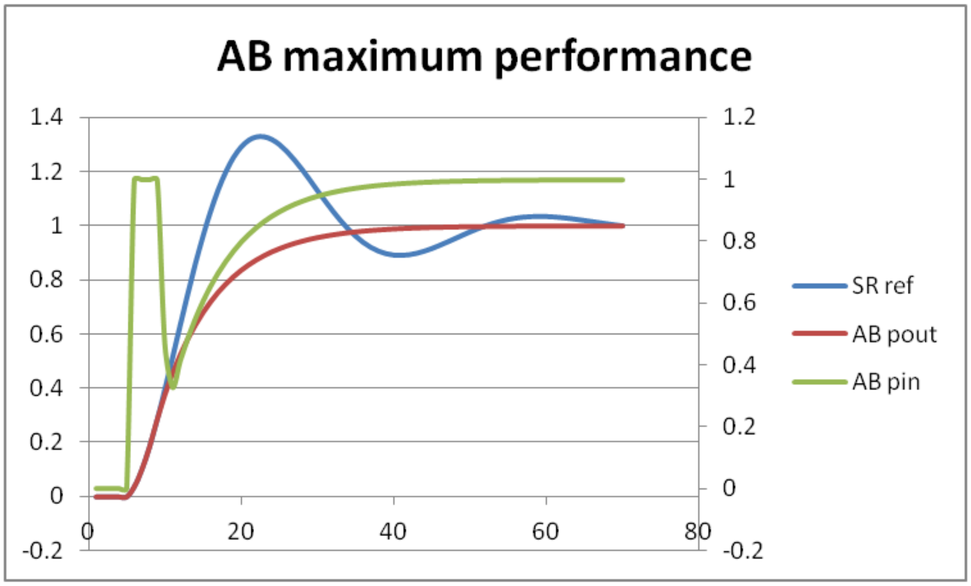

Figure 6

Figure 6 shows a maximum performance compensator and plant (Active Compensation™). The uncompensated Step Response is shown as the benchmark against which we compare the performance of our system. The maximum performance plant input illustrates the concept of driving (or overdriving) the plant input to the limit for multiple cycles, then manipulating the control effort as the plant approaches the setpoint.

Figure 6 also shows the improvement in plant output – the system is on-setpoint much faster than the reference system, without overshoot or oscillation.

Since we are satisfied with this maximum performance, the next step is constructing the compensator that achieves identical closed-loop performance. Let's do that now.

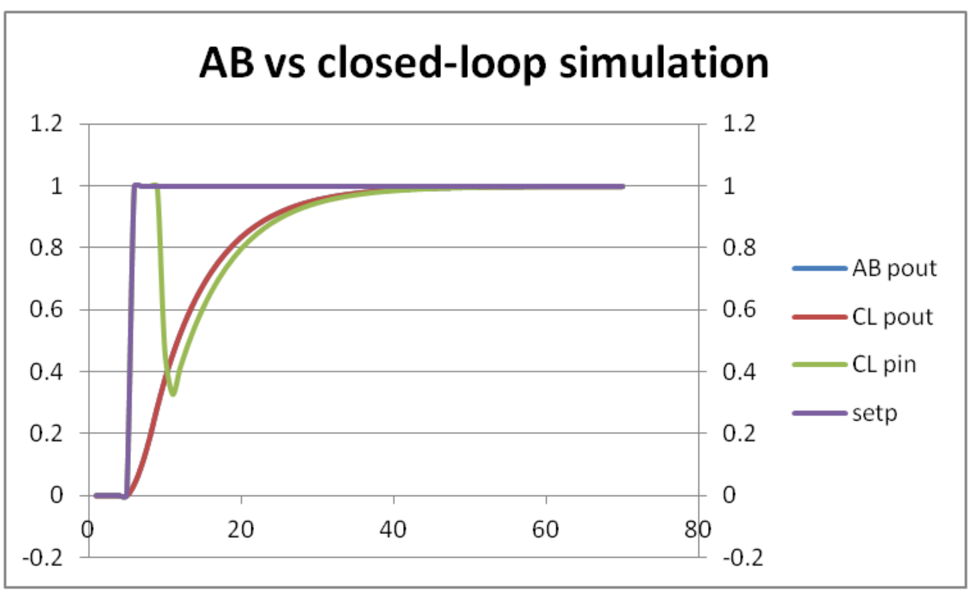

Figure 7

As shown in Figure 7, the simulation shows both the AB and closed-loop response to the setpoint sequence to be identical. The plant input shows the control effort shape and magnitude required to achieve this performance.

Summary:

This method of compensator construction starts with a derived plant model already in hand, and creates a compensator that drives (or overdrives) the plant to the defined limit for an extended number of cycles to achieve maximum performance. The plant must be able to tolerate the shape and magnitude of the plant input.

High performance is achieved without overshoot and oscillation.