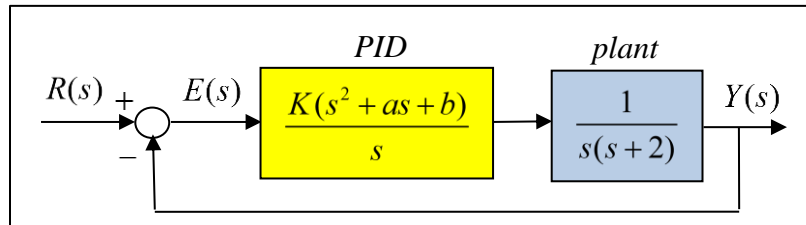


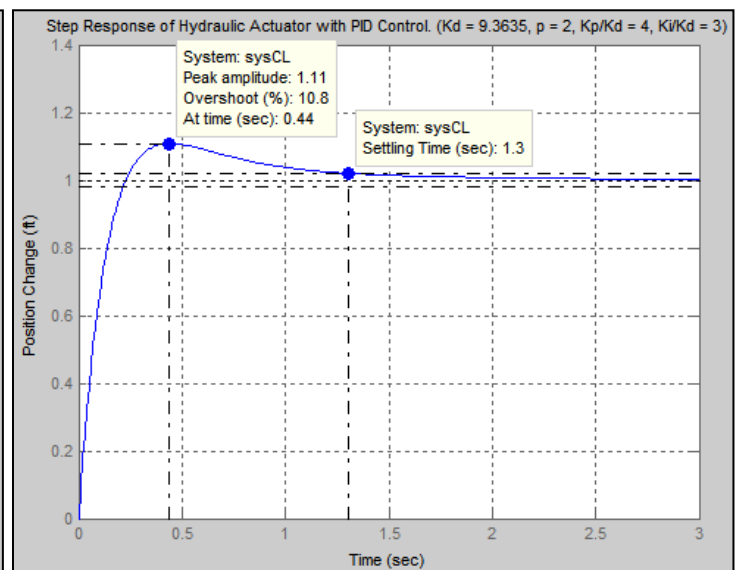
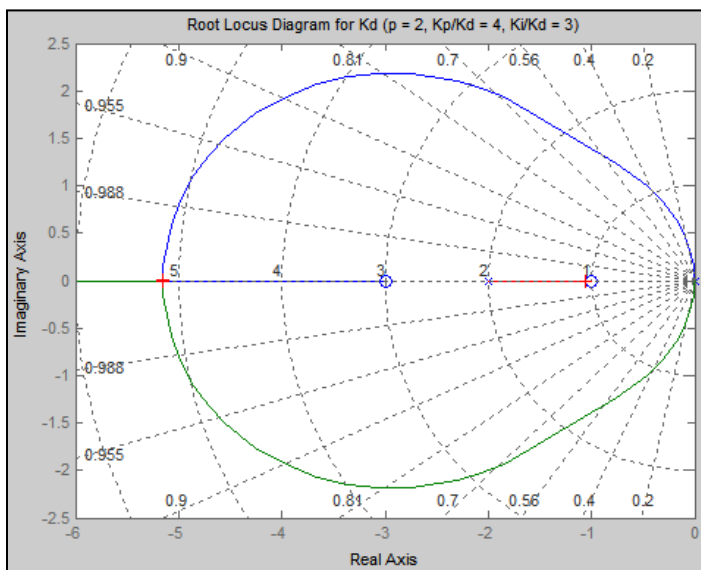
## ME 4710 Motion and Control

### PID Root Locus Design with a First Order Noise Filter

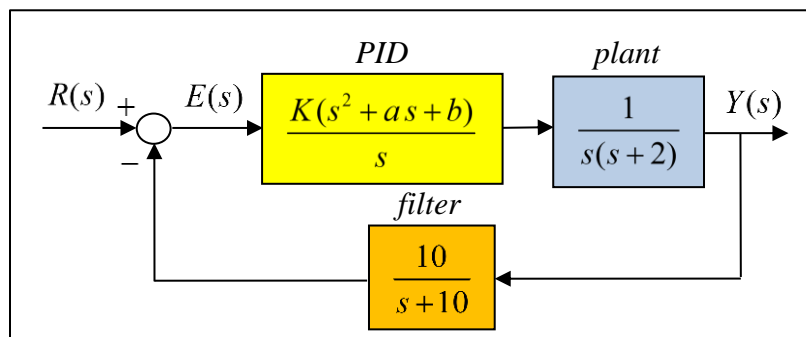
Previously we designed a *PID compensator* for a hydraulic actuator. Here,  $K = K_D$  is the *derivative gain*,  $a = K_p / K_D$  is the *ratio* of the *proportional* to *derivative* gains, and  $b = K_I / K_D$  is the *ratio* of the *integral* to *derivative* gains.



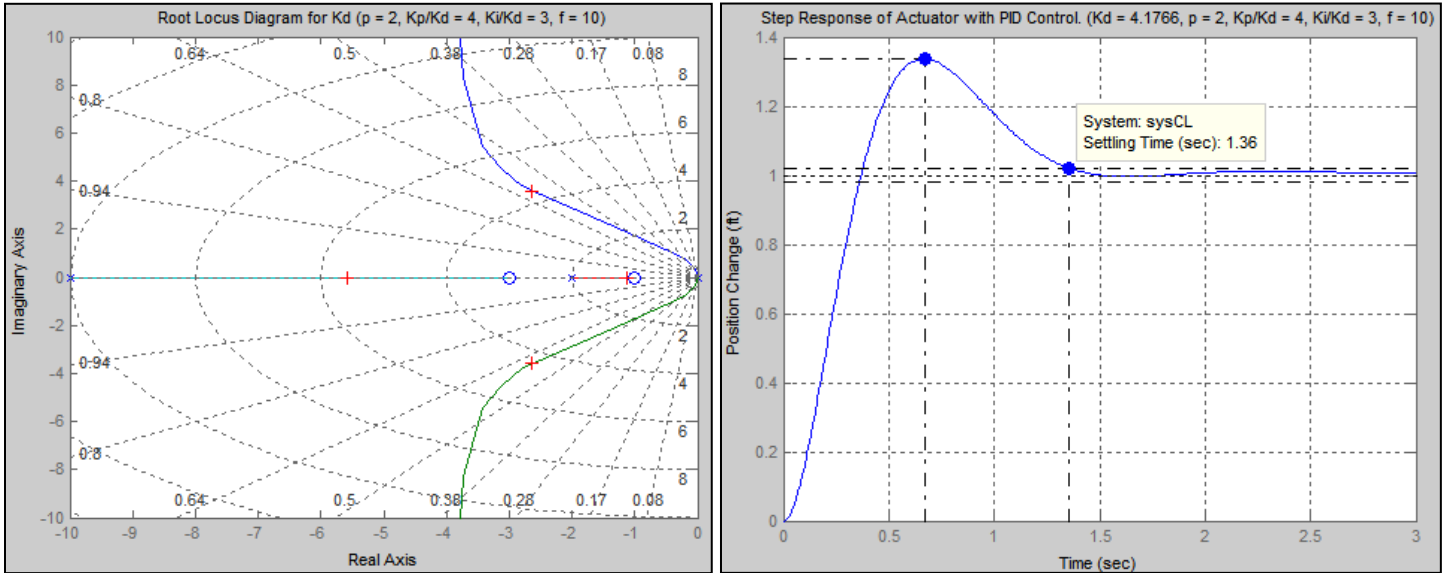
This is a *type 2* system and has *zero steady-state error* to *both* step and ramp inputs. The figures below show the *root locus diagram* for the parameter  $K_D$  with  $a = K_p / K_D = 4$  and  $b = K_I / K_D = 3$ , and a *step response* for  $K_D = K \approx 9.36$ .



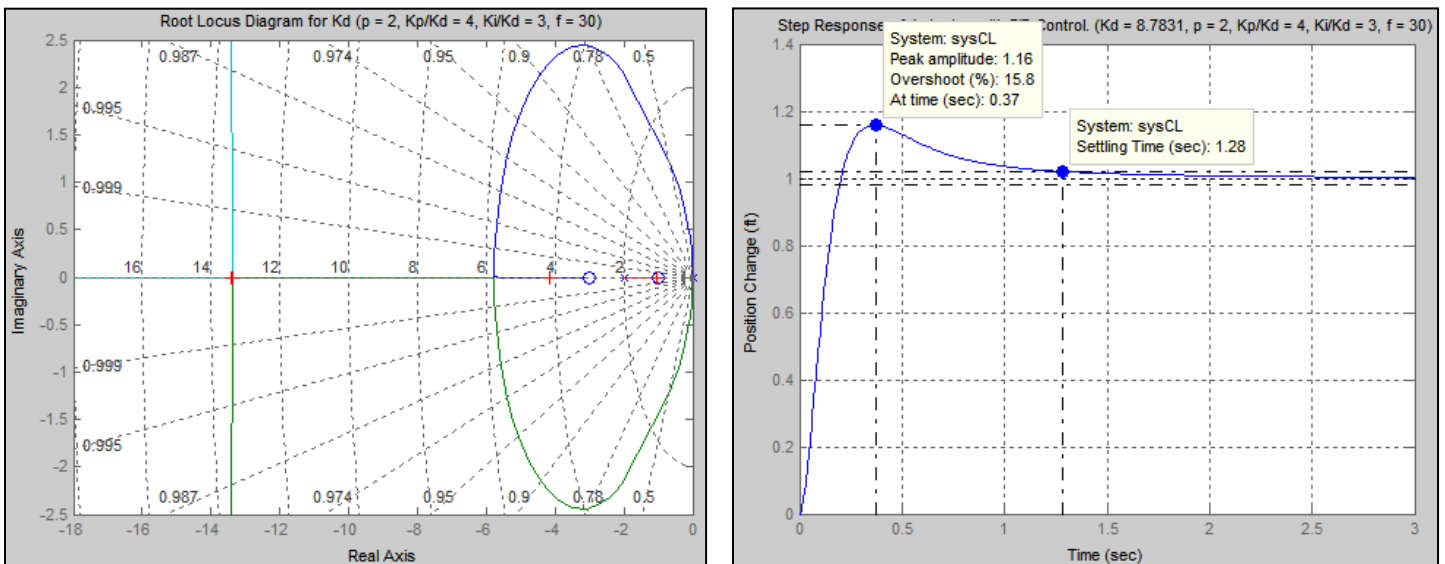
Now consider *PID control* of the same actuator with a normalized *first-order noise filter* in the feedback path as shown in the diagram below. The cut-off frequency of the filter is 10 (rad/sec).



The figures below show the *root locus diagram* for the parameter  $K = K_D$  with  $a = K_p / K_D = 4$  and  $b = K_i / K_D = 3$ , and the *step response* for  $K = K_D \approx 4.18$ . The filter has had *little effect* on the *settling time*, but it has *increased* the *system overshoot*. Note on the *root locus diagram* the complex poles approach *vertical asymptotes* at  $s = -4$  and *do not* break into the real axis as they did when no filter was present.



The figures below show the *root locus diagram* for the parameter  $K = K_D$  with  $a = K_p / K_D = 4$  and  $b = K_i / K_D = 3$ , and a *step response* for  $K = K_D \approx 8.78$ . Here, the filter cut-off frequency was changed from 10 to 30 (rad/sec). This causes the complex poles to *break into* the real axis *before breaking out* and moving along the vertical asymptotes. The step response is like the system with no filter but has a slightly *higher overshoot*.



The figures below show the *root locus diagram* for the parameter  $K = K_D$  with  $a = K_p/K_D = 4$  and  $b = K_I/K_D = 3$ , and a *step response* for  $K_D = K \approx 13.64$ . Here, the cut-off frequency of the filter was *increased* further to 50 (rad/sec). As in the previous case, the complex poles break into the real axis before breaking out and moving along the asymptotes. This system has the *same overshoot* as the system with no filter, and it has a slightly *lower settling time* probably due to the higher gain.

