ECE 3510 Control System Characteristics & Performance

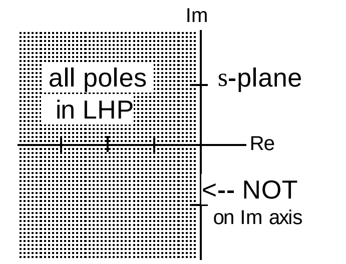
The objective of a control system is to allow an input to set or control and output.

Except in very rare circumstances:

The output should behave in a stable, predictable, manner regardless of noise, disturbances, perturbations, and system parameters that change over time. The output should track the input (or the meaning of the input) smoothly and quickly, adding as little as possible to the output that was not in the input.

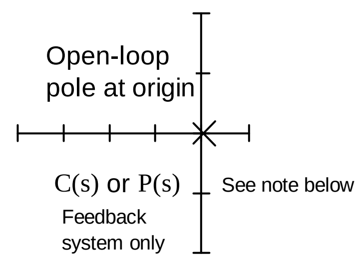
A GOOD Control System — Corresponding system poles

1. Is Stable. At the very minimum it needs to be BIBO stable. (Often the concept of stability is enlarged into areas we will consider minimal tracking.)



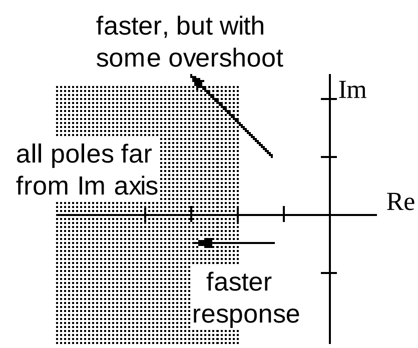
2. Tracks the input (or the meaning of the input) well.
   a) Converges to steady state values set by the input with little or no error.

   A pole at origin is an **integrator**.

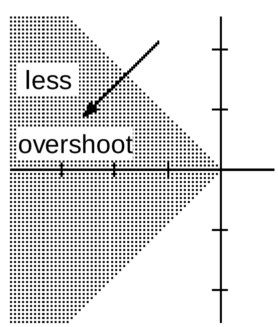


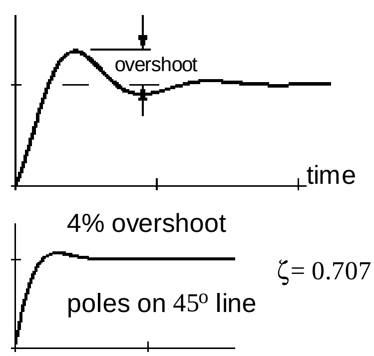
   b) Tracks varying inputs with little error.

      i) Responds quickly (fast response with little lag and short settling time).



      ii) Little or no overshoot.





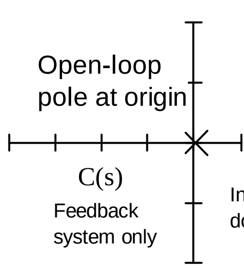
$$\%OS = 100\%\cdot e^{-\pi\cdot\frac{a}{b}}$$

See also Nise, Fig 4.19, p199 & earlier pages

$$\operatorname{atan}\left(\frac{-\pi}{\ln(2\cdot\%)}\right) = 38.8\cdot\text{deg}$$

$$\operatorname{atan}\left(\frac{-\pi}{\ln(8\cdot\%)}\right) = 51.2\cdot\text{deg}$$

3. Rejects disturbances



In reality, C(s) never just has a pole at zero by itself, that would slow down the system too much. Usually there will also be a nearby zero.

4. Be sufficiently insensitive to plant uncertainties and variations with time.

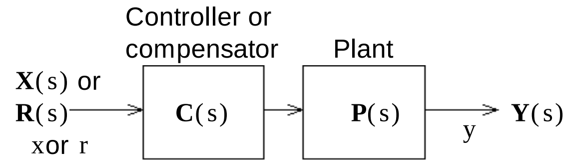
   Generally requires more loop gain and/or integrator (pole at origin) in C(s) or P(s)

5. Tolerant of noise, especially in the feedback measurements.

   Generally requires less gain and/or lower frequency response (slower).

Feedforward system

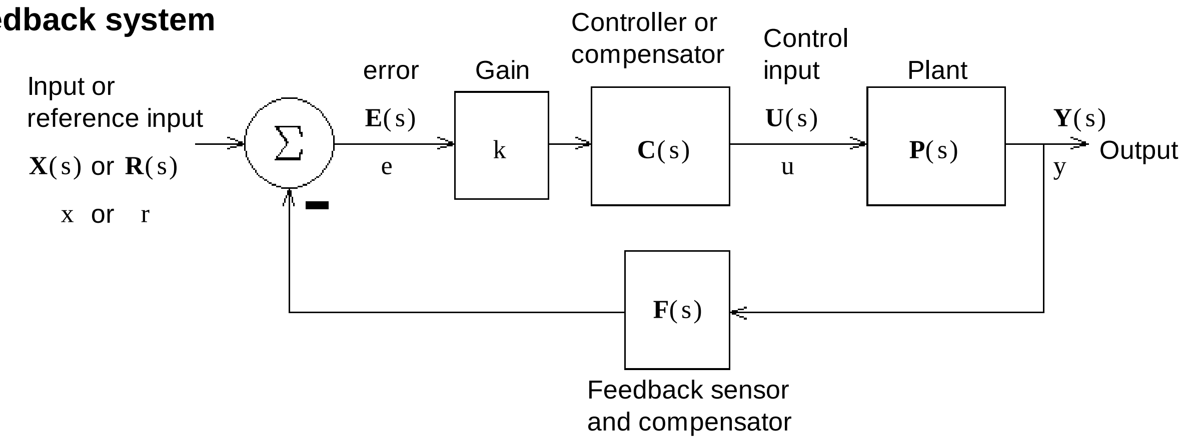
(prefiltering)



CANNOT stabilize an inherently unstable plant

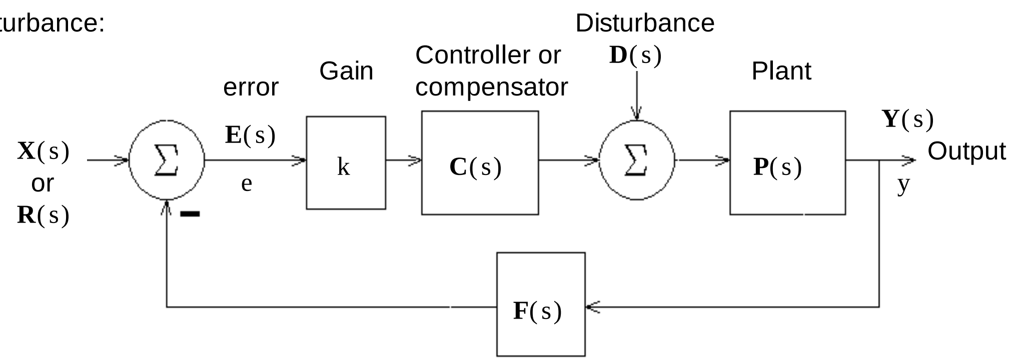
Feedforward compensation (prefiltering) is most often used in conjunction with feedback to improve the feedback system response.

Feedback system



Open-loop transfer function: $\mathbf{G}(s) = \mathbf{C}(s)\cdot\mathbf{P}(s)\cdot\mathbf{F}(s)$ **Closed-loop** transfer function: $\mathbf{H}(s) = \dfrac{k\cdot(\mathbf{C}(s)\cdot\mathbf{P}(s))}{1 + k\cdot\mathbf{C}(s)\cdot\mathbf{P}(s)\cdot\mathbf{F}(s)}$

With disturbance:



Error Want this to go to zero

$$\mathbf{E}(s) = \frac{1}{1 + k\cdot\mathbf{C}(s)\cdot\mathbf{P}(s)\cdot\mathbf{F}(s)}\cdot\mathbf{R}(s) - \frac{\mathbf{P}(s)\cdot\mathbf{F}(s)}{1 + k\cdot\mathbf{C}(s)\cdot\mathbf{P}(s)\cdot\mathbf{F}(s)}\cdot\mathbf{D}(s) = \frac{1}{1 + k\cdot\mathbf{G}(s)}\cdot\mathbf{R}(s) - \frac{\mathbf{P}(s)\cdot\mathbf{F}(s)}{1 + k\cdot\mathbf{G}(s)}\cdot\mathbf{D}(s)$$

$$= \frac{\mathbf{D}_\mathbf{C}(s)\cdot\mathbf{D}_\mathbf{P}(s)\cdot\mathbf{D}_\mathbf{F}(s)}{\mathbf{D}_\mathbf{C}(s)\cdot\mathbf{D}_\mathbf{P}(s)\cdot\mathbf{D}_\mathbf{F}(s) + k\cdot\mathbf{N}_\mathbf{C}(s)\cdot\mathbf{N}_\mathbf{P}(s)\cdot\mathbf{N}_\mathbf{F}(s)}\cdot\mathbf{R}(s) - \frac{\mathbf{N}_\mathbf{P}(s)\cdot\mathbf{N}_\mathbf{F}(s)\cdot\mathbf{D}_\mathbf{C}(s)}{\mathbf{D}_\mathbf{C}(s)\cdot\mathbf{D}_\mathbf{P}(s)\cdot\mathbf{D}_\mathbf{F}(s) + k\cdot\mathbf{N}_\mathbf{C}(s)\cdot\mathbf{N}_\mathbf{P}(s)\cdot\mathbf{N}_\mathbf{F}(s)}\cdot\mathbf{D}(s)$$

For constant input and constant disturbance

$$e(\infty) = \frac{\mathbf{D}_\mathbf{C}(0)\cdot\mathbf{D}_\mathbf{P}(0)\cdot\mathbf{D}_\mathbf{F}(0)}{\mathbf{D}_\mathbf{C}(0)\cdot\mathbf{D}_\mathbf{P}(0)\cdot\mathbf{D}_\mathbf{F}(0) + k\cdot\mathbf{N}_\mathbf{C}(0)\cdot\mathbf{N}_\mathbf{P}(0)\cdot\mathbf{N}_\mathbf{F}(0)}\cdot R_m - \frac{\mathbf{N}_\mathbf{P}(0)\cdot\mathbf{N}_\mathbf{F}(0)\cdot\mathbf{D}_\mathbf{C}(0)}{\mathbf{D}_\mathbf{C}(0)\cdot\mathbf{D}_\mathbf{P}(0)\cdot\mathbf{D}_\mathbf{F}(0) + k\cdot\mathbf{N}_\mathbf{C}(0)\cdot\mathbf{N}_\mathbf{P}(0)\cdot\mathbf{N}_\mathbf{F}(0)}\cdot D_m$$

Perfect tracking of DC input:

$\mathbf{C}(s)$ or $\mathbf{P}(s)$ has a pole at the origin (integrator)

Perfect rejection of constant disturbance:

$\mathbf{C}(s)$ has a pole at the origin (integrator)

Note: Nise devotes an entire chapter (7) to steady-state errors from different types of inputs. Refer to that chapter to learn much more than we cover in this class. The short version is: The more integrators, the better.