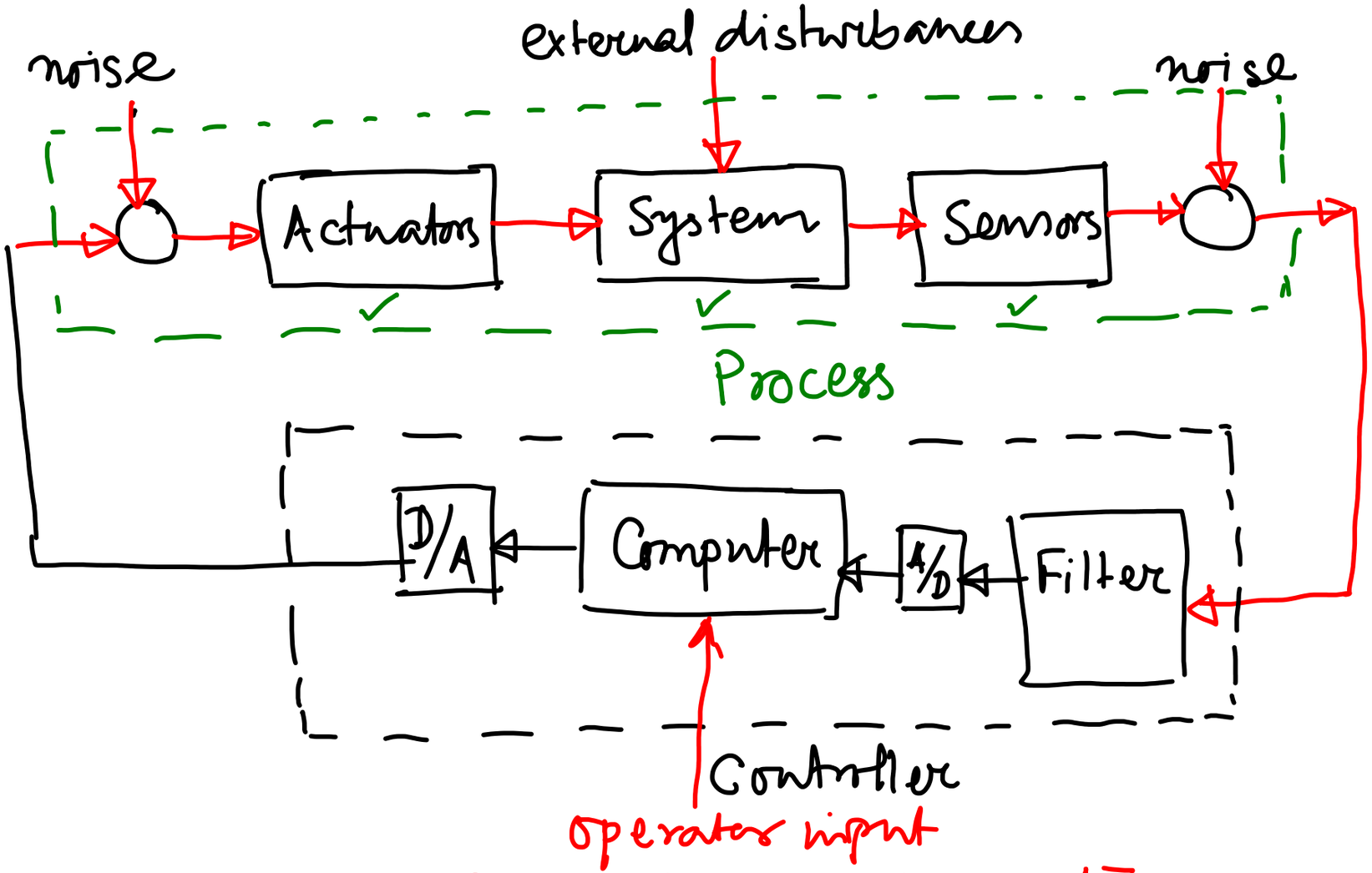
What is Control?

- the use of algorithms and feedback in engineered system (in present context)



Components of Compture-Controlled system

- The upper dashed box represents the process dynamics that includes sensors, actuators and the dynamical system. Noise and disturbance can perturb the dynamics of the process.

- The controller block contains a filter, A/D, D/A, a computer (processor) that implements the control algorithm.
- three important tasks are involved — sensing, computing and actuation.
- uncertainty enters through noise, external disturbances and model dynamics.
- the algorithm that computes the control action as a function of the sensor values is called Control law.
- Control engineering relies on and shares tools from physics (dynamics and modelling), Computer science (information and software) and operation research (optimization, probability theory and game theory).
- Control-oriented modelling is input-output modelling that gives many new insights related to the behavior of system.
- Modern control algorithms for engineering system are implemented in software.

- Control algorithm and software are very different from traditional computer software because of the central role of the dynamics of the system and real-time nature of implementation.

Control structures:

Open-loop control (non-feedback) ✓

Closed-loop Control (Feedback) ✓

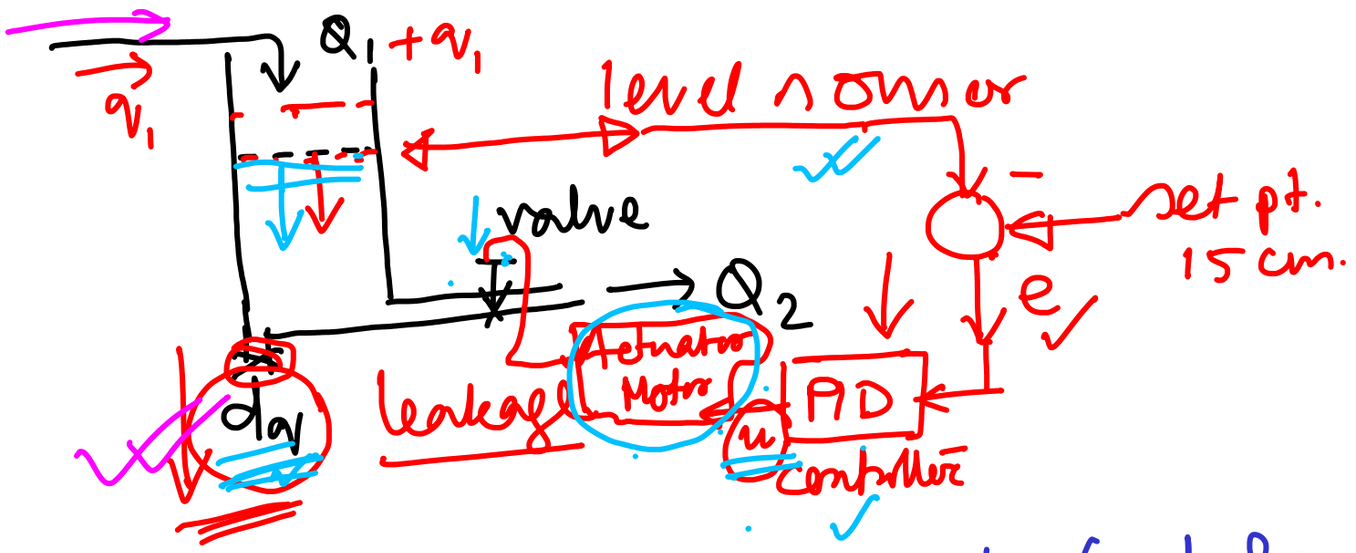
Feed forward Control

Feedforward Control:

- If it is possible to measure a disturbance before it enters the system, this control is effective.
- feedback and feedforward controls are applied together.

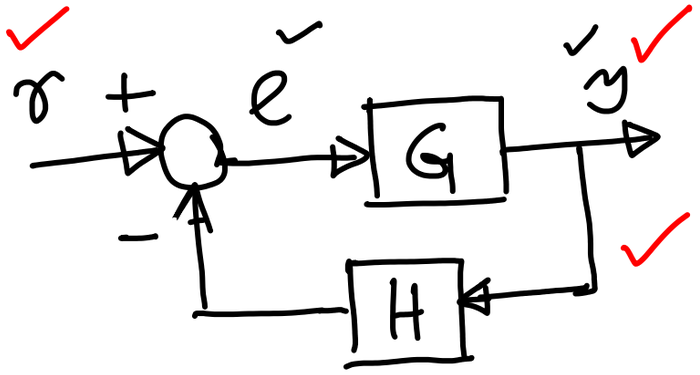
Examples:

- Market based economy — feedback
- Planned economy — feedforward
- Level control in a water tank



What are the effects of feedback in Control?

1) It may increase or decrease the overall system gain.



We consider single-input single-output case

$$e = r - Hy \quad \Rightarrow \quad e = r - HGe$$

$$y = Ge$$

$$e = \frac{r}{1+HG}$$

$$y = \frac{G}{1+HG} \cdot r$$

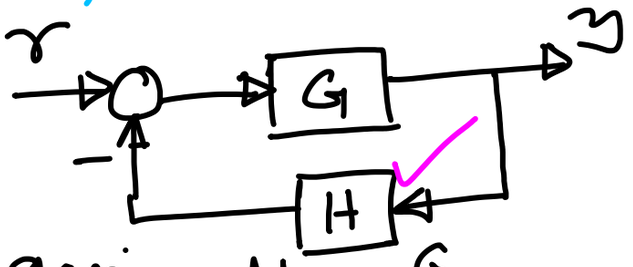
$$\boxed{\frac{y}{r} = \frac{G}{1+HG}}$$

Overall gain is different from that of initial gain G.

2) It can make the overall system stable.
   - A feedback can make an overall system unstable although the original system is stable.

3) It can make an overall system fast or slow, i.e., it changes the bandwidth.

4) It reduces the sensitivity w.r.t. parameter changes, i.e., it makes the system robust.



$$\frac{y}{r} = \frac{G}{1+GH}$$

The overall gain $= M = \frac{G}{1+GH}$

If there is a change in G, what is its effect on the overall gain M.

$$S_G^M = \frac{\partial M/M}{\partial G/G} = \frac{\text{percentage change in } M}{\text{percentage change in } G}$$

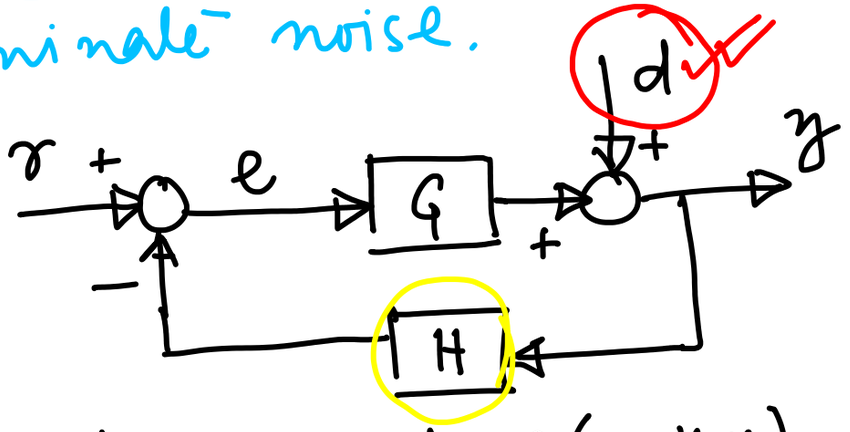
Sensitivity

$$= \frac{\partial M}{\partial G} \times \frac{G}{M} = \frac{(1+GH)-GH}{(1+GH)^2} \times \frac{G}{G} \times (1+GH)$$

$$= \frac{1}{1+GH}$$

– by choosing a high gain H, we can make $GH \gg 1$. Hence the change in M can be reduced.

5) It can attenuate the disturbance and can eliminate noise.



$$y = d + Ge = d + G(r - Hy) = d + Gr - GHy$$

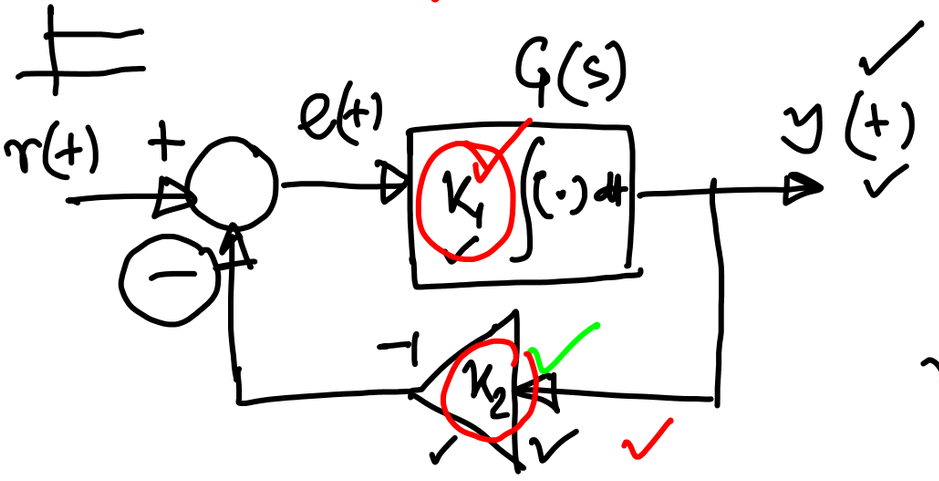
$$y = \frac{d}{1+GH} + \frac{G}{1+GH} r$$

disturbance

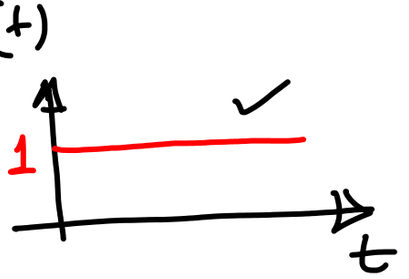
reference signal

large

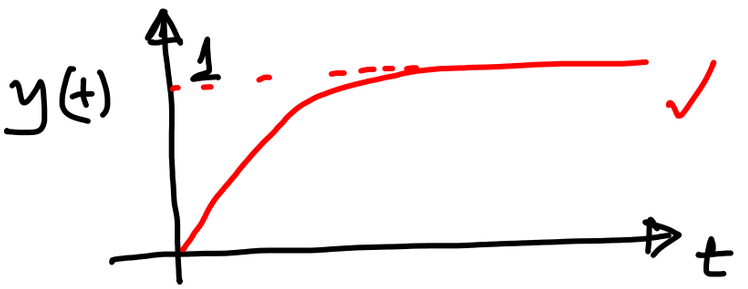
Example:



r(t) Reference signal: unit step

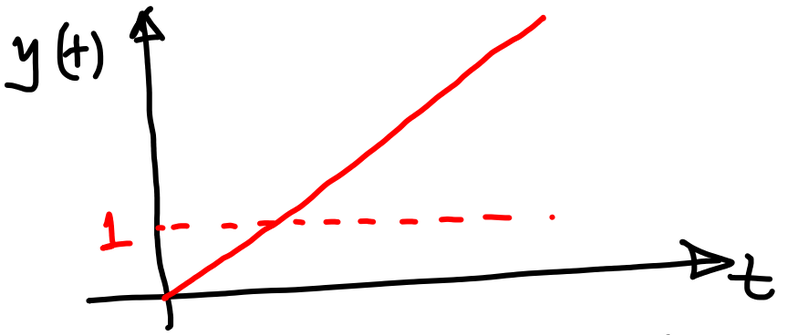


Case 1: $K_2 = +1$ (negative feedback), $K_1 = 1$

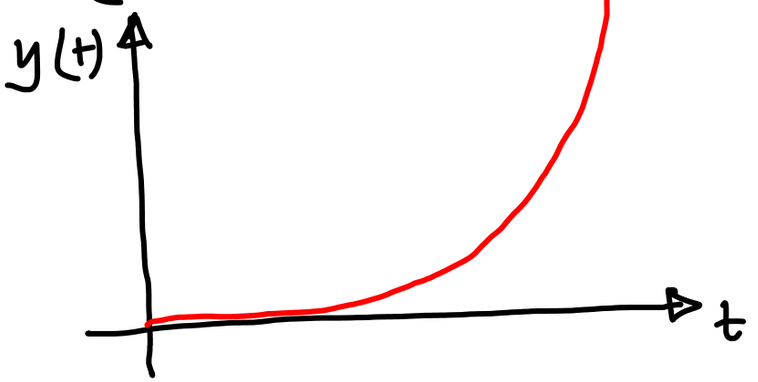


Tracking the ref. command

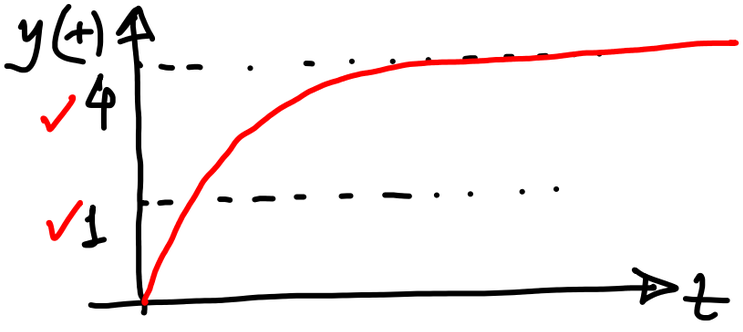
Case 2: $K_2 = 0$ (no feedback, open-loop), $K_1 = 1$



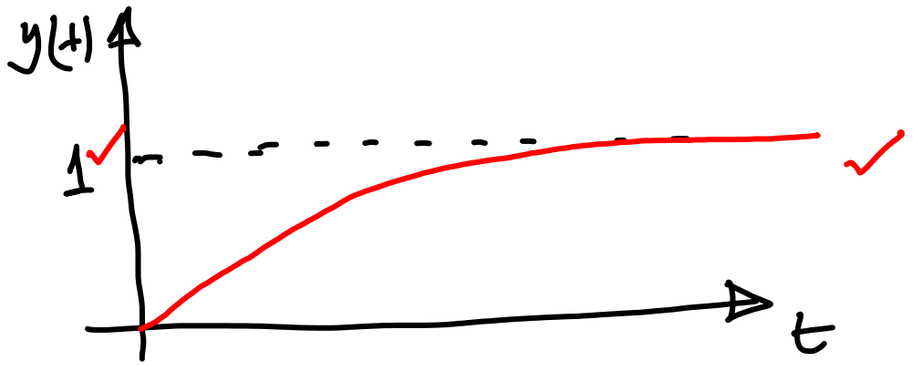
Case 3: $K_2 = -1$ (positive feedback), $K_1 = 1$



Case-4: $K_2 = 0.25$, $K_1 = 1$



Case 5: $K_2 = +1$, $K_1 = 0.1$



- Case 1 and Case 5: Output tracks the reference input, but Case 5 is sluggish compared to Case 1.
- Positive feedback (Case 3) makes the system unstable.
- Case 4: Output doesn't track the reference input, but stable.