Control system objectives:

1) Reject disturbance (minimize plant response to disturbances)

2) Acceptable long-term errors (steady-state response)

3) Acceptable short-term behavior (transient response)

4) Minimize sensitivity to plant parameter variations (Robustness)

Methodology:

0. Choose sensors and actuators.

→ 1. Develop models.

2. Design controller → based on models
   ↳ design criteria

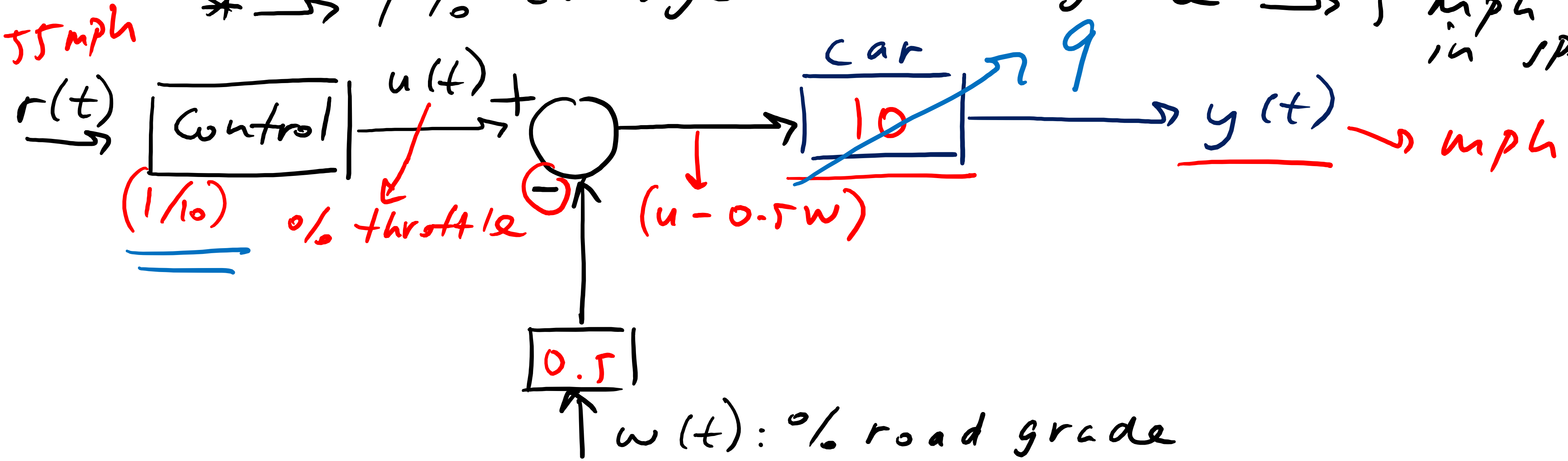
3. Evaluate design (simulations, experiments)
   MATLAB

4. iterate!

Ex: Auto Cruise Control:

1. Reference: 55 mph constant speed

   * → 1% change in throttle → 10 mph change in speed.
   * → 1% change in road grade → 5 mph change in speed



2. Design: open-loop

$$y = 10(u - 0.5w) = \cancel{10}^{\,9}u - 5w \cong \boxed{r - 5w}$$

$u = (r/10)$ $\qquad$ 0

3. Evaluate:

$y = r - 5w$

$r = 55,\ w = 0 \Rightarrow y = 55$ mph ✓ — steady-state error ✓

$r = 55,\ w = 1 \Rightarrow y = 50$ mph : 10% error ✗

$w = 2 \Rightarrow y = 45$ mph : 20% error ✗ — ✗ Disturbance rejection

Parameter variations:

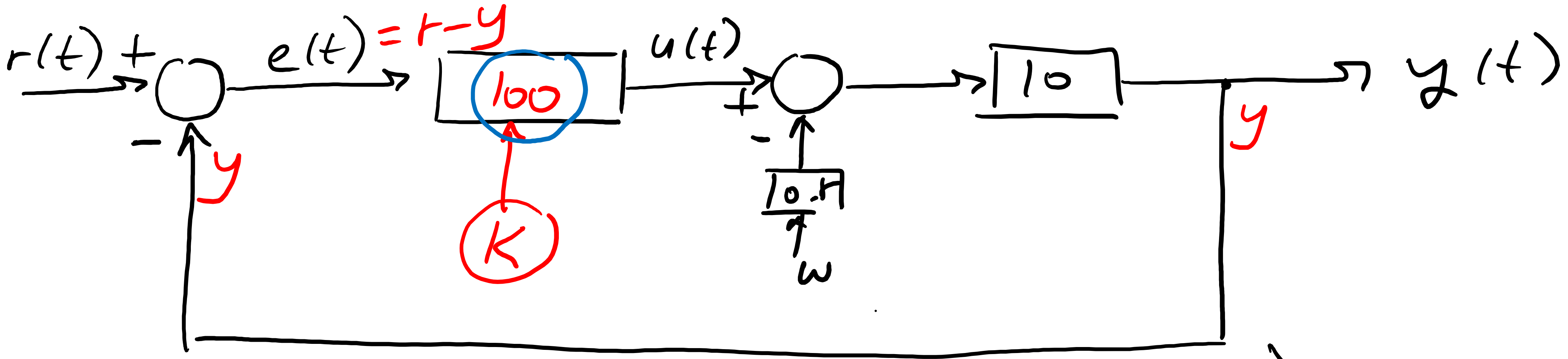
$$\boxed{y = 0.9r - 4.5w}$$

✗ Robustness

$r = 55,\ w = 0 \Rightarrow y = 49.5$ mph : 10% error

4. Iterate:

↳ 2. Feedback Control



$\rightarrow y = 10(u - 0.5w) = 10(100r - 100y - 0.5w)$

$\rightarrow u = 100(r - y)$

$\Rightarrow y = 1000r - 1000y - 5w$

$1001y = 1000r - 5w$

$$\boxed{y = \underline{0.999}\,r - 0.005w}$$

3. Evaluate

$r = 55, \; w = 0 \Rightarrow y = 54.945 \neq 55$ s-s error X

$'' \;, \; w = 1 \Rightarrow y = 54.94$ ✓ Disturbance

$w = 2 \Rightarrow y = 54.895 \Rightarrow 0.2\%$ error rejection

✓ Robust

Block Diagrams

→ identify signal flows

→ graphical representation of algebraic equations (differential)

↳ using Laplace transforms

Common Blocks

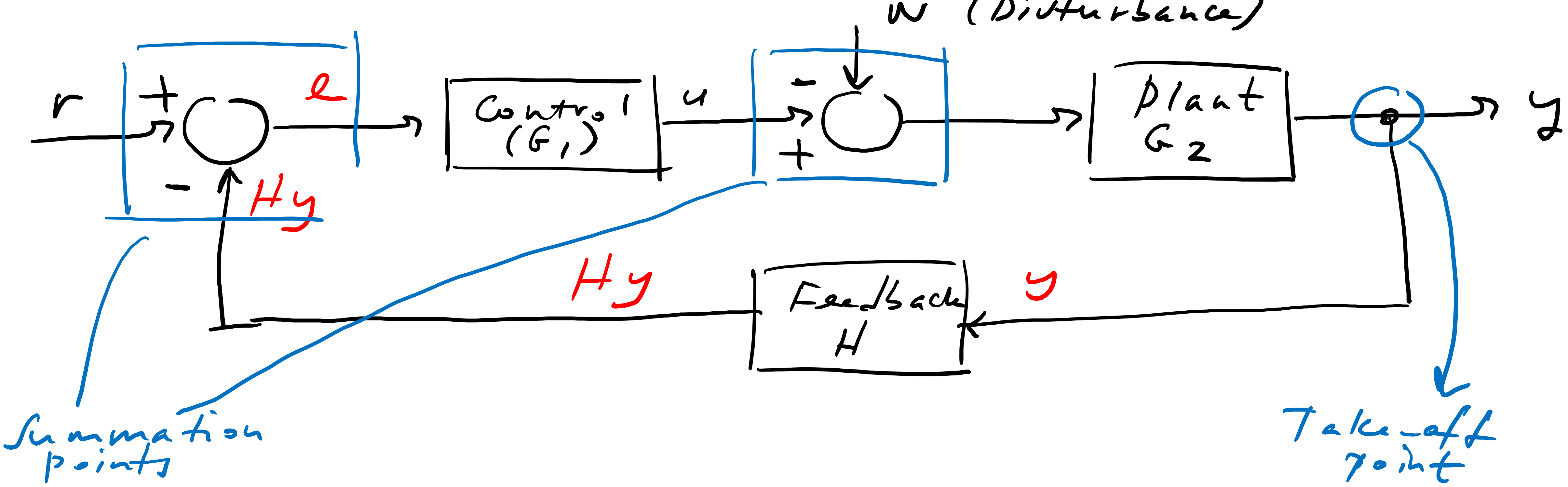
1- Gain $\quad u \rightarrow \boxed{K} \xrightarrow{y} \quad \equiv \quad y = Ku$

2- Integration $\quad \xrightarrow{x} \boxed{\int} \xrightarrow{y} \quad \equiv \quad y = \int x\,dt$

3- Differentiation $\quad \xrightarrow{x} \boxed{d/dt} \rightarrow y \quad \equiv \quad y = \frac{dx}{dt}$

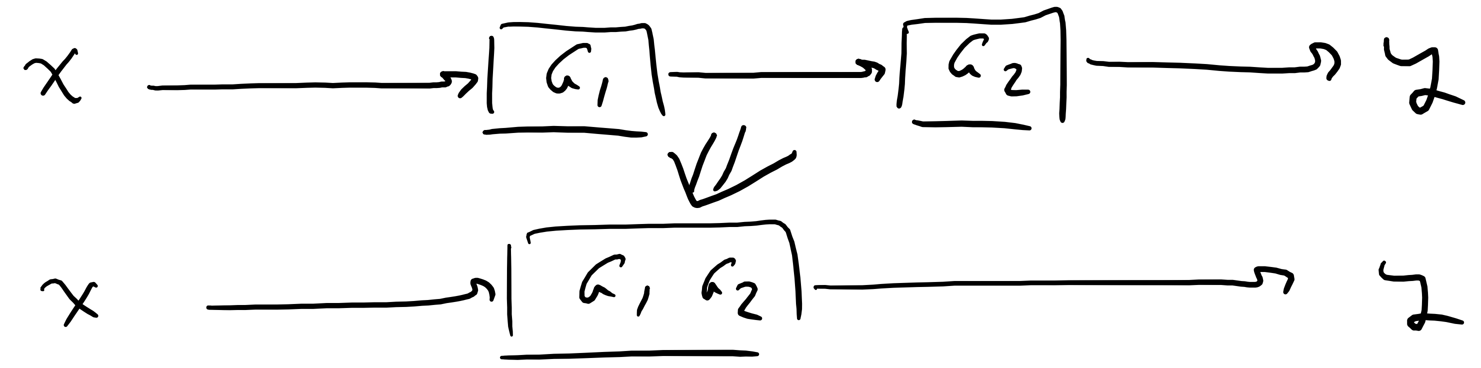
↳ will be converted to algebraic using Laplace

Feedback Control System

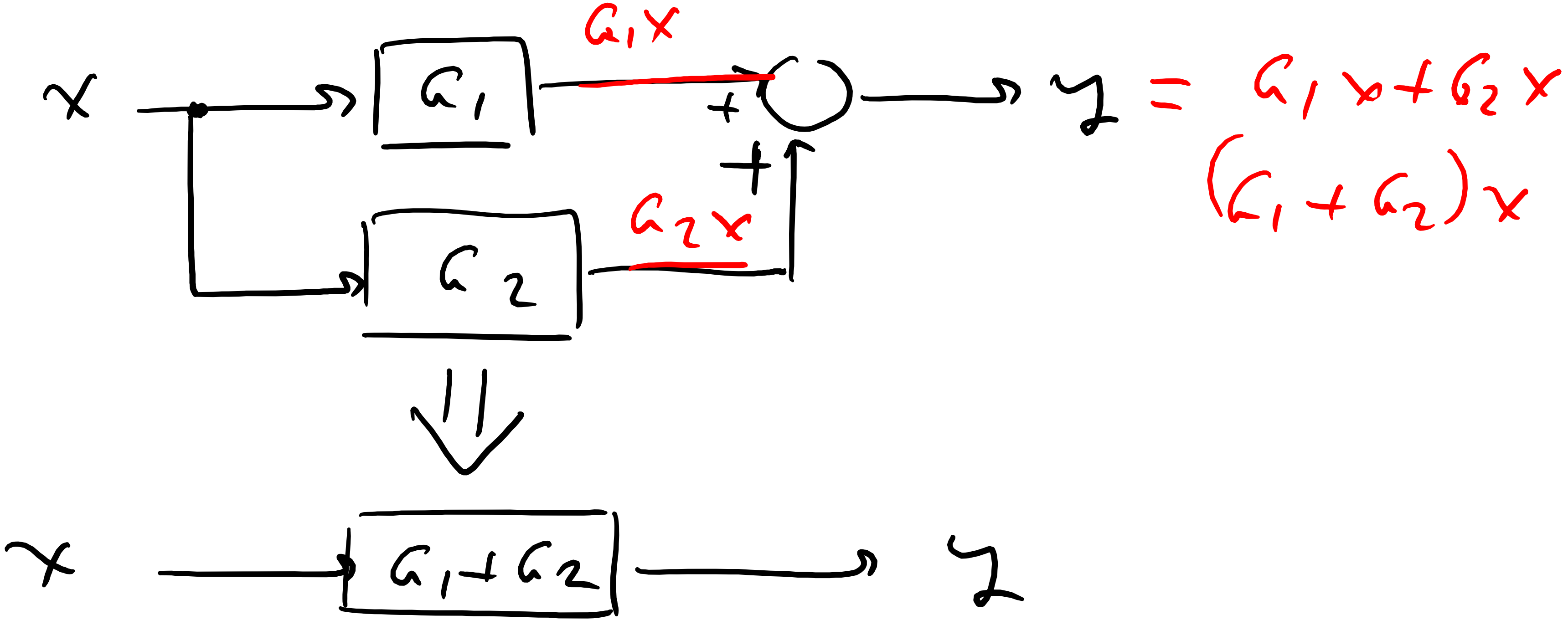


Common Interconnections: (Familiar Forms)

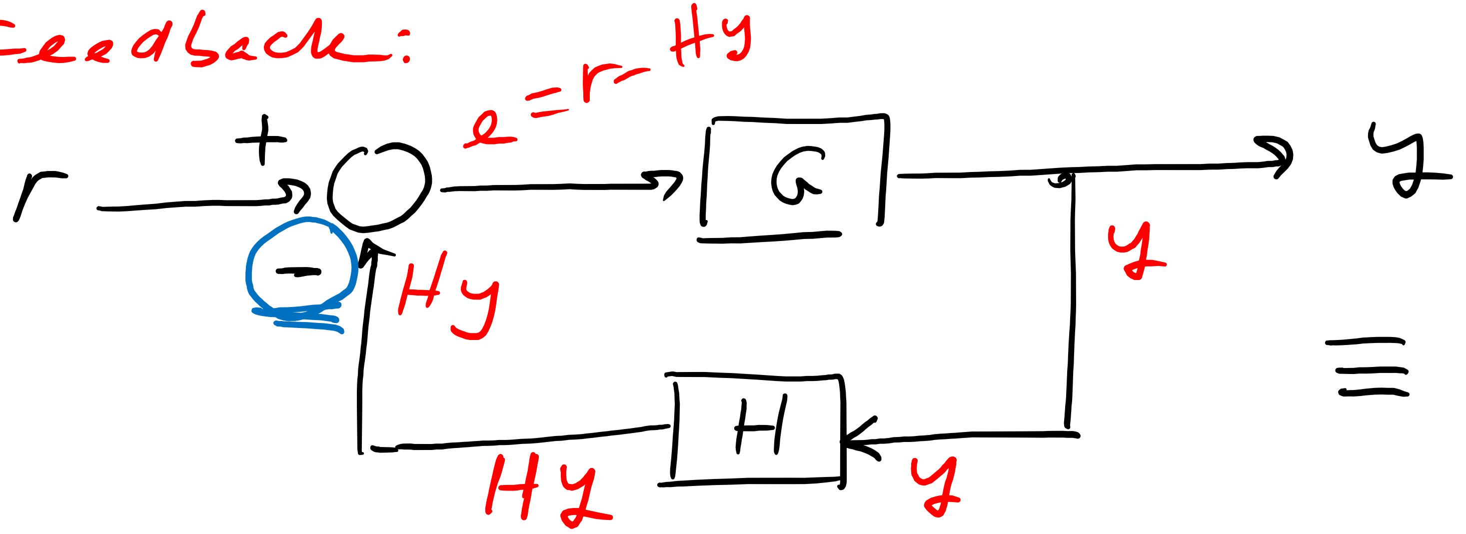
1) Cascade

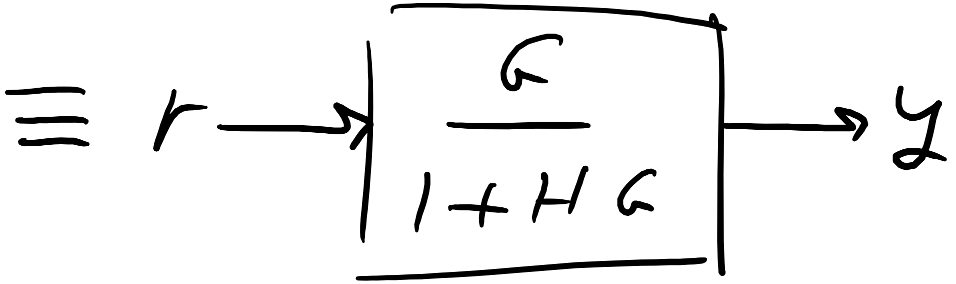


2) parallel



3. Feedback:





$$y = Ge$$

$$e = r - Hy$$

$$y = G(r - Hy)$$

$$y = Gr - GHy$$

$$y(1 + GH) = Gr$$

$$y = \left(\frac{G}{1+HG}\right)(r) \Rightarrow \boxed{\frac{y}{r} = \frac{G}{1+HG}}$$

transfer function

opposite the sign of the feedback