BASIC CONTROL SYSTEMS

03 BLOCK DIAGRAMS

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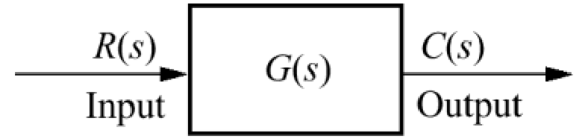
WHERE STUDENTS MATTER

Normalisation & definitions



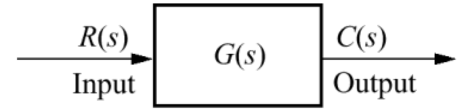
- Only one input and one output

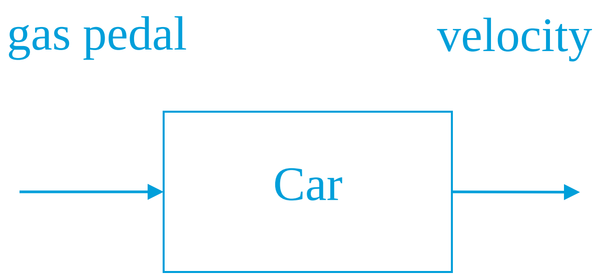
- Output signal changes as a function of the input signal
  - ✓ Formula: H = Y / X (transfer function)

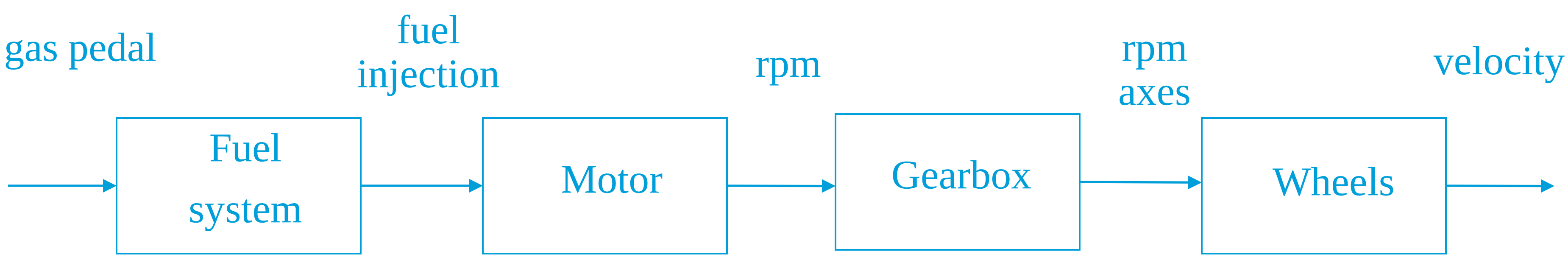
  - ✓ This means also that: $Y = H \cdot X$

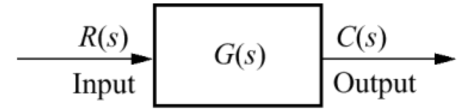
- Process $\rightarrow$ sub processes $\rightarrow$ several boxes

Example of block diagram
with several subprocesses









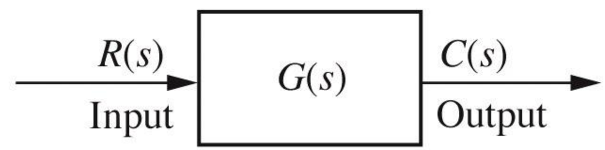
Block diagram

Why using a block diagram?

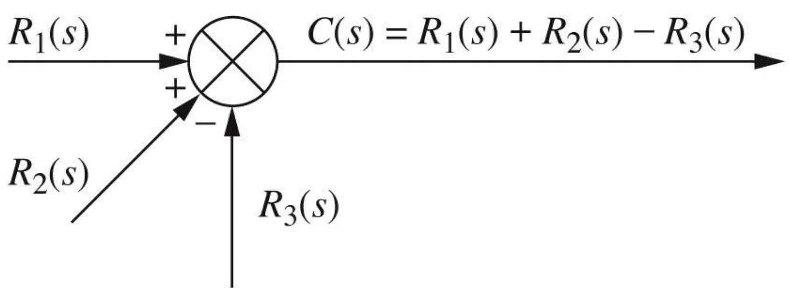
- Blocks draw easier than real physical systems
- Systems look alike (analogy)
- Block diagram easier to read
- Easier to manipulate and calculate →
  - Block properties
  - Rules

Elements involved:

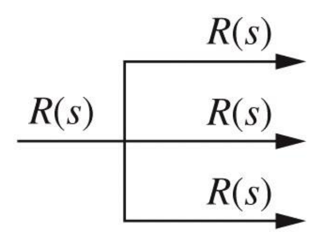
Signals



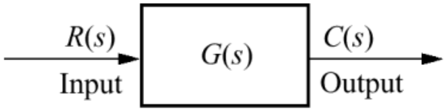
Block (system)



Summing junction

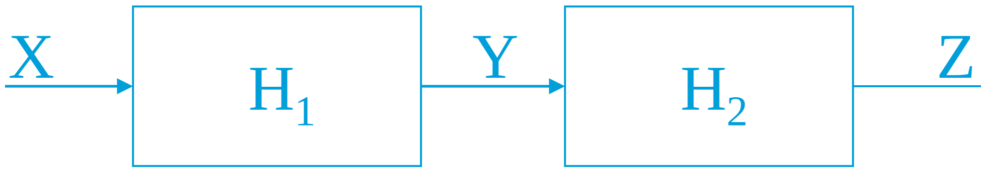


Pickoff point



Block properties

1. Series



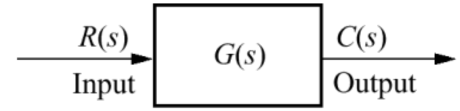
$Y = H_1 \cdot X$

and $Z = H_2 \cdot Y$

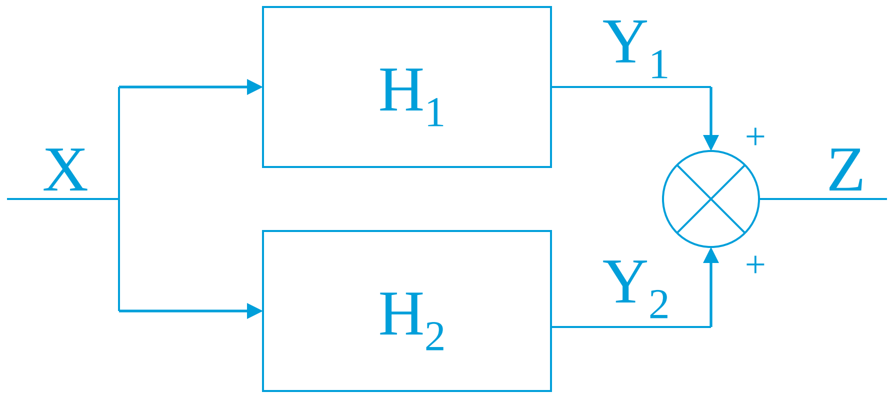
hence $Z = \boxed{H_1 \cdot H_2} \cdot X$

$H_{new} = H_1 \cdot H_2$

Block properties



2. Parallel



$Y_1 = H_1 \cdot X,$

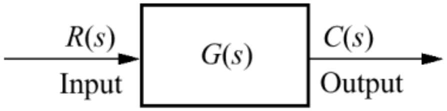
$Y_2 = H_2 \cdot X$ and

$Z = Y_1 + Y_2 =$

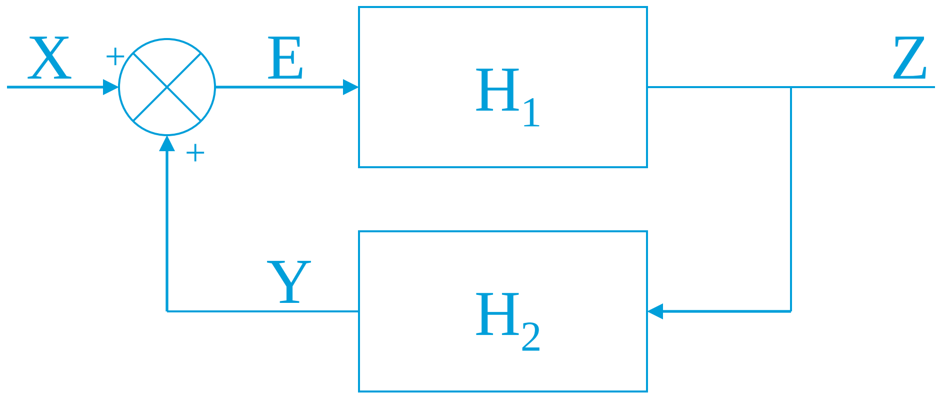
$Z = \boxed{(H_1 + H_2)} \cdot X$

$H_{new} = H_1 + H_2$

Block properties



3. Positive feedback



$E = X + Y$ and $Y = H_2 \bullet Z$, hence

$E = X + H_2 \bullet Z$

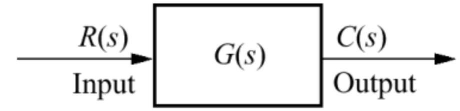
$Z = H_1 \bullet E$, hence

$Z = H_1 \bullet (X + H_2 \bullet Z) \Leftrightarrow$

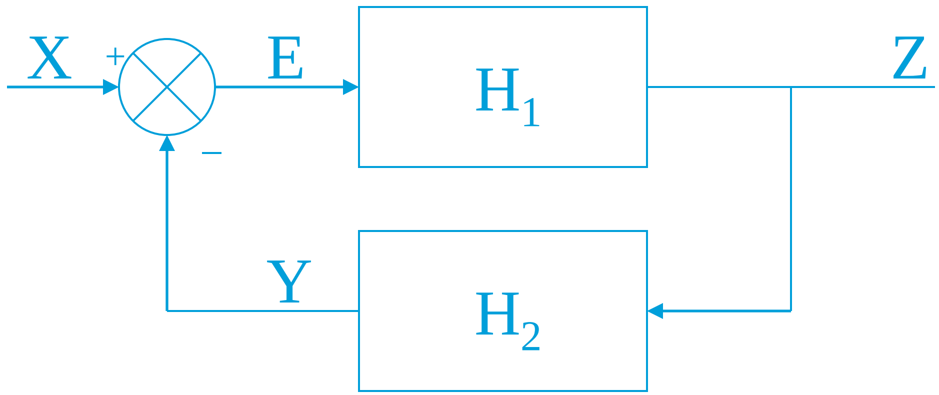
$Z = [H_1 / (1 – H_1 \bullet H_2)] \bullet X$

$$H_{new} = \frac{Z}{X} = \frac{H_1}{1 - H_1 \cdot H_2} = \frac{H_{forward}}{1 - H_{loop}}$$

Block properties



4. Negative feedback



$E = X - Y$ and $Y = H_2 \cdot Z$, hence

$E = X - H_2 \cdot Z$

$Z = H_1 \cdot E$, hence

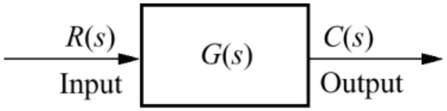
$Z = H_1 \cdot (X - H_2 \cdot Z) \Leftrightarrow$

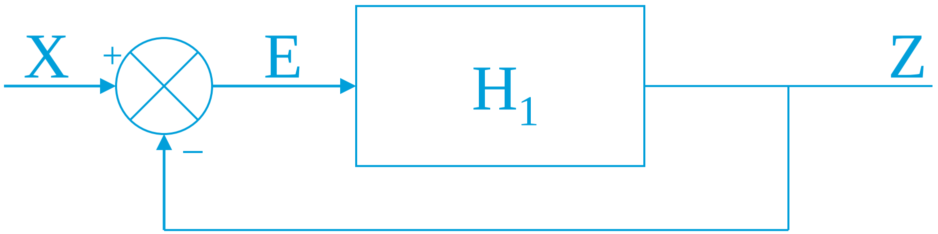
$Z = [H_1 / (1 + H_1 \cdot H_2)] \cdot X$

$$H_{new} = \frac{Z}{X} = \frac{H_1}{1 + H_1 \cdot H_2} = \frac{H_{forward}}{1 + H_{loop}}$$

Block properties

5. Unity feedback



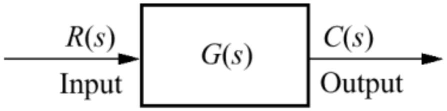


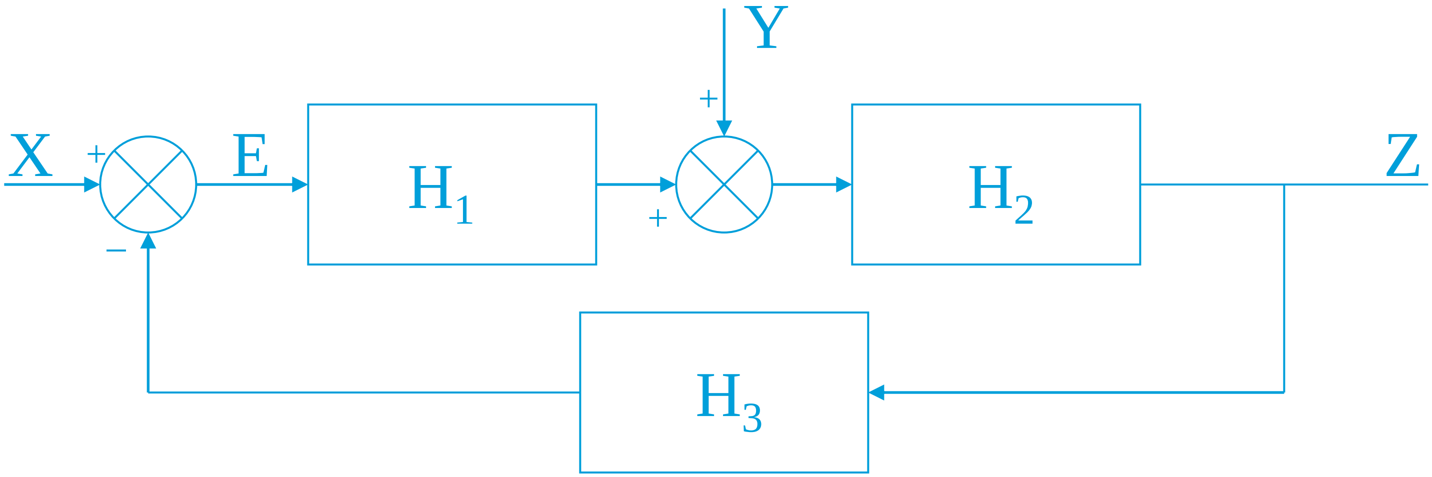
Special case of feedback: $H_2 = 1$, so

$$H_{new} = \frac{H_1}{1 + H_1}$$

Block properties

6. Disturbance





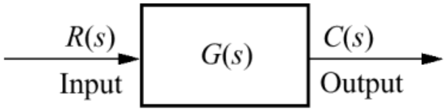
now $E = X - H_3 \cdot Z$

and $Z = H_1 \cdot H_2 \cdot E + H_2 \cdot Y$, this gives:

$$Z = \frac{H_1 \cdot H_2}{1 + H_1 \cdot H_2 \cdot H_3} \cdot X + \frac{H_2}{1 + H_1 \cdot H_2 \cdot H_3} \cdot Y$$

$$Z = H_{control} \cdot X + H_{disturbance} \cdot Y$$

Block properties summary



- Series $H_{new} = H_1 \cdot H_2$
- Parallel $H_{new} = H_1 + H_2$
- Positive feedback $H_{new} = H_1 / (1 - H_1 \cdot H_2)$
- Negative feedback $H_{new} = H_1 / (1 + H_1 \cdot H_2)$

- Alternative way to calculate H_{new} for negative feedback

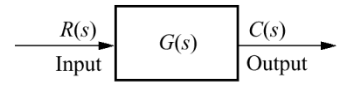
$$H_{new} = \frac{H_{forward}}{1 + H_{loop}}$$

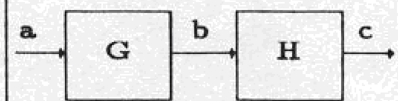
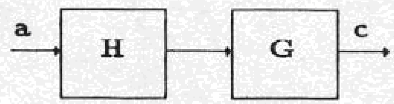
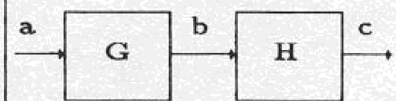
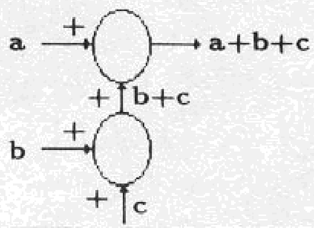
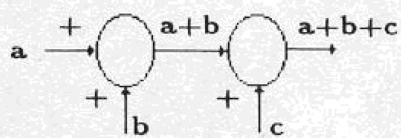
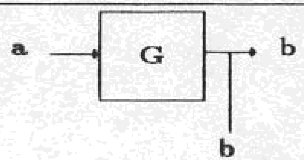
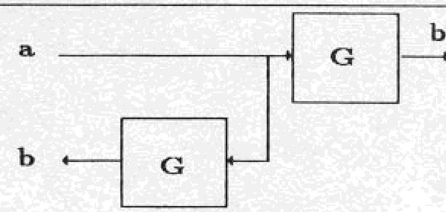
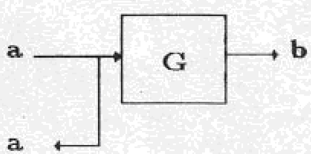
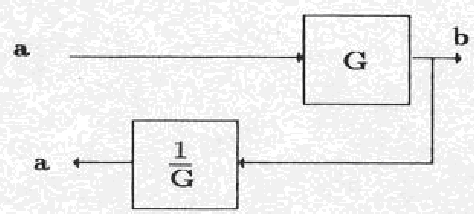
- Disturbance

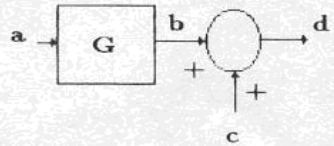
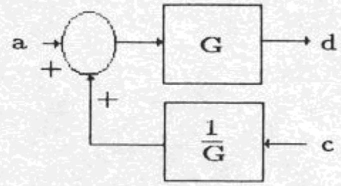
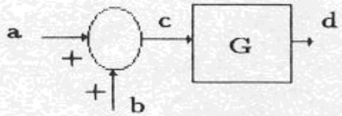
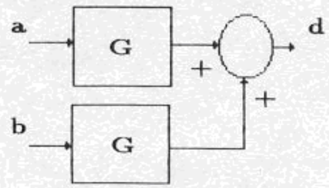
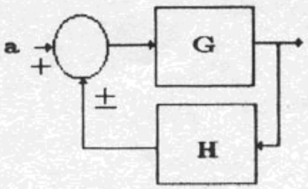
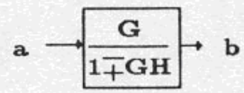
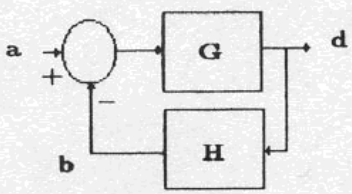
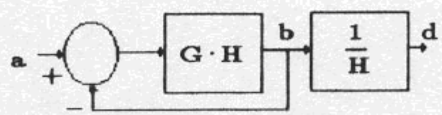
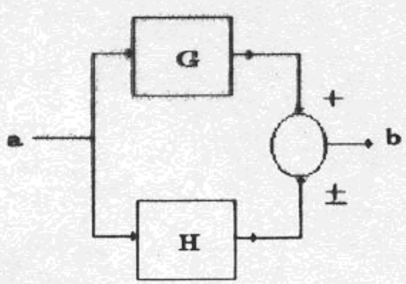
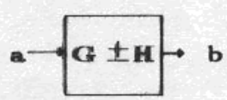
$$Z = \frac{H_1 \cdot H_2}{1 + H_1 \cdot H_2 \cdot H_3} \cdot X + \frac{H_2}{1 + H_1 \cdot H_2 \cdot H_3} \cdot Y$$

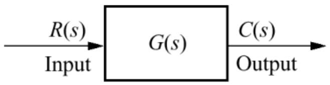
$$Z = H_{control} \cdot X + H_{disturbance} \cdot Y$$

More rules to modify block diagrams

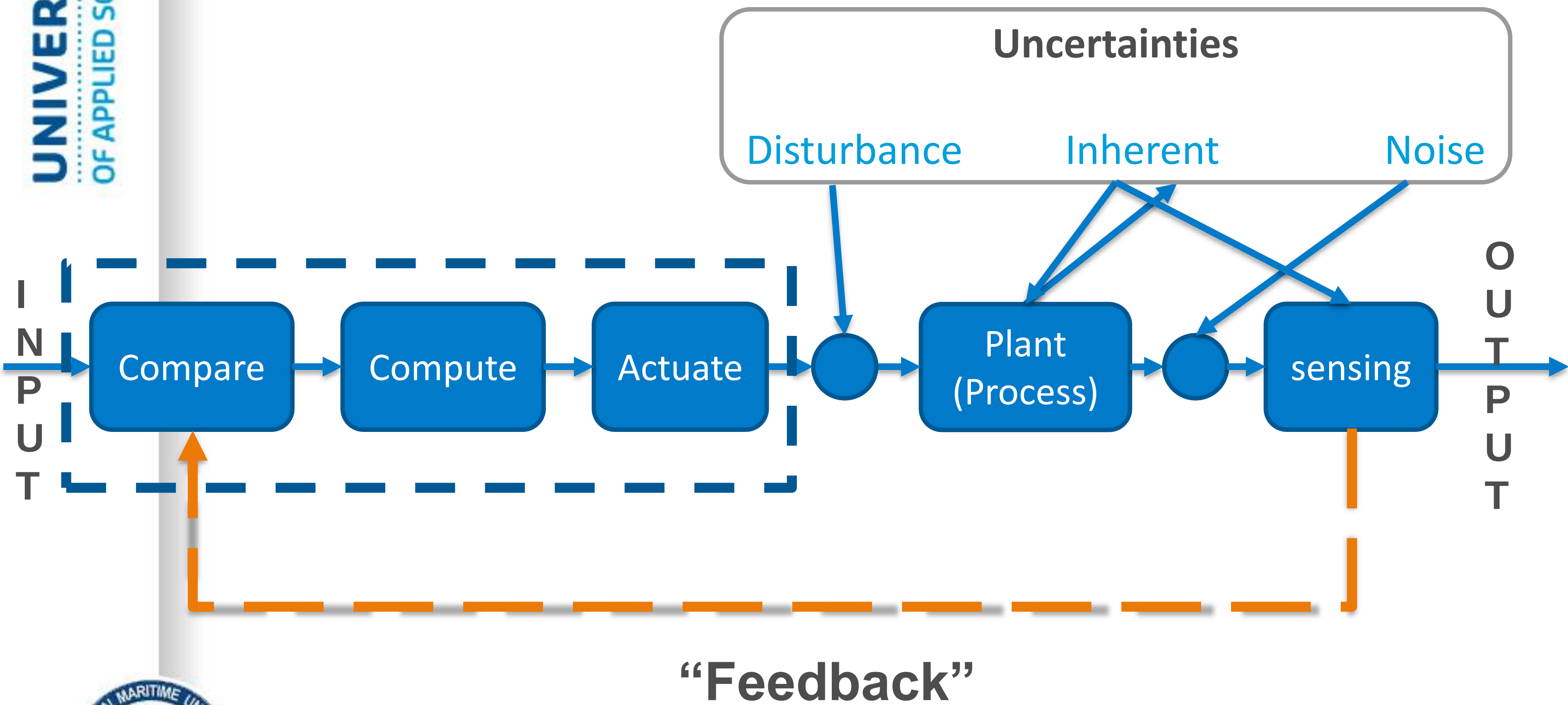


NR	Original block diagram	Alternative block diagram	Manipulation
1			Exchanging elements
2			Combining elements
3			Regroup summing junction
4			Move pickoff point
5			Move pickoff point

6			Move summing junction
7			Move summing junction
8			Eliminate feedback loop
9			Remove element from feedback loop
10			Combining elements



THE STANDARD MODEL WHY? AND WHY NOT?



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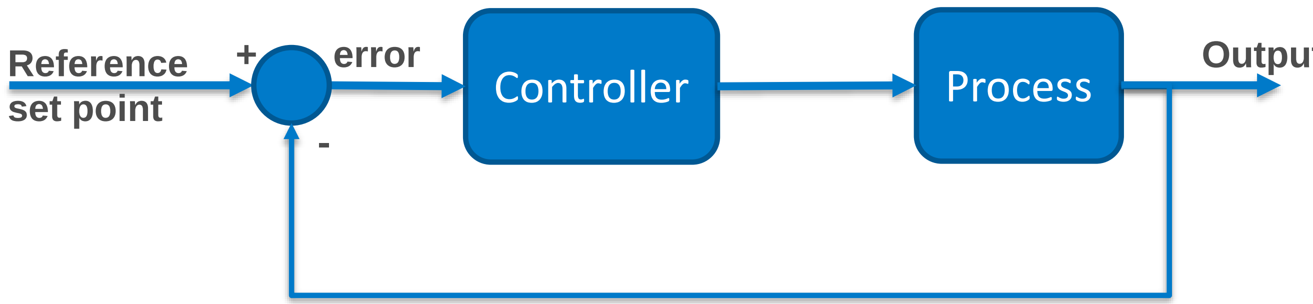

Why unit feedback?

- By playing with block diagram, all LTI system can be represented in this form
- Simple & convenient
- The “error” is quite straight forward, just output-input

Why not unit feedback?

- It is mathematically correct, however you are manipulating physical signals. Many times the physical systems and signals are not easily manipulatable.

Practice!

Solve exercises together with your team!

HOMEWORK

Stage ONE exercise:

- Problem 9

Test exam 3:

- Problem 1

Test exam 4:

- Problem 1

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