Block diagrams

Contents map

developed content units	taxonomy levels
block diagrams	u1, e1

prerequisite content units	taxonomy levels
transfer function	u1, e1

Main ILO of sub-module "Block diagrams"

Describe the purpose and advantages of using block diagrams to a peer unfamiliar with them

Identify standard blockdiagram components (e.g., sum, integral, derivative, multiplication, generic function) when interpreting or constructing block representations of time-domain systems, using the lecture-provided visual notation

Construct a block diagram representation for a first-order linear differential equation of the form $\dot{y} = ay + bu$, using basic functional blocks (integrators, multipliers, summations)

Derive the closed-loop transfer function for a system with negative feedback, using the algebraic manipulation of Laplace-domain expressions

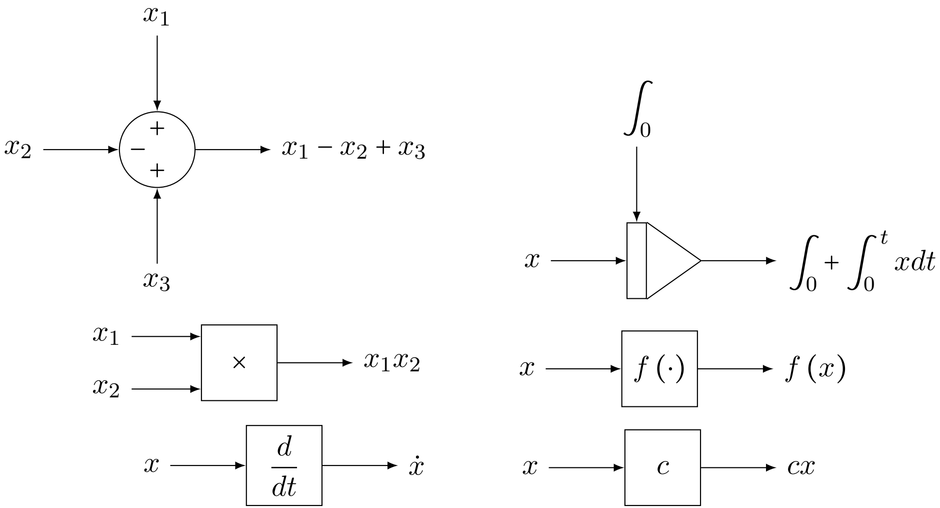
Roadmap

- recap of the diagrams in the time domain
- recap of the diagrams in the frequency domain
- rules for how to transform the diagrams
- examples

Block diagrams - why?

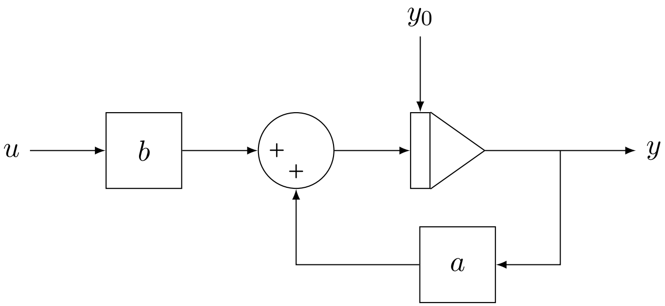
- used very often in companies
- aid visualization *(until a certain complexity is reached. . .)*
- enable “drag & drop” way of programming
- here primarily used for interpretations

Most common block diagrams in the time domain



Representing a first order DE with a block scheme

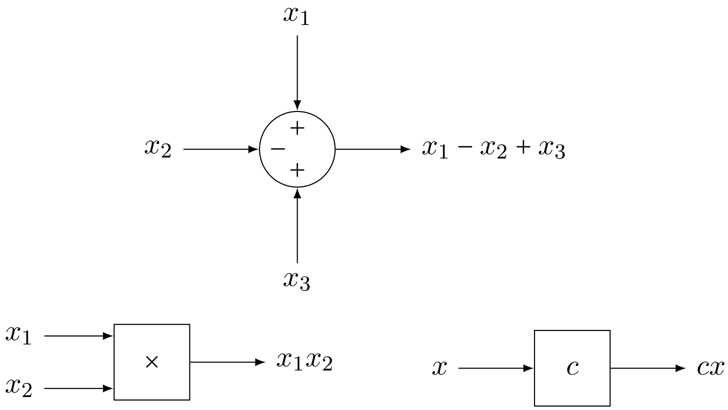
$$\dot{y} = ay + bu$$



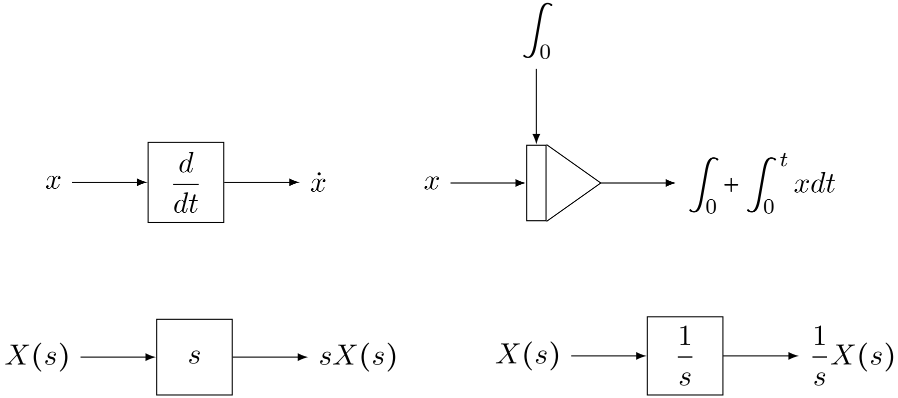
Discussion: how do we represent $\ddot{x} + \frac{f}{m}\dot{x} + \frac{k}{m}x = \frac{1}{m}u$?

Block diagrams that are equal in both time and frequency domains

(Here we may use both $x(t)$ and $X(s)$)



Block diagrams that are logically the same in both time and frequency domains



A block diagram that does not exist in the frequency domain

$$x \longrightarrow \boxed{f\left(\cdot\right)} \longrightarrow f\left(x\right)$$

Discussion: why?

in the following:

rules for manipulating block diagrams in the frequency domain

Series of transfer functions

$$U(s) \longrightarrow \boxed{H_a(s)} \longrightarrow \boxed{H_b(s)} \longrightarrow Y(s)$$

is equivalent to

$$U(s) \longrightarrow \boxed{H_a(s)H_b(s)} \longrightarrow Y(s)$$

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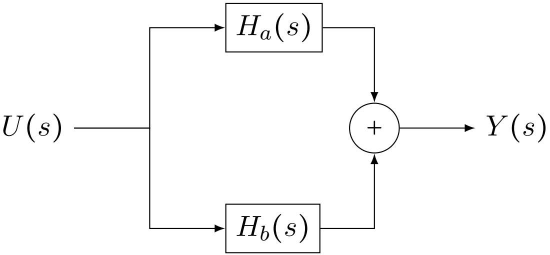
Discussion: why?

Parallel of transfer functions



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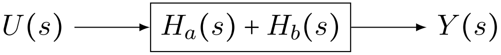
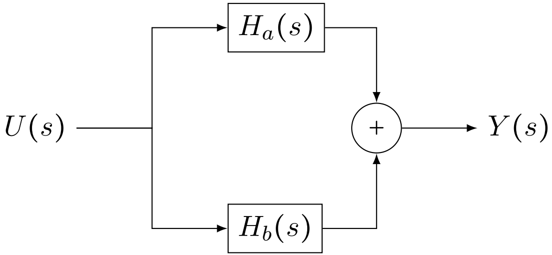


Parallel of transfer functions



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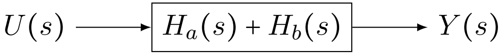
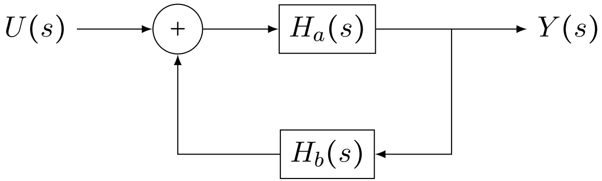


Discussion: why?

Elimination of feedback loops



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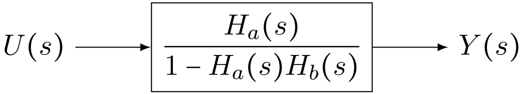
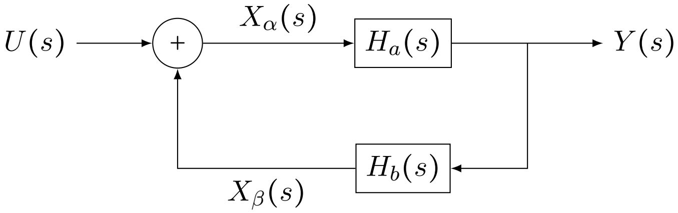


Elimination of feedback loops: how to remember the formula



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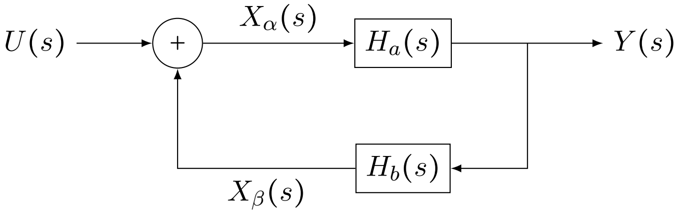

- $Y = H_a X_\alpha$
- $X_\alpha = U + X_\beta$
- $X_\beta = H_b Y$

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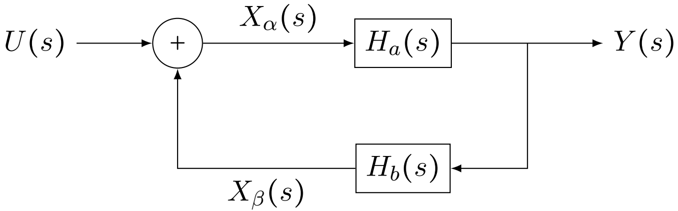

- $Y = H_a X_\alpha$
- $X_\alpha = U + X_\beta$
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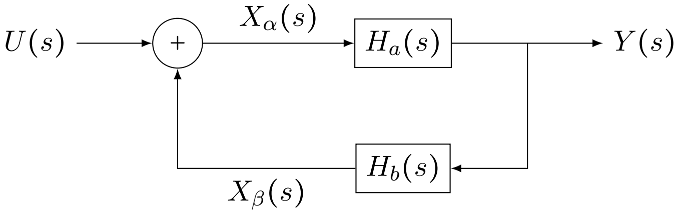
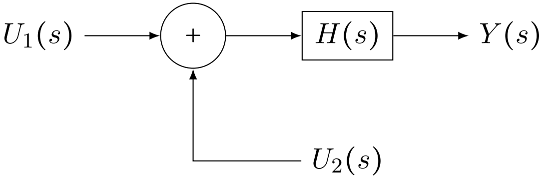
- $\implies Y = H_a\left(U + H_b Y\right)$

Elimination of feedback loops: how to remember the formula



- $Y = H_a X_\alpha$
- $X_\alpha = U + X_\beta$
- $X_\beta = H_b Y$
- $\implies Y = H_a \left(U + H_b Y\right)$
- $\implies Y - H_a H_b Y = H_a U$

Moving blocks around sum operators



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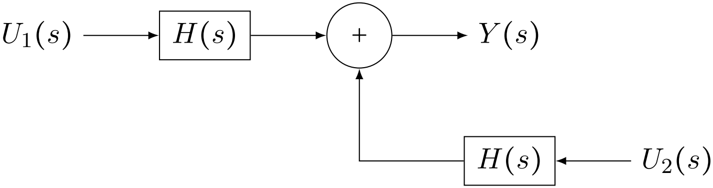

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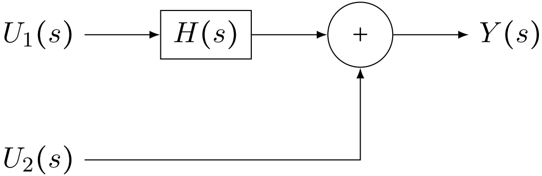

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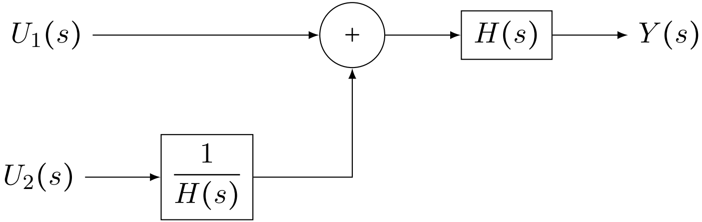
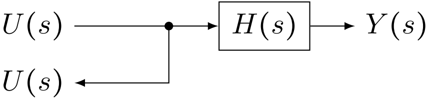


Moving blocks around connections



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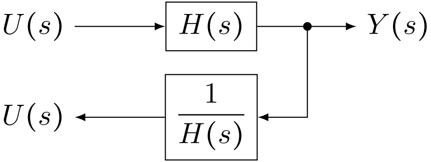

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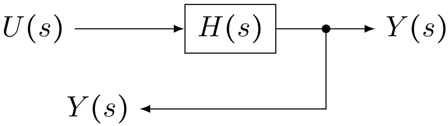

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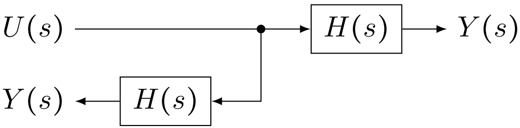
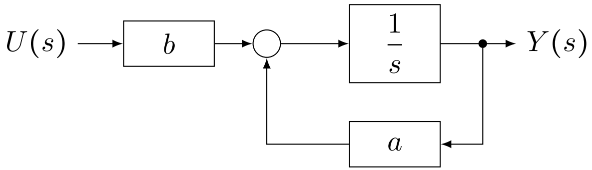


Combining the example above to model $\dot{y} = ay + bu$



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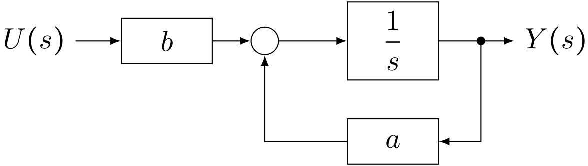

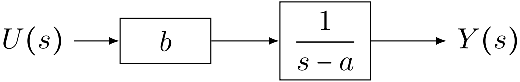

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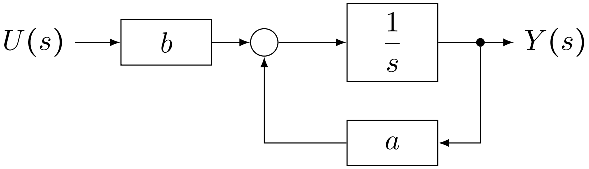

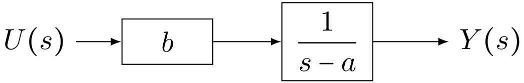

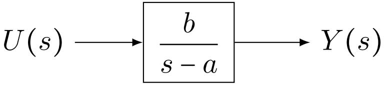

Self-assessment material

Question 1

transfer function Which of the following block operations has **no equivalent representation** in the frequency domain?

1. Multiplication by a constant
2. Nonlinear transformation by a generic function $f(\cdot)$
3. Summation of signals
4. Integration
5. I do not know

Solution 1: *Nonlinear operations like $f(y(t))$ do not generally have a direct equivalent in the frequency domain. In contrast, operations like multiplication, summation, and integration do, as they correspond to algebraic operations in the Laplace domain.*

Question 2

transfer function What is the equivalent transfer function of two blocks with transfer functions $H_a(s)$ and $H_b(s)$ connected **in series**?

1. $H_a(s) + H_b(s)$
2. $H_a(s) - H_b(s)$
3. $H_a(s) \cdot H_b(s)$
4. $H_a(s)/H_b(s)$
5. I do not know

Solution 1: *Blocks in series multiply: the output of the first is the input of the second, so the overall transfer function is* $H_a(s) \cdot H_b(s)$.

Question 3

transfer function Which of the following statements about the feedback loop formula $\dfrac{H_a(s)}{1 - H_a(s)H_b(s)}$ is **correct**?

1. It is only valid for time-domain systems
2. It represents the series connection of two systems
3. It gives the closed-loop transfer function for a negative feedback loop
4. It requires $H_b(s)$ to be zero
5. I do not know

Solution 1: *The formula $\dfrac{H_a(s)}{1 - H_a(s)H_b(s)}$ is the standard expression for the closed-loop transfer function in the case of negative feedback.*

Question 4

transfer function Which operation is **equivalent in both time and frequency domains** for block diagrams?

1. Integration
2. Derivation
3. Multiplication by a constant
4. Nonlinear transformation
5. I do not know

Solution 1: *Multiplication by a constant is equivalent in both time and frequency domains since it does not involve any transformation or differentiation/integration.*

Question 5

transfer function In a parallel connection of two transfer functions $H_a(s)$ and $H_b(s)$, the resulting system has the transfer function:

1. $H_a(s) \cdot H_b(s)$
2. $\dfrac{H_a(s)}{H_b(s)}$
3. $H_a(s) + H_b(s)$
4. $H_b(s) - H_a(s)$
5. I do not know

Solution 1: *In a parallel configuration, the outputs of $H_a(s)$ and $H_b(s)$ are added together. The resulting transfer function is therefore $H_a(s) + H_b(s)$.*

Recap of the module “Block diagrams”

1. you are suppose to know how to work with block diagrams
2. the rules are quite simple, and can be re-derived by hands