Operational Amplifiers
Scheme Outlines

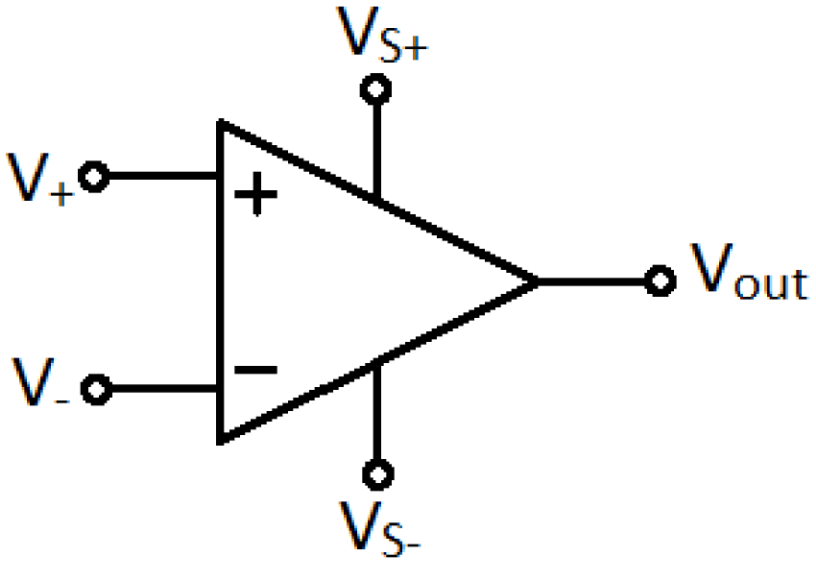
Applied Mechatronics

Module 5.3.1

by Wolfgang Neff

Basics (1)

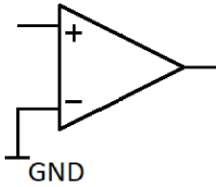
- Electronic Symbol



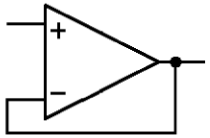
  - V_+: non-inverting input
  - V_-: inverting input
  - V_{out}: output
  - V_{S+}: positive power supply
  - V_{S-}: negative power supply

Basics (2)

- Terms
  - Open-Loop
    - Circuit without feedback



  - Closed-Loop
    - Circuit with feedback



  - Differential Input Voltage
    - $V_d = V_+ - V_-$
  - Gain of the Amplifier
    - $A = \frac{V_{out}}{V_d}$

Basics (3)

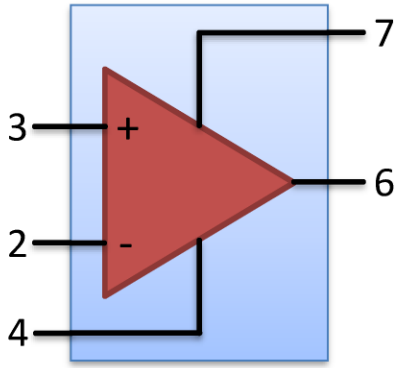
- Characteristics (Ideal Op-Amp)
  - Open-Loop Gain
    - $A_{OL} \rightarrow \infty$
  - Closed-Loop Differential Voltage Input
    - $V_d = 0$ V
  - Input Resistance
    - $R_{in} \rightarrow \infty$
    - Zero Input Current
      - $I_+ = 0$ A, $I_- = 0$ A

Basics (4)

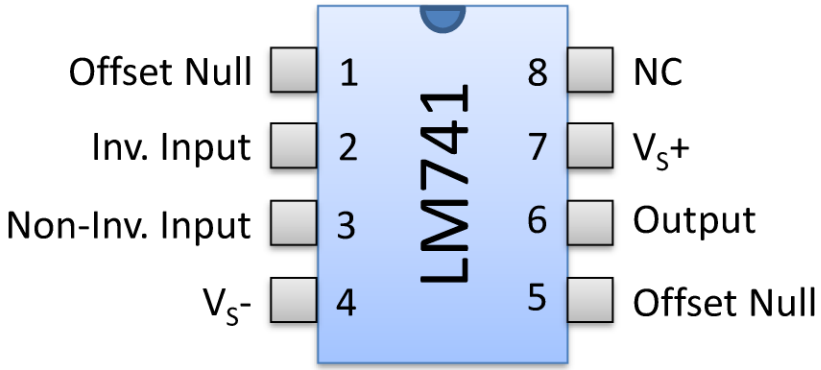
- Characteristics (continued)
  - Output Resistance
    - R_{out} = 0 Ω
    - Any load can be driven
  - Output Voltage
    - $V_{out} = \begin{cases} V_{S+}, & V_+ > V_- \\ V_{S-}, & V_+ < V_- \end{cases}$

Basics (5)

- Example: LM741



Block Diagram

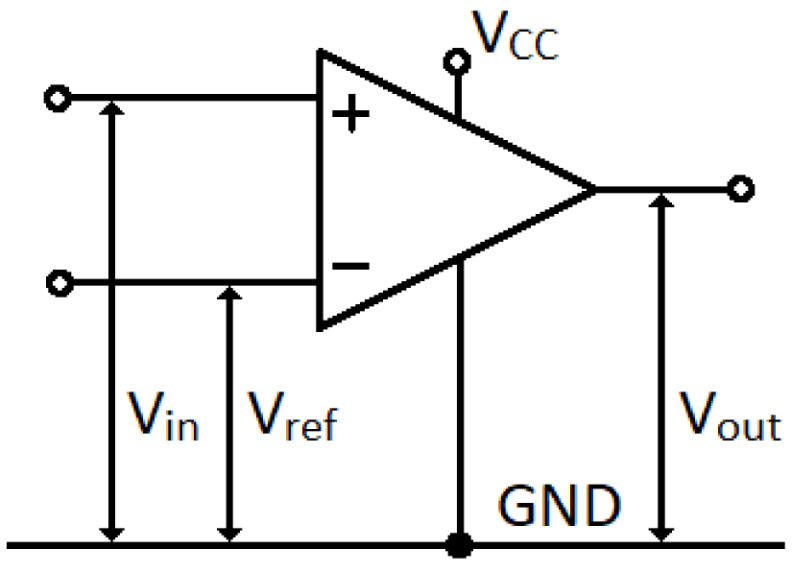


Pin Configuration

Voltage Comparator (1)

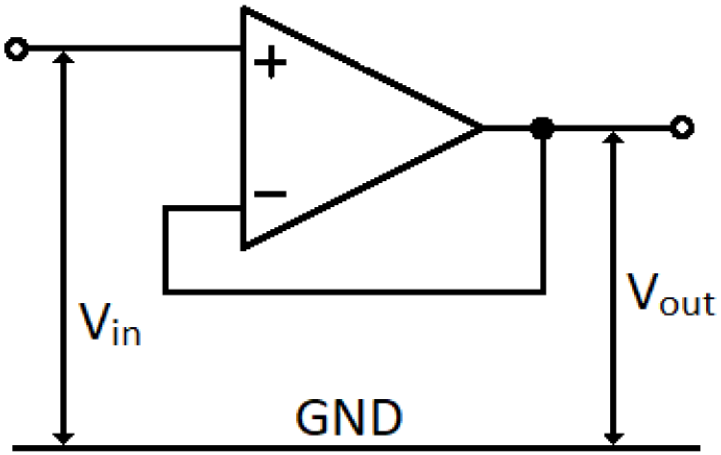
- Setup and Mode of Operation
  - Compares two Voltages
    - V_{ref}: reference voltage
    - V_{in}: probed voltage
  - Output
    - Logic Levels
      - V_{CC} = 1, GND = 0
    - $V_{out} = \begin{cases} 1, V_{in} > V_{ref} \\ 0, V_{in} < V_{ref} \end{cases}$

Cf. NWES Module 4.2.6



Impedance Converter (1)

- Setup and Mode of Operation
  - Basic Equations
    - $V_d = V_+ - V_-$
    - $V_+ = V_{in}$, $V_- = V_{out}$
  - Closed Loop
    - $V_d = 0$ V
    - $V_{out} = V_{in}$

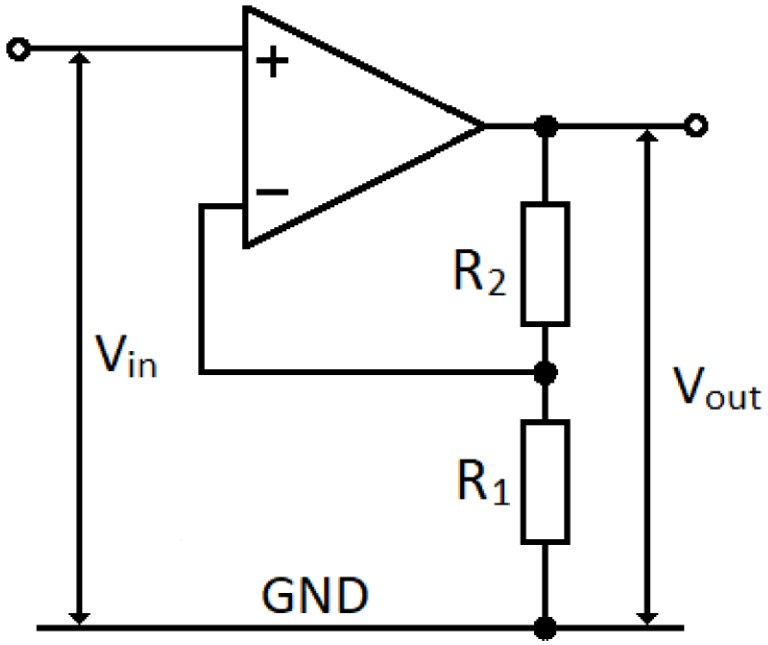


Impedance Converter (2)

- Implications
  - Input and output voltage are equal
  - High input resistance
  - Low output resistance
- Application
  - Reduce internal resistance of power sources
  - Usually desired: $R_{int} \ll R_{load}$
  - Cf. [SEY14] Ch. 2.16: Innenwiderstand von Span.

Non-Inverting Amplifier (1)

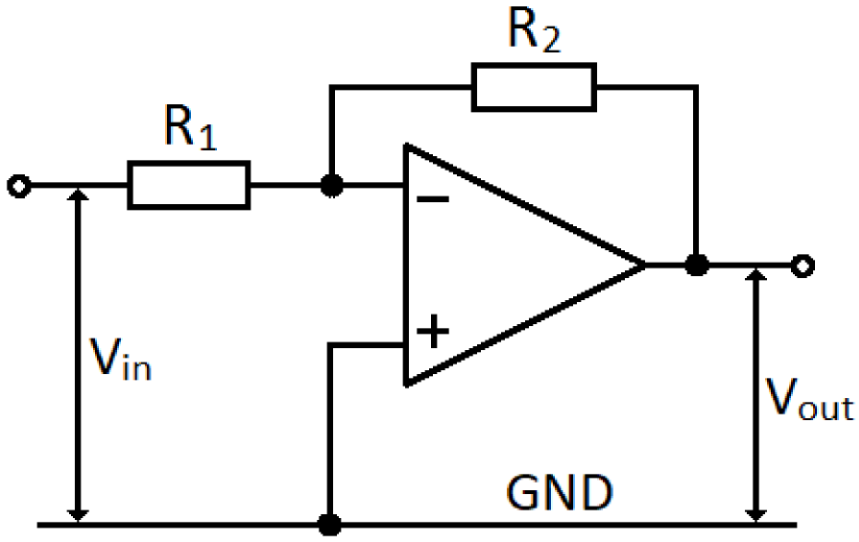
- Setup and Mode of Operation
  - Basic Equations
    - $V_{out} = A_{CL} \cdot V_{in}$
    - $A_{CL} = 1 + \frac{R_2}{R_1}$
  - Implication
    - Max amplification is 1
  - Application
    - Control theory
      - Proportional controller



AMEC IX

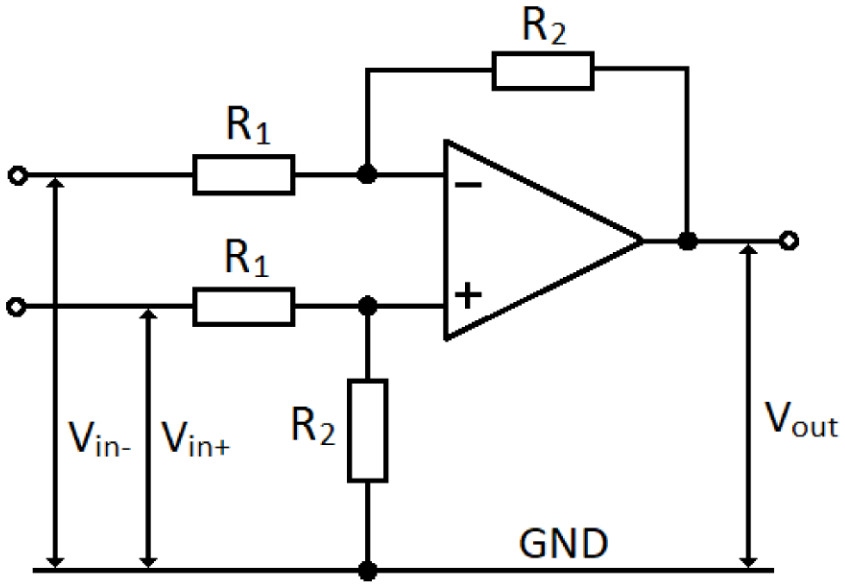
Inverting Amplifier (1)

- Setup and Mode of Operation
  - Basic Equations
    - $V_{out} = - A_{CL} \cdot V_{in}$
    - $A_{CL} = \frac{R_2}{R_1}$
  - Implications
    - Input and Output have opposite sign.
    - Amplification is adjustable at will.



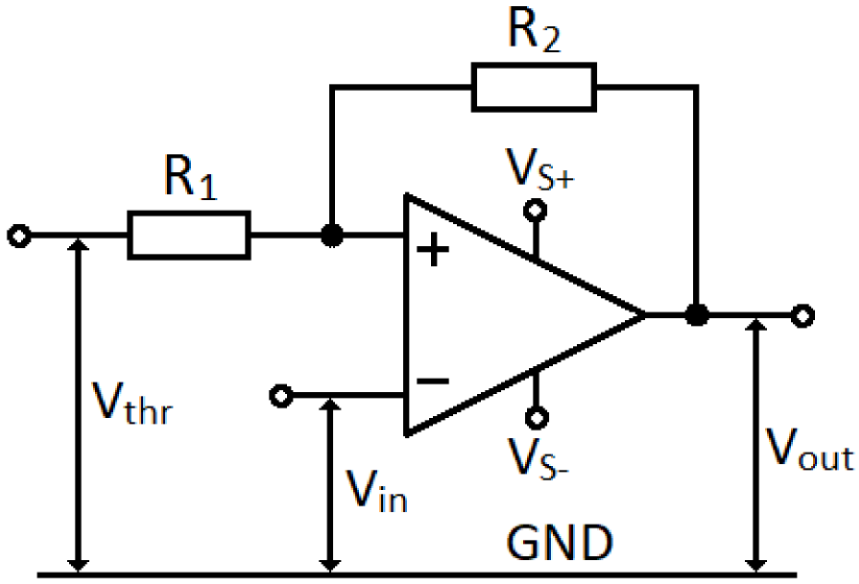
Differential Amplifier (1)

- Setup and Mode of Operation
  - Basic Equations
    - $V_{out} = A_{CL} \cdot (V_{in+} - V_{in-})$
    - $A_{CL} = \frac{R_2}{R_1}$
  - Application
    - Control theory
      - Comparing element



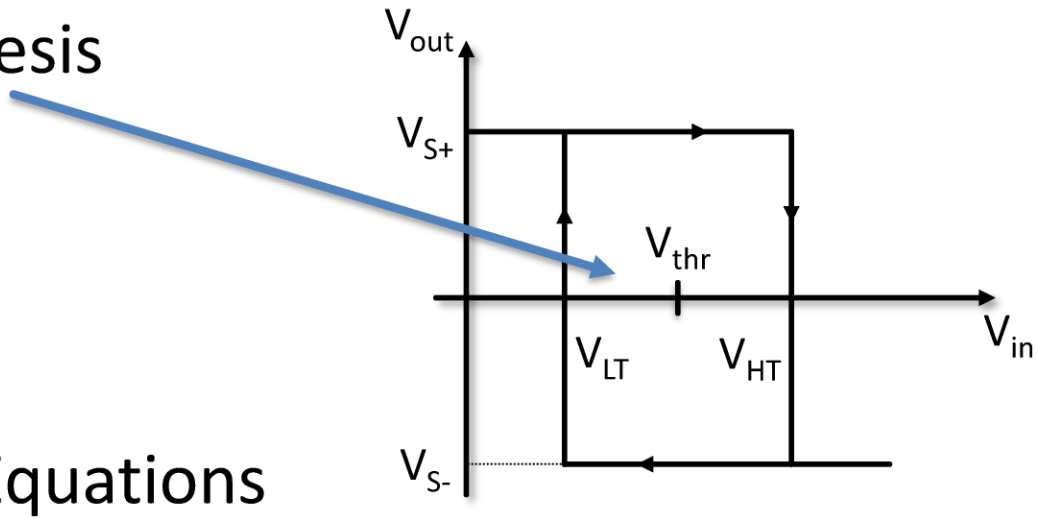
Schmitt Trigger (1)

- Setup (inverting)
  - Terms
    - V_{thr}: Threshold voltage
    - V_{HT}: High threshold
    - V_{LT}: Low threshold
    - Hysteresis: see blow
  - Applications
    - Cf. NWES module 3.4.7



Schmitt Trigger (2)

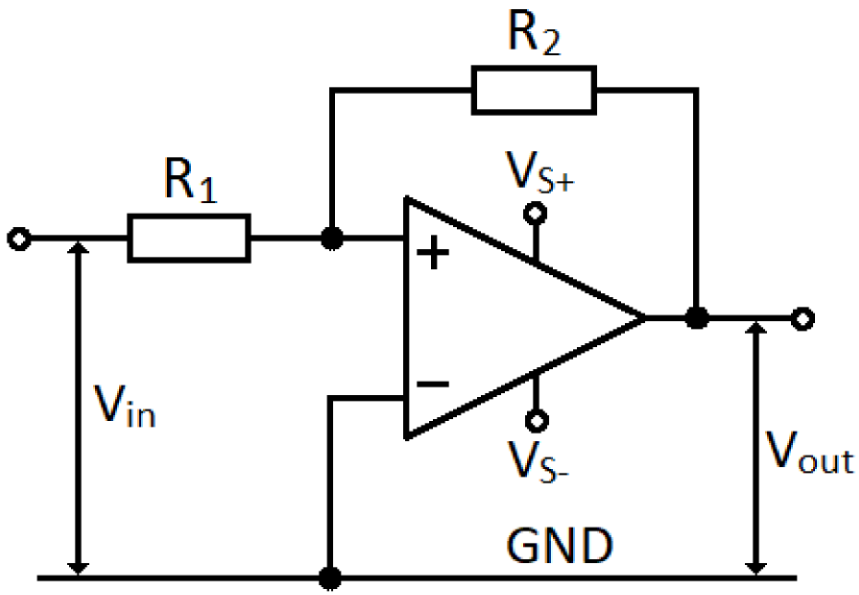
- Mode of Operation
  - Hysteresis



  - Basic Equations
    - $V_{HT} = V_{thr} + \frac{R_1}{R_1+R_2} \cdot (V_{S+} - V_{thr})$
    - $V_{LT} = V_{thr} + \frac{R_1}{R_1+R_2} \cdot (V_{S-} - V_{thr})$

Schmitt Trigger (3)

- Setup (non-inverting)
  - Cf. [BRI13] Ch. 3.2.7
  - Basic Equations
    - $V_{HT} = -\frac{R_1}{R_2} \cdot V_{S+}$
    - $V_{LT} = -\frac{R_1}{R_2} \cdot V_{S-}$

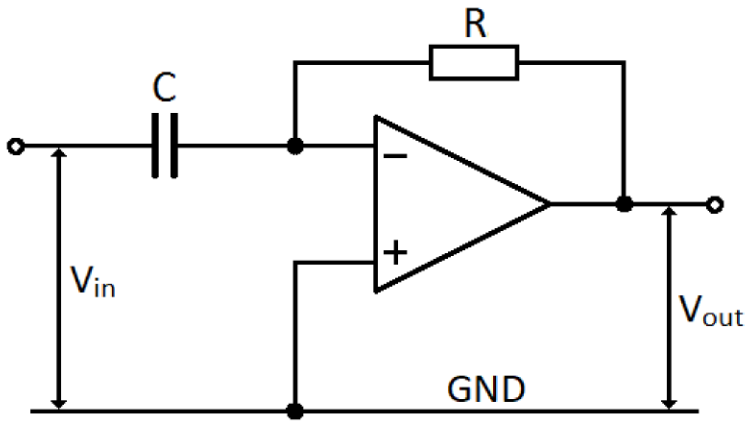


Differentiator (1)

- Setup
  - Basic Equations
    - $V_{out} = -R \cdot C \cdot \frac{\Delta V_{in}}{\Delta t}$
    - $v_{out}(t) = -\boxed{R \cdot C} \cdot \frac{dv_{in}(t)}{dt} = -\tau \cdot \dot{v}_{in}(t)$

Difference Quotient

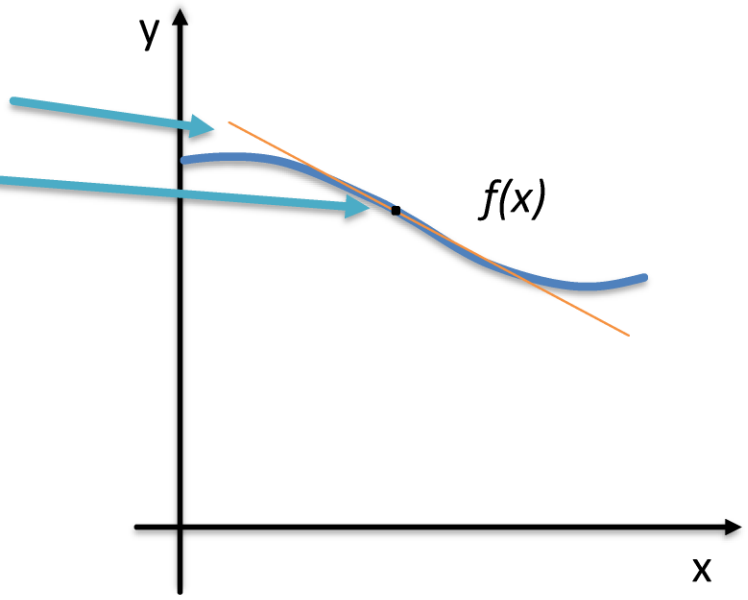
Time Constant τ
Cf. [SEY14] Ch. 5.7
Kondensator an Gleichspannung



Differentiator (2)

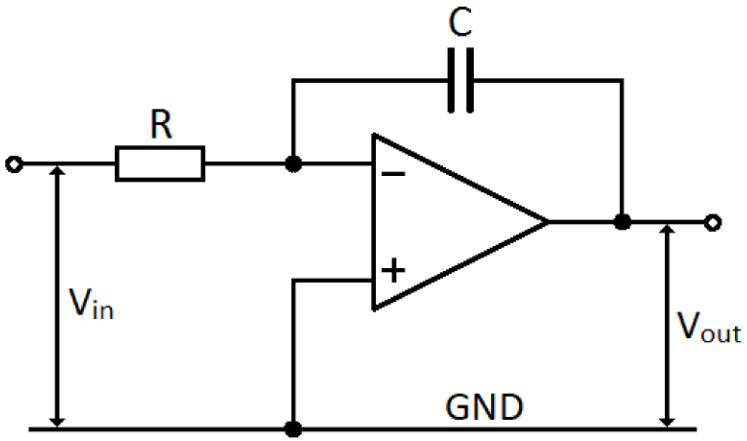
- Mode of Operation
  - Differential
    - Slope of the tangent line of a function at a point
  - Application
    - Control theory
      - Derivative controller

AM V



Integrator (1)

- Setup
  - Basic Equations
    - $\Delta V_{out} = -\frac{1}{R \cdot C} \cdot \boxed{V_{in} \cdot \Delta t}$ — Riemann Summand
    - $v_{out}(t) = -\frac{1}{R \cdot C} \cdot \boxed{\int_0^t v_{in}(t)dt} + v_{out}(0)$ — Integral



Integrator (2)

- Mode of Operation
  - Integral
    - Area of a region bounded by a function graph
  - Application
    - Control theory
      - Integral controller

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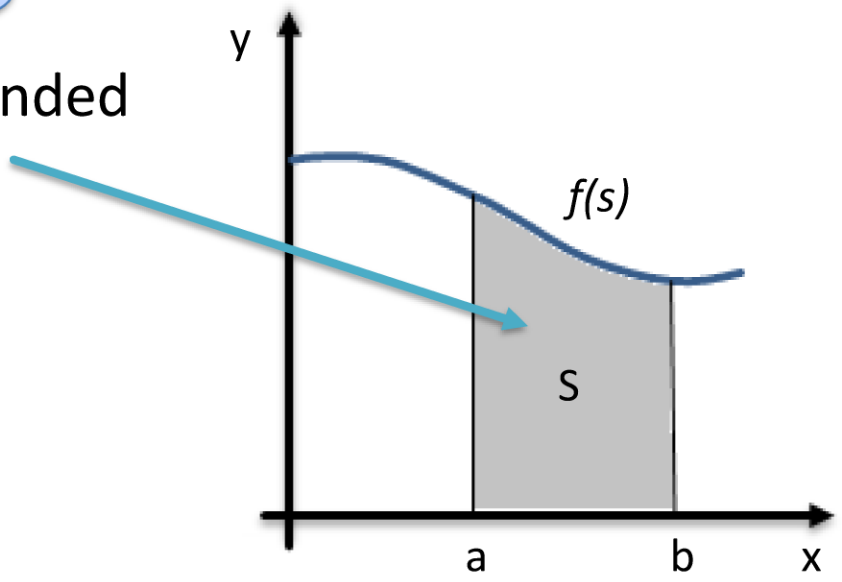

Addendum

- Further Information
  - [BRI13] Ch. 3.2.7 Operationsverstärker

Bibliography

- [SEY14]: SEYR, SIGURD and SCHWAIGER, HERBERT, 2014, Elektrotechnik Grundlagen mit angewandter Mathematik. Wien : Jugend & Volk. ISBN 978-3-7100-2873-1.
- [BRI13]: BRIEGLER, ADOLF and others, 2013, Elektrotechnik Fachkunde 1. Wien : Jugend & Volk. ISBN 978-3-7100-2911-0.