ANALOG CIRCUITS DESIGN

AE1: Basic analog-circuit equations

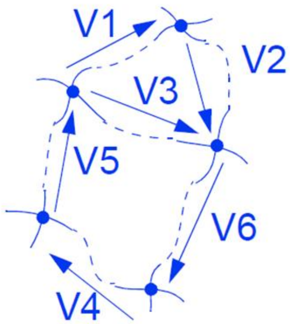
JUNIA ISEN

Course overview

1. Kirchoff's laws
2. Murphy's laws
3. Ground node is neither a black hole nor black magic
4. Series and parallel association of dipoles
5. Voltage source (Thevenin's model)
6. Current source (Norton's model)
7. Thevenin-Norton equivalence
8. Controlled sources
9. The voltage divider & the current divider
10. Superimposition
11. The concept of equivalent impedance

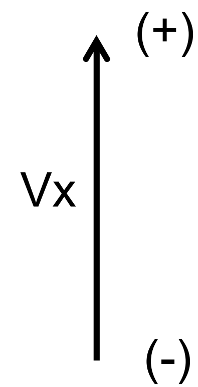
1. Kirchoff’s laws

- Kirchoff’s voltage law (KVL)

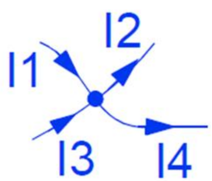


- ✓ In a loop, the sum of the voltages is zero

  Some examples:
  -V1 -V2 +V3 = 0
  V5 + V4 + V6 + V3 = 0



- Kirchoff’s voltage law (KVL)



- ✓ At a node, the sum of the currents is zero

  example: +I1 -I2 +I3 -I4 = 0

- ✓ Corollary: the sum of the inflows equals the sum of the outflows (no accumulation)

- ✓ Convention: the current entering a node is positive

2. Murphy's laws

Edward Aloysius Murphy Jr
1918-1990

American aerospace engineer who worked on safety-critical systems

"Anything that can go wrong will go wrong"

"If anything simply cannot go wrong, it will anyway"

"If there is a possibility of several things going wrong, the one that will cause the most damage will be the one to go wrong"

3. Ground node is neither a black hole nor black magic

- What is ground?

The ground is a node that was arbitrarilly chosen as the reference for voltage measurement in a circuit.

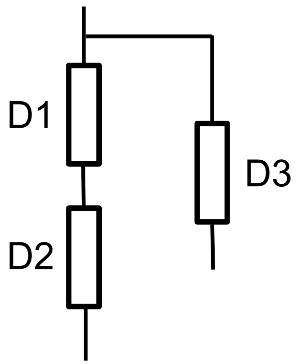
- What happens in the ground?

Nothing else than in any other node, the sum of currents is still zero

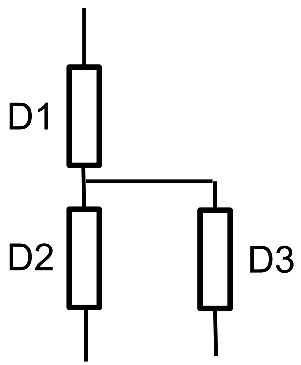
Corollary:
in the ground, currents do not disappear any more than they are generated

4. Series and parallel association of dipoles

- Series association: one common node **not shared** with other dipoles, impedances add

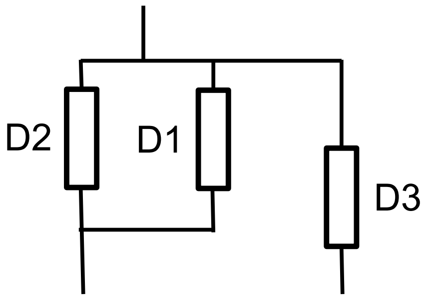


D1 and D2 are in series

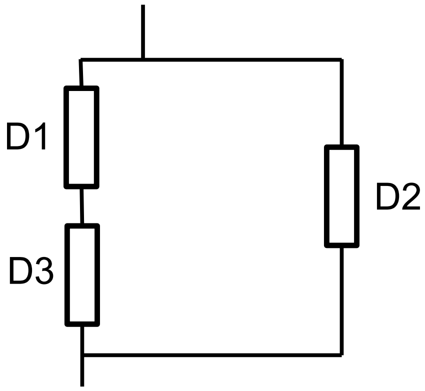


D1 and D2 are not in series

- Parallel association: two nodes in common **possibly shared** with other dipoles, admitances add

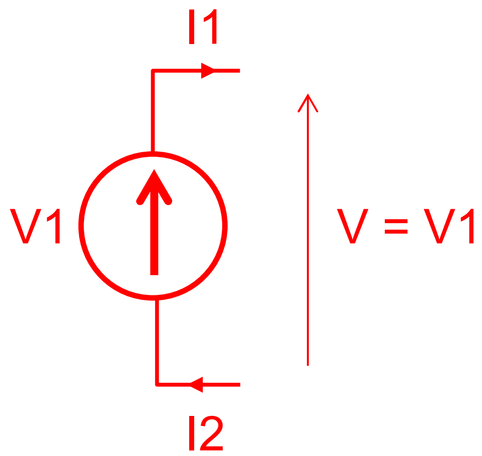


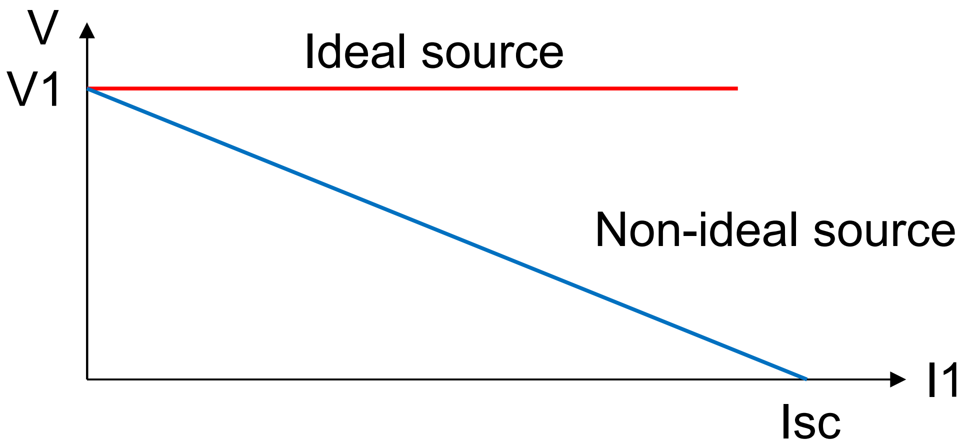
D1 and D2 are in parallel



D1 and D2 are not in parallel

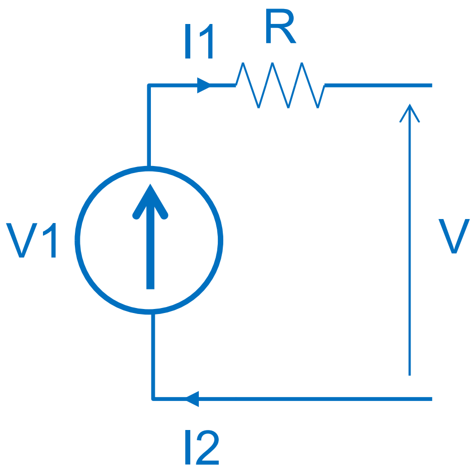
5. Voltage source (Thevenin's model)





- Voltage source:
  - I1 = |I2|
  - Current may be positive, negative or zero

  - V1: open-circuit voltage
  - Isc: short-circuit current
  - R: internal resistance (linear model)



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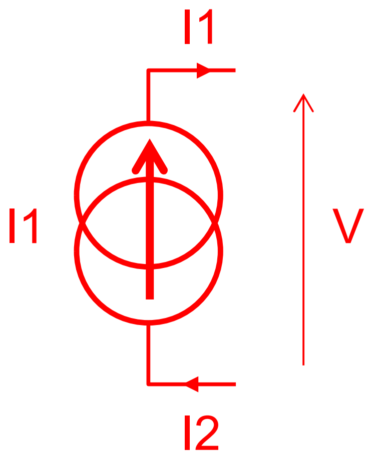
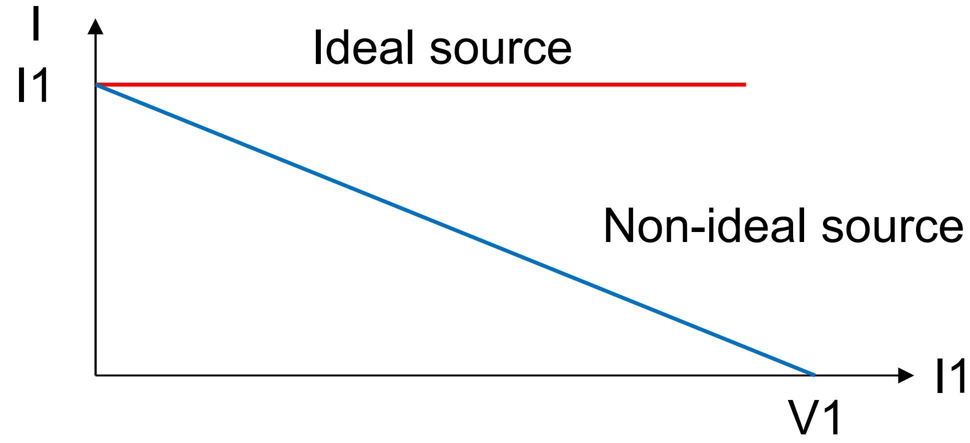
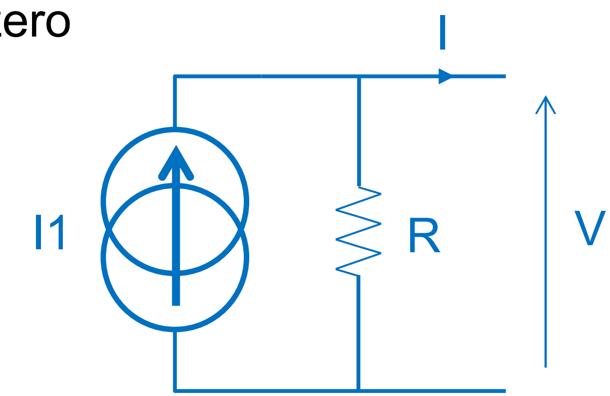
6. Current source (Norton's model)





- Current source:
  - I1 = |I2|
  - voltage may be positive, negative or zero

  - V1: open-circuit voltage
  - I1: short-circuit current
  - R: internal resistance (linear model)



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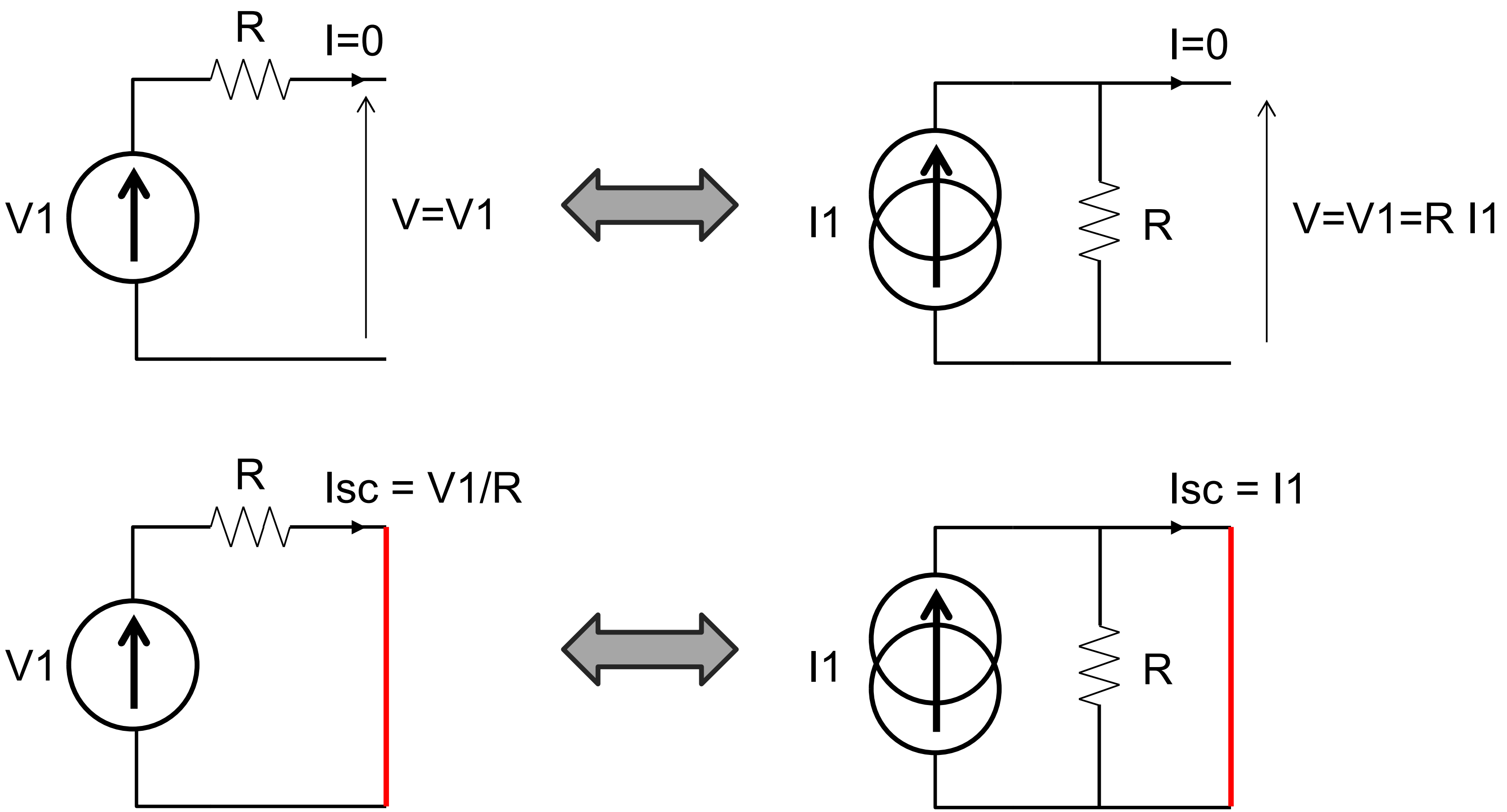
7. Thevenin-Norton equivalence

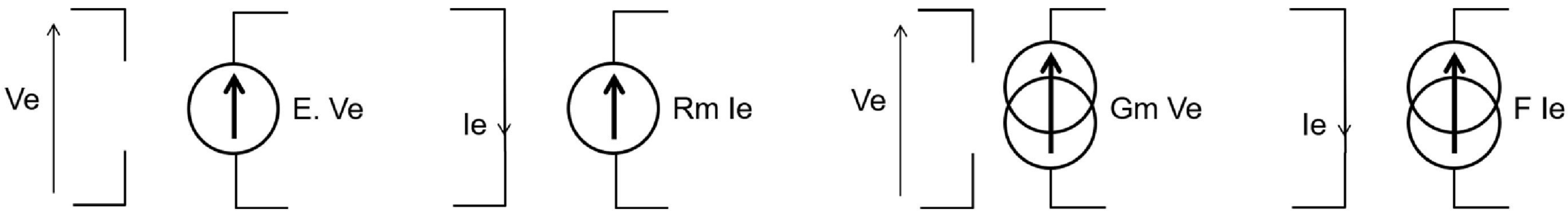
➢ Thevenin’s and Norton’s models are equivalent for a **non-ideal** source



1. 8. Controlled sources

- Voltage/current source which value depends on another voltage/current

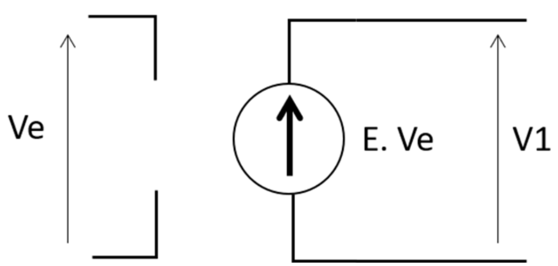
- Four possible combinations:



VCVS CCVS VCCS CCCS

- Used to model complex circuits (operational amplifiers…)

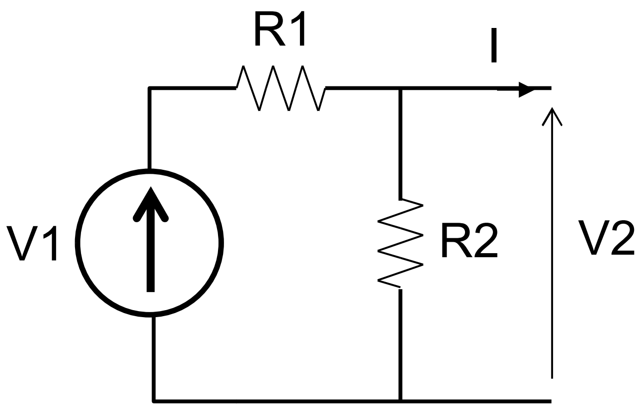
- Unilateral devices



V1 = E Ve means that output voltage V1 depends on the voltage Ve applied to the input.

Ve = V1 / E is mathematically correct. However, applying a voltage to output V1 will **not** change the value of input voltage Ve.

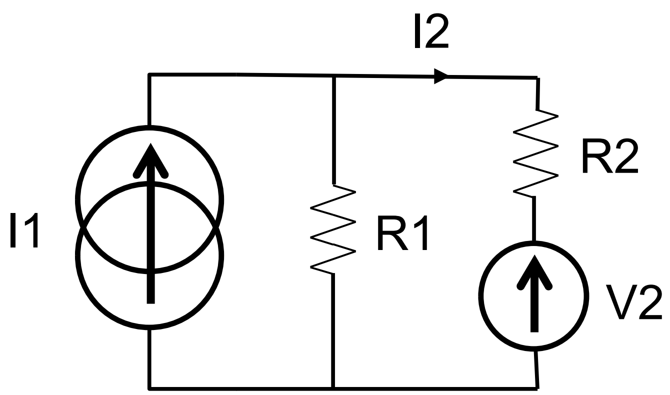
9. The voltage divider & the current divider



if I = 0 (Exact solution)

$$V2 = V1\frac{R2}{R1 + R2}$$

Good approximation provided $I \ll \frac{V1}{R1}$



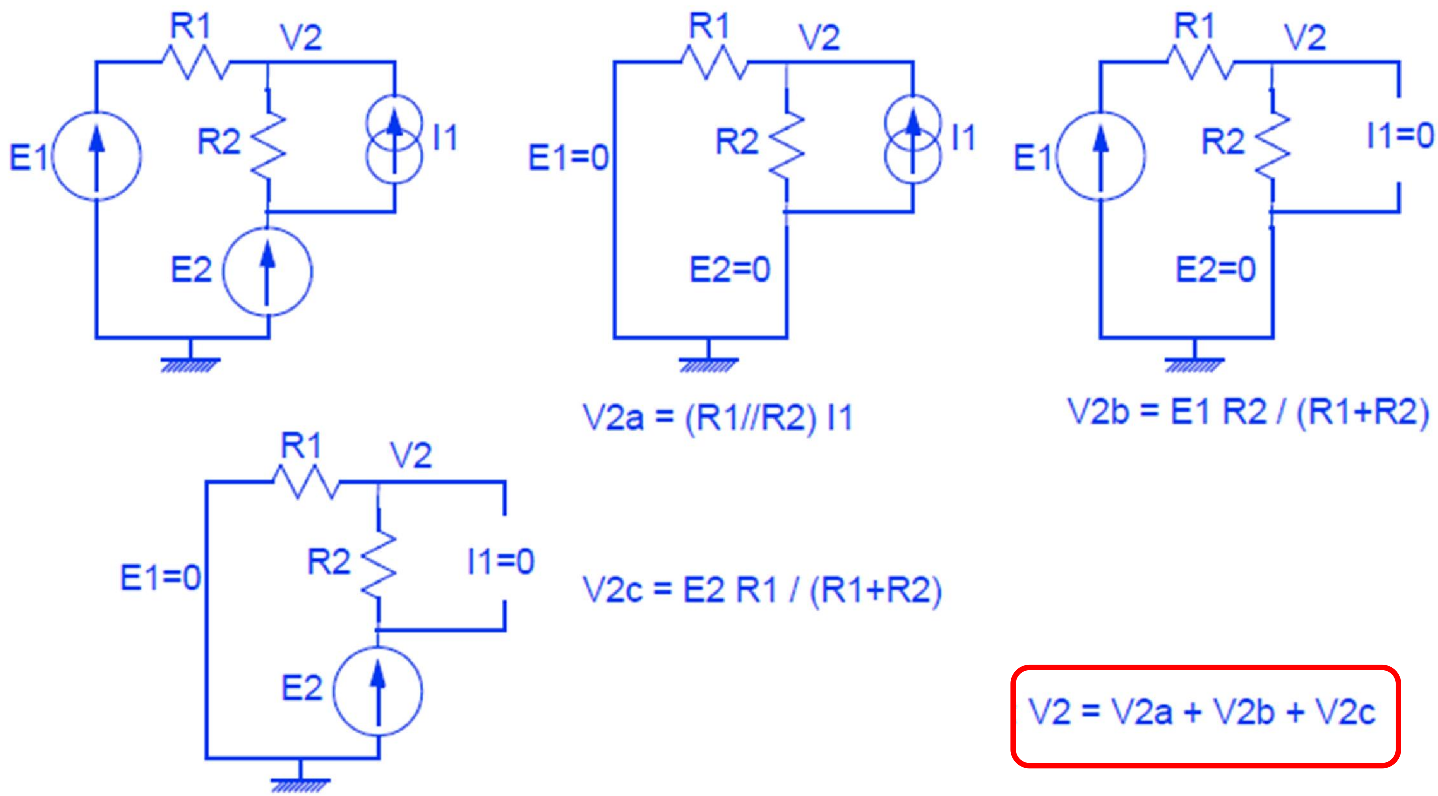
if V2 = 0 (Exact solution)

$$\mathrm{I}2 = I1\frac{R1}{R1+R2}$$

Good approximation provided $I1 \gg \frac{V2}{R1}$

10. Superimposition

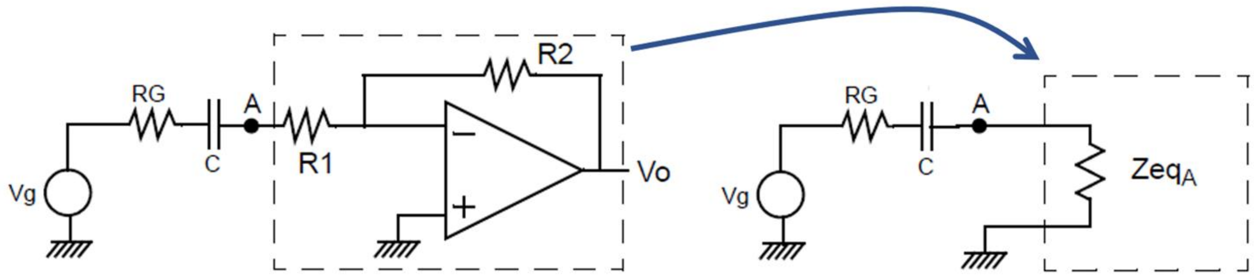
- Voltage and current sources must be independent,
- Voltages and currents in the circuit are the sum of individual contributions from the sources,
- The individual contribution of source Sx is calculated when all sources but Sx are set to zero



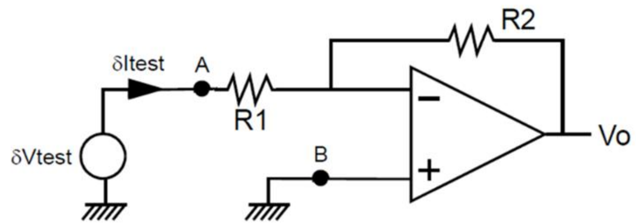
11. The concept of equivalent impedance

- Used to model part of a complex circuit

  Example: determine the capacitor value for a given cut-off frequency



- Defined as $Z_{eq} = \frac{\partial V}{\partial I}$



- May be real or complex:
  - Impedance: Z = R +jX
  - Admittance: Y = G + jS

- Linearization of the I-V characteristic at the operating point V1-I1