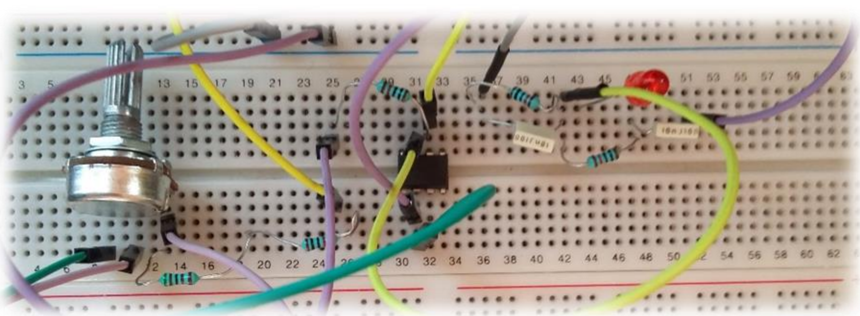
ELECTRONIC DEVICES

Assoc.prof. Laura-Nicoleta IVANCIU, Ph.D.

C1 – Introduction. Fundamentals.



Contents

- Course presentation
- Desired outcome. Evaluation.
- Fundamentals

Course presentation

Fundamentals

- Electrical signals
- Relations and laws for electrical circuits
- RC circuits – time and frequency response

Diodes (D)

- Types, operating principle, characteristic, parameters
- Diode circuits
- Zener diodes, LEDs

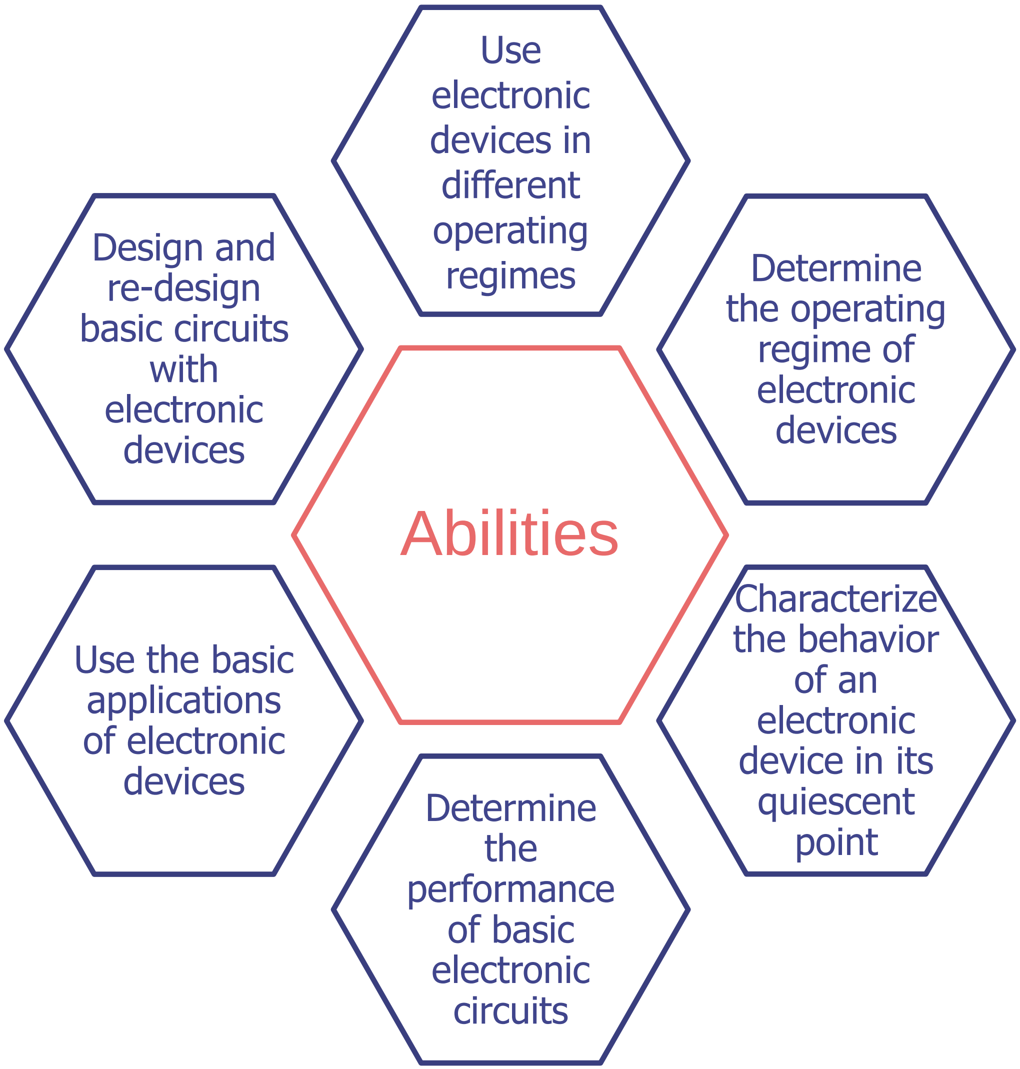
Operational Amplifiers (OpAmps)

- Ideal OpAmp, operating principle, characteristics, parameters, operating modes
- OpAmp comparators
- OpAmp amplifiers
- Applications with OpAmp

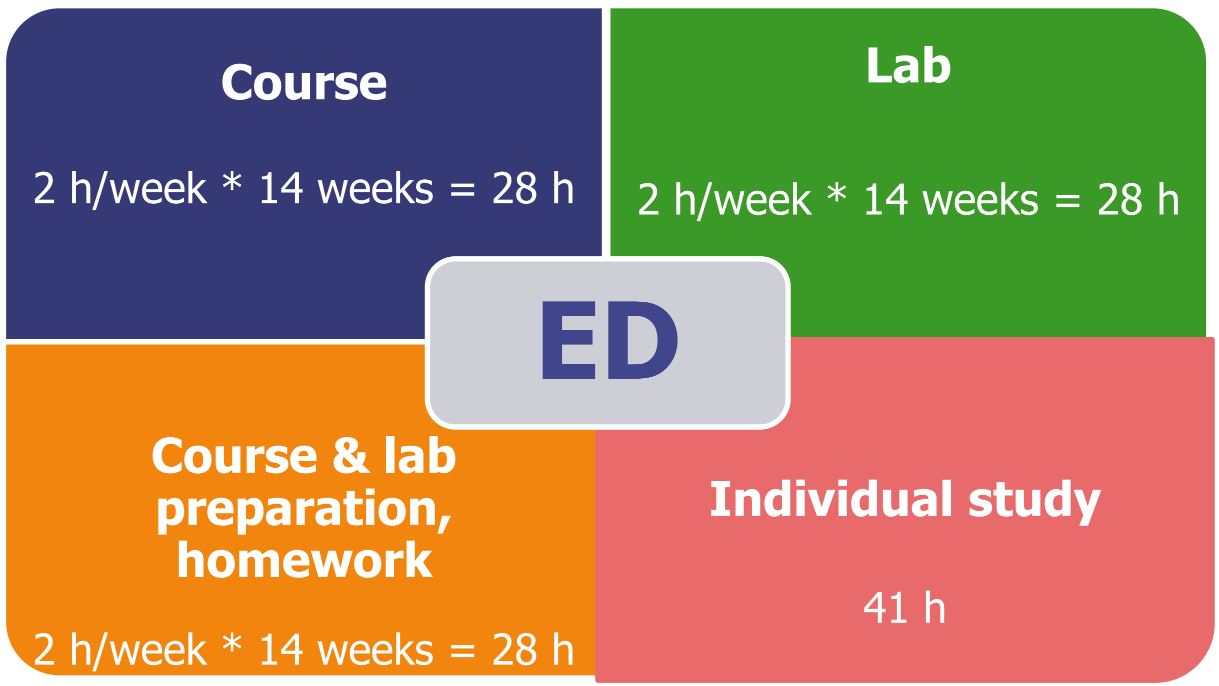
Transistors (T)

- Types, operating principles, characteristics, parameters
- Bipolar junction transistors (BJTs)
- Field-effect transistors (MOSFET)

At the end of the semester, you will be able to



Provided that you spend



www.bel.utcluj.ro/dce/didactic/ed/

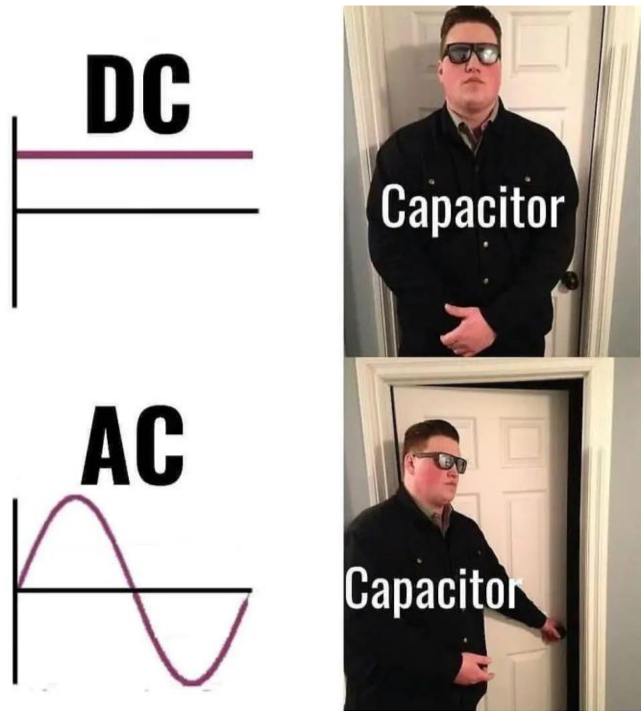
Activities - weekly

- Course – optional attendance

  Tuesday, 10-12, room 41

Reasons to attend:

- complete solutions for examples
- not everything is on the slides
- inside jokes and memes

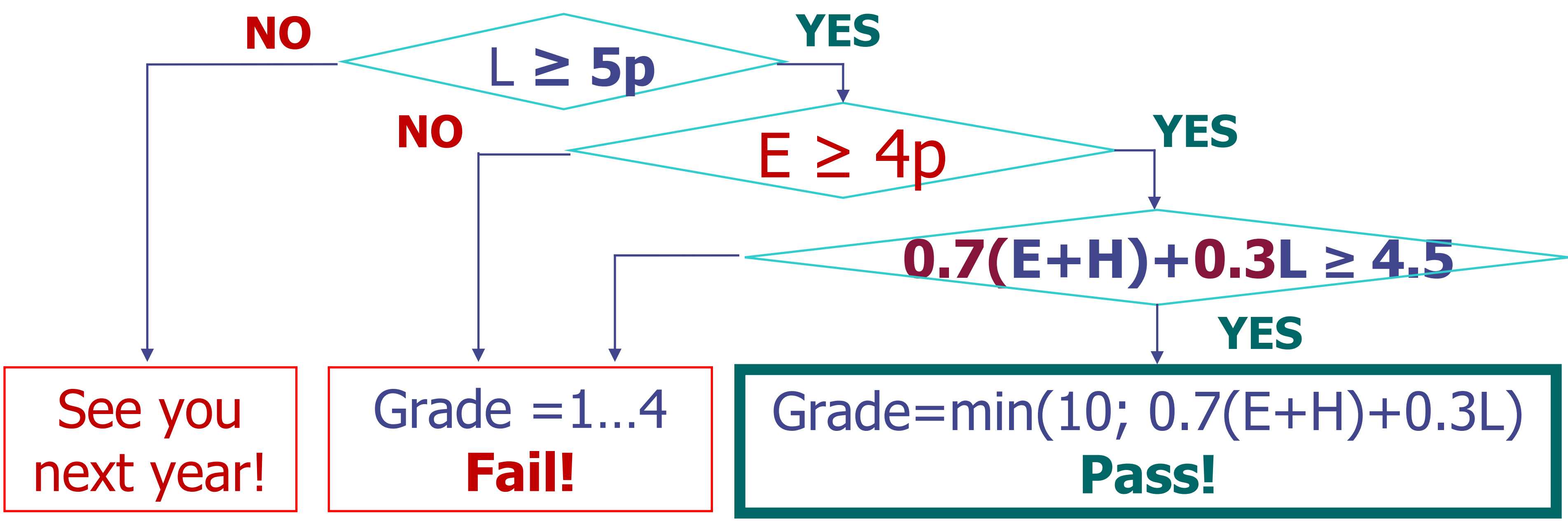


- Lab – mandatory attendance

  as scheduled, room BT 1.03

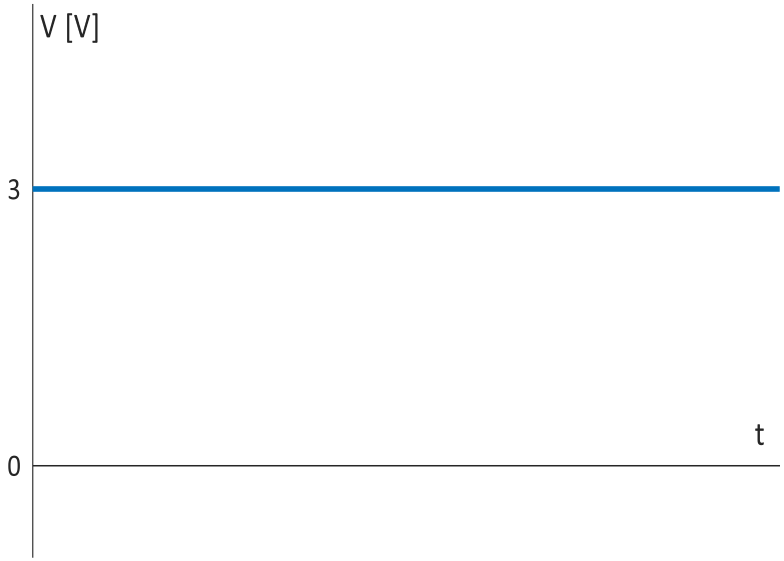
Evaluation

Written exam **(E)** 0…10 points	Laboratory **(L)** 0…10 points	Course homework **(H)** 0…1 point
• problem solving	• full attendance • activity • practical test	• problems - optional

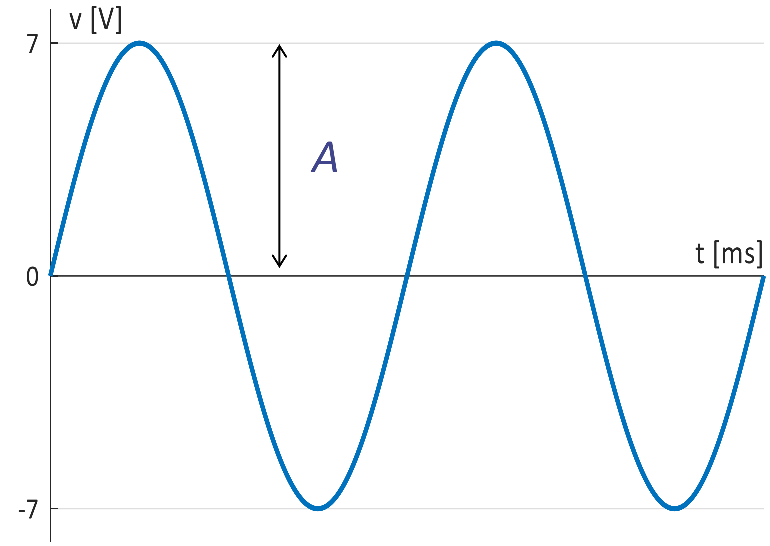


Fundamentals

➢ Electrical signals



a)



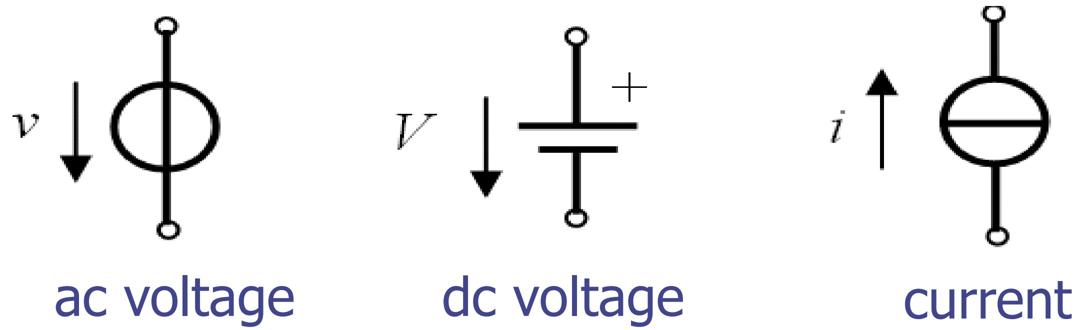
b)

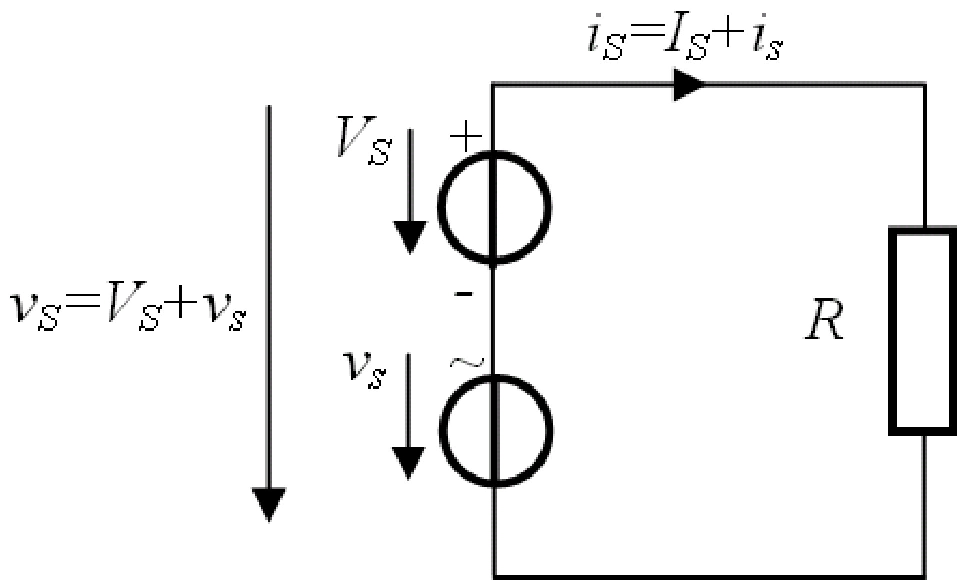
Time variation of a:

a) continuous voltage (dc); b) sinusoidal voltage (ac)

Fundamentals

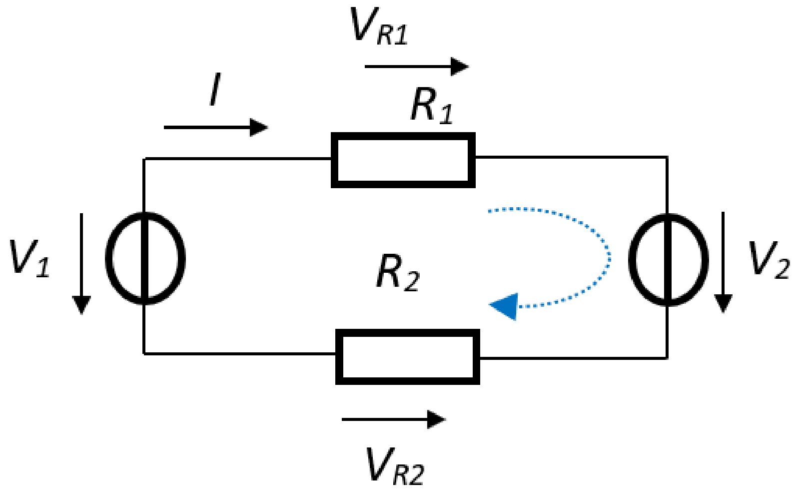
- Sources. Notations.



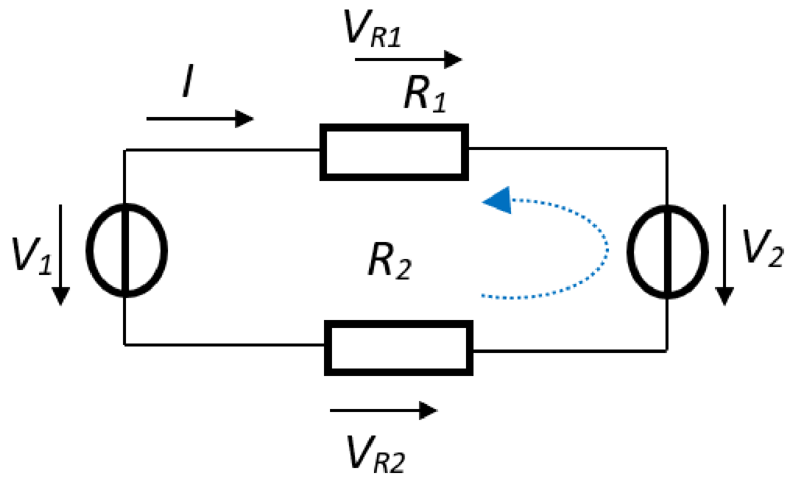


Fundamentals

- Ohm's law. Kirchhoff's laws.



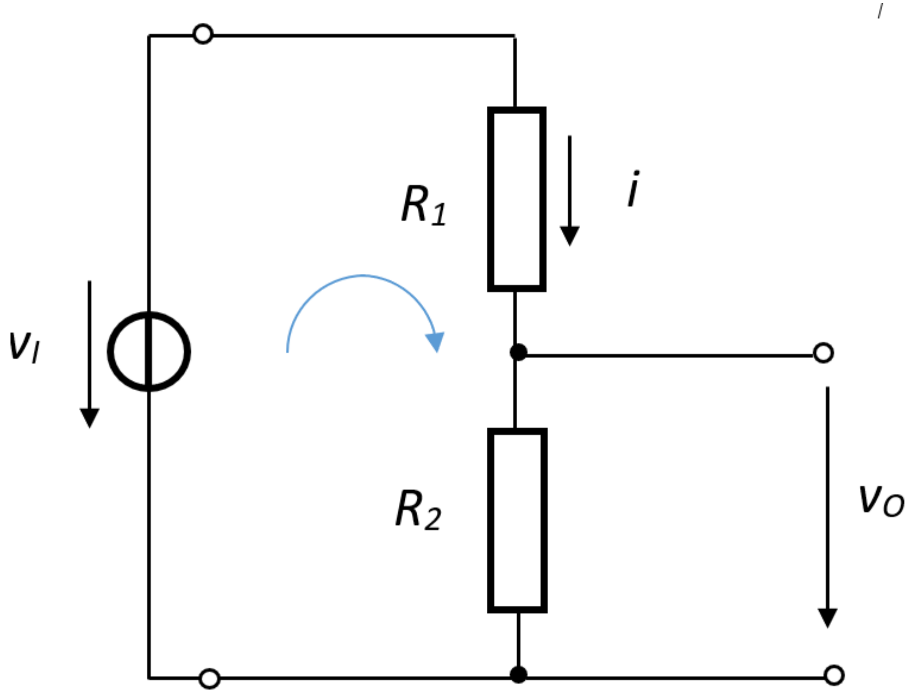
$$-V_1 + R_1 \cdot I + V_2 - R_2 \cdot I = 0$$



$$V_1 - R_1 \cdot I - V_2 + R_2 \cdot I = 0$$

Fundamentals

- Resistive divider

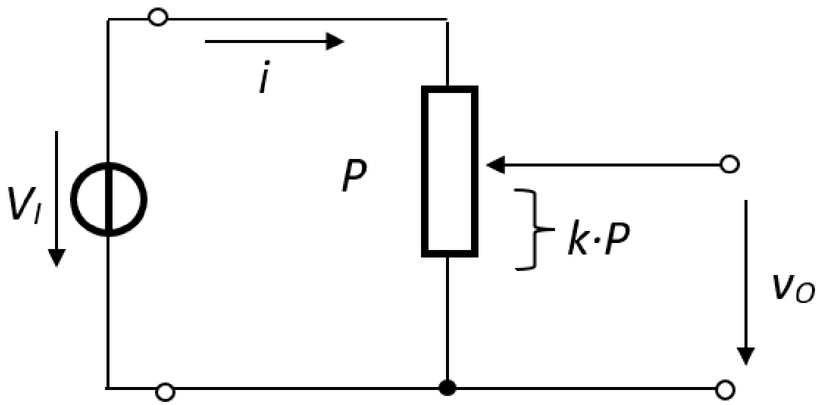


$$i = \frac{v_I}{R_1 + R_2}$$

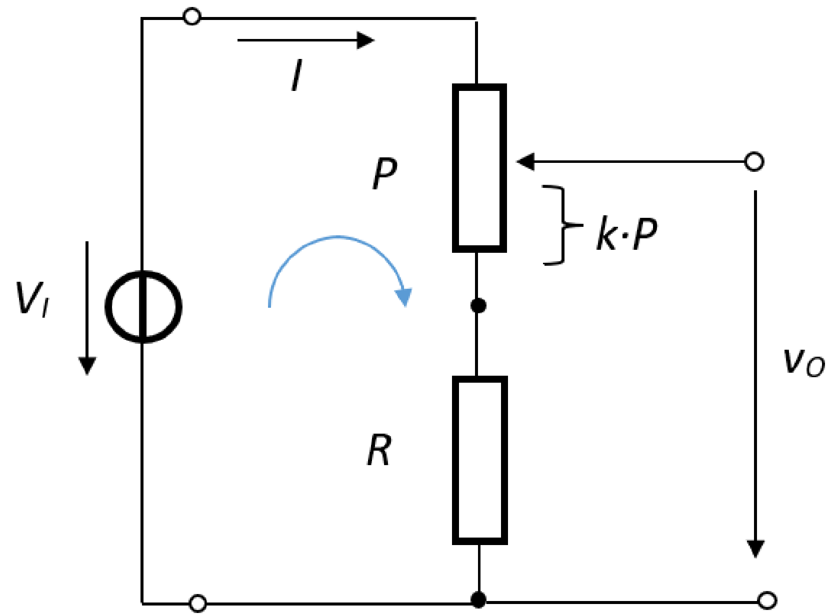
$$v_O = i \cdot R_2 = \frac{R_2}{R_1 + R_2} \cdot v_I$$

Fundamentals

- Adjustable resistive divider



$$v_O = \frac{k\cdot P}{P} v_I = k \cdot v_I$$

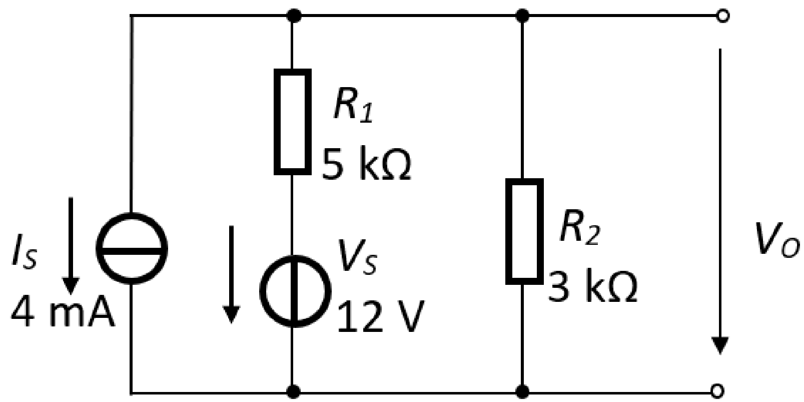


$$V_O = \frac{k\cdot P + R}{P + R}\cdot V_I$$

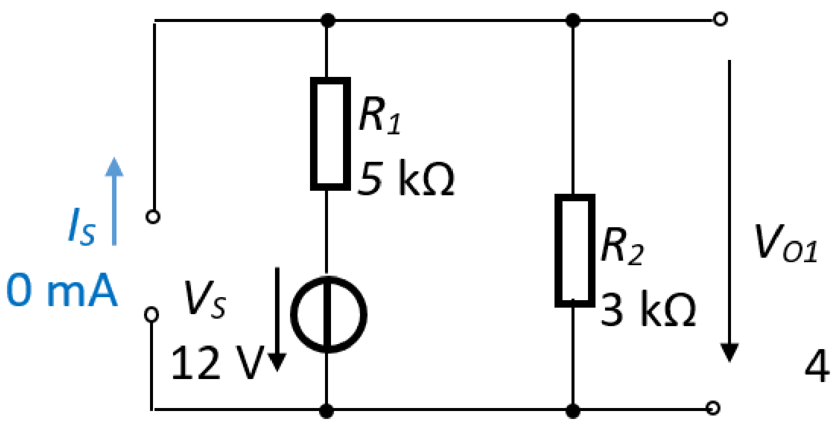
$V_{O\ \text{min/max}} = ?$

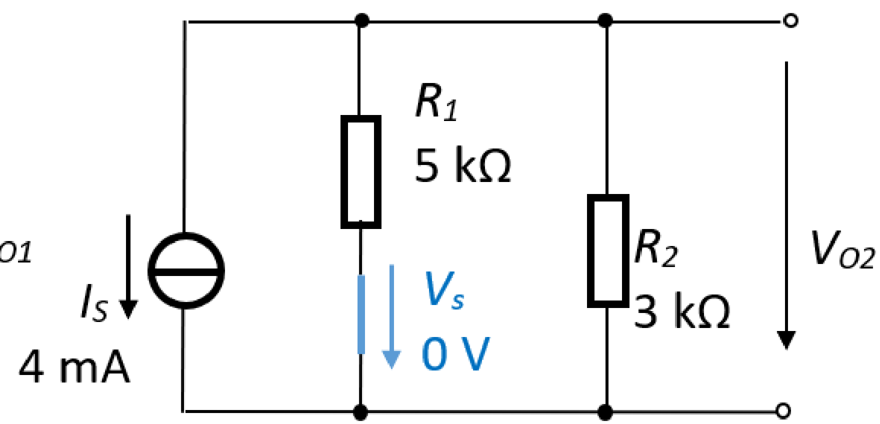
Fundamentals

- Superposition method



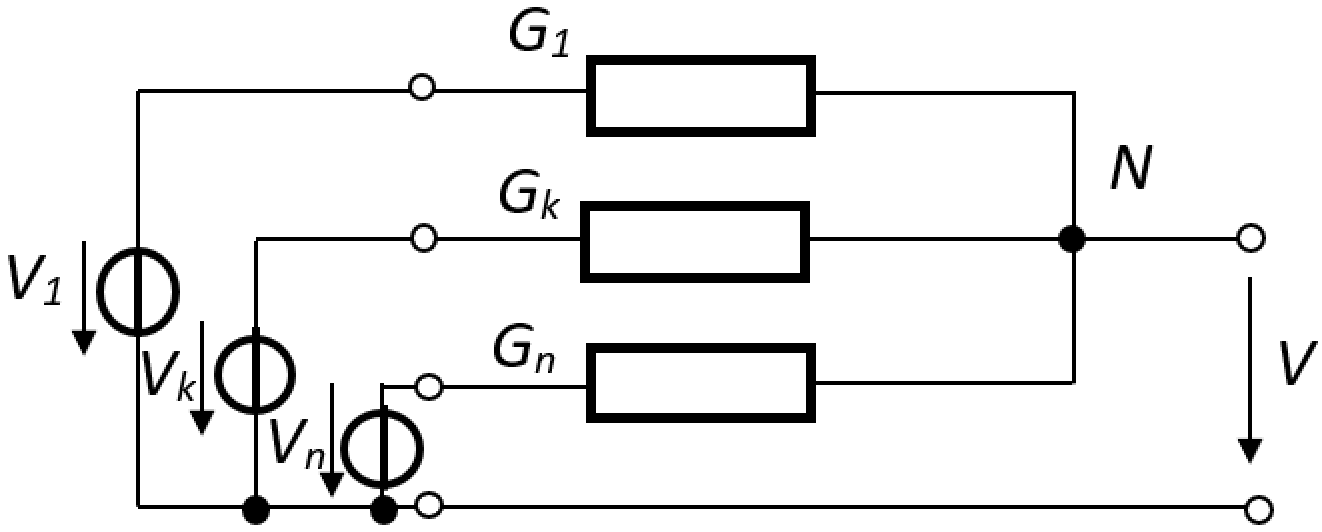
$$V_O = V_{O1} + V_{O2}$$





Fundamentals

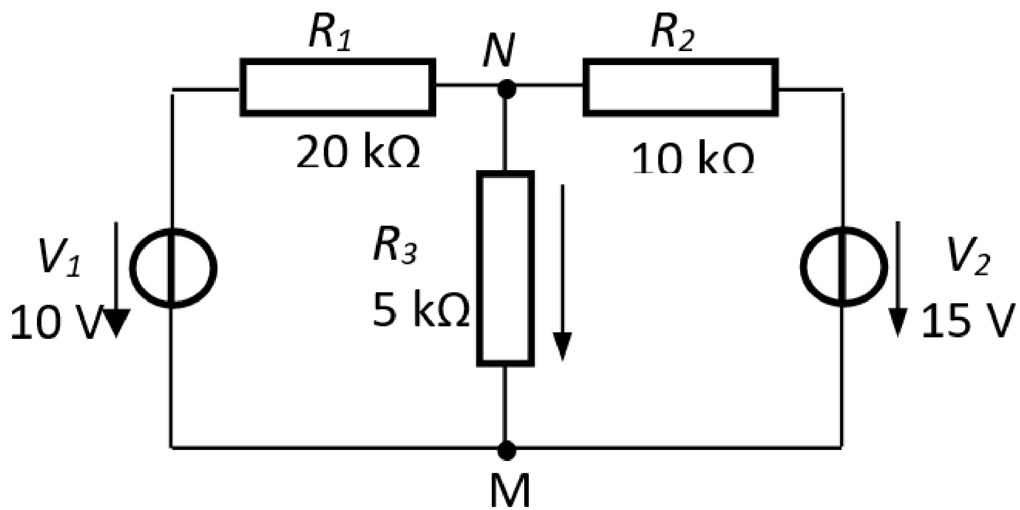
- Millman's theorem (nodes potential theorem)



$$V = \frac{\sum_{k=1}^{n} V_k \cdot G_k}{\sum_{k=1}^{n} G_k} = \frac{\sum_{k=1}^{n} V_k \cdot \frac{1}{R_k}}{\sum_{k=1}^{n} \frac{1}{R_k}}$$

Fundamentals

➢ Millman's theorem (nodes potential theorem)

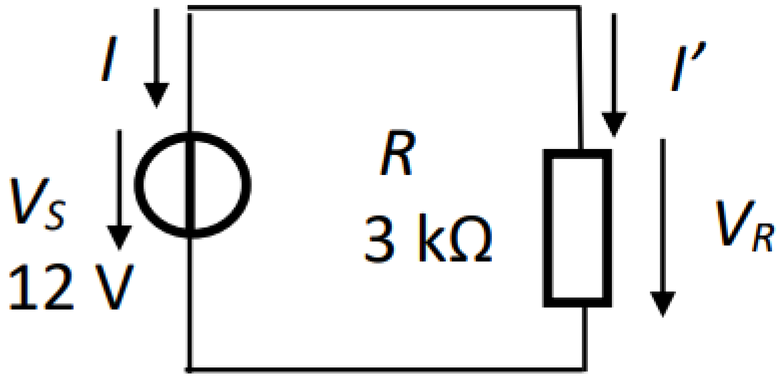


M - the reference point (ground)

$$V_N = \frac{V_1 \cdot G_1 + V_2 \cdot G_2 + 0 \cdot G_3}{G_1 + G_2 + G_3} = \frac{V_1 \cdot \frac{1}{R_1} + V_2 \cdot \frac{1}{R_2} + 0 \cdot \frac{1}{R_3}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = \frac{\frac{10}{20} + \frac{15}{10}}{\frac{1}{20} + \frac{1}{10} + \frac{1}{5}} = 5.71\text{ V}$$

Fundamentals

- Power. Power transfer.



$$I = -\frac{V_S}{R} = -3\ \text{mA}$$

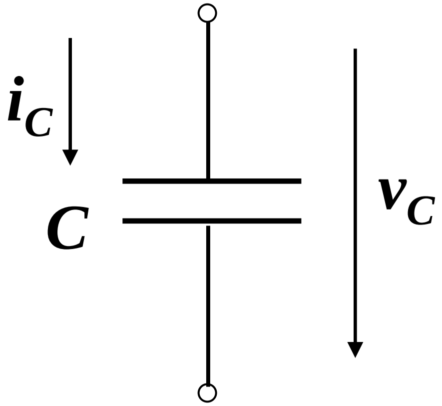
$$I' = -I = 3\ \text{mA}$$

$P_S = V_S I$ = 12V·(-3mA) = -36mW; the power is **generated** by the source.

$P_R = V_R I'$ = 12V·3mA = 36mW; the power is **dissipated** by the resistor.

Fundamentals

- RC circuits



Relation between current and voltage:

$$C dv_C(t) = i_C(t) dt$$

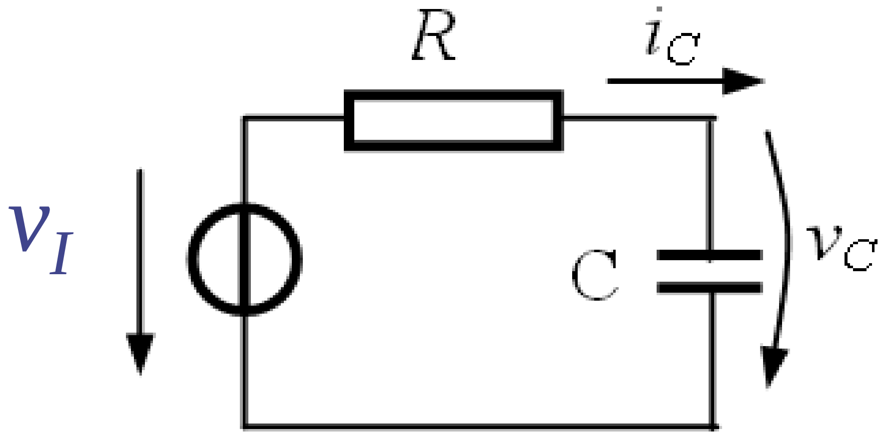
Assuming finite variations:

$$C \Delta v_C = i_C \Delta t$$

Fundamentals

- RC circuits – time domain analysis

RC circuit with a dc voltage source



$$Ri_C(t)+v_C(t)=v_I(t)$$

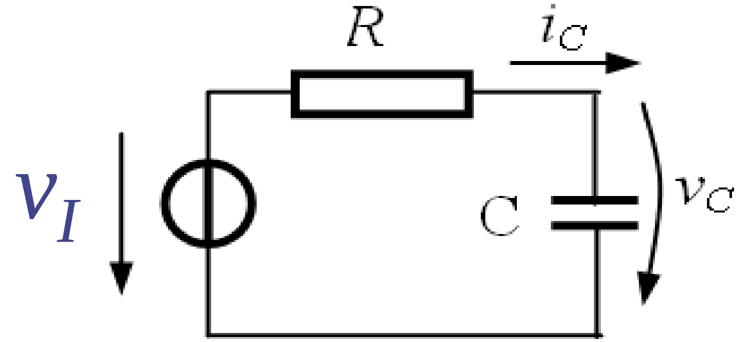
$$Cdv_C(t)=i_C(t)dt$$

$$i_C(t)=C\frac{dv_C(t)}{dt}$$

$$RC\frac{dv_C(t)}{dt}+v_C(t)=v_I(t)$$

$\tau = RC$ time constant of the circuit

$$v_C(t)=v_C(0)e^{\frac{-t}{\tau}}+(1-e^{\frac{-t}{\tau}})v_C(\infty)$$

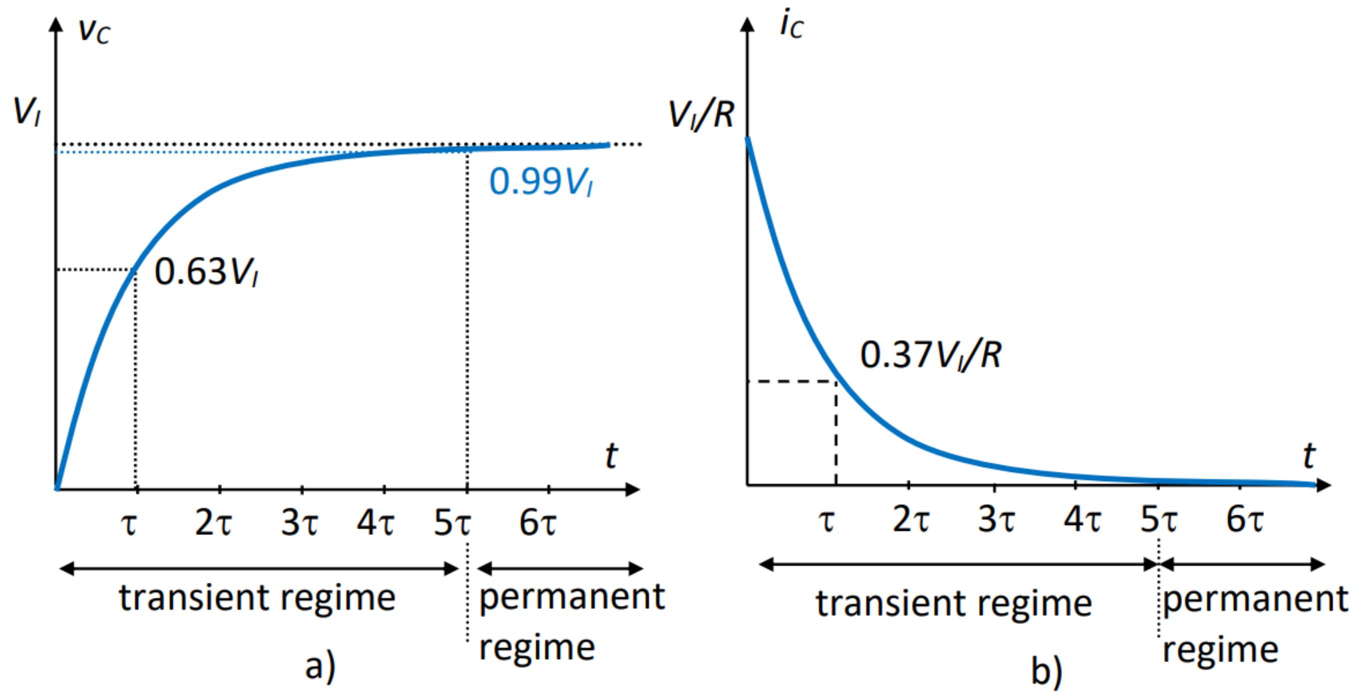


Fundamentals

- RC circuits – time domain analysis

RC circuit with a dc voltage source

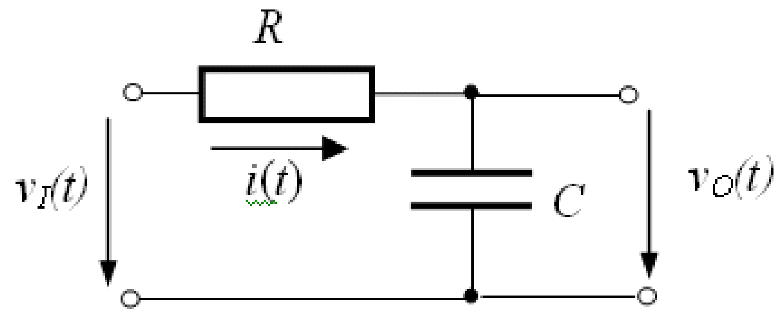
$$v_C(t) = v_C(0)e^{\frac{-t}{\tau}} + (1 - e^{\frac{-t}{\tau}})v_C(\infty)$$



Fundamentals

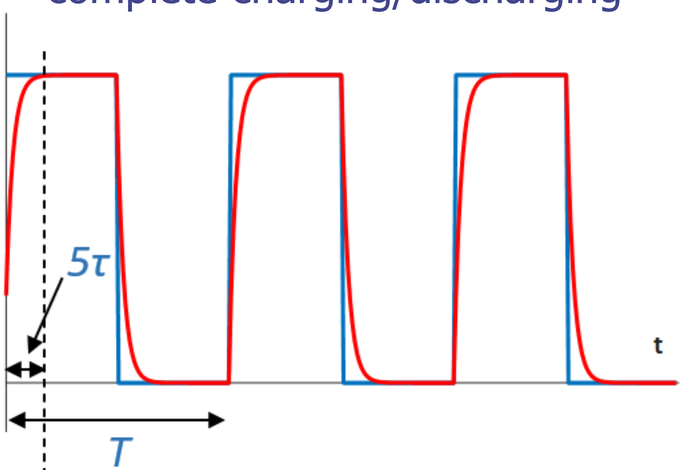
- RC circuits – time domain analysis

  RC circuit with an ac voltage source



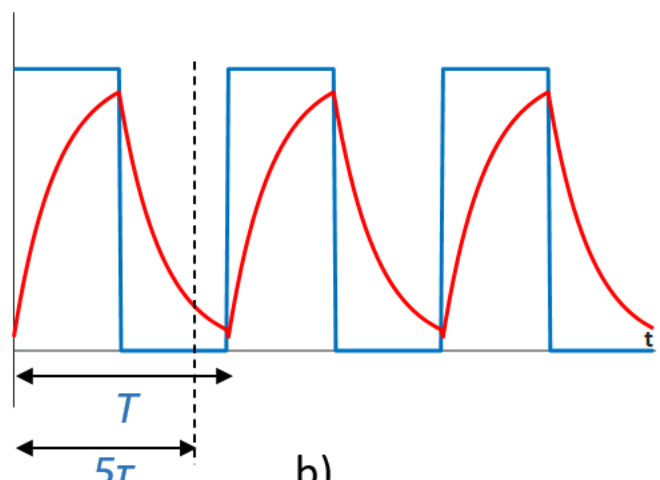
$$v_C(t) = v_C(0)e^{\frac{-t}{\tau}} + (1 - e^{\frac{-t}{\tau}})v_C(\infty)$$

complete charging/discharging



a)

partial charging/discharging



b)

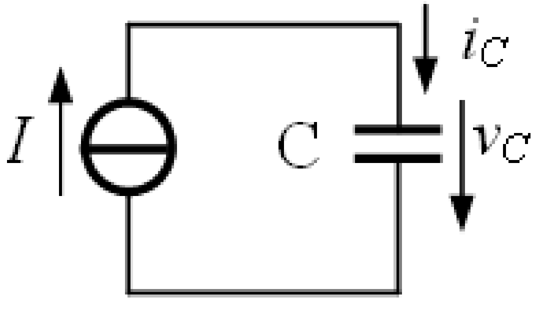
Fundamentals

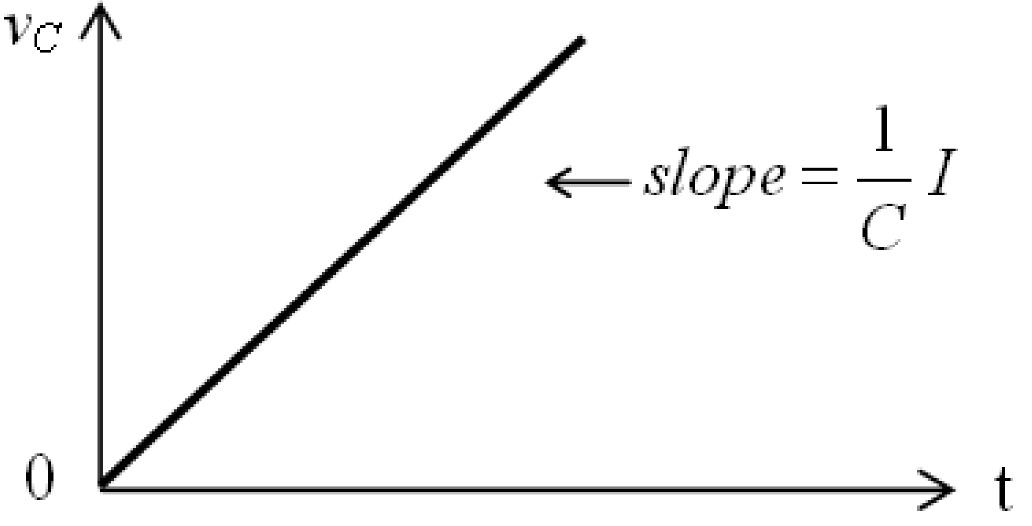
- Capacitor charging under a constant current

$$C dv_c(t) = i_c(t) dt$$

$$v_C(t) = \frac{1}{C}\int_0^t i_C(t) dt + v_C(0)$$

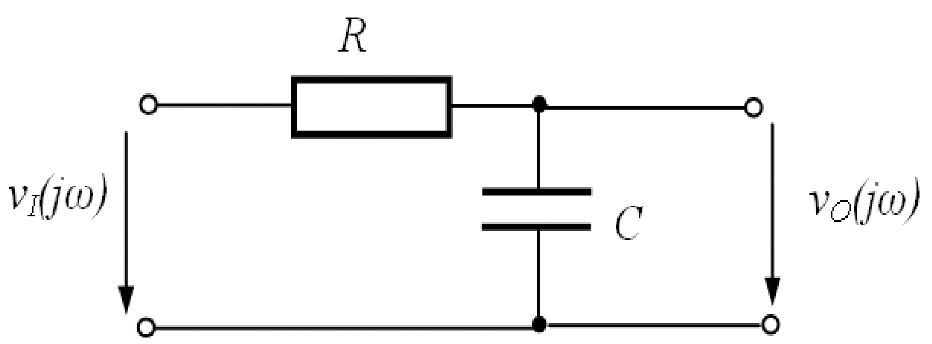
$$v_C(t) = \frac{1}{C} It + v_C(0)$$





Fundamentals

- RC circuit – frequency response



$$Z_C = \frac{1}{j\omega C}$$

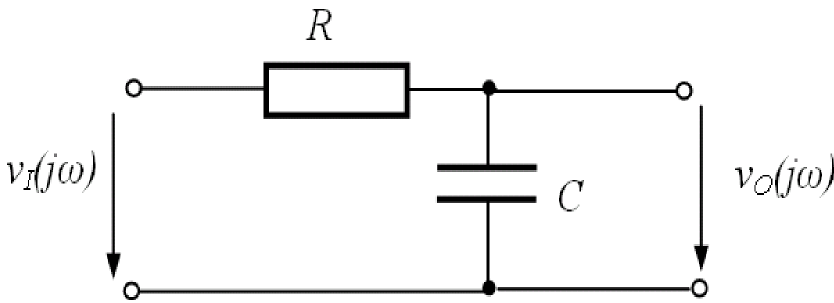
Low frequency:

$f \to 0;\ \ Z_C \to \infty;\ \ \text{output} \to \text{open circuit};\ v_O(j\omega) \to v_I(j\omega)$ **pass**

High frequency:

$f \to \infty;\ \ Z_C \to 0;\ \ \text{output} \to \text{short-circuit};\ v_O(j\omega) \to 0$ **don't pass (reject)**

First order, passive, low-pass filter (LPF)



passive low-pass filter (LPF)

Fundamentals

➢ RC circuit – frequency response

Transfer function

$$F(j\omega)=\frac{v_O(j\omega)}{v_I(j\omega)}=\frac{1}{1+j\omega RC}$$

$$\left|F(j\omega)\right|=\frac{1}{\sqrt{1+(\omega RC)^2}}$$

$$\Phi(\omega)=-arctg(\omega RC)$$

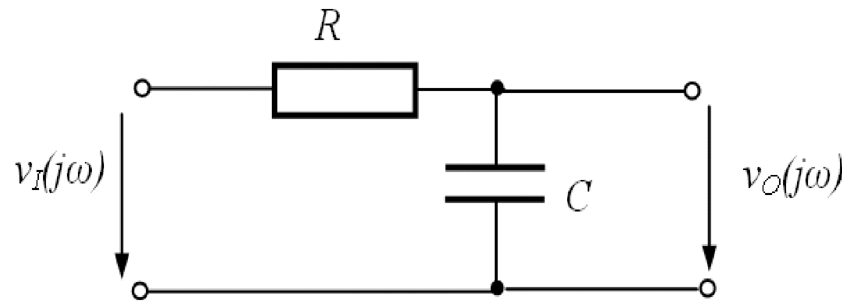
$$f\ -\text{very low;}\ |F(j\omega)|\approx 1$$

$$f\ -\text{high;}\ |F(j\omega)|\approx \frac{1}{\omega RC}$$

$$1=\frac{1}{\omega_0 RC}\ \Rightarrow \omega_0=\frac{1}{RC}\ \Rightarrow$$

$$f_0=\frac{1}{2\pi RC}$$

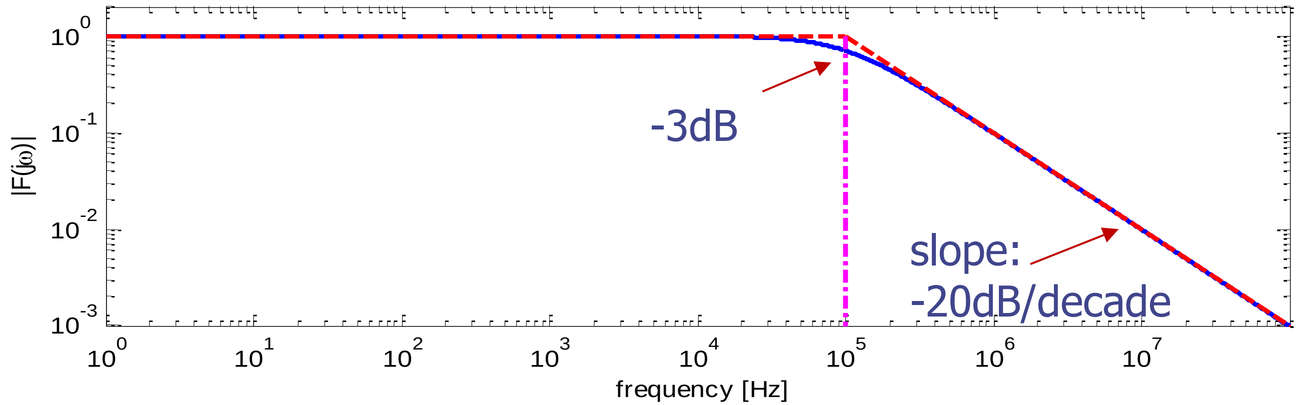
Cut-off frequency



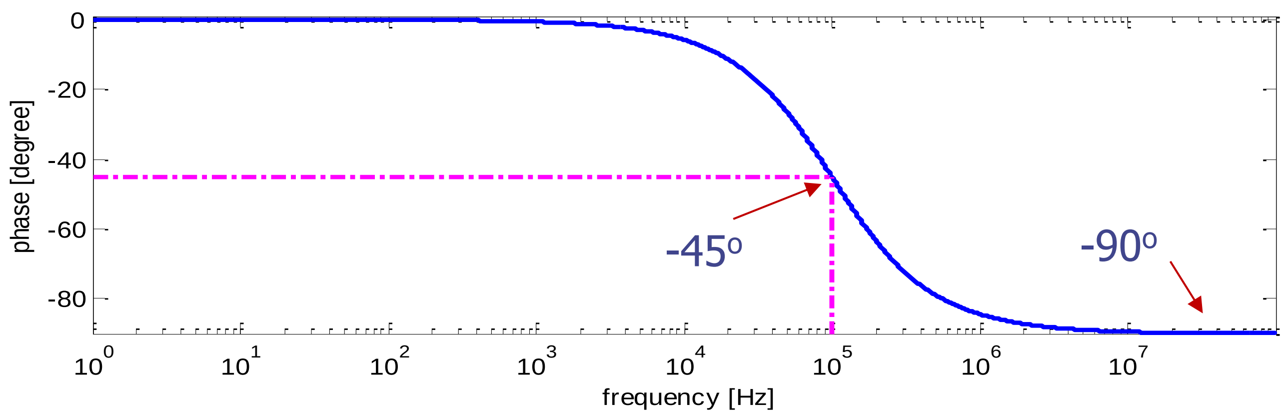
passive low-pass filter (LPF)

Fundamentals

➢ RC circuit – frequency response



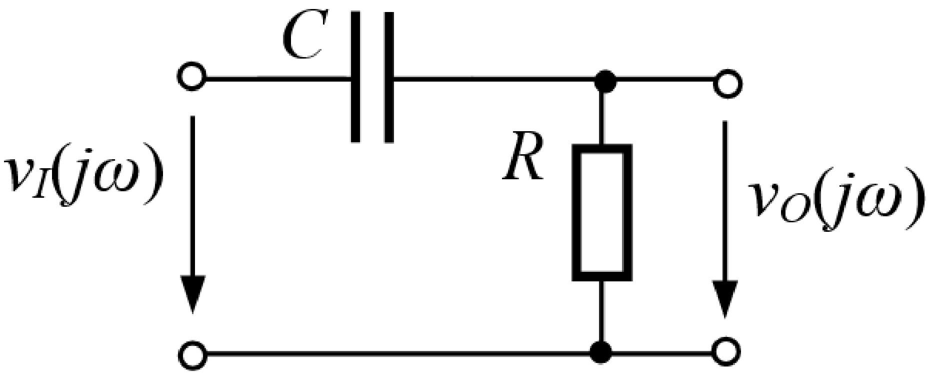
magnitude response (log-log plot)



phase response (lin-log plot)

Fundamentals

- RC circuit – frequency response



$$Z_C = \frac{1}{j\omega C}$$

Low frequency:

$$f \to 0; \quad Z_C \to \infty; \quad \text{input} - \text{output} \to \text{open circuit}; \; v_O(j\omega) \to 0$$

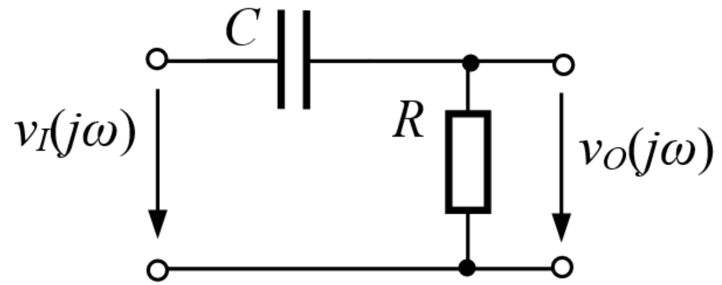
don't pass (reject)

High frequency:

$$f \to \infty; \quad Z_C \to 0; \quad \text{input} - \text{output} \to \text{short-circuit}; \; v_O(j\omega) \to v_I(j\omega)$$

pass

First order, passive, high-pass filter (HPF)



passive high-pass filter (HPF)

Fundamentals

➢ RC circuit – frequency response

Transfer function

$$F(j\omega)=\frac{v_O(j\omega)}{v_I(j\omega)}=\frac{j\omega RC}{1+j\omega RC}$$

$$\left|F(j\omega)\right|=\frac{\omega RC}{\sqrt{1+(\omega RC)^2}}$$

$$\Phi(\omega)=90^o-arctg(\omega RC)$$

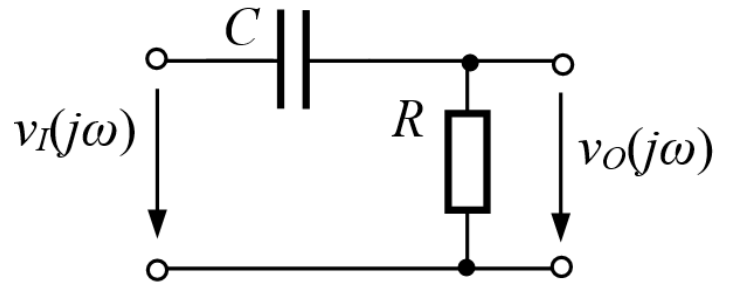
$$f\ -\text{very low};\ |F(j\omega)|\approx\omega RC$$

$$f\ -\text{high};\ |F(j\omega)|\approx 1$$

$$\omega_0 RC=1\ \Rightarrow\omega_0=\frac{1}{RC}\ \Rightarrow$$

$$f_0=\frac{1}{2\pi RC}$$

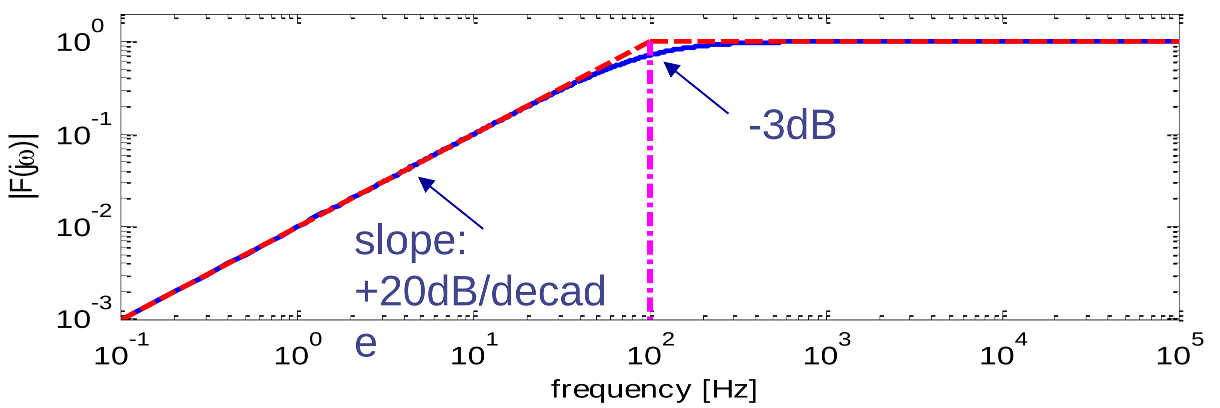
Cut-off frequency



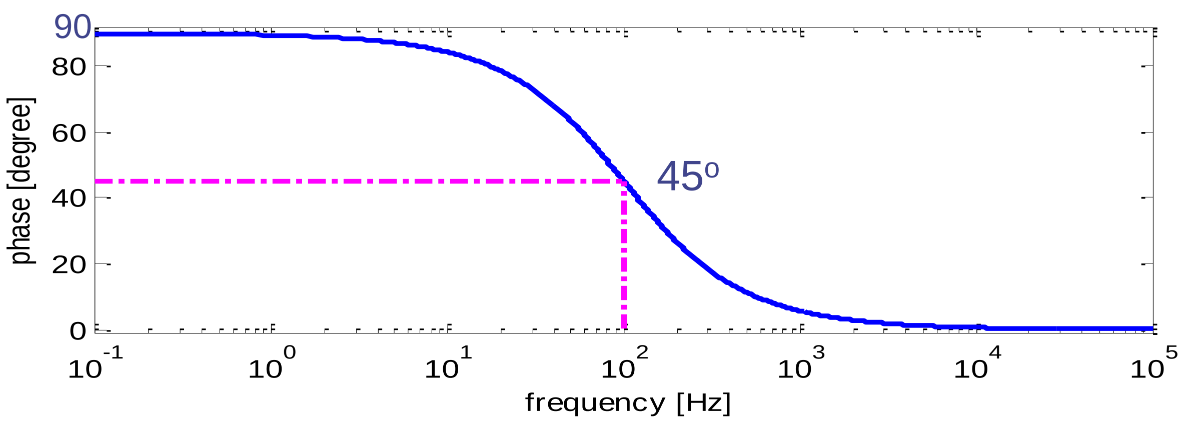
passive high-pass filter (HPF)

Fundamentals

➢ RC circuit – frequency response



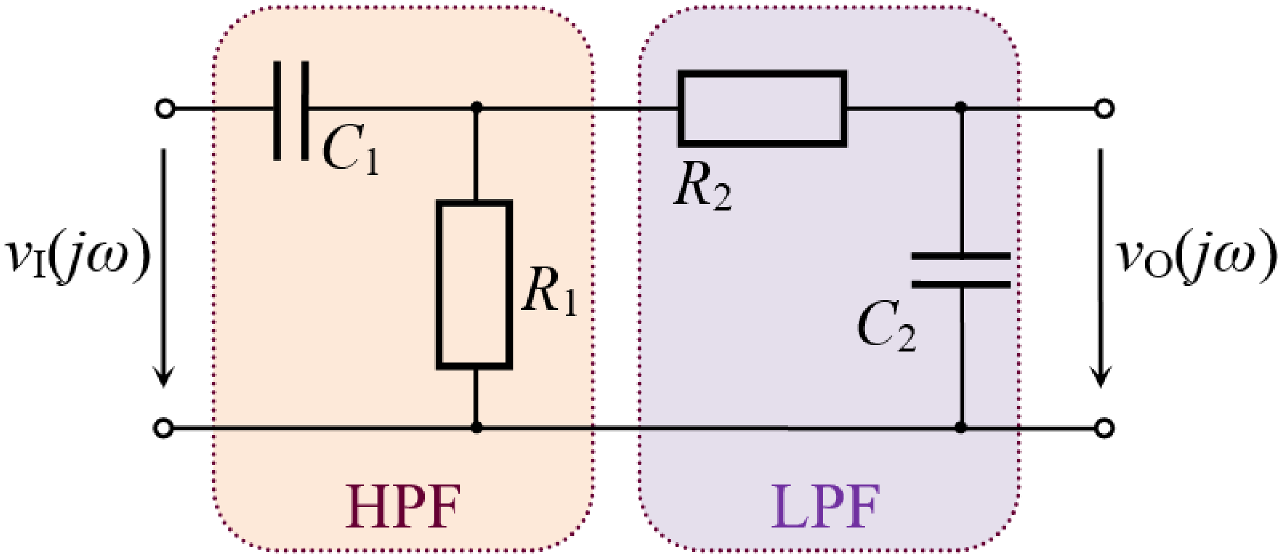
magnitude response (log-log plot)



phase response (lin-log plot)

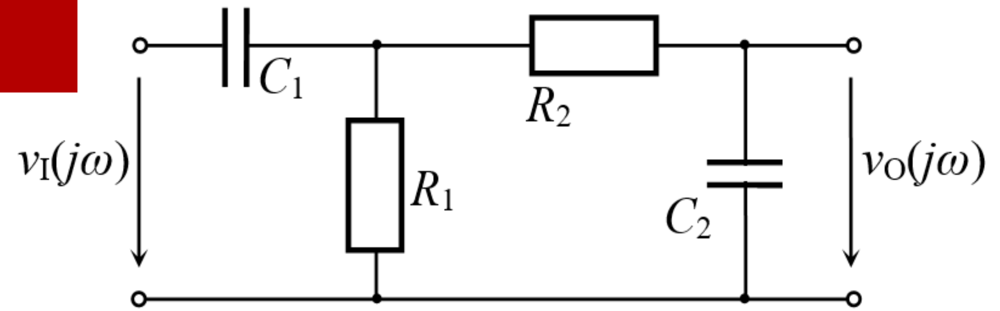
Fundamentals

- RC circuit – frequency response



$$Z_C = \frac{1}{j\omega C}$$

Second order, passive, band-pass filter (BPF)



Fundamentals

- RC circuit – frequency response

passive band-pass filter (BPF)

Transfer function

$$F(j\omega) = \frac{v_O(j\omega)}{v_I(j\omega)} = \frac{j\omega R_1 C_1}{(1 + j\omega R_1 C_1)(1 + j\omega R_2 C_2)}$$

$$|F(j\omega)| = \frac{\omega R_1 C_1}{\sqrt{1 + (\omega R_1 C_1)^2}\sqrt{1 + (\omega R_2 C_2)^2}}$$

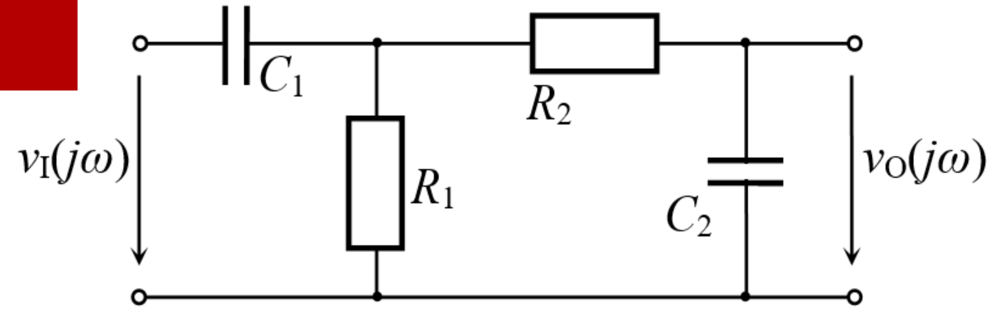
$$\Phi(\omega) = 90^o - arctg(\omega R_1 C_1) - arctg(\omega R_2 C_2)$$

Cut-off frequencies

$$f_L = \frac{1}{2\pi R_1 C_1} \qquad f_H = \frac{1}{2\pi R_2 C_2}$$

Bandwidth

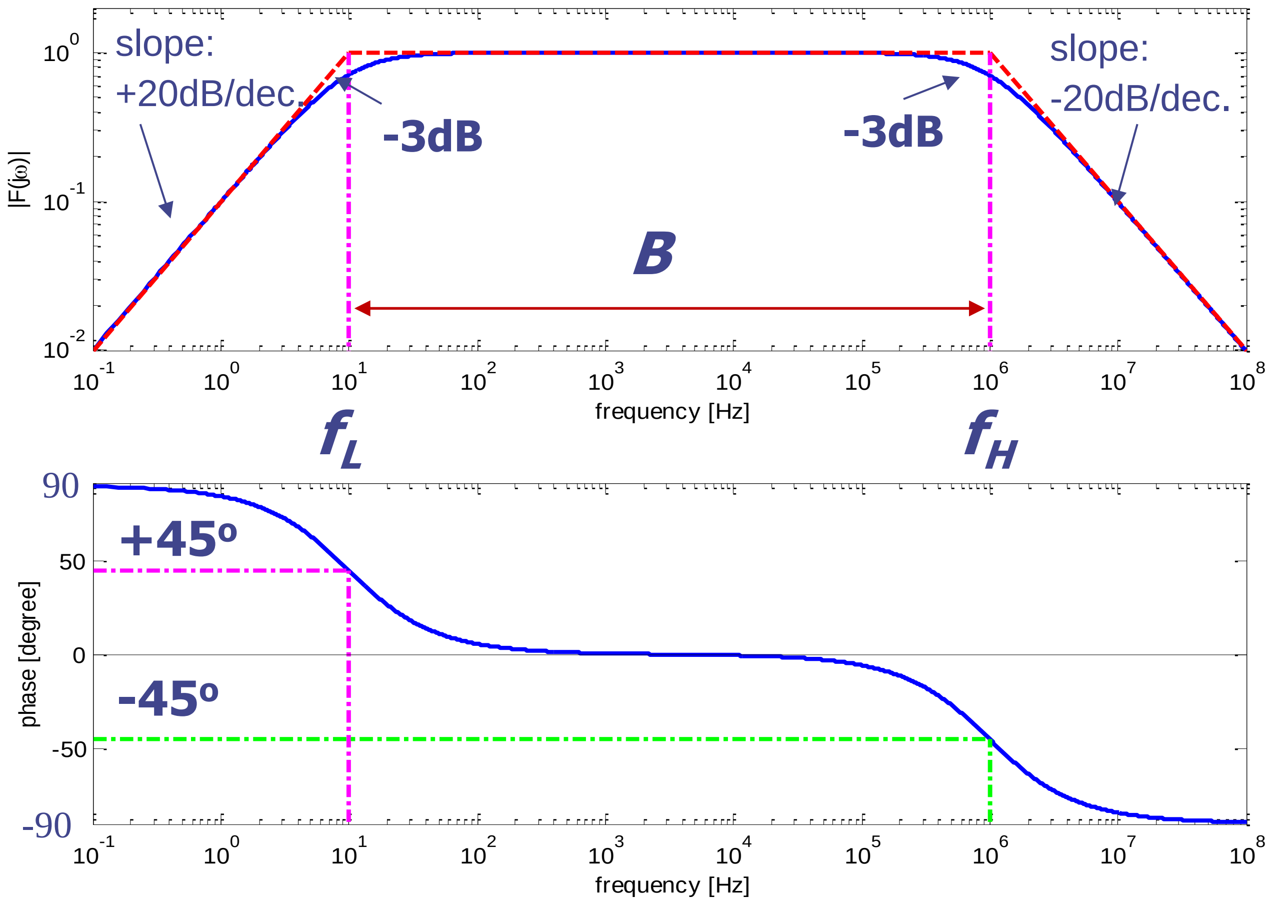
$$B = f_H - f_L$$



Fundamentals

- RC circuit – frequency response

passive band-pass filter (BPF)



magnitude response (log-log plot)

phase response (lin-log plot)

Summary

The trip down memory lane revived knowledge about:

- Electrical signals, sources
- Ohm's law
- Kirchhoff's law
- Resistive divider
- Superposition method
- Millman's theorem
- RC circuits – time and frequency domain behaviors, filters

Next week: Diodes. DR circuits.