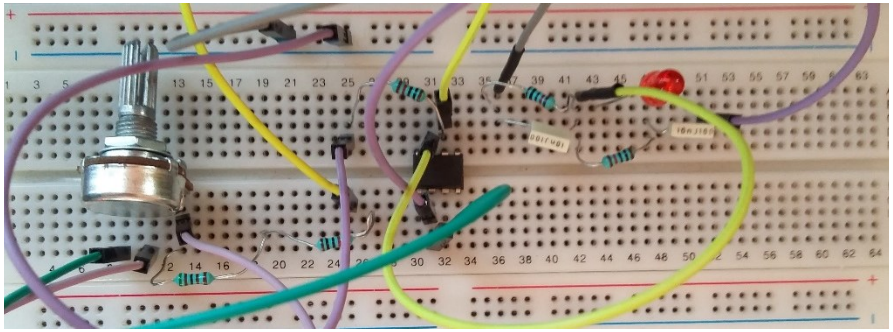
ELECTRONIC DEVICES

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

C1 – Introduction. Fundamentals.



Contents

- Course presentation
- Desired outcome. Evaluation.
- Fundamentals

Course presentation

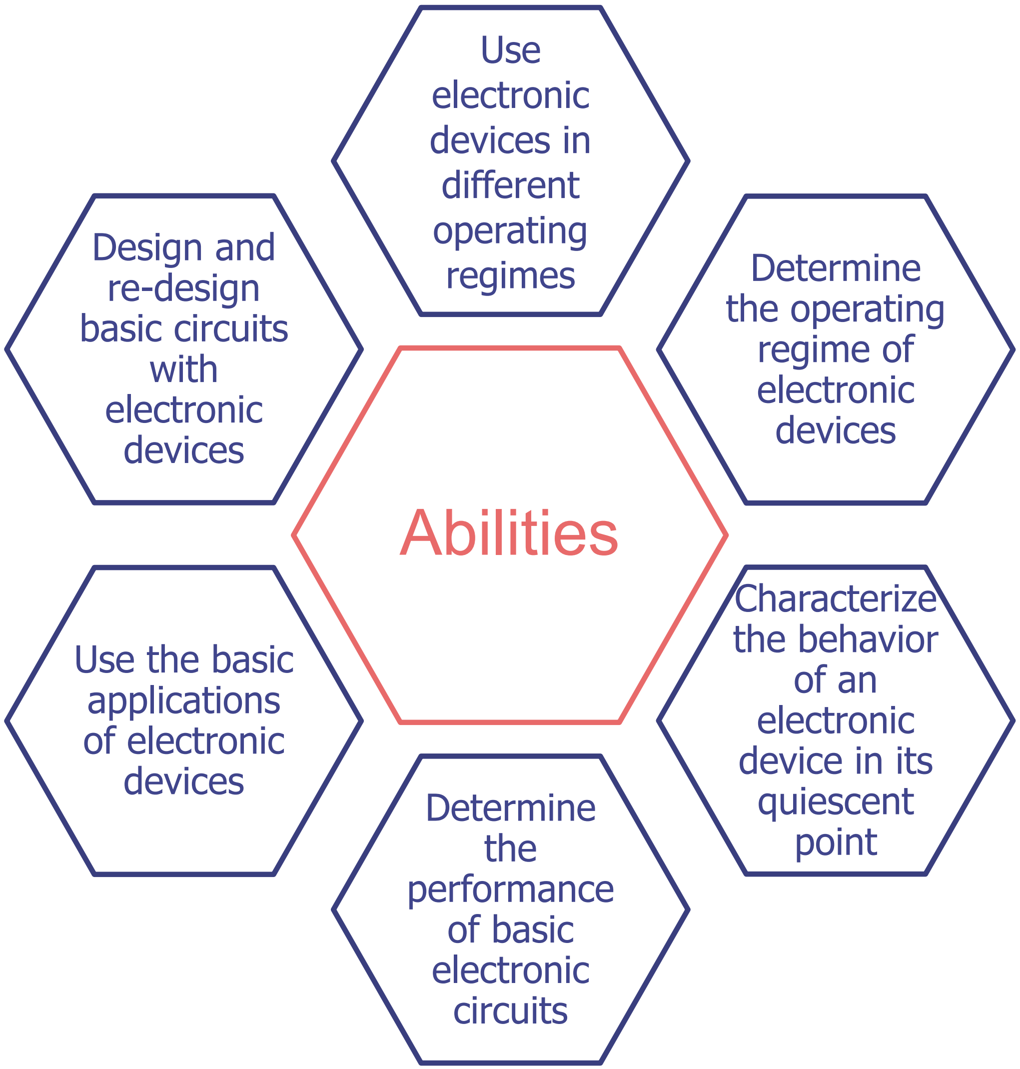
Fundamentals
- Electrical signals
- Relations and laws for electrical circuits
- RC circuits – time and frequency response

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

Course

2 h/week * 14 weeks = 28 h

Lab

2 h/week * 14 weeks = 28 h

ED

Course & lab preparation, homework

2 h/week * 14 weeks = 28 h

Individual study

41 h

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

Evaluation

Written exam (E)
0…10 points

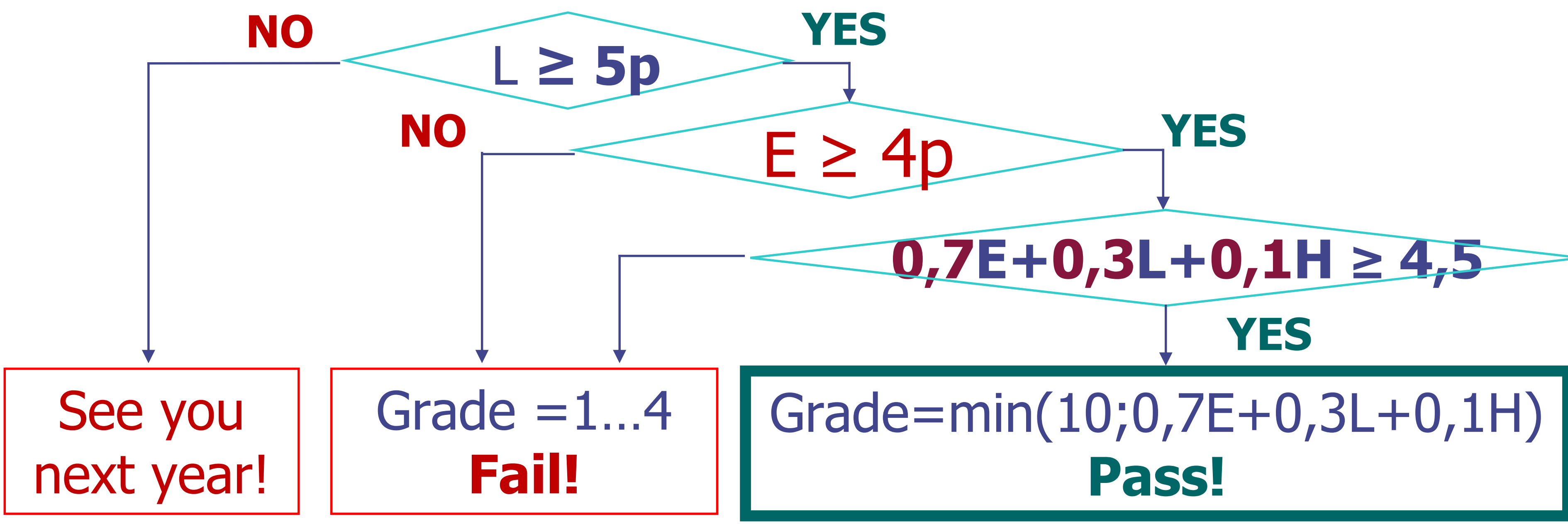
- problem solving

Laboratory (L)
0…10 points

- full attendance
- activity
- practical test

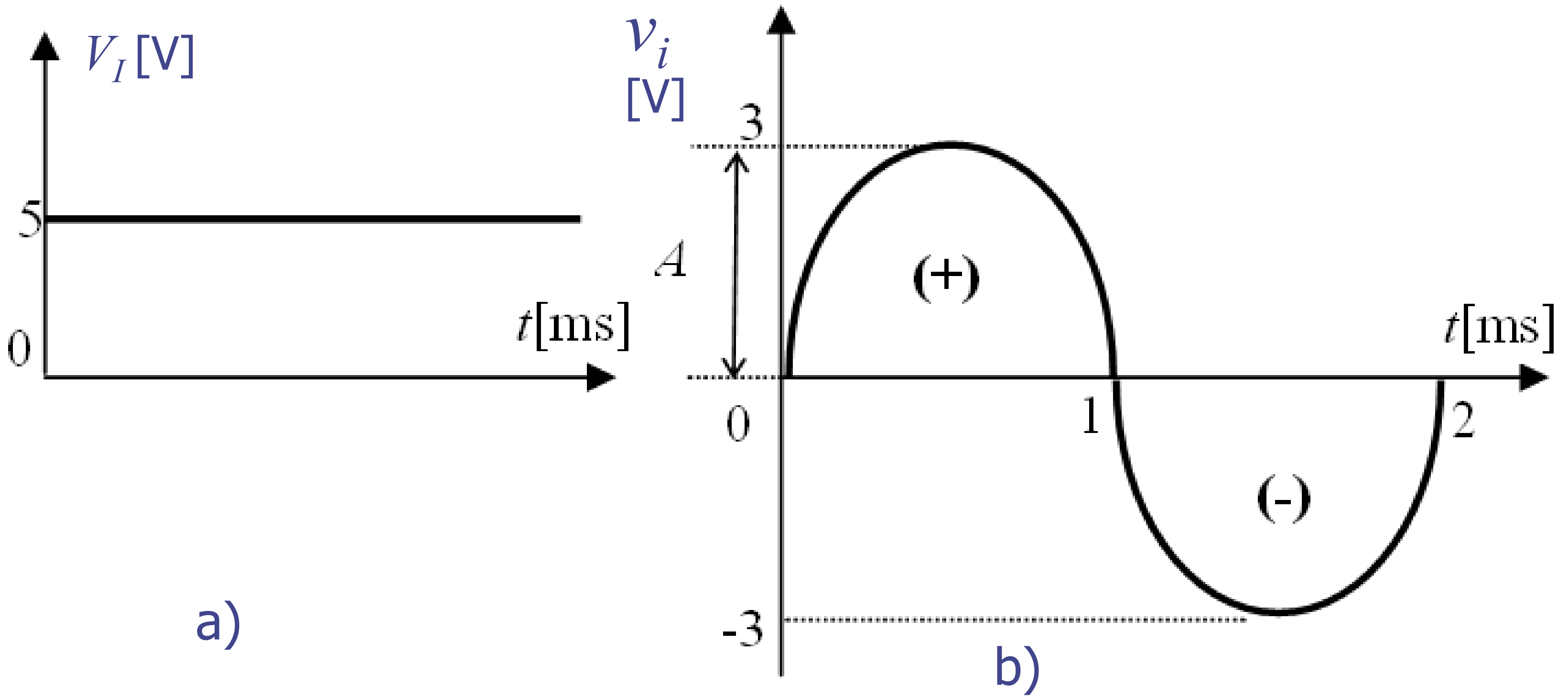
Course homeworks (H)
0…10 points

- 10 homeworks - optional



Fundamentals

- Electrical signals

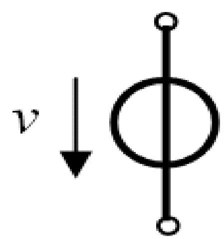


Time variation of a:

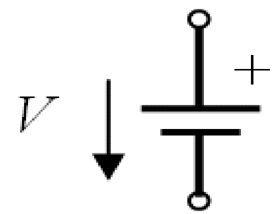
a) continuous voltage (dc); b) sinusoidal voltage (ac)

Fundamentals

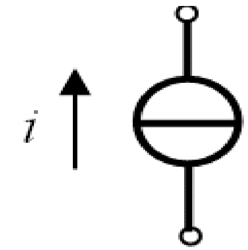
- Sources. Notations.



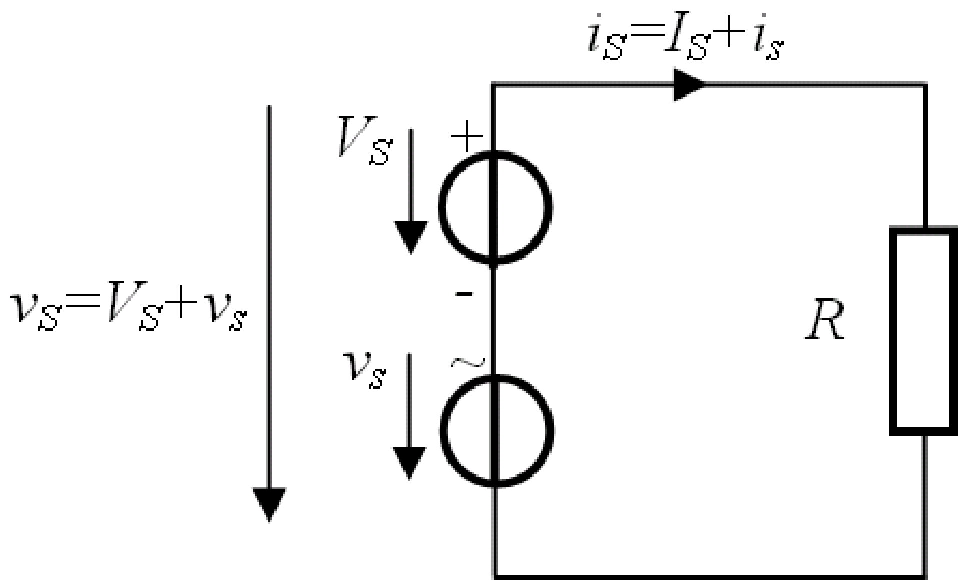
ac voltage



dc voltage

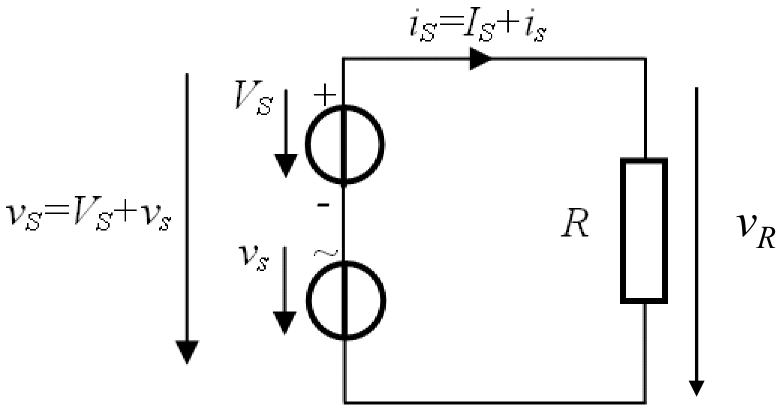


current



Fundamentals

- Ohm's law. Kirchhoff's laws.



Ohm's law

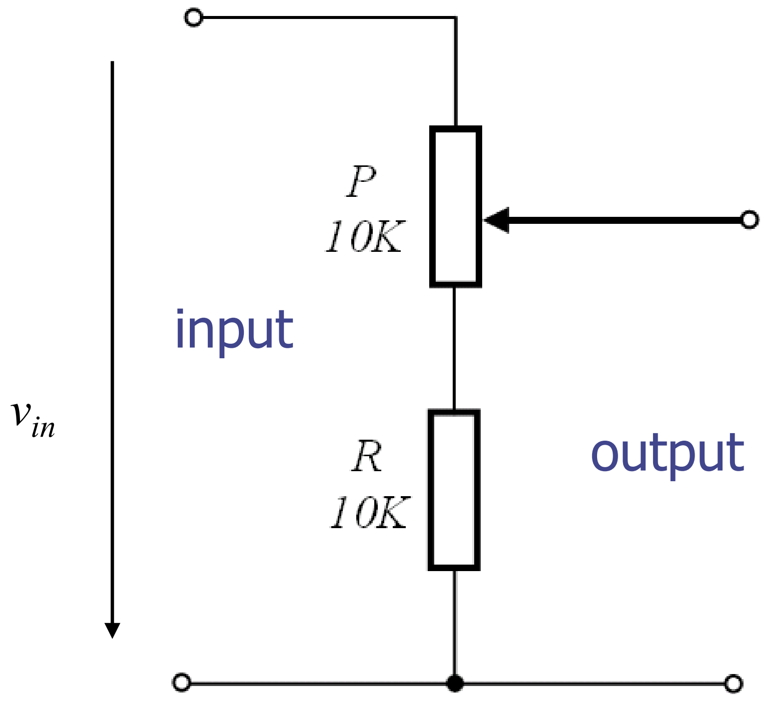
$$v_R = i_S R$$

Kirchhoff's voltage law (KVL)

$$v_S - v_R = 0$$

Fundamentals

➢ Resistive divider

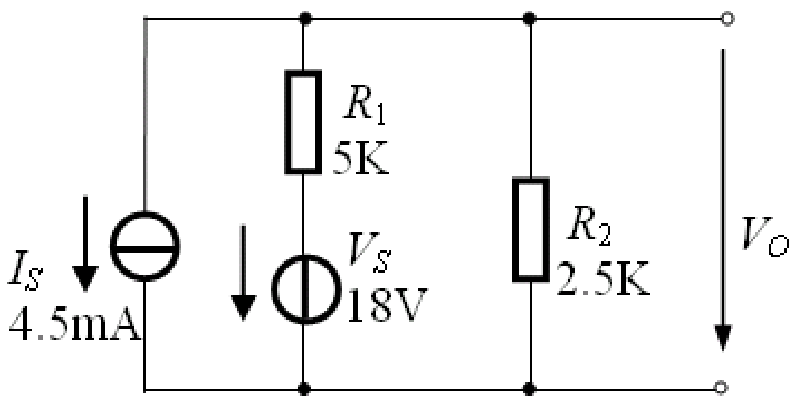


$$v_{out} = \frac{R + kP}{R + P} v_{in}$$

Adjustable voltage divider

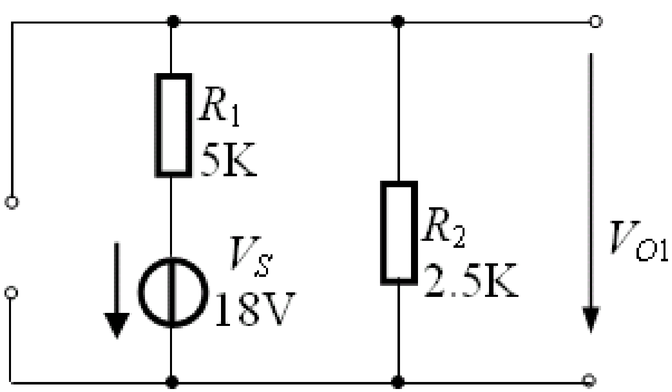
Fundamentals

- Superposition method

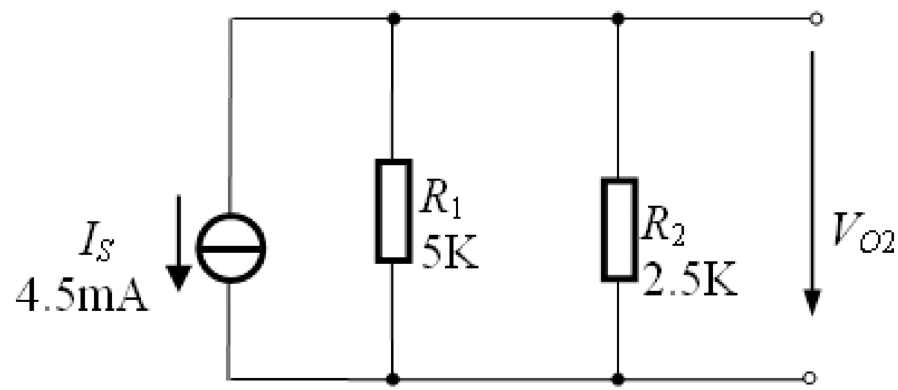


a)

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



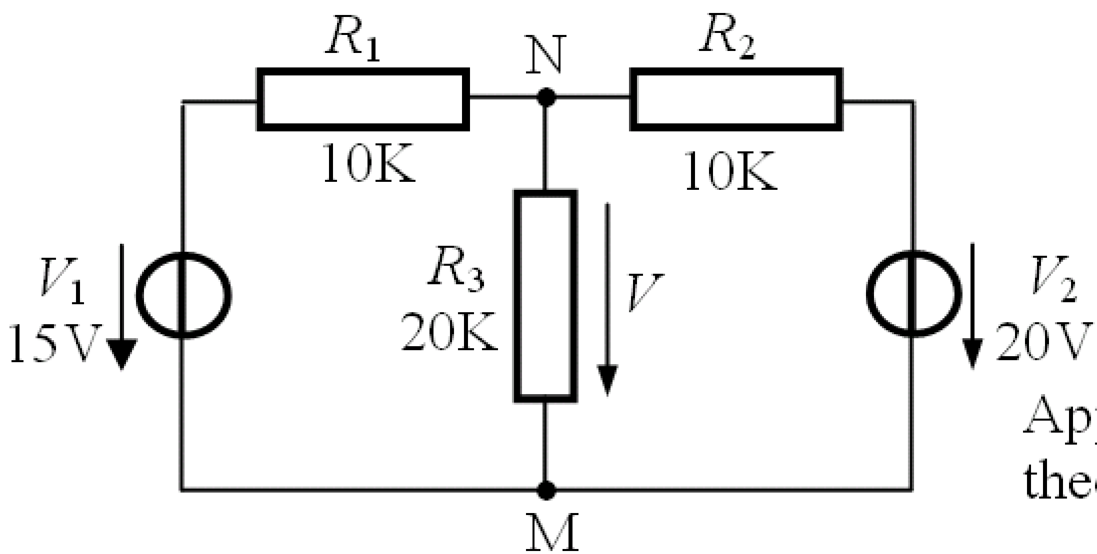
b)



c)

Fundamentals

- Millman's theorem (nodes potential theorem)



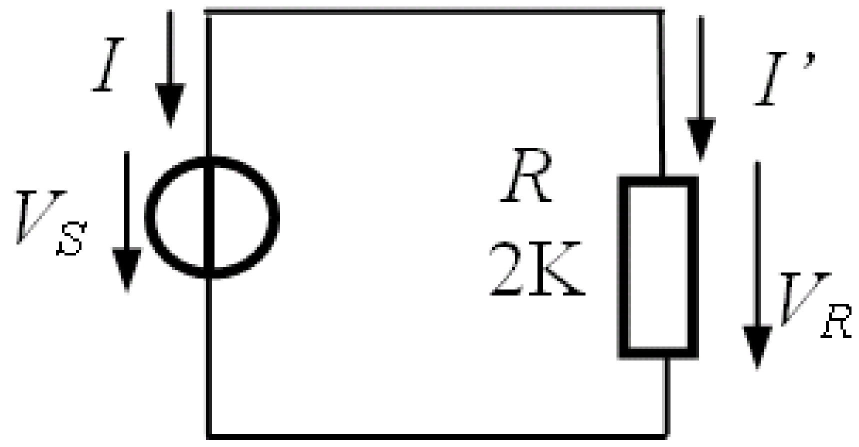
Application of Millman's theorem.

M - the reference point (ground)

$$V_N = \frac{\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2}}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}} = \frac{\dfrac{15}{10} + \dfrac{20}{20}}{\dfrac{1}{10} + \dfrac{1}{20} + \dfrac{1}{20}} = 12.5\ \text{V}$$

Fundamentals

- Power. Power transfer.



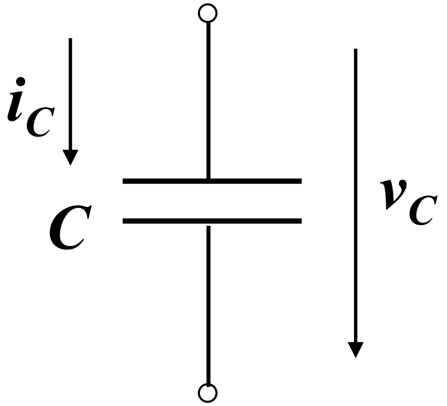
$$I = -\frac{Vs}{R} = -5\,\mathrm{mA}; \qquad I' = -I = 5\,\mathrm{mA}$$

$P_S = V_S I = 10V \cdot (-5mA) = -50mW$; the power is **generated** by the source.

$P_R = V_R I' = 10V \cdot 5mA = 50mW$; the power is **dissipated** by the resistor.

Fundamentals

- RC circuits



Relation between current and voltage:

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

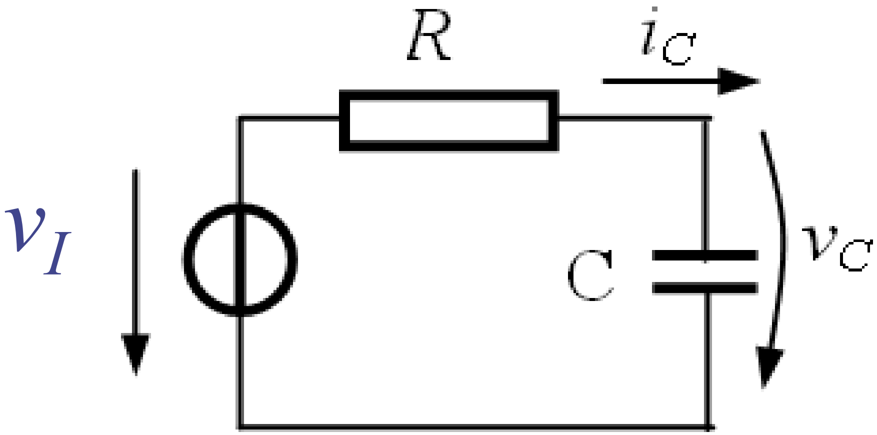
Assuming finite variations:

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

Fundamentals

- RC circuits – time domain analysis

  RC circuit with a dc voltage source



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

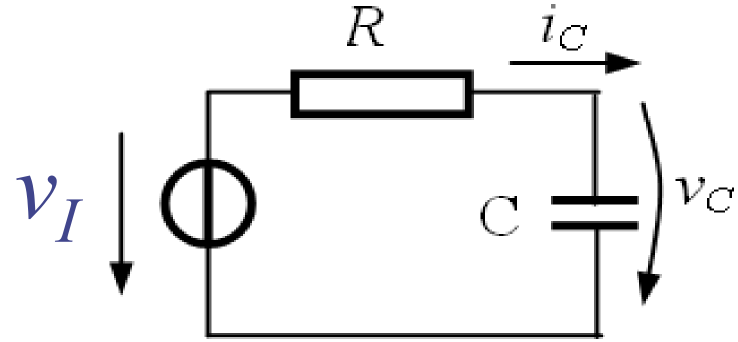
$$Cdv_C(t) = i_C(t)dt$$

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

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

$\tau = RC$ time constant of the circuit

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

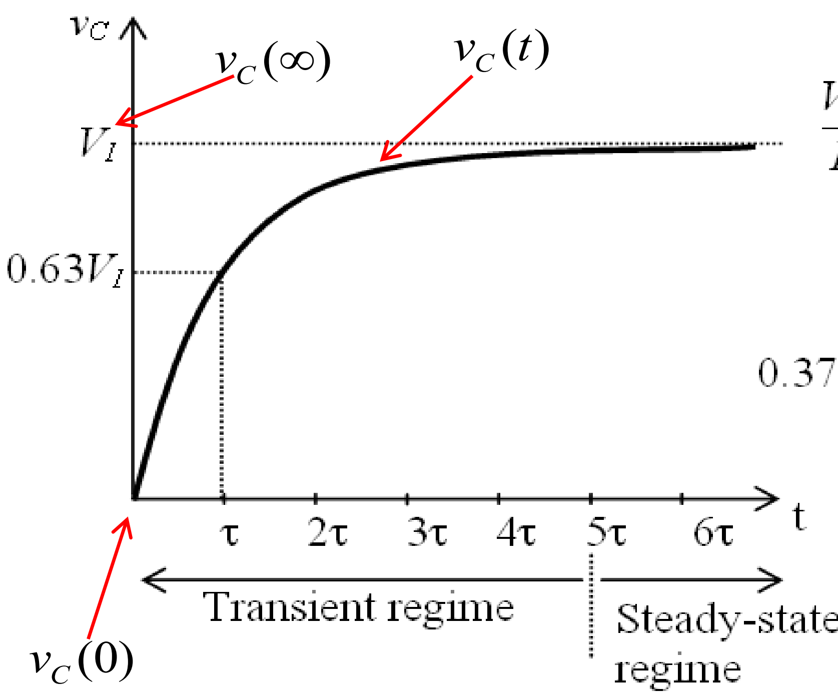


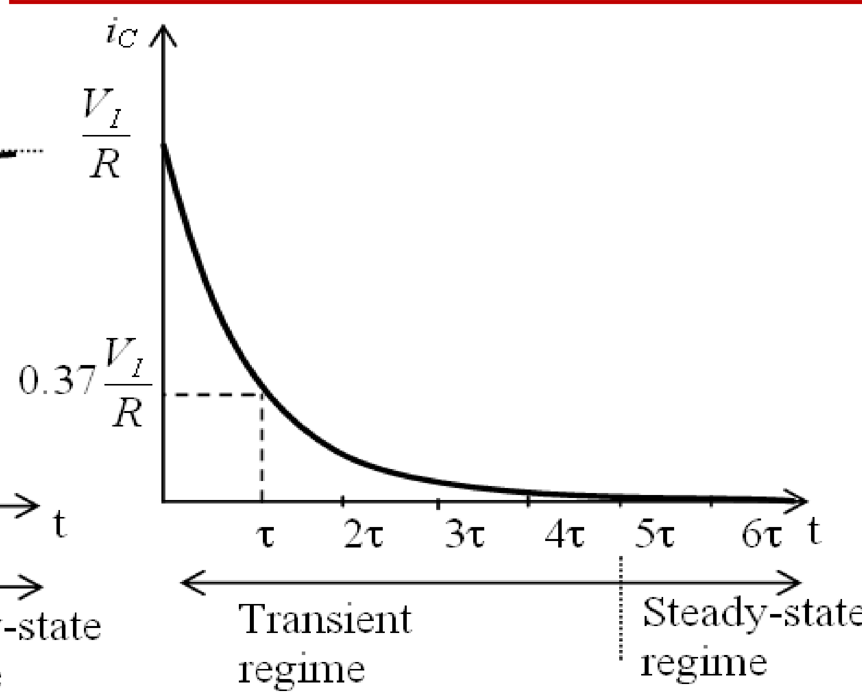
Fundamentals

- RC circuits – time domain analysis

  RC circuit with a dc voltage source

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

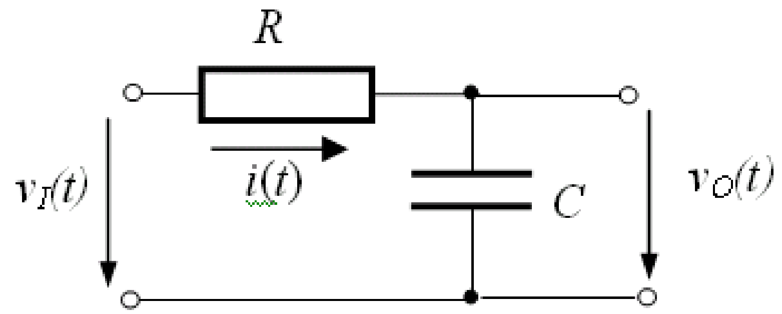




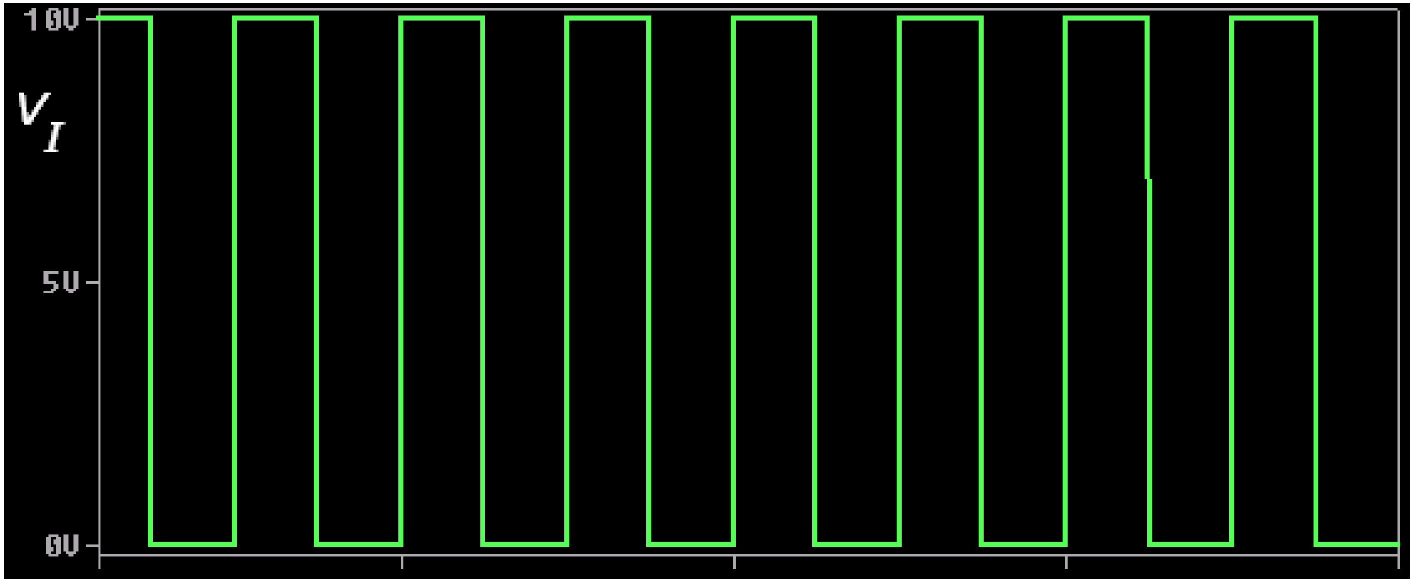
Fundamentals

- RC circuits – time domain analysis

  RC circuit with an ac voltage source



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

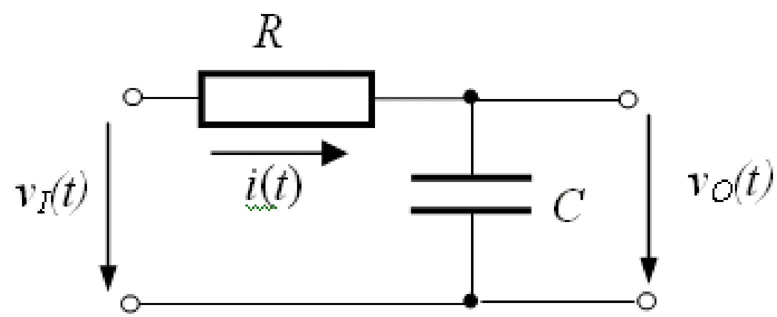


$$v_O(t) = ?$$

Fundamentals

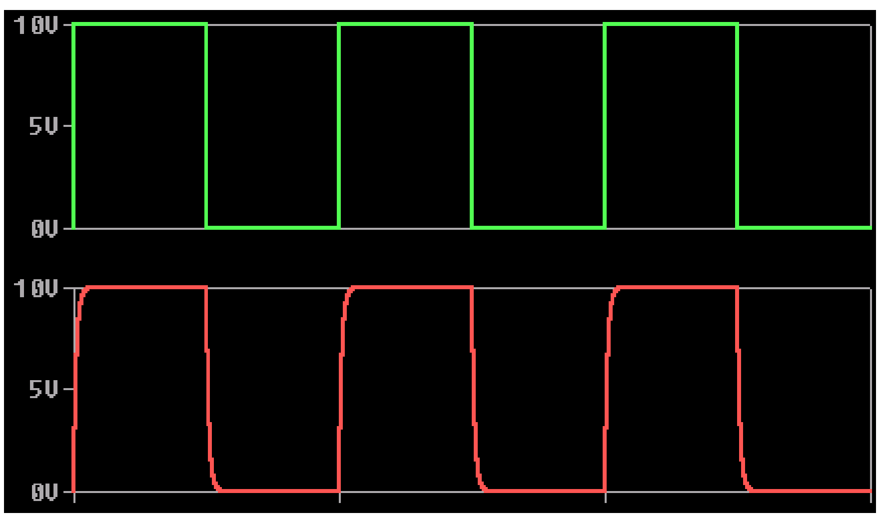
- RC circuits – time domain analysis

  RC circuit with an ac voltage source

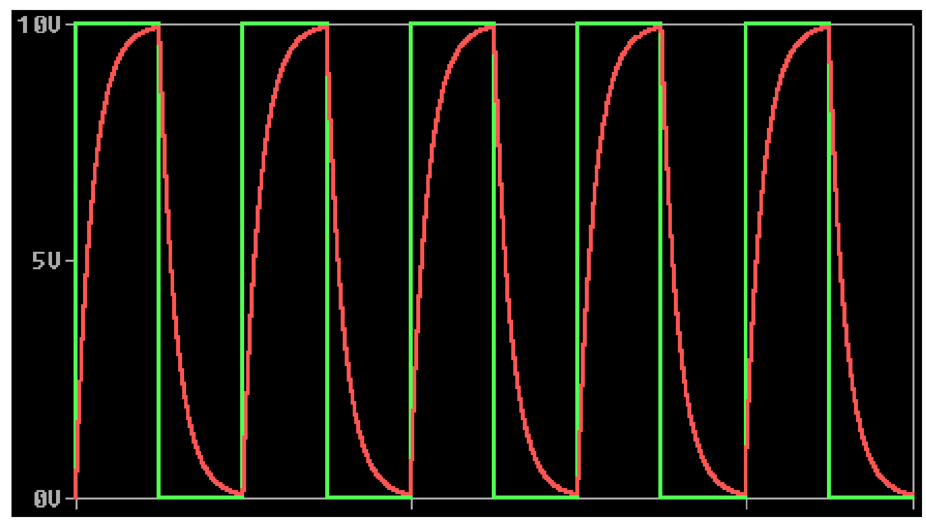


$$v_C(t) = v_C(0)e^{\frac{-t}{\tau}} + (1 - e^{\frac{-t}{\tau}})v_C(\infty)$$

$$5\tau << \frac{T}{2}; \quad \tau << \frac{T}{10}$$



$$\frac{T}{2} \approx 5\tau$$



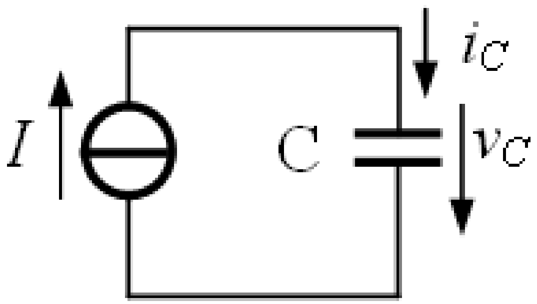
Fundamentals

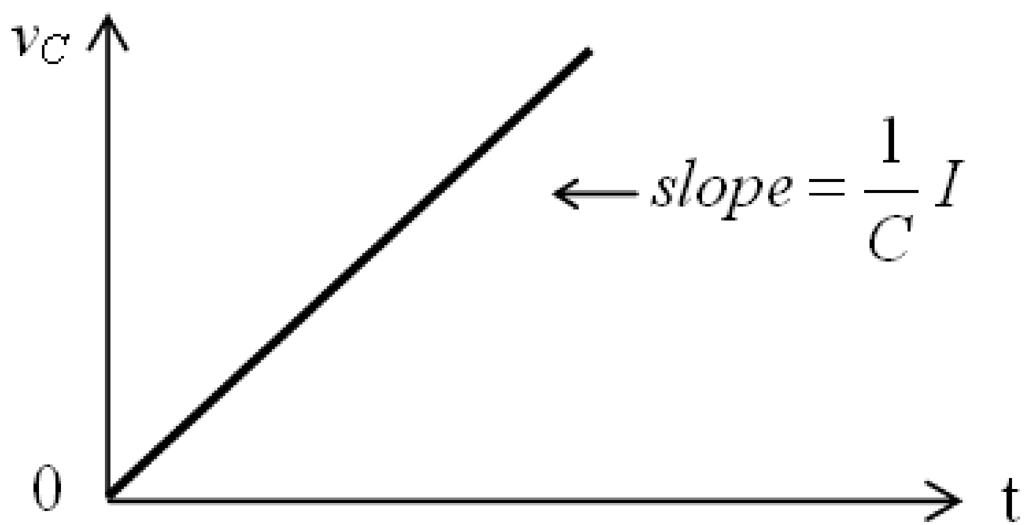
- Capacitor charging under a constant current

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

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

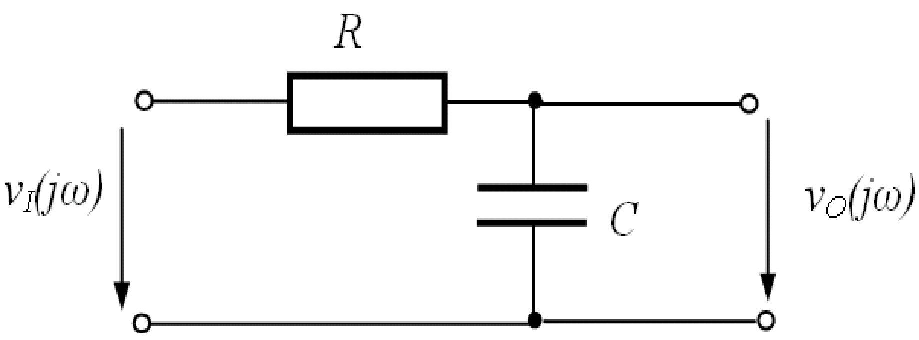
$$\boxed{v_C(t) = \frac{1}{C} It + v_C(0)}$$





Fundamentals

- RC circuit – frequency response



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

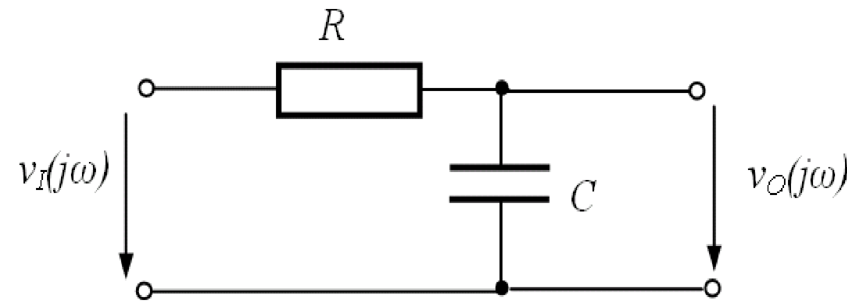
Low frequency:

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

High frequency:

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

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



passive low-pass filter (LPF)

Fundamentals

➢ RC circuit – frequency response

Transfer function

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

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

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

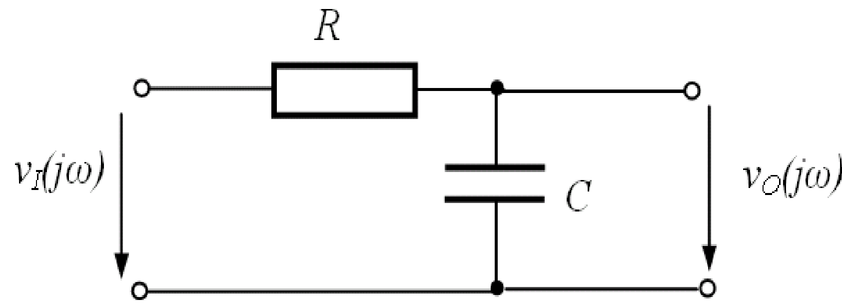
$$f\ -\text{very low};\ |F(j\omega)|\approx 1$$

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

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

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

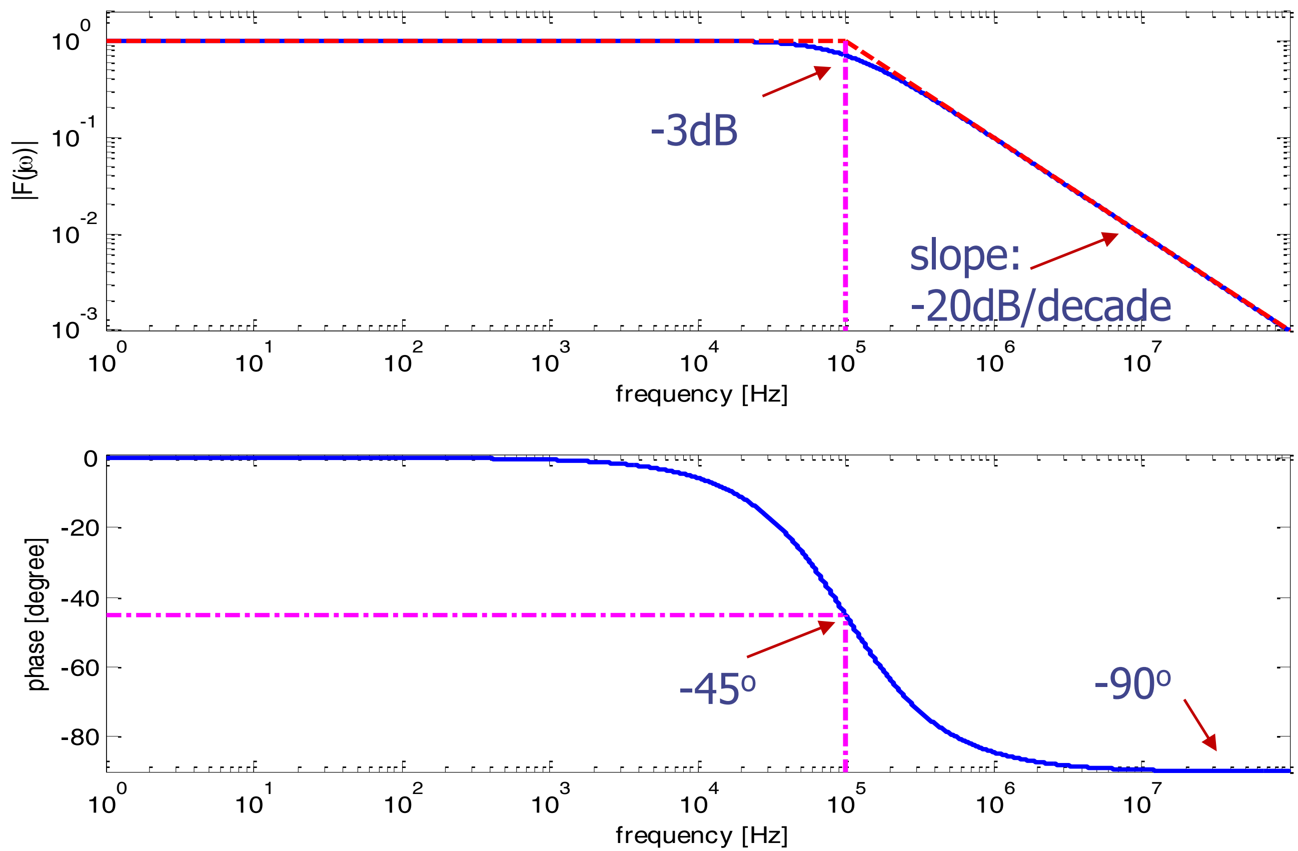
Cut-off frequency



passive low-pass filter (LPF)

Fundamentals

- RC circuit – frequency response

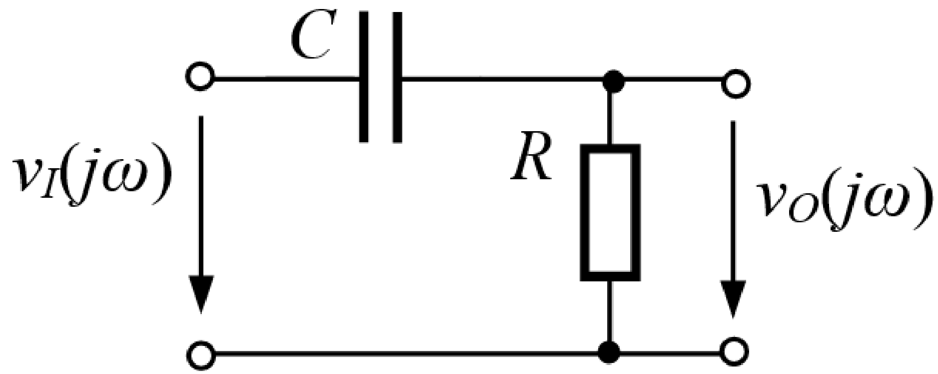


magnitude response (log-log plot)

phase response (lin-log plot)

Fundamentals

➢ RC circuit – frequency response



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

Low frequency:

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

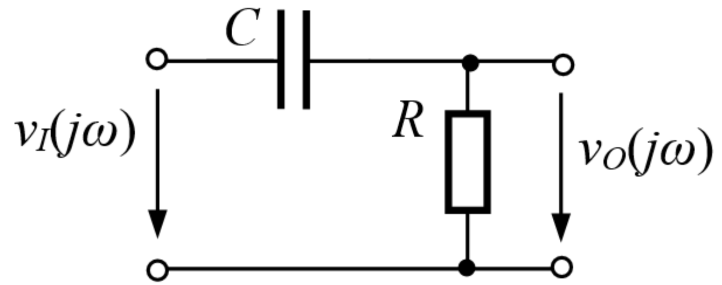
don't pass (reject)

High frequency:

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

pass

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



passive high-pass filter (HPF)

Fundamentals

- RC circuit – frequency response

Transfer function

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

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

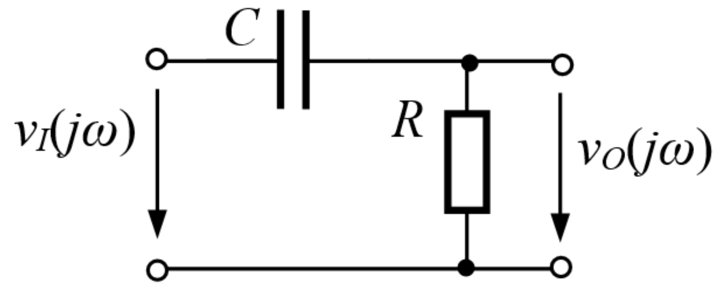
$$\Phi(\omega) = 90^o - arctg(\omega RC)$$

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

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

$$\omega_0 RC = 1 \quad \Rightarrow \omega_0 = \frac{1}{RC} \quad \Rightarrow \quad f_0 = \frac{1}{2\pi RC}$$

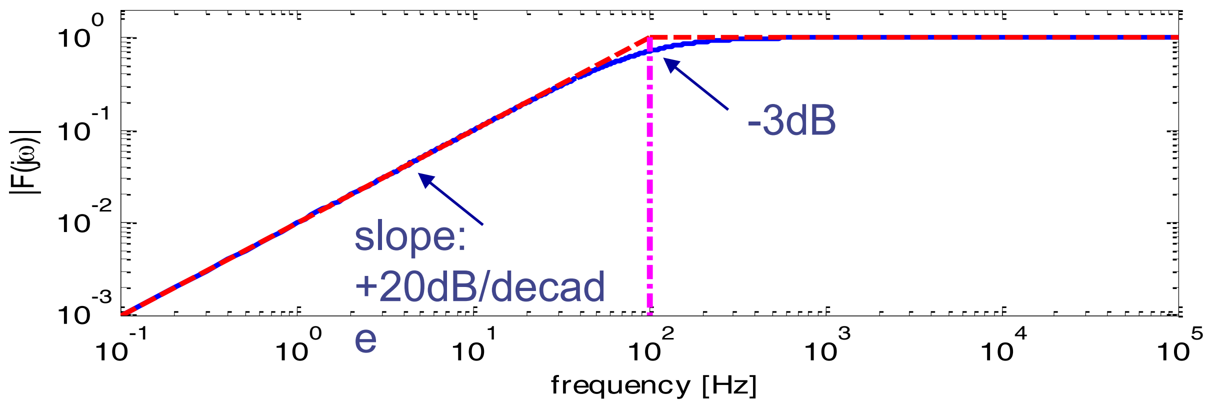
Cut-off frequency



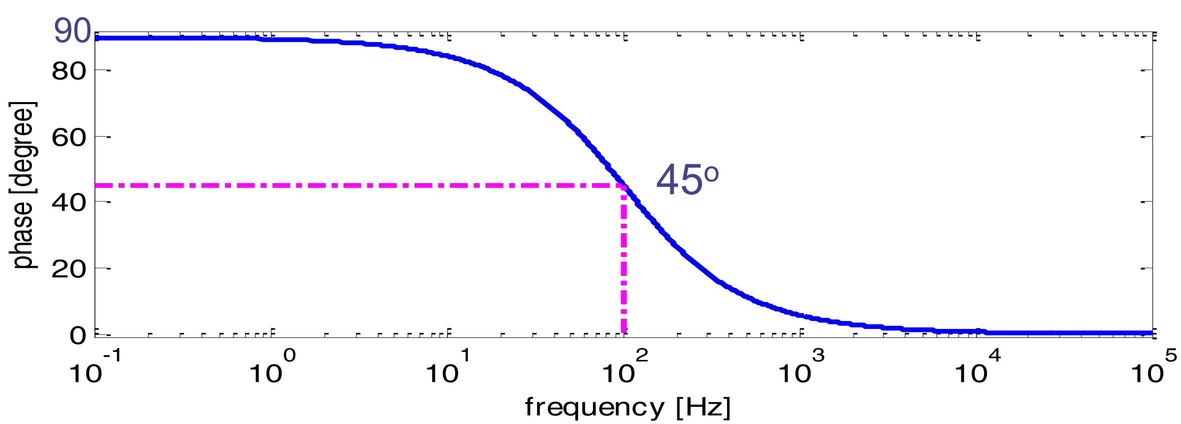
passive high-pass filter (HPF)

Fundamentals

➢ RC circuit – frequency response



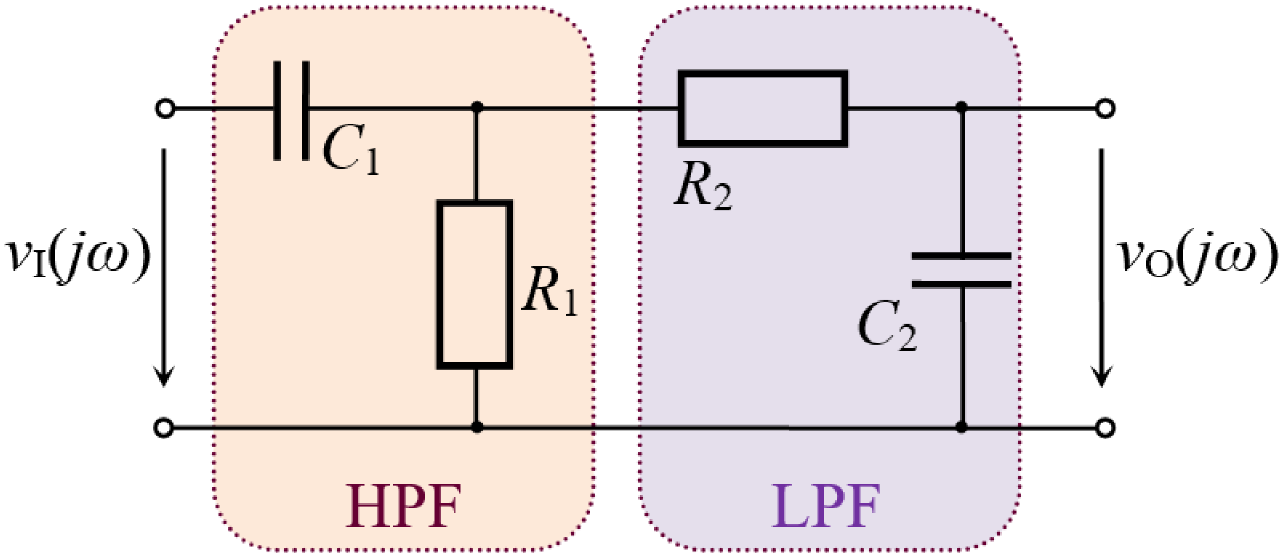
magnitude response (log-log plot)



phase response (lin-log plot)

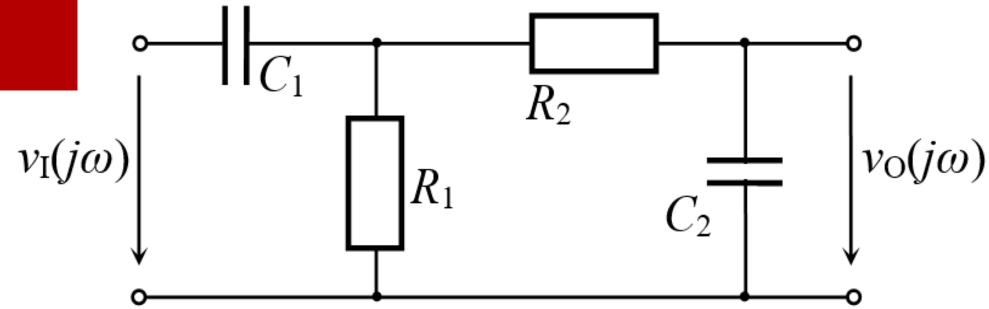
Fundamentals

- RC circuit – frequency response



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

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



Fundamentals

➢ RC circuit – frequency response

passive band-pass filter (BPF)

Transfer function

$$F(j\omega)=\frac{v_O(j\omega)}{v_I(j\omega)}=\frac{j\omega R_1C_1}{(1+j\omega R_1C_1)(1+j\omega R_2C_2)}$$

$$|F(j\omega)|=\frac{\omega R_1C_1}{\sqrt{1+(\omega R_1C_1)^2}\sqrt{1+(\omega R_2C_2)^2}}$$

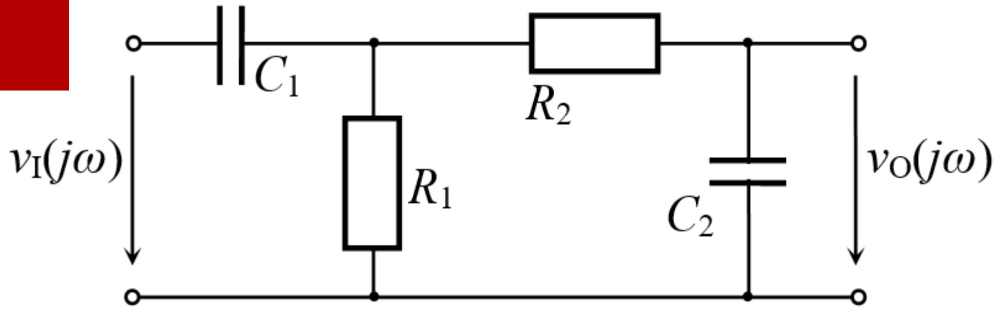
$$\Phi(\omega)=90^o-arctg(\omega R_1C_1)-arctg(\omega R_2C_2)$$

Cut-off frequencies

$$f_L=\frac{1}{2\pi R_1C_1} \qquad f_H=\frac{1}{2\pi R_2C_2}$$

Bandwidth

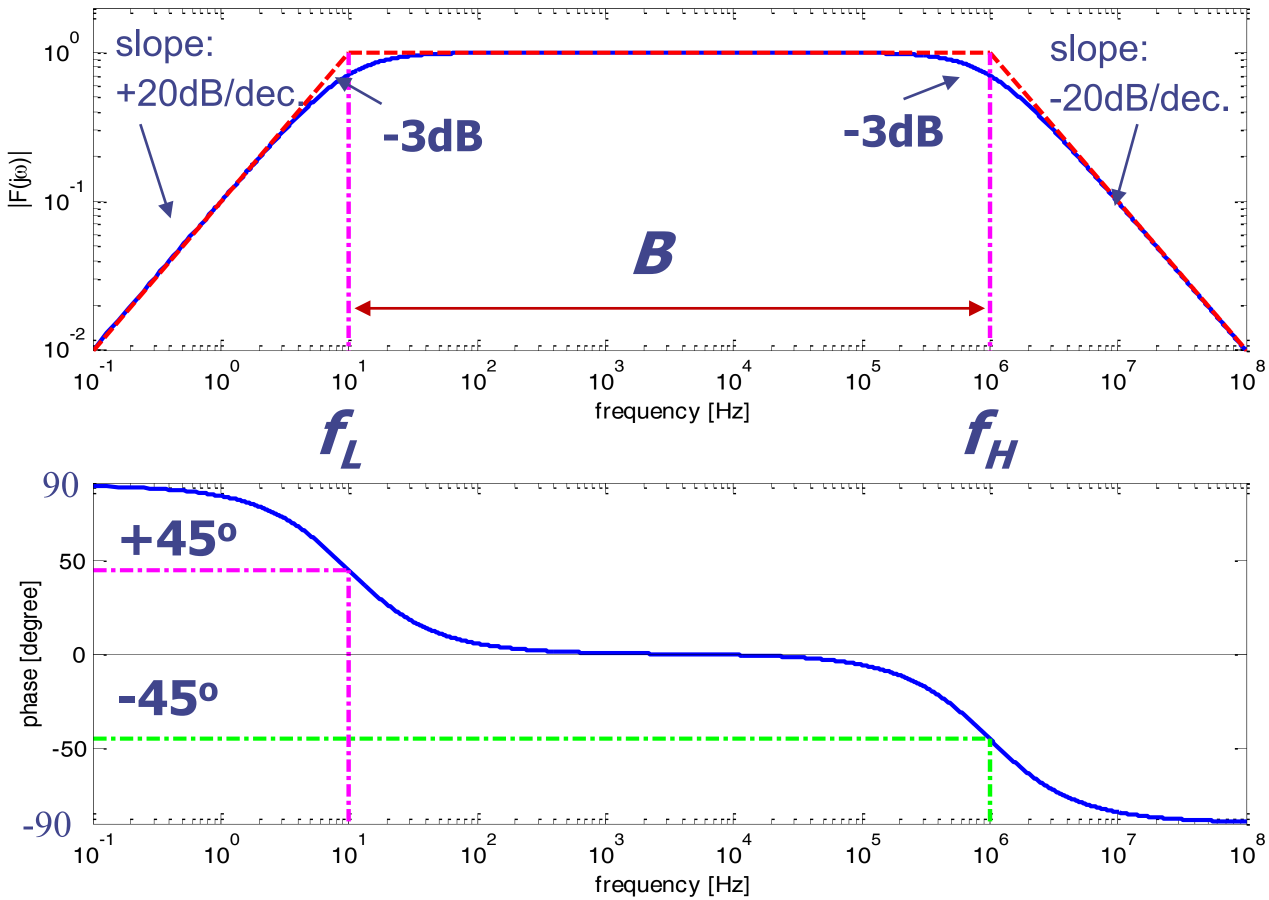
$$B=f_H-f_L$$



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.