Universidad
Carlos III de Madrid
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Session 2
Electronic circuits analysis

Electronic Components and Circuits

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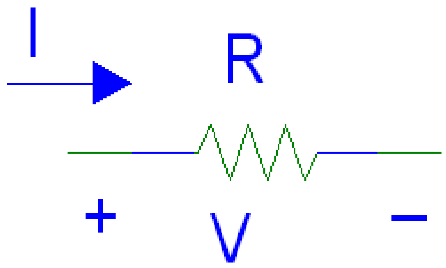
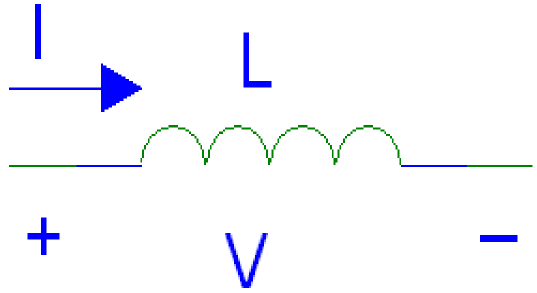
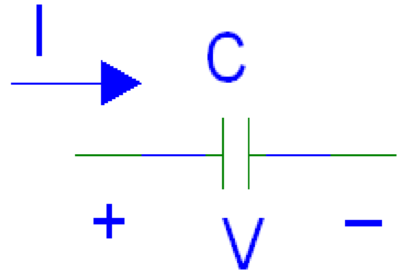
Electronic circuits analysis

OBJECTIVES

- R, L, C circuits
- Application of circuit analysis theorems
- Signal generators and dependent sources
- Transient response: Time constants
- Permanent sinusoidal regime (PSR): Frequency response

R L C circuits

			
Eq.	$V = I \cdot R$	$V = L \cdot \frac{dI}{dt}$	$I = C \cdot \frac{dV}{dt}$
DC	$R = 1k\Omega$ $V = 5V$ $I = 5mA$	$I_{DC} = const$ $s.c. \rightarrow V = 0$	$V_{DC} = const$ $o.c. \rightarrow I = 0$
AC	$v = 5\sin(\omega t)$ $V = 5V_{peak}$ $I = 5mA_{peak}$	$i = I_0 \sin(\omega t)$ $v = L\omega I_0 \cos(\omega t)$ $Z_L = j\omega L$	$v = V_0 \sin(\omega t)$ $i = C\omega V_0 \cos(\omega t)$ $Z_C = 1/ j\omega C$

Circuit analysis in DC and AC

- Ohm's law and the concept of impedance
- Kirchoff's circuit laws for voltages and currents
- Superposition Theorem
- Thevenin and Norton theorems
- Mobility of Voltage and Current sources

Ohm's law and the concept of impedance

$$V = I \cdot R$$

$$V_{DC} = R \cdot I_{DC}$$

$$v(t) = R \cdot i(t)$$

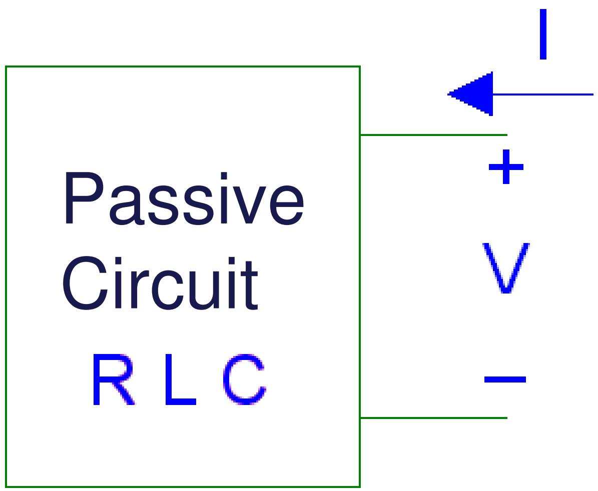
$$V_{AC} = R \cdot I_{AC}$$

$$V_p = R \cdot I_p \qquad \phi_R = 0$$

$$V_{RMS} = R \cdot I_{RMS}$$

$$P.S.R.$$

$$V = I \cdot Z$$



$$Z = \frac{V}{I} \qquad Y = \frac{1}{Z}$$

Ohm's law and the concept of impedance

$$i = I_0 \cos(\omega t + \phi_I) \qquad \Longrightarrow \qquad I = \left|I_0\right|_{\phi_I}$$

$$v = V_0 \cos(\omega t + \phi_V) \qquad \qquad V = \left|V_0\right|_{\phi_V}$$

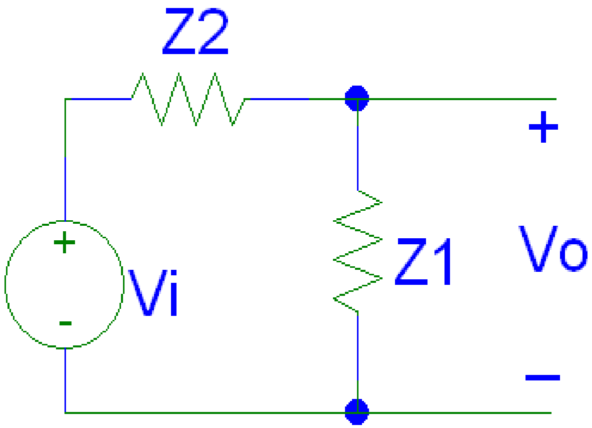
$$\left|V\right| = \left|I\right| \cdot \left|Z\right| \qquad \phi_V = \phi_I + \phi_Z$$

$$Z_R = R \qquad Z_L = j\omega L \qquad Z_C = \frac{1}{j\omega C}$$

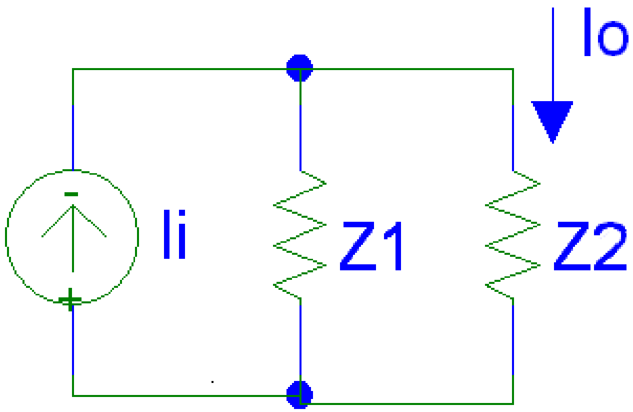
Kirchoff laws for voltages and currents

$$\sum V's\Big|_{LOOP} = 0 \qquad \sum I's\Big|_{NODE} = 0$$

Voltage Divider



Current Divider



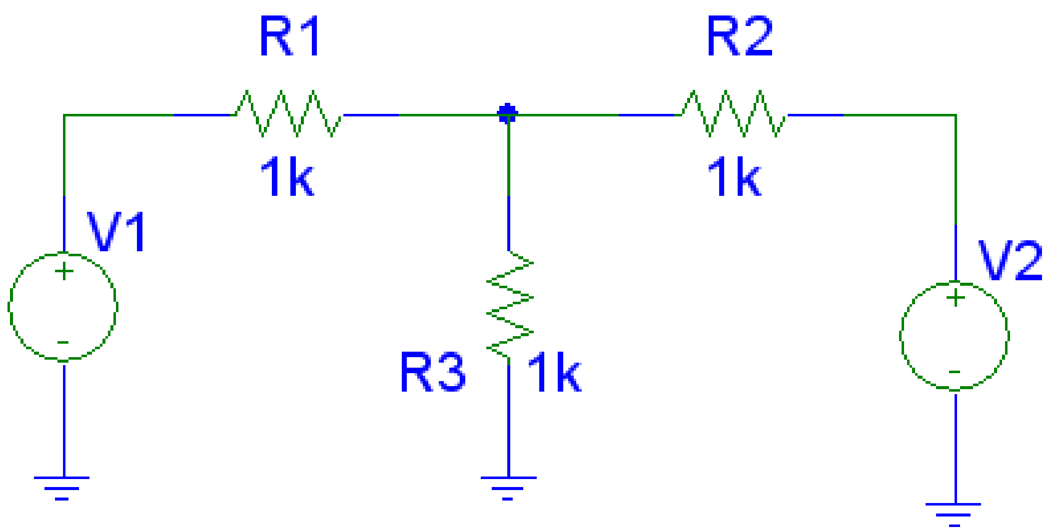
$$V_0 = V_i \frac{Z_1}{Z_1 + Z_2}$$

$$I_0 = I_i \frac{Y_2}{Y_1 + Y_2} = I_i \frac{Z_1}{Z_1 + Z_2}$$

Superposition theorem

- Only for linear circuits

  A circuit with multiple independent sources can be analyzed separately for each of the generators (assuming canceled the rest) and adding the individual responses to the final.



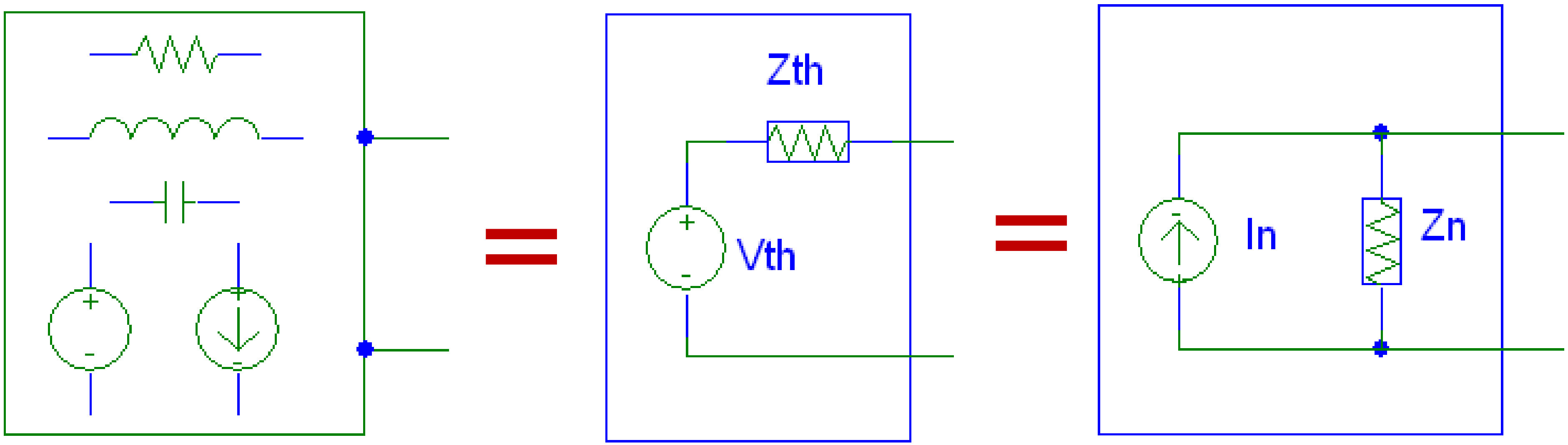
Theorems of Thevenin and Norton

- Any linear circuit can be replaced by an equivalent voltage source and a series impedance (between the two terminals of the circuit under consideration).
- Any linear circuit can be replaced by an equivalent current generator and a parallel impedance (between the two terminals).

How do I get? Review

Theorems of Thevenin and Norton

Linear Circuit | Thevenin equivalent | Norton equivalent



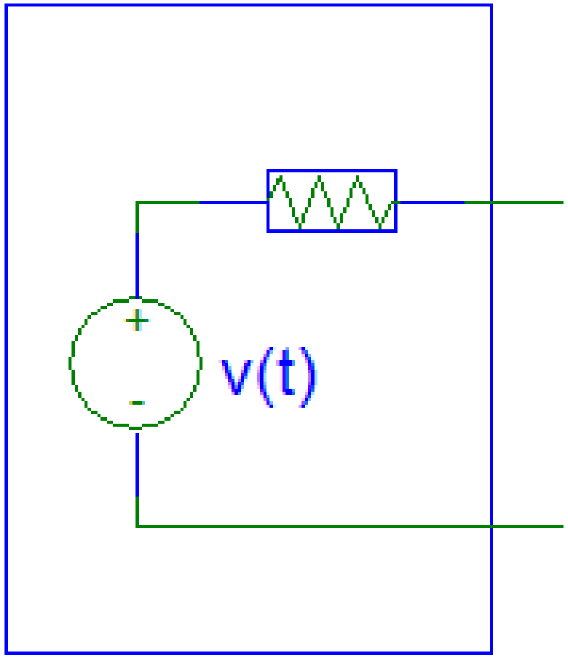
- Apply Thevenin's theorem to relate Vth, Zth with In, Zn
- Apply Norton's theorem to relate In, Zn with Vth, Zth

Types of signal generators

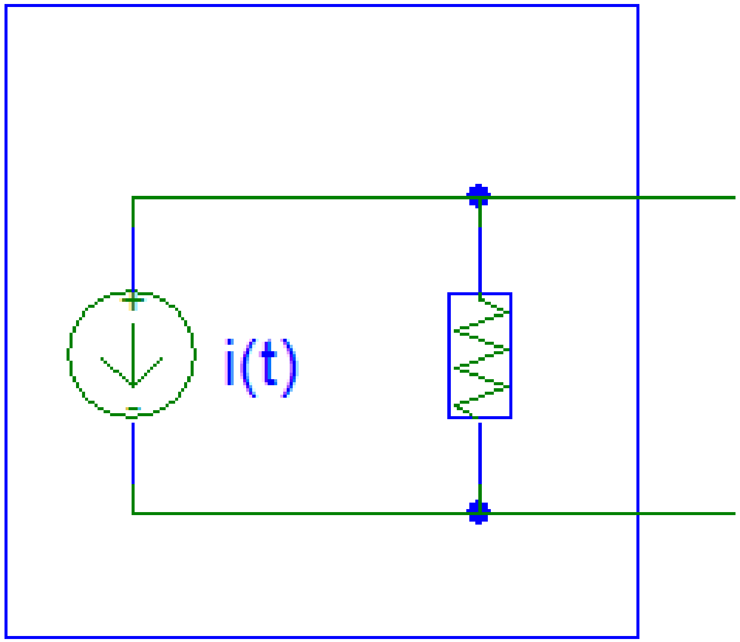
- Voltage and current generators
- Dependent sources
- Real generators and ideal generators

Independent generators

Equivalent voltage generator

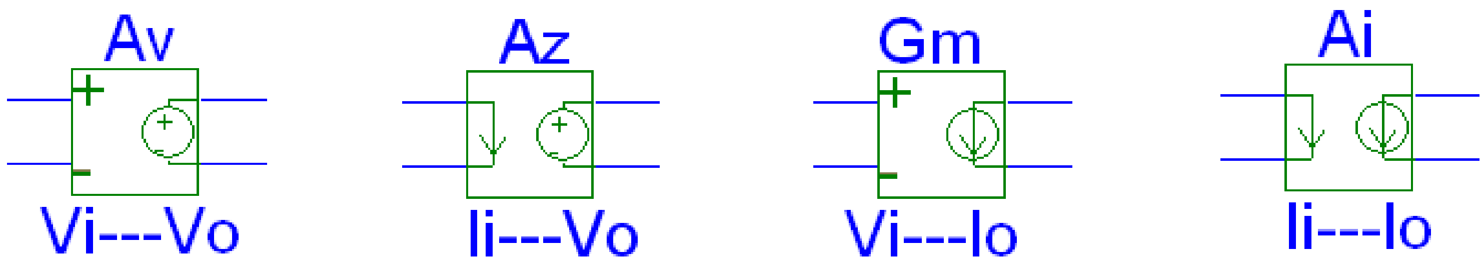


Equivalent current generator



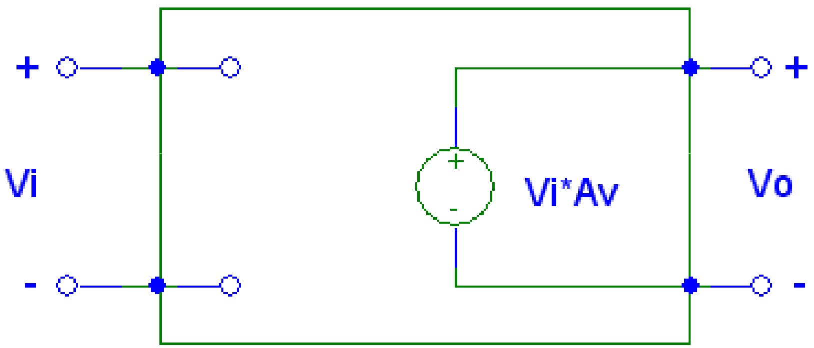
Dependent sources

- Idea of amplification (gain)
  - V controlled V generators (Av)
  - V controlled V generators (Az)
  - V controlled I generators (Gm)
  - I controlled I generators (Ai)

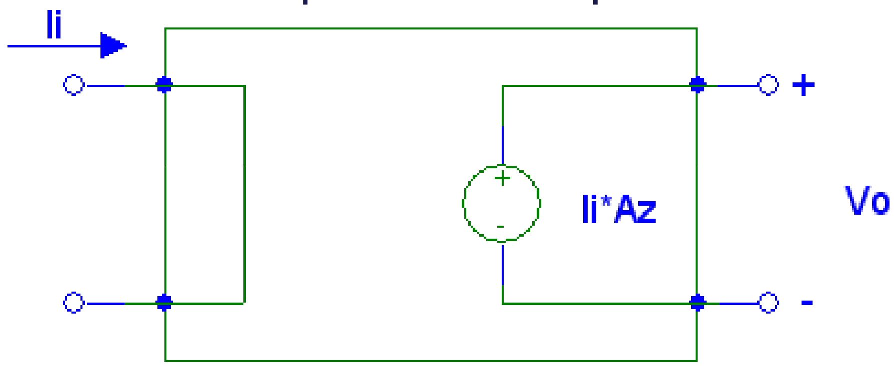


Ideal amplifiers

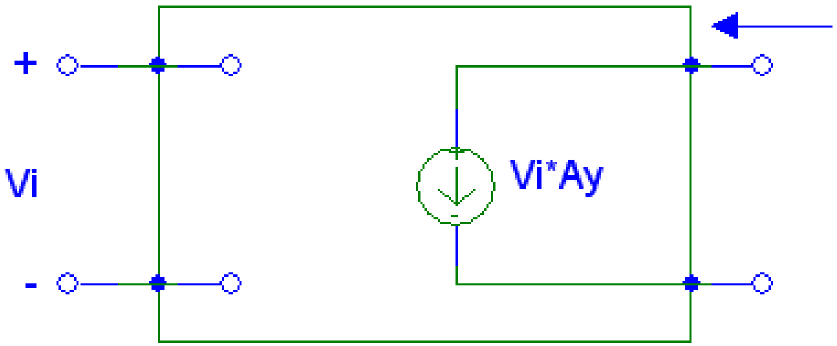
Voltage amplifier



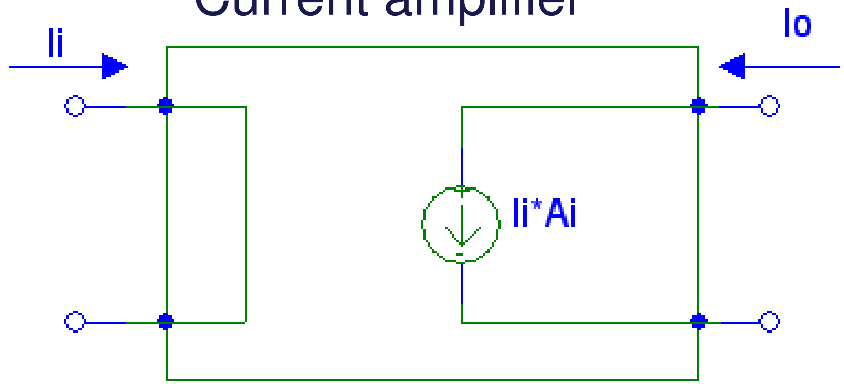
Transimpedance amplifier



Transconductance amplifier

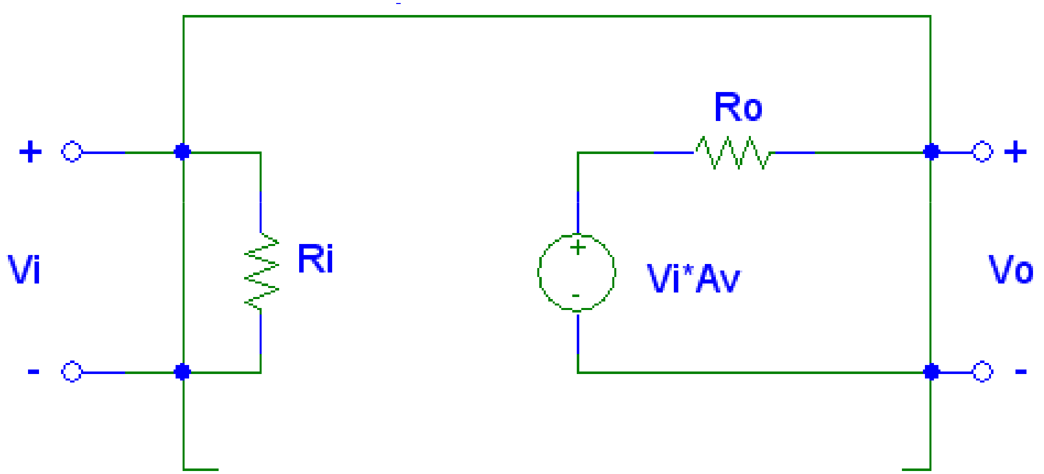


Current amplifier

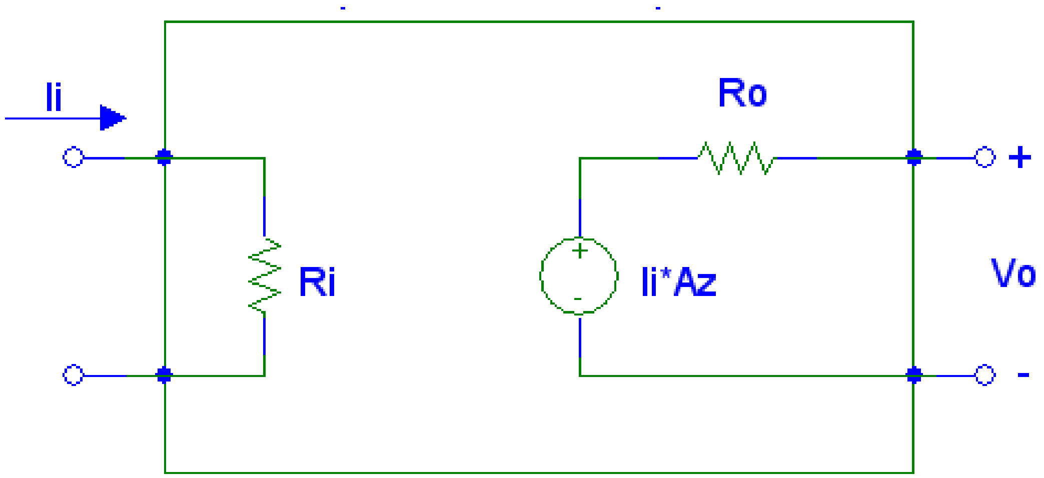


Real Amplifiers

Voltage amplifier

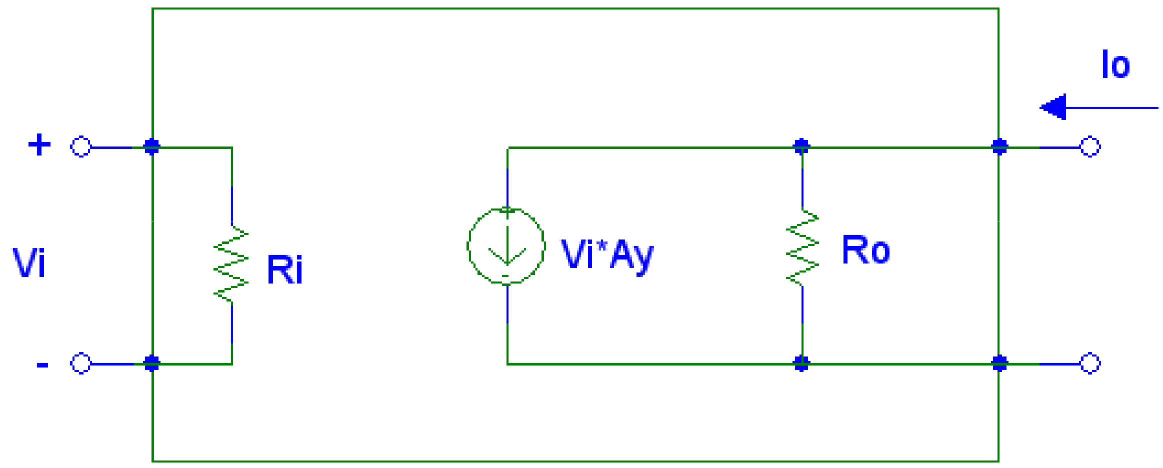


Transimpedance amplifier

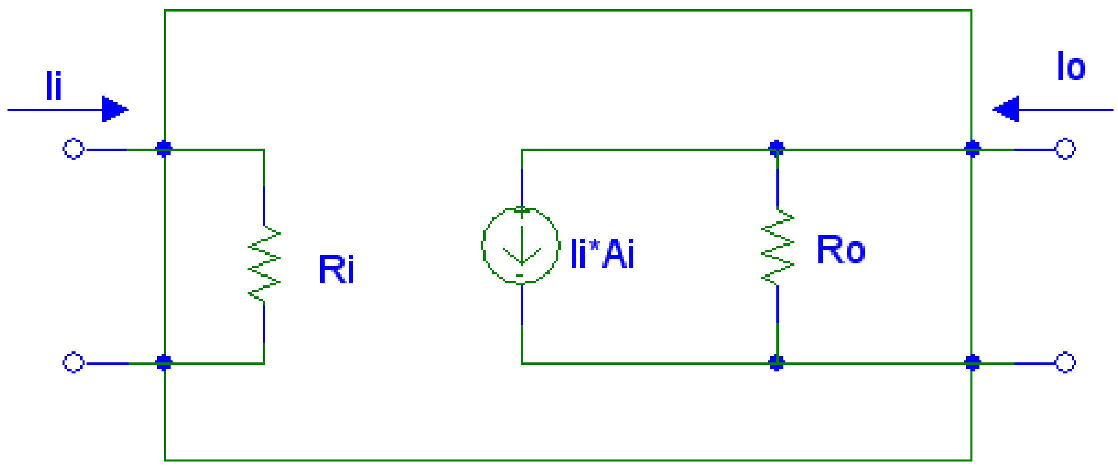


Real Amplifiers

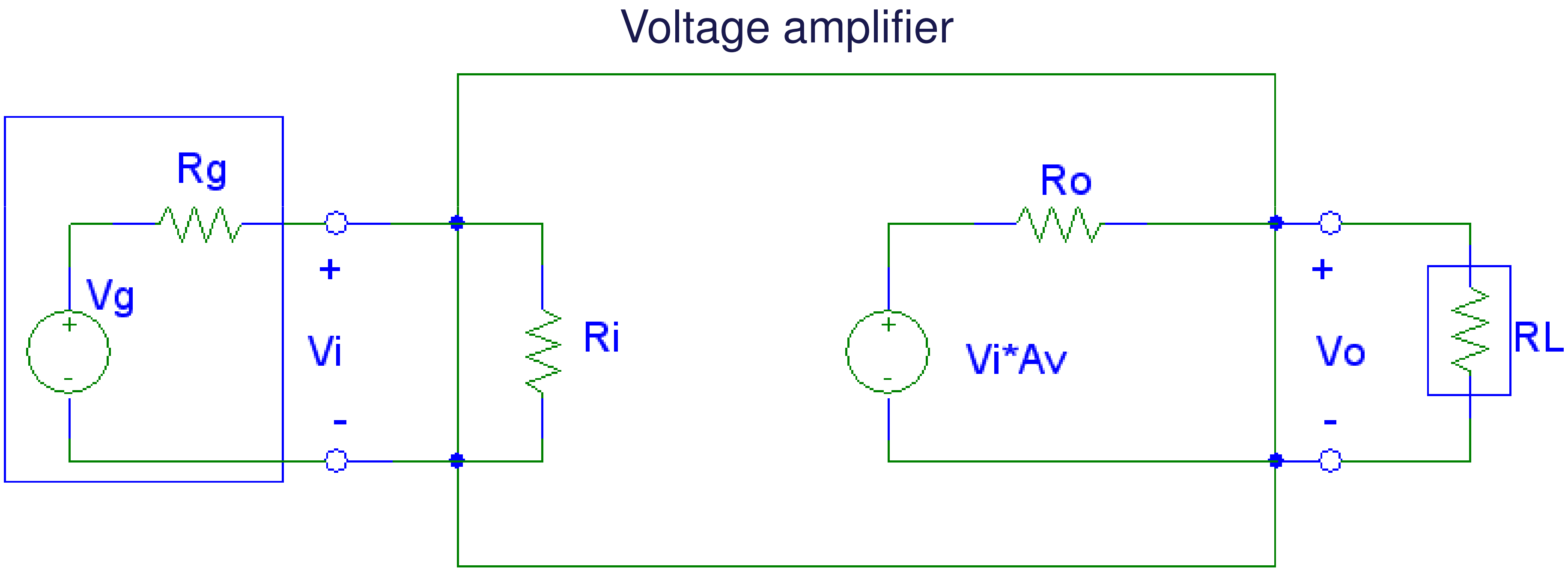
Transconductance amplifier



Current amplifier



Loading Efects



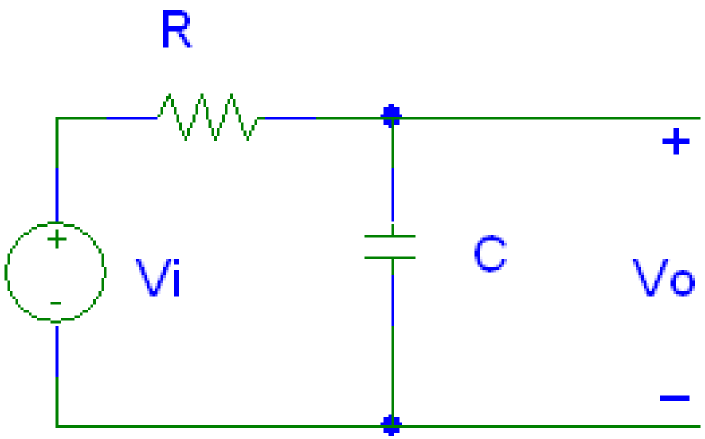
Input Divider Rg – Ri (Ri input impedance)
Divisor de salida RL – Ro (Ro impedancia de salida)

$$V_o = A_V \cdot \frac{R_i}{R_i + R_g} \cdot \frac{R_L}{R_o + R_L} \cdot V_g$$

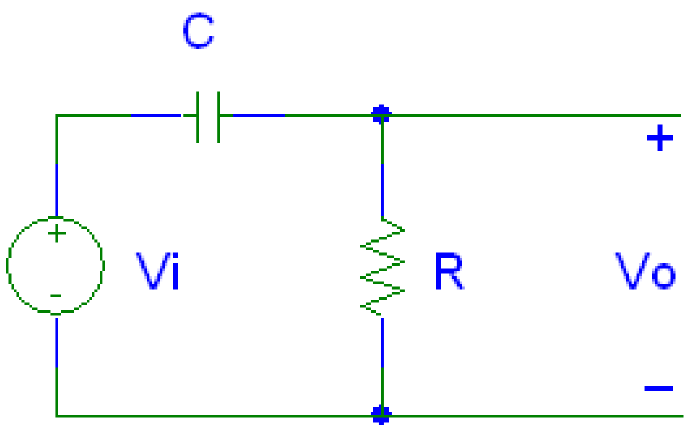
Time and frequency response of RC circuits

- Continuous response
- Transient response (and pulses)
- Frequency Response

Low-pass network

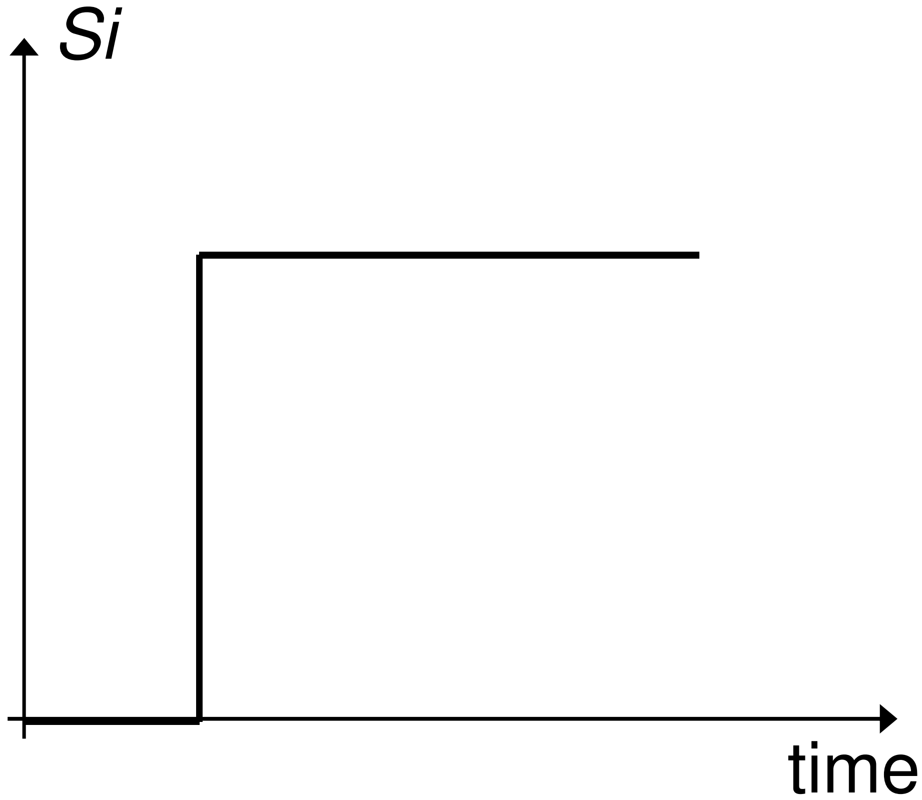


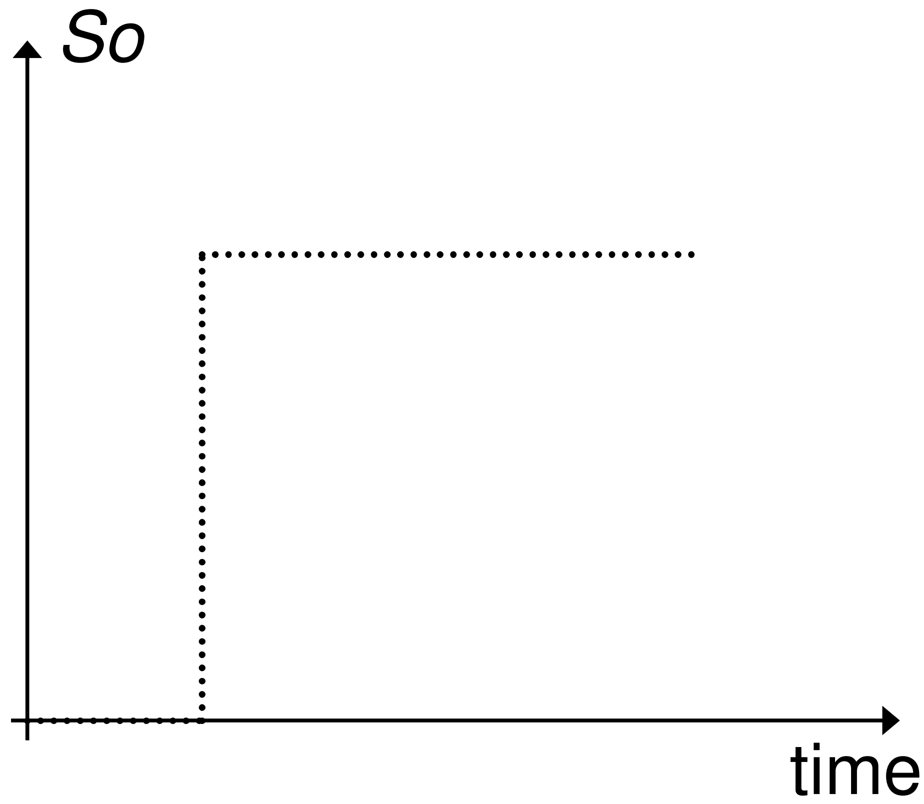
High-pass network



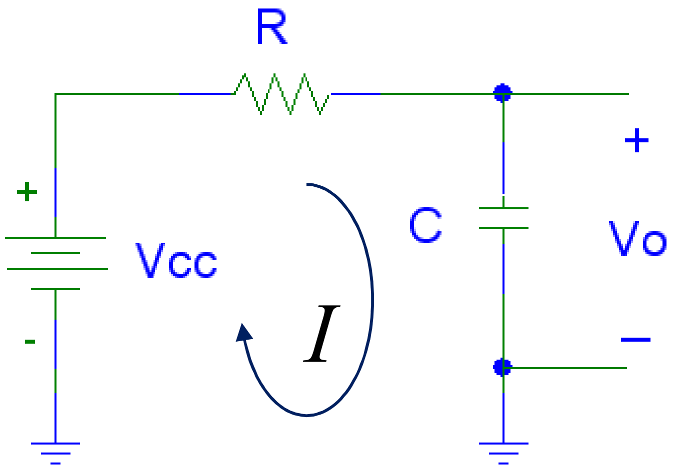
Time response (1 st order)

Plot the exponential response and point out the instant and amplitude after one time constant τ_p



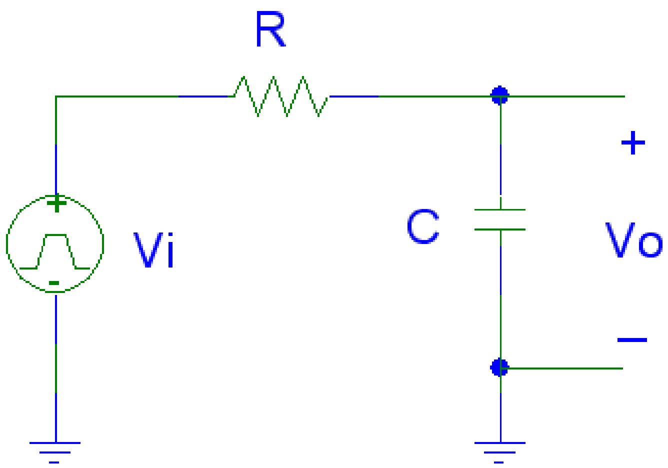


RC circuit in DC and transient

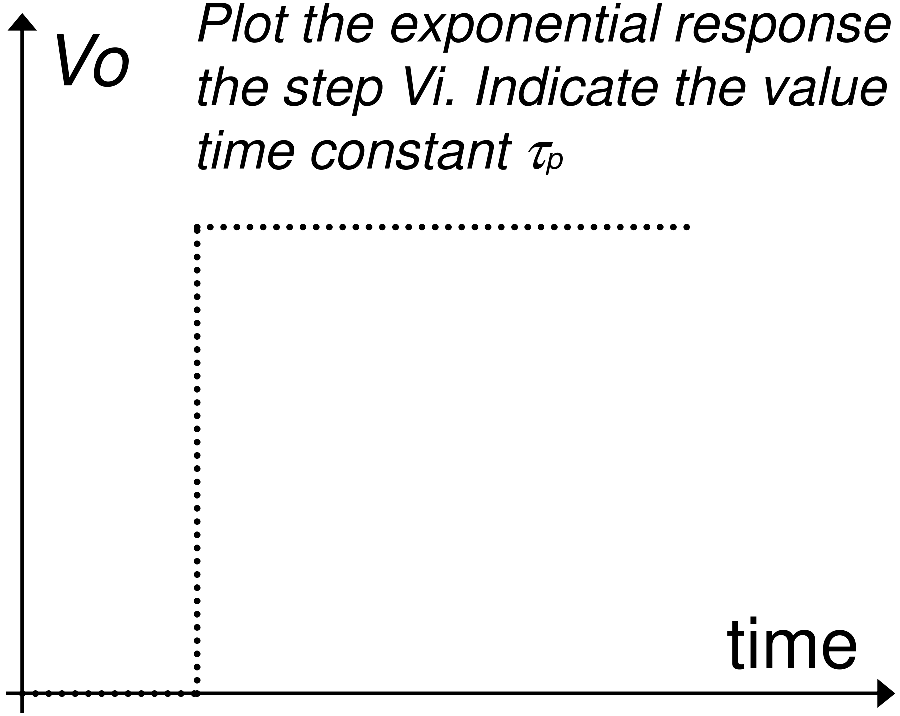


Calculate the current in the circuit and Vo

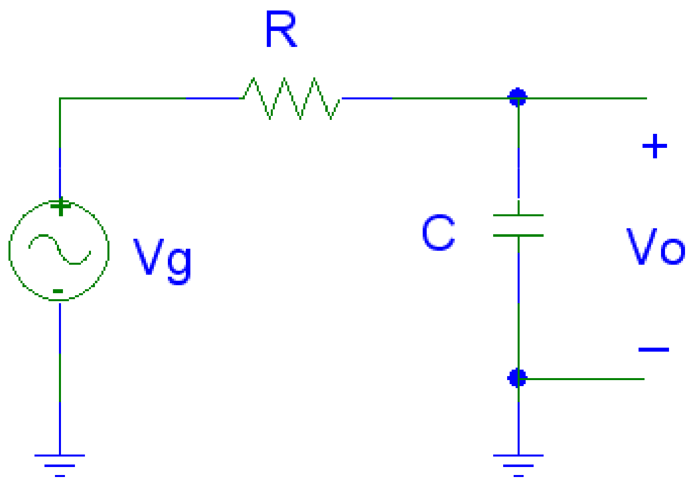
$$I = 0 \Rightarrow V_0 = V_{CC}$$



Plot the exponential response Vo to the step Vi. Indicate the value of the time constant τ_p



RC circuit in AC (PSR) Frequency response



Get the transfer function Vo / Vg in amplitude and phase.

$$V_0 = V_g \frac{Z_C}{R+Z_C} = V_g \frac{1}{1+j\omega CR}$$

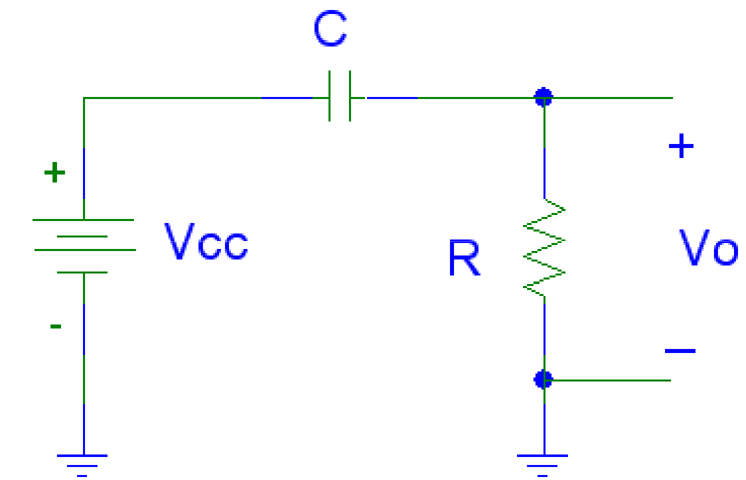
Calculate the amplitude and phase values when the frequency of Vg is:

- $\omega 1 = 0$
- $\omega 2 = 1/(10 \cdot R \cdot C)$
- $\omega 3 = 1/(R \cdot C)$
- $\omega 4 = 10/(R \cdot C)$
- $\omega 5 \to \infty$

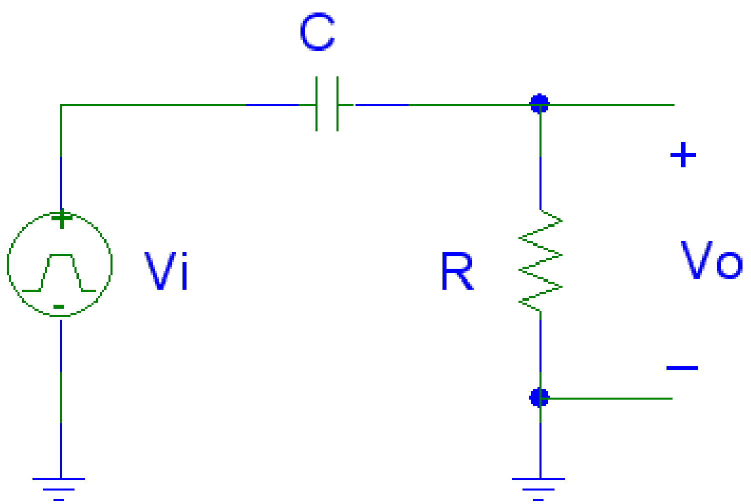
$$\left|\frac{V_0}{V_g}\right| = \frac{1}{\sqrt{1+(\omega CR)^2}} \begin{cases} =1 \\ \approx 1 \\ = \frac{1}{\sqrt{2}} \\ \approx \frac{1}{10} \\ =0 \end{cases}$$

$$\angle V_0 - \angle V_g = -arctg(\omega CR) \begin{cases} =0 & (0^{\circ}) \\ \approx 0 & \\ = -\pi/4 & (-45^{\circ}) \\ \approx -\pi/2 & \\ = -\pi/2 & (-90^{\circ}) \end{cases}$$

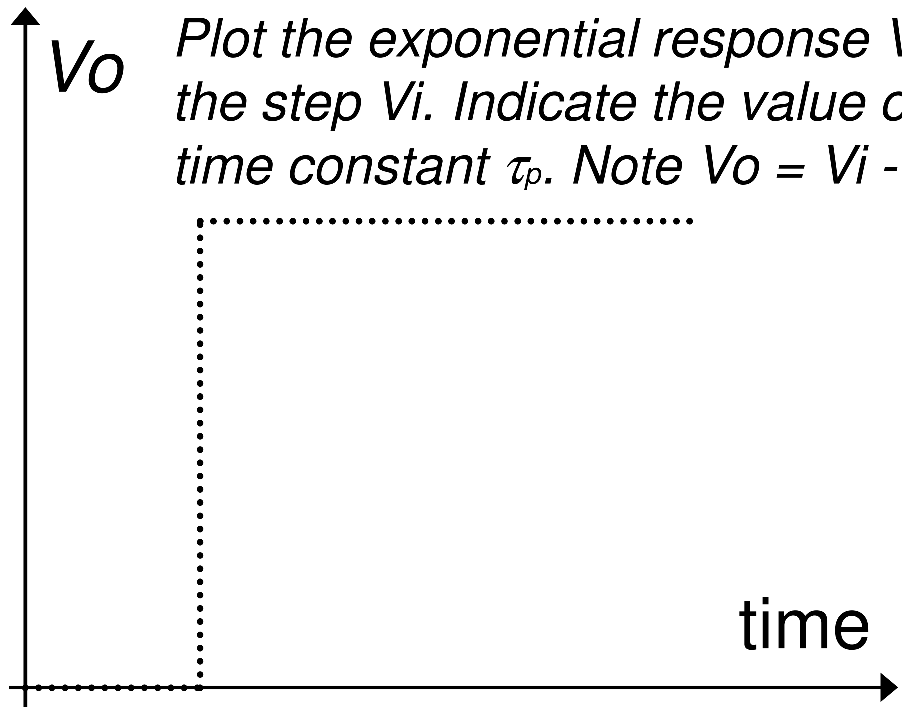
RC circuit in DC and transient (II)



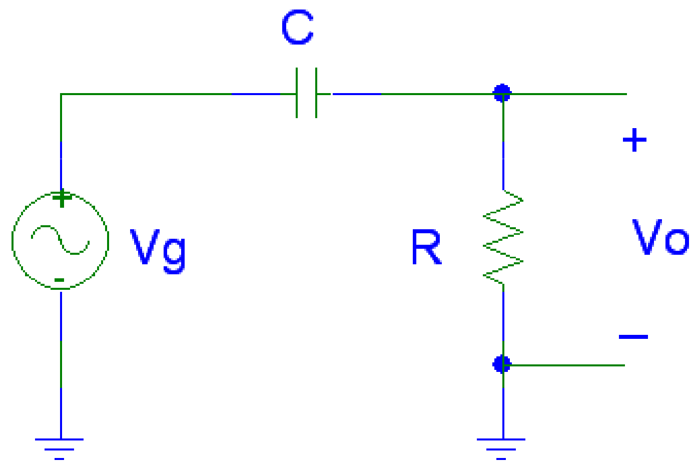
Calculate the current in the circuit and Vo



Plot the exponential response Vo to the step Vi. Indicate the value of the time constant τ_p. Note Vo = Vi - Vc



RC circuit in AC (RPS) Frequency Response (II)



Get the transfer function Vo / Vg in amplitude and phase.

Calculate the amplitude and phase values when the frequency of Vg is:

$\omega 1 = 0$

$\omega 2 = 1/(10 \cdot R \cdot C)$

$\omega 3 = 1/(R \cdot C)$

$\omega 4 = 10/(R \cdot C)$

$\omega 5 \rightarrow \infty$

Frequency Response Diagrams (Bode)