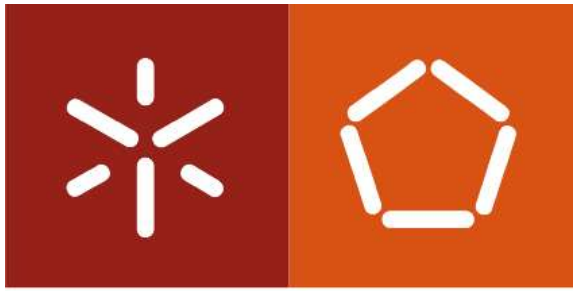


Universidade do Minho
Escola de Engenharia
Departamento de Electrónica Industrial

Instrumentação e Projeto de Circuitos

Circuitos RC e RL

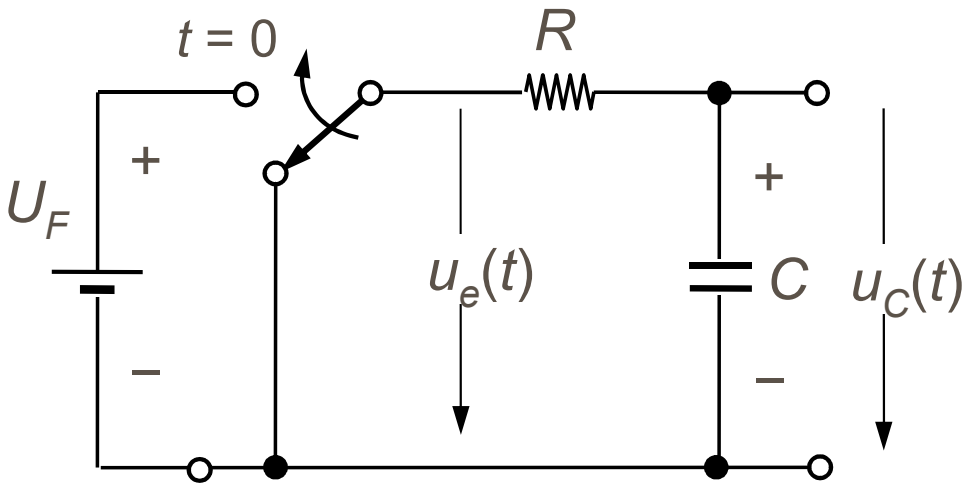
LETI – Licenciatura em Engenharia de Telecomunicações e Informática

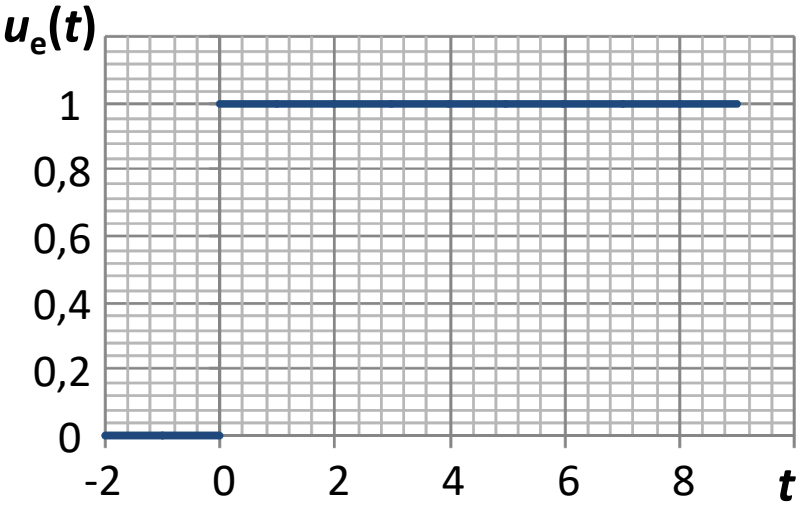
Resposta Transitória

Circuito *RC*

Universidade do Minho
Dep. de Electrónica Industrial

- **Resposta a um "degrau" de tensão**





Circuito *RC*

Universidade do Minho
Dep. de Electrónica Industrial

- **Resposta a um "degrau" de tensão**

$$U_F = u_R + u_C = Ri + \frac{1}{C}\int_0^t i dt + v_C(0^+)$$

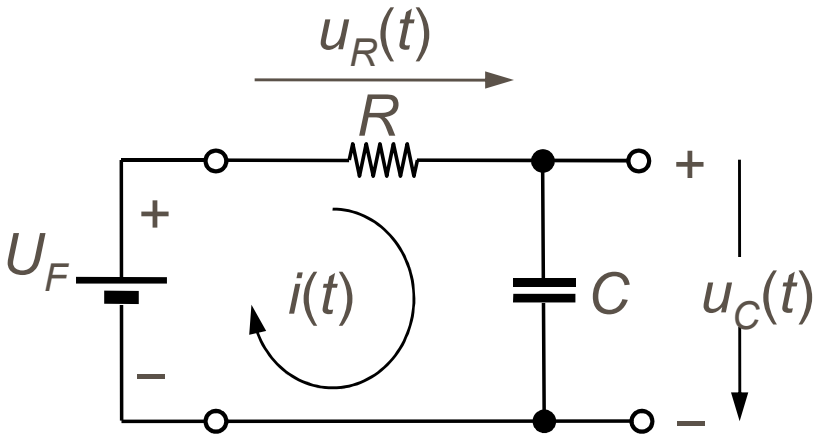
Solucionando a equação diferencial

(para $u_C(0^+) = 0\text{V}$) e fazendo $\tau = RC$,

$$\rightarrow i(t) = \frac{U_F}{R} e^{-\frac{t}{\tau}}$$

$$\rightarrow u_R = R \cdot i = U_F e^{-\frac{t}{\tau}}$$

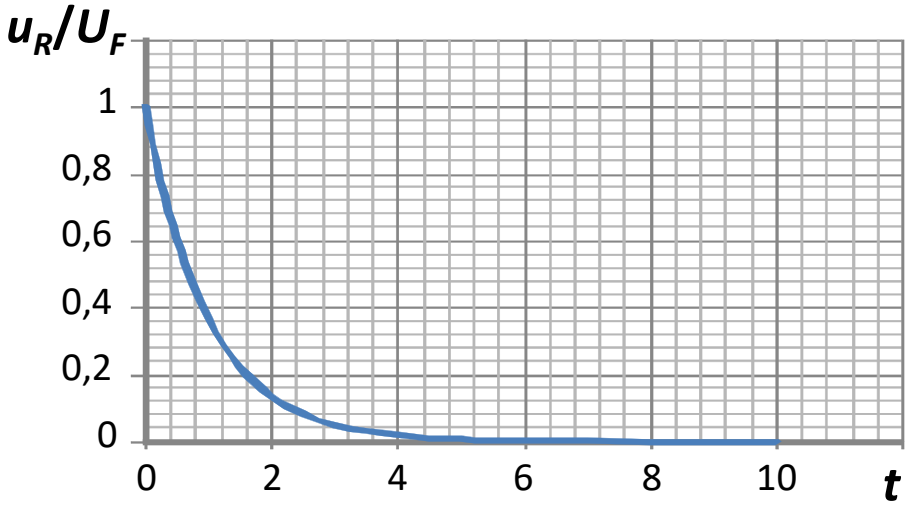
$$\rightarrow u_C = U_F - u_R = U_F (1 - e^{-\frac{t}{\tau}})$$



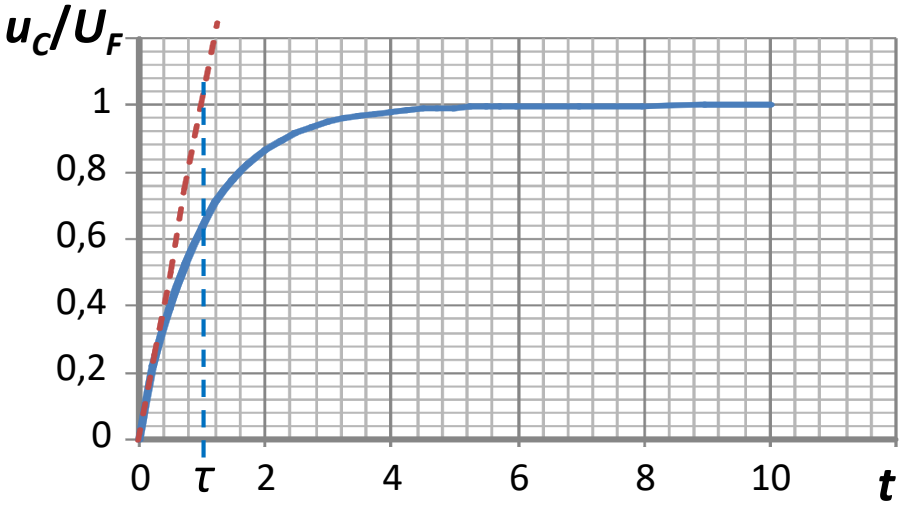
Circuito *RC*

Universidade do Minho
Dep. de Electrónica Industrial

- **Resposta a um "degrau" de tensão**



$$u_R = U_F e^{-\frac{t}{\tau}}$$

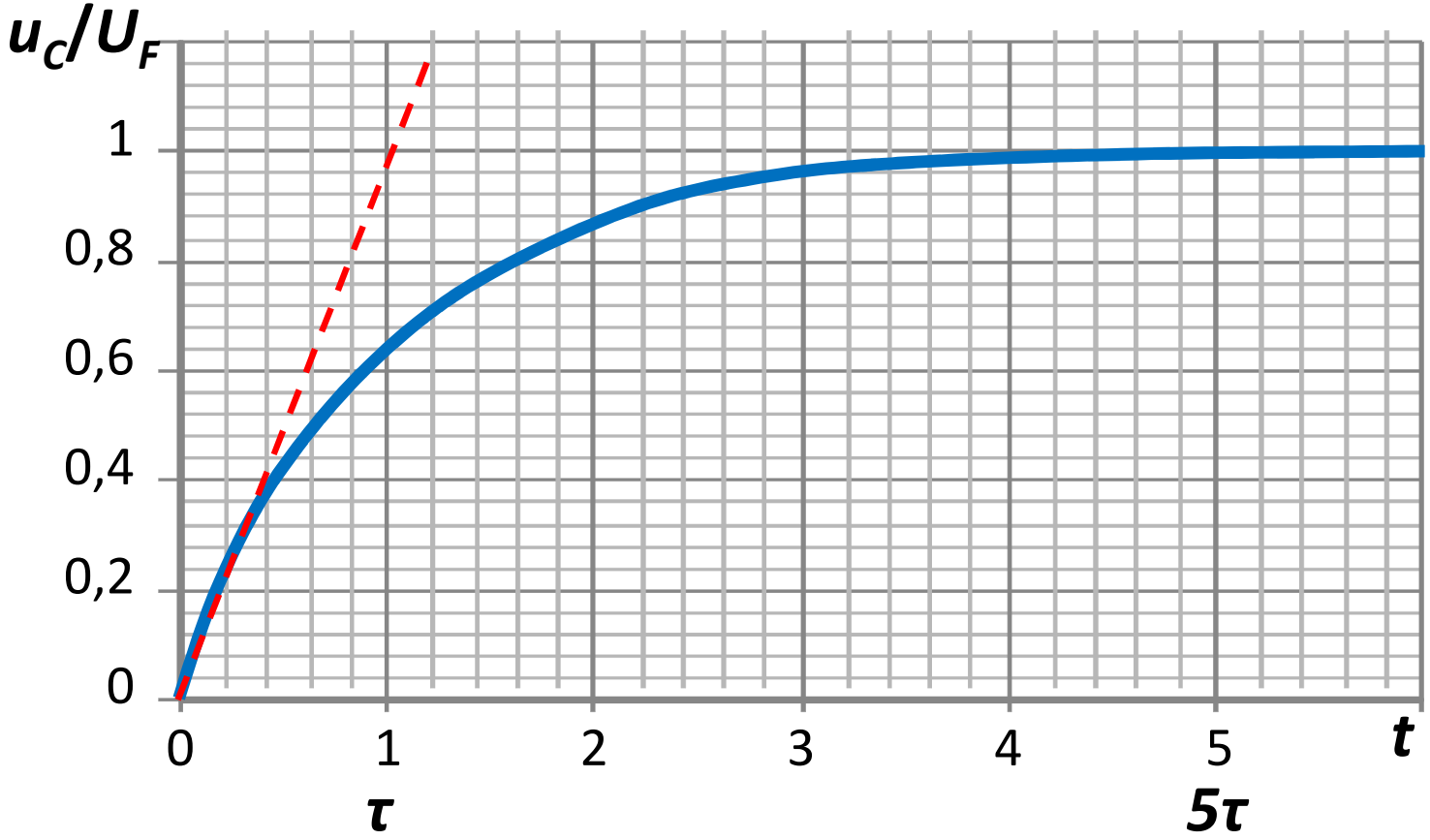


$$u_C = U_F(1 - e^{-\frac{t}{\tau}})$$

Circuito *RC*

Universidade do Minho
Dep. de Electrónica Industrial

- **Resposta a um "degrau" de tensão**

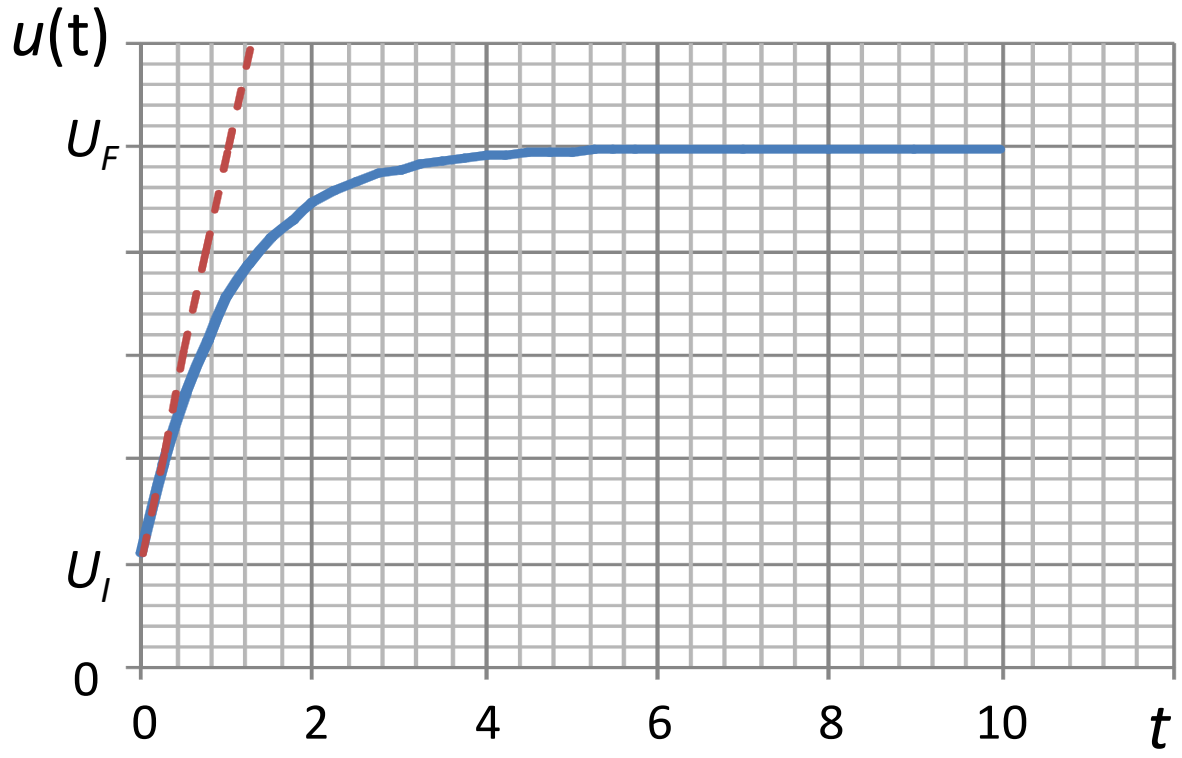


$$u_C = U_F(1 - e^{-\frac{t}{\tau}})$$

Circuito RC

Universidade do Minho
Dep. de Electrónica Industrial

- Caso geral para qualquer tensão inicial (U_I) e tensão final (U_F)

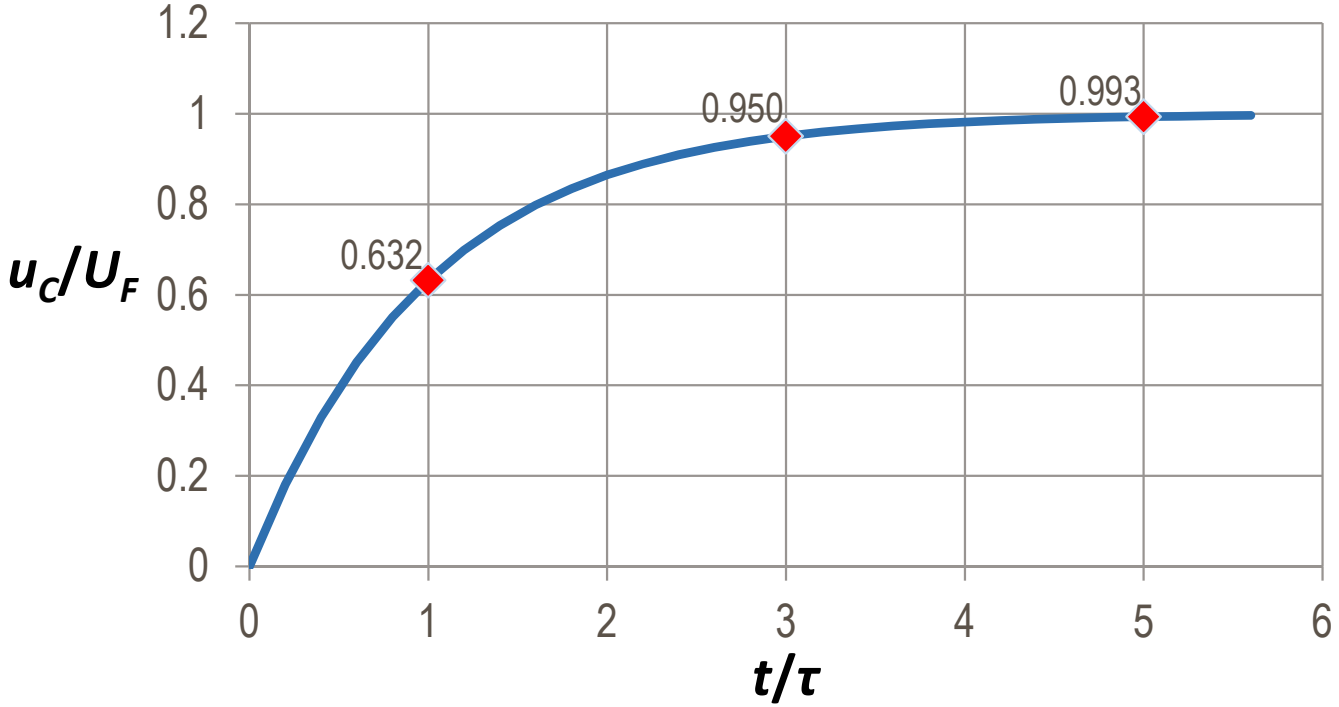


$$u(t) = U_F + (U_I - U_F) \cdot e^{-\frac{t}{\tau}} \qquad \text{ou} \qquad u(t) = U_I + (U_F - U_I)(1 - e^{\frac{-t}{\tau}})$$

Circuito *RC*

Universidade do Minho
Dep. de Electrónica Industrial

- **Resposta a um "degrau" de tensão**



t	u_C/U_f
τ	0.632
3τ	0.950
5τ	0.993

Circuito *RC*

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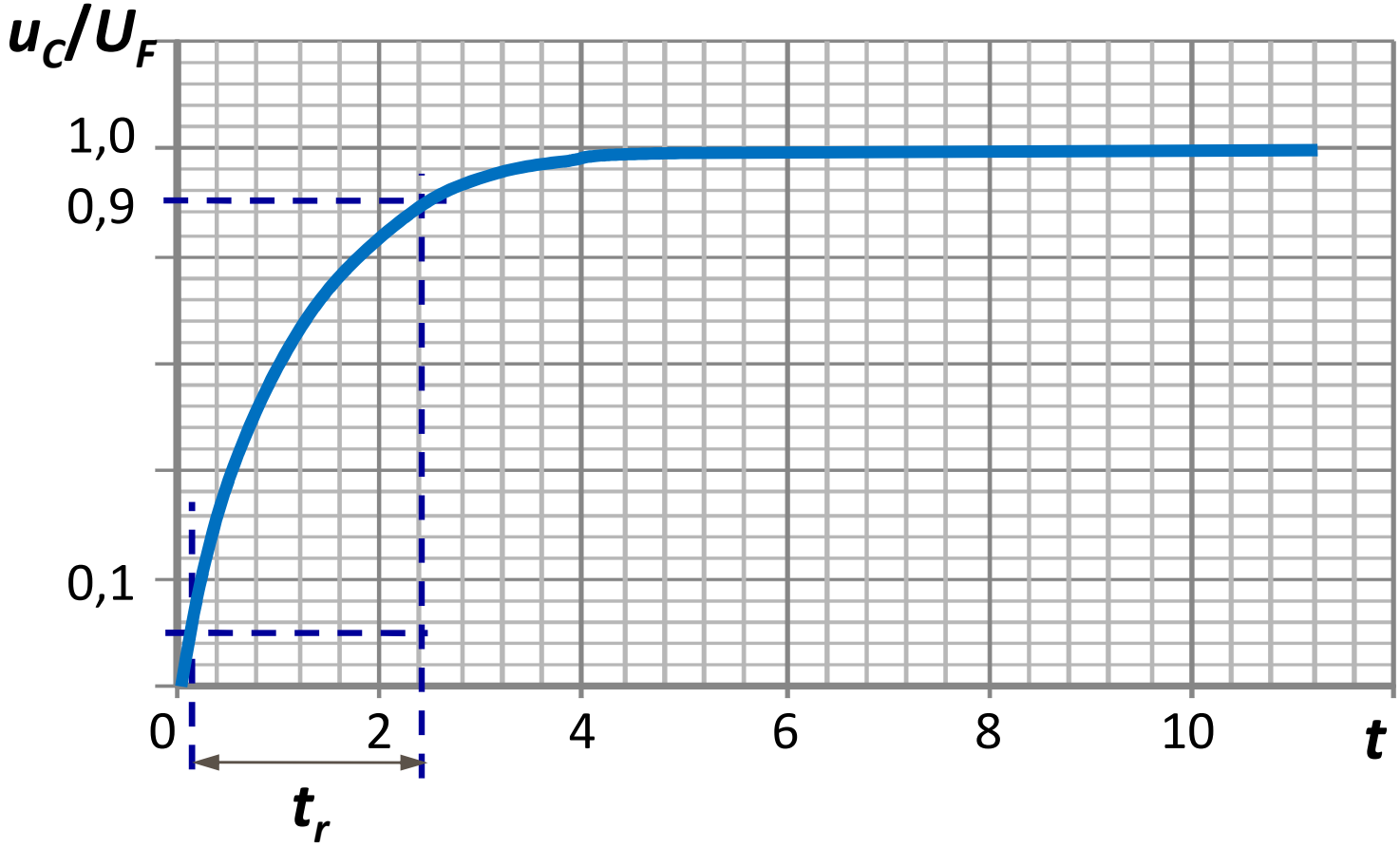
Dep. de Electrónica Industrial

- Resposta a um "degrau" de tensão

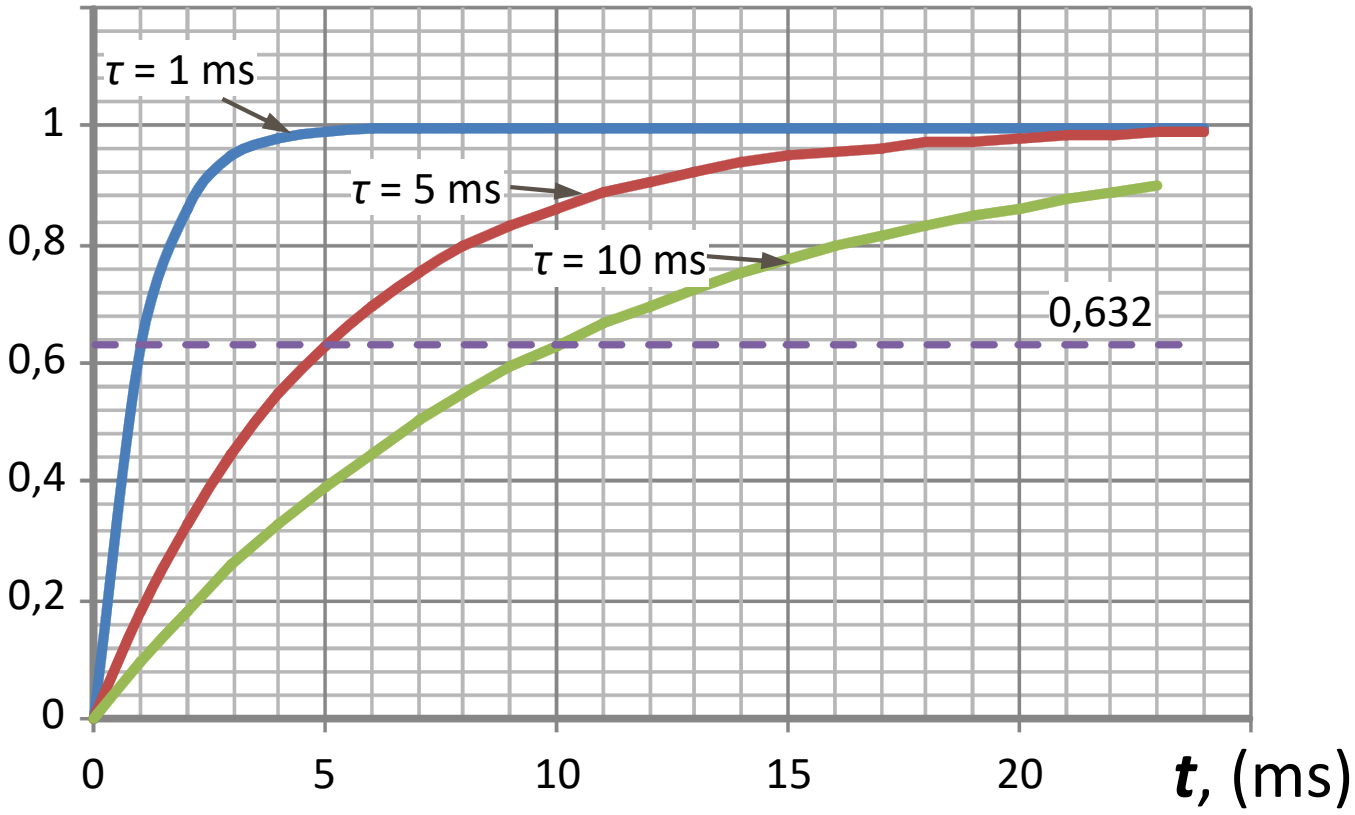


$$t_r \approx 2{,}197\tau$$

Circuito *RC*

Universidade do Minho
Dep. de Electrónica Industrial

- **Resposta a um "degrau" de tensão**

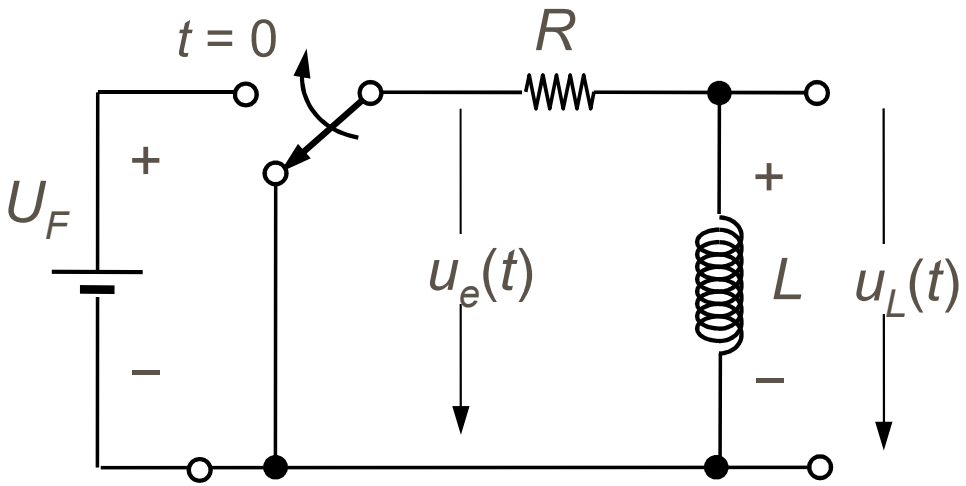


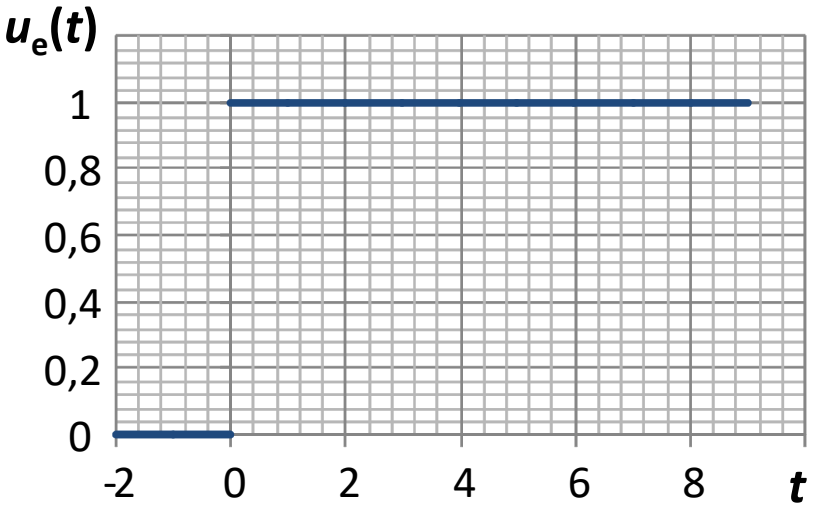
$$\text{Para } t = \tau \rightarrow u_C \approx 0{,}632\, U_F$$

Circuito *RL*

Universidade do Minho
Dep. de Electrónica Industrial

- **Resposta a um "degrau" de tensão**





Circuito *RL* - Resposta ao Degrau

Universidade do Minho
Dep. de Electrónica Industrial

- **Resposta a um "degrau" de tensão**

$$U_F = u_R + u_L = Ri + L\frac{di}{dt}$$

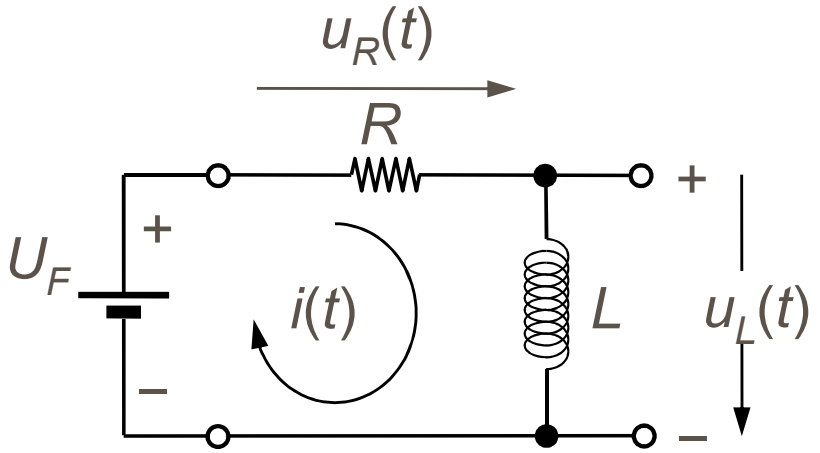
Solucionando a equação diferencial

(para $i_L(0^+) = 0A$) e fazendo $\tau = \frac{L}{R}$,

$$\rightarrow i(t) = \frac{U_F}{R}(1 - e^{-\frac{t}{\tau}})$$

$$\rightarrow u_R = R \cdot i = U_F(1 - e^{-\frac{t}{\tau}})$$

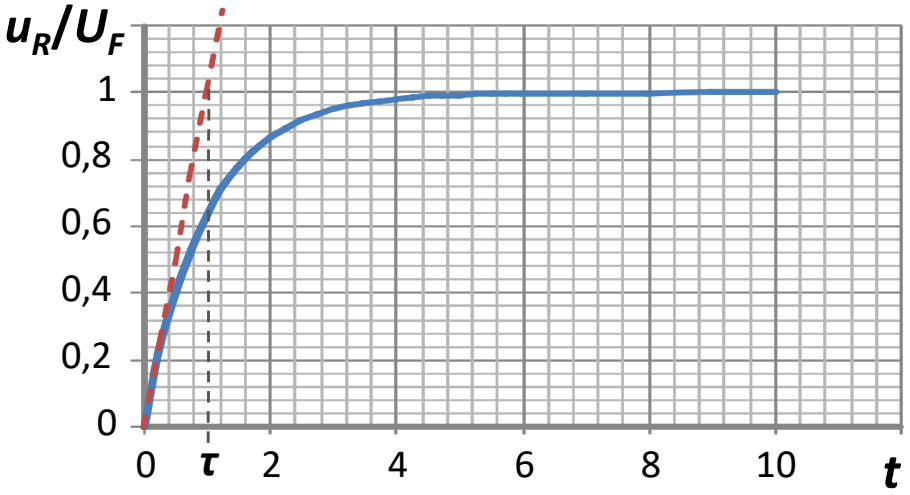
$$\rightarrow u_L = U_F - u_R = U_F e^{-\frac{t}{\tau}}$$

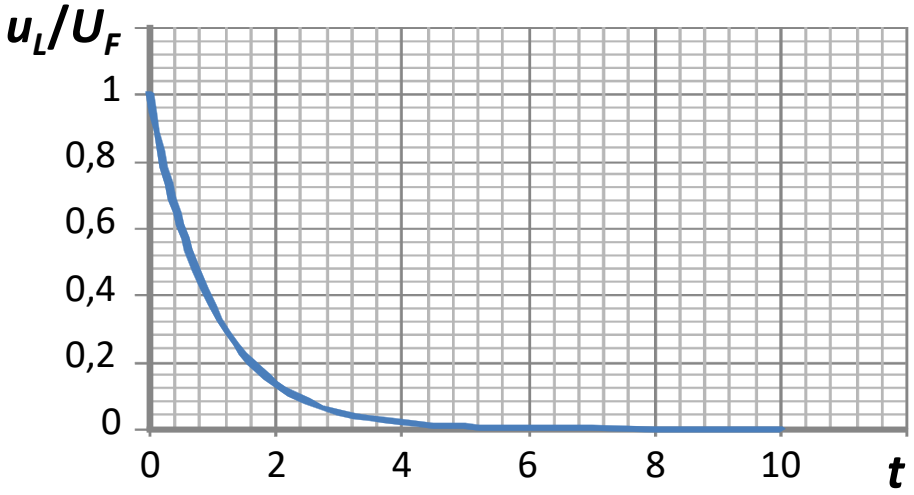


Circuito *RL* - Resposta ao Degrau

Universidade do Minho
Dep. de Electrónica Industrial

- Resposta a um "degrau" de tensão





$$u_R = U_F(1 - e^{-\frac{t}{\tau}})$$

$$u_L = U_F e^{-\frac{t}{\tau}}$$

$$\left(\tau = \frac{L}{R}\right)$$

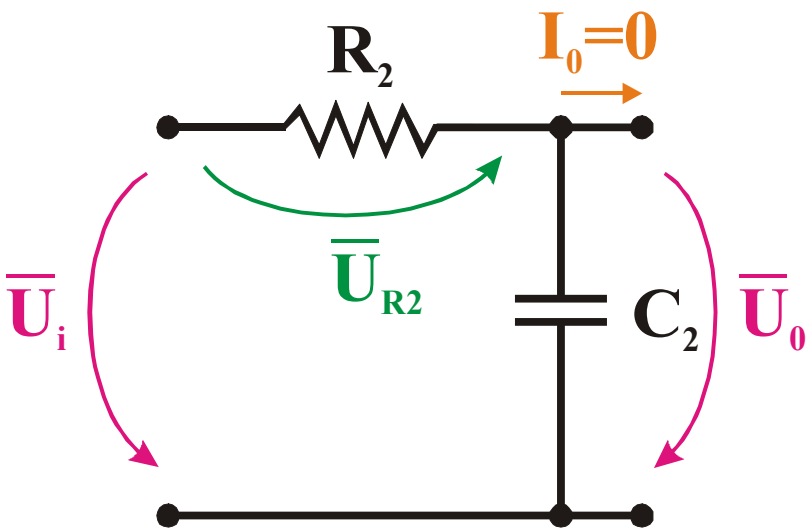
Resposta em Frequência

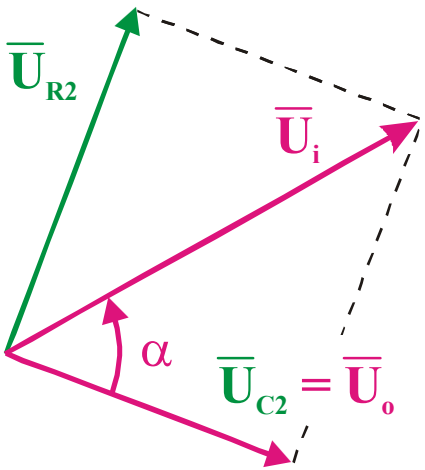
Resposta em Frequência

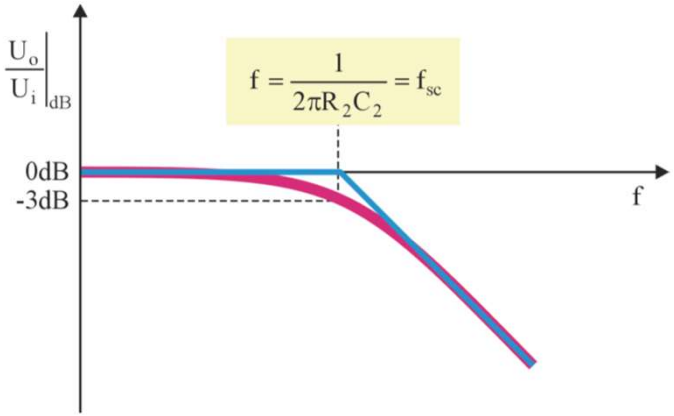
Universidade do Minho
Dep. de Electrónica Industrial

- **Resposta a entradas sinusoidais em regime permanente (após transitório)**
- **Impedância**
  - Medida da oposição à passagem de corrente elétrica em circuitos de corrente alternada (CA)
  - Análogo à resistência em circuitos de corrente contínua (CC)
  - A impedância tem parte real e/ou imaginária
- **Impedância dos componentes (* $\omega = 2\pi f$)**
  - Resistência $Z_R = R$
  - Condensador $Z_C = \frac{1}{j\omega C} = -j\frac{1}{\omega C}$
  - Indutor (bobina) $Z_L = j\omega L$
- **Circuitos RC e RL de 1ª ordem**
  - Filtros passa-baixo e passa-alto

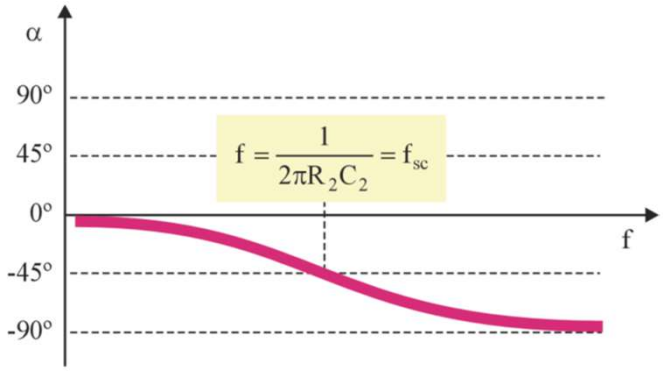
Filtro RC Passa-Baixo







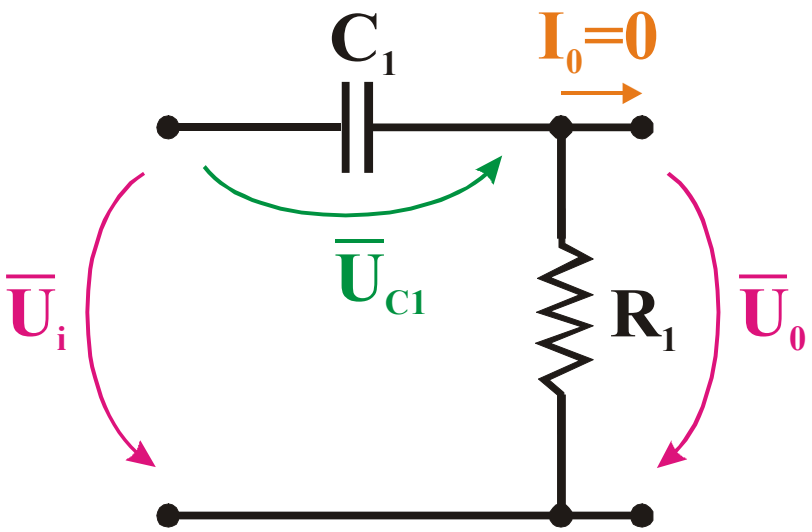
$$\left.\frac{U_o}{U_i}\right|_{dB} = 20\log_{10}\left(\frac{1}{\sqrt{(\omega R_2 C_2)^2 + 1}}\right)$$

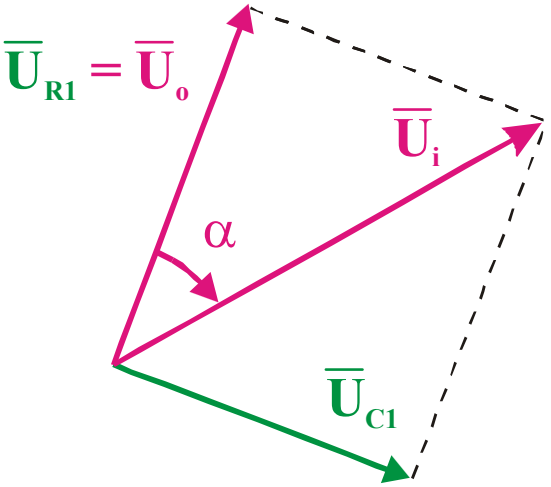


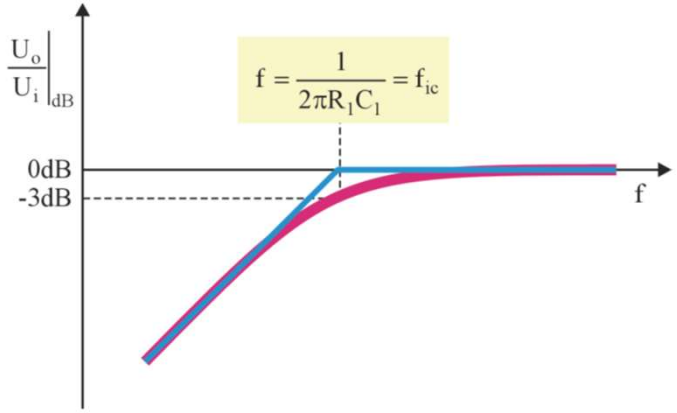
$$\alpha = -\text{arctg}(\omega R_2 C_2)$$

João Sena Esteves

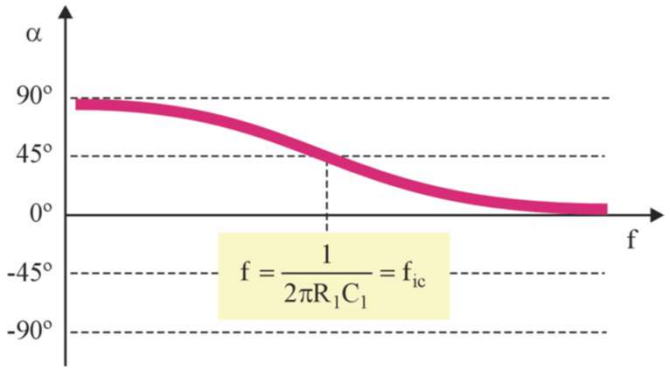
Filtro RC Passa-Alto





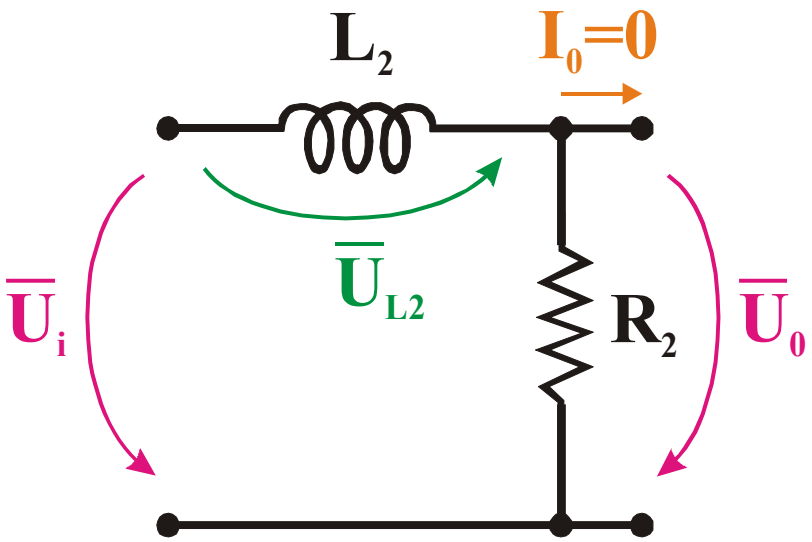


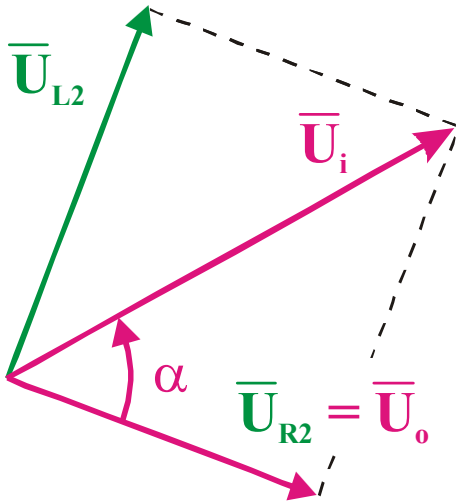
$$\left.\frac{U_o}{U_i}\right|_{dB} = 20\log_{10}\left(\frac{\omega R_1 C_1}{\sqrt{(\omega R_1 C_1)^2 + 1}}\right)$$

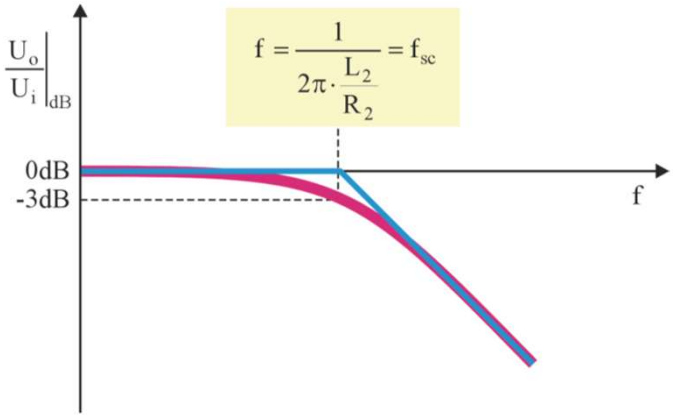


$$\alpha = 90^{o} - \text{arctg}(\omega R_1 C_1)$$

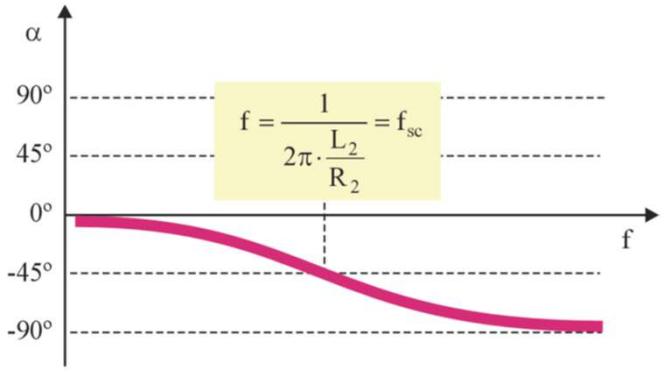
Filtro RL Passa-Baixo





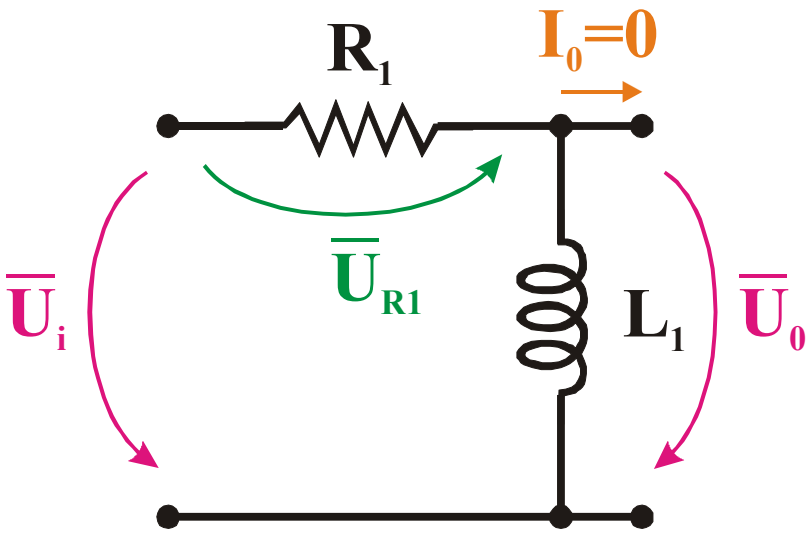


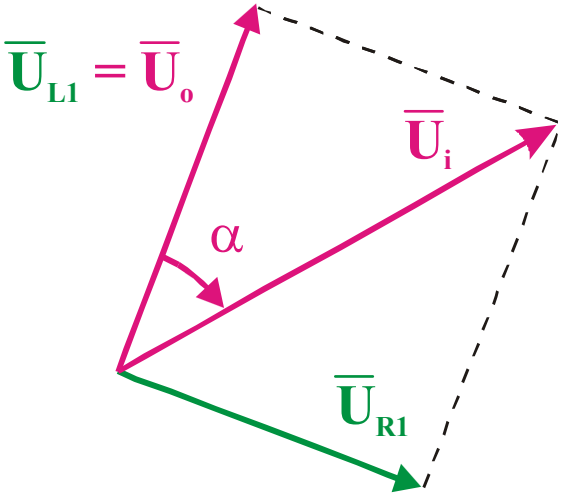
$$\left.\frac{U_o}{U_i}\right|_{dB} = 20\log_{10}\left(\frac{1}{\sqrt{\left(\omega\cdot\frac{L_2}{R_2}\right)^2+1}}\right)$$

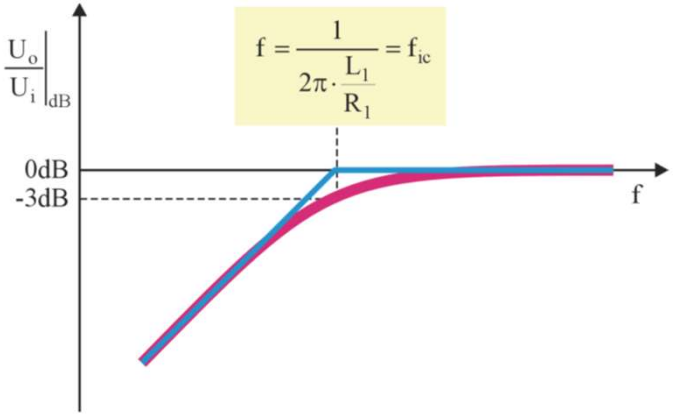


$$\alpha = -\text{arctg}\left(\omega\cdot\frac{L_2}{R_2}\right)$$

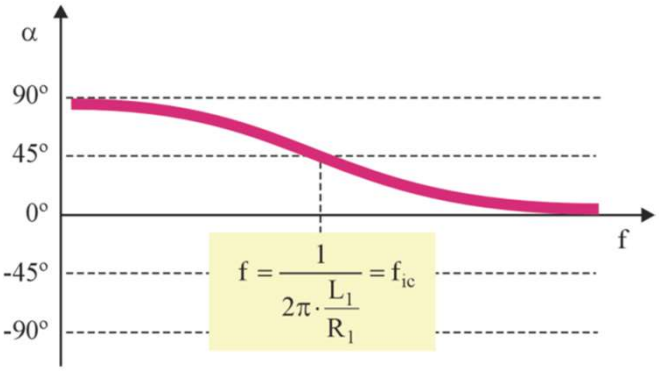
Filtro RL Passa-Alto







$$\left.\frac{U_o}{U_i}\right|_{dB} = 20\log_{10}\left(\frac{\omega\cdot\frac{L_1}{R_1}}{\sqrt{\left(\omega\cdot\frac{L_1}{R_1}\right)^2+1}}\right)$$



$$\alpha = 90^{o} - \text{arctg}\left(\omega\cdot\frac{L_1}{R_1}\right)$$