8. Előadás (2017.10.24.)

Bode diagram:

K(s) transzfer függvény → $s=j\omega$ → *K(jω)* frekvencia karakterisztika Bode diagramjai:

- logaritmikus abszolút érték logaritmikus fr. tengely felett
- és lineáris fázis logaritmikus fr. tengely felett
- töréspontos közelítéssel (aszimptóták)

$$K(s) = c \cdot s^n \frac{\prod_i \left(1+\frac{s}{\omega_{zi}}\right)}{\prod_i \left(1+\frac{s}{\omega_{pi}}\right)} \Rightarrow \ln(K(j\omega)) = a^{Np}(\omega) + j\varphi(\omega)$$

$$a^{Np}(\omega) = \ln|K(j\omega)| \qquad \varphi(\omega) = arc(K(j\omega))$$

$$a^{dB}(\omega) = 20\log_{10}|K(j\omega)|$$

Logaritmikus amplitúdó karakterisztika elemi karakterisztikák összege:

$$a^{dB}(\omega) = 20\log_{10}|c| + n20\log_{10}\omega + \sum_i 20\log_{10}\left|1+j\frac{\omega}{\omega_{zi}}\right| - \sum_i 20\log_{10}\left|1+j\frac{\omega}{\omega_{zi}}\right|$$

Fázis karakterisztika elemi karakterisztikák összege:

$$\varphi(\omega) = arc(c) + n\frac{\pi}{2} + \sum_i arc\left(1+j\frac{\omega}{\omega_{zi}}\right) - \sum_i arc\left(1+j\frac{\omega}{\omega_{pi}}\right)$$

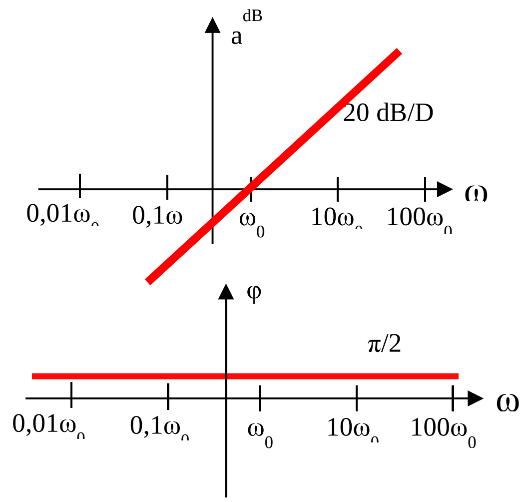
Bode diagram elemi karakterisztikák (elsőfokú építőkockák):

Origóban lévő zérus (*s=0*):

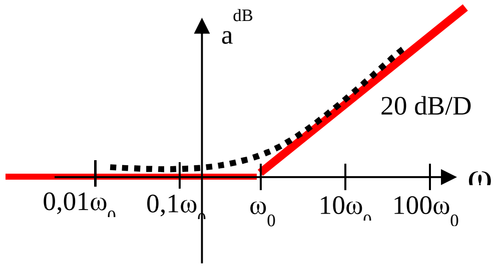
$$c \cdot s = \frac{s}{\omega_0}$$

$$a(\omega) = 20\log_{10}\left|\frac{\omega}{\omega_0}\right|$$

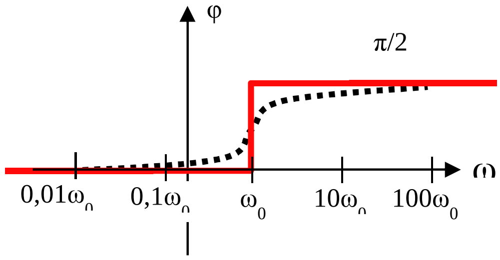
$$\varphi(\omega) = arc\left(j\frac{\omega}{\omega_0}\right)$$



Valós tengelyen zérus ($s = -\omega_o$):

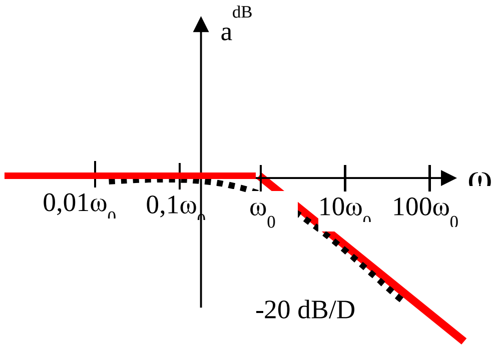


$$\left(1+\frac{s}{\omega_0}\right) \qquad a(\omega) = 20\log_{10}\left|1+j\frac{\omega}{\omega_0}\right|$$



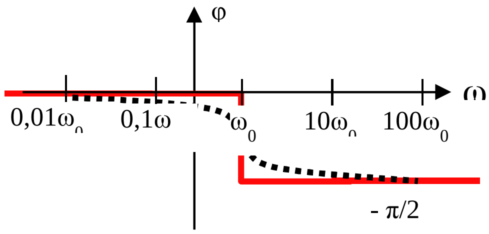
$$\varphi(\omega) = arc\left(1+j\frac{\omega}{\omega_0}\right)$$

Valós tengelyen pólus ($s = -\omega_o$):

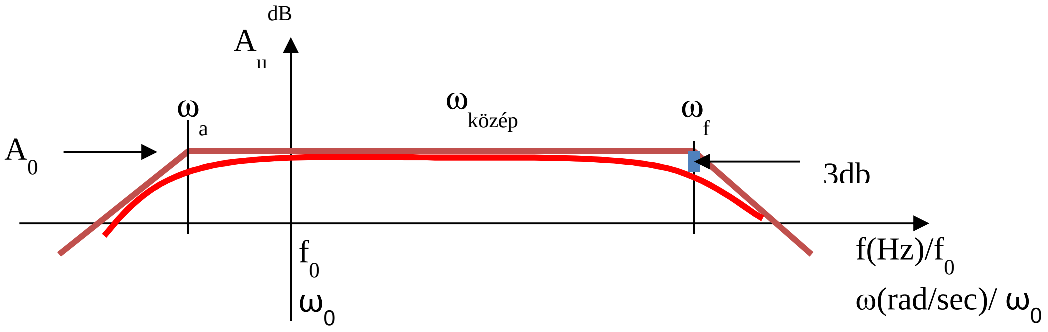


$$\frac{1}{\left(1+\frac{s}{\omega_0}\right)} \qquad a(\omega) = 20\log_{10}\left|\frac{1}{1+j\frac{\omega}{\omega_0}}\right|$$

$$= -20\log_{10}\left|1+j\frac{\omega}{\omega_0}\right|$$

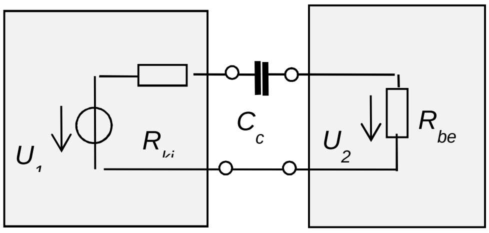


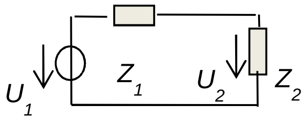
Erősítők frekvencia függése:



- Kisfrekvenciás hatások → ω_a
  az áramkörbe beépített, szándékoltan nagy értékű kondenzátorok hatásai
  - csatoló kondenzátor hatása
  - hidegítő (emitter, source)kondenzátor hatása
  -
- Nagyfrekvenciás hatások → ω_f
  parazita, (nem szándékolt de tudomásul veendő) kis értékű kapacitások hatásai
  - kapacitív terhelés hatása
  - visszaható kapacitás hatása

A csatoló kondenzátor hatása:

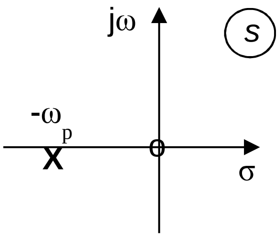


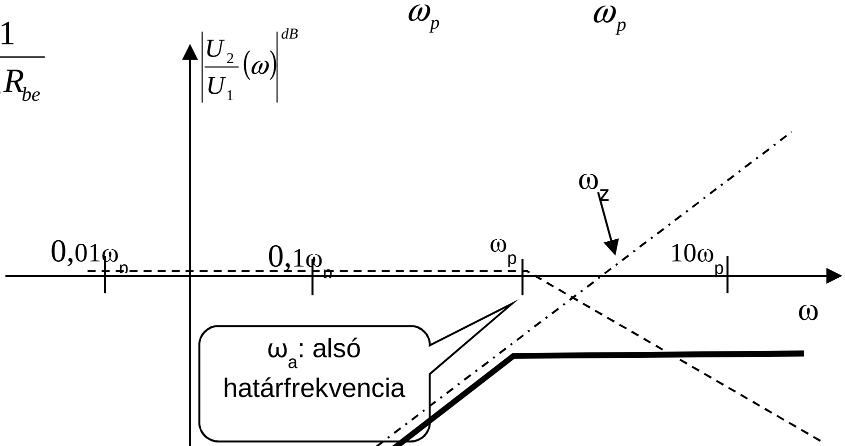


$$Z_1(s) = R_{ki} + \frac{1}{sC} \qquad Z_2(s) = R_{be}$$

$$\frac{U_2}{U_1}(s) = \frac{Z_2}{Z_1 + Z_2} = \frac{R_{be}}{R_{ki} + \frac{1}{sC} + R_{be}} = \frac{sC_cR_{be}}{1 + sC_c\left(R_{ki} + R_{be}\right)} = \frac{\frac{s}{\omega_z}}{1 + \frac{s}{\omega_p}} = K_\infty \frac{\frac{s}{\omega_p}}{1 + \frac{s}{\omega_p}}$$

$$\omega_p = \frac{1}{C_c\left(R_{ki} + R_{be}\right)} < \omega_z = \frac{1}{C_cR_{be}}$$

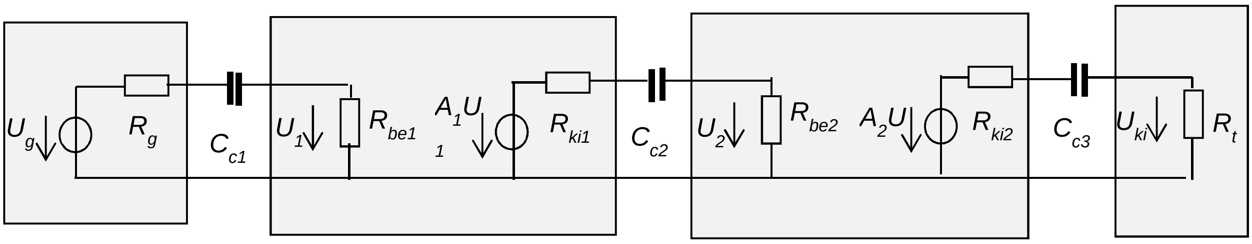




$$K_\infty = \frac{\omega_p}{\omega_z} = \frac{R_{be}}{R_{ki} + R_{be}}$$

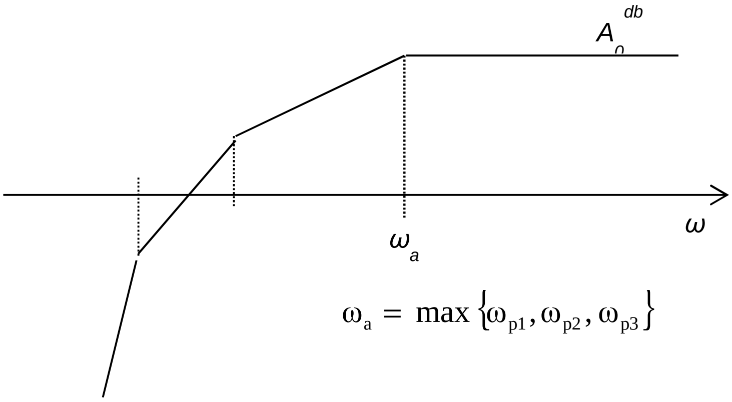
Csatoló kondenzátor lehet:

a bemeneten, a fokozatok közt, a kimeneten.



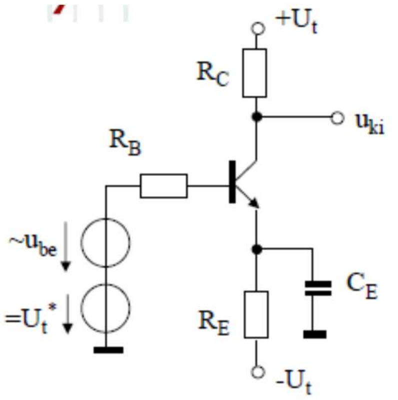
$$\omega_{p1} = \frac{1}{C_{c1}(R_g + R_{be1})} \qquad \omega_{p2} = \frac{1}{C_{c2}(R_{ki1} + R_{be2})} \qquad \omega_{p1} = \frac{1}{C_{c3}(R_{ki2} + R_t)}$$

$$A(s) = \frac{U_{ki}}{U_g} = A_0 \frac{\frac{s}{\omega_{p1}}\frac{s}{\omega_{p2}}\frac{s}{\omega_{p3}}}{\left(1+\frac{s}{\omega_{p1}}\right)\left(1+\frac{s}{\omega_{p2}}\right)\left(1+\frac{s}{\omega_{p3}}\right)} \qquad A_0 = \frac{U_{ki}}{U_g} = \frac{R_{be1}}{R_g + R_{be1}} A_1 \frac{R_{be2}}{R_{ki1} + R_{be2}} A_2 \frac{R_t}{R_{ki2} + R_t}$$



$$\omega_a = \max\{\omega_{p1}, \omega_{p2}, \omega_{p3}\}$$

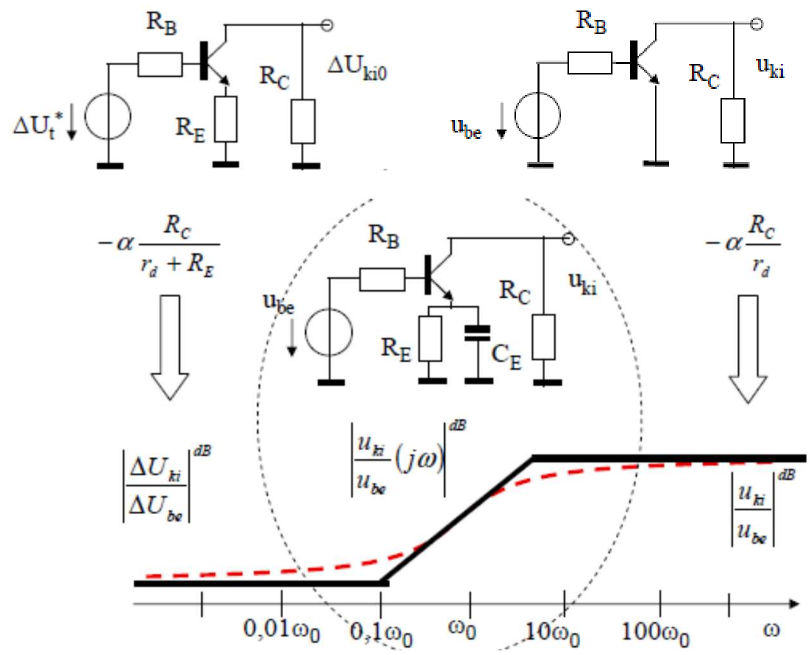
Az emitter (hidegítő) kondenzátor hatása



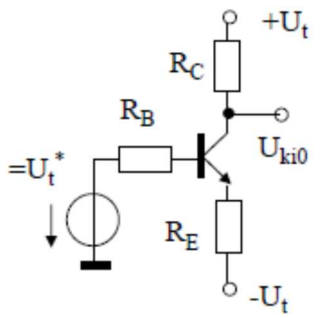
Váltóáramú modell(ek):

statikus változás
kisfrekvenciás,
frekvencia független

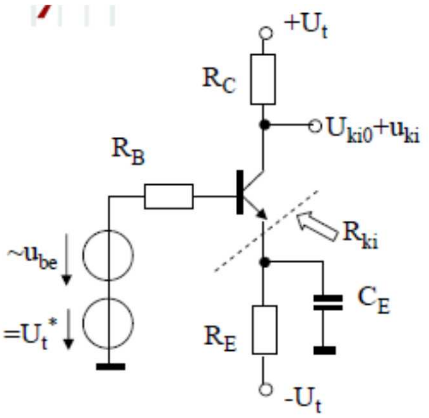
dinamikus változás
nagyfrekvenciás,
frekvenciafüggetlen

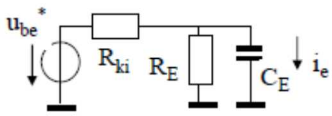


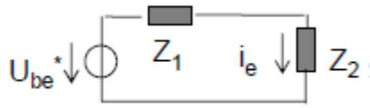
Egyenáramú modell:



Részletes frekvenciafüggő analízis:







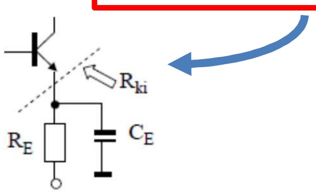
$$Z_1(s) = R_{ki}$$

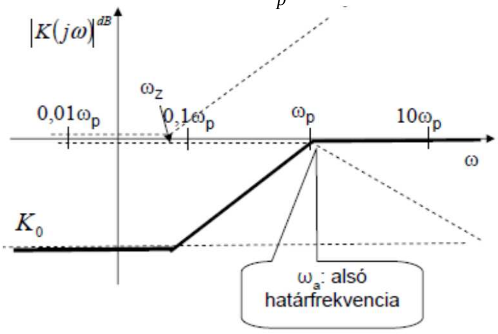
$$Z_2(s) = R_E \times \frac{1}{sC_E} = \frac{R_E}{1 + sR_E C_E}$$

$$\frac{u_{ki}}{u_{bei}}(s) = (-\alpha R_C)\frac{i_e}{u^*_{bei}}(s)\frac{u^*_{be}}{u_{be}} \qquad \frac{i_e}{u^*_{bei}}(s) = ?$$

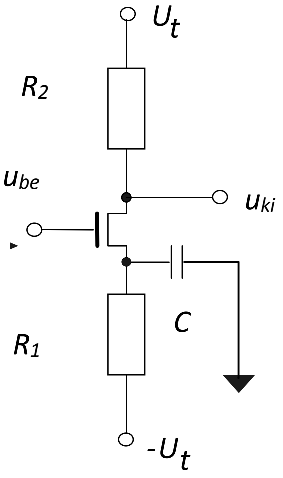
$$\frac{i_e}{u^*_{be}}(s) = \frac{1}{Z_1 + Z_2} = \frac{1 + sR_E C_E}{R_{ki} + R_E + sC_E R_E R_{ki}} = \frac{1}{R_{ki} + R_E}\,\frac{1 + sR_E C_E}{1 + s(R_E \times R_{ki})C_E} = \frac{1}{R_{ki}} K_0 \frac{1 + \frac{s}{\omega_z}}{1 + \frac{s}{\omega_p}} = \frac{1}{R_{ki}} K(s)$$

$$K_0 = \frac{R_{ki}}{R_{ki} + R_E} \qquad \omega_z = \frac{1}{C_E R_E} \qquad \boxed{\omega_p = \frac{1}{C_E (R_E \times R_{ki})}}$$



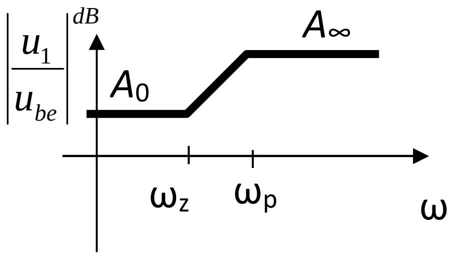


Példa:



R_1 = 6 kΩ, R_2 = 12 kΩ, C = 10 µF

a tranzisztor meredeksége: S = 1 mS



$$\omega_z = \frac{1}{C\ R_1} = \frac{1}{10*10^{-6}*6*10^3} = \frac{1000}{60} = 16.63\frac{rad}{\sec}$$

$$\omega_p = \frac{1}{C(R_1 \times R_{Ski})}\Bigg|_{R_{Ski}=1/S} = \frac{1+SR_1}{CR_1} = \frac{1+1*6}{10*10^{-6}*6*10^3} = \frac{7000}{60} = 116.7\frac{rad}{\sec}$$

$$A_{10} == -\frac{R_2 S_1}{1+S_1 R_1} = -\frac{12}{7}$$

a_o = 4,7 dB

$$A_{1\infty} == A_{10}\frac{\omega_{p1}}{\omega_{z1}} = A_1 = -R_2 S_1 = -12$$

a_∞=21,6 dB