TSTE05 Elektronik & mätteknik

Föreläsning 14

GE-steg - Småsignalschema

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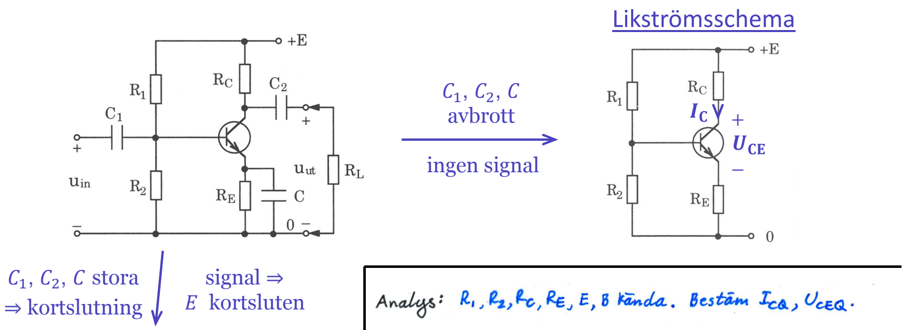
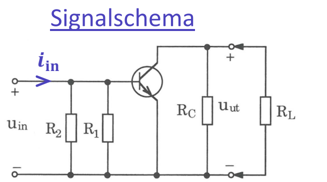
Superposition – Separera likström och signal



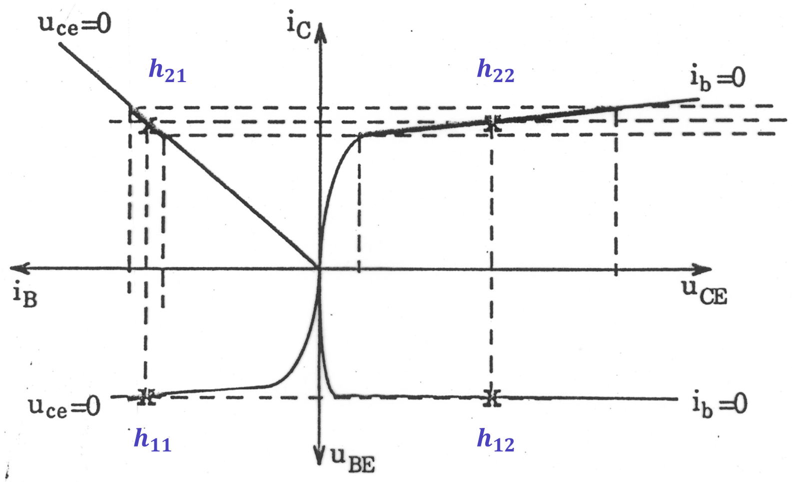


Analys: R_1, R_2, R_C, R_E, E, B kända. Bestäm I_{CQ}, U_{CEQ}.

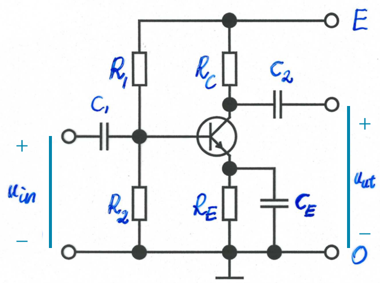
Syntes: I_{CQ}, U_{CEQ} givna. Bestäm R_1, R_2, R_C, R_E.
E och B kan ev. vara givna eller behöva bestämmas.

Av intresse: Förstärkning $F = \frac{u_{ut}}{u_{in}}$.
Ibland frekvenssvar $H(\omega)$.
Inimpedans $Z_{in} = u_{in}/i_{in}$
Utimpedans Z_{ut}

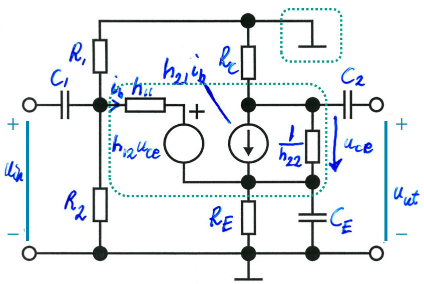
h-parametrar – derivator i arbetspunkten



GE-stegets småsignalschema 1(2)

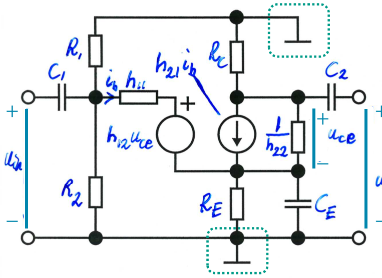


Förstärkarsteget

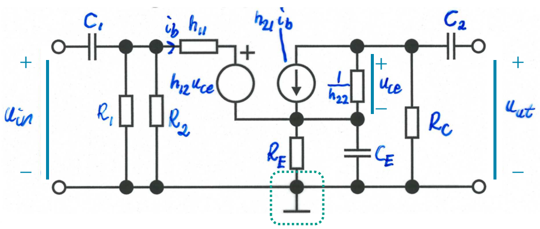


Ekvivalent småsignalschema

GE-stegets småsignalschema 2(2)

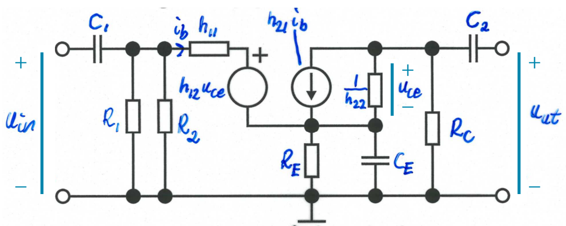


Ursprungligt
ekvivalent småsignalschema

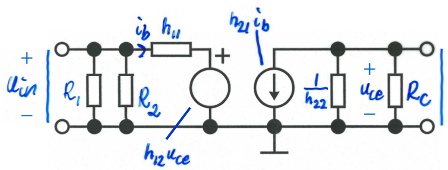


Omritat
ekvivalent småsignalschema

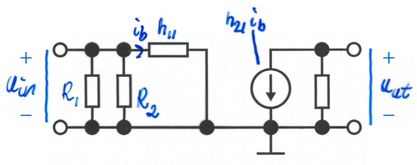
Vanliga approximationer



Fullständigt småsignalschema

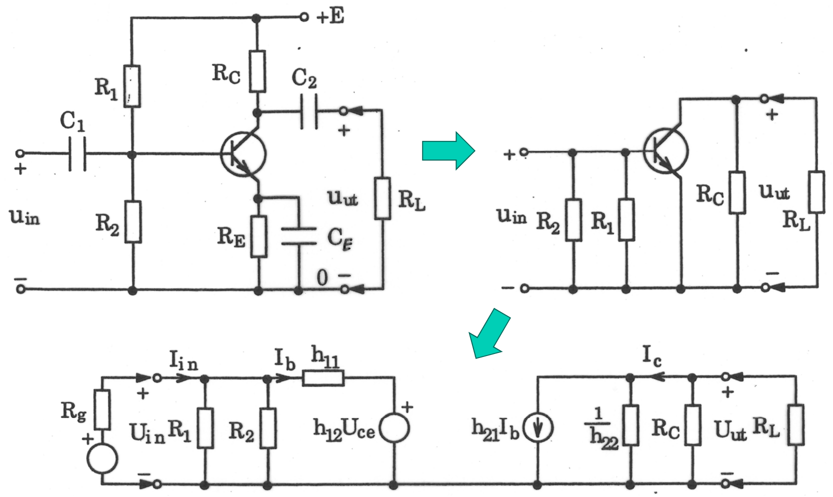


Stora kapacitanser



Förenklad transistormodell

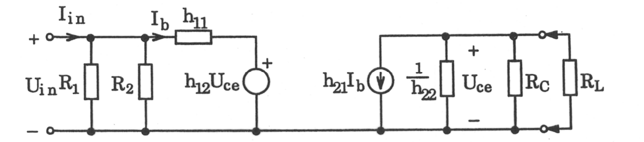
Småsignalschema – bokens väg



Inimpedans, utimpedans, förstärkning

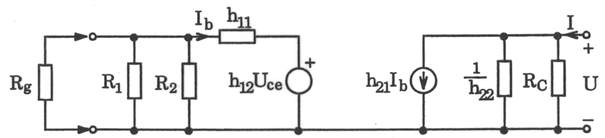
Bestämning av Z_{in}
(Inimpedans)

$$Z_{in} = \frac{U_{in}}{I_{in}}$$



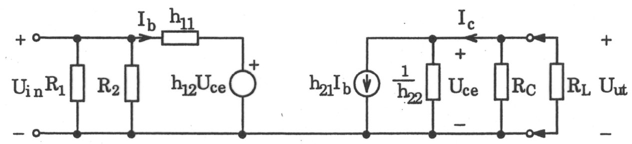
Bestämning av Z_{ut}
(Utimpedans)

$$Z_{ut} = \frac{U}{I}$$

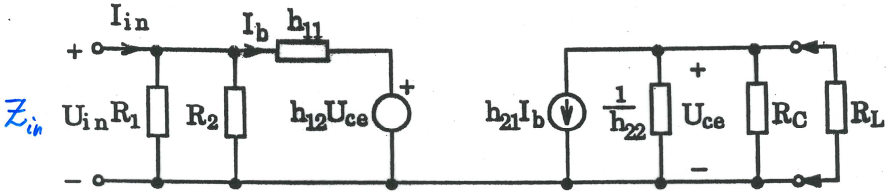


Bestämning av F
(Förstärkning)

$$F = \frac{U_{ut}}{U_{in}}$$



Bestämning av inimpedansen $\boldsymbol{Z}_{\mathbf{in}}$



$$Z_{in} = \frac{U_{in}}{I_{in}} \qquad R_P = \frac{1}{h_{22}} // R_C // R_L$$

KVL: $U_{in} - h_{11}I_b - h_{12}U_{ce} = 0$

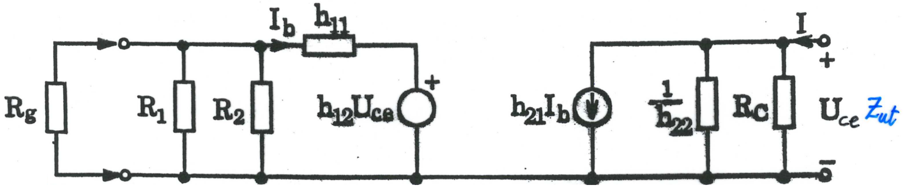
KCL: $I_{in} - I_b - \frac{U_{in}}{R_1} - \frac{U_{in}}{R_2} = 0$

Ohms lag: $U_{ce} = -h_{21}I_bR_P$

$$\Rightarrow \quad Z_{in} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{h_{11}} - \frac{h_{12}}{h_{11}\left(h_{12} - \frac{1}{h_{21}R_P}\right)}} \approx R_1 // R_2 // h_{11}$$

$h_{12} \approx 0$

Bestämning av utimpedansen $\boldsymbol{Z}_{\mathbf{ut}}$



$$R_A \approx R_g // R_1 // R_2 \qquad Z_{ut} = \frac{U_{ce}}{I} \qquad R = \frac{1}{h_{22}} // R_C$$

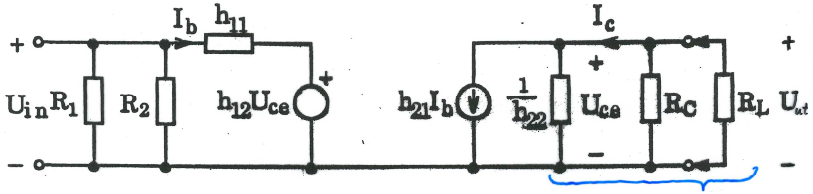
KVL: $h_{12}U_{ce} + I_b \cdot (h_{11} + R_A) = 0$

KCL: $I - h_{21}I_b - \frac{U_{ce}}{R} = 0$

$$\Rightarrow \quad Z_{ut} = \frac{1}{h_{22} + \frac{1}{R_C} - \frac{h_{12}h_{21}}{h_{11} + R_A}} \approx \frac{1}{h_{22}} // R_C$$

$h_{12} \approx 0$

Bestämning av resulterande förstärkning $\boldsymbol{F}$



R_P

KVL: $U_{in} - h_{11}I_b - h_{12}U_{ce} = 0$ $\qquad U_{ce} = U_{ut}$

Ohms lag: $U_{ut} = -h_{21}I_b \cdot R_P$

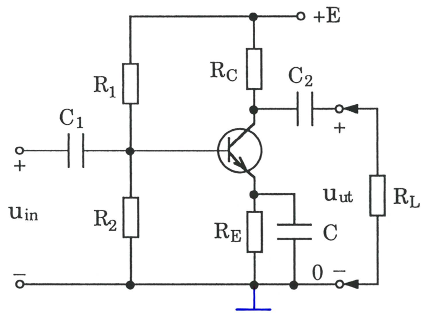
$$\Rightarrow \quad F = \frac{1}{h_{12} - \frac{h_{11}}{h_{21}\cdot\left(\frac{1}{h_{22}} // R_C // R_L\right)}} \approx -\frac{h_{21}(\ldots)}{h_{11}} \approx -\frac{h_{21}}{h_{11}} \cdot (R_C // R_L)$$

Råförstärkning (Ta bort R_L): $\qquad h_{12} \approx 0 \qquad h_{22} \approx 0$

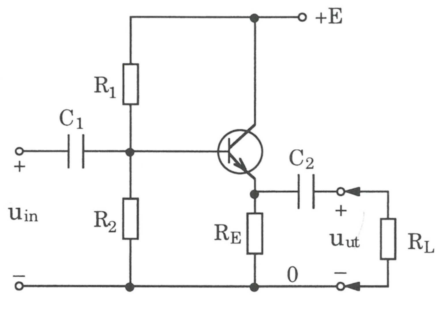
$$A = \frac{1}{h_{12} - \frac{h_{11}}{h_{21}\cdot\left(\frac{1}{h_{22}} // R_C\right)}} \approx -\frac{h_{21}}{h_{11}}\left(\frac{1}{h_{22}} // R_C\right) \approx -\frac{h_{21}}{h_{11}} \cdot R_C$$

GE-steget vs EF-steget (emitterföljare)

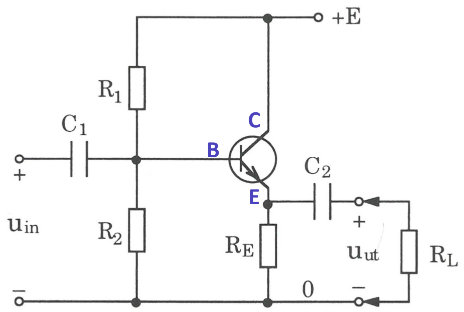
GE-steget



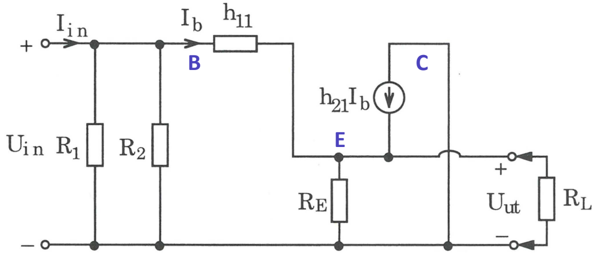
EF-steget



EF-steget



Ekvivalent småsignalschema



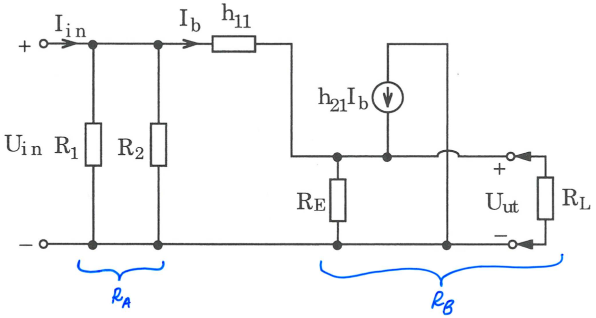
Förenklad transistormodell

$h_{12} \approx 0$

$h_{22} \approx 0$

EF-stegets inimpedans

$Z_{in} = \frac{U_{in}}{I_{in}} \Rightarrow$



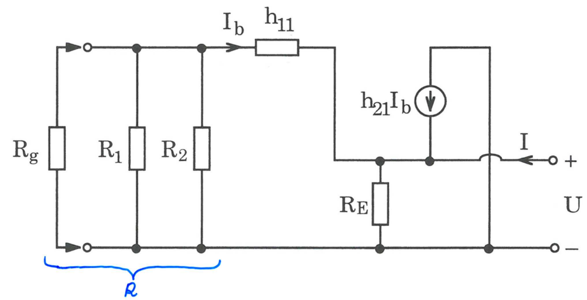
KVL: $U_{in} - h_{11} I_b - R_B(1+h_{21}) I_b = 0$

KCL: $I_{in} - I_b - \frac{U_{in}}{R_A} = 0 \Rightarrow I_b = I_{in} - \frac{U_{in}}{R_A}$

$\Rightarrow$

$$\Rightarrow Z_{in} = \frac{U_{in}}{I_{in}} = R_1 // R_2 // \left(h_{11} + (1+h_{21})(R_E // R_L)\right) \overset{h_{21}\text{ stor}}{\approx} R_1 // R_2$$

EF-stegets utimpedans



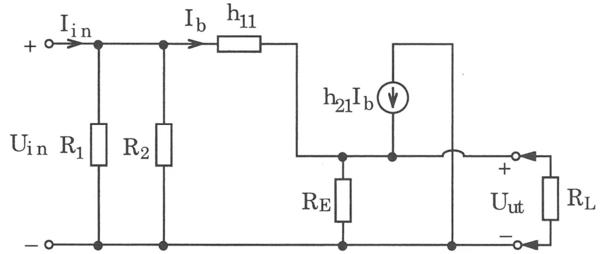
Ohms lag: $U = R_E \cdot (I_b + h_{21} I_b + I)$

Ohms lag: $U = -I_b \cdot (h_{11} + R) \Rightarrow I_b = -\frac{U}{h_{11} + R}$

$\Rightarrow$

$$\Rightarrow Z_{ut} = \frac{U}{I} = R_E // \frac{h_{11} + R_g // R_1 // R_2}{1 + h_{21}} \underset{h_{21}\text{ stor}}{\approx} \frac{h_{11} + R_g // R_1 // R_2}{h_{21}} \underset{h_{11}\text{ liten}}{\approx} \frac{R_g // R_1 // R_2}{h_{21}}$$

EF-stegets förstärkning



KVL: $U_{in} - h_{11} I_b - (R_E // R_L) \cdot (h_{21} + 1) I_b = 0$

Ohms lag: $U_{ut} = (R_E // R_L) \cdot (h_{21} + 1) \cdot I_b$

$\Rightarrow$

$$\Rightarrow F = \frac{U_{ut}}{U_{in}} = \frac{(R_E // R_L) \cdot (h_{21} + 1)}{h_{11} + (R_E // R_L) \cdot (h_{21} + 1)} \underset{h_{21}\text{ stor}}{\approx} 1$$

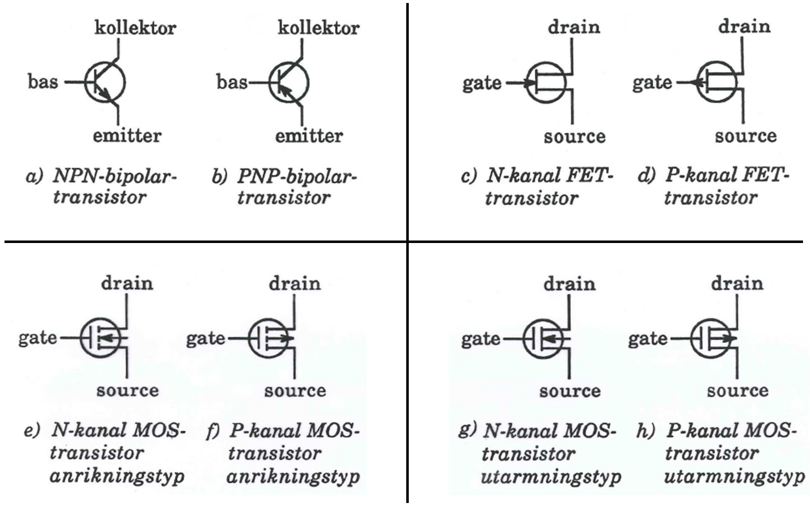
Sammanställning EF-steget

$$Z_{in} = \frac{U_{in}}{I_{in}} = R_1 // R_2 // \left(h_{11} + (1+h_{21})(R_E // R_L)\right) \overset{h_{21}\text{ stor}}{\approx} R_1 // R_2$$

$$Z_{ut} = \frac{U}{I} = R_E // \frac{h_{11} + R_g // R_1 // R_2}{1 + h_{21}} \underset{h_{21}\text{ stor}}{\approx} \frac{h_{11} + R_g // R_1 // R_2}{h_{21}} \underset{h_{11}\text{ liten}}{\approx} \frac{R_g // R_1 // R_2}{h_{21}}$$

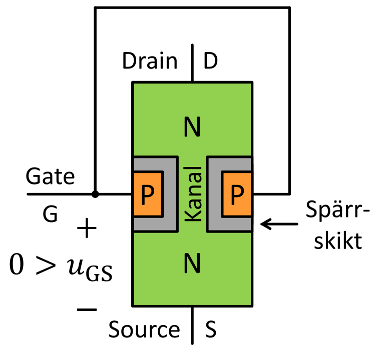
$$F = \frac{U_{ut}}{U_{in}} = \frac{(R_E // R_L)\cdot(h_{21}+1)}{h_{11} + (R_E // R_L)\cdot(h_{21}+1)} \underset{h_{21}\text{ stor}}{\approx} 1$$

Några transistortyper

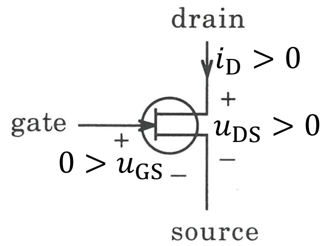


N-kanal JFET-transistor
Junction – Field Effect Transistor

Konstruktion



Symbol



Ju mer negativ u_{GS} görs, desto smalare blir kanalen.

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