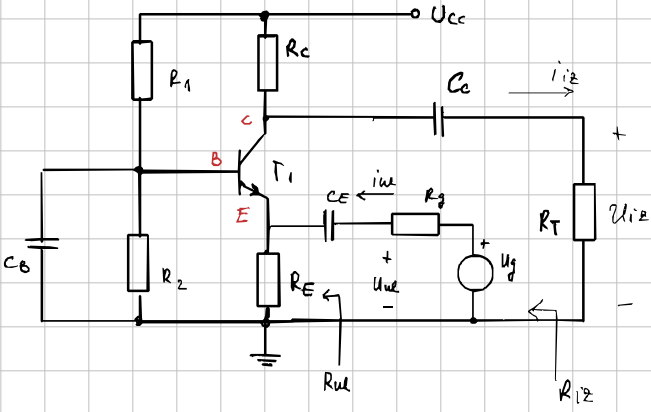
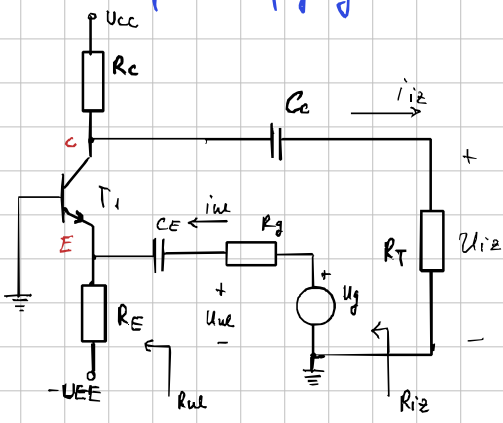
8.3. Pojačalo u SZB i SZC

Pojačalo u SZB

▸ jedan izvor napajanja

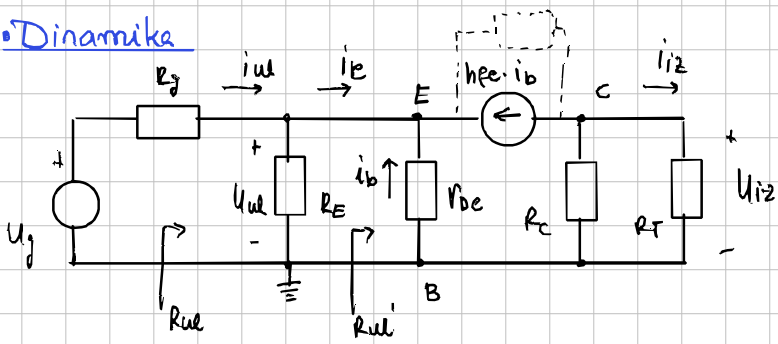


▸ dva napona napajanja



→ statiku znamo izračunati u dva slučaja

• Dinamika



Naponsko pojačanje $u_{ul} = -i_b \cdot r_{be}$ $u_{iz} = -h_{fe} \cdot i_b (R_C \parallel R_T)$

$$A_V = \frac{u_{iz}}{u_{ul}} = h_{fe} \frac{R_C \parallel R_T}{r_{be}} = g_m (R_C \parallel R_T)$$

Strujno pojačanje

$$R_{ul}' = \frac{u_{ul}}{i_e} = \frac{-i_b \cdot r_{be}}{-i_b - h_{fe} \cdot i_b} = \frac{r_{be}}{1+h_{fe}} \approx \boxed{\frac{r_{be}}{h_{fe}} = \frac{1}{g_m} = R_{ul}'}$$

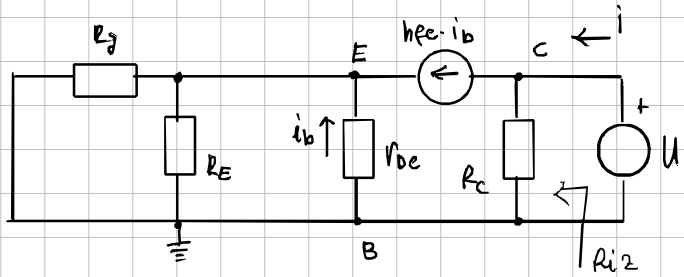
$$i_{iz} = -h_{fe} \cdot i_b \cdot \frac{R_C}{R_C + R_T} \qquad i_c = -(1+h_{fe}) i_b = i_{ul} \cdot \frac{R_E}{R_E + R_{ul}'}$$

$$\boxed{A_I = \frac{i_{iz}}{i_{ul}} = \frac{h_{fe}}{1+h_{fe}} \frac{R_C}{R_C + R_T} \frac{R_E}{R_E + R_{ul}'}}$$

$$\hookrightarrow i_{ul} = -(1+h_{fe}) \cdot \frac{R_E + R_{ul}'}{R_E} \cdot i_b$$

Ulazni i izlazni otpor

$$\boxed{R_{ul} = \frac{u_{ul}}{i_{ul}} = R_E \parallel R_{ul}' \approx R_E \parallel \frac{1}{g_m}}$$



$R_{iz} = \frac{U}{i}$

$u_{ul} = -i_b \cdot r_{be} = i_b (R_g \parallel R_E) + h_{fe} \cdot i_b (R_g \parallel R_E) \longrightarrow i_b' = 0$

$$\boxed{R_{iz} = R_C}$$

Primjer 8.8.) npn

$U_{CC} = U_{EE} = 15V$ $\quad U_T = 25mV$

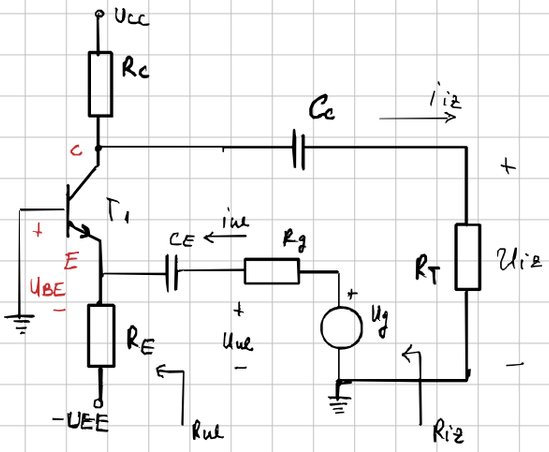
$R_g = 500\Omega$ $\quad R_E = ?$ $\quad \hookrightarrow I_{CQ} = 3mA$

$R_C = 2k\Omega$

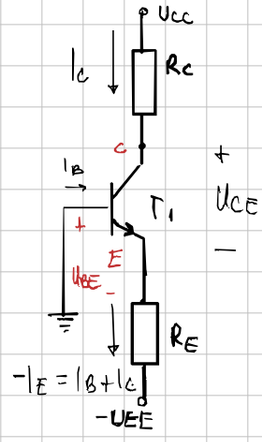
$R_T = 1.2k\Omega$ $\quad A_V = ?$

$\beta \approx h_{fe} = 100$ $\quad A_I = ?$

$U_\gamma = 0.7V$ $\quad A_{VG} = ?$



Statika



$$-U_{CC} + R_C \cdot I_C + U_{CE} + I_C \cdot R_E - U_{EE} = 0$$

$$U_{CC} + U_{EE} - (R_C + R_E) I_{CQ} = U_{CEQ} \rightarrow \text{izlazni}$$

$$U_{BEQ} + R_E (I_{BQ} + I_{CQ}) - U_{EE} = 0 \qquad I_C = \beta I_{BQ}$$

$$U_{EE} = U_{BEQ} + R_E \cdot I_{CQ} \left(\frac{1}{\beta} + 1\right) \rightarrow \text{ulazni}$$

$$R_E = \frac{U_E - U_{BEQ}}{I_{CQ}\left(\frac{1}{\beta} + 1\right)} = \frac{15 - 0.7}{3 \cdot 10^{-3}(0.01 + 1)}$$

$$\boxed{R_E = 4.719k\Omega}$$

Dinamički parametri

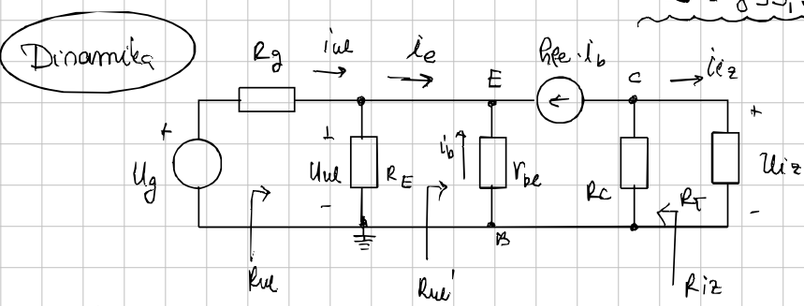
$$g_m \approx \frac{I_C}{U_T} \qquad r_{be} = \frac{U_T}{I_B} \qquad r_c = \frac{U_A}{I_C}$$

$$g_m = \frac{3 \times 10^{-3}}{25 \times 10^{-3}} \rightarrow g_m = 120 mA/V$$

$$r_{be} = \frac{U_T}{I_C} \cdot \beta = \frac{25}{3} \cdot 100$$

$$r_{be} = 833.3\Omega \rightarrow r_{be} = \frac{h_{ee}}{g_m}$$

Dinamika



Av2 ?
AI = ?
AVG = ?

$$A_V = \frac{U_{iz}}{U_{ul}} \qquad i_e = i_{ul} \cdot \frac{R_E}{R_E + R_{ul}'} \qquad U_{iz} = -h_{fe} \cdot i_b (R_C \| R_T)$$

$$U_{ul} = -i_b \cdot r_{be} \rightarrow A_V = h_{fe} \cdot \frac{R_C \| R_T}{r_{be}} \rightarrow g_m (R_C \| R_T)$$

$$\boxed{A_V = 90}$$

$$A_I = \frac{i_{iz}}{i_{ul}} \qquad i_{iz} = -h_{fe} \cdot i_b \frac{R_C}{R_C + R_T}$$

$$i_e = i_{ul} \cdot \frac{R_E}{R_E + R_{ul}} = -(1 + h_{fe}) i_b$$

$$i_{ul} = -(1 + h_{fe}) \cdot \left(\frac{R_E}{R_E + R_{ul}'}\right)^{-1} \cdot i_b$$

$$\Rightarrow A_I = \frac{h_{fe}}{1 + h_{fe}} \cdot \frac{R_C}{R_C + R_T} \cdot \frac{R_E}{R_E + R_{ul}'} = 0.62$$

$$A_{VG} = \frac{U_{iz}}{U_g} = \frac{U_{iz}}{U_{ul}} \cdot \frac{U_{ul}}{U_g} = A_V \cdot \frac{1}{U_g} \cdot U_g \cdot \frac{R_{ul}}{R_g + R_{ul}}$$

$$\boxed{A_{VG} = 1.46}$$

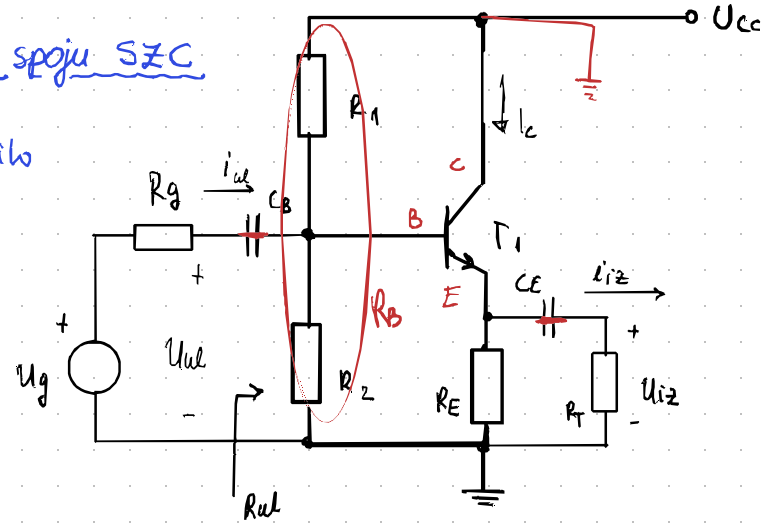
$R_{ul} = R_E \| R_{ul}'$

$R_{ul} = 824\Omega$

$R_{iz} = R_C = 2k\Omega$

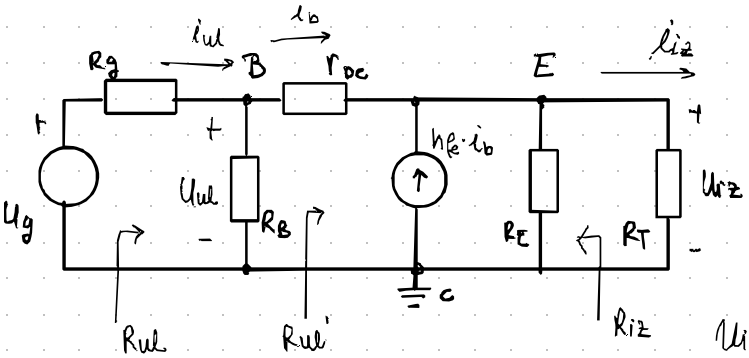
Pojačalo u spoju SZC

→ emiterski sljedilo



Statika: ostaje ista

▸ Dinamika



$$U_{ul} = i_b \cdot r_{be} + i_b (R_E \| R_T) + h_{fe} i_b (R_E \| R_T)$$

$$U_{ul} = i_b \cdot r_{be} + \underbrace{(1+h_{fe})(R_E \| R_T) i_b}_{U_{iz}}$$

$$U_{iz} = (1+h_{fe}) i_b (R_E \| R_T)$$

Naponsko pojačanje

$$A_V = \frac{U_{iz}}{U_{ul}} = \frac{(1+h_{fe})(R_E \| R_T)}{r_{be} + (1+h_{fe})(R_E \| R_T)}$$

$$A_V \approx \frac{h_{fe}(R_E \| R_T)}{r_{be} + h_{fe}(R_E \| R_T)} = \frac{g_m (R_E \| R_T)}{1 + g_m (R_E \| R_T)}$$

$$R_{ul}' = \frac{U_{ul}}{i_b} = r_{be} + (1+h_{fe})(R_E \| R_T) \approx r_{be} + h_{fe}(R_E \| R_T)$$

$$R_{ul} = R_B \| R_{ul}' \rightarrow \text{Ulazni otpor}$$

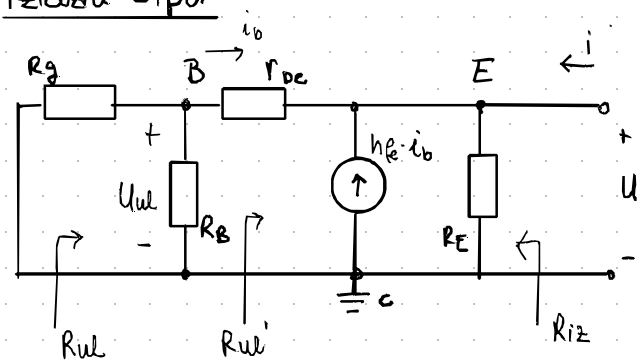
Strujno pojačanje

$$i_b = i_{ul} \cdot \frac{R_B}{R_B + R_{ul}'} \rightarrow i_{ul} = i_b \cdot \left(\frac{R_B}{R_B + R_{ul}'}\right)^{-1}$$

$$i_{iz} = (1+h_{fe}) \cdot i_b \cdot \frac{R_E}{R_E + R_T}$$

$$A_I = \frac{(1+h_{fe})\frac{R_E}{R_E+R_T}}{\left(\frac{R_B}{R_B+R_{ul}'}\right)^{-1}} = (1+h_{fe})\frac{R_E}{R_E+R_T} \cdot \frac{R_B}{R_B+R_{ul}'}$$

Izlazni otpor



$$U = U_E - U_C = U_E$$

$$U = -i_b (r_{be} + R_g \| R_B)$$

i = nam treba

$$\frac{i}{u} = \frac{1}{R_E} - \frac{(1+h_{fe}) i_b}{u} = \frac{1}{R_E} + \frac{1+h_{fe}}{R_g \| R_B + r_{be}}$$

$$\Rightarrow R_{iz} = R_E + \frac{R_g \| R_B + r_{be}}{1+h_{fe}}$$

Usporedba osnovnih spojeva pojačala s bipT

Spoj pojačala	SZE	SZB	SZC
A_V	$-g_m(R_C \parallel R_T)$	$g_m(R_C \parallel R_T)$	$\frac{g_m(R_E \parallel R_T)}{1+g_m(R_E \parallel R_T)}$
A_I	$-h_{fe}\frac{R_C}{R_C+R_T}\frac{R_B}{R_B+r_{be}}$	$\frac{h_{fe}}{1+h_{fe}}\frac{R_C}{R_C+R_T}\frac{R_E}{R_E+\frac{r_{be}}{1+h_{fe}}}$	$(1+h_{fe})\frac{R_E}{R_E+R_T}\frac{R_B}{R_B+r_{be}+(1+h_{fe})(R_E \parallel R_T)}$
R_{ul}	$R_B \parallel R_T$	$R_E \parallel \frac{r_{be}}{1+h_{fe}}$	$R_B \parallel \left[r_{be}+(1+h_{fe})(R_E \parallel R_T)\right]$
R_{iz}	R_C	R_C	$R_E \parallel \frac{R_g \parallel R_B + r_{be}}{1+h_{fe}}$