

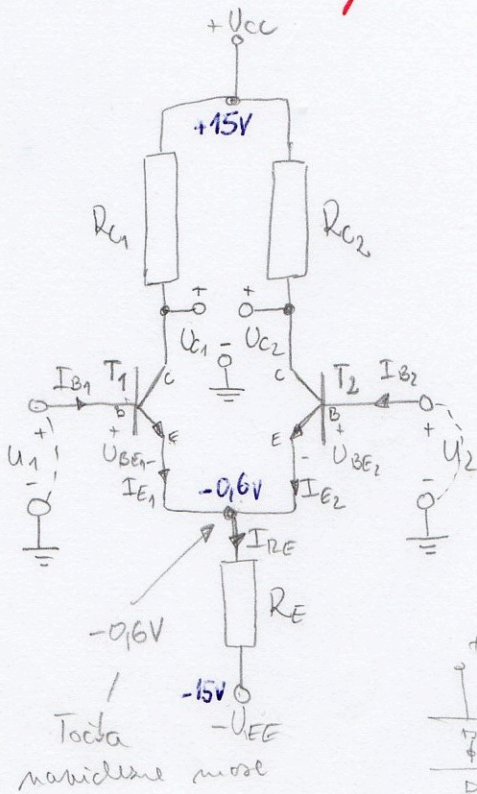
Diferencični ojačevalnik

Indeks:

A_{u12} → nred
1-riod

A_{uds} → simetrično
difuzija

A_{uss} → nred
složi



$$I_{RE} = \frac{U_{RE}}{R_E} = \frac{-U_{BE} - U_{BE}}{R_E}$$

$$U_{BE} + U_{RE} + U_{BE} = 0$$

$$U_{RE} = -U_{BE} - U_{BE} = 15V - 0,6V = \boxed{14,4V}$$

$$I_{RE} = I_{E1} + I_{E2} \approx I_{C1} + I_{C2}$$

Če je ojačanje dovolj veliko.

Zgled:

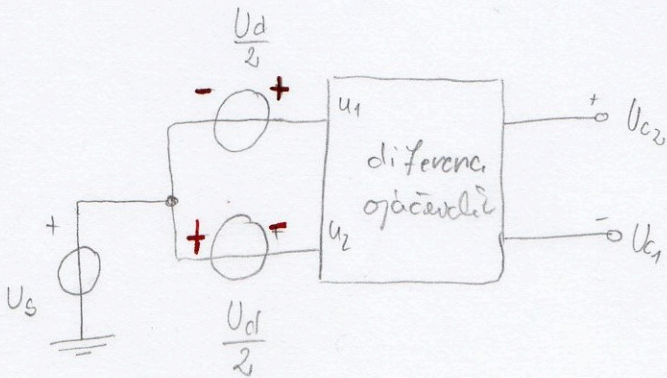
$$U_{CC} = 15V$$

$$U_{BE} = 0,6V$$

Za največjo izkoriščenost elementa:

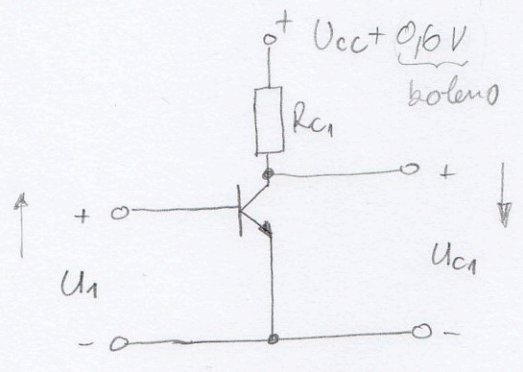
$$U_{CE_{DP}} = \frac{U_{CC} + U_{BE}}{2} = \frac{15V + 0,6V}{2} = \boxed{7,8V}$$

$$U_{C1}, U_{C2} = U_{CC} - U_{CE_{DP}} = 15V - 7,8V = \boxed{7,2V}$$



Na ulozu je diferencni ulazni signal

- Ce se na ulozu toz ali napetost poveca, se na izlazu napetost zmanjsa, toz pa se poveca



Simetrični izhod:

opacuj TR₁

$$A_{u1} = \frac{-R_{c1}}{V_{E1}} = \frac{-R_{c1}}{\frac{U_T}{I_{c1}}} = \frac{U_{c1}}{U_1}$$

$$A_{u2} = \frac{-R_{c2}}{V_{E2}} = \frac{-R_{c2}}{\frac{U_T}{I_{c2}}} = \frac{U_{c2}}{U_2}$$

diferencno opacuj

$$A_{ds} = \frac{U_{c2} - U_{c1}}{U_2 - U_1} = \frac{A_{u2} \cdot U_2 - A_{u1} \cdot U_1}{U_2 - U_1} = \frac{-\frac{R_{c2}}{V_{E2}} \cdot U_2 + \frac{R_{c1}}{V_{E1}} \cdot U_1}{U_2 - U_1}$$

Če velja:

$$R_{c1} = R_{c2}$$

$$V_{E1} = V_{E2}$$

$$\Rightarrow A_{ds} = -\frac{R_c}{V_E} \left(\frac{U_2 - U_1}{U_2 - U_1} \right) = \boxed{\boxed{-\frac{R_c}{V_E}}}$$

Diferencno opacuj stopnje, je avto opacujen enega tranzistorja.

nesimetrični izhod

$$A_{dn1} = \frac{-U_{c1}}{U_2 - U_1} = \frac{-A_{u1} \cdot U_1}{U_2 - U_1} = \frac{-R_{c1}}{V_{E1}} \cdot \frac{-U_1}{U_2 - U_1} = -\frac{R_{c1}}{V_{E1}} \cdot \frac{U_1}{U_2 - U_1}$$

$$U_1 = \frac{U_d}{2}$$

$$U_2 = -\frac{U_d}{2}$$

$$A_{dn1} = \boxed{\boxed{+\frac{R_{c1}}{V_{E1}} \cdot \frac{1}{2}}}$$

- Opacuj nesimetrični signal je avto opacujen enega tranzistorja

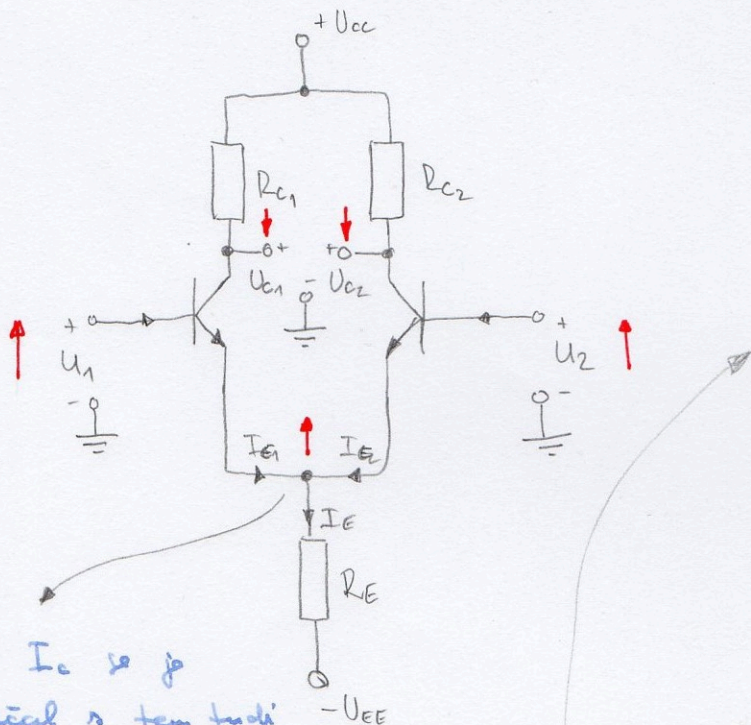


Predznak A_{v1} ... ni toliko pomemben, saj v primeru, da je negativen (inverziven) lahko le premenja signal na vrhodu.

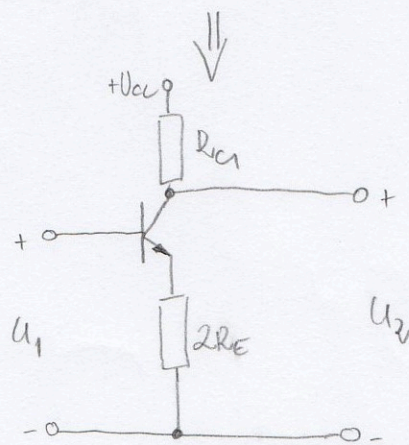
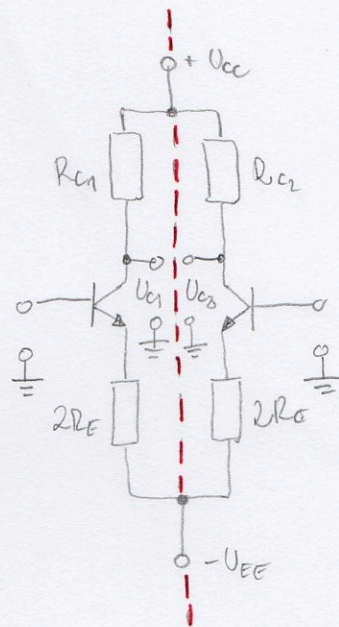
$$R_{vhd1} = (1 + \beta_1) \cdot r_{E1}$$

$$R_{vhd2} = (1 + \beta_2) \cdot r_{E2}$$

Na vrhodu je sofazi signal



Tudi I_C se je povečal s tem tudi toš I_E , tem priimno je tudi padec napetosti na R_E večji. S tem se točka nevtralizacije more drizigue in izgubi ponos, zato nekaj vzdehino:



$$A_{v1s} = - \frac{R_{C1}}{r_{E1} + 2R_{E}} = \frac{U_{C1}}{U_1}$$

opazuj TB.

$$A_{v2s} = - \frac{R_{C2}}{r_{E2} + 2R_{E}} = \frac{U_{C2}}{U_2}$$

$$A_{us} = \frac{U_{c2} - U_{c1}}{u_2 - u_1} = \frac{U_{c2}}{u_2 - u_1} - \frac{U_{c1}}{u_2 - u_1}$$

$$= \frac{A_{us2} \cdot u_2 - A_{us1} \cdot u_1}{u_2 - u_1} = \frac{\frac{-R_{c2}}{r_{E2} + 2R_E} \cdot u_2 + \frac{R_{c1}}{r_{E1} + 2R_E} \cdot u_1}{u_2 - u_1}$$

$$\left. \begin{array}{l} R_{c1} = R_{c2} = R_c \\ r_{E1} = r_{E2} = r_E \end{array} \right\} \Rightarrow A_{us} = \boxed{\frac{-R_c}{r_E + 2R_E}}$$

gledajući saforzni signal
pri simetričnom izlodu A_{us}

$$A_{us_{om1}} = \frac{-U_{c1}}{u_2 - u_1} = \frac{-A_{us} u_1}{u_2 - u_1} = \frac{\frac{R_{c1}}{r_{E1} + 2R_E} \cdot u_1}{u_2 - u_1}$$

$$A_{us_{om2}} = \frac{U_{c2}}{u_2 - u_1}$$

$$H = \left| \frac{A_d}{A_s} \right| = \frac{\cancel{R_c}}{r_E} = \frac{r_E + 2R_E}{\cancel{R_c}} = \boxed{1 + \frac{2R_E}{r_E}}$$

↑
najveći faktor

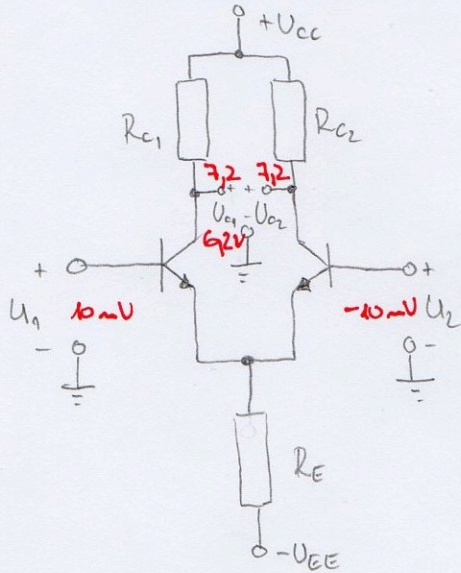
$$CMRR = H[dB] = 20 \log \left| \frac{A_d}{A_s} \right|$$

$$= 20 \log \left| 1 + \frac{2R_E}{r_E} \right|$$

↑
želimo čim veći
najveći faktor.

Tak ojačevalnik ojača enosmerne in izmenične signale, njegova
 $f_{sp} = \emptyset$ Hz.

Če bi obravnavali iz enosmerni:

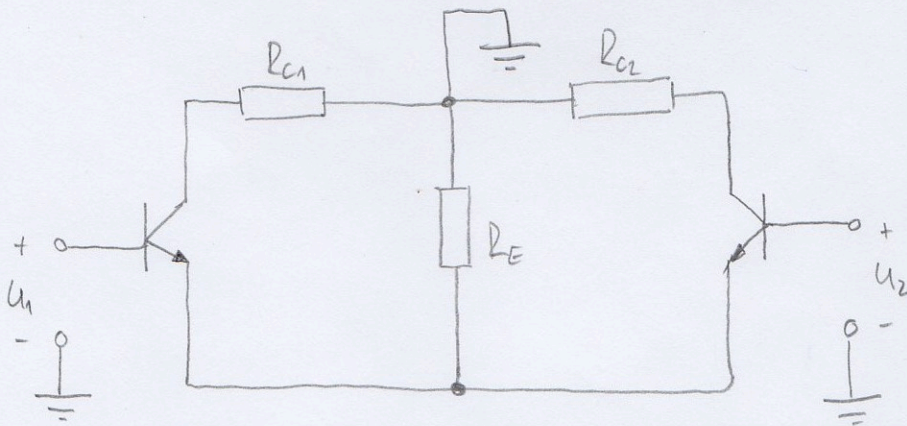


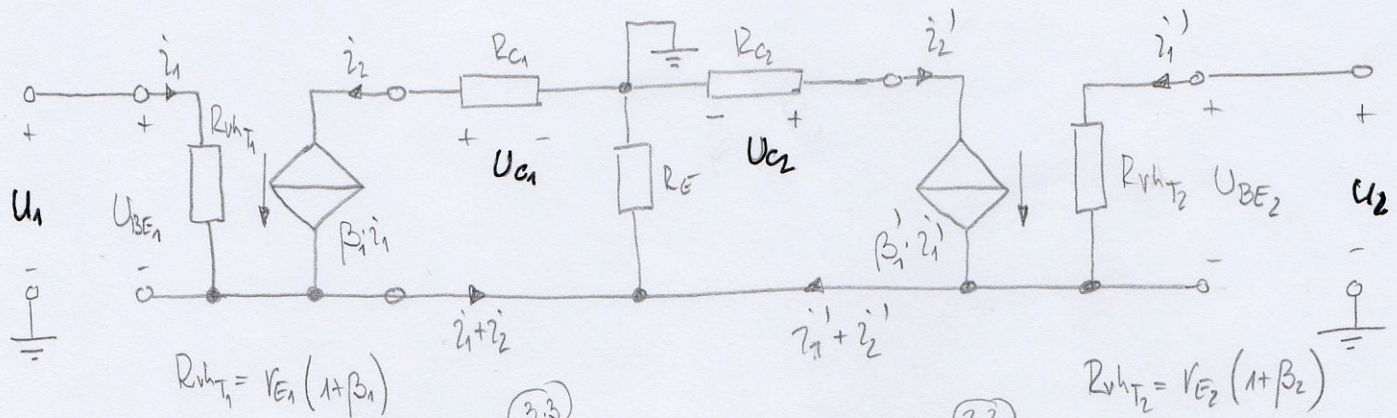
$$A_d = \frac{\Delta U_{02k1} - \Delta U_{02k2}}{\Delta U_{0k1} - \Delta U_{0k2}}$$

$$= \frac{(6,2V - 8,2V) - (8,2V - 6,2V)}{10mV - (-10mV)}$$

$$= \boxed{-200}$$

Izmenično nadomestno vezje, za majhne signale





$$U_{C1} = -i_2 R_{C1}$$

$$U_{C2} = -i_2' R_{C2}$$

$$U_{RE} = (i_1 + i_2 + i_1' + i_2') \cdot R_E$$

$$U_1 = U_{BE1} + U_{RE}$$

$$U_2 = U_{BE2} + U_{RE}$$

$$i_2 = \beta_1 i_1$$

$$i_2' = \beta_1' i_1'$$

$$U_{BE1} = i_1 \cdot R_{vhT1}$$

$$U_{BE2} = i_1' \cdot R_{vhT2}$$

Auf, Auv, H

(zu Anfang in Differenz)

$$U_{RE} = \left(\frac{i_2}{\beta_1} + \frac{i_2'}{\beta_1'} + i_2 + i_2' \right) \cdot R_E = \left(i_2 \left(1 + \frac{1}{\beta_1} \right) + i_2' \left(1 + \frac{1}{\beta_1'} \right) \right) \cdot R_E$$

$$= \left[-\frac{U_{C1}}{R_{C1}} \left(1 + \frac{1}{\beta_1} \right) - \frac{U_{C2}}{R_{C2}} \left(1 + \frac{1}{\beta_1'} \right) \right] \cdot R_E$$

$$U_1 = \frac{i_2}{\beta_1} R_{vhT1} + U_{RE} = -\frac{U_{C1}}{R_{C1}} \cdot \frac{1}{\beta_1} R_{vhT1} + U_{RE}$$

$$U_2 = \frac{i_2'}{\beta_1'} R_{vhT2} + U_{RE} = -\frac{U_{C2}}{R_{C2}} \cdot \frac{1}{\beta_1'} R_{vhT2} + U_{RE}$$

$$U_{abh} = U_2 - U_1$$

$$U_1 = -\frac{U_{C1}}{R_{C1}} \cdot V_{E1} - \frac{U_{C1} R_E}{R_{C1}} \left(1 + \frac{1}{\beta_1}\right) - \frac{U_{C2} R_E}{R_{C2}} \left(1 + \frac{1}{\beta_1}\right)$$

→ će do β ući, so
te sprema zelo
malu ≈ 1 .

$$U_2 = -\frac{U_{C2}}{R_{C2}} \cdot V_{E2} - \frac{U_{C1} R_E}{R_{C1}} \left(1 + \frac{1}{\beta_1}\right) - \frac{U_{C2} R_E}{R_{C2}} \left(1 + \frac{1}{\beta_1}\right)$$

$$U_2 - U_1 = U_{BE2} + U_{CE} - (U_{BE1} + U_{CE})$$

$$= -\frac{U_{C2}}{R_{C2}} V_{E2} + \frac{U_{C1}}{R_{C1}} V_{E1}$$

Izvoditi

$$U_{C1} \left(\frac{V_{E1}}{R_{C1}} - \frac{R_E}{R_{C1}} \right) = -\frac{U_{C2} R_E}{R_{C2}} - U_1$$

ostali

$$U_2 = -U_{C2} \left(\frac{V_{E2}}{R_{C2}} - \frac{R_E}{R_{C2}} \right) - \frac{R_E}{R_{C1}} \cdot \frac{-U_{C2} R_E - U_1}{\frac{V_{E1}}{R_{C1}} - \frac{R_E}{R_{C1}}}$$

$$U_2 \cdot \frac{V_{E1} - R_E}{R_{C1}} - U_1 \cdot \frac{R_E}{R_{C1}} = -U_{C2} \left(\frac{V_{E2} + R_E}{R_{C2}} \cdot \frac{V_{E1} + R_E}{R_{C1}} - \frac{R_E^2}{R_{C1} R_{C2}} \right)$$

$$U_{C2} = \frac{U_1 \frac{R_E}{R_{C1}} - U_2 \frac{V_{E1} + R_E}{R_{C1}}}{\frac{V_{E2} + R_E}{R_{C2}} \cdot \frac{V_{E1} + R_E}{R_{C1}} - \frac{R_E^2}{R_{C1} R_{C2}}} = \frac{U_1 R_E R_{C2} - U_2 (V_{E1} + R_E) R_{C2}}{(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2}$$

ostali

$$\Rightarrow U_{C1} \left(\frac{V_{E1} + R_E}{R_{C1}} \right) = -\frac{R_E}{R_{C2}} \cdot \frac{U_1 R_E R_{C2} - U_2 (V_{E1} + R_E) R_{C2}}{(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2} - U_1$$

$$U_{c1} \left(\frac{V_{E1} + R_E}{R_{c1}} \right) = \frac{-U_1 \frac{R_E}{R_{c1}} \cdot \frac{R_E}{R_{c2}}}{\frac{V_{E2} + R_E}{R_{c2}} \cdot \frac{V_{E1} + R_E}{R_{c1}} - \frac{R_E^2}{R_{c1} R_{c2}}} + \frac{U_2 \frac{V_{E1} + R_E}{R_{c1}} \cdot \frac{R_E}{R_{c2}}}{\frac{V_{E2} + R_E}{R_{c2}} \cdot \frac{V_{E1} + R_E}{R_{c1}} - \frac{R_E^2}{R_{c1} R_{c2}}} - U_1$$

$$U_{c1} \left(\frac{V_{E1} + R_E}{R_{c1}} \right) = \frac{-U_1 R_E^2}{(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2} + \frac{U_2 (V_{E1} + R_E) R_E}{(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2} - U_1$$

$$= \frac{-U_1 (\cancel{R_E^2} + (V_{E2} + R_E)(V_{E1} + R_E) - \cancel{R_E^2})}{(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2} + \frac{U_2 (V_{E1} + R_E) R_E}{(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2}$$

$$U_{c1} = \frac{-U_1 (V_{E2} + R_E)(V_{E1} + R_E) R_{c1} + U_2 R_E R_{c1}}{(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2}$$

$U_{i2k} = U_{c2} - U_{c1} = A_S U_S + A_D U_D$ *Vstavimo U_{c1} in U_{c2}*

$U_1, U_2:$ $U_1 = U_S + \frac{U_D}{2}$

$U_2 = U_S - \frac{U_D}{2}$

$$U_{i2k} = \frac{+U_1 [(V_{E2} + R_E)(V_{E1} + R_E) R_{c1} - R_E R_{c2}] + U_2 [R_E R_{c1} - (V_{E1} + R_E) R_{c2}]}{(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2}$$

$$U_{i2k} = \left(U_S + \frac{U_D}{2} \right) \cdot \text{---} \text{---} \text{---} + \left(U_S - \frac{U_D}{2} \right) \cdot \text{---} \text{---} \text{---}$$



$$U_{\text{reh}} = U_S \cdot \frac{+(V_{E2} + R_E)R_{C1} + R_E R_{C2} + R_E R_{C1} - (V_{E1} + R_E)R_{C2}}{(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2} +$$

$$\frac{U_d}{2} \cdot \frac{+(V_{E2} + R_E)R_{C1} + R_E R_{C2} - R_E R_{C1} + (V_{E1} + R_E)R_{C2}}{(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2} \text{ Aud}$$

D.N.

Au, H

$$U_{cc} = \pm 15V$$

$$I_{C1} = I_{C2} = 2 \text{ mA}$$

$$D_0: 7,5V - C \rightarrow \text{I}$$

$$R_{C1} = \frac{U_{CC}}{I_{C1}} = \frac{U_{CC} - U_{D0}}{I_{C1}} = \frac{15V - 7,5V}{2 \text{ mA}} = \boxed{3750 \Omega}$$

$$R_{C1} = R_{C2}$$

$$I_E = I_{C1} + I_{C2} = 2 \cdot 2 \text{ mA} = \boxed{4 \text{ mA}}$$

$$R_E = \frac{U_{RE}}{I_E} = \frac{-U_{BE} - U_{CE}}{I_E} = \frac{-0,6V + 15V}{4 \text{ mA}} = \boxed{3,6 \text{ k}\Omega}$$

$$V_{E1} = V_{E2} = \frac{U_I}{I_{E1}} = \frac{U_I}{I_{C1}} = \frac{25,9 \mu V}{2 \mu A} = \boxed{12,95 \Omega}$$

$$R_{C1} = R_{C2}; V_{E1} = V_{E2} \Rightarrow \begin{matrix} = R_C & = V_E \end{matrix}$$

$$A_{us} = \frac{+(V_{E2} + R_E)R_{C1} + R_E R_{C2} + R_E R_{C1} - (V_{E1} + R_E)R_{C2}}{(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2} = \emptyset$$

$$A_{u_{sh}} = \frac{+(V_{E2} + R_E)R_{C1} + R_E R_{C2} - R_E R_{C1} + (V_{E1} + R_E)R_{C2}}{2 \cdot [(V_{E2} + R_E)(V_{E1} + R_E) - R_E^2]} = \frac{2[(V_E + R_E)R_C - R_E^2]}{2[(V_E + R_E)(V_E + R_E) - R_E^2]}$$

$$= \frac{361295 \cdot 3750 - 3600 \cdot 3750}{361295^2 - 3600^2} = \frac{48562,5}{93407,7025}$$



\downarrow
 općenito
 diferencijal signal
 pri simetričnom
 odjenu

$$A_{ds} = \frac{U_{c2} - U_{c1}}{U_2 - U_1} = \frac{A_{u2} U_2 + A_{u1} U_1}{U_2 - U_1} = \frac{-\frac{R_{c2}}{r_{e2}} \cdot U_2 - \frac{R_{c1}}{r_{e1}} U_1}{U_2 - U_1}$$

$$R_{c1} = R_{c2}; r_{e1} = r_{e2} \Rightarrow -\frac{R_c}{r_e} \left(\frac{U_2 - U_1}{U_2 - U_1} \right)$$

$$A_{ds} = -\frac{R_c}{r_e} = -\frac{3750 \Omega}{12,95 \Omega} = \underline{\underline{289,58}}$$

$$A_{u1SS} = -\frac{R_{c1}}{r_{e1} + 2R_E} = \frac{U_{c1}}{U_1}$$

$$A_{u2SS} = -\frac{R_{c2}}{r_{e2} + 2R_E} = \frac{U_{c2}}{U_2}$$

$$A_{usS} = \frac{U_{c2} - U_{c1}}{U_2 - U_1} = \frac{A_{u2SS} U_2 - A_{u1SS} U_1}{U_2 - U_1} = \frac{-\frac{R_{c2}}{r_{e2} + 2R_E} U_2 + \frac{R_{c1}}{r_{e1} + 2R_E} U_1}{U_2 - U_1}$$

$$\Rightarrow A_{us} = \frac{-R_c}{r_e + 2R_E} = \frac{-3750 \Omega}{12,95 \Omega + 2 \cdot 3600 \Omega} = \underline{\underline{-0,52}}$$

$$H = \left| \frac{A_d}{A_s} \right| = \frac{\frac{R_c}{r_e}}{\frac{R_c}{r_e + 2R_E}} = 1 + \frac{2R_E}{r_e} = 1 + \frac{2 \cdot 3600 \Omega}{12,95 \Omega} = \underline{\underline{556,99}}$$

$$CMRR = H [dB] = 20 \log \left| \frac{A_d}{A_s} \right| = 20 \log 556,99$$

$$= \underline{\underline{54,92 \text{ dB}}}$$