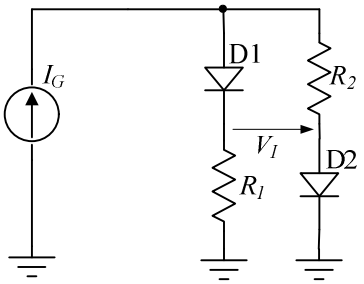
Elementi elektronike – KOLOKVIJUM 2013 - REŠENJA

2. Rešavanje kola za veliki signal



$$V_{D1} + R_1 I_{D1} = V_{D2} + R_2 I_{D2}$$

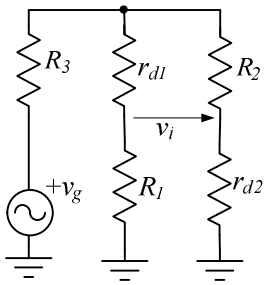
$$I_{D1} + I_{D2} = I_G$$

$$I_{D2} = \frac{I_G}{1 + R_2 / R_1} = 6 \text{ mA}$$

$$I_{D1} = 12 \text{ mA}$$

$$V_I = V_D - R_1 I_{D1} = 0.58 \text{ V}$$

Rešavanje kola za mali signal



$$r_{d1} = \frac{V_T}{I_{D1}} = 2.1\,\Omega$$

$$r_{d2} = \frac{V_T}{I_{D2}} = 4.2\,\Omega$$

$$v_i = \frac{r_{d2}}{R_2 + r_{d2}} v_x - \frac{R_1}{R_1 + r_{d1}} v_x$$

$$v_x = \frac{(R_1 + r_{d1}) \| (R_2 + r_{d2})}{R_3 + (R_1 + r_{d1}) \| (R_2 + r_{d2})} v_g$$

$$v_i = \left(\frac{r_{d2}}{R_2 + r_{d2}} - \frac{R_1}{R_1 + r_{d1}} \right) \frac{(R_1 + r_{d1}) \| (R_2 + r_{d2})}{R_3 + (R_1 + r_{d1}) \| (R_2 + r_{d2})} v_g$$

$$v_i = -0.19 v_g$$

Ukupni izlazni napon je

$v_I = V_I + v_i = 0.58 \text{ V} - 0.19 \text{ V} \sin t$

3. Kroz oba tranzistora teče ista struja. Ako su oba tarnzistora u zasićenju, važi

$$\frac{k_{n2}}{2} {V_{T2}}^2 = \frac{k_{n1}}{2} (V_0 - V_{T1})^2$$

Odavde se za dobija

$$V_0 = V_T \left(1 + \sqrt{\frac{k_{n2}}{k_{n1}}} \right)$$

Tranzistor M1 je sigurno u zasićenju jer su mu drejn i gejt kratko spojeni. Ostaje da se proveri uslov zasićenja za tranzistor M2

$$v_{DS2} \le v_{GS2} - V_{T2}$$

$$V_0 - V_{DD} \le -V_{T2}$$

$$V_0 \le V_{DD} - V_T$$

$$V_T\left(1+\sqrt{\frac{k_{n2}}{k_{n1}}}\right) \le V_{DD} - V_T$$

$$k_{n2} \le k_{n1}\left(\frac{V_{DD}-2V_T}{V_T}\right)^2$$

$$k_{n2} \le k_{n1} = 2\ \text{mA/V}^2$$

Konačno se dobija

$$V_0 = V_T\left(1+\sqrt{\frac{k_{n2}}{k_{n1}}}\right) = 2\ \text{V}$$

$$I_0 = \frac{k_{n2}}{2} V_{T2}{}^2 = 1\ \text{mA}$$

4. a) Deo kola povezan na bazu tranzistora se može predstaviti ekvivalentnim Tevenenovim generatorom:

$V_{TT} = V_{CC}\dfrac{R_2}{R_1+R_2} = 4\ \text{V}$,

$R_{TT} = \dfrac{R_1 R_2}{R_1+R_2} = 2.4\ \text{k}\Omega$.

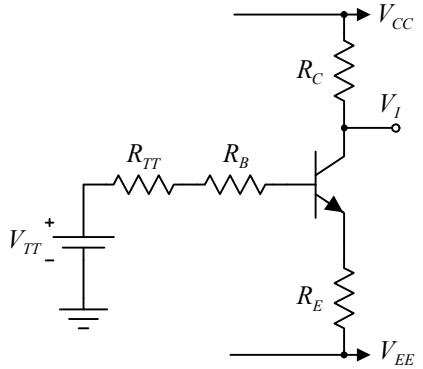
Uz pretpostavku da tranzistor radi u aktivnom režimu, na osnovu slike važi

$V_{TT} - (R_{TT}+R_B)\dfrac{I_C}{\beta} - V_{BE} - R_E\dfrac{1+\beta}{\beta}I_C = 0$,

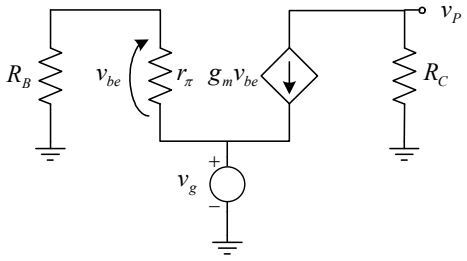
odakle sledi

$I_C = \beta\dfrac{V_{TT}-V_{BE}}{R_{TT}+R_B+(1+\beta)R_E} = 13.41\ \text{mA}$,

$V_I = V_{CC} - R_C I_C = 7.31\ \text{V}$



b) Ekvivalentno kolo pojačavača za male signale je prikazano na slici:



Za kolo sa slike može se pisati:

$v_p = -g_m v_{be} R_C$,

$v_{be} = -\dfrac{r_\pi}{R_B+r_\pi} v_g$.

Na osnovu prethodnih jednačina određuje se naponsko pojačanje pojačavača

$A_v = \dfrac{v_p}{v_g} = \dfrac{g_m r_\pi R_C}{r_\pi + R_B}$.

Ulazna otpornost je:

$$R_u = R_E \left\| \frac{R_B + r_\pi}{1+\beta} \right. .$$

c) Parametri u modelu tranzistora za male signale u mirnoj radnoj tački su:

$$g_m = \frac{I_C}{V_T} = 0.54\,\mathrm{S},$$

$$r_\pi = \frac{\beta}{g_m} = 186\,\Omega,$$

te je naponsko pojačanje pojačavača

$$A_v = 9.13,$$

a ulazna otpornost

$$R_u = 19\,\Omega$$