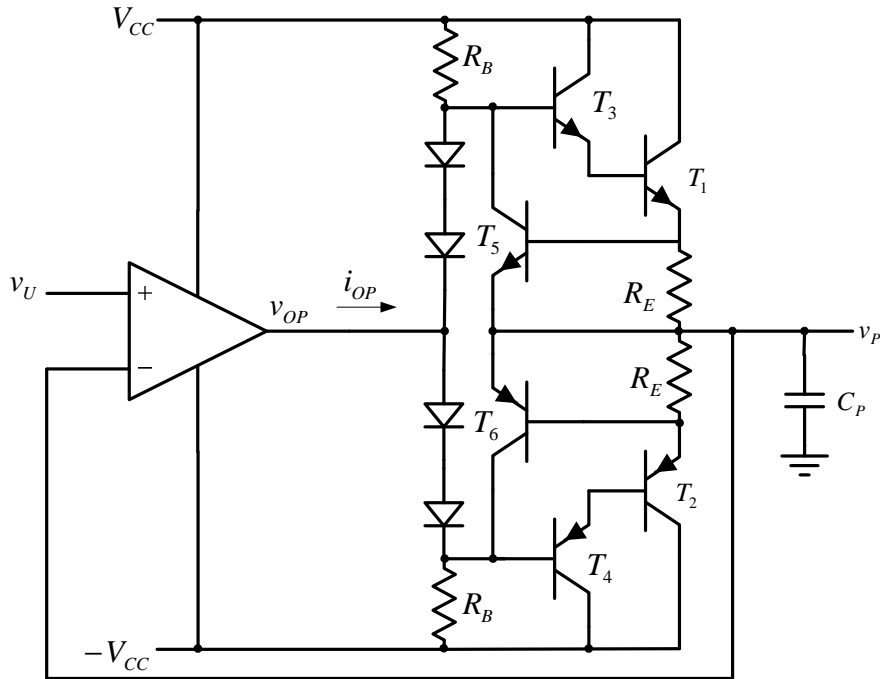


1. U kolu pojačavača snage sa slike 1 ulazni napon je sinusoidalnog talasnog oblika, amplitude V_m i ugaone učestanosti ω . Poznati parametri u kolu su: $V_{CC} = 15 \text{ V}$, $R_B = 1 \text{ k}\Omega$, $R_E = 0.1 \Omega$, $\beta_F = 49$, $C_P = 100 \mu\text{F}$, $V_{BE} = V_D = V_\gamma = 0.7 \text{ V}$, $V_{CES} \approx 0 \text{ V}$.

a) [7] Ako je $V_m = 10 \text{ V}$ i $\omega = 1000 \text{ rad/s}$, odrediti i nacrtati vremenske oblike napona v_P i v_{OP} , struja i_P , i_1 , i_2 i i_{OP} , i snaga p_{D1} i p_{D2} .

b) [3] Za ulazni signal kao u prethodnoj tački, odrediti srednju snagu disipacije na tranzistoru T_1 .

c) [5] Odrediti i skicirati zavisnost maksimalne moguće amplitude neizobličienog izlaznog napona od ugaone učestanosti ulaznog signala.



Slika 1

Rešenje:

a)

$$v_P = v_U = V_m \sin \omega t = 10 \text{ V} \sin \omega t$$

$$v_{OP} = v_P = V_m \sin \omega t = 10 \text{ V} \sin \omega t$$

$$i_P = C \frac{v_P}{dt} = \omega C V_m \cos \omega t = 1 \text{ A} \cos \omega t$$

$$i_1 = \begin{cases} \frac{\beta}{\beta+1} i_P & i_P > 0 \\ 0 & i_P < 0 \end{cases} \approx \begin{cases} \omega C V_m \cos \omega t & 2k\pi < t < (4k+1)\frac{\pi}{2} \vee (4k+3)\frac{\pi}{2} < t < 2(k+1)\pi \\ 0 & (4k+1)\frac{\pi}{2} < t < (4k+3)\frac{\pi}{2} \end{cases}$$

$$i_2 = \begin{cases} -\frac{\beta}{\beta+1} i_P & i_P < 0 \\ 0 & i_P > 0 \end{cases} \approx \begin{cases} -\omega C V_m \cos \omega t & (4k+1)\frac{\pi}{2} < t < (4k+3)\frac{\pi}{2} \\ 0 & 2k\pi < t < (4k+1)\frac{\pi}{2} \vee (4k+3)\frac{\pi}{2} < t < 2(k+1)\pi \end{cases}$$

$$i_P > 0: i_{OP} = \frac{v_P - 2V_D + V_{CC}}{R_B} - \left(\frac{V_{CC} - (v_P + 2V_{BE})}{R_B} - \frac{i_P}{(1 + \beta_F)^2} \right) = \frac{2v_P}{R_B} + \frac{i_P}{(1 + \beta_F)^2}$$

$$i_P < 0: i_{OP} = \frac{v_P - 2V_D + V_{CC}}{R_B} - \frac{i_P}{(1 + \beta_F)^2} - \frac{V_{CC} - (v_P + 2V_{BE})}{R_B} = \frac{2v_P}{R_B} - \frac{i_P}{(1 + \beta_F)^2}$$

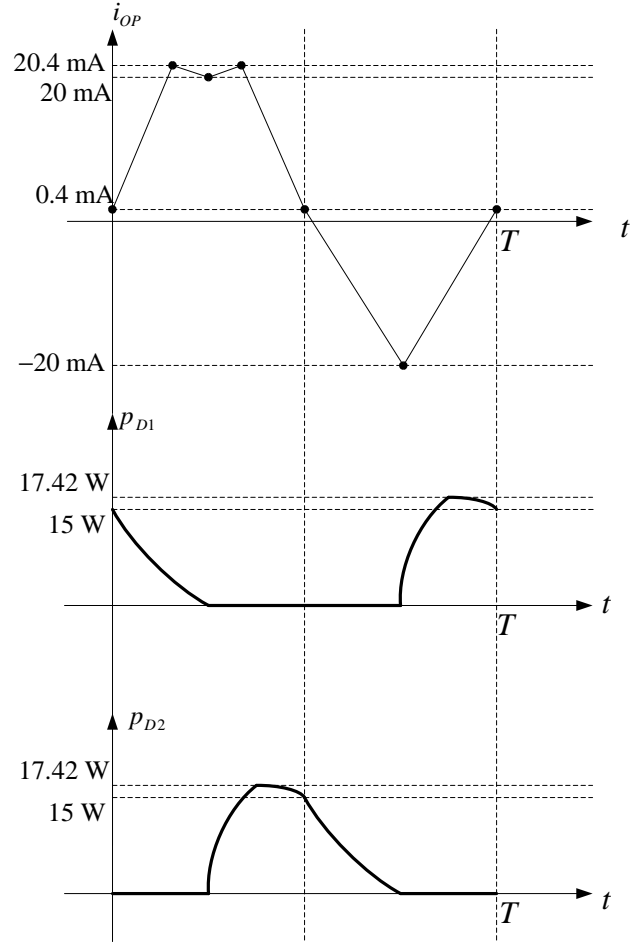
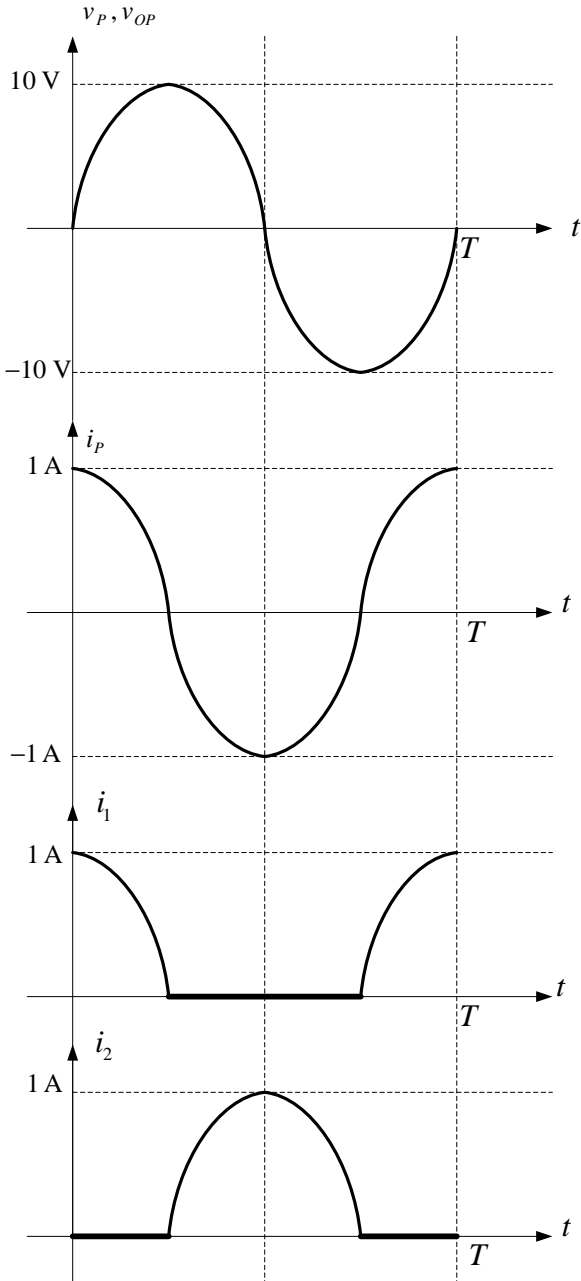
$$i_{OP} = \frac{2v_P}{R_B} + \frac{|i_P|}{(1 + \beta_F)^2} = 20 \text{ mA} \sin \omega t + 0.4 \text{ mA} |\cos \omega t|$$

$$p_{D1} = v_{CE1} i_1 = (V_{CC} - v_P) i_1 = \begin{cases} \frac{\beta}{\beta+1} (V_{CC} - V_m \sin \omega t) \omega C V_m \cos \omega t & 2k\pi < t < (4k+1)\frac{\pi}{2} \vee (4k+3)\frac{\pi}{2} < t < 2(k+1)\pi \\ 0 & (4k+1)\frac{\pi}{2} < t < (4k+3)\frac{\pi}{2} \end{cases} \approx$$

$$\begin{cases} (15 \text{ V} - 10 \text{ V} \sin \omega t) 1 \text{ A} \cos \omega t & 2k\pi < t < (4k+1)\frac{\pi}{2} \vee (4k+3)\frac{\pi}{2} < t < 2(k+1)\pi \\ 0 & (4k+1)\frac{\pi}{2} < t < (4k+3)\frac{\pi}{2} \end{cases}$$

$$P_{D2} = v_{EC2} i_{21} = (v_P + V_{CC}) i_2 = \begin{cases} -\frac{\beta}{\beta+1} (V_m \sin \omega t + V_{CC}) \omega C V_m \cos \omega t & (4k+1)\frac{\pi}{2} < t < (4k+3)\frac{\pi}{2} \\ 0 & 2k\pi < t < (4k+1)\frac{\pi}{2} \vee (4k+3)\frac{\pi}{2} < t < 2(k+1)\pi \end{cases} \approx$$

$$\begin{cases} -(10 \text{ V} \sin \omega t + 15 \text{ V}) 1 \text{ A} \cos \omega t & (4k+1)\frac{\pi}{2} < t < (4k+3)\frac{\pi}{2} \\ 0 & 2k\pi < t < (4k+1)\frac{\pi}{2} \vee (4k+3)\frac{\pi}{2} < t < 2(k+1)\pi \end{cases}$$



b)

$$P_{D1} = \frac{1}{T} \left(\int_{2k\pi}^{(4k+1)\frac{\pi}{2}} \frac{\beta}{\beta+1} (V_{CC} - V_m \sin \omega t) \omega C V_m \cos \omega t dt + \int_{(4k+3)\frac{\pi}{2}}^{2(k+1)\pi} \frac{\beta}{\beta+1} (V_{CC} - V_m \sin \omega t) \omega C V_m \cos \omega t dt \right) = \frac{\beta}{\beta+1} \frac{\omega C V_{CC} V_m}{\pi} \approx$$

$$\frac{\omega C V_{CC} V_m}{\pi} = 4.77 \text{ W}$$

c)

Strujna zaštita uključuje se kada:

$$R_E i_P = V_\gamma \Rightarrow R_E \omega C V_m = V_\gamma$$

Oдавде се добија максимално дозволјена амплитуда по овом критеријуму:

$$V_m \leq \frac{V_\gamma}{R_E C \omega} = \frac{70000}{\omega}$$

Naponsko zasićenje je kritično za tranzistore T_3 i T_4 .

$$v_{CE3} = V_{CC} - (v_P + V_{BE}) \geq V_{CES}$$

Odavde se dobija maksimalno dozvoljena amplitda po ovom kriterijumu:

$$V_m \leq V_{CC} - V_{BE} - V_{CES} = 14.3 \text{ V}$$

Strujno zasićenje javlja se kada sva struja kroz otpornik R_B ode u bazu tranzistora T_3 :

$$\frac{V_{CC} - (v_P + 2V_{BE})}{R_B} \geq \frac{i_P}{(1 + \beta_F)^2} \Rightarrow \frac{V_{CC} - (V_m + 2V_{BE})}{R_B} \geq \frac{\omega C V_m}{(1 + \beta_F)^2}$$

Odavde se dobija maksimalno dozvoljena amplitda po ovom kriterijumu:

$$V_m \leq \frac{V_{CC} - 2V_{BE}}{1 + \frac{\omega R_B C}{(1 + \beta_F)^2}}$$

Konačno:

$$V_{m \max} = \begin{cases} \frac{V_{CC} - 2V_{BE}}{1 + \frac{\omega R_B C}{(1 + \beta_F)^2}} & \omega \leq \omega_{gr} \\ \frac{V_\gamma}{R_E C \omega} & \omega > \omega_{gr} \end{cases}$$

$$\omega_{gr} = \frac{V_\gamma}{C \left(R_E (V_{CC} - 2V_{BE}) - \frac{R_B V_\gamma}{(1 + \beta_F)^2} \right)} = 6481 \text{ rad/s}$$