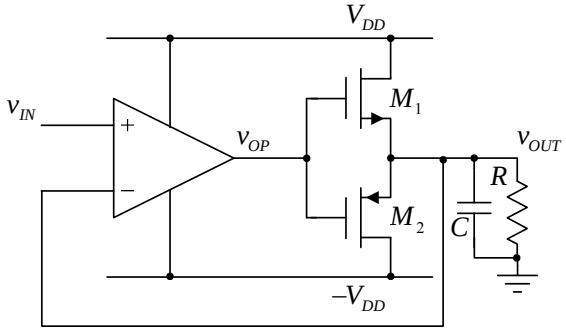
1. U kolu pojačavača snage sa slike 1 ulazni napon je trougaonog talasnog oblika, amplitude V_m i periode T. Poznati parametri u kolu su: $V_{DD}=15\,\text{V}$, $B_1=B_2=1\,\text{A/V}^2$, $V_{T1}=|V_{T2}|=1\,\text{V}$, $P_{D1\max}=P_{D2\max}=30\,\text{W}$.

a) [4] Ako je $V_m=5\,\text{V}$, $T=10\,\mu\text{s}$, $C=1\,\mu\text{F}$, $R\to\infty$, odrediti i nacrtati vremenske oblike napona v_{OUT} i v_{OP}, struja i_{OUT}, i_1 i i_2, i snaga p_{D1} i p_{D2}.

b) [4] Ako je $T=10\,\mu\text{s}$, $C=1\,\mu\text{F}$, $R\to\infty$, odrediti maksimalnu amplitudu ulaznog napona tako da se na izlazu dobija maksimalno moguća amplituda simetričnog neizobličenog napona.

c) [8] Ako je $C=1\,\mu\text{F}$, $R\to\infty$, odrediti i skicirati zavisnost maksimalne amplitude ulaznog napona od T, tako da se na izlazu dobija maksimalno moguća amplituda simetričnog neizobličenog napona.

d) [4] Ako je $T=10\,\mu\text{s}$, $R=1\,\Omega$, $C\to 0$, odrediti maksimalnu amplitudu ulaznog napona tako da se na izlazu dobija maksimalno moguća amlituda simetričnog neizobličenog napona.



Slika 1

Rešenje:

a)

$$v_{OUT}(t)=V_m\Delta(t)=5\,\text{V}\Delta(t)$$

$$i_{OUT}(t)=-\frac{4CV_m}{T}\Pi(t)=-2\,\text{A}\Pi(t)$$

$$i_1(t)=\begin{cases}0, & kT<t<\dfrac{2k+1}{2}T\\[2ex] 2\,\text{A}, & \dfrac{2k+1}{2}T<t<(k+1)T\end{cases}$$

$$i_2(t)=\begin{cases}2\,\text{A}, & kT<t<\dfrac{2k+1}{2}T\\[2ex] 0, & \dfrac{2k+1}{2}T<t<(k+1)T\end{cases}$$

$$v_{OP}(t)=\begin{cases}v_{OUT}(t)-v_{GS2}(t), & kT<t<\dfrac{2k+1}{2}T\\[2ex] v_{OUT}(t)+v_{GS1}(t), & \dfrac{2k+1}{2}T<t<(k+1)T\end{cases}=V_m\Delta(t)-\left(V_T+\sqrt{\frac{8CV_m}{BT}}\right)\Pi(t)$$

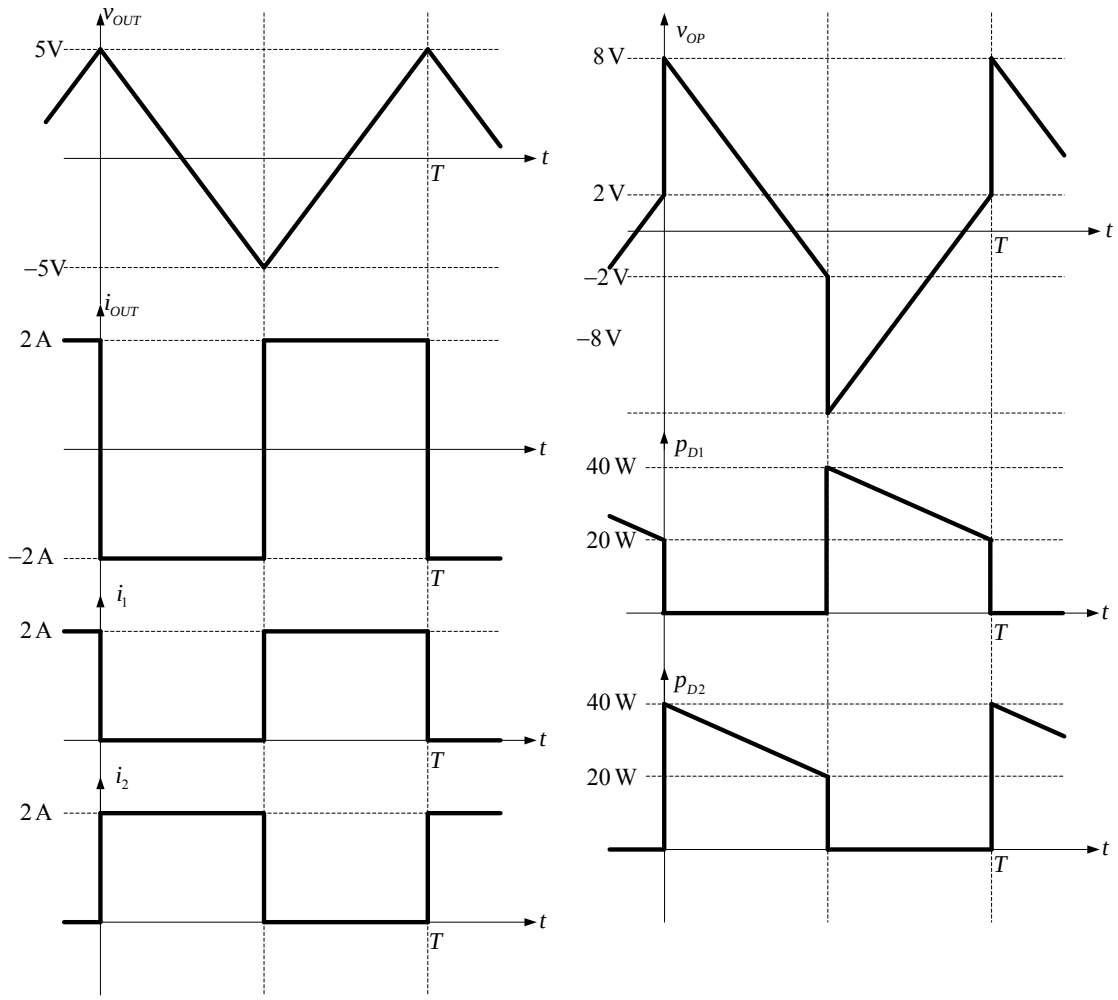
$$v_{OP}(t)=5\,\text{V}\Delta(t)-3\,\text{V}\Pi(t)$$

$$p_{D1}(t) = (V_{DD} - v_{OUT})\, i_1(t) = \begin{cases} 0, & kT < t < \dfrac{2k+1}{2}T \\ \left(V_{DD} - V_m \Delta(t)\right)\dfrac{4CV_m}{T}, & \dfrac{2k+1}{2}T < t < (k+1)T \end{cases}$$

$$p_{D1}(t) = \begin{cases} 0, & kT < t < \dfrac{2k+1}{2}T \\ \left(15\,\mathrm{V} - 5\,\mathrm{V}\Delta(t)\right)2\,\mathrm{A}, & \dfrac{2k+1}{2}T < t < (k+1)T \end{cases}$$

$$p_{D2}(t) = (V_{DD} - v_{OUT})\, i_2(t) = \begin{cases} \left(V_{DD} - V_m \Delta(t)\right)\dfrac{4CV_m}{T}, & kT < t < \dfrac{2k+1}{2}T \\ 0, & \dfrac{2k+1}{2}T < t < (k+1)T \end{cases}$$

$$p_{D2}(t) = \begin{cases} \left(15\,\mathrm{V} - 5\,\mathrm{V}\Delta(t)\right)2\,\mathrm{A}, & kT < t < \dfrac{2k+1}{2}T \\ 0, & \dfrac{2k+1}{2}T < t < (k+1)T \end{cases}$$



b)

Postoje dva uslova:

1. Operacioni pojačavač ne sme otići u zasićenje:

$$-V_{DD} \le v_{OP}(t) \le V_{DD}$$

$$V_m + V_T + \sqrt{\frac{8CV_m}{BT}} \le V_{DD}$$

$$V_{m\max 1} = \frac{1}{4}\left(\sqrt{\frac{8C}{BT} + 4\left(V_{DD} - V_T\right)} - \sqrt{\frac{8C}{BT}}\right)^2 = 11.03\,\mathrm{V}$$

2. Disipacija na tranzistorima mora biti manja od maksimalno dozvoljene

$$P_{D1} \le P_{D\max}$$

$$\frac{2CV_{DD}V_m}{T} \le P_{D\max}$$

$$V_{m\max 1} = \frac{P_{D\max}T}{2CV_{DD}} = 10\,\mathrm{V}$$

Bira se strožiji od dva uslova:

$$V_{m\max} = 10\,\mathrm{V}$$

c)

1. Zasićenje operacionog pojačavača:

$$V_{m\max 1}(T) = \frac{1}{4}\left(\sqrt{\frac{8C}{BT} + 4\left(V_{DD} - V_T\right)} - \sqrt{\frac{8C}{BT}}\right)^2 = \frac{1}{4}\left(\sqrt{\frac{8}{T[\mu\mathrm{s}]} + 56} - \sqrt{\frac{8}{T[\mu\mathrm{s}]}}\right)^2$$

2. Ograničenje zbog disipacije:

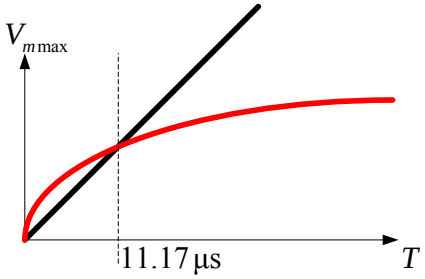
$$V_{m\max 2}(T) = T[\mu\mathrm{s}]$$

Tačka preseka:

$$\frac{1}{4}\left(\sqrt{\frac{8}{T[\mu\mathrm{s}]} + 56} - \sqrt{\frac{8}{T[\mu\mathrm{s}]}}\right)^2 = T[\mu\mathrm{s}]$$

$$T = 11.17\,\mu\mathrm{s}$$

$$V_{m\max}(T) = \begin{cases} T[\mu\mathrm{s}], & T \le 11.17\,\mu\mathrm{s} \\ \frac{1}{4}\left(\sqrt{\frac{8}{T[\mu\mathrm{s}]} + 56} - \sqrt{\frac{8}{T[\mu\mathrm{s}]}}\right)^2, & T \ge 11.17\,\mu\mathrm{s} \end{cases}$$



d)

$$v_{OUT}(t) = V_m \Delta(t)$$

$$i_{OUT}(t) = \frac{V_m}{R}\Delta(t)$$

$$i_1(t) = \begin{cases} \frac{V_m}{R}\Delta(t), & kT < t < \frac{4k+1}{4}T \wedge \frac{4k+3}{4}T < t < (k+1)T \\ 0, & \frac{4k+1}{4}T < t < \frac{4k+3}{4}T \end{cases}$$

$$i_2(t) = \begin{cases} 0, & kT < t < \frac{4k+1}{4}T \wedge \frac{4k+3}{4}T < t < (k+1)T \\ \frac{V_m}{R}\Delta(t), & \frac{4k+1}{4}T < t < \frac{4k+3}{4}T \end{cases}$$

$$v_{OP}(t) = \begin{cases} v_{OUT}(t) - v_{GS2}(t), & kT < t < \frac{2k+1}{2}T \\ v_{OUT}(t) + v_{GS1}(t), & \frac{2k+1}{2}T < t < (k+1)T \end{cases} = V_m\Delta(t) - \left(V_T + \sqrt{\frac{8CV_m}{BT}}\right)\Pi(t)$$

1. Zasićenje operacionog pojačavača:

$$v_{OP\max} = V_m + V_T + \sqrt{\frac{2V_m}{BR}} \le V_{DD}$$

$$V_{m\max 1} = \frac{1}{4}\left(\sqrt{\frac{2}{BR} + 4\left(V_{DD} - V_T\right)} - \sqrt{\frac{2}{BR}}\right)^2 = 9.61\,\mathrm{V}$$

2. Ograničenje zbog disipacije:

$$P_{D1} \le P_{D\max}$$

$$\frac{V_m\left(3V_{DD} - 2V_m\right)}{12R} \le P_{D\max}$$

$$0 \le 2{V_m}^2 - 3V_m V_{DD} - 12RP_{D\max}$$

$$V_m = \frac{3V_{DD} \pm \sqrt{9{V_{DD}}^2 + 96RP_{D\max}}}{4}$$

U opsegu $8.69\,\mathrm{V} \le V_m \le 13.81\,\mathrm{V}$ snaga disipacije tranzistora je veća od maksimalno dozvoljene. Analiza dobijenih ograničenja daje

$$V_{m\max} = 8.69\,\mathrm{V}$$