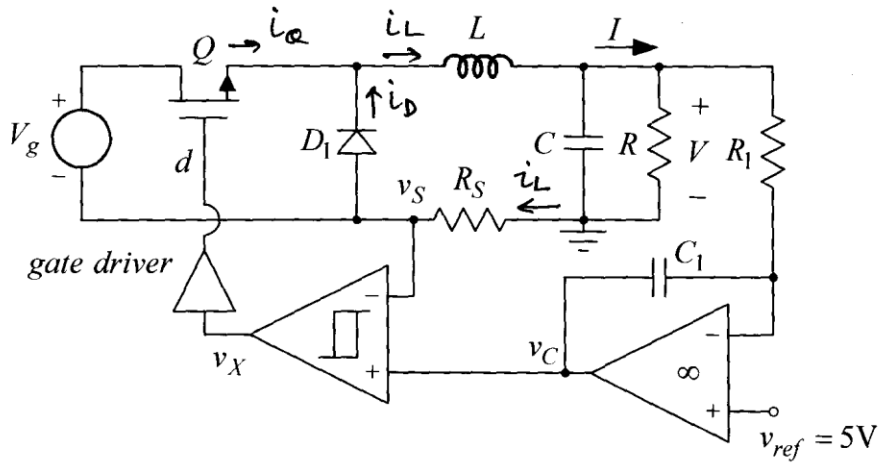
Na slici je prikazan Buck konvertor sa kolom za regulaciju napona na potrošaču. Upotrebljeni su idealni prekidači, operacioni pojačavač i komparator se napajaju iz baterija $V_{CC} = -V_{EE} = 12\,\text{V}$, dok je: $L = 30\,\mu\text{H}$, $R_S = 10\,\text{m}\Omega$, $R_1 C_1 \gg T_S$, a širina histerezisne petlje komparatora je $V_H = 30\,\text{mV}$. Smatrati da je talasnost napona na potrošaču zanemarljiva i da otpornost R_S ne utiče na rad konvertora. Odrediti i nacrtati, u ustaljenom stanju, vremenske dijagrame označenih napona, struja prekidača i induktivnosti kada je:

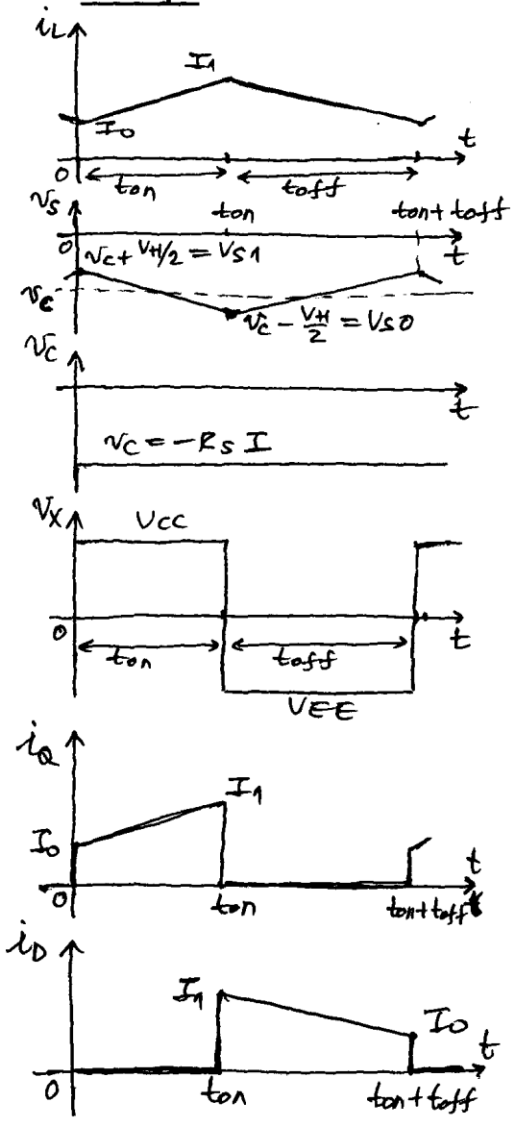
a) $V_g = 12\,\text{V}$ i $R = 0{,}5\,\Omega$,

b) $V_g = 12\,\text{V}$ i $R = 0{,}25\,\Omega$ i

c) $V_g = 15\,\text{V}$ i $R = 0{,}5\,\Omega$.



Rešenje:



a) $I_1 - I_0 = \frac{V_g - V}{L} t_{on} = \frac{V}{L} t_{off}$

$\frac{I_1 + I_0}{2} = \frac{V}{R} = \frac{V_{REF}}{R} = 10\,\text{A}$

$I_1 - I_0 = \frac{V_H}{R_S} = 3\,\text{A}$

$\frac{V_H}{R_S} = \frac{V_g - V}{L} t_{on} = \frac{V}{L} t_{off}$

$\Rightarrow T_S = t_{on} + t_{off} = \frac{V_H \cdot L}{R_S}\left[\frac{1}{V_g - V} + \frac{1}{V}\right] = 30{,}86\,\mu\text{s}$

$\Rightarrow t_{on} = 12{,}85\,\mu\text{s}$, $t_{off} = 18\,\mu\text{s}$ i $T_S = 30{,}85\,\mu\text{s}$

$D = \frac{t_{on}}{t_{on} + t_{off}} = 0{,}417$, $f_S = \frac{1}{T_S} \cong 32{,}4\,\text{kHz}$

$v_C = -R_S \frac{I_1 + I_0}{2} = -R_S I = -100\,\text{mV}$

$V_{S1} = v_C + V_H/2 = -85\,\text{mV}$, $V_{S0} = v_C - \frac{V_H}{2} = -115\,\text{mV}$

$I_1 = I + \frac{V_H}{2R_S} = 11{,}5\,\text{A}$, $I_0 = I - \frac{V_H}{2R_S} = 8{,}5\,\text{A}$.

b) $V_g = 12\,\text{V} \Rightarrow f_S \approx 32{,}4\,\text{kHz}$

$v_C = -R_S I = -R_S \frac{V_{REF}}{R} = -200\,\text{mV}$

$\Rightarrow V_{S1} = -185\,\text{mV}$ i $V_{S0} = -215\,\text{mV}$

$I_1 = I + \frac{V_H}{2R_S} = 21{,}5\,\text{A}$, $I_0 = I - \frac{V_H}{2R_S} = 18{,}5\,\text{A}$.

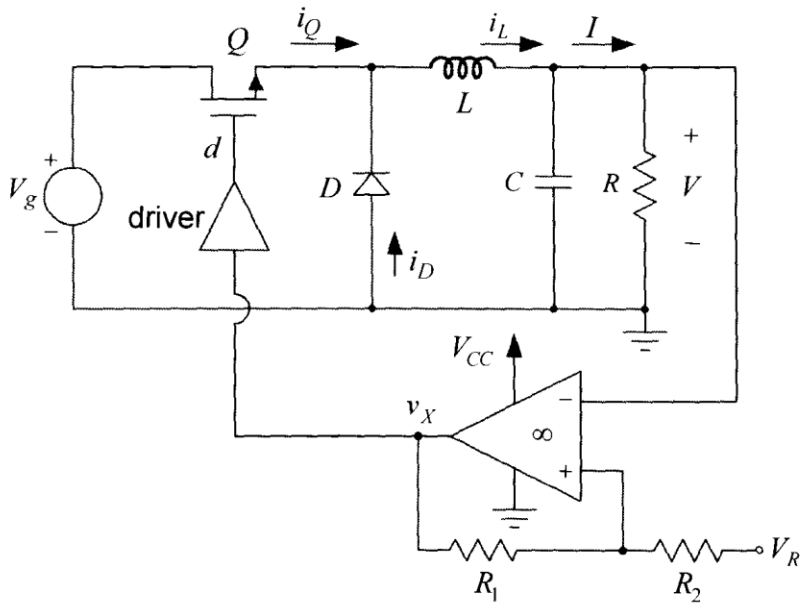
c) $T_S = \frac{V_H \cdot L}{R_S}\left[\frac{1}{V_g - V} + \frac{1}{V}\right] = 27\,\mu\text{s}$

$t_{on} = \frac{V_H}{R_S}\frac{L}{V_g - V} = 9\,\mu\text{s}$, $t_{off} = \frac{V_H}{R_S}\frac{L}{V} = 18\,\mu\text{s}$

$f_S = \frac{1}{T_S} \cong 37\,\text{kHz}$

$v_C = -R_S \frac{V_{REF}}{R} = -100\,\text{mV}$

$V_{S1} = -85\,\text{mV}$ i $V_{S0} = -115\,\text{mV}$.



U buck konvertoru sa slike ulazni napon i potrošnja se menjaju u opsegu $15\,\mathrm{V} \le V_g \le 25\,\mathrm{V}$ i $2\,\mathrm{A} \le I \le 5\,\mathrm{A}$. Prekidački tranzistor i operacioni pojačavač se mogu smatrati idealnim, dok je $V_{CC} = 12\,\mathrm{V}$, $V_D = 0{,}5\,\mathrm{V}$, $L = 50\,\mu\mathrm{H}$, $C = 100\,\mu\mathrm{F}$ i $R_2 = 1\,\mathrm{k\Omega}$.

a) Odrediti otpornost R_1 i napon V_R tako da srednja vrednost izlaznog napona bude $V = 5\,\mathrm{V}$, a talasnost $\Delta v_{p-p} = 1\%V$.

b) Odrediti zavisnost prekidačke učestanosti konvertora u funkciji ulaznog napona $f_S = f(V_g)$. Pri proračunu struje induktivnosti zanemariti talasnost izlaznog napona.

Rešenje:

a) Operacioni pojačavač sa otpornostima R_1 i R_2 čini komparator sa histerezisom. Pragovi ovog komparatora su

$$V_1 = \frac{V_{CC}R_2 + V_R R_1}{R_1 + R_2} \quad \text{i} \quad V_2 = V_R \frac{R_1}{R_1 + R_2}.$$

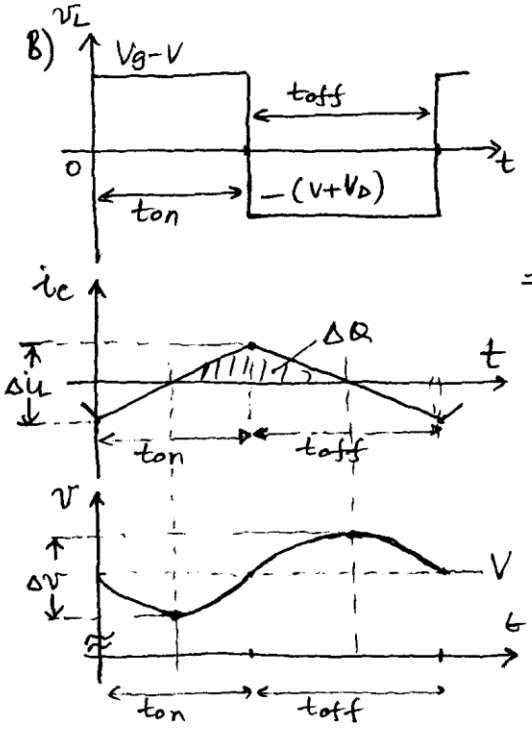
Izlazni napon se menja između ova dva praga

$$\Delta v_{p-p} = V_1 - V_2 = V_{CC}\frac{R_2}{R_1+R_2} \Rightarrow R_1 = R_2\left(\frac{V_{CC}}{\Delta v_{p-p}} - 1\right) = 239\,\mathrm{k\Omega},$$

$$V = \frac{V_1+V_2}{2} = \frac{1}{2}\,\frac{V_{CC}R_2 + 2V_R R_1}{R_1+R_2} \Rightarrow V_R = V\left(1+\frac{R_2}{R_1}\right) - \frac{V_{CC}}{2}\frac{R_2}{R_1}$$

$$\Rightarrow V_R \approx V = 5\,\mathrm{V}$$

b)



VSB: $\bar{v}_L = 0 \Rightarrow (V_g - V)t_{on} - (V_D + V)t_{off} = 0$

$$\Rightarrow V = (V_g + V_D)\frac{t_{on}}{T_S} - V_D \Rightarrow \frac{t_{on}}{T_S} = \frac{V+V_D}{V_g+V_D}$$

$$\Delta v = \frac{\Delta Q}{C} = \frac{1}{C}\cdot\frac{1}{2}\,\frac{\Delta i_L}{2}\left(\frac{t_{on}}{2} + \frac{t_{off}}{2}\right)$$

$$\Rightarrow \Delta v_{\%} = \frac{\Delta i_L \cdot T_S}{8C}, \quad \Delta i_L = \frac{V+V_D}{L}\left(1 - \frac{t_{on}}{T_S}\right)T_S$$

$$\Rightarrow \Delta v_{\%} = \frac{T_S^2}{8LC}(V+V_D)\left(1 - \frac{t_{on}}{T_S}\right)$$

$$\Rightarrow \Delta v_{\%} = \frac{(V+V_D)\,\frac{V_g - V}{V_g + V_D}}{8LC f_S^2}$$

$$\Rightarrow f_S = \sqrt{\frac{1}{8LC\,\Delta v}\,\frac{(V_g - V)(V+V_D)}{V_g + V_D}}$$

$$f_S(V_g = 15\,\mathrm{V}) = 42{,}12\,\mathrm{kHz},$$

$$f_S(V_g = 25\,\mathrm{V}) = 46{,}44\,\mathrm{kHz}.$$