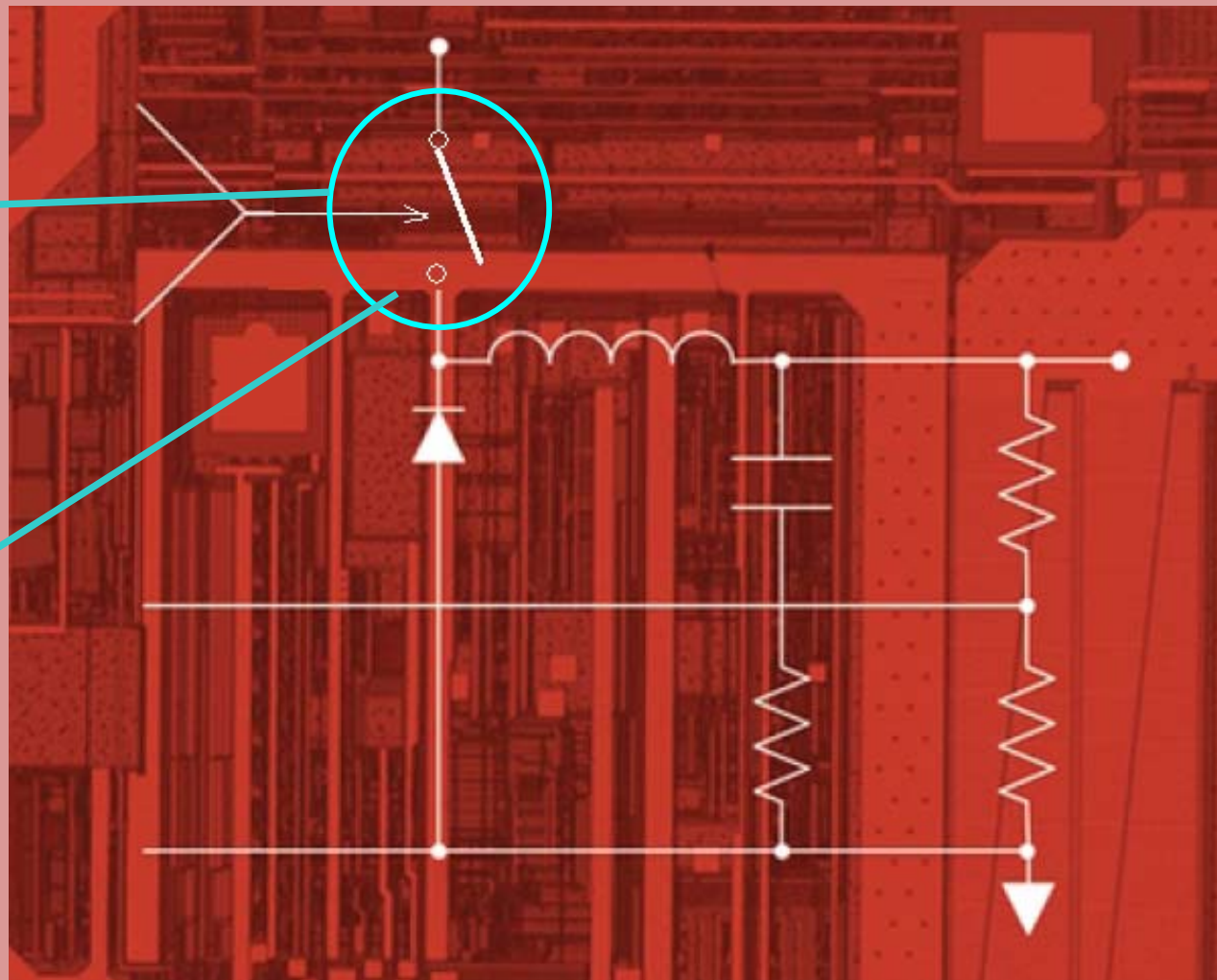


DC/DC PRETVARAČI-ČOPERI

IGBT



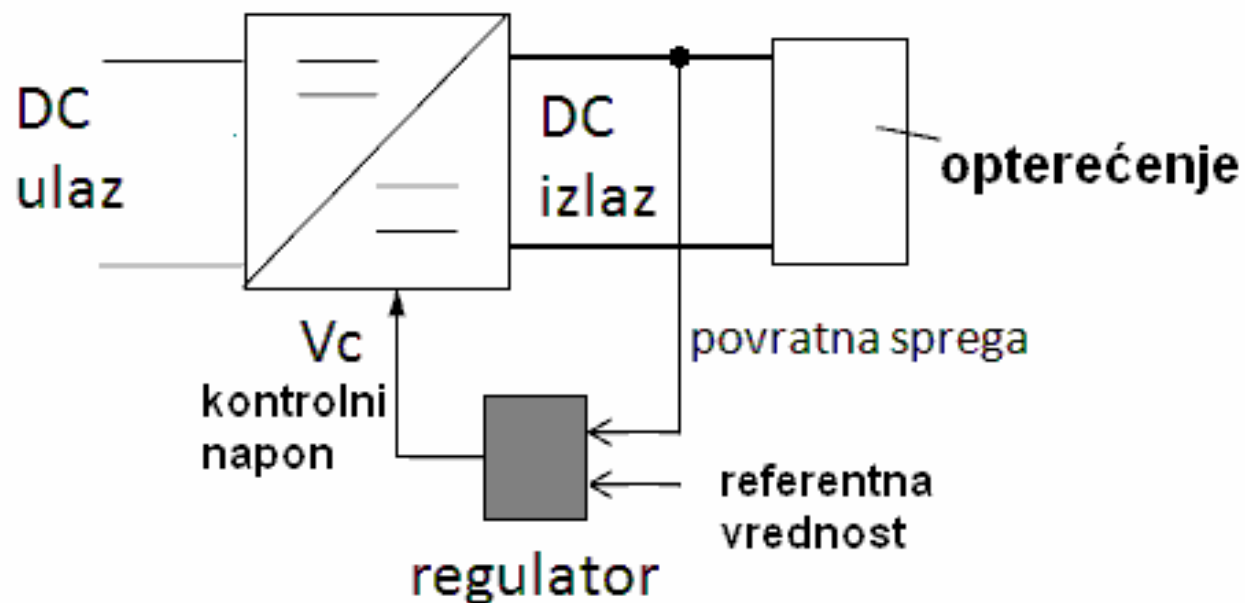
SCR, GTO



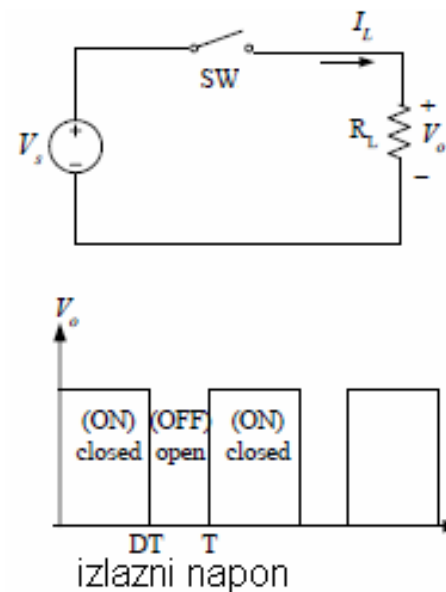
Predavač: Prof.dr Željko Despotović

OPŠTE DC/DC pretvarači-ČOPERI

Pretvaraju nestabilisani DC ulazni napon u stabilisani DC izlazni napon zahtevanog nivoa



CHOPPER=sekač

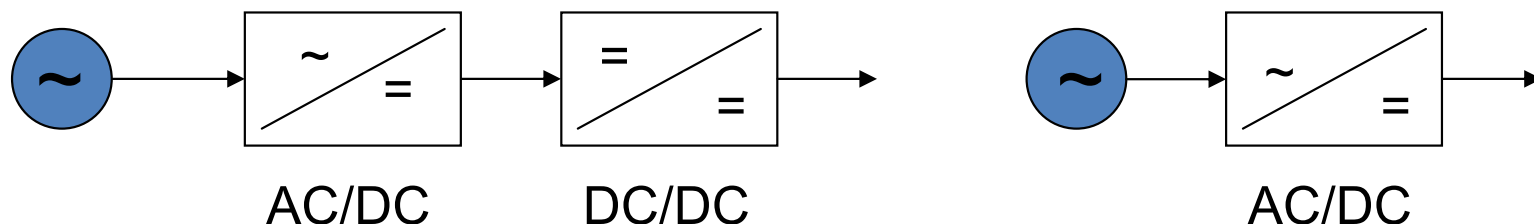


- Čoperi su DC/DC pretvarači koji pretvaraju jednosmernu struju jednog naponskog nivoa u jednosmernu struju drugog naponskog nivoa.
- Oni se često nazivaju i transformatori napona – ili ČOPERI (engl. CHOPPER=sekač).

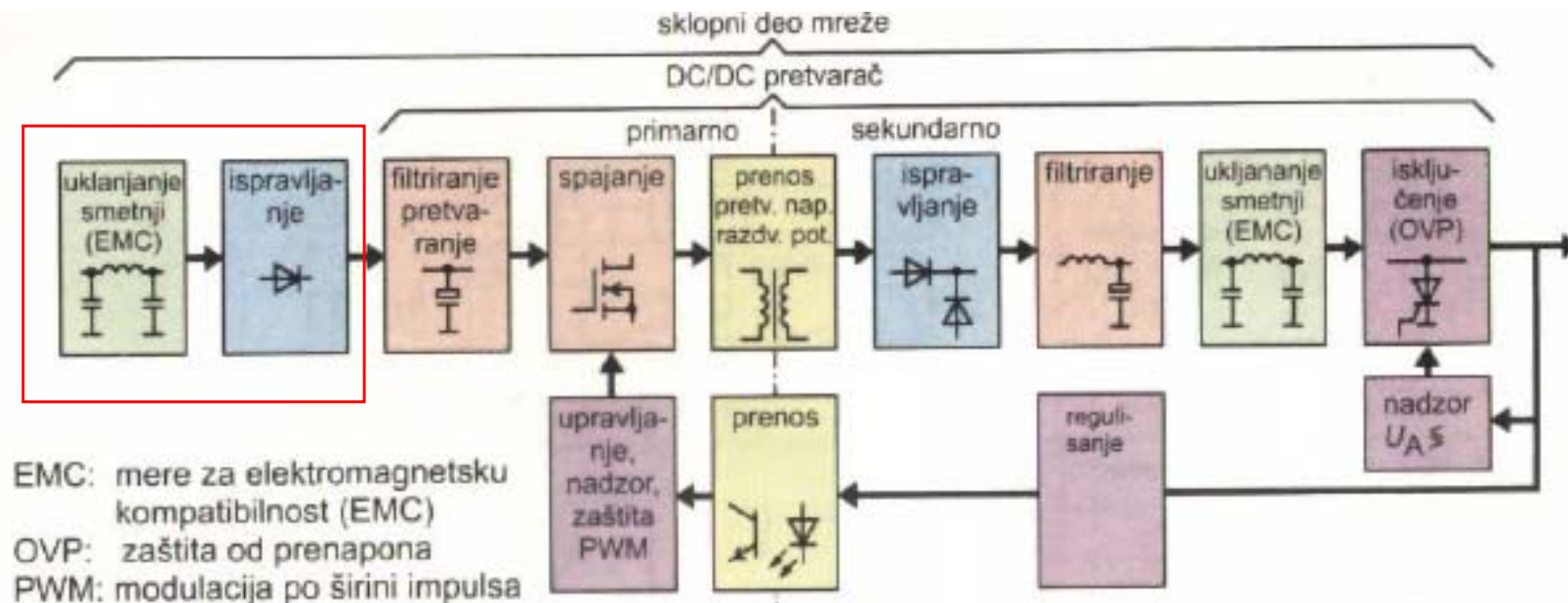
DC ulaz: jednosmerni izvori napajanja, izlaz ispravljačkih jedinica, solarne ćelije, DC vetrogeneratori, baterije, gorivne ćelije i sl.

PRIMENA: PRIMENA: Prekidački izvori napajanja- *Switch Mode Power Supply* (SMPS), kontrola jednosmernih motora, punjači baterija, električna vozila, električna vuča i sl.

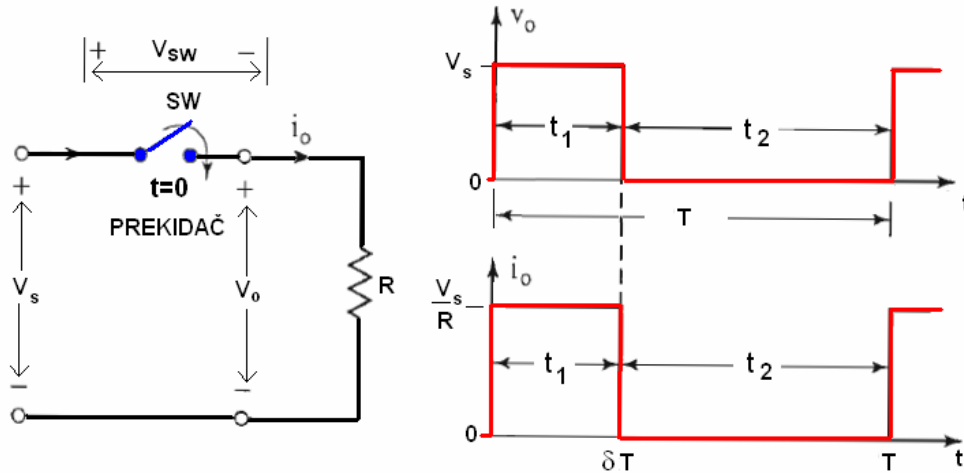
Kombinovani AC/DC i DC/DC pretvarači = AC/DC pretvarači (ispravljači)



Ulazni
AC/DC
pretvarač



OSNOVNO ČOPERSKO KOLO BEZ AKUMULACIONIH ELEMENATA



Srednja vrednost izlaznog napona

$$V_{0SR} = \frac{1}{T} \cdot \int_0^T v_o dt = \frac{t_1}{T} \cdot V_s = f \cdot t_1 \cdot \frac{1}{T} \cdot V_s = \delta \cdot V_s$$

Srednja vrednost izlazne struje

$$I_0 = \frac{V_{0SR}}{R} = \frac{\delta \cdot V_s}{R}$$

Nekad se δ označava i sa **D**

T-Perioda čopovanja

f-Učestanost čopovanja

$\delta = D = \frac{t_1}{T}$ koeficijent radnog režima čopera (*duty-cycle*)

$0 \leq \delta \leq 1$ odnosno $0\% \leq \delta \leq 100\%$

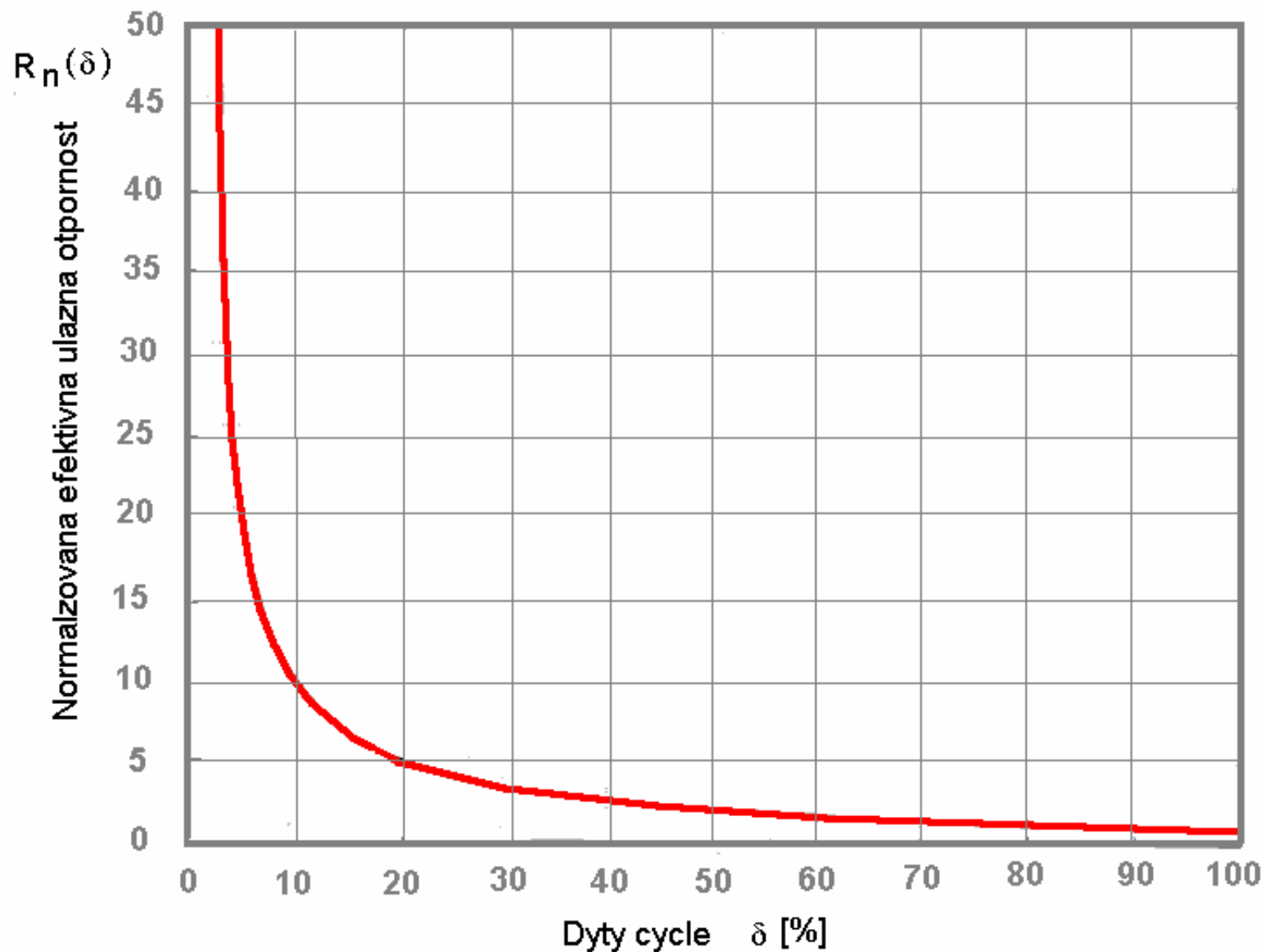
EKVIVALENTNA ULAZNA OTPORNOST $R_{in_ekv} = \frac{V_s}{I_0} = \frac{R}{\delta} = \frac{R}{D}$

$\delta = 0$ $R_{in_ekv} = \infty$

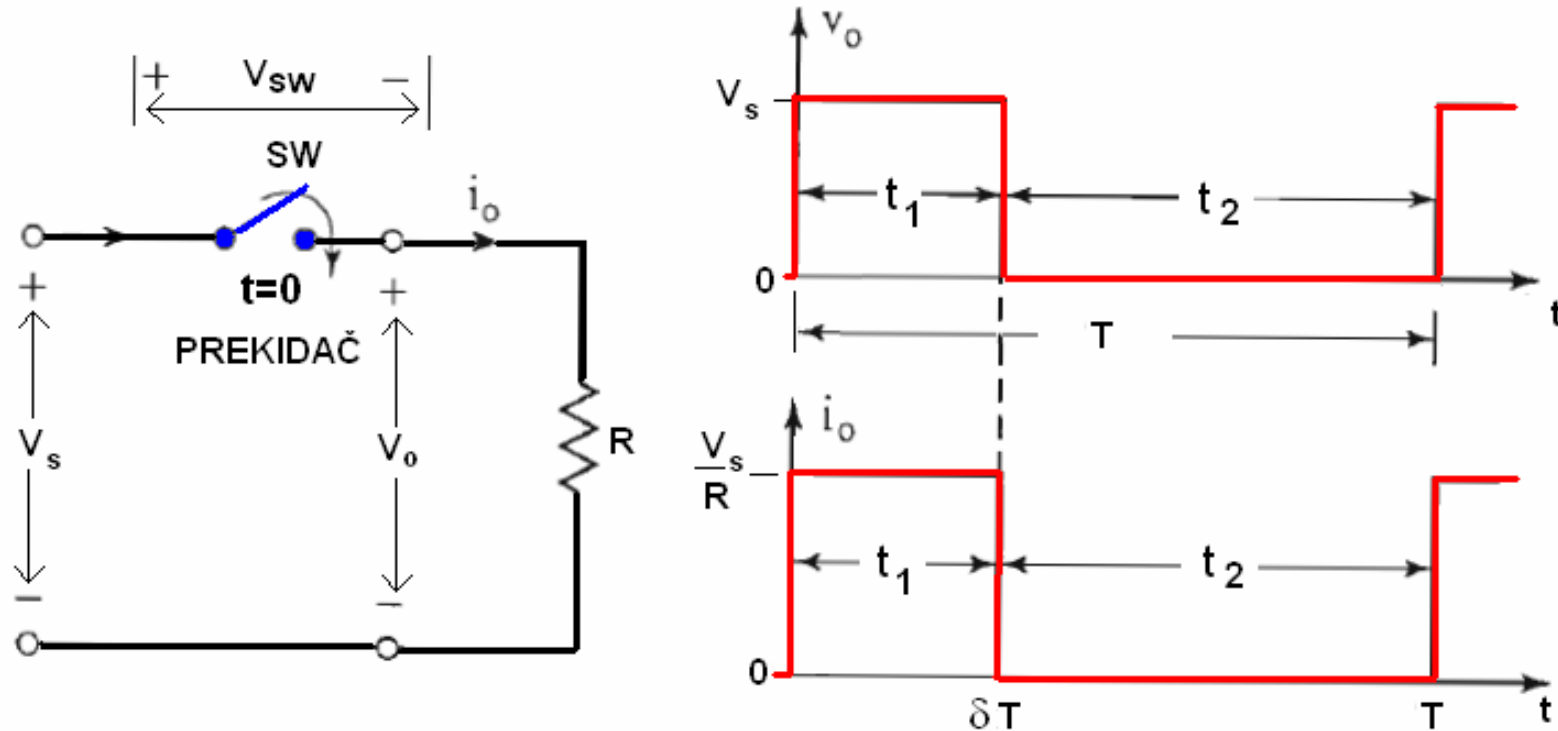
$\delta = 1$ $R_{in_ekv} = R$

ZAKLJUČAK: Čopersko kolo obezbeđuje kontinualnu promenu ulazne otpornosti.

PROMENA NORMALIZOVANE ULAZNE OTPORNOSTI ČOPERA BEZ AKUMULACIONIH ELEMENATA SA ČISTO OMSKIM OPTEREĆENJEM U ZAVISNOSTI OD KOEFICIJENTA RADNOG REŽIMA δ



IZRAČUNAVANJE EFEKTIVNE VREDNOSTI IZLAZNOG NAPONA I IZLAZNE SNAGE



$$V_{0eff} = \sqrt{\frac{1}{T} \int_0^T v_o^2 dt} = \sqrt{\frac{t_1}{T}} \cdot V_s = \sqrt{\delta} \cdot V_s = \sqrt{D} \cdot V_s$$

SREDNJA VREDNOST IZLAZNE SNAGE

$$P_{iSR} = \frac{1}{T} \cdot \int_0^{\delta \cdot T} v_o \cdot i \cdot dt = \frac{t_1}{T} \cdot V_s^2 \cdot \frac{1}{R} = \delta \cdot \frac{V_s^2}{R} = D \cdot \frac{V_s^2}{R}$$

OSNOVNE TOPOLOGIJE ČOPERA SA AKUMULACIONIM ELEMENTIMA I DIODOM

- Čoperi za sniženje napona
- ([engl. buck converters](#))

$$V_{OUT} < V_{IN}$$

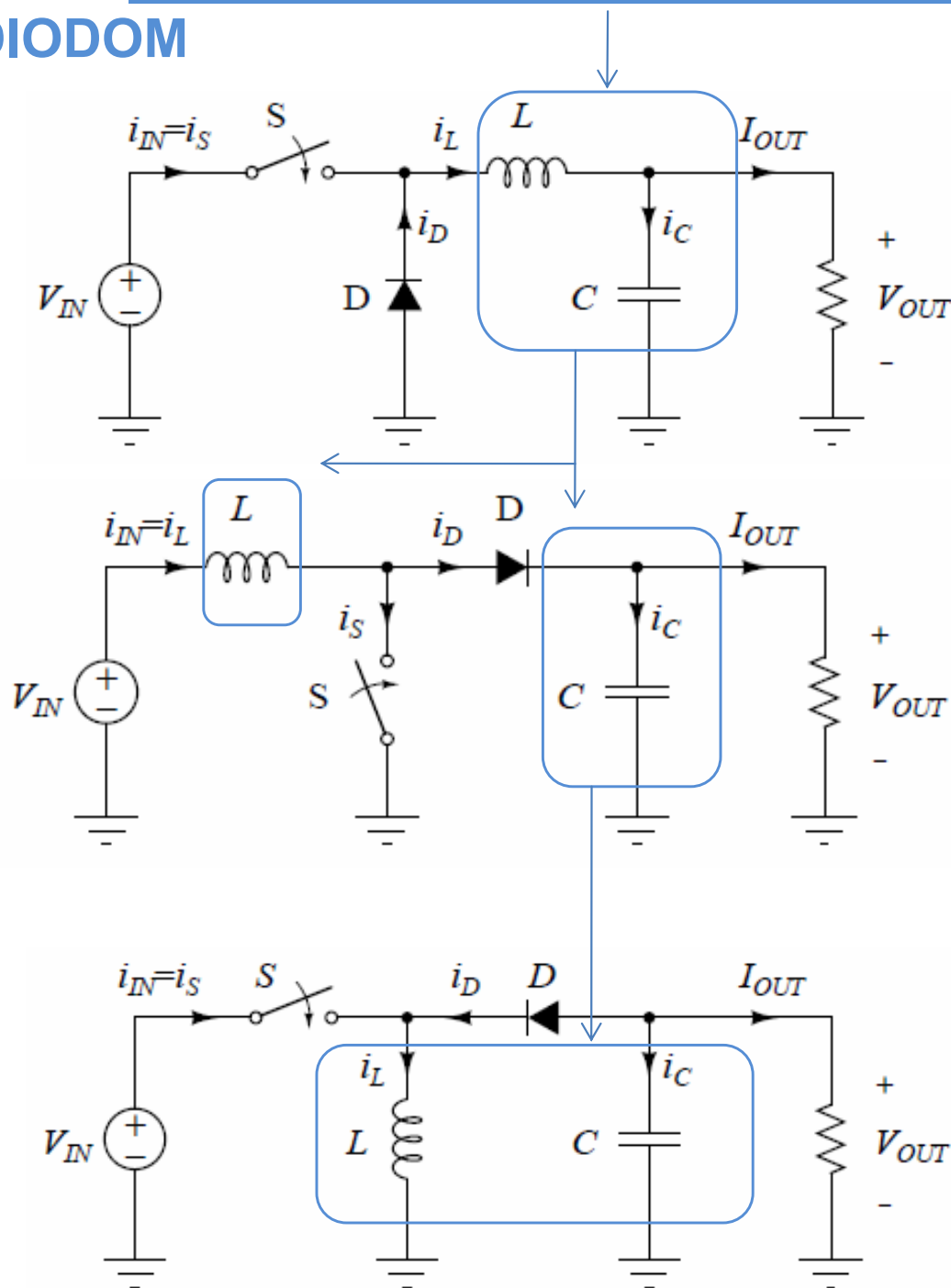
- Čoperi za povečanje napona
- ([engl. boost converters](#))

$$V_{OUT} > V_{IN}$$

- Čoperi za sniženje/povečanje napona (obrtachi napona)
- ([engl. buck-boost converters](#))

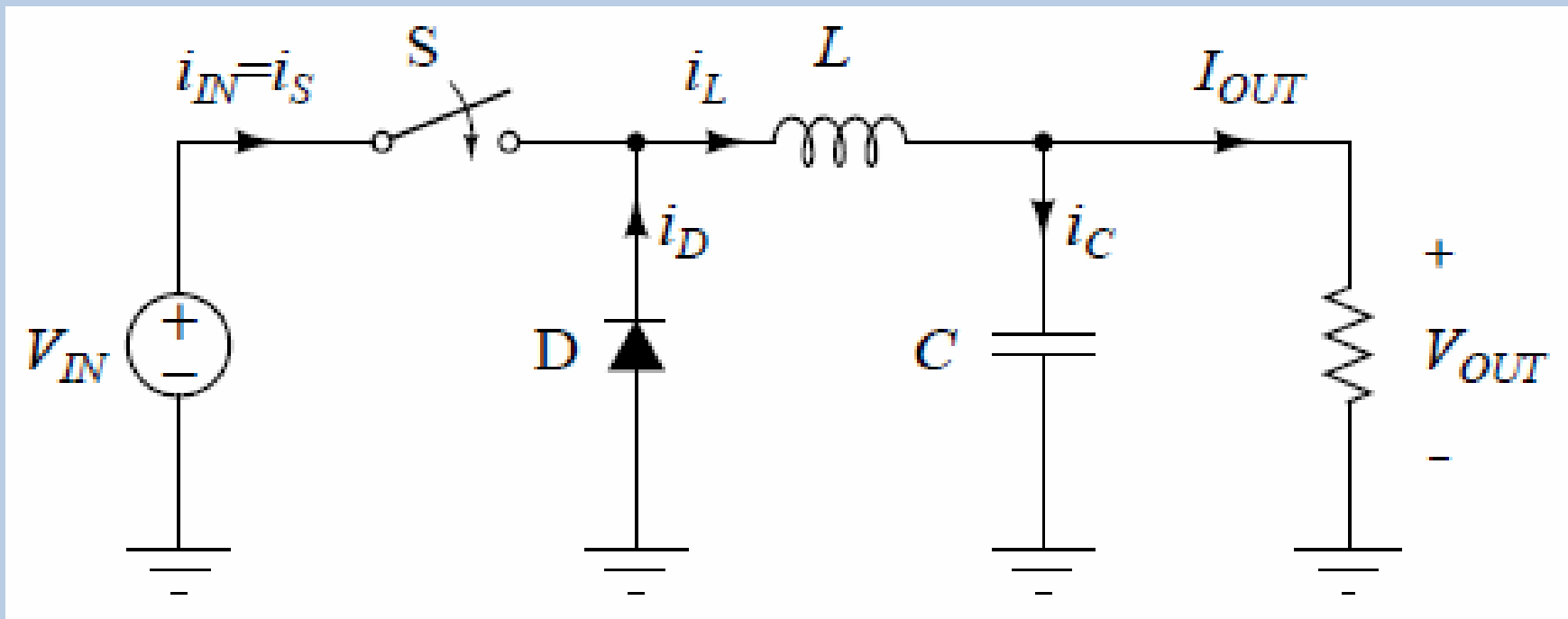
$$V_{OUT} < V_{IN}$$

$$V_{OUT} > V_{IN}$$



ČOPER SPUŠTAČ NAPONA

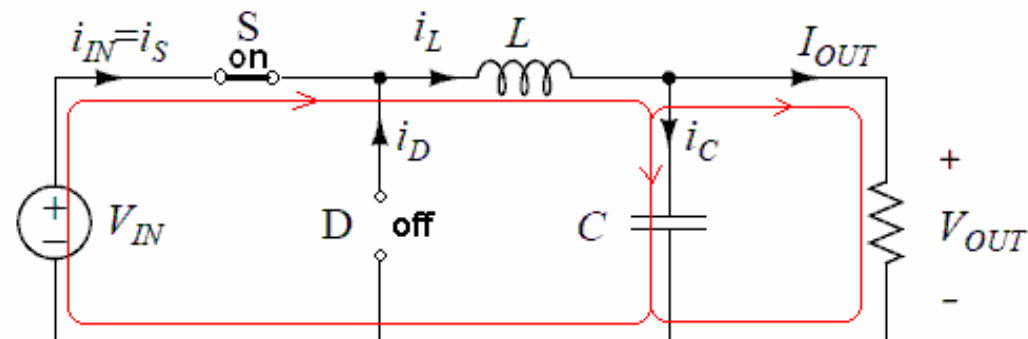
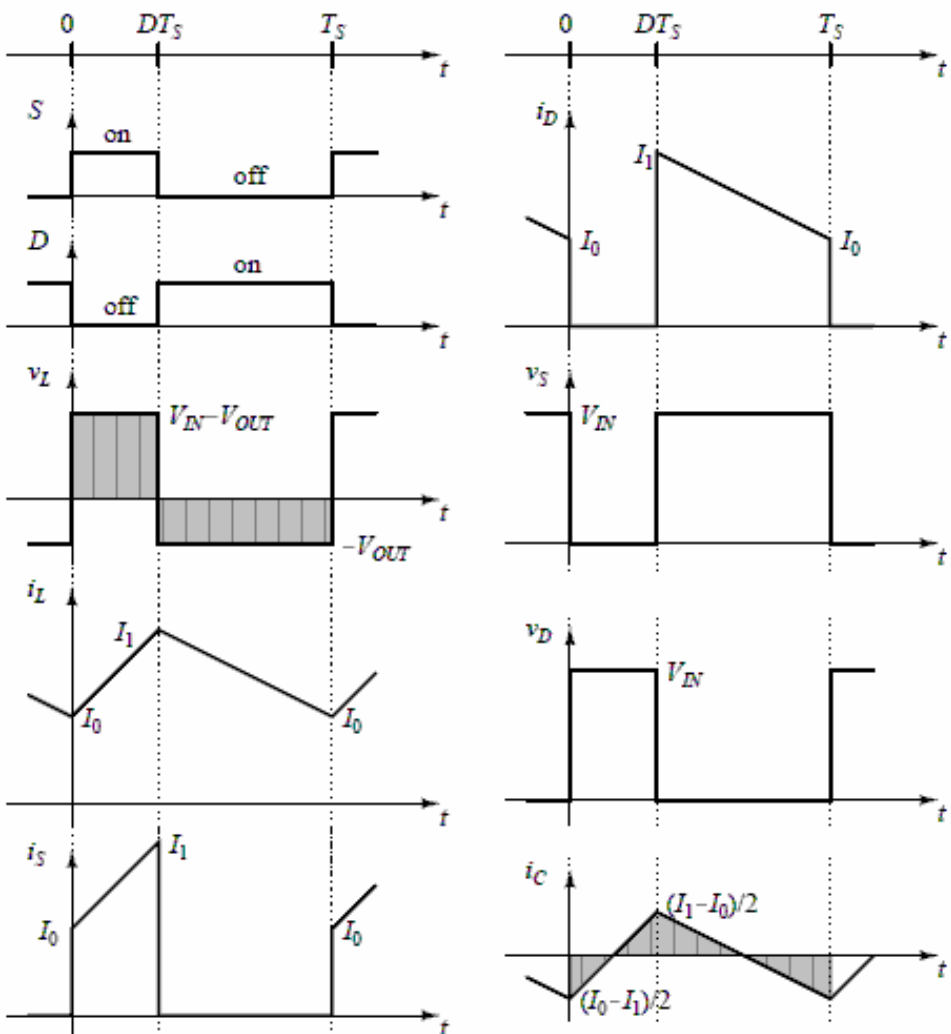
– *BUCK* PRETVARAČ



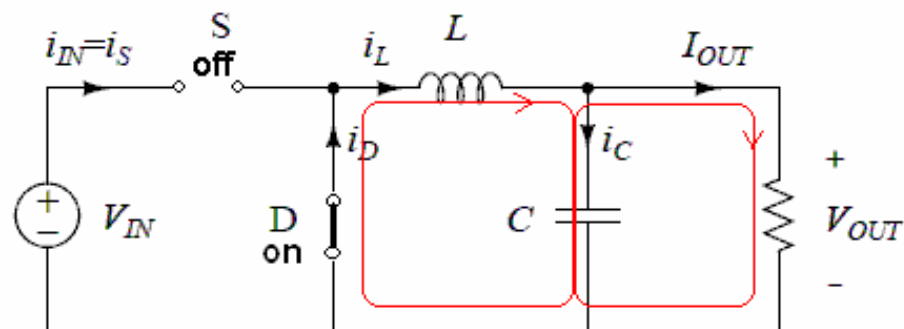
DVA MOGUĆA REŽIMA RADA:

- KONTINUALNI (NEPREKIDNI) REŽIM RADA
- DISKONTINUALNI (PREKIDNI) REŽIM RADA

TALASNI OBLICI I EKVIVALENTNO KOLO ZA ČOPER SPUŠTAČ NAPONA – BUCK PRETVARAČ U KONTINUALNOM REŽIMU

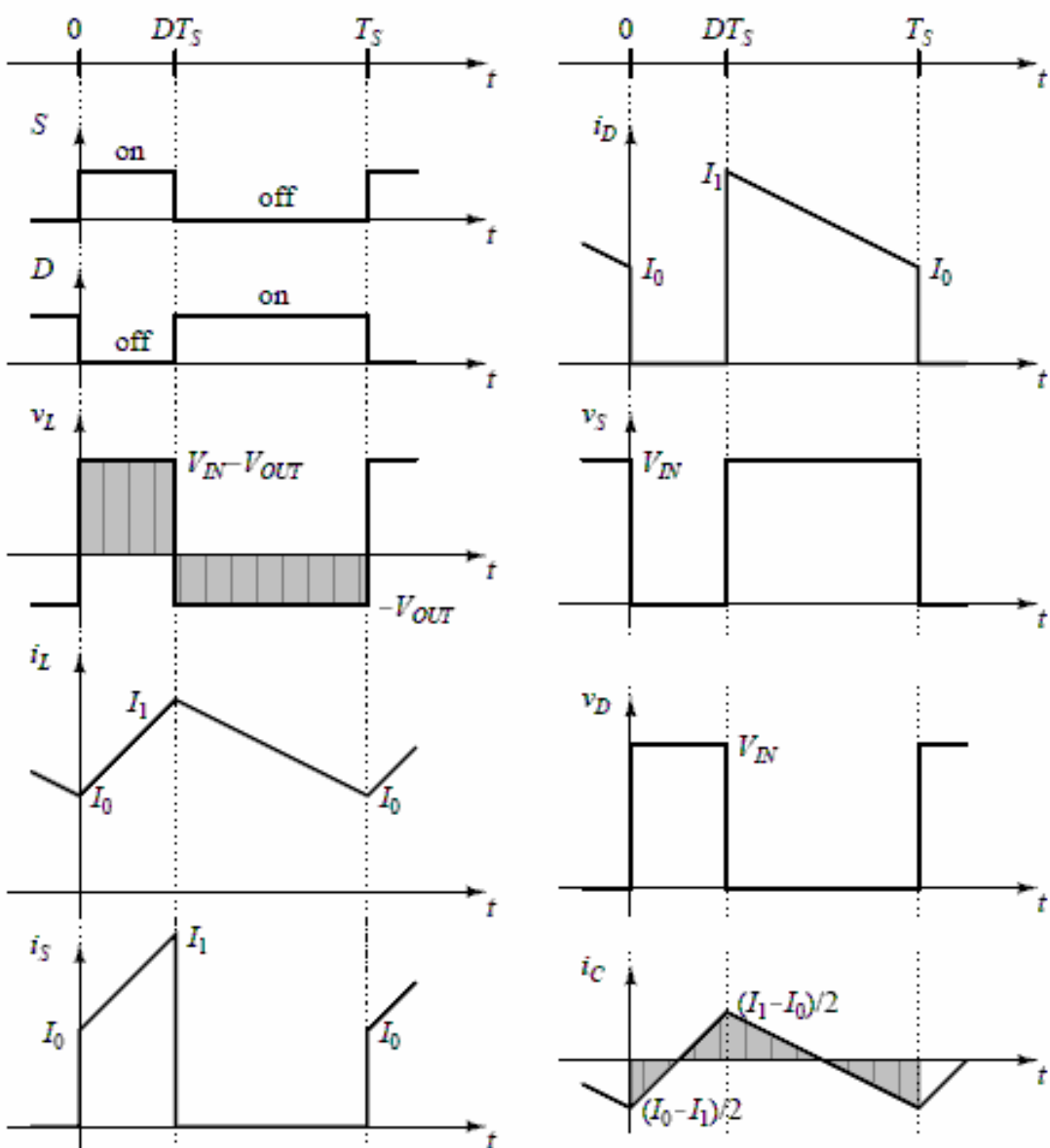


EKVIVALENTNO KOLO ČOPERA SPUŠTAČA NAPONA U INTERVALU t_{on} KAD JE UKLJUČEN PREKIDAČ



EKVIVALENTNO KOLO ČOPERA SPUŠTAČA NAPONA U INTERVALU t_{off} KAD JE ISKLJUČEN PREKIDAČ (UKLJUČENA DIODA)

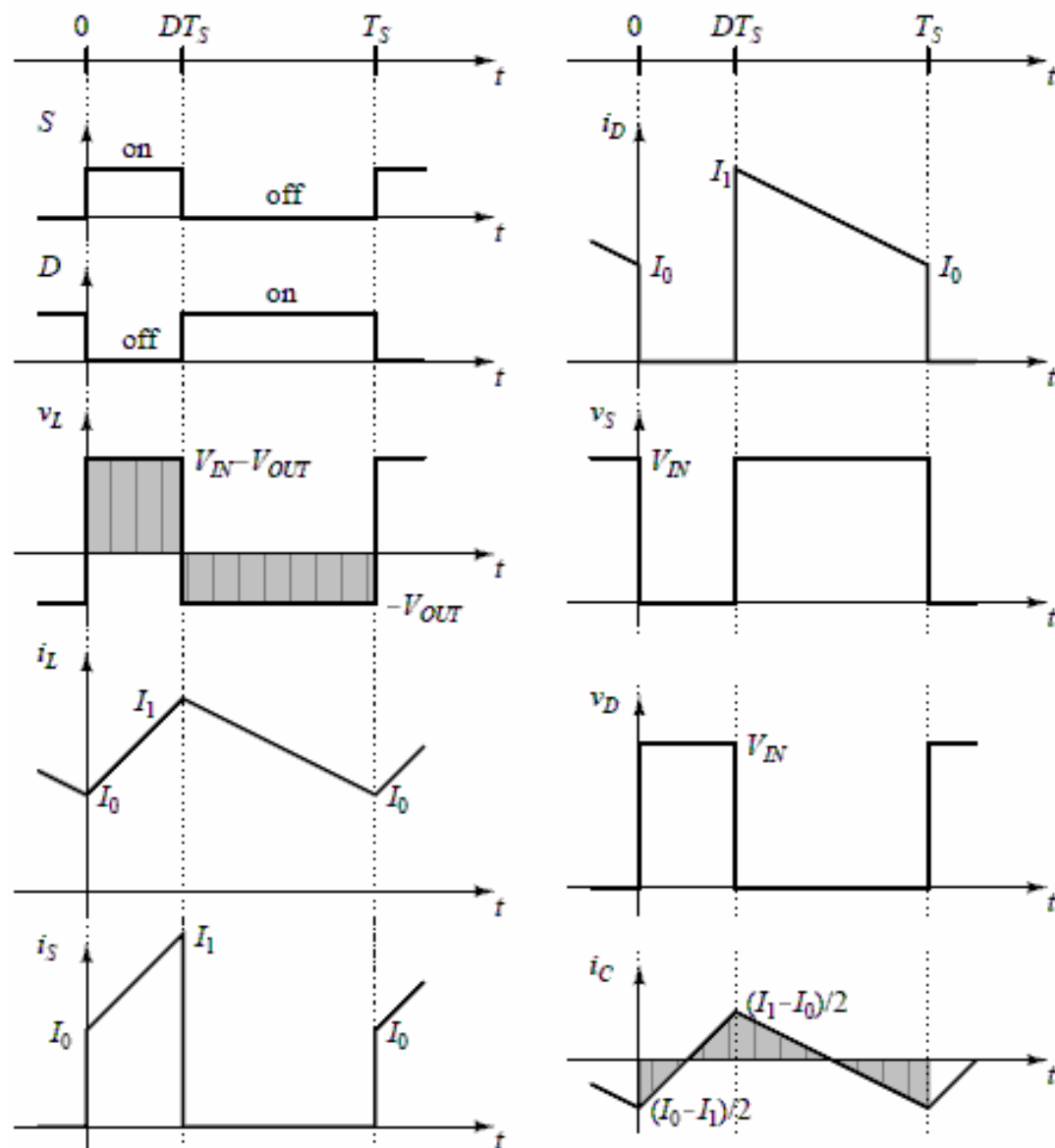
ČOPER SPUŠTAČ NAPONA-BUCK u KONTINUALNOM REŽIMU



NAPONI I STRUJE ČOPERA SPUŠTAČA U KONTINUALNOM REŽIMU $I_0 > 0$

t	$0 < t < DT_s$	$DT_s < t < T_s$
trajanje	DT_s	$D'T_s = (1 - D)T_s$
v_L	$V_{IN} - V_{OUT}$	$-V_{OUT}$
i_L	$I_0 + \frac{v_L}{L}t$	$I_1 + \frac{v_L}{L}(t - DT_s)$
i_S	i_L	0
i_D	0	i_L
v_S	0	V_{IN}
v_D	V_{IN}	0
i_C	$i_L - I_{OUT}$	$i_L - I_{OUT}$

ČOPER SPUŠTAČ-BUCK u KONTINUALNOM REŽIMU



SREDNJA VREDNOST NAPONA NA INDUKTIVNOSTI L JE:

$$DT_S (V_{IN} - V_{OUT}) + D'T_S (-V_{OUT}) = 0$$

SREDNJA VREDNOST IZLAZNOG NAPONA JE:

$$V_{OUT} = DV_{IN}.$$

SREDNJA VREDNOST STRUJE KALEMA JE:

$$I_L = \frac{I_0 + I_1}{2}$$

SREDNJA VREDNOST IZLAZNE STRUJE:

$$I_{OUT} = I_L$$

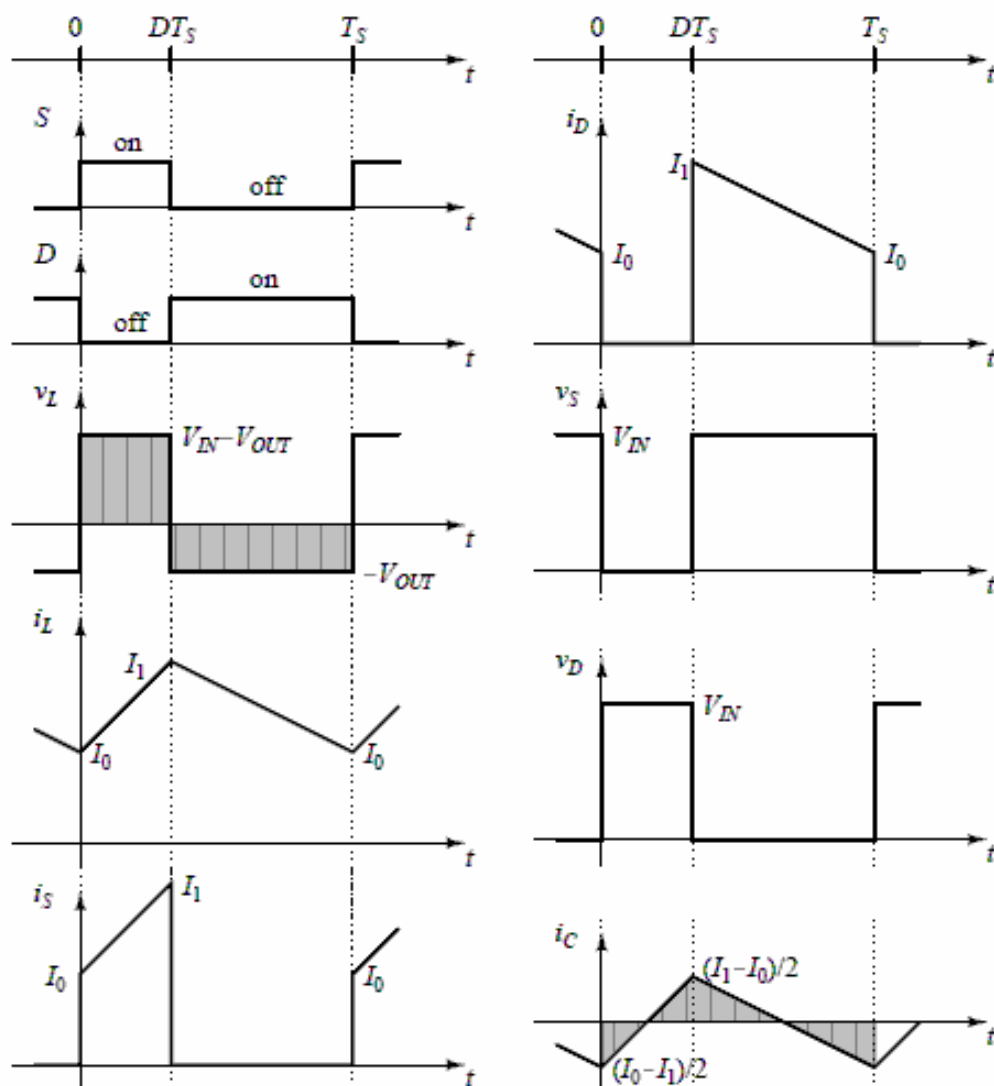
SREDNJA VREDNOST ULAZNE STRUJE:

$$I_{IN} = DI_{OUT}$$

PRENOSNI ODNOS PRETVARAČA:

$$M = \frac{V_{OUT}}{V_{IN}} \quad M(D) = D$$

ČOPER SPUŠTAČ NAPONA -BUCK u KONTINUALNOM REŽIMU



MAKSIMALNA VREDNOST STRUJE KALEMA:

$$I_1 = I_0 + \frac{V_{IN} - V_{OUT}}{L} DT_s$$

$$I_1 - I_0 = \frac{V_{IN} - V_{OUT}}{L} DT_s$$

$$I_1 + I_0 = 2I_{OUT}$$

MINIMALNA VREDNOST STRUJE KALEMA:

$$I_0 = I_{OUT} - \frac{V_{IN} - V_{OUT}}{2f_s L} D$$

$$I_1 = I_{OUT} + \frac{V_{IN} - V_{OUT}}{2f_s L} D$$

$$f_s = \frac{1}{T_s}$$

AMLITUDA TALASNOSTI STRUJE KALEMA:

$$\Delta i_L = \frac{1}{2} (I_1 - I_0)$$

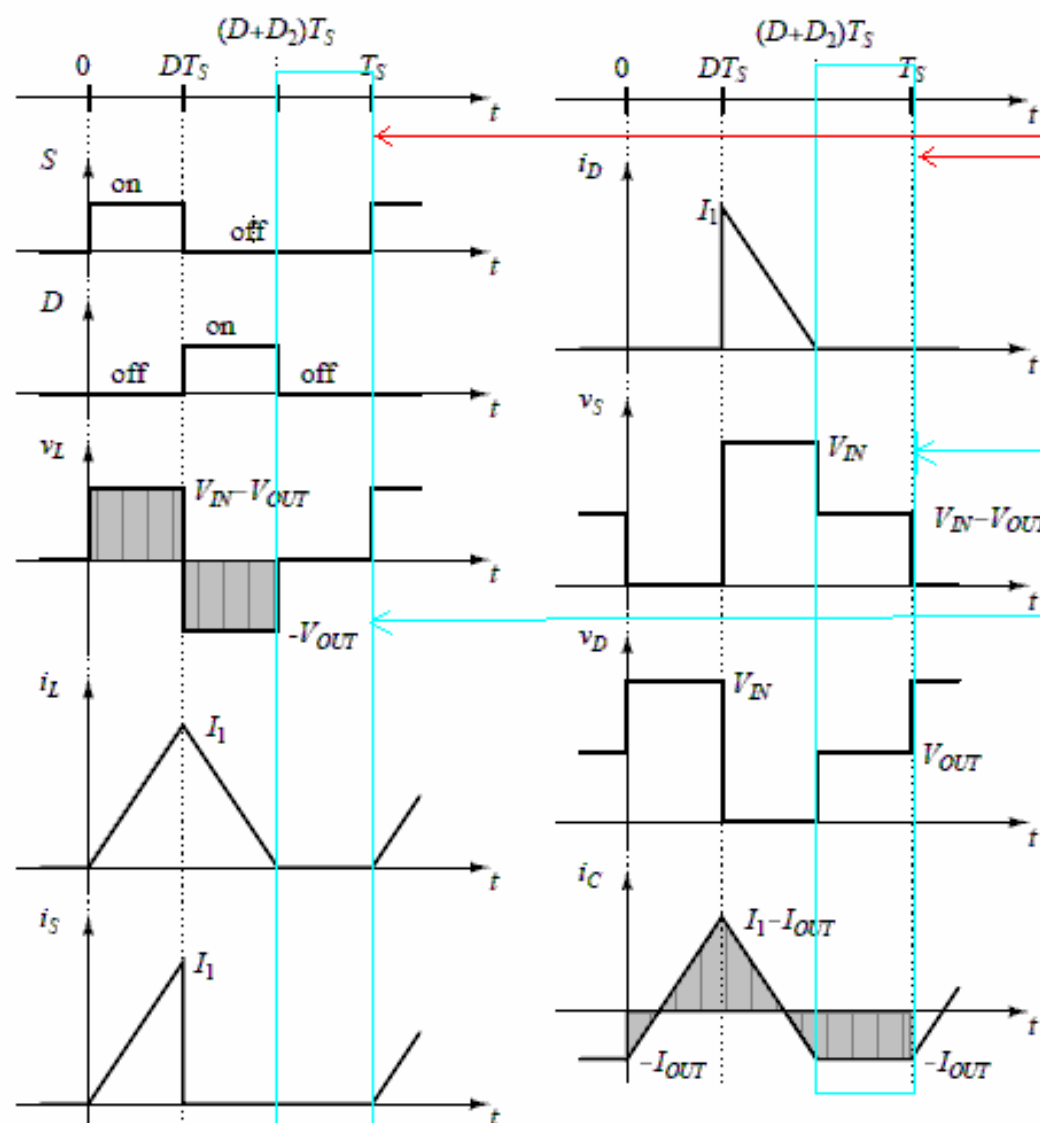
USLOV ZA KONTINUALNI REŽIM:

$$I_{OUT} > \frac{V_{IN} - V_{OUT}}{2f_s L} D$$

$$V_{OUT} = DV_{IN}$$

$$I_{OUT} > \frac{V_{IN}}{2f_s L} D(1 - D)$$

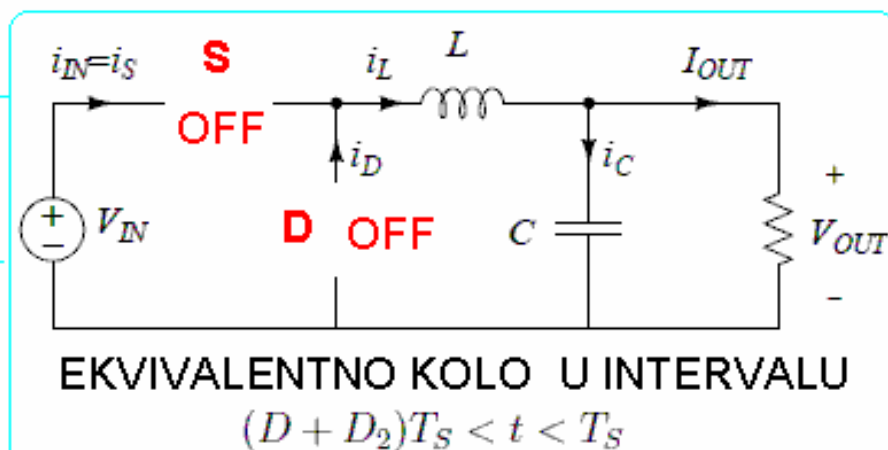
ČOPER SPUŠTAČ NAPONA -BUCK u DISKONTINUALNOM (PREKIDNOM) REŽIMU



ČOPER SPUŠTAČ NAPONA U DISKONTINUALNOM REŽIMU

$$I_{OUT} < \frac{V_{IN}}{2f_s L} D(1-D) \quad V_{OUT} \neq DV_{IN}$$

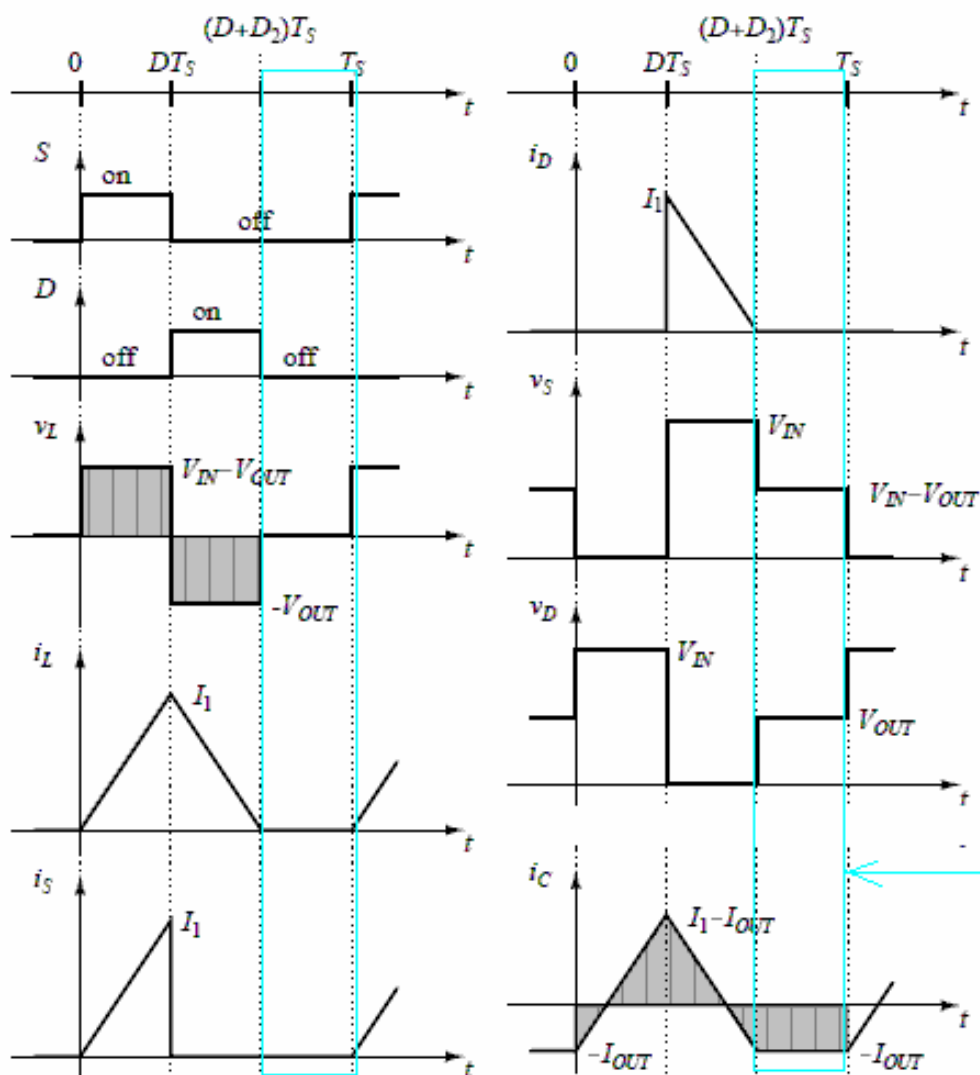
USLOVI $v_L = L \frac{di_L}{dt} = 0$



MAKSIMALNA STRUJA KALEMA

$$I_1 = \frac{V_{IN} - V_{OUT}}{L} DT_S$$

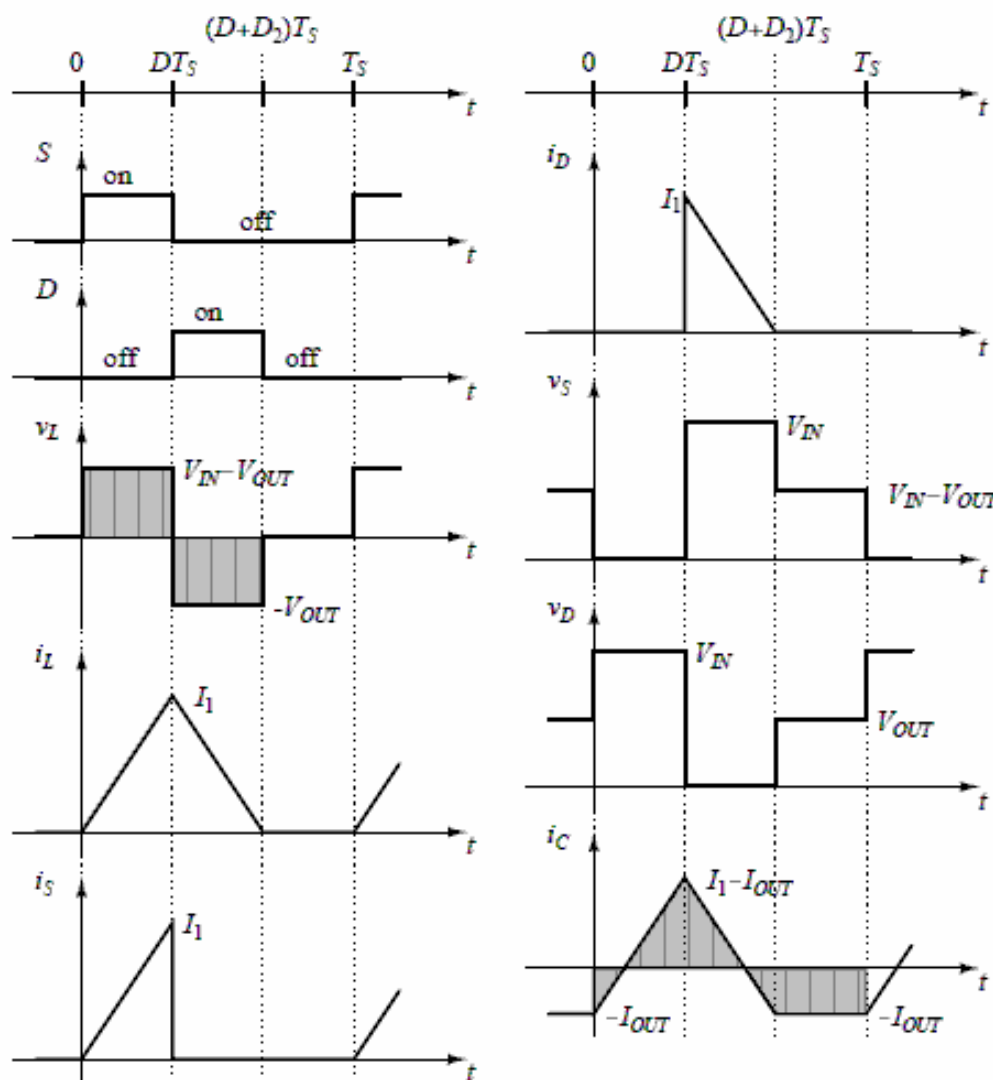
ČOPER SPUŠTAČ NAPONA -BUCK u DISKONTINUALNOM (PREKIDNOM)REŽIMU



NAPONI I STRUJE ČOPERA SPUŠTAČA
NAPONA U DISKONTINUALNOM REŽIMU

t	$0 < t < DT_s$	$DT_s < t < (D + D_2)T_s$	$(D + D_2)T_s < t < T_s$
trajanje	DT_s	D_2T_s	$(1 - D - D_2)T_s$
v_L	$V_{IN} - V_{OUT}$	$-V_{OUT}$	0
i_L	$\frac{v_L}{L}t$	$I_1 + \frac{v_L}{L}(t - DT_s)$	0
i_S	i_L	0	0
i_D	0	i_L	0
v_S	0	V_{IN}	$V_{IN} - V_{OUT}$
v_D	V_{IN}	0	V_{OUT}
i_C	$i_L - I_{OUT}$	$i_L - I_{OUT}$	$i_L - I_{OUT}$

ČOPER SPUŠTAČ NAPONA -BUCK u DISKONTINUALNOM (PREKIDNOM) REŽIMU



SREDNJA VREDNOST NAPONA KALEMA

$$DT_S (V_{IN} - V_{OUT}) + D_2 T_S (-V_{OUT}) = 0$$

$$D_2 = \frac{V_{IN} - V_{OUT}}{V_{OUT}} D$$

SREDNJA VREDNOST IZLAZNE STRUJE

$$I_{OUT} = \overline{i_L} = \langle i_L \rangle = \frac{1}{T_S} \frac{1}{2} (D + D_2) T_S I_1 = \frac{1}{2} (D + D_2) I_1$$

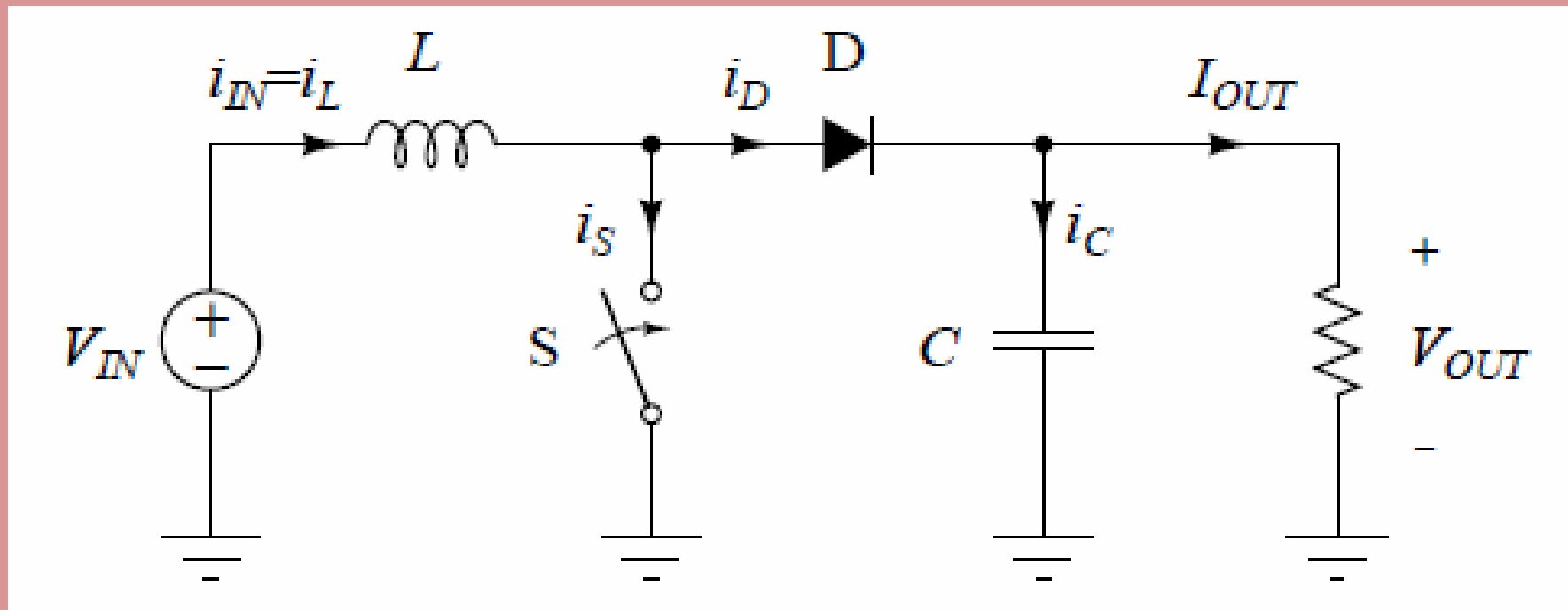
$$I_{OUT} = \frac{D^2}{2f_S L} V_{IN} \frac{V_{IN} - V_{OUT}}{V_{OUT}}$$

PRENOSNI ODNOS ČOPERA

$$M = \frac{V_{OUT}}{V_{IN}}$$

$$M(D, k) = \frac{2}{1 + \sqrt{1 + \frac{4k}{D^2}}} \rightarrow k = \frac{2f_S L}{R}$$

ČOPEK PODIZAČ NAPONA – *BOOST* PRETVARAČ

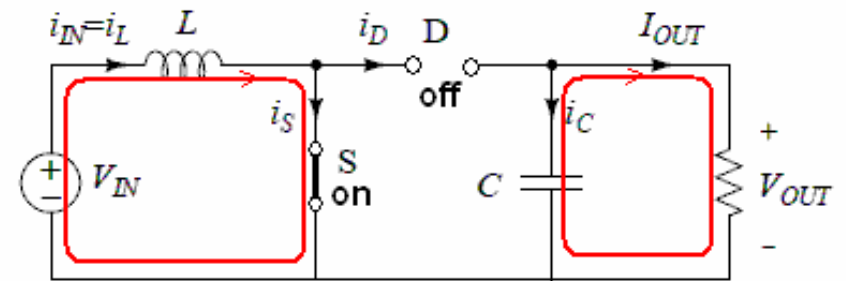
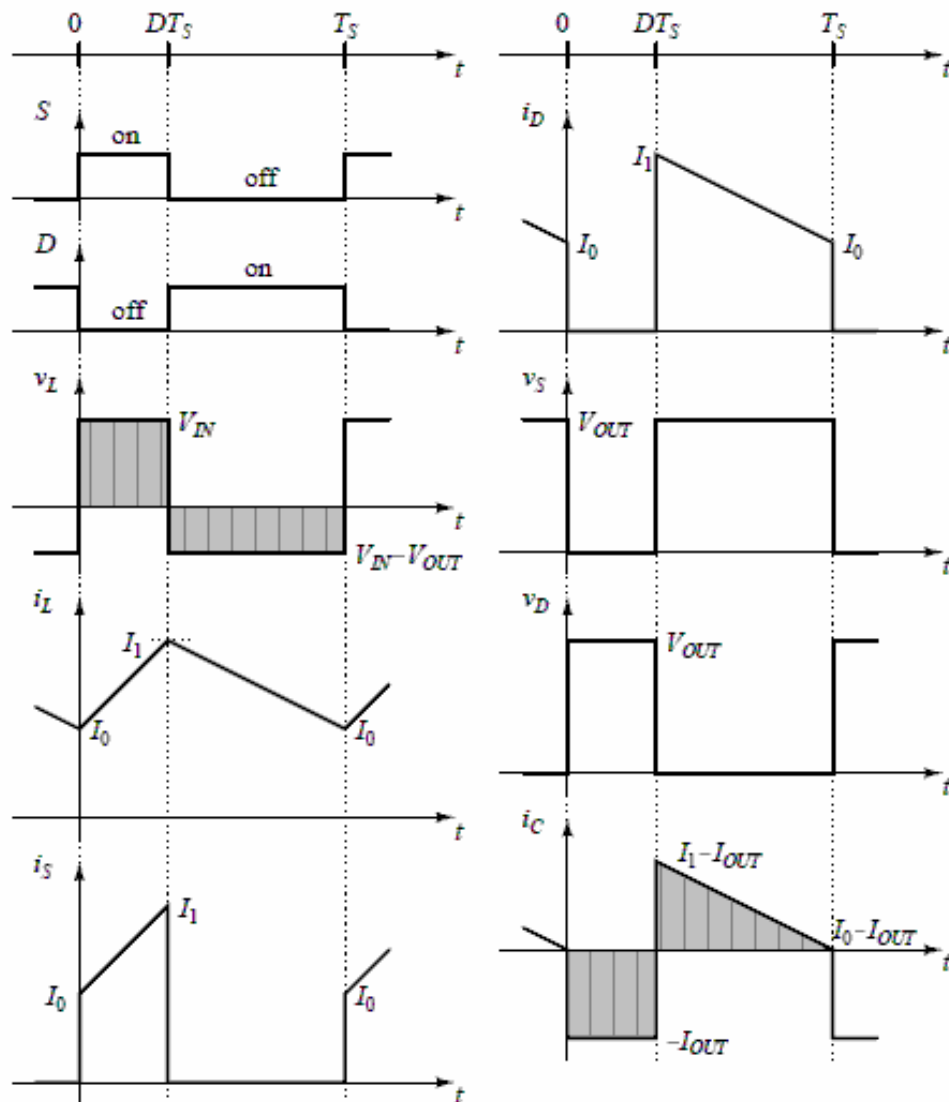


DVA MOGUĆA REŽIMA RADA:

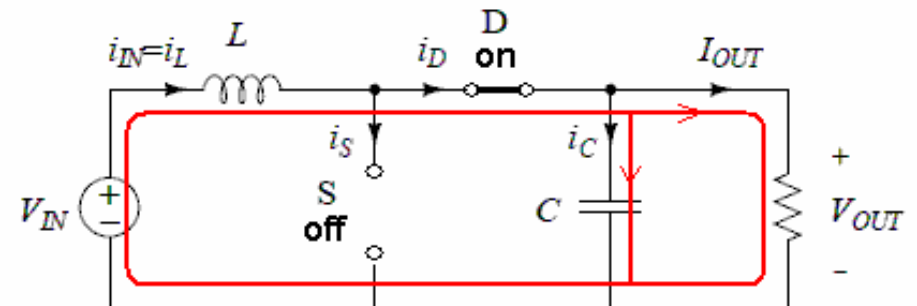
- KONTINUALNI (NEPREKIDNI) REŽIM RADA
- DISKONTINUALNI (PREKIDNI) REŽIM RADA

TALASNI OBLICI I EKVIVALENTNO KOLO ZA ČOPER PODIZAČ NAPONA

– BOOST PRETVARAČ U KONTINUALNOM REŽIMU

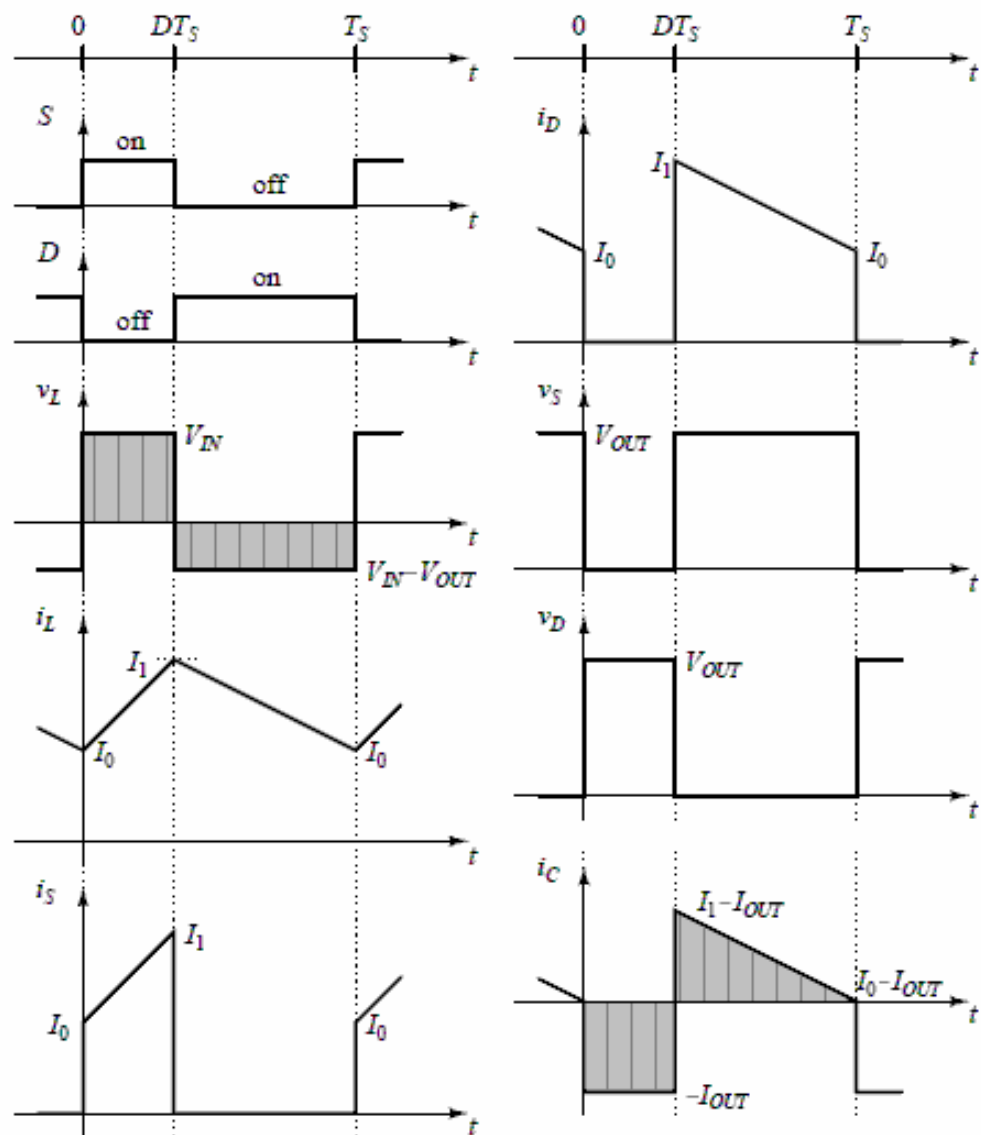


EKVIVALENTNO KOLO ČOPERA PODIZAČA NAPONA U INTERVALU t_{on} KAD JE UKLJUČEN PREKIDAČ



EKVIVALENTNO KOLO ČOPERA PODIZAČA NAPONA U INTERVALU t_{off} KAD JE ISKLJUČEN PREKIDAČ (UKLJUČENA DIODA)

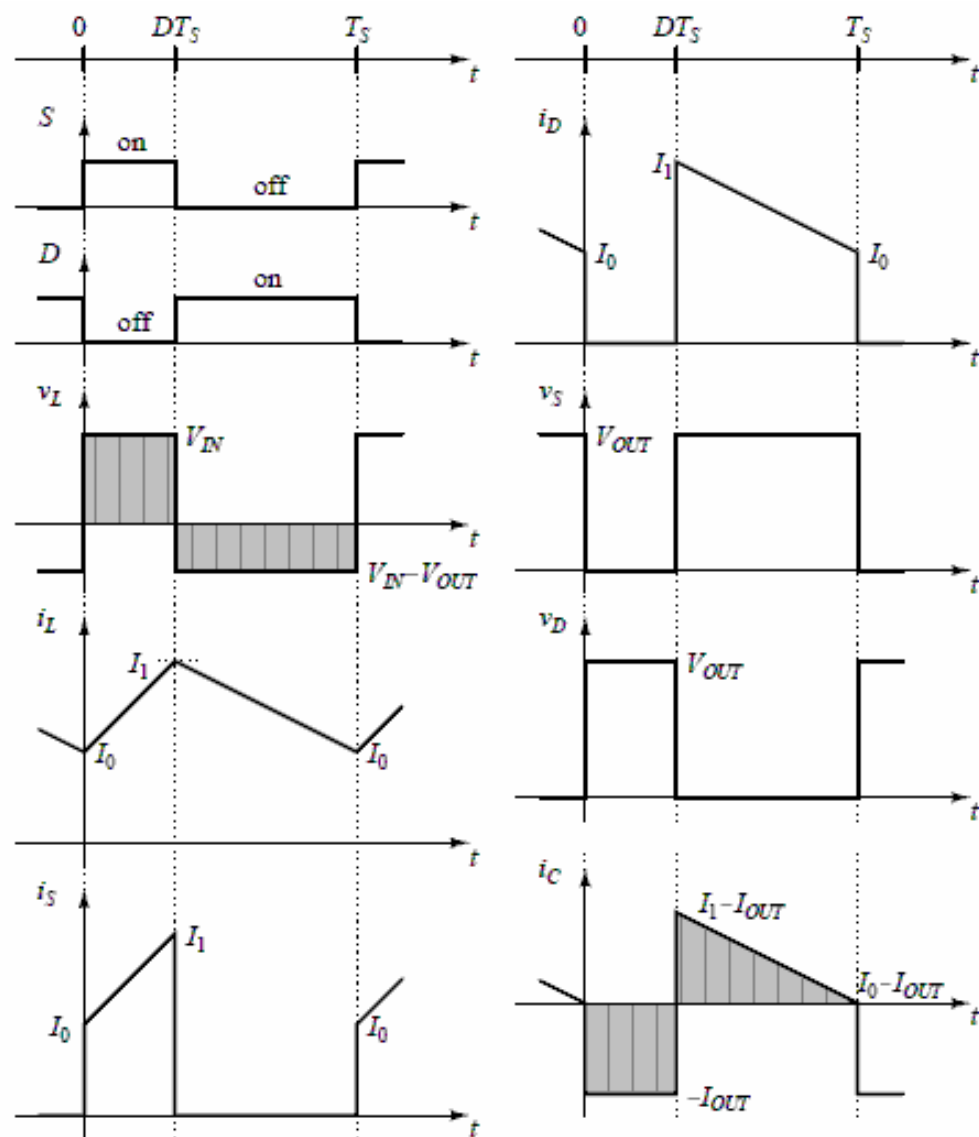
ČOPER PODIZAČ NAPONA-BOOST u KONTINUALNOM REŽIMU



NAPONI I STRUJE ČOPERA PODIZAČA U KONTINUALNOM REŽIMU $I_0 > 0$

t	$0 < t < DT_s$	$DT_s < t < T_s$
trajanje	DT_s	$D'T_s = (1 - D)T_s$
v_L	V_{IN}	$V_{IN} - V_{OUT}$
i_L	$I_0 + \frac{v_L}{L}t$	$I_1 + \frac{v_L}{L}(t - DT_s)$
i_S	i_L	0
i_D	0	i_L
v_S	0	V_{OUT}
v_D	V_{OUT}	0
i_C	$i_D - I_{OUT}$	$i_D - I_{OUT}$

ČOPER PODIZAČ NAPONA-BOOST u KONTINUALNOM REŽIMU



SREDNJA VREDNOST NAPONA NA INDUKTIVNOSTI L JE:

$$DT_S V_{IN} + D'T_S (V_{IN} - V_{OUT}) = 0$$

SREDNJA VREDNOST IZLAZNOG NAPONA JE:

$$V_{OUT} = \frac{1}{1-D} V_{IN}$$

SREDNJA VREDNOST STRUJE KALEMA JE:

$$I_L = \frac{I_0 + I_1}{2} \quad I_{IN} = I_L$$

SREDNJA VREDNOST IZLAZNE STRUJE:

$$I_{OUT} = \frac{1}{T_S} D'T_S \frac{I_1 + I_0}{2} = D' I_L$$

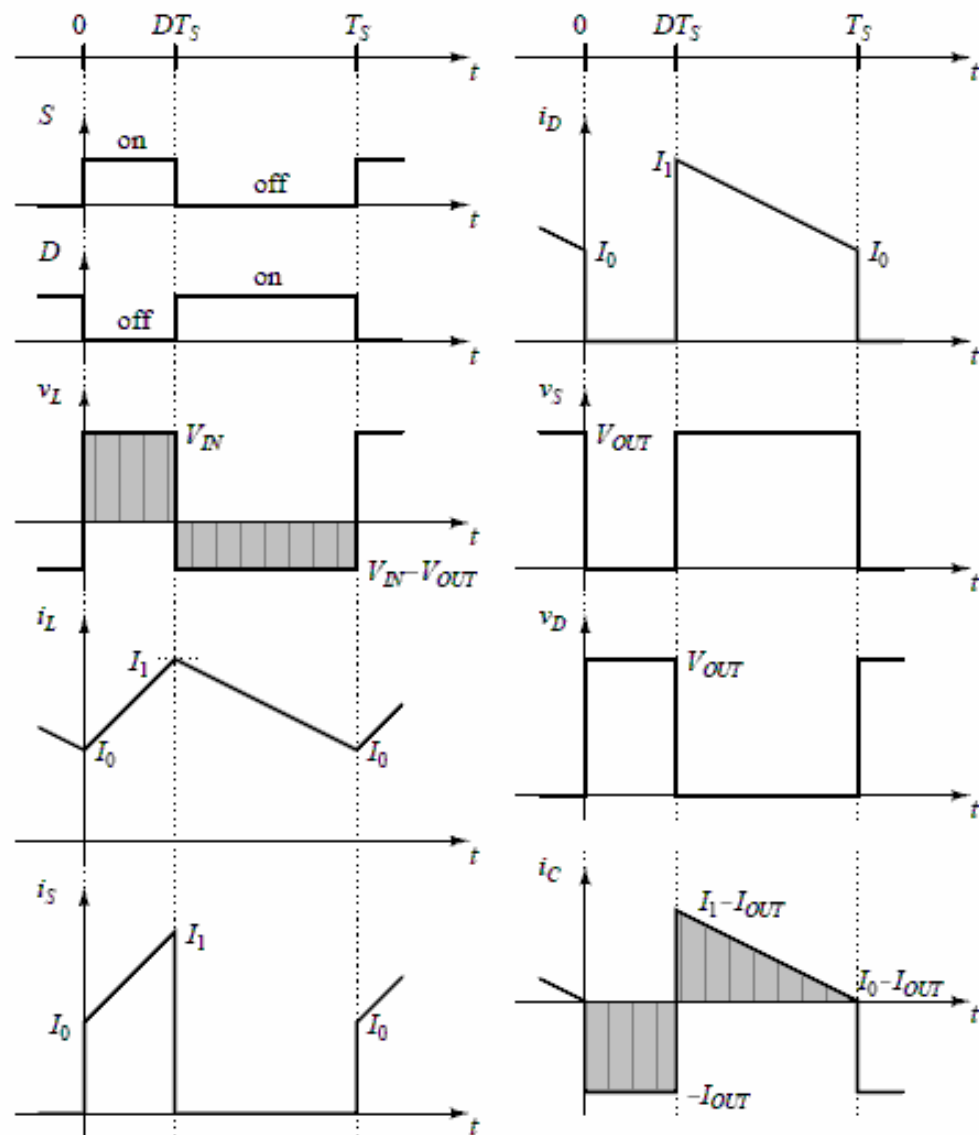
$$I_{OUT} = (1-D) I_{IN}$$

PRENOSNI ODNOS PRETVARAČA:

$$M = \frac{V_{OUT}}{V_{IN}}$$

$$M(D) = \frac{1}{1-D}$$

ČOPER PODIZAČ NAPONA-BOOST u KONTINUALNOM REŽIMU



MAKSIMALNA VREDNOST STRUJE KALEMA:

$$I_1 = I_0 + \frac{V_{IN}}{L} DT_S$$

$$I_1 - I_0 = \frac{V_{IN}}{L} DT_S \quad I_1 + I_0 = 2I_{IN}$$

MINIMALNA VREDNOST STRUJE KALEMA:

$$I_0 = I_{IN} - \frac{V_{IN}}{2f_s L} D = \frac{I_{OUT}}{1 - D} - \frac{V_{IN}}{2f_s L} D$$

MAKSIMALNA VREDNOST STRUJE KALEMA:

$$I_1 = I_{IN} + \frac{V_{IN}}{2f_s L} D = \frac{I_{OUT}}{1 - D} + \frac{V_{IN}}{2f_s L} D$$

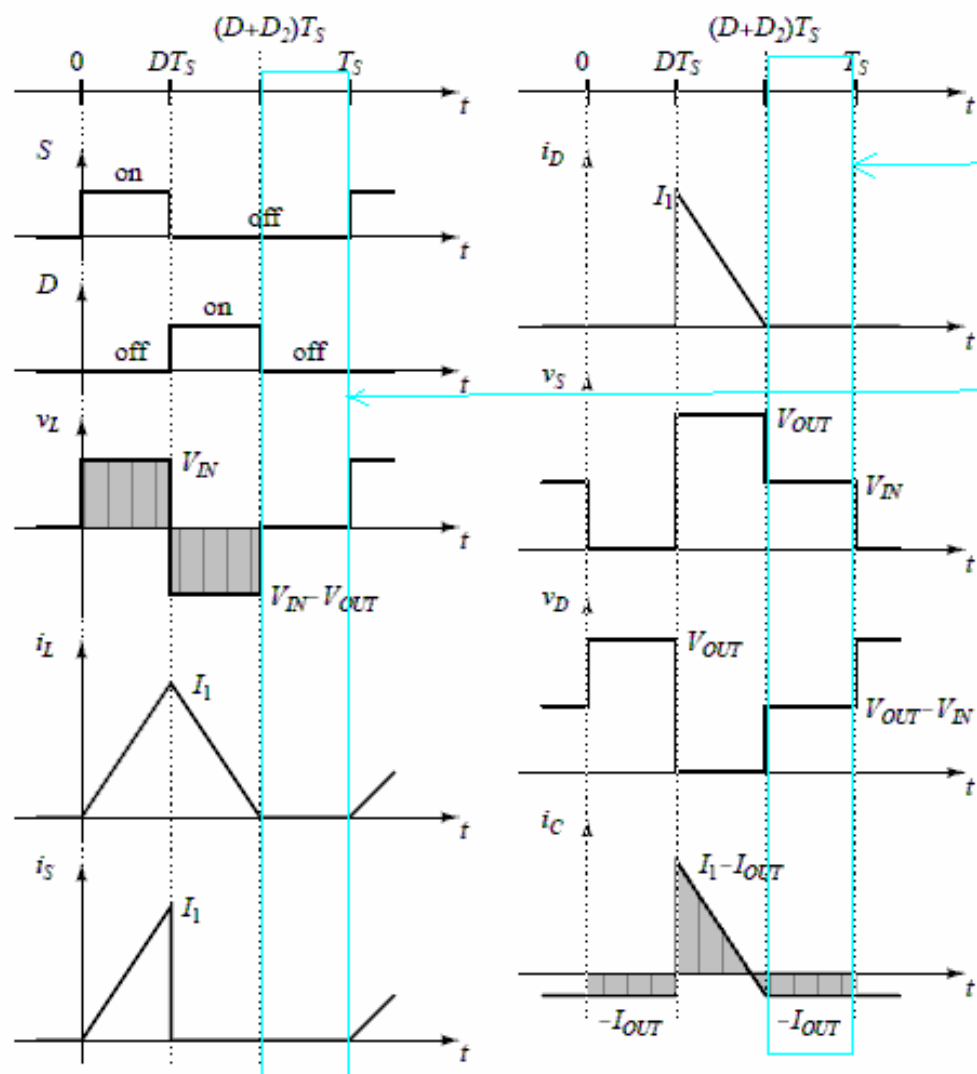
USLOV ZA KONTINUALNI REŽIM:

$$I_0 > 0 \quad \text{tj.} \quad I_{IN} > \frac{V_{IN}}{2f_s L} D$$

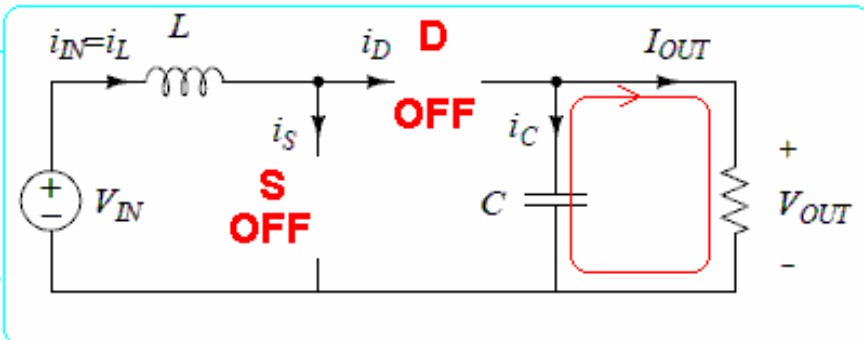


$$I_{OUT} > \frac{V_{IN}}{2f_s L} D (1 - D)$$

ČOPER PODIZAČ NAPONA -BOOST u DISKONTINUALNOM (PREKIDNOM) REŽIMU



ČOPER PODIZAČ NAPONA U DISKONTINUALNOM REŽIMU



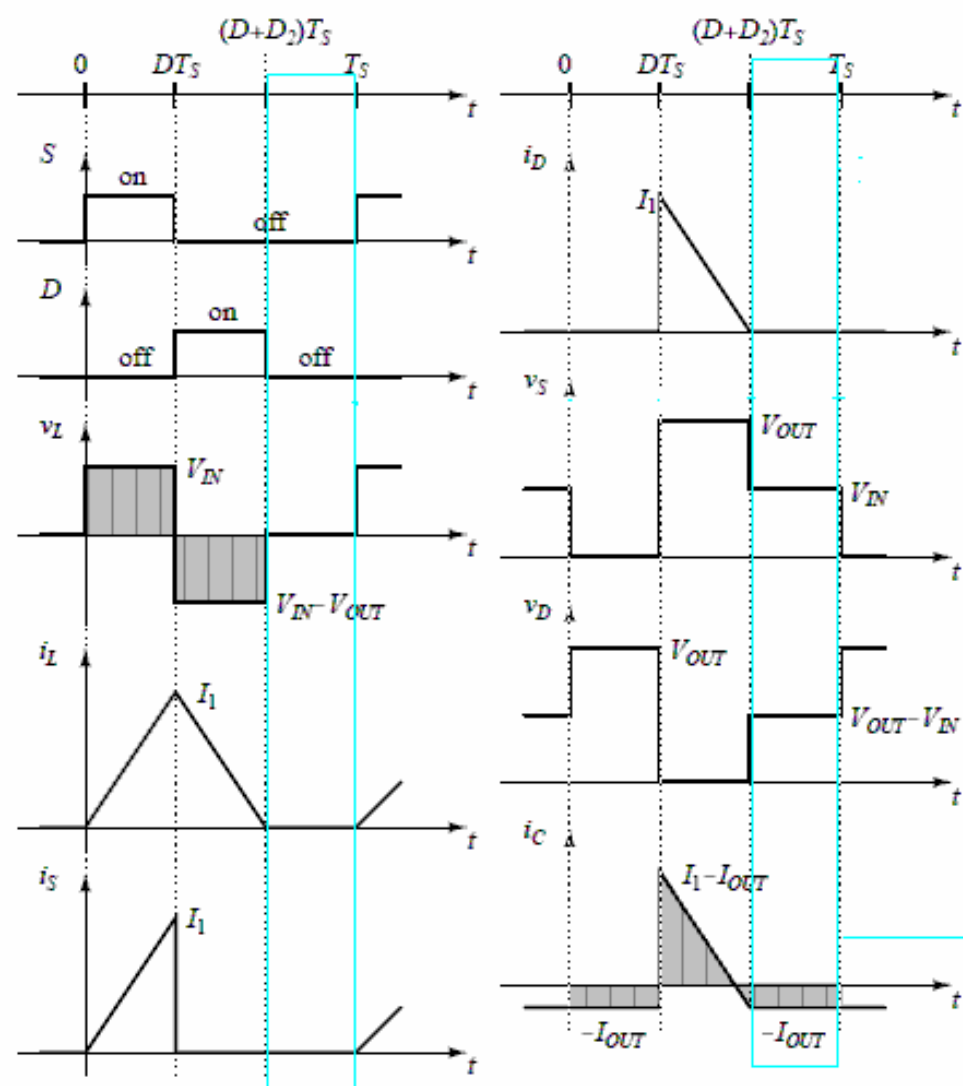
EKVIVALENTNO KOLO U INTERVALU
 $(D + D_2)T_S < t < T_S$

$$I_{OUT} < \frac{V_{IN}}{2f_s L} D(1 - D)$$

$$V_{OUT} \neq \frac{V_{IN}}{1 - D} \quad v_L = L \frac{di_L}{dt} = 0$$

USLOVI

ČOPER PODIZAČ NAPONA -BOOST u DISKONTINUALNOM (PREKIDNOM) REŽIMU



NAPONI I STRUJE ČOPERA PODIZAČA
NAPONA U DISKONTINUALNOM REŽIMU

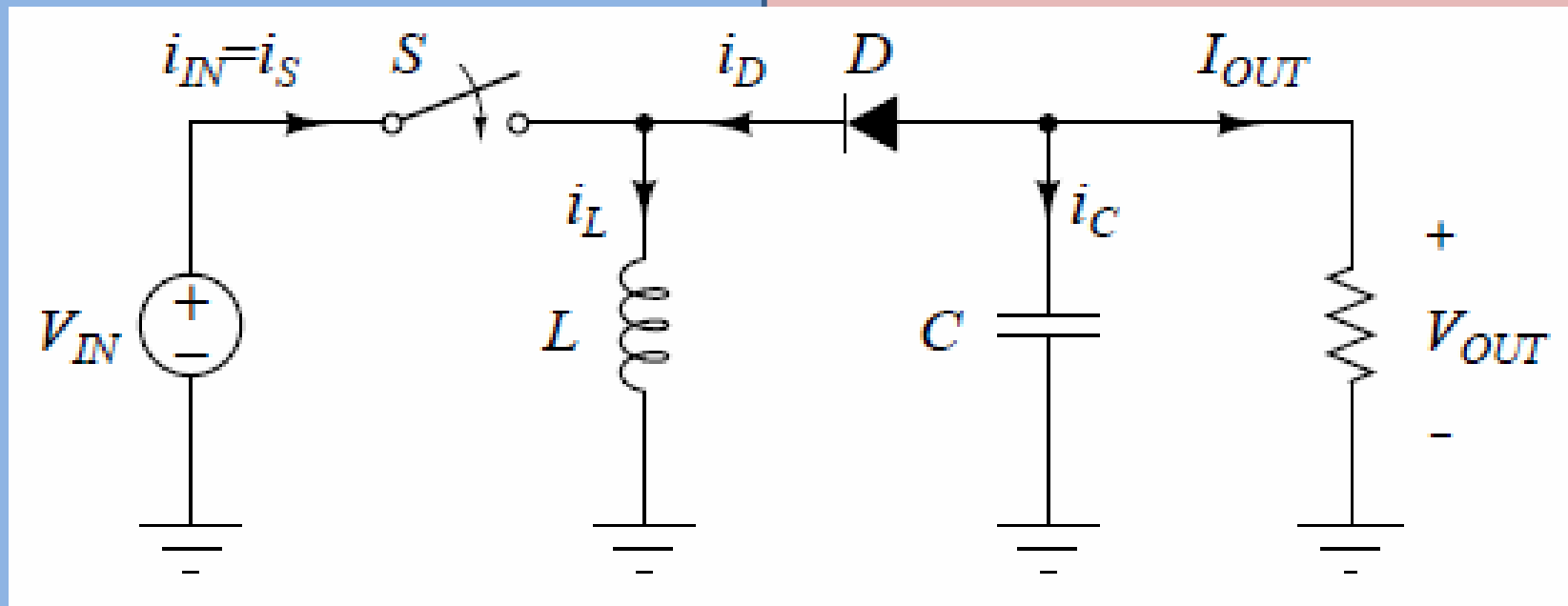
t	$0 < t < DT_S$	$DT_S < t < (D + D_2)T_S$	$(D + D_2)T_S < t < T_S$
trajanje	DT_S	D_2T_S	$(1 - D - D_2)T_S$
v_L	V_{IN}	$V_{IN} - V_{OUT}$	0
i_L	$\frac{v_L}{L}t$	$I_1 + \frac{v_L}{L}(t - DT_S)$	0
i_S	i_L	0	0
i_D	0	i_L	0
v_S	0	V_{OUT}	V_{IN}
v_D	V_{OUT}	0	$V_{OUT} - V_{IN}$
i_C	$i_D - I_{OUT}$	$i_D - I_{OUT}$	$i_D - I_{OUT}$

$$M = \frac{V_{OUT}}{V_{IN}}, \quad M(D, k) = \frac{1}{2} \left(1 + \sqrt{1 + \frac{4D^2}{k}} \right), \quad k = \frac{2f_s L}{R}$$

ČOPER OBRTAČ NAPONA

BUCK $\longleftrightarrow$ *BOOST*

PRETVARAČ

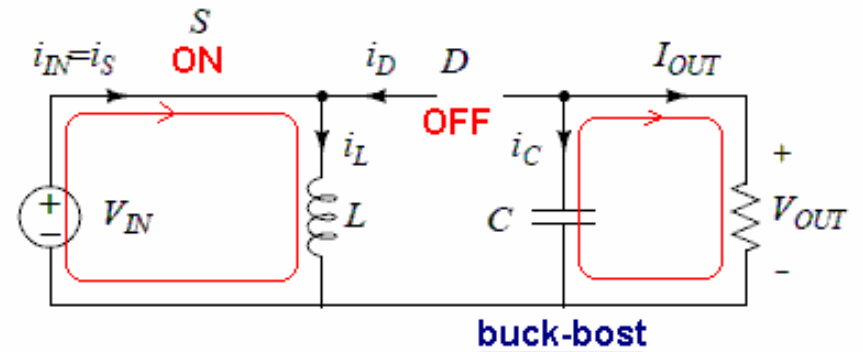
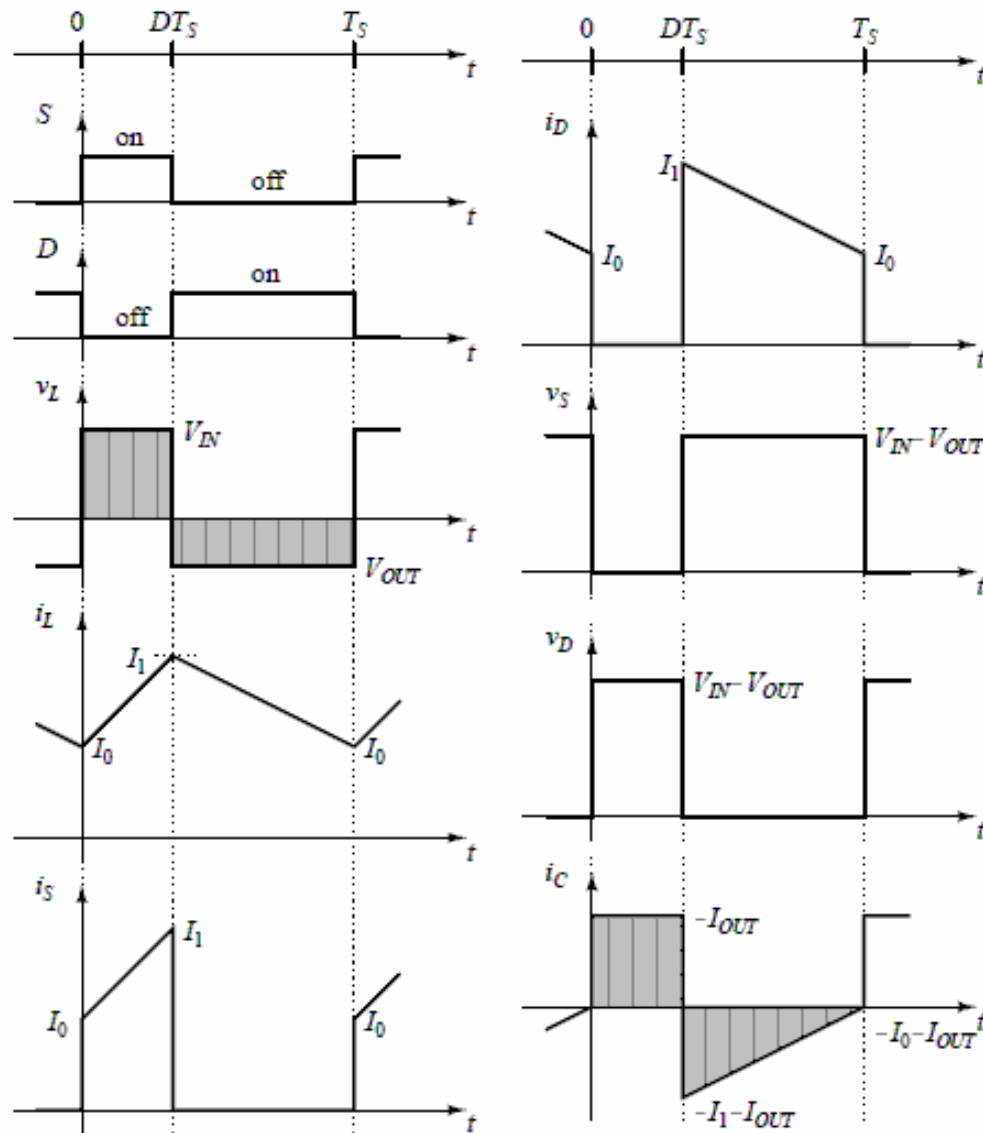


DVA MOGUĆA REŽIMA RADA:

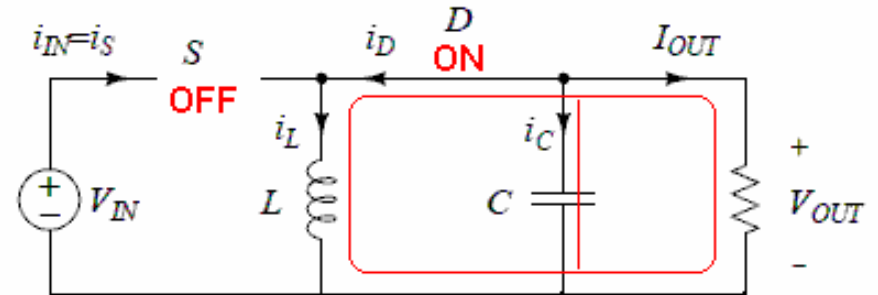
- KONTINUALNI (NEPREKIDNI) REŽIM RADA
- DISKONTINUALNI (PREKIDNI) REŽIM RADA

TALASNI OBLICI I EKVIVALENTNO KOLO ZA ČOPER OBRTAČ NAPONA

BUCK - BOOST PRETVARAČ U KONTINUALNOM REŽIMU

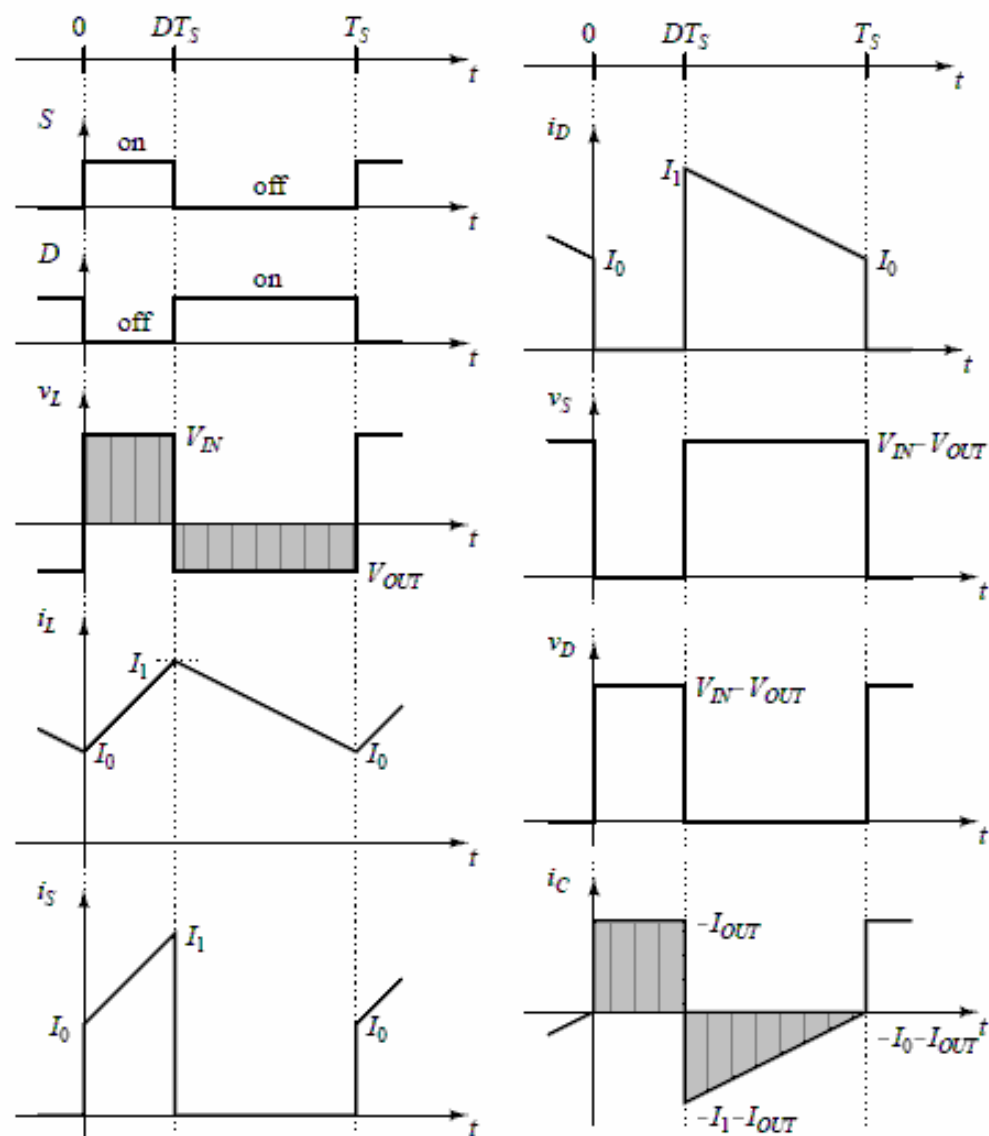


EKVIVALENTNO KOLO ČOPERA **OBRTAČA** NAPONA U INTERVALU t_{on} KAD JE UKLJUČEN PREKIDAČ



EKVIVALENTNO KOLO ČOPERA **OBRTAČA** NAPONA U INTERVALU t_{off} KAD JE ISKLJUČEN PREKIDAČ (UKLJUČENA DIODA)

ČOPER OBRTAČ NAPONA BUCK - BOOST PRETVARAČ u KONTINUALNOM REŽIMU

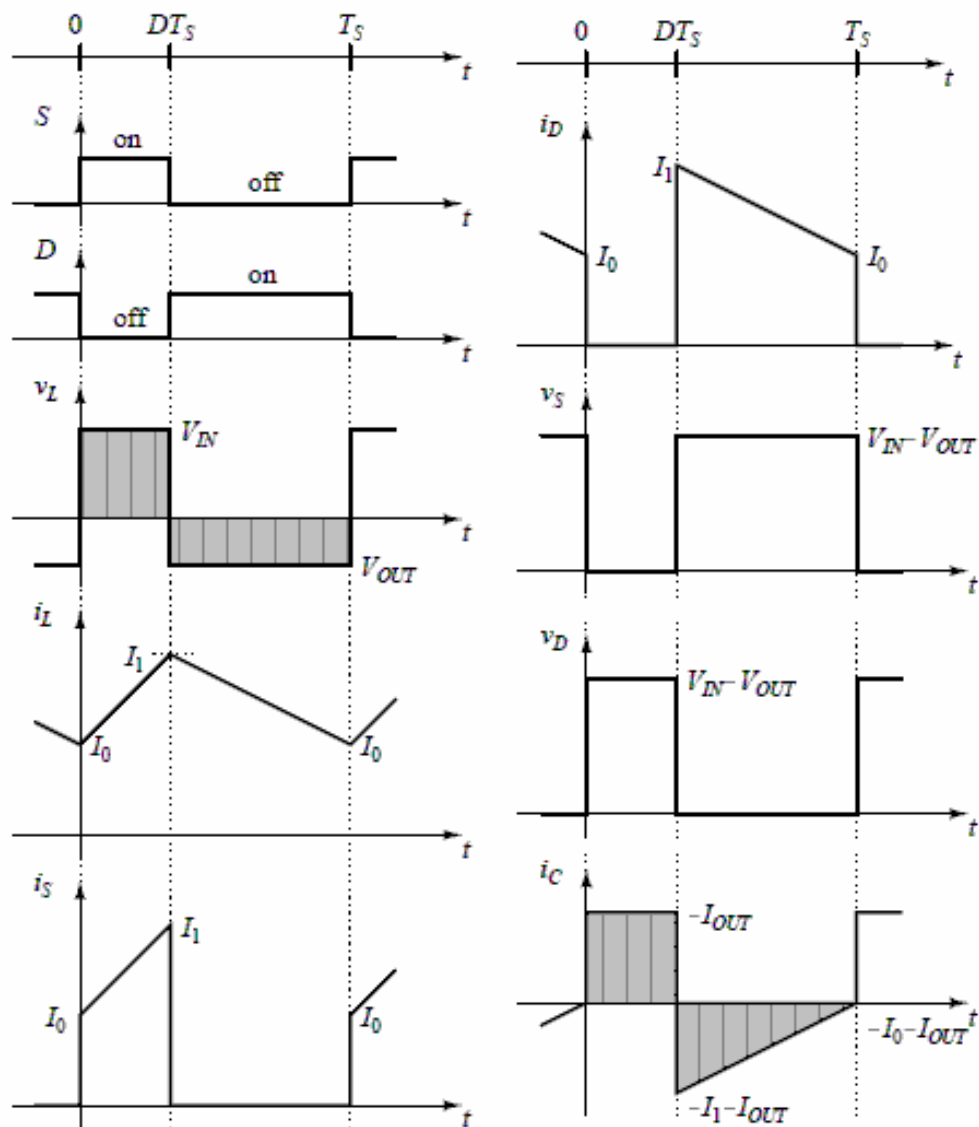


NAPONI I STRUJE ČOPERA PODIZAČA **OBRTAČA NAPONA**

U KONTINUALNOM REŽIMU $I_0 > 0$

t	$0 < t < DT_s$	$DT_s < t < T_s$
trajanje	DT_s	$D'T_s = (1 - D)T_s$
v_L	V_{IN}	V_{OUT}
i_L	$I_0 + \frac{v_L}{L}t$	$I_1 + \frac{v_L}{L}(t - DT_s)$
i_S	i_L	0
i_D	0	i_L
v_S	0	$V_{IN} - V_{OUT}$
v_D	$V_{IN} - V_{OUT}$	0
i_C	$-i_D - I_{OUT}$	$-i_D - I_{OUT}$

ČOPER OBRTAČ NAPONA BUCK - BOOST PRETVARAČ u KONTINUALNOM REŽIMU



SREDNJA VREDNOST NAPONA NA INDUKTIVNOSTI L JE:

$$DT_S V_{IN} + D'T_S V_{OUT} = 0$$

SREDNJA VREDNOST IZLAZNOG NAPONA JE:

$$V_{OUT} = -\frac{D}{1-D} V_{IN}$$

SREDNJA VREDNOST STRUJE KALEMA JE:

$$I_L = \frac{I_0 + I_1}{2}$$

SREDNJA VREDNOST IZLAZNE STRUJE:

$$I_{OUT} = -\frac{1}{T_S} D'T_S \frac{I_1 + I_0}{2} = -D'I_L$$

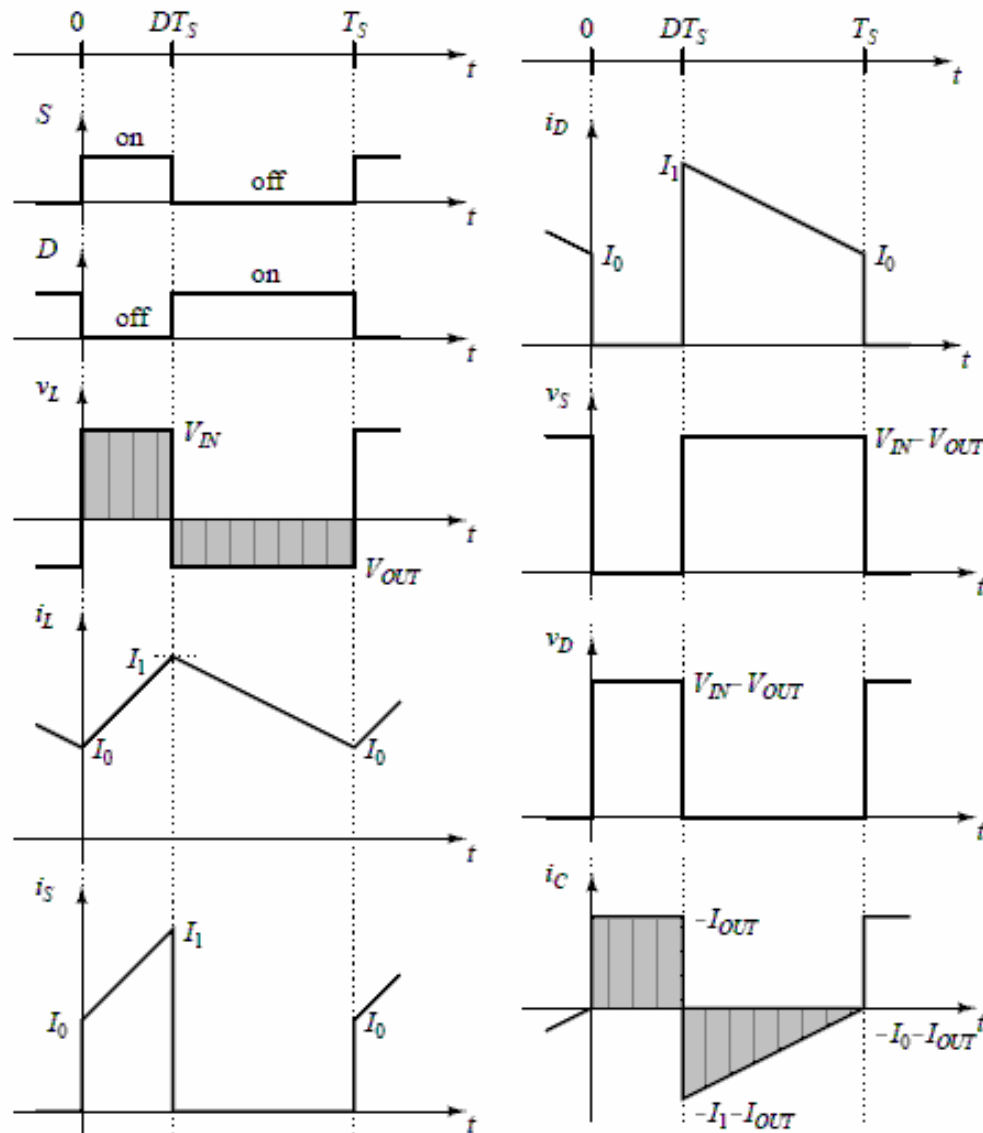
$$I_{OUT} = -\frac{1-D}{D} I_{IN}$$

PRENOSNI ODNOS PRETVARAČA:

$$M = \frac{V_{OUT}}{V_{IN}}$$

$$M(D) = -\frac{D}{1-D}$$

ČOPER OBRTAČ NAPONA BUCK - BOOST PRETVARAČ u KONTINUALNOM REŽIMU



MAKSIMALNA VREDNOST STRUJE KALEMA:

$$I_1 = I_0 + \frac{V_{IN}}{L} DT_S$$

$$I_1 - I_0 = \frac{V_{IN}}{L} DT_S \quad I_1 + I_0 = 2I_L$$

MINIMALNA VREDNOST STRUJE KALEMA:

$$I_0 = I_{IN} - \frac{V_{IN}}{2f_s L} D = \frac{I_{OUT}}{1-D} - \frac{V_{IN}}{2f_s L} D$$

MAKSIMALNA VREDNOST STRUJE KALEMA:

$$I_1 = I_L + \frac{V_{IN}}{2f_s L} D = -\frac{I_{OUT}}{1-D} + \frac{V_{IN}}{2f_s L} D$$

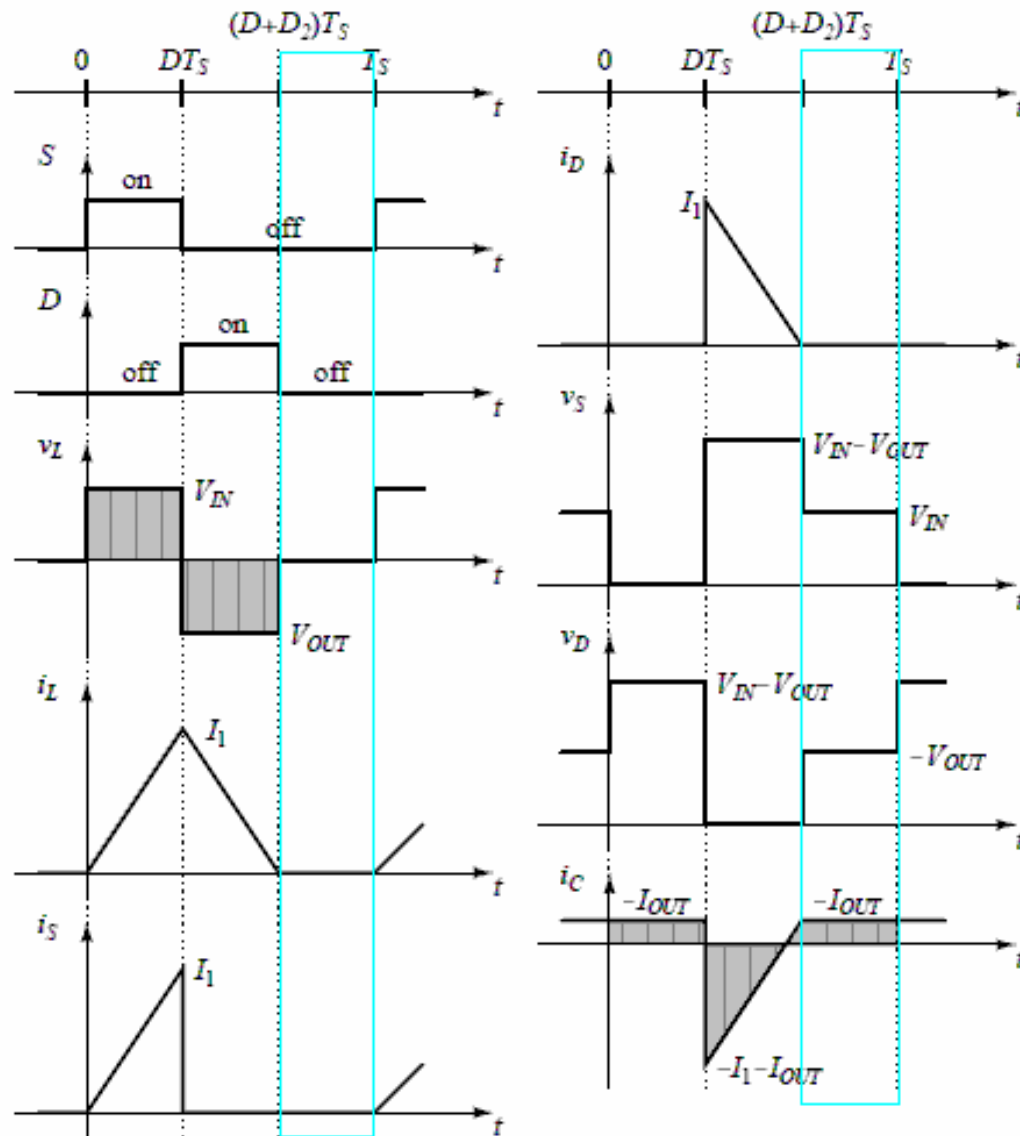
USLOV ZA KONTINUALNI REŽIM:

$$I_0 > 0 \quad \text{tj.} \quad I_{IN} > \frac{V_{IN}}{2f_s L} D$$

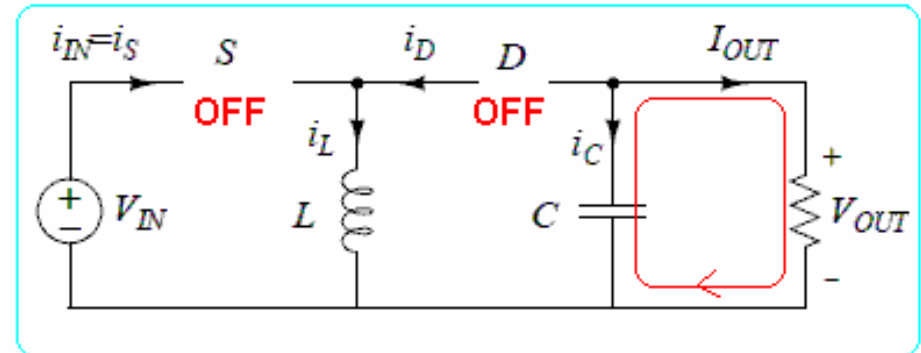


$$I_{OUT} < -\frac{V_{IN}}{2f_s L} D(1-D)$$

ČOPER OBRTAČ NAPONA BUCK - BOOST PRETVARAČ U PREKIDNOM (DISKONTINUALNOM) REŽIMU



buck-boost ČOPER OBRTAČ NAPONA U DISKONTINUALNOM REŽIMU



EKVIVALENTNO KOLO U INTERVALU
 $(D + D_2)T_S < t < T_S$

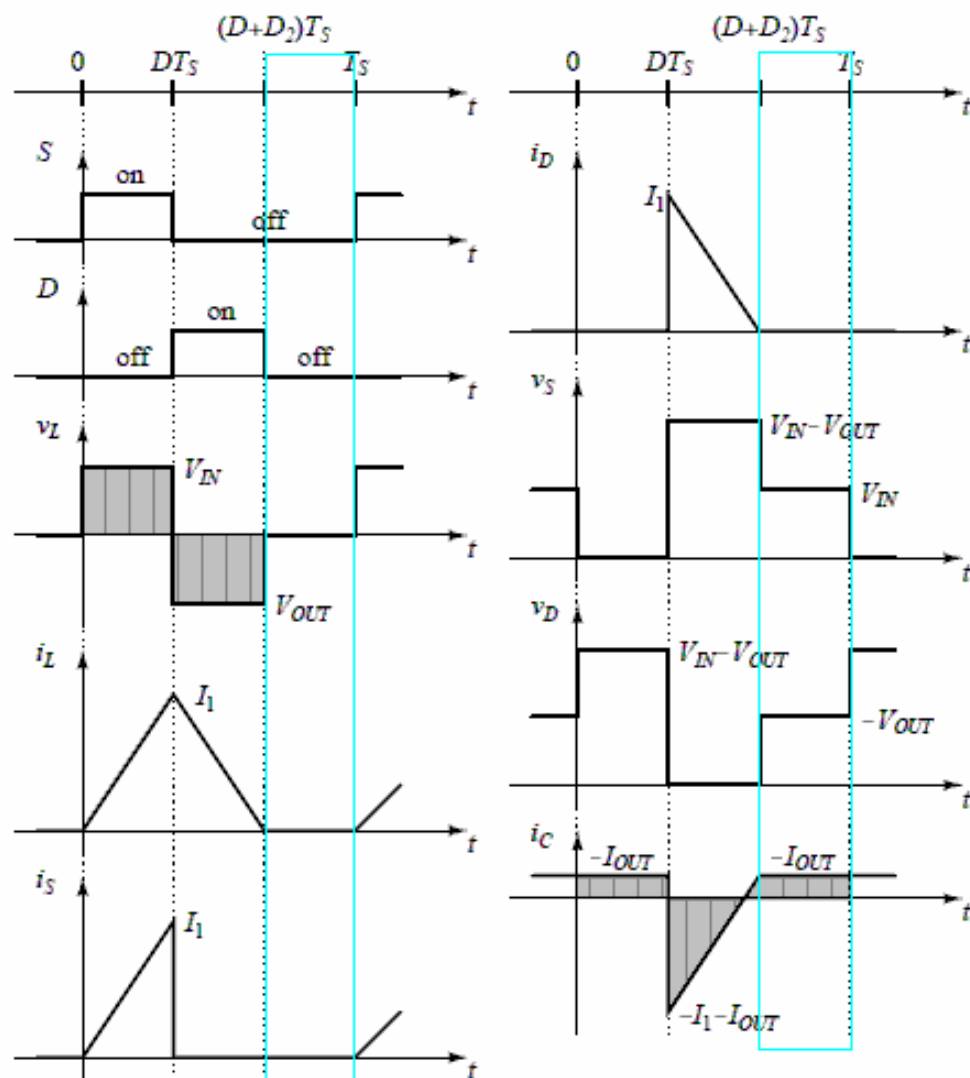
$$|I_{OUT}| < \frac{V_{IN}}{2f_s L} D(1 - D)$$

$$V_{OUT} \neq -\frac{D}{1 - D} V_{IN}$$

$$v_L = L \frac{di_L}{dt} = 0$$

USLOVI

ČOPER OBRTAČ NAPONA BUCK - BOOST PRETVARAČ u PREKIDNOM (DISKONTINUALNOM) REŽIMU

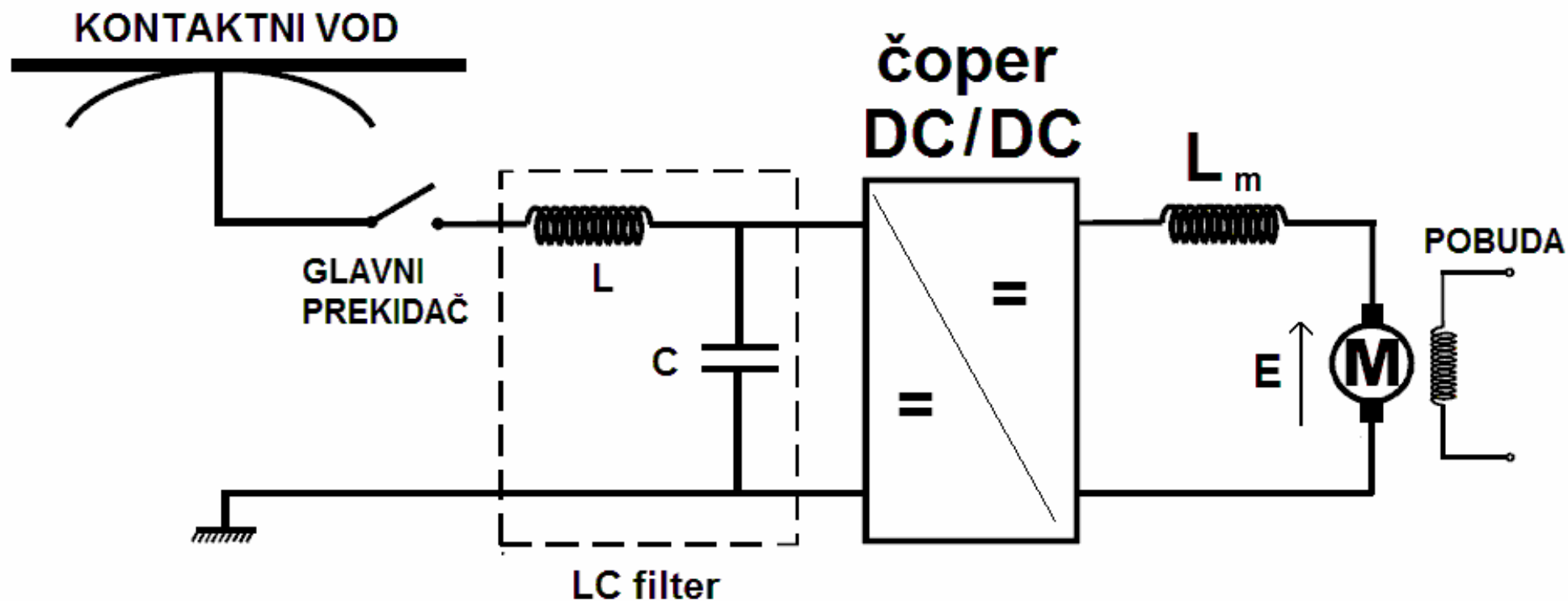


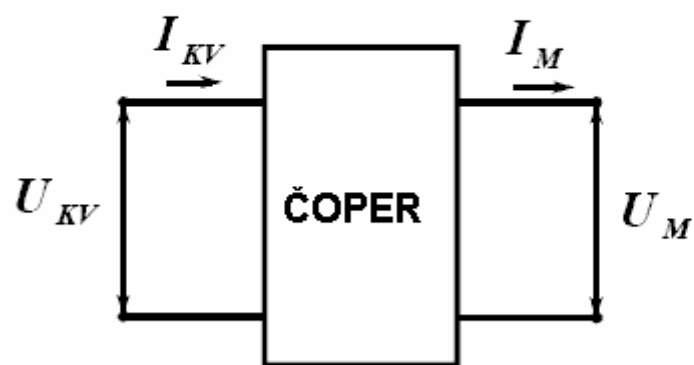
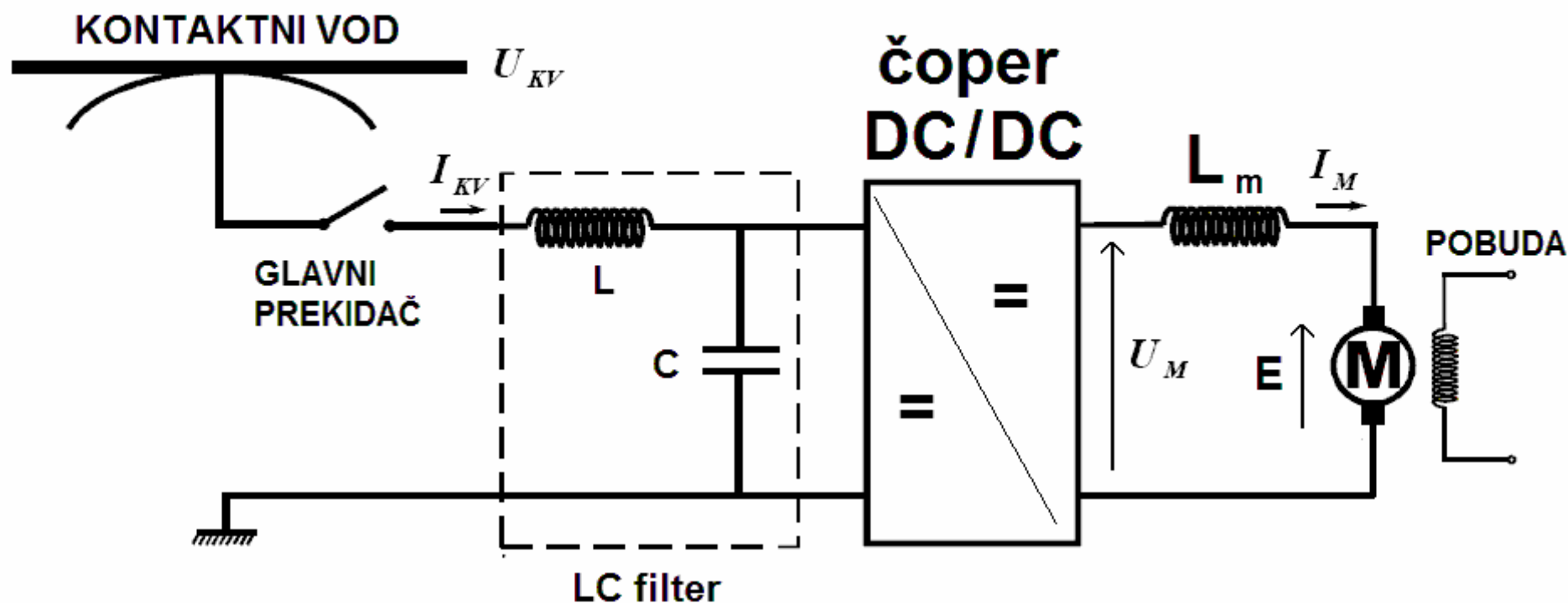
NAPONI I STRUJE ČOPERA **buck-boost OBRTAČA**
NAPONA U DISKONTINUALNOM REŽIMU

t	$0 < t < DT_S$	$DT_S < t < (D + D_2)T_S$	$(D + D_2)T_S < t < T_S$
trajanje	DT_S	D_2T_S	$(1 - D - D_2)T_S$
v_L	V_{IN}	V_{OUT}	0
i_L	$\frac{v_L}{L}t$	$I_1 + \frac{v_L}{L}(t - DT_S)$	0
i_S	i_L	0	0
i_D	0	i_L	0
v_S	0	$V_{IN} - V_{OUT}$	V_{IN}
v_D	$V_{IN} - V_{OUT}$	0	$-V_{OUT}$
i_C	$-i_D - I_{OUT}$	$-i_D - I_{OUT}$	$-i_D - I_{OUT}$

$$M = \frac{V_{OUT}}{V_{IN}}, \quad M(D, k) = -\frac{D}{\sqrt{k}}, \quad k = \frac{2f_S L}{R}$$

PRIMENA ČOPERA : REGULACIJA MOMENTA (VUČNE SILE) I BRZINE JEDNOSMERNIH MOTORA SA NEZAVISNOM POBUDOM





$\eta \rightarrow 1$ (zanemarujemo gubitke u čoperu) $\Rightarrow P_M = P_{KV}$
 pri tome je ključna osobina čopera
 podešavanje napona bez gubitaka
 snage: $U \in [0, U_{KV}]$

ČOPER Spuštač napona "BUCK"

Pošto je $L \rightarrow \infty$ struju možemo smatrati konstantnom!

$$D = \frac{t_{on}}{T}$$

D - indeks modulacije

I_L - struja prigušnice

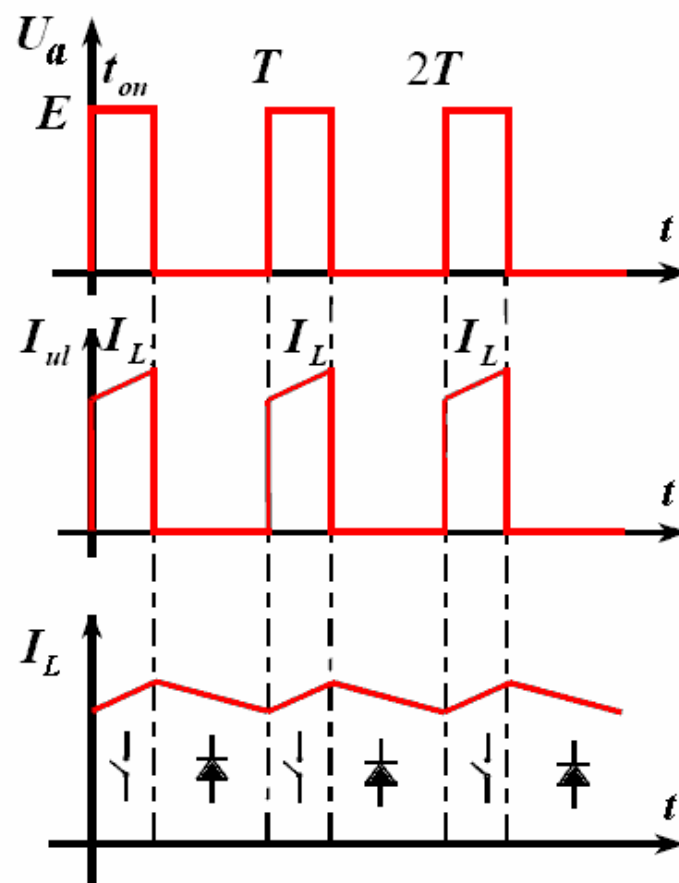
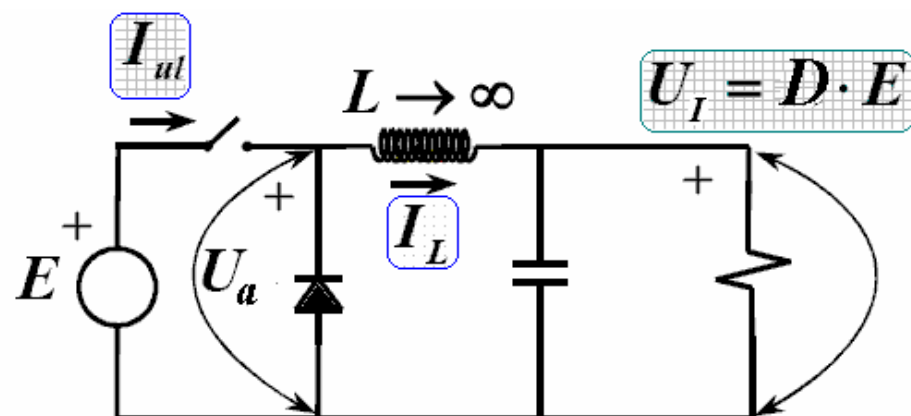
$$I_{ul_{sr}} = D \cdot I_L$$

KONTINUALNO PODEŠAVANJE
IZLAZNOG NAPONA

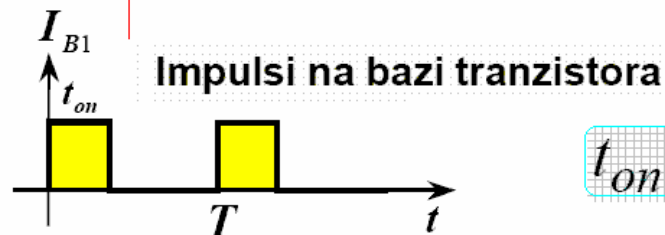
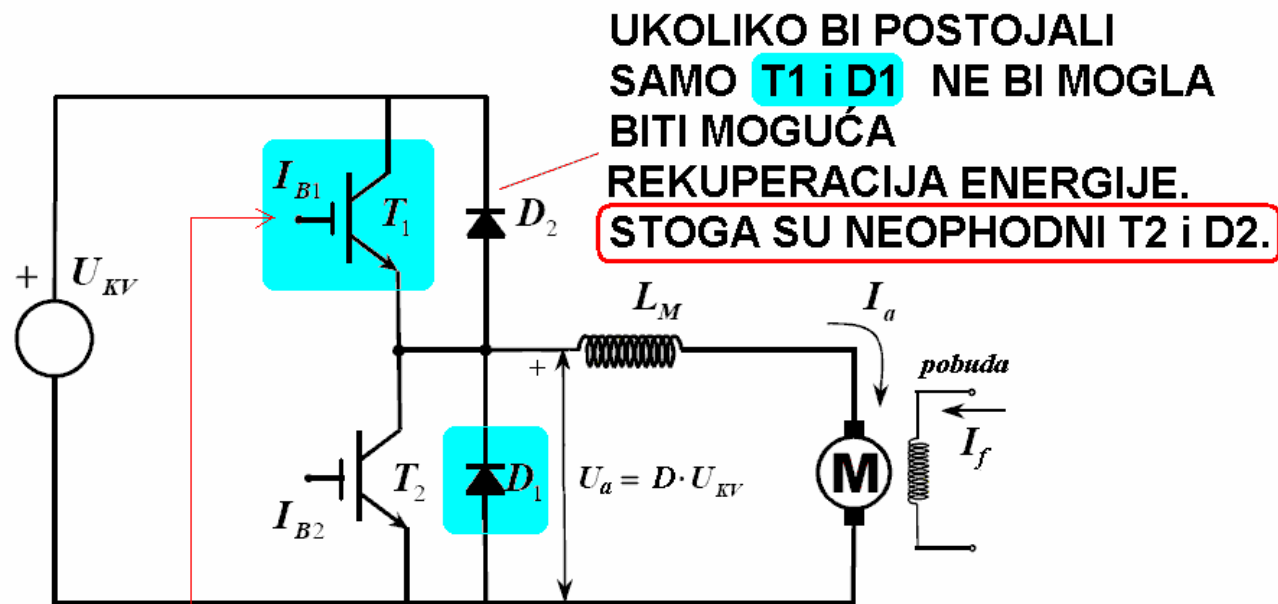
od 0 do E

ULAZNA SNAGA

$$P = E \cdot D \cdot I_L$$



Čoper spuštač napona sa rekuperacijom



$$t_{on} = D \cdot T$$

Promenom t_{on} može se podešavati kontinualno brzina i vučna sila

napon

$$U_a = D \cdot U_{kv} = K_e \cdot \Phi \cdot \omega + R_a \cdot I_a \Rightarrow \omega = \frac{D \cdot U_{kv} - R_a \cdot I_a}{K_e \cdot \Phi}$$

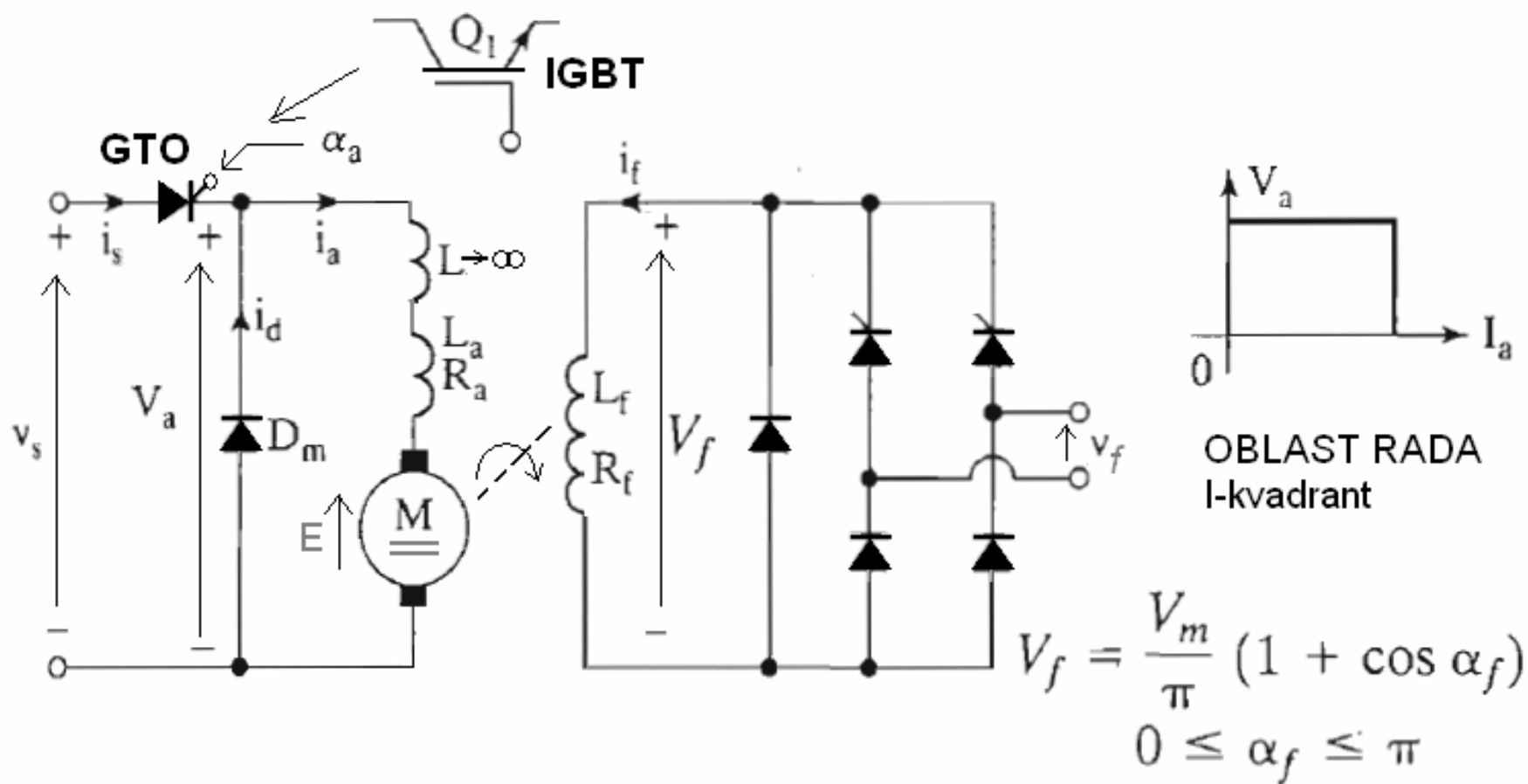
vučna sila ~ momenat ~ struja motora

$$F_v \sim M_{em} \sim I_a = \frac{D \cdot U_{kv} - K_e \cdot \Phi \cdot \omega}{R_a^*}$$

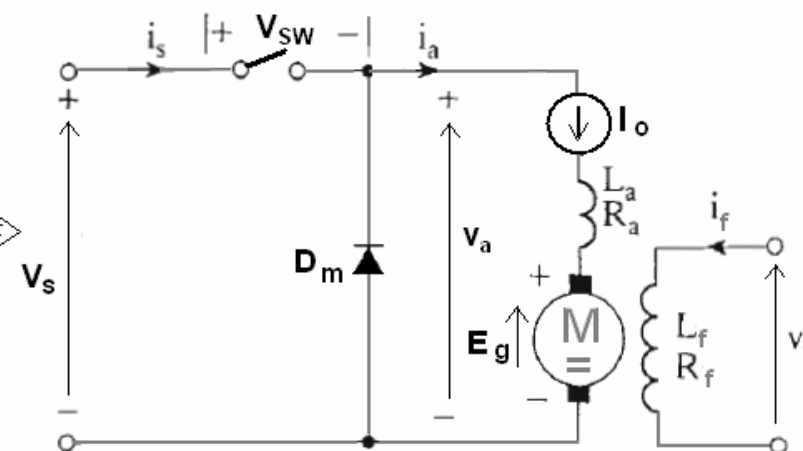
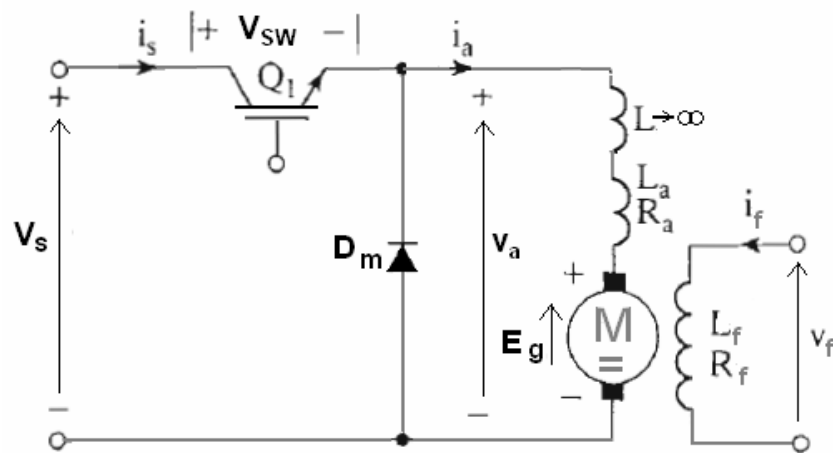
$$R_a^* = R_a + R_L$$

Omski otpor prigušnice

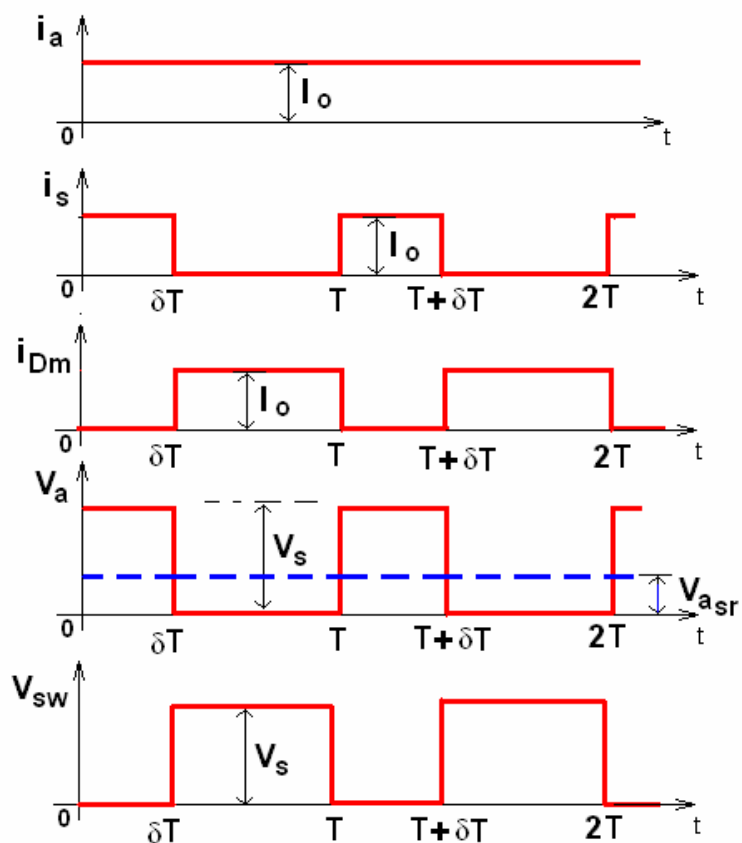
ČOPERSKO KOLO ZA POBUDU DC MOTORA SA TIRISTORSKI KONTROLISANOM NEZAVISNOM POBUDOM



OSNOVNO ČOPERSKO KOLO ZA POBUDU DC MOTORASA NEZAVISNOM POBUDOM-ANALIZA RADA



EKVIVALENTNO KOLO



STACIONARNI REŽIM:

NAPONSKA JEDNAČINA MOTORA

$$V_{asr} = R_a I_o + E_g$$

$$V_{asr} = \delta V_s$$

KEMS ELEKTROMOTORA

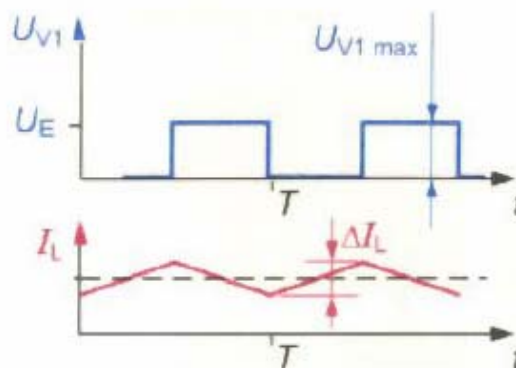
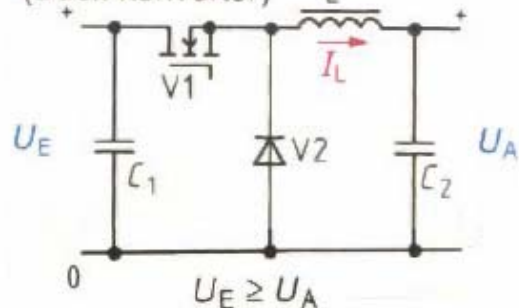
$$E_g = k I_f n$$

ULAZNA SNAGA MOTORA

$$P_{IN} = E_g I_o$$

OSNOVNI TIPOVI ČOPERA: REKAPITULACIJA

Regulator smanjenja napona
(Buck-konvertor)



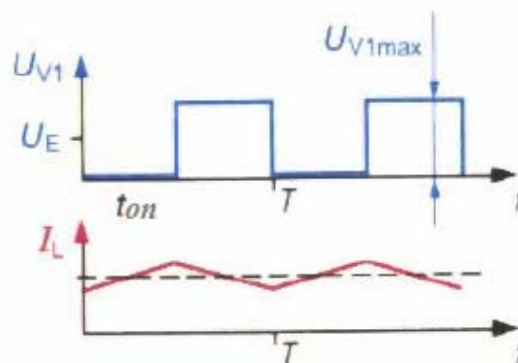
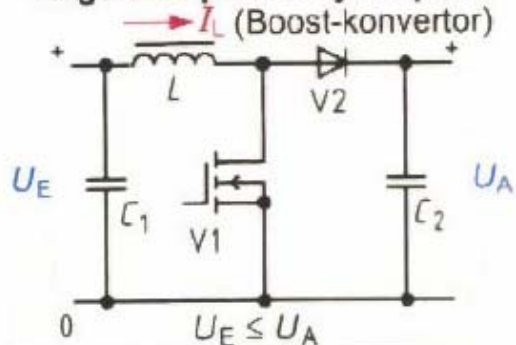
$$U_A = g \cdot U_E$$

$$L = \frac{(U_E - U_A) \cdot U_A}{\Delta I_L \cdot f \cdot U_E}$$

$$I_L = I_A$$

$$U_{V1max} = U_E$$

Regulator povećanja napona
(Boost-konvertor)



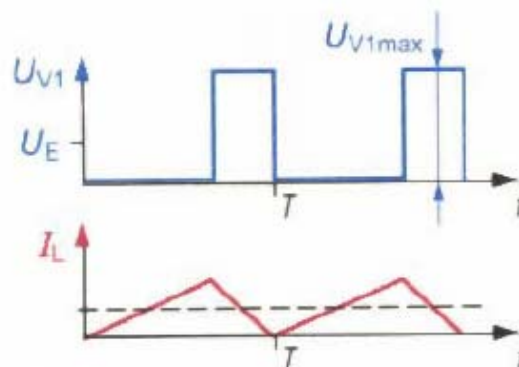
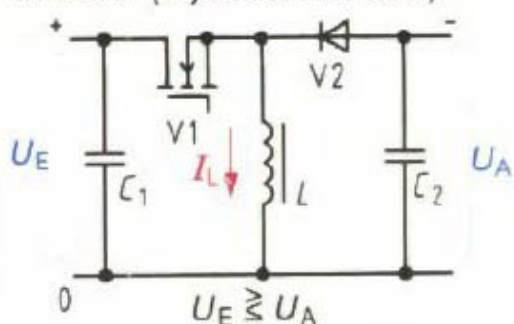
$$U_A = \frac{1}{1-g} \cdot U_E$$

$$L = \frac{(U_A - U_E) \cdot U_E}{\Delta I_L \cdot f \cdot U_A}$$

$$I_L = \frac{1}{1-g} \cdot I_A$$

$$U_{V1max} = 2 \cdot U_E$$

Invertor (Flyback-konvertor)



$$U_A = \frac{1}{1-g} \cdot U_E$$

$$L = \frac{U_A \cdot U_E}{\Delta I_L \cdot f \cdot (U_A + U_E)}$$

$$I_L = \frac{1}{1-g} \cdot I_A$$

$$U_{V1max} = 2 \cdot U_E$$

Faktor režima $g = \frac{t_{on}}{T}$; $g = \frac{\text{trajanje uključenja}}{\text{trajanje periode}}$