

Stikalni pretvorniki

Seminar: Načrtovanje elektronike za EMC – 9. 3. 2016

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Univerza v Ljubljani

Fakulteta za elektrotehniko

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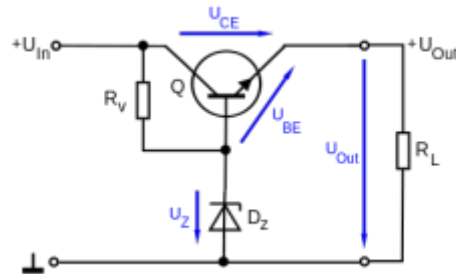


Vsebina

- Prednosti stikalnih pretvornikov
- Neizolirani pretvorniki
- Izolirani pretvorniki
- Parazitne lastnosti transformatorja / sklopljene induktivnosti
- Pomožna vezja
- PFC

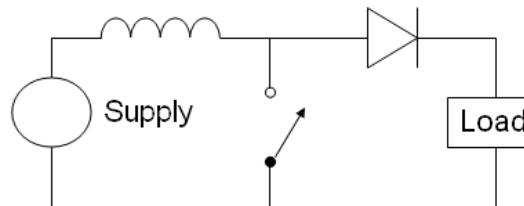
Zakaj stikalni pretvornik

- Izkoristek



$$\eta < \frac{U_{out}}{U_{in}}$$

- $U_{out} > U_{in}$

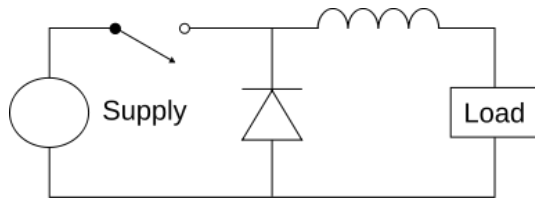


- Velikost

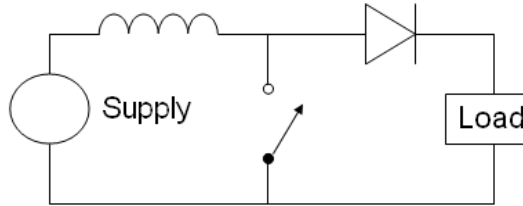


Neizolirani pretvorniki I

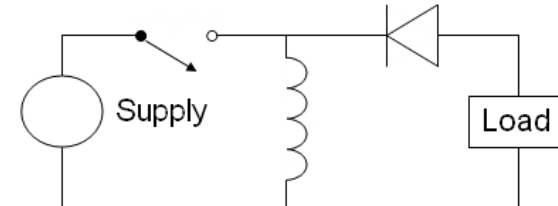
- Navzdol
(step-down, buck)



- Navzgor
(step-up, boost)



- Navzdol/Navzgor
(buck-boost)



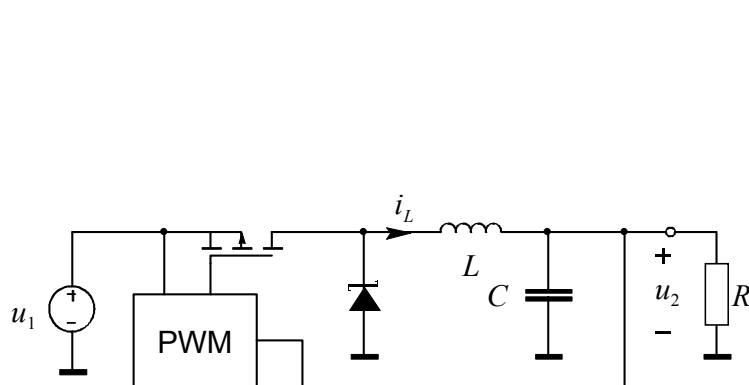
- Osnovne enačbe za neprekinjeno delovanje:

$$U_{out} = D \cdot U_{in}$$

$$U_{out} = \frac{1}{1-D} \cdot U_{in}$$

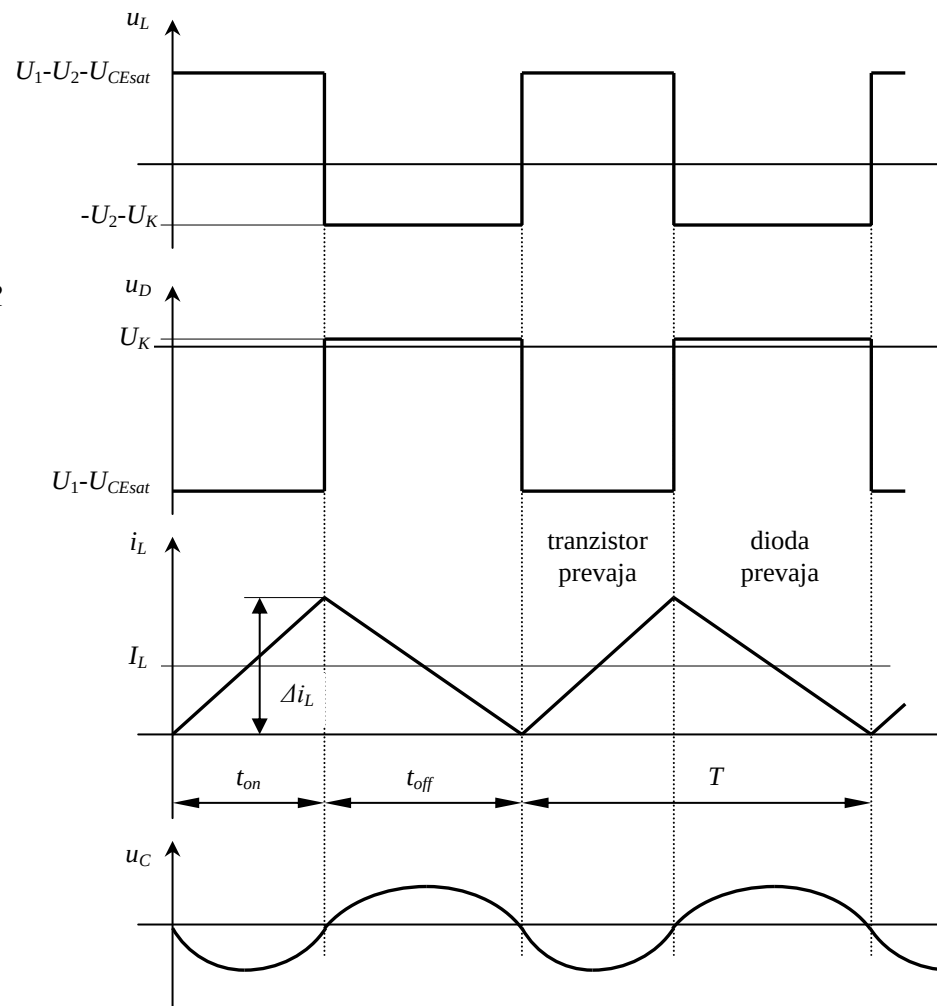
$$U_{out} = -\frac{D}{1-D} \cdot U_{in}$$

Pretvornik navzdol (step-down, buck)

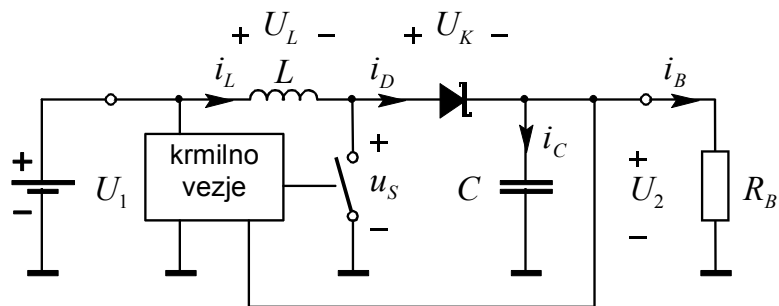


$$U_{out} = D \cdot U_{in}$$

$$\Delta I_L = D \cdot T \cdot \frac{U_{in} - U_{out}}{L}$$

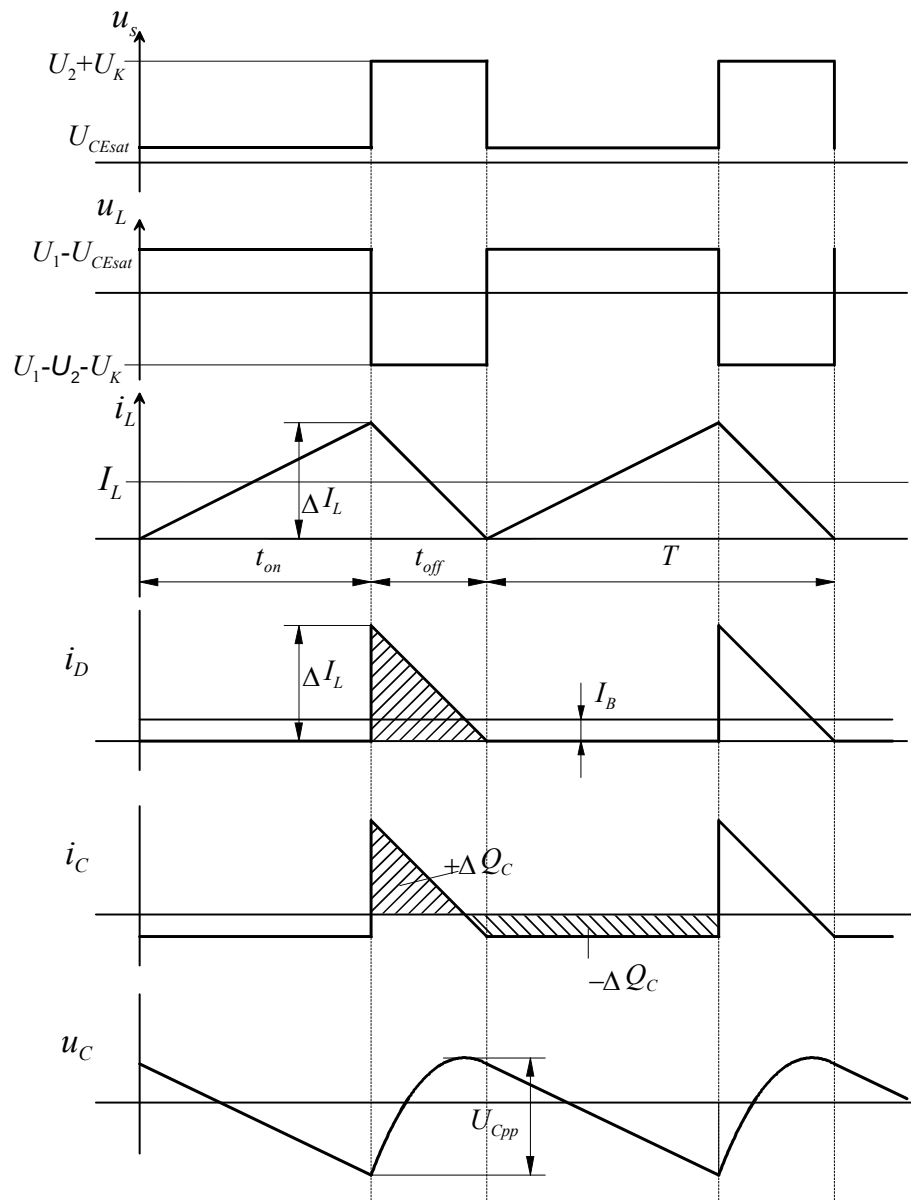


Pretvornik navzgor (step-up, boost)

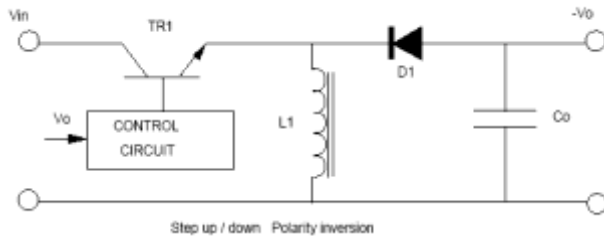


$$U_{out} = \frac{1}{1-D} \cdot U_{in}$$

$$\Delta I_L = D \cdot T \cdot \frac{U_{in}}{L}$$

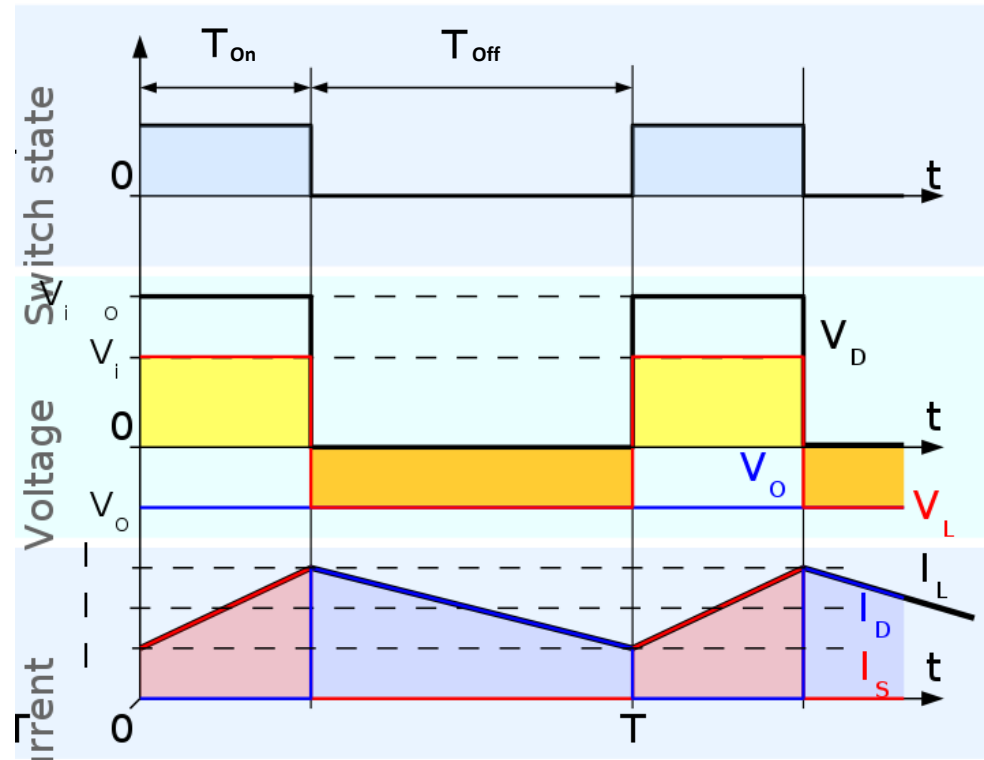


Pretvornik navzdol/navzgor invertirajoči (buck/boost, inverting, non-isolated flyback)



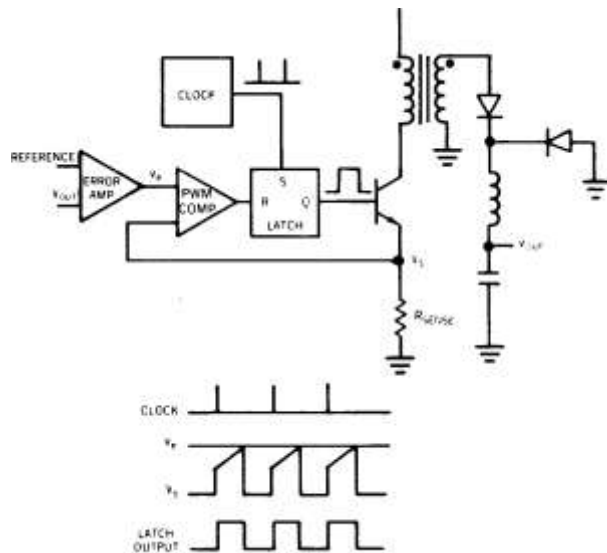
$$U_{out} = -\frac{D}{1-D} \cdot U_{in}$$

$$\Delta I_L = D \cdot T \cdot \frac{U_{in}}{L}$$

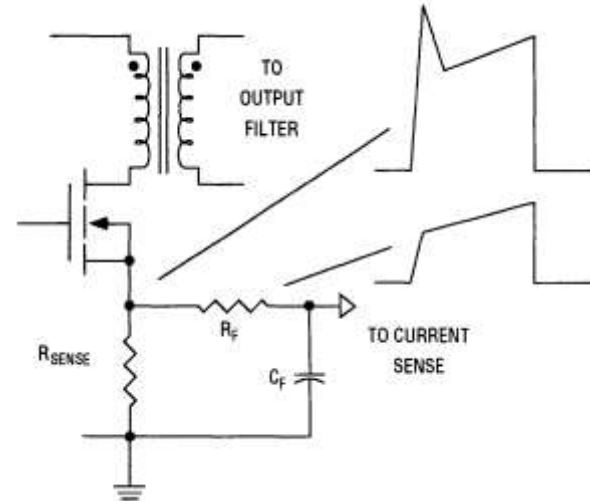


Krmiljenje

- Napetostno (voltage-mode)
 - › Signal napake – žaga > PWM
- Tokovno (current-mode)

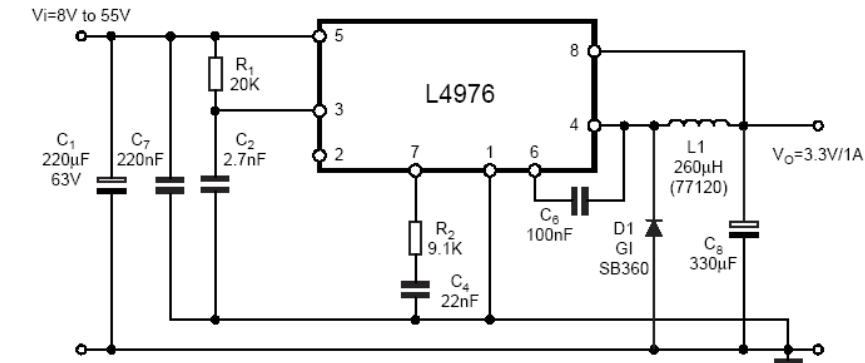


- Filtriranje špic



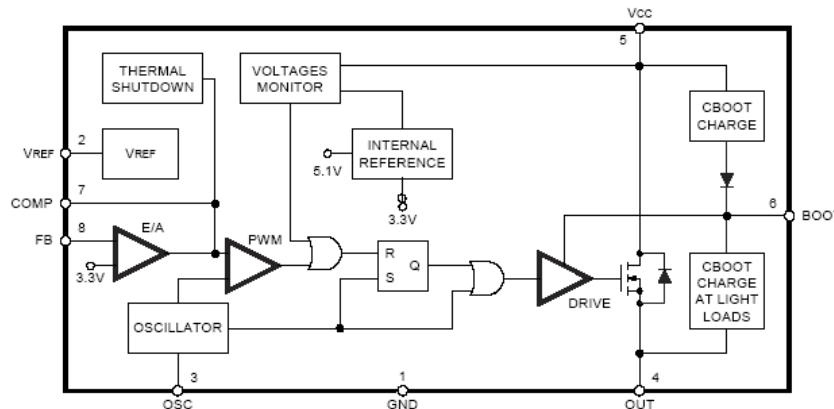
Vir slik: Unitrode U-93, U-128 app.note

Primer izvedbe – pretvornik navzdol

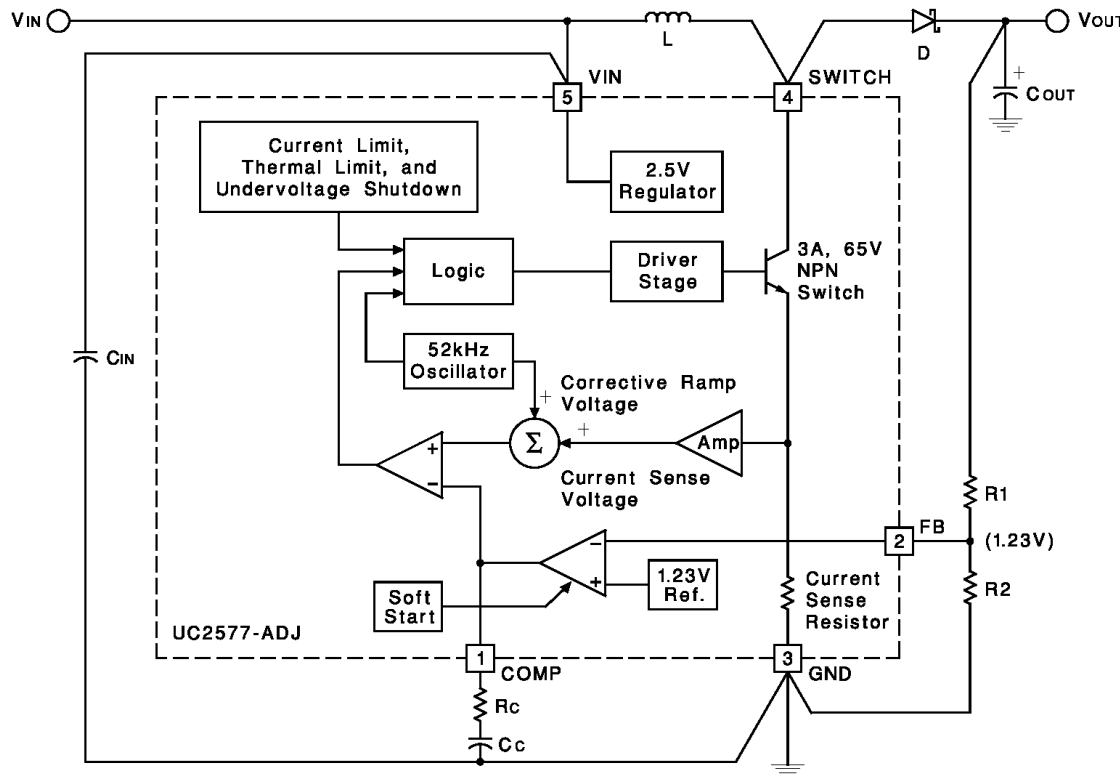


■ ST L4976

- › Vhod: 8 – 55 V
- › Izhod: do 1 A
- › Frekvenca do 300 kHz
- › DIP8, SO16
- › Izkoristek: 85 % @ 24/3,3 V



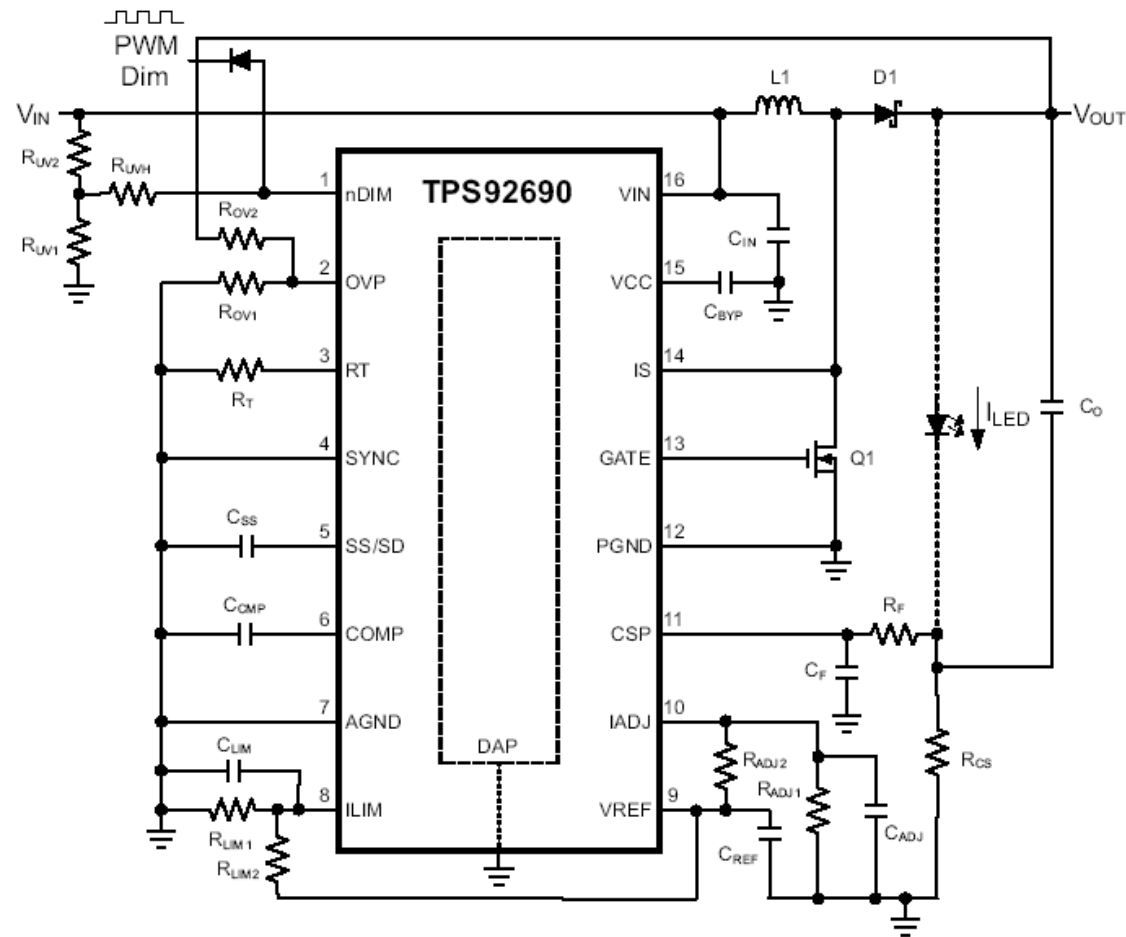
Primer izvedbe – pretvornik navzgor



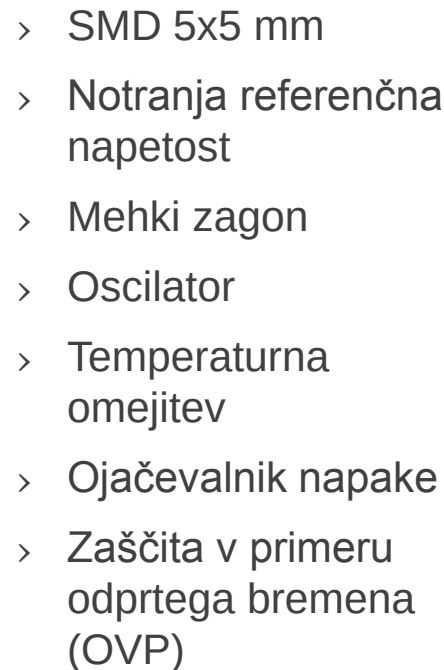
■ Texas Instruments (Unitrode) UC2577

- › Topologije: navzgor, flyback, forward
- › Vhod: do 40 V
- › Stikalo: 3 A, 65 V
- › To-220-5
- › Izkoristek: 80 % @ 5 / 12 V, 800 mA

Primer izvedbe – pretvornik navzgor s konstantnim izhodnim tokom



- Texas Instruments TPS92690
 - › Topologije: navzgor, flyback, SEPIC, Čuk
 - › Vhod: 4,5 – 75 V
 - › Oscilator: do 2 MHz
 - › PWM zatemnjevanje



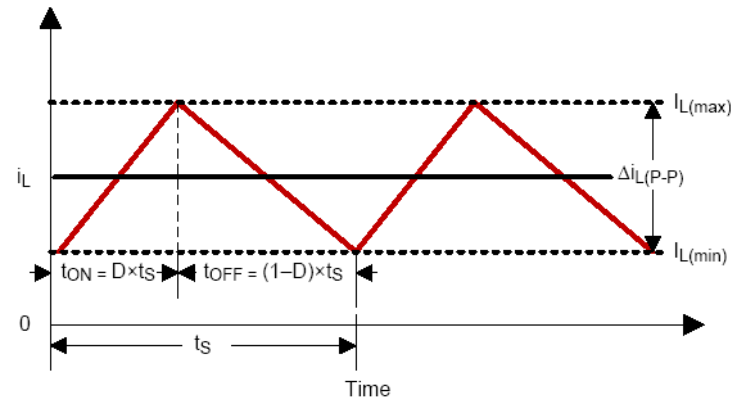
Pretvornik navzgor – potek načrtovanja

Specifikacije: U_{in} , U_{out} , P , f

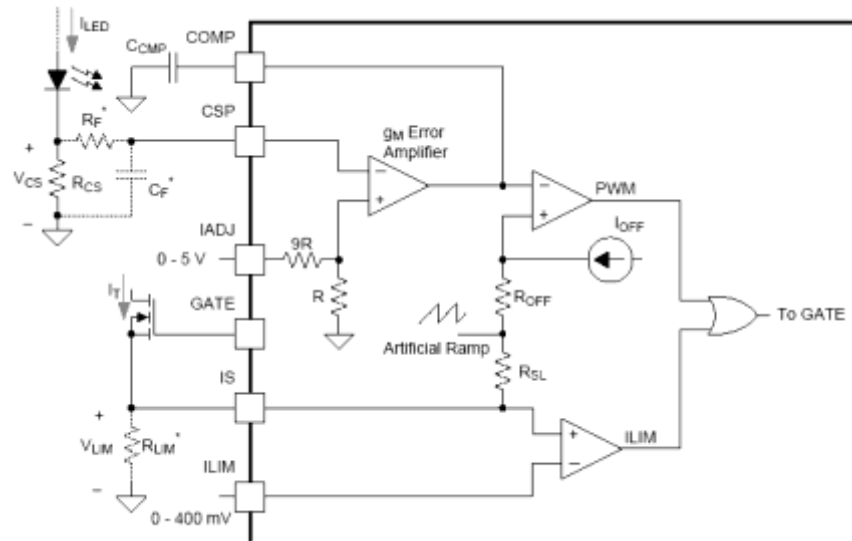
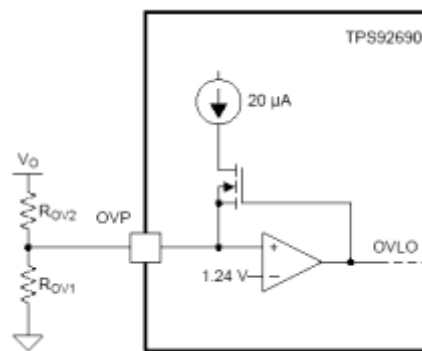
> $\Delta I_L \rightarrow L, D, Q1, C_{in}$

> $U_{out(p-p)} \rightarrow C_{out}$, $U_{in(p-p)} \rightarrow C_{in}$

$$f_{sw} = \frac{1}{2.29 \times 10^{-11} \times R_T + 80 \times 10^{-9}}$$

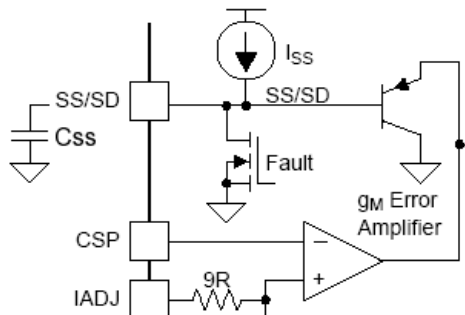


Povratna vezava: I_{out} , U_{outMAX}

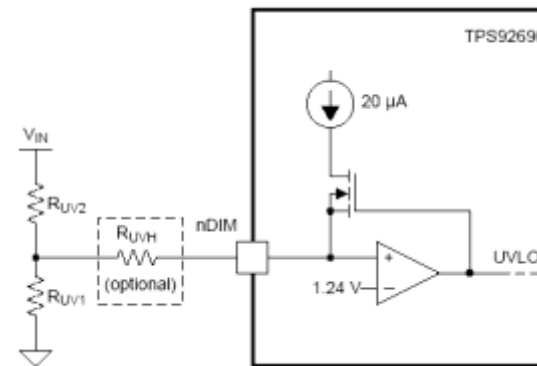


Pretvornik navzgor – potek načrtovanja

▪ Mehki zagon

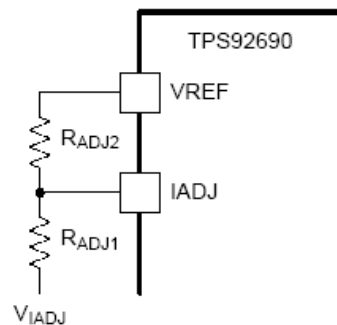


▪ Onemogočenje pri nizki vhodni napetosti (UVLO)

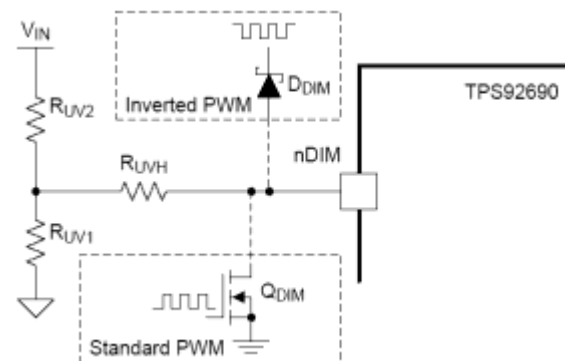


▪ Zatemnjevanje

> Zvezno (analog)



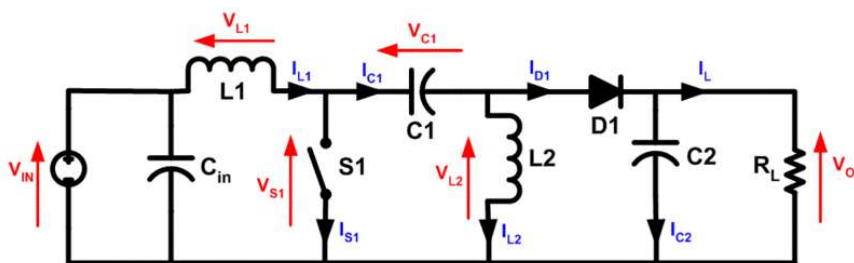
> PWM



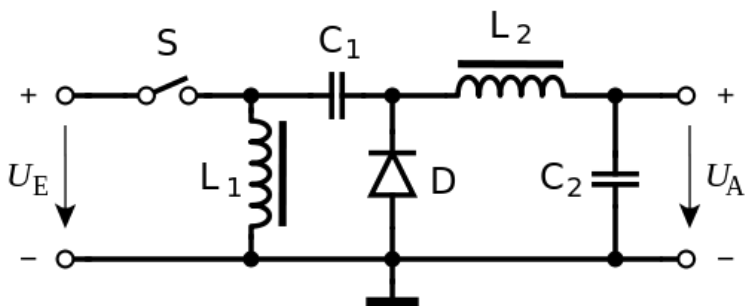
Neizolirani pretvorniki II

▪ SEPIC

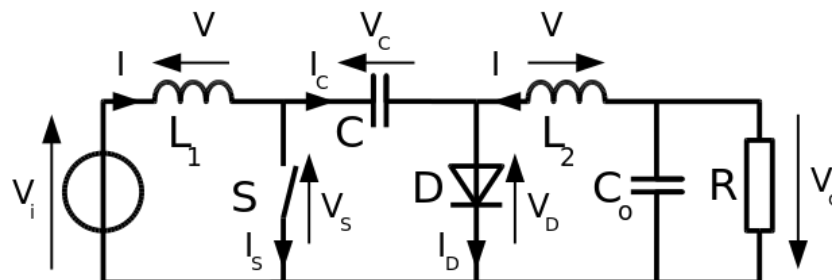
(Single-ended primary-inductor converter)



▪ Zeta



▪ Čuk



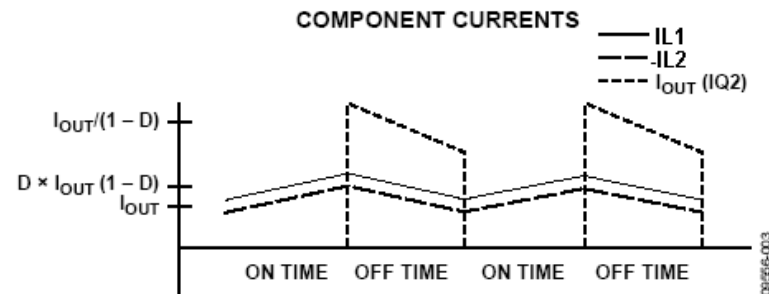
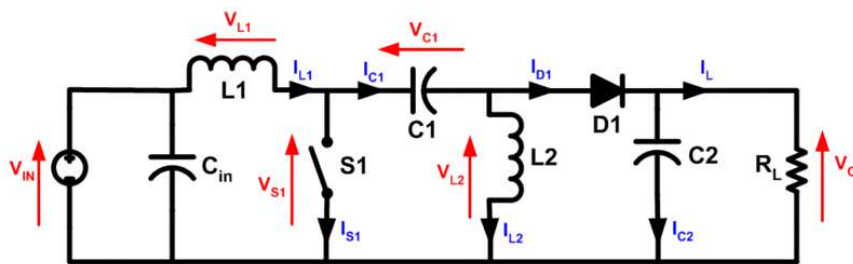
▪ Neprekinjeno delovanje:

$$U_{out} = -\frac{D}{1-D} \cdot U_{in}$$

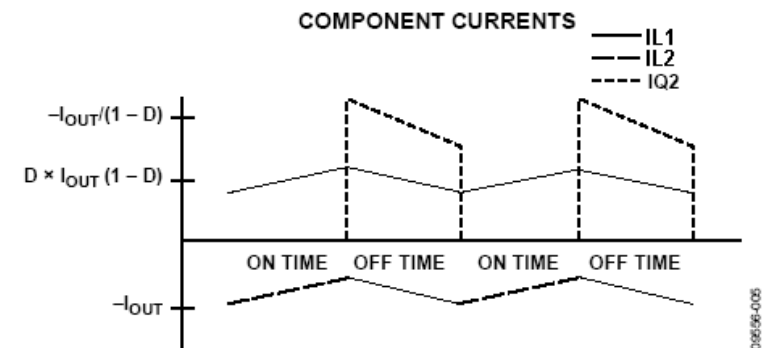
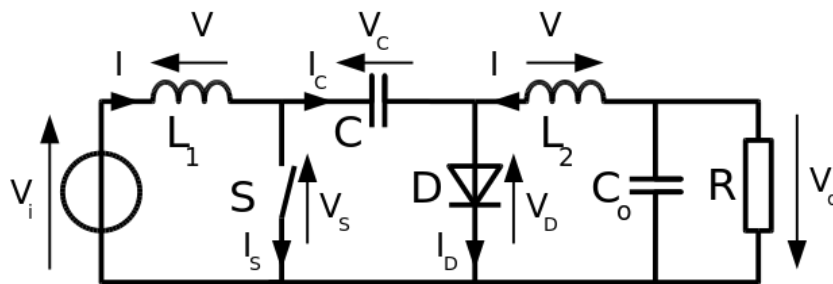
$$U_{out} = \frac{D}{1-D} \cdot U_{in}$$

Neizolirani pretvorniki II

SEPIC

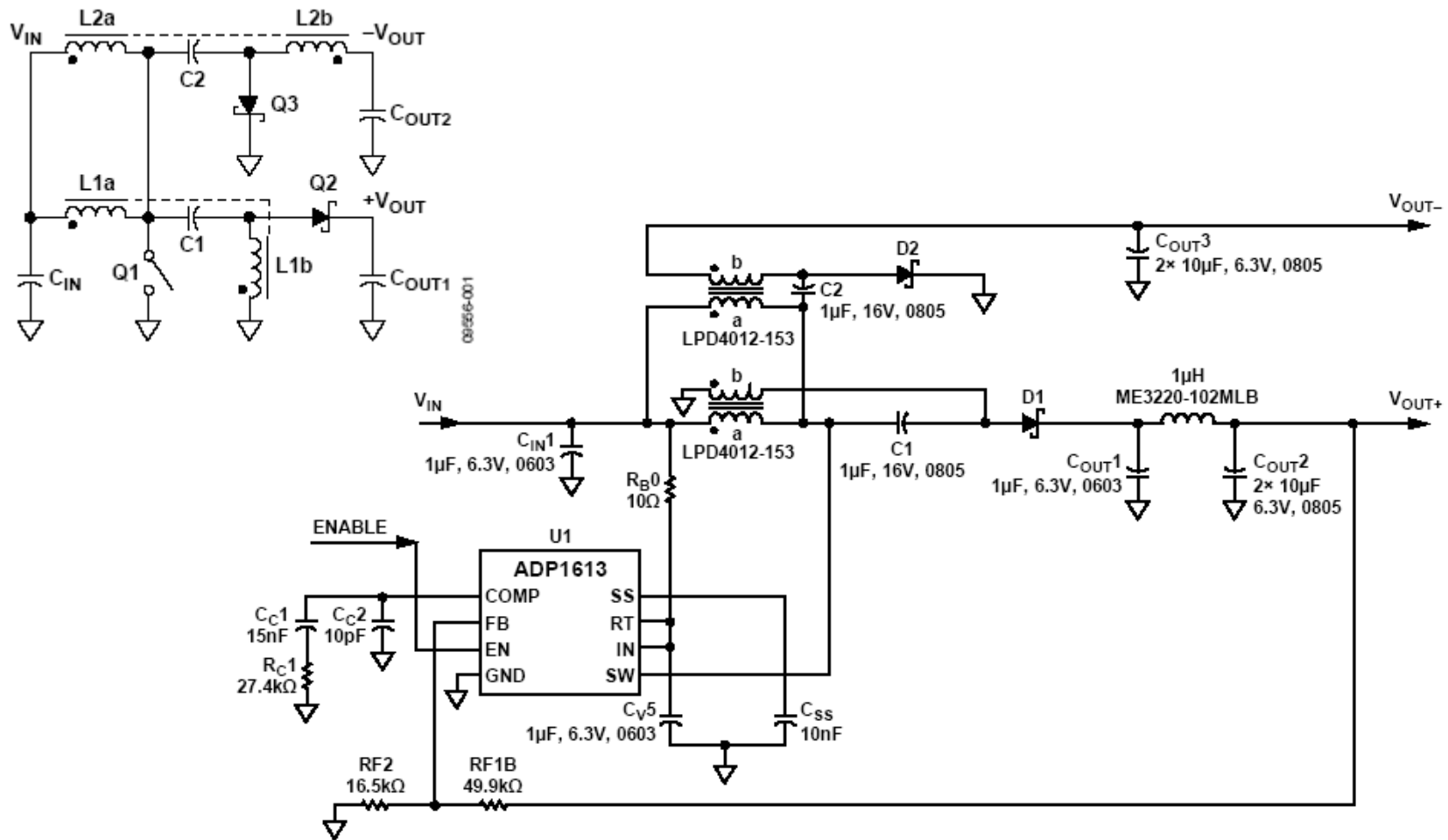


Ćuk



Avtorji slik: shemi: Cyril BUTTAY, Mclausma (Wikipedia); grafa: Analog Devices AN-1106

Primer izvedbe – Dvojni pretvornik

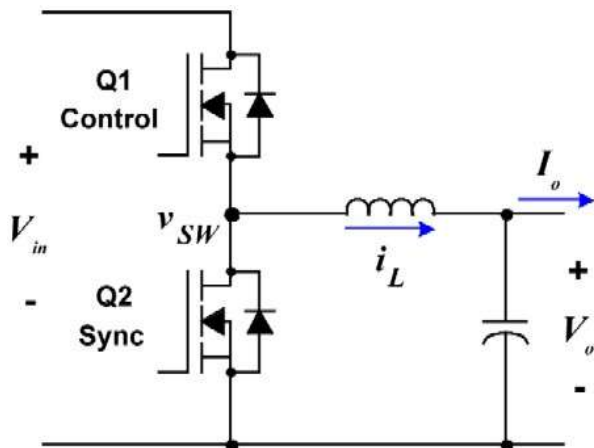


Vir: Application note Analog Devices AN-1106

Izboljšave

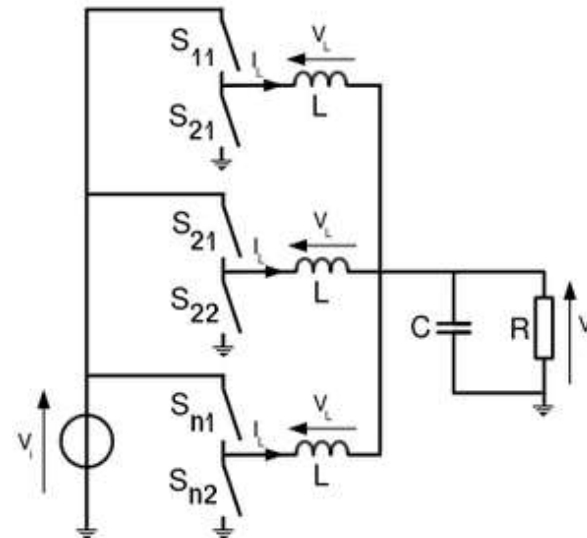
▪ Sinhroni pretvornik

- › Tranzistor namesto diode



▪ Večfazni pretvornik

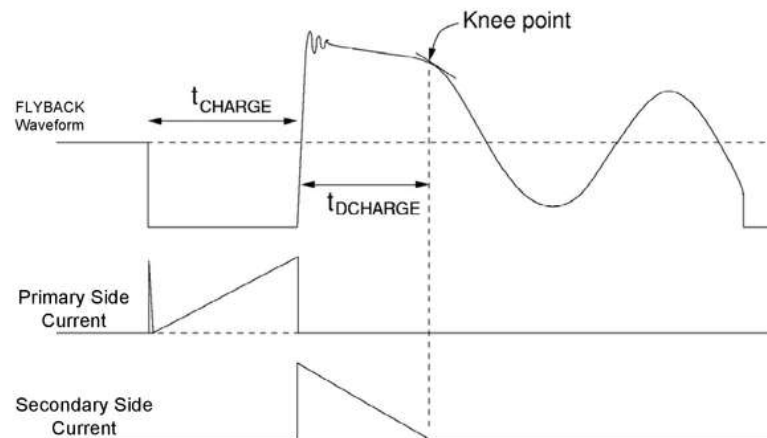
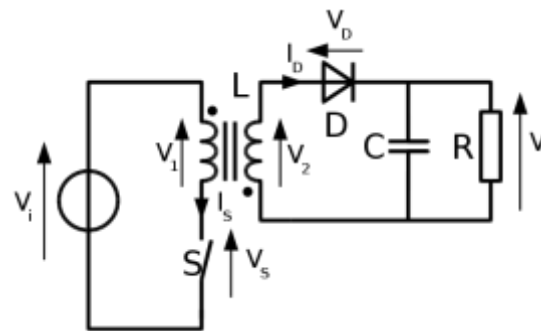
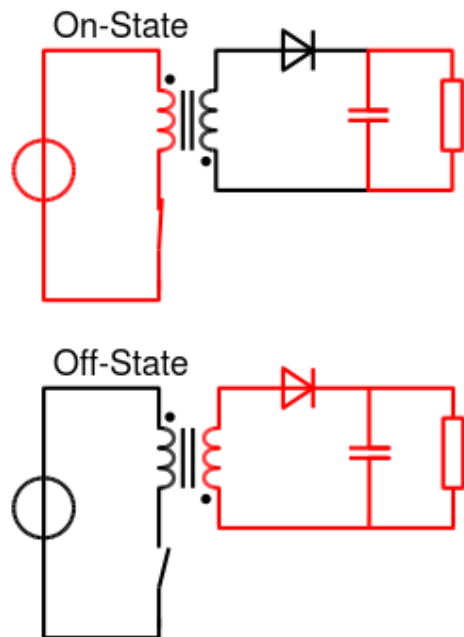
- › Velik izhodni tok
- › Hitrejši odziv
- › Manjša valovitost toka



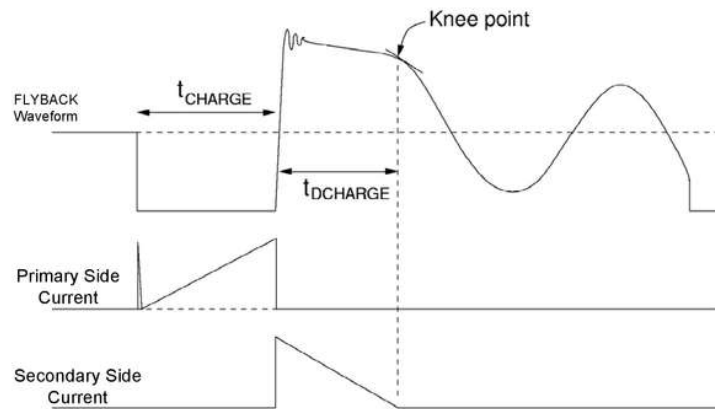
Vir slik: Eric Persson, How FET selection can optimize synchronous buck converter efficiency, EEtimes;

Izolirani pretvorniki I

▪ Flyback



Flyback



■ Neprekinjeno delovanje

$$U_{out} = \frac{N_2}{N_1} \cdot \frac{D}{1-D} \cdot U_{in}$$

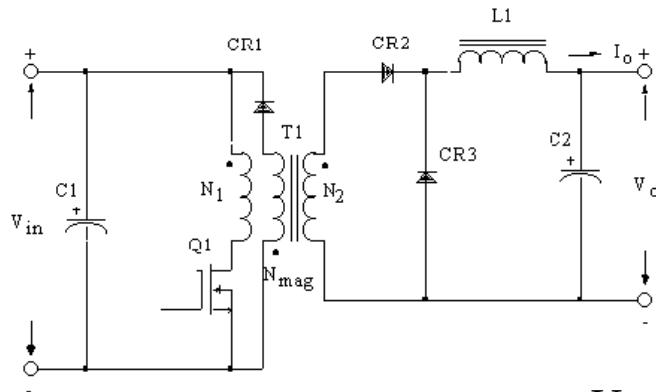
■ Prekinjeno delovanje

$$I_{primP} = \frac{U_{in} \cdot t_{on}}{L_{prim}}$$

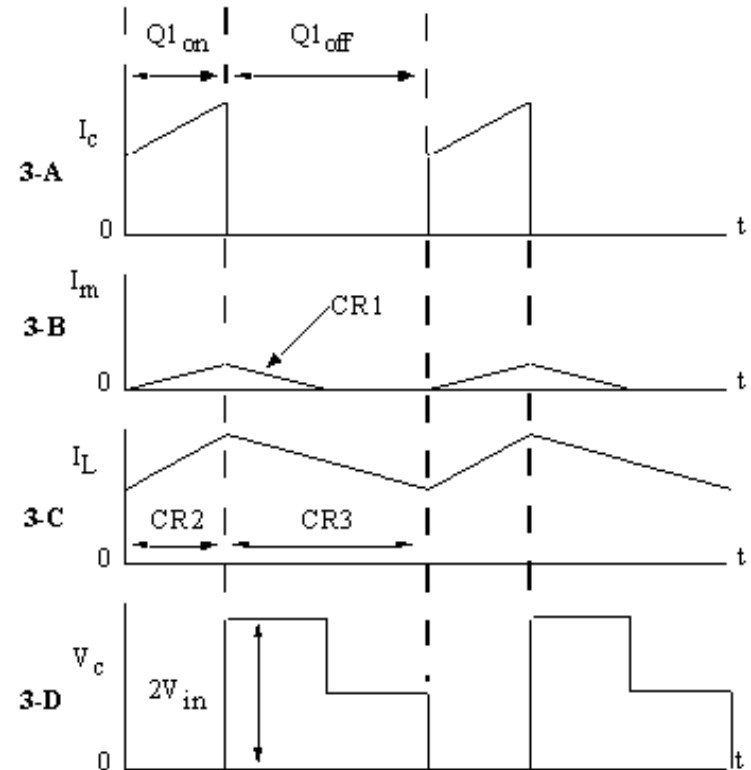
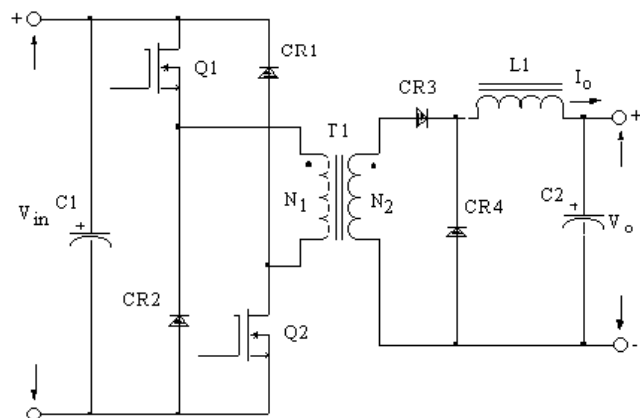
$$P_{DCM} = \frac{I_{primP}^2 \cdot L_{prim}}{2} \cdot f$$

$$U_{out} = D \cdot \sqrt{\frac{R_L \cdot T}{2 \cdot L_{prim}}} \cdot U_{in}$$

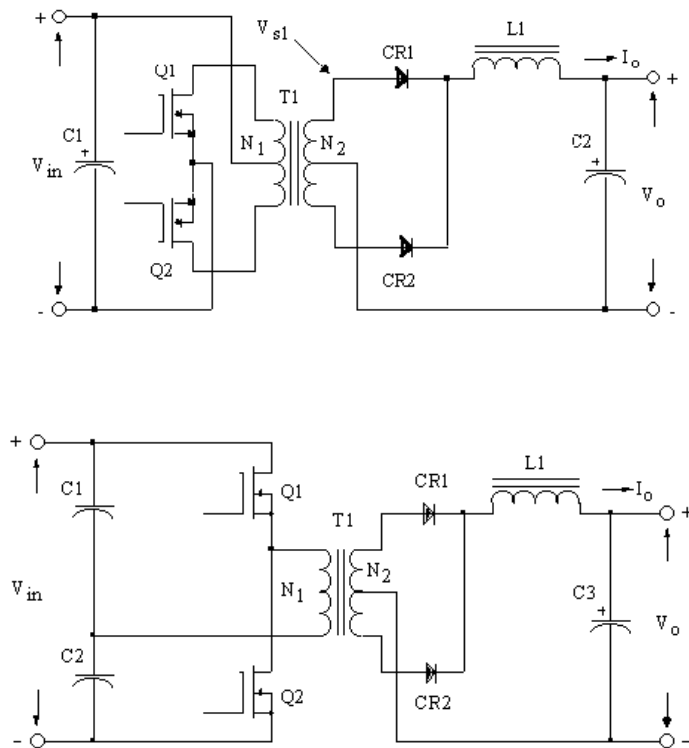
Izolirani p. II - Forward (magnetenje v eni smeri)



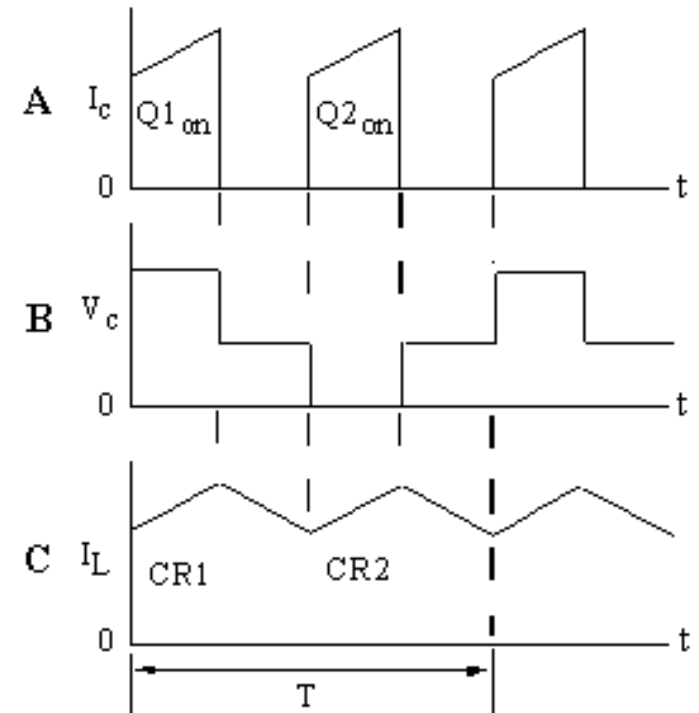
$$U_{out} = D \cdot \frac{N_2}{N_1} \cdot U_{in}$$



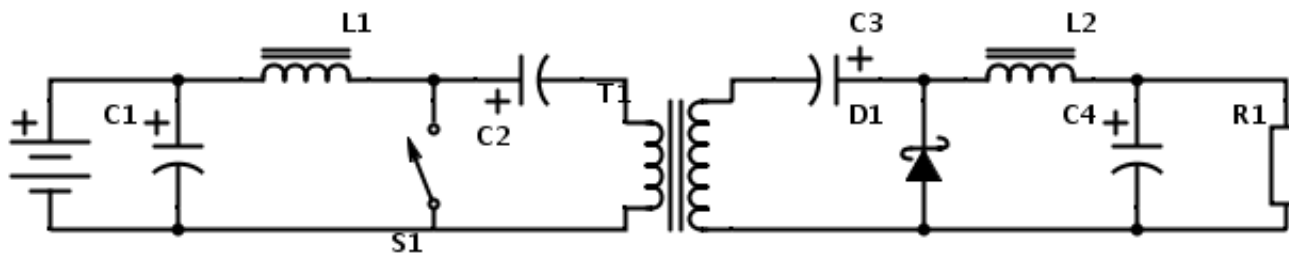
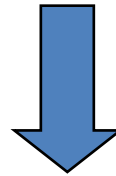
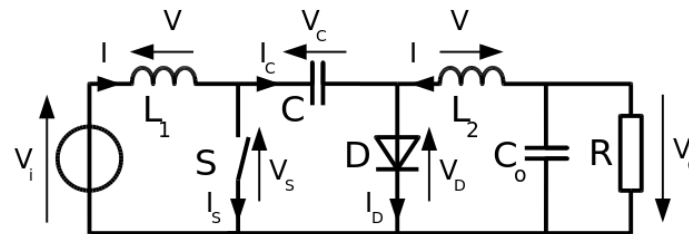
Izolirani p. II - Forward (magnetenje v obe smeri)



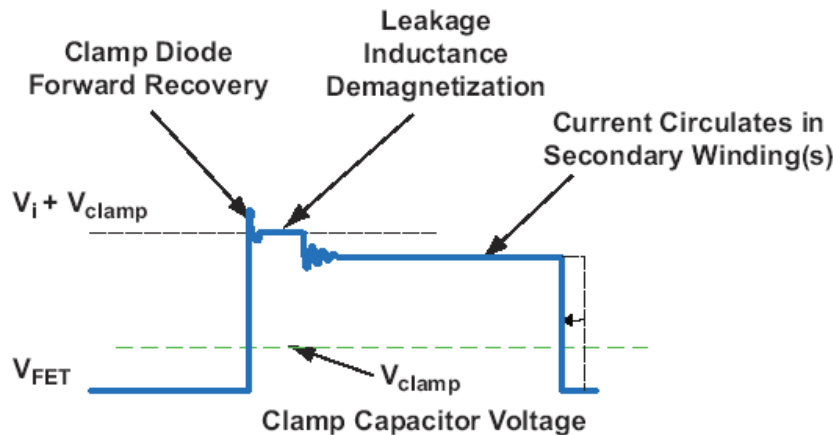
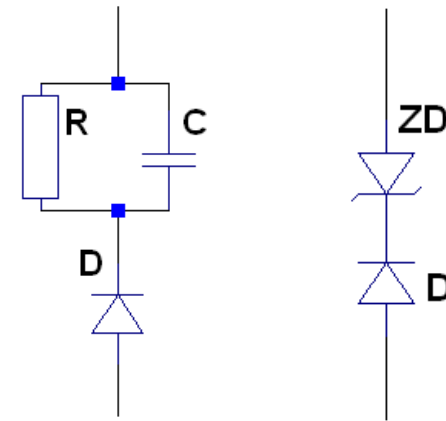
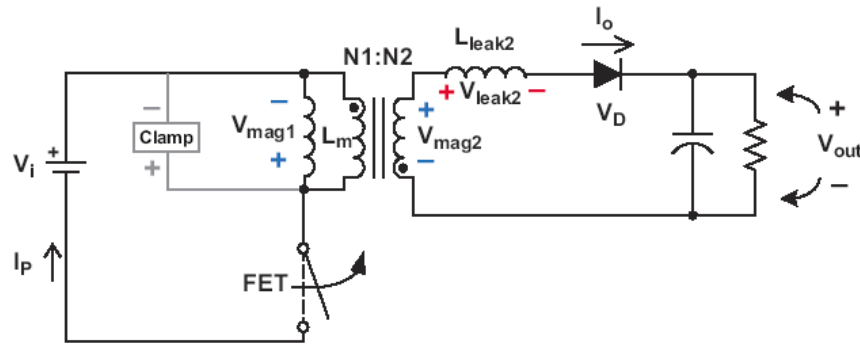
$$U_{out} = D \cdot \frac{N_2}{N_1} \cdot U_{in}$$



Izolirani p. III – Čuk pretvornik



Sklopljena tuljava – stresana induktivnost



Vir slik: shema in graf: Under the Hood of Flyback SMPS Designs, Texas Instruments

Sklopljena tuljava – medovojna kapacitivnost

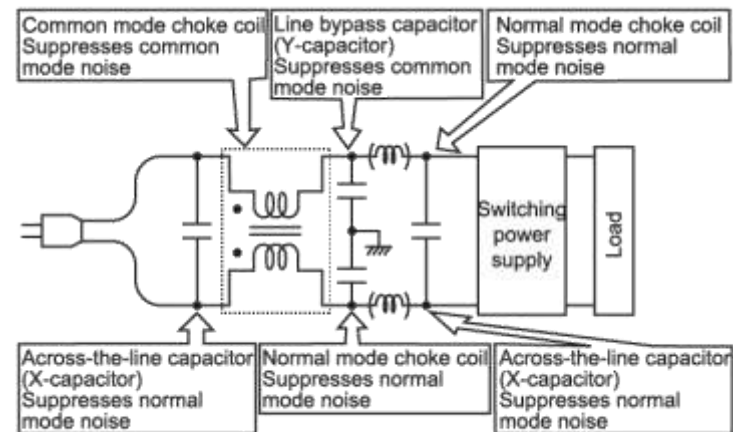
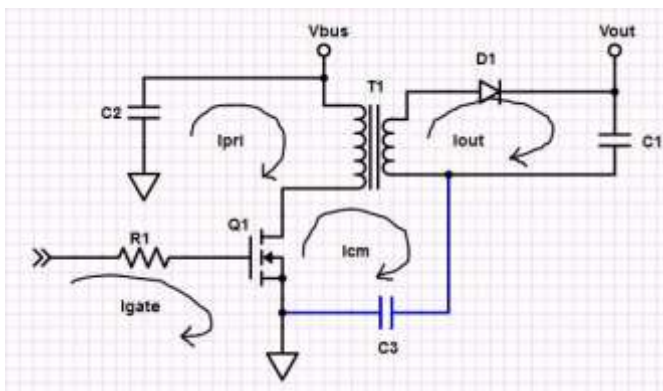
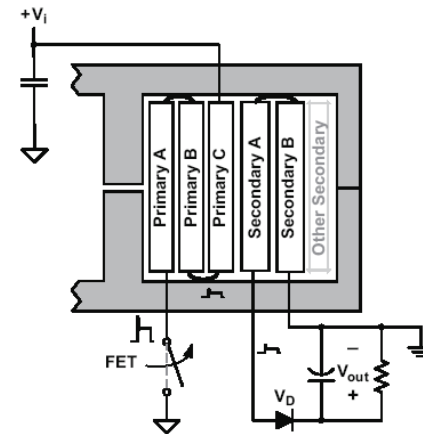
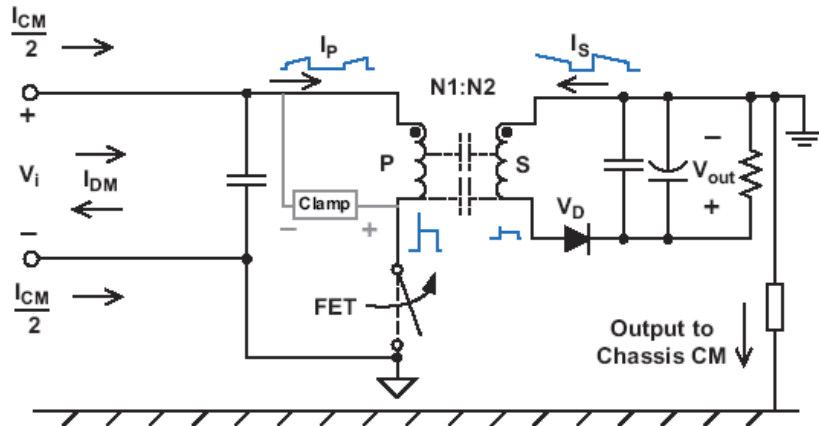


Fig. 3. Example of a filter configuration for a commercial power supply line

Vir slik: Under the Hood of Flyback SMPS Designs, Texas Instruments; Justin Clack, Minimizing EMI Problems in Noisy Switching Converter Circuits ...and Bears, EEWiki; Murata

Konec

Hvala za vašo pozornost

bostjan.glazar@fe.uni-lj.si