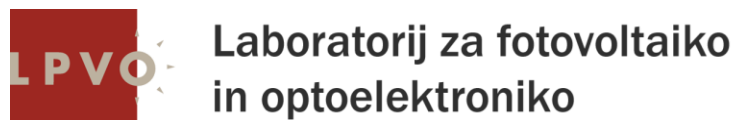


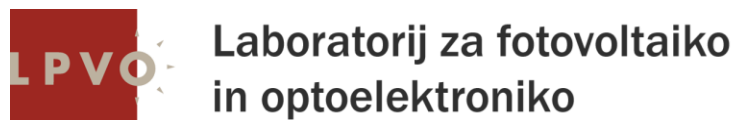
Načrtovanje elektronike za **EMC**²

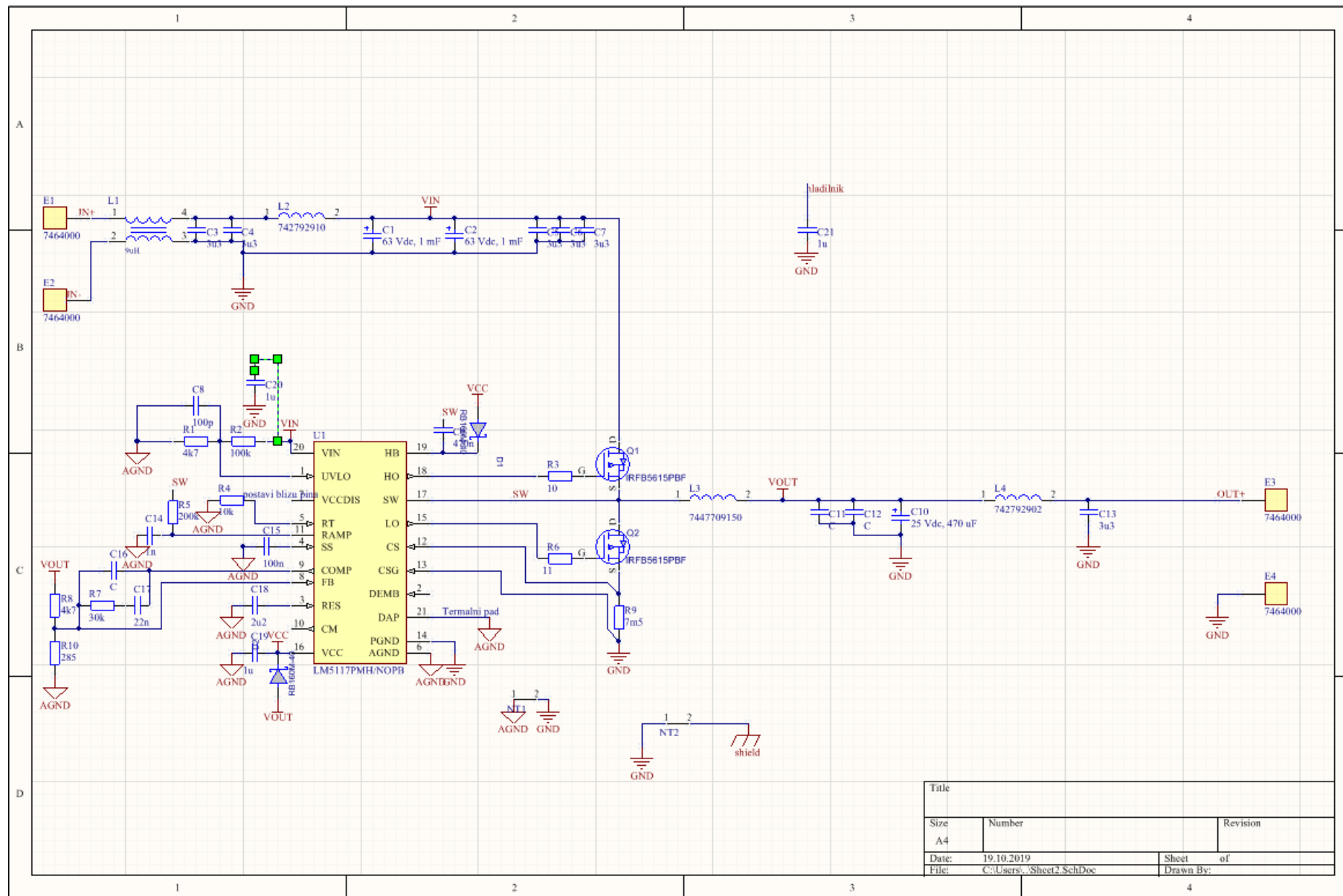
Predstavitve projektov



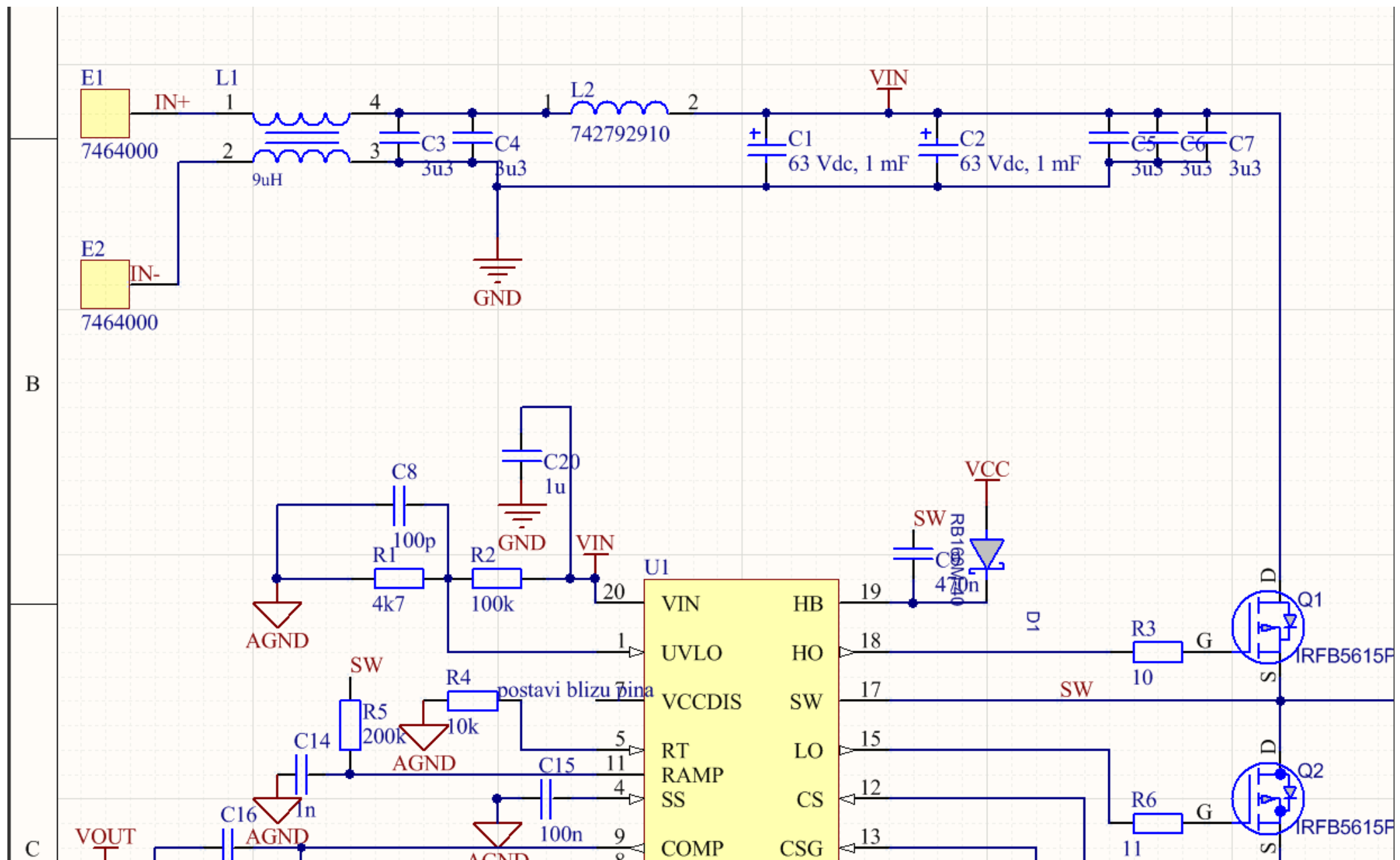
Načrtovanje elektronike za **EMC**²

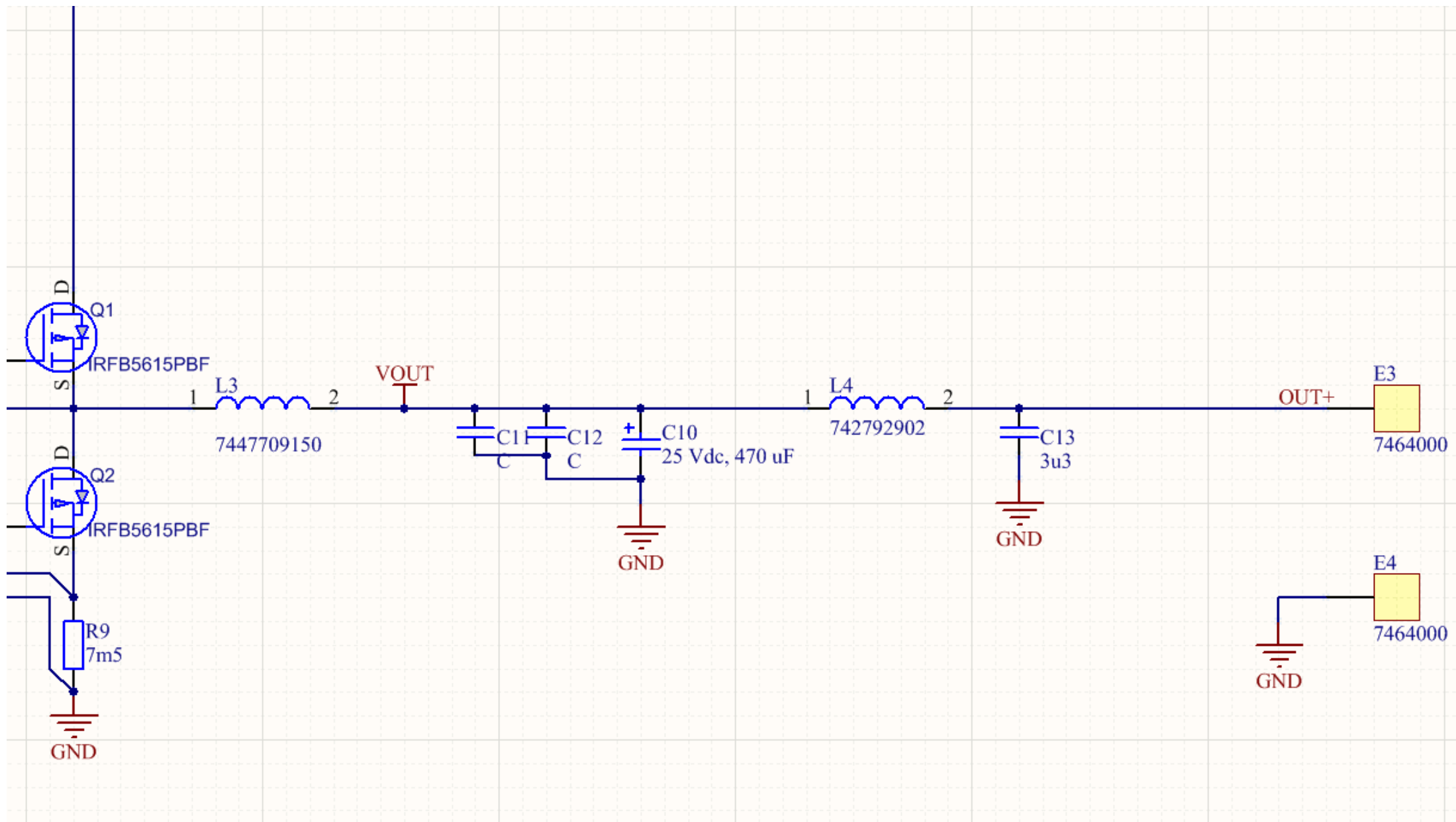
SO1 Jurij Tratar

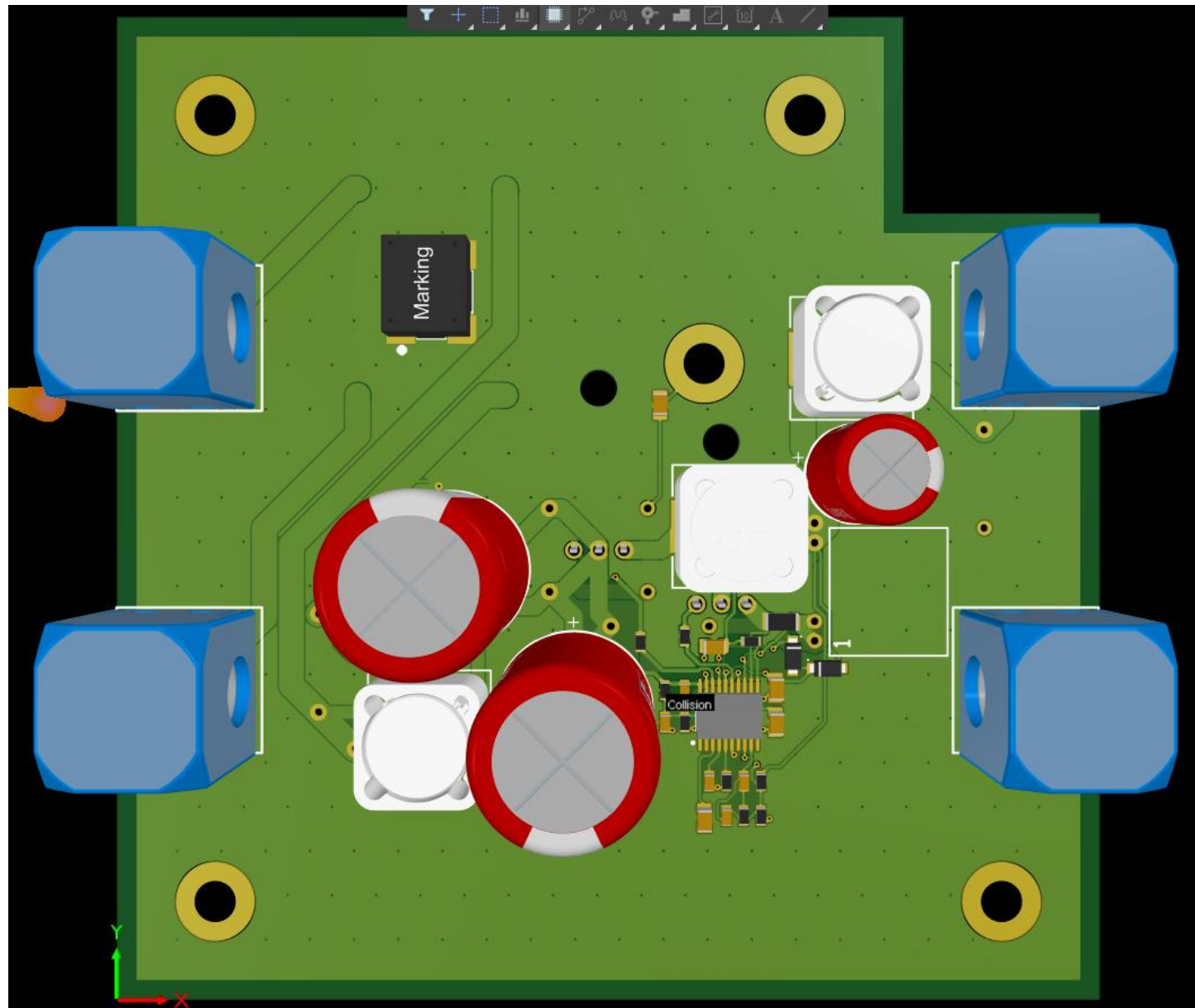


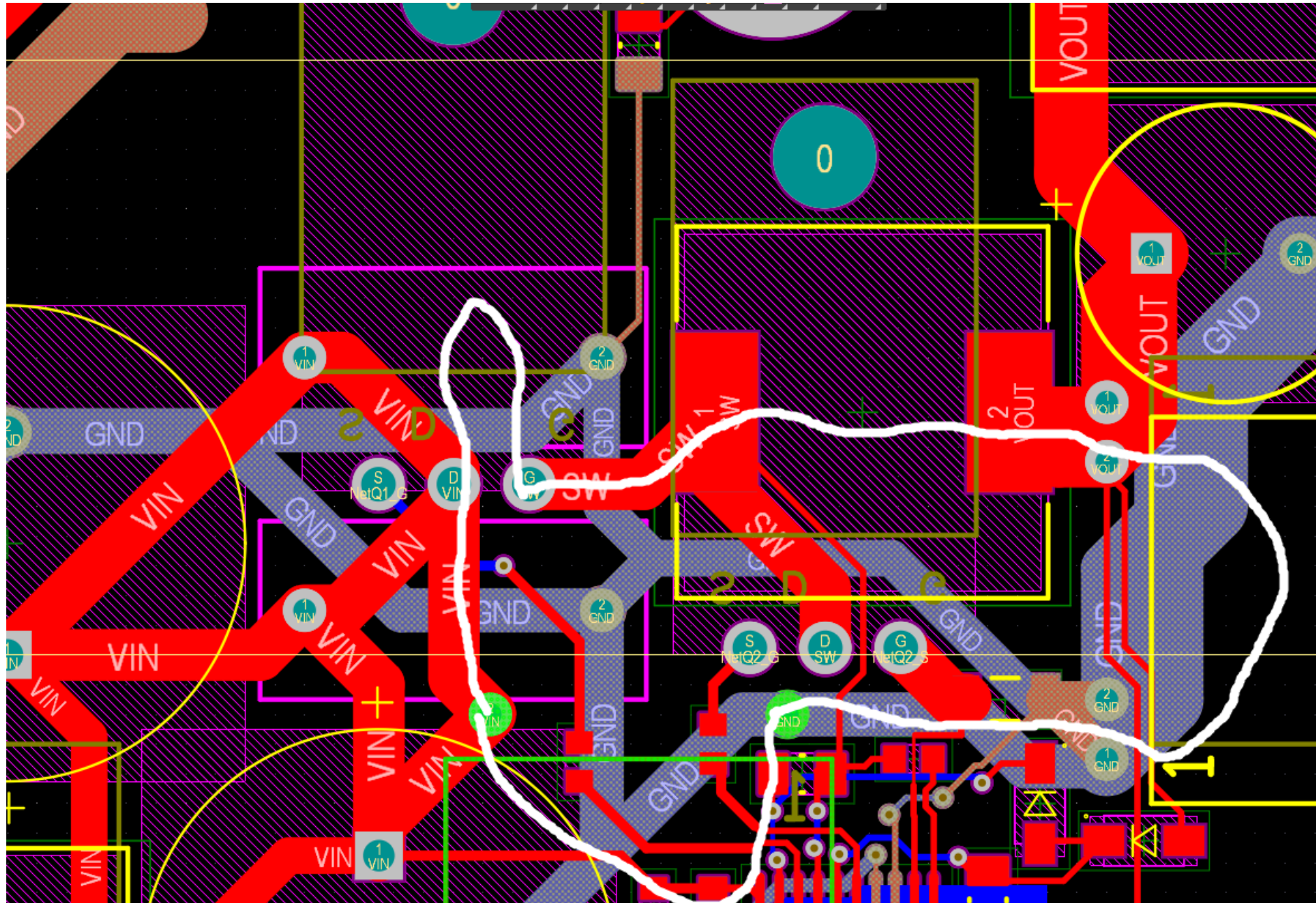


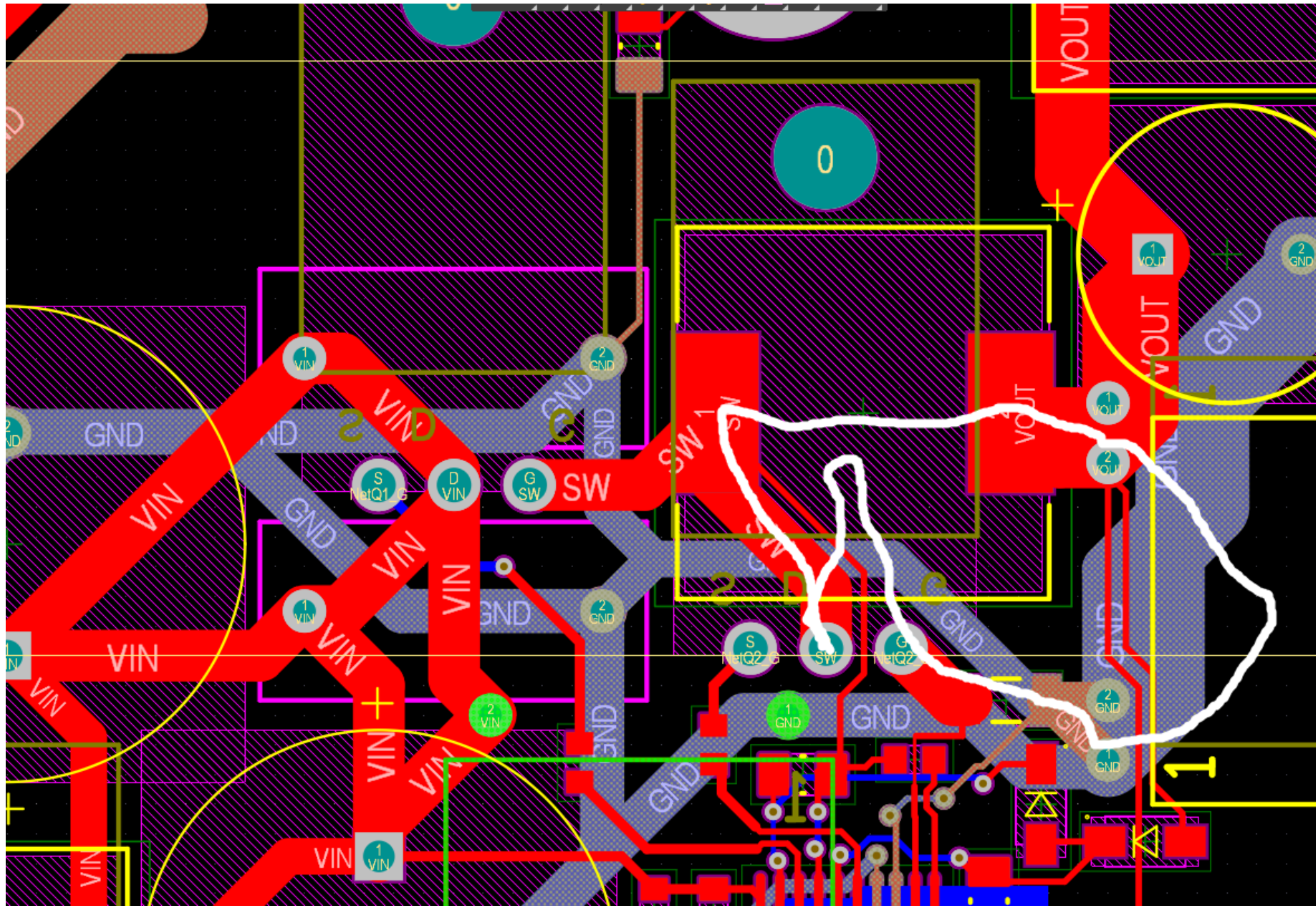
Title		
Size	Number	Revision
A4		
Date:	19.10.2019	Sheet of
File:	C:\Users\...Sheet2.SchDoc	Drawn By:





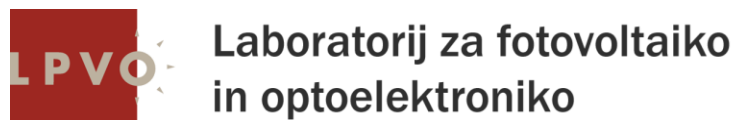






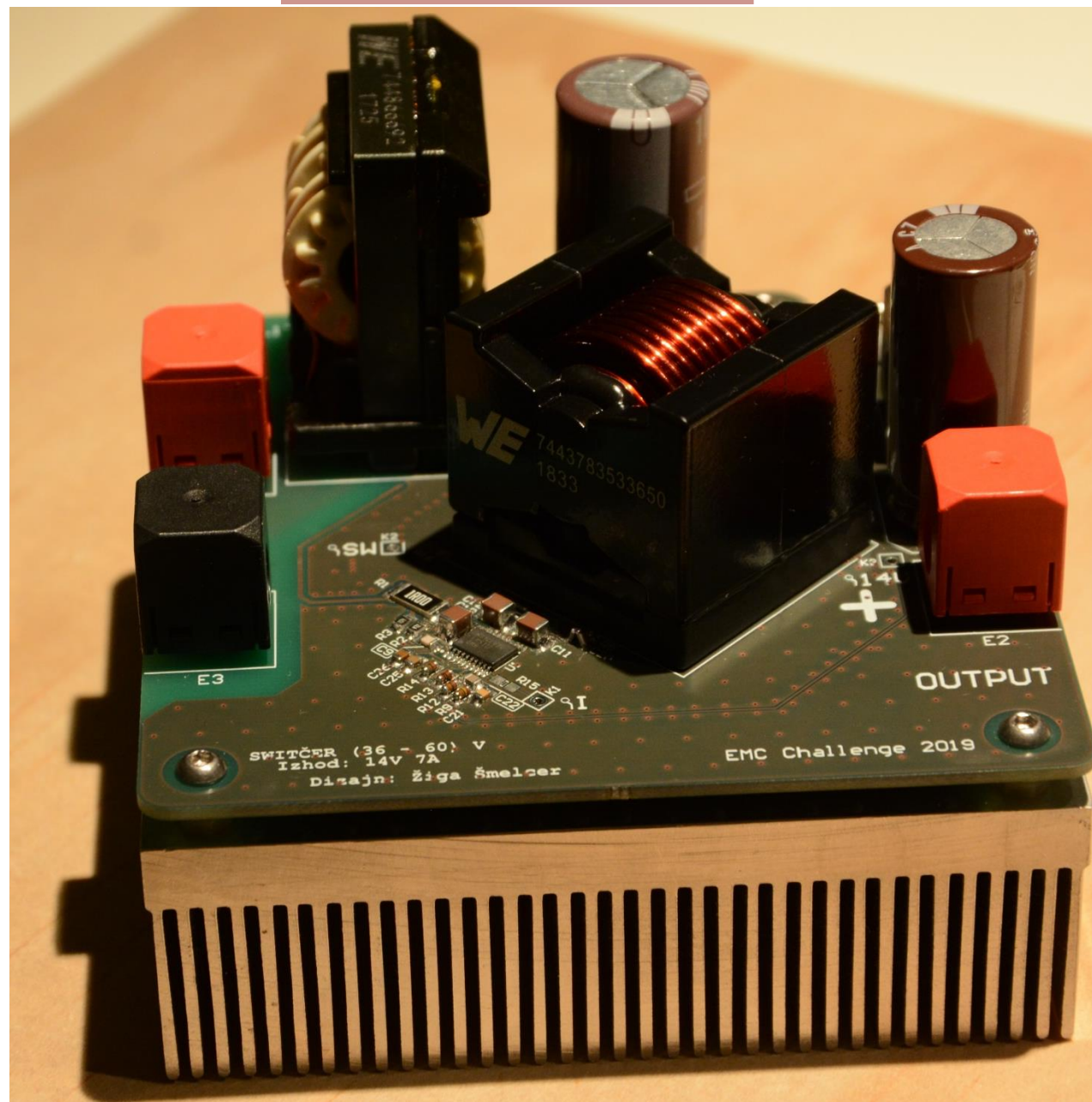
Načrtovanje elektronike za **EMC**²

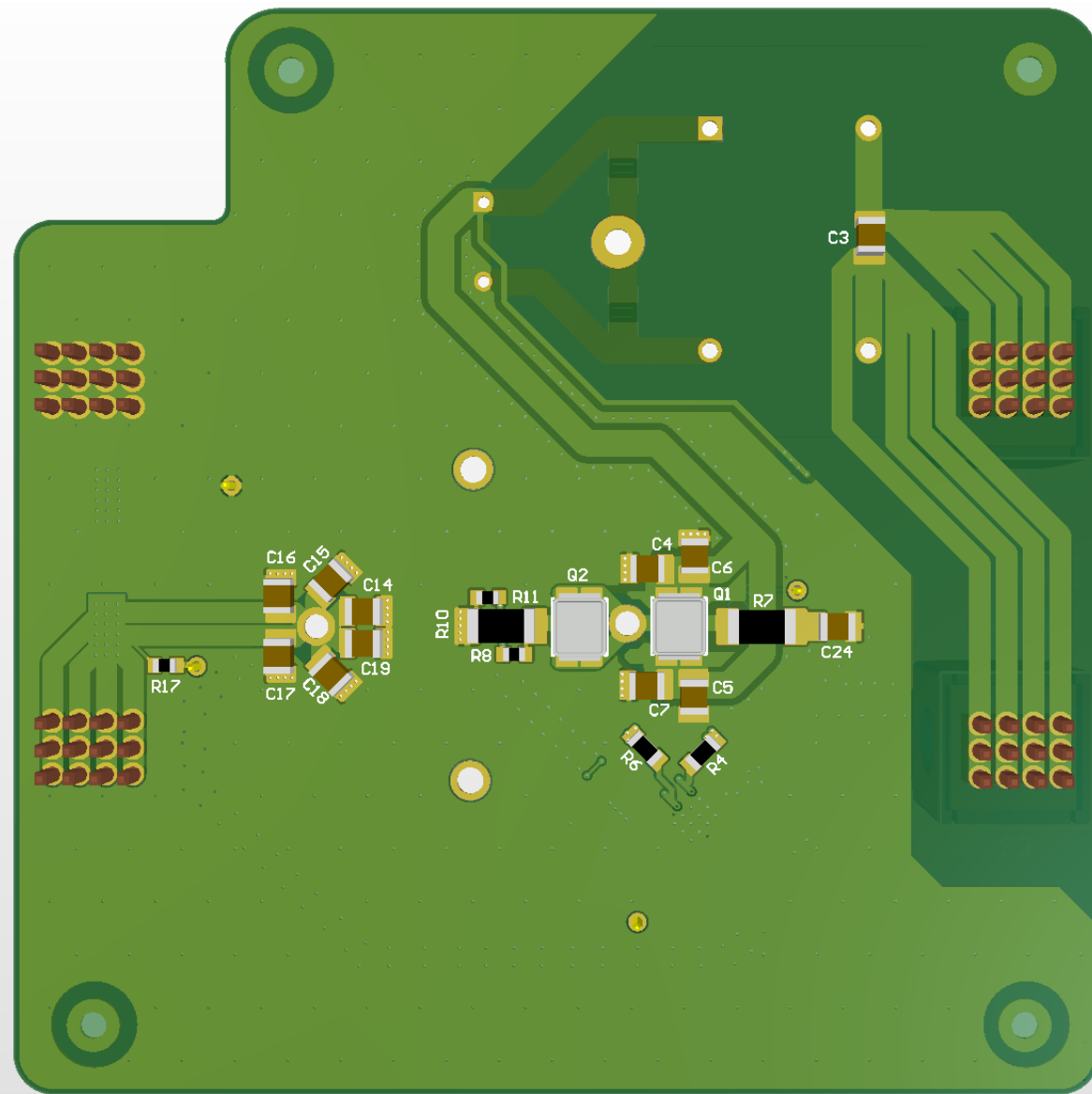
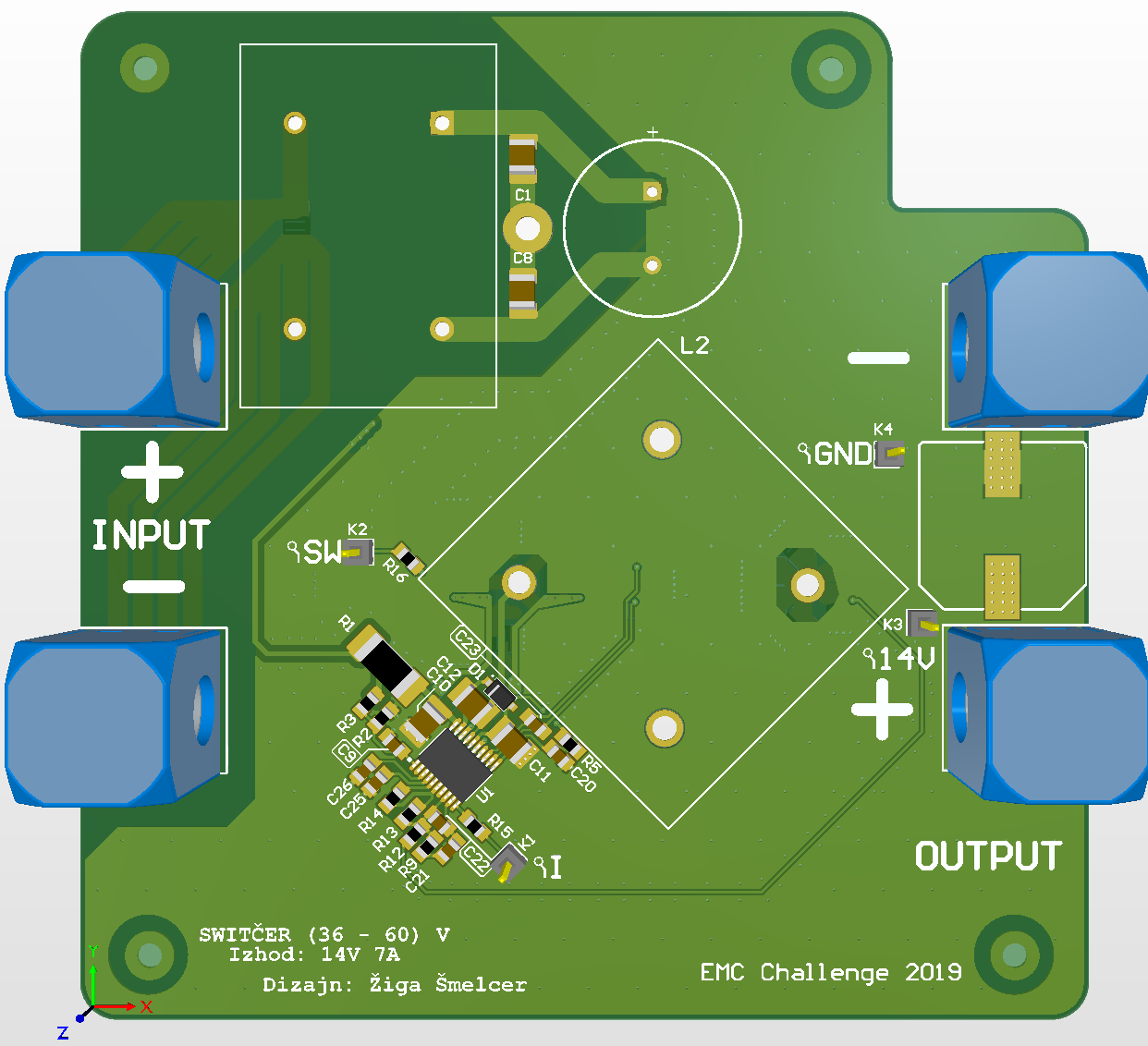
SO2 žiga šmelcer

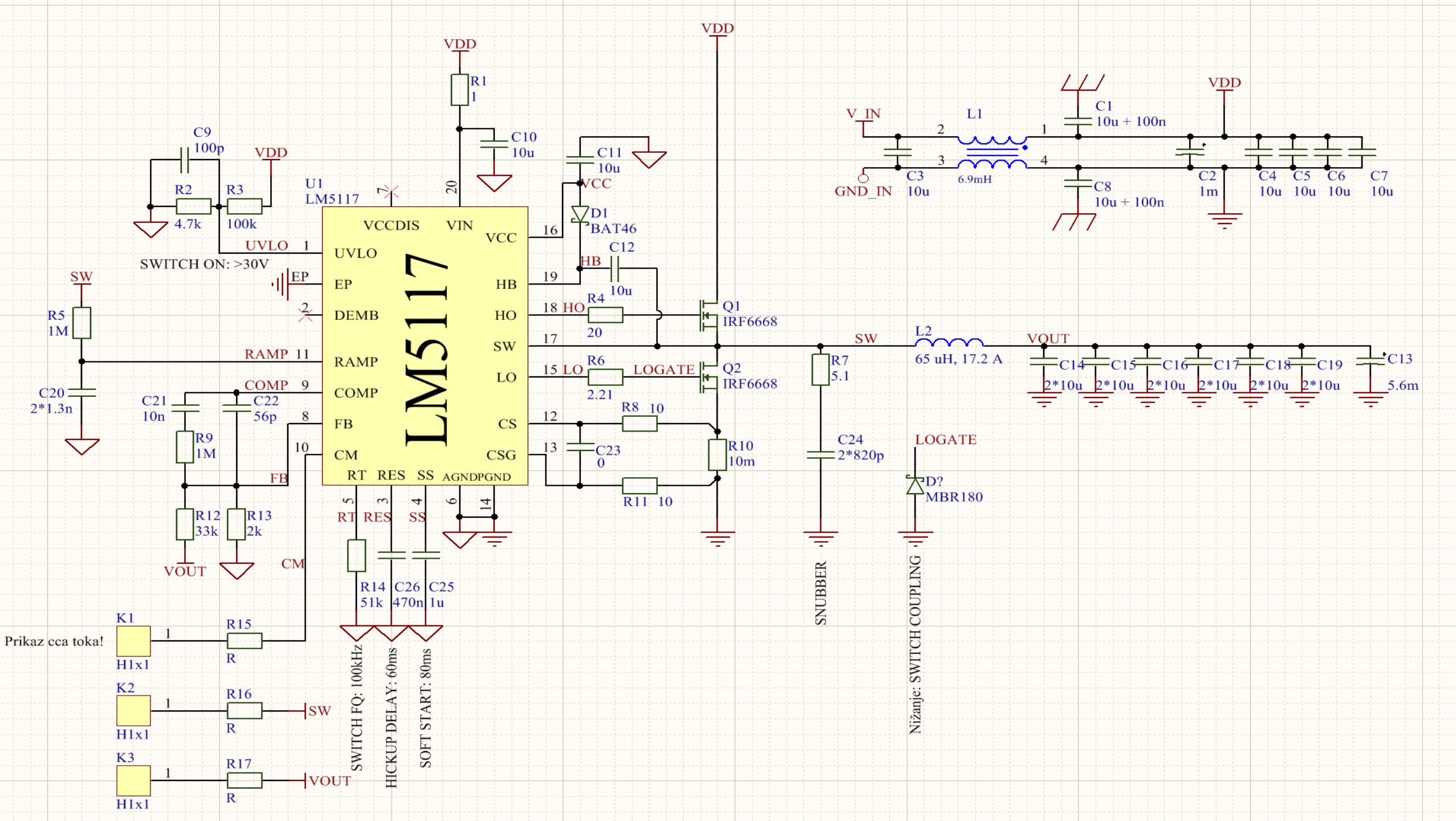


Žiga Šmelcer

- 100 kHz (51k MELF upor)
- >30 V Start-Switch
- 65 μ H tuljava
- 1 mF + 40 μ F VHOD
- 5.6 mF + 120 μ F IZHOD
- MELF SENSE delilnik (stabilnost)







TRANZISTORJA

- Infineon IRF6668

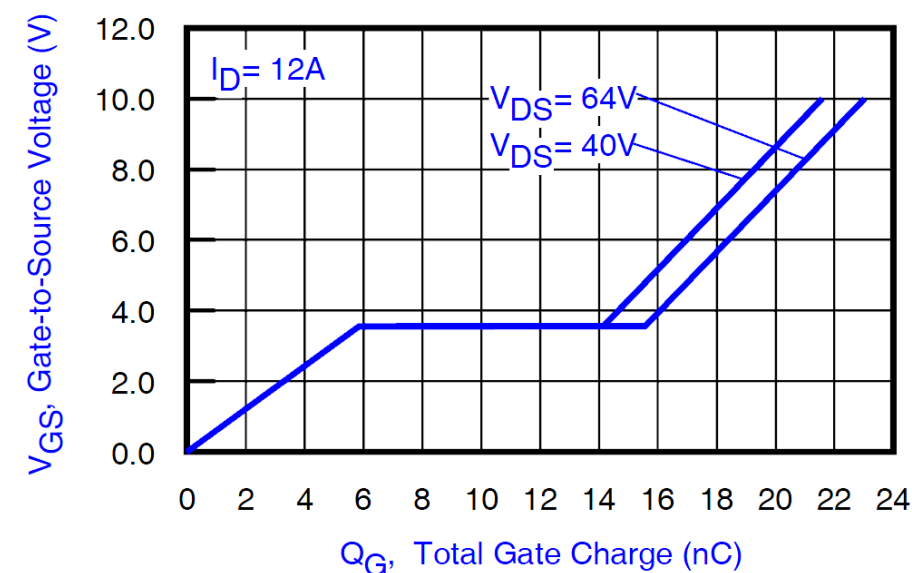
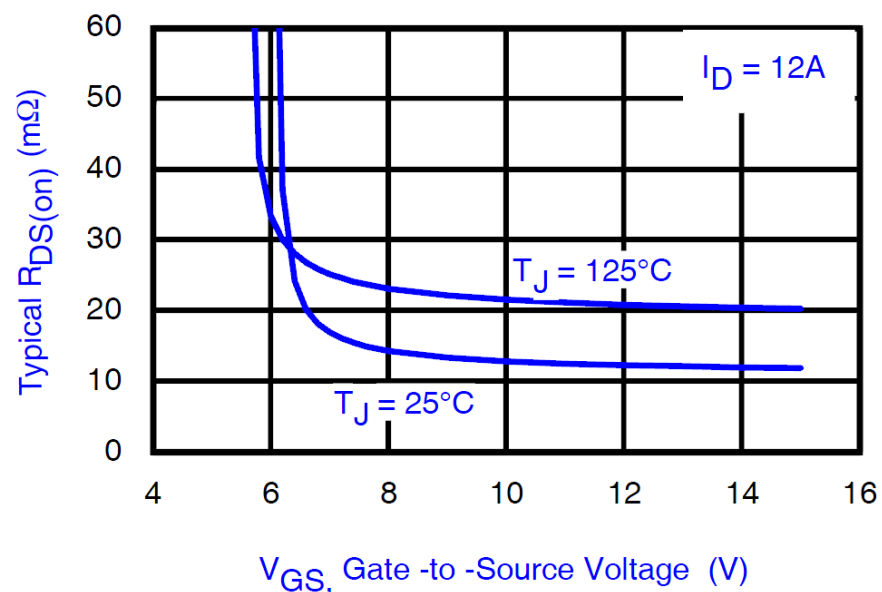
N-MOS



DirectFET™ Power MOSFET ②

Typical values (unless otherwise specified)

V_{DSS}	V_{GS}	$R_{DS(on)}$			
80V max	±20V max	12mΩ @ 10V			
$Q_{g\ tot}$	Q_{gd}	Q_{gs2}	Q_{rr}	Q_{oss}	$V_{gs(th)}$
22nC	7.8nC	1.6nC	40nC	12nC	4.0V



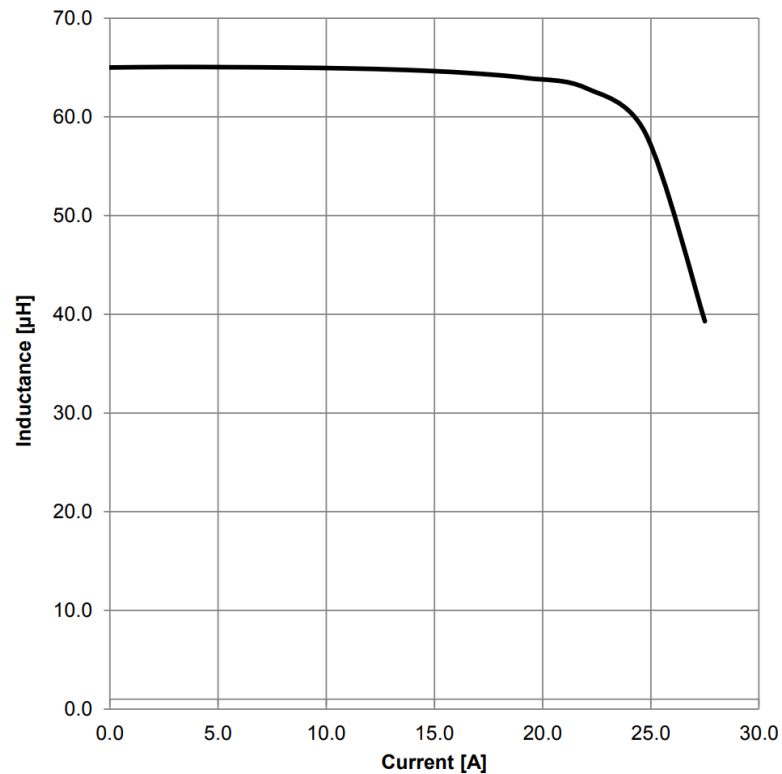
TULJAVA

- WURTH
7443783533650

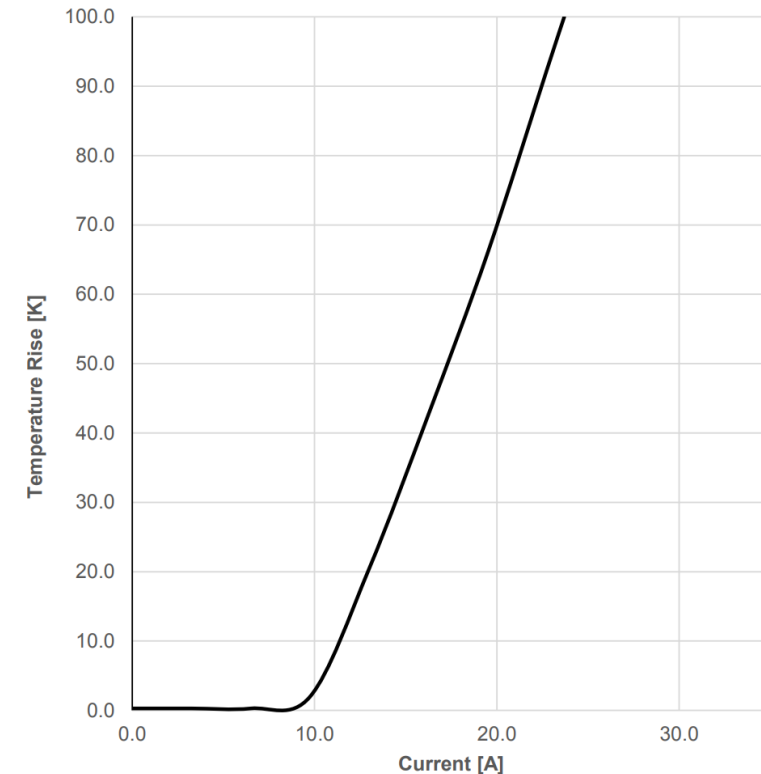


Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 10 mA	65	μH	±20%
Rated Current	I_R	$\Delta T = 50\text{ K}$	17.2	A	max.
Saturation Current	I_{SAT}	$ \Delta L/L < 30\%$	26.6	A	typ.
DC Resistance	R_{DC}	@ 20 °C	13.13	mΩ	typ.
DC Resistance	R_{DC}	@ 20 °C	14.44	mΩ	max.
Self Resonant Frequency	f_{res}		4.28	MHz	typ.

Typical Inductance vs. Current Characteristics:

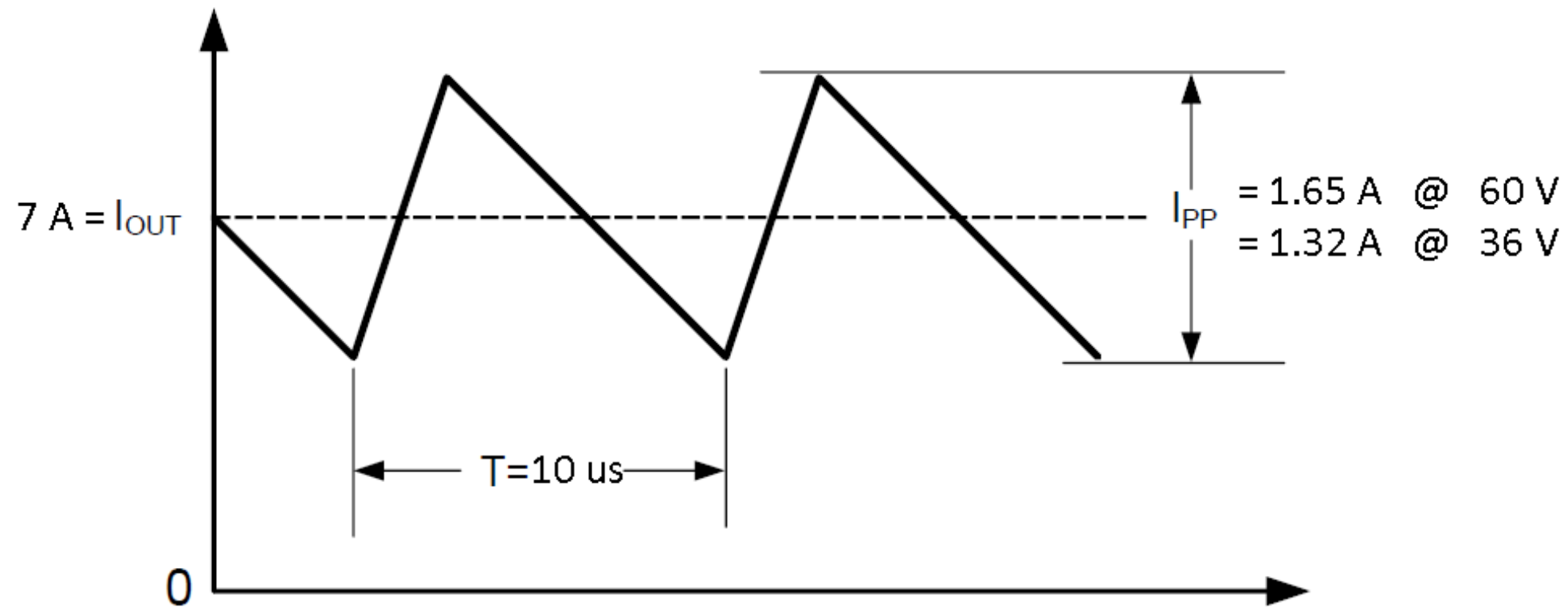


Typical Temperature Rise vs. Current Characteristics:



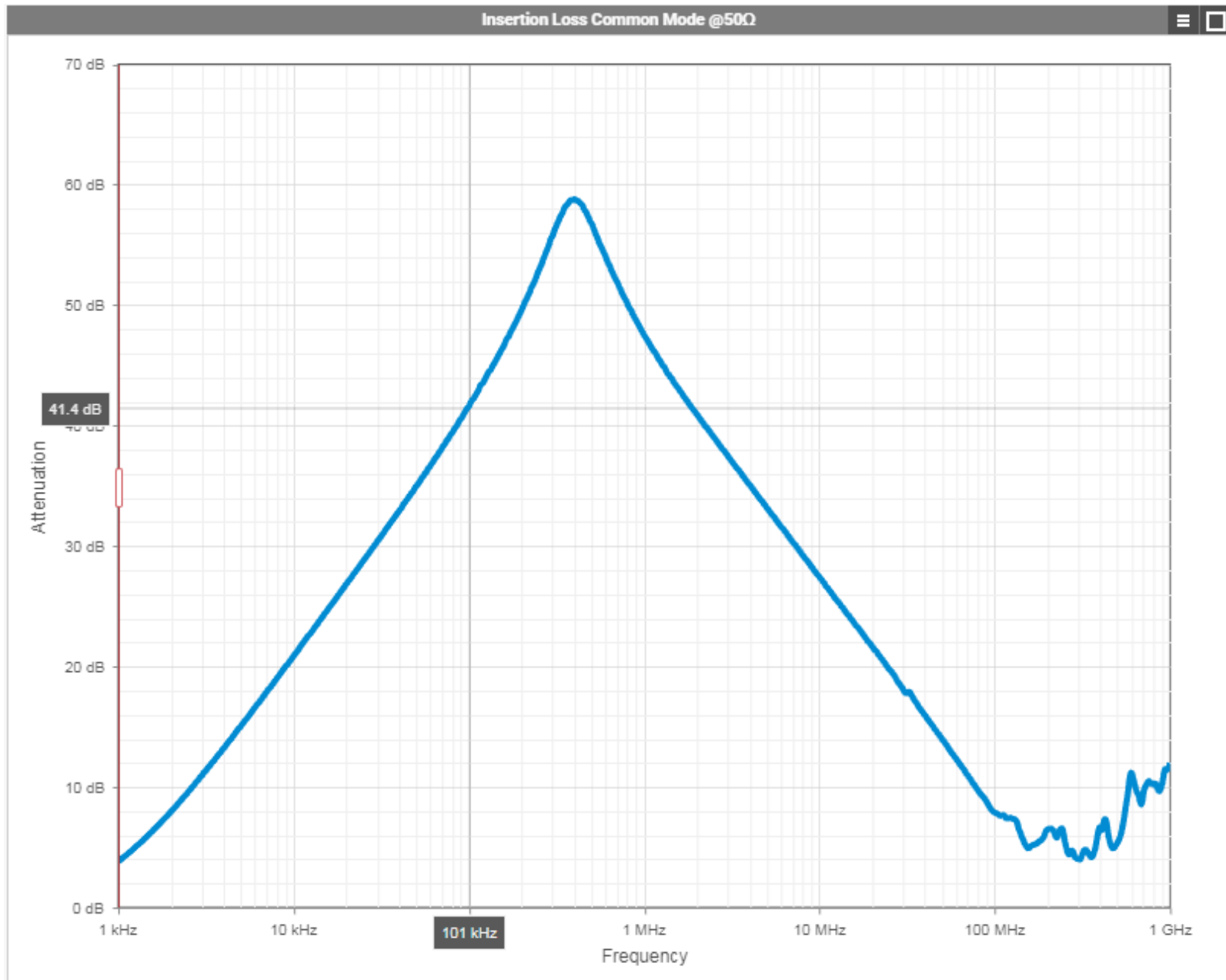
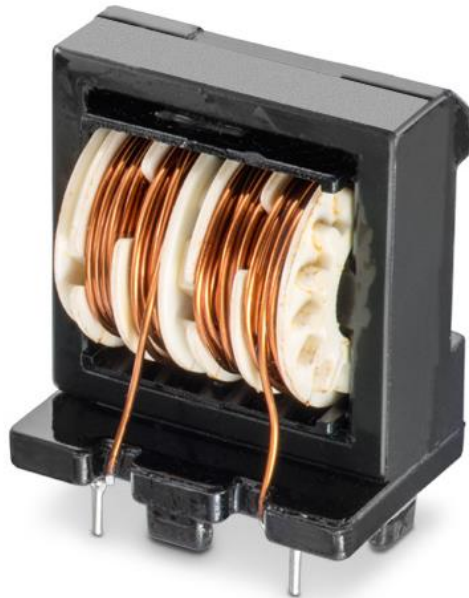
RIPPLE

$$I_{PP} = \frac{V_{OUT}}{L_O \times f_{SW}} \times \left(1 - \frac{V_{OUT}}{V_{IN}} \right) [A]$$

**Figure 23. Inductor Current**

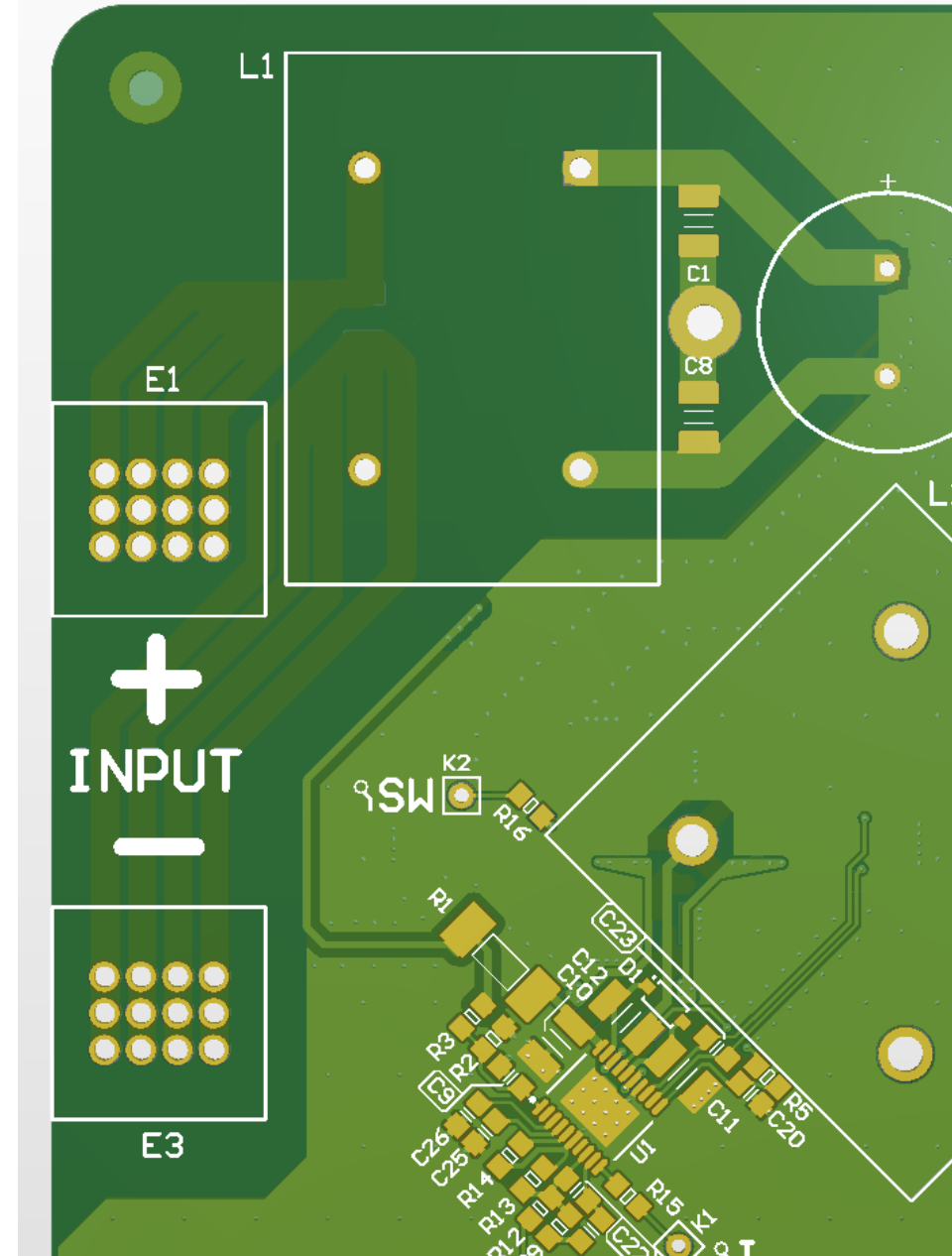
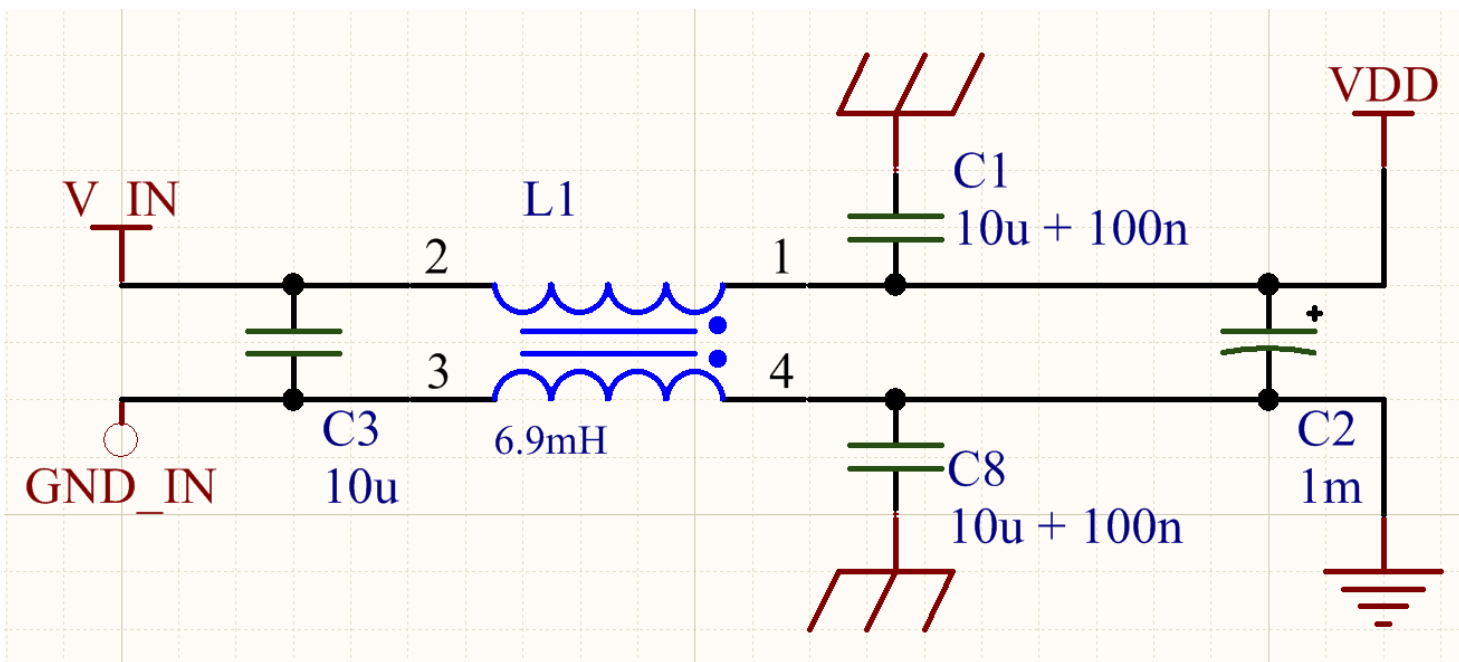
Vhodni filter (L)

- Wurth 744866692
- 41.4 dB pri 100kHz
- 6.9 mH
- 4 A
- 68 mΩ
- 250 V



Vhodni filter

- 10 μF MLCC, X7R 1.8 μF @ 60V
- 100 nF MLCC, NP0 100 nF @ 60V



VHODNI C

- United Chemi-Con

100 V

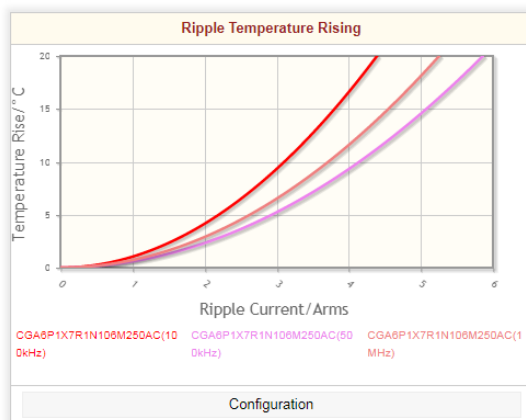
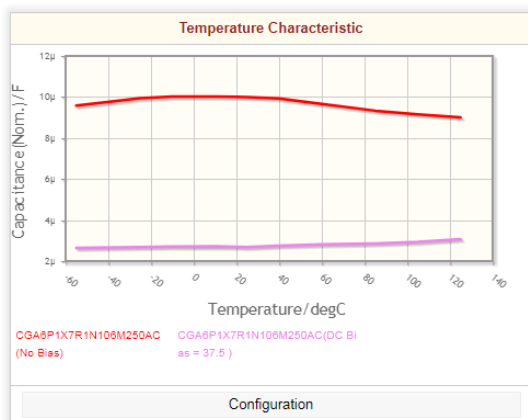
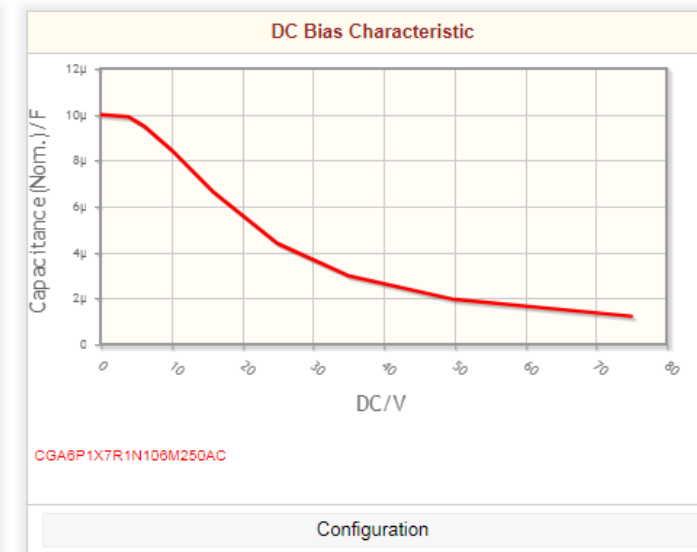
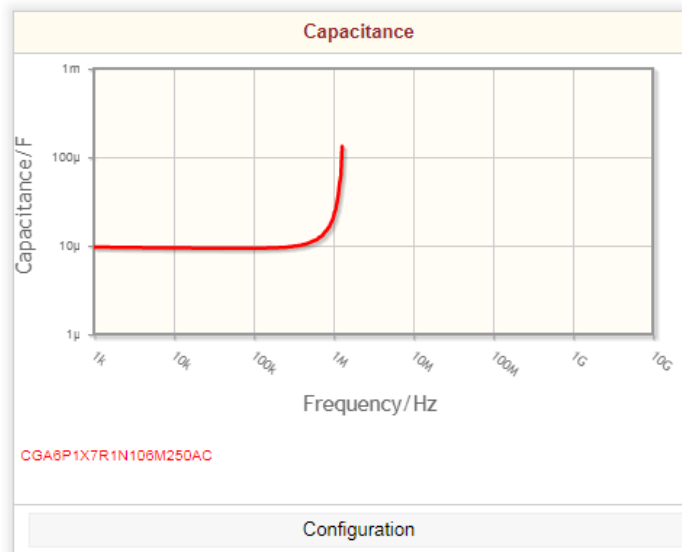
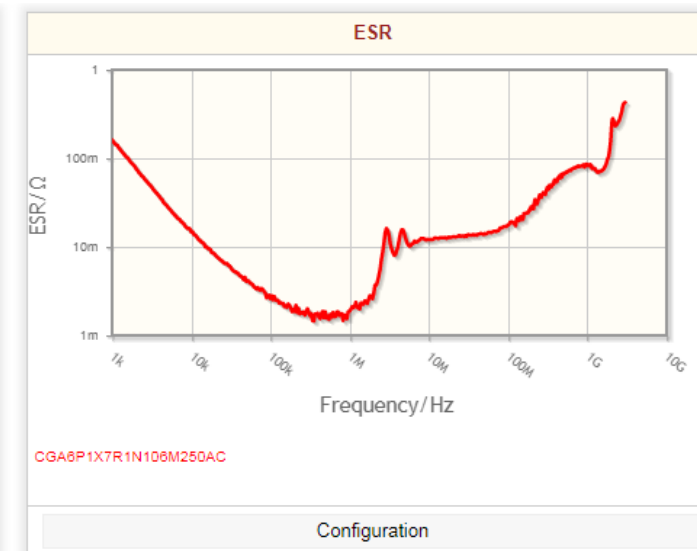
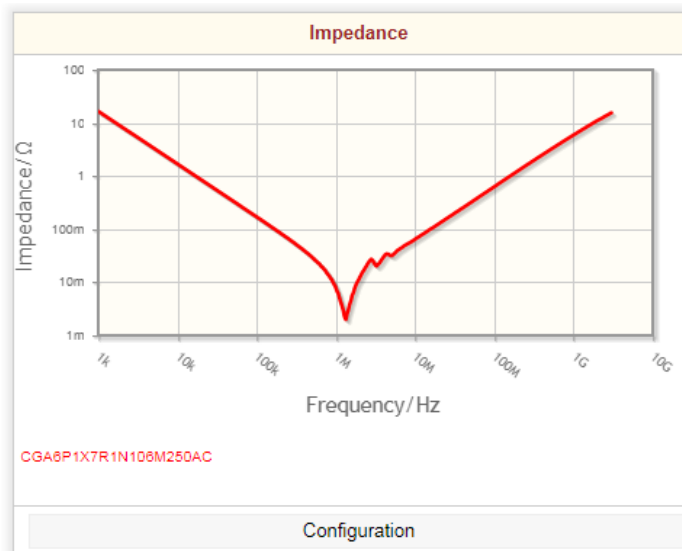
1.0 mF

3.86 A ripple

- TDK 4x

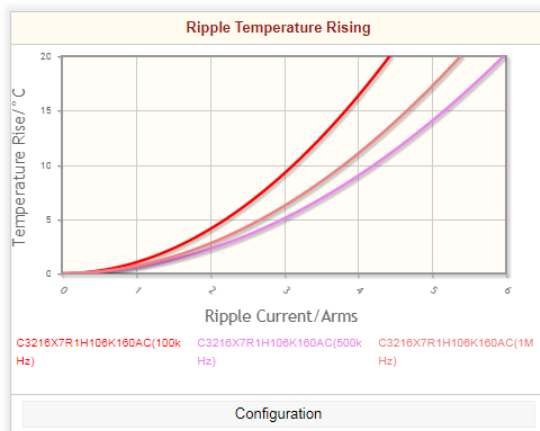
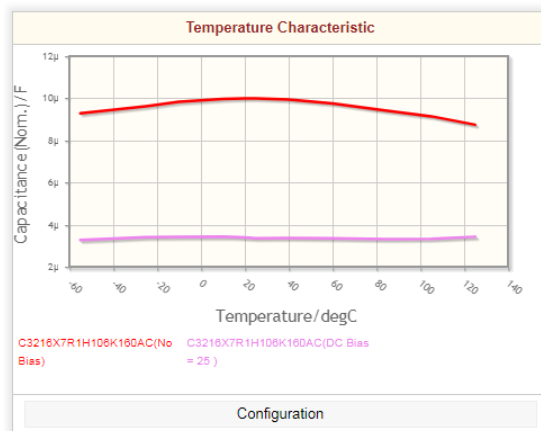
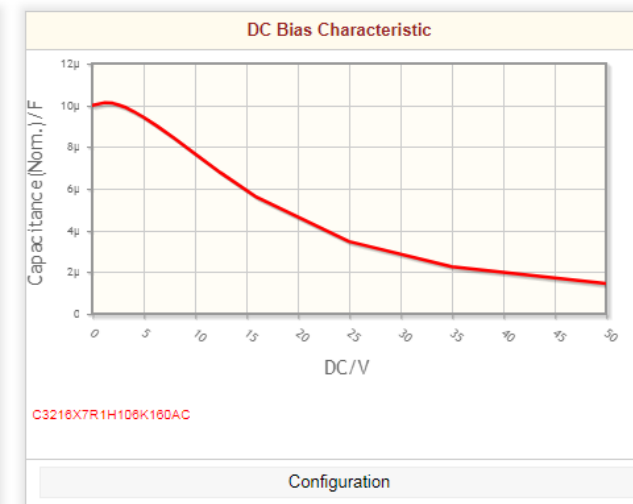
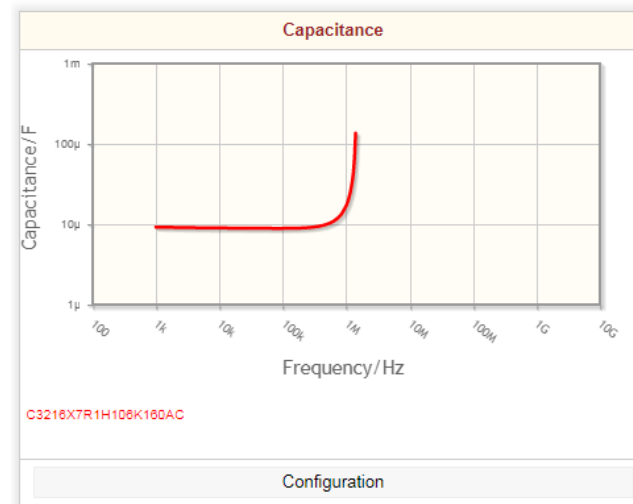
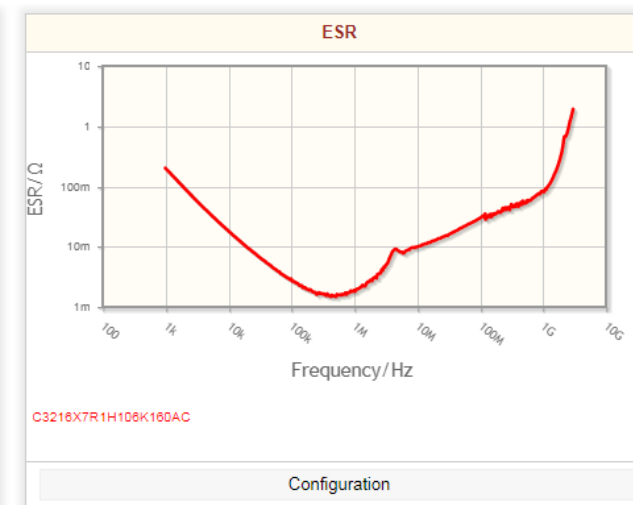
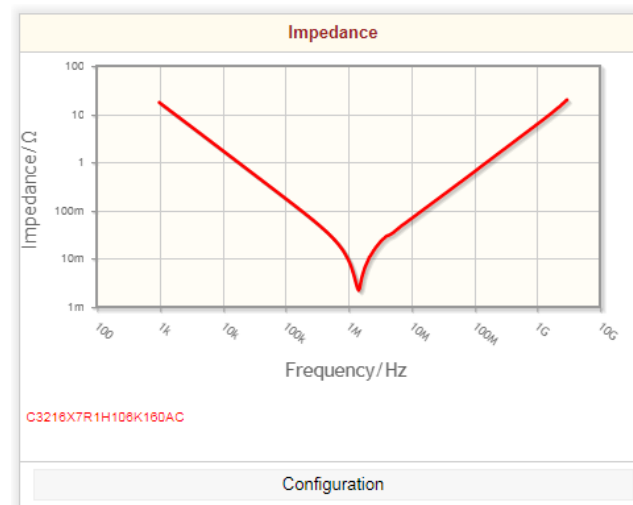
75 V

10 μ F (1.8 μ F @ 60 V)

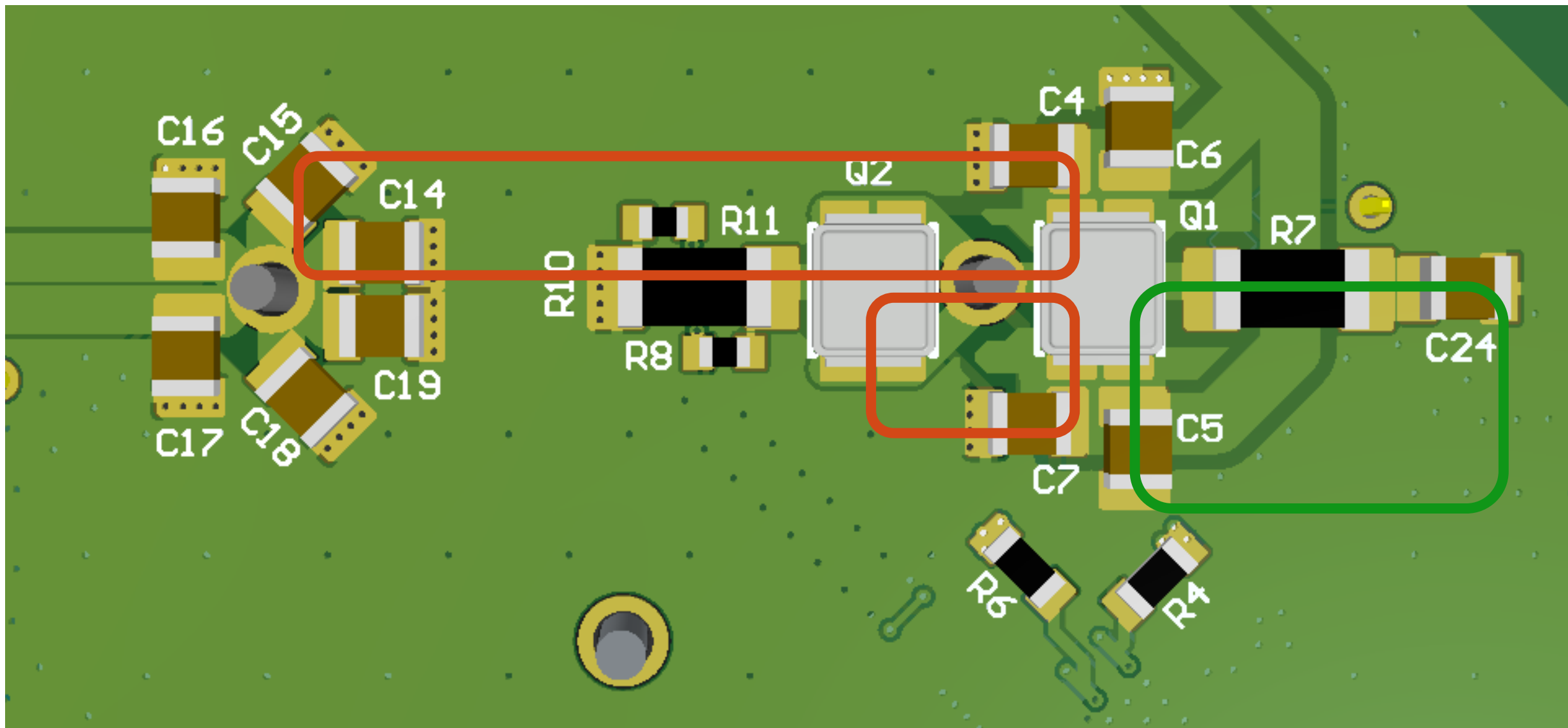


IZHODNI C

- United Chemi-Con
 - 25 V
 - 5.6 mF
 - 4 A ripple
- TDK 12x -> 120 uF
 - 50 V
 - 10 uF (6.5 uF @ 14 V)

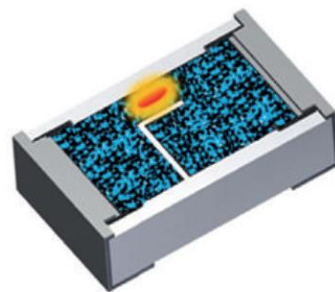


TOKOVNE ZANKE

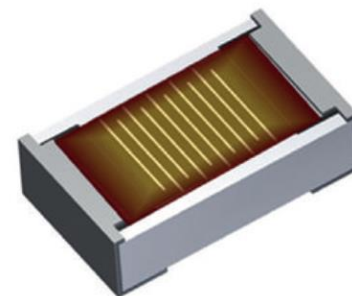


GATE UPOR

MELF zaradi visokih pulzov



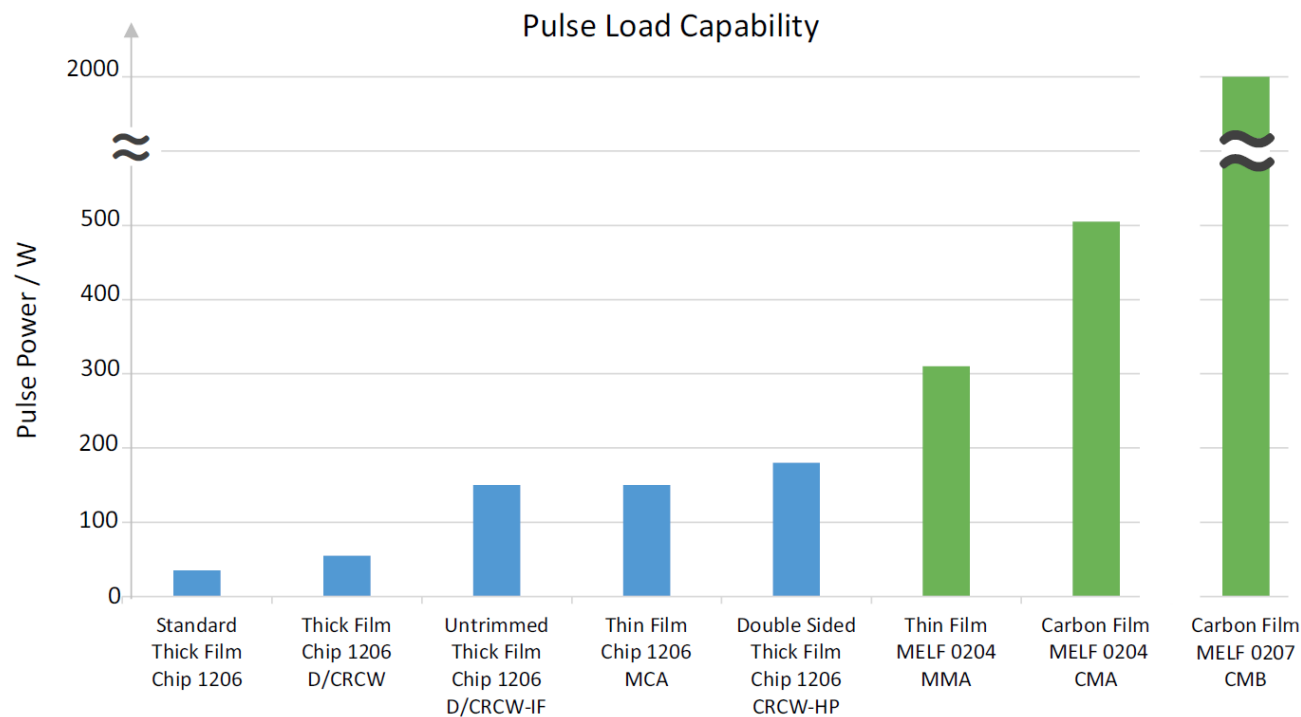
Thick Film Chip Resistor



Thin Film Chip Resistor



Fig. 6 - Schematic of the helical trimming pattern of the MELF resistor.



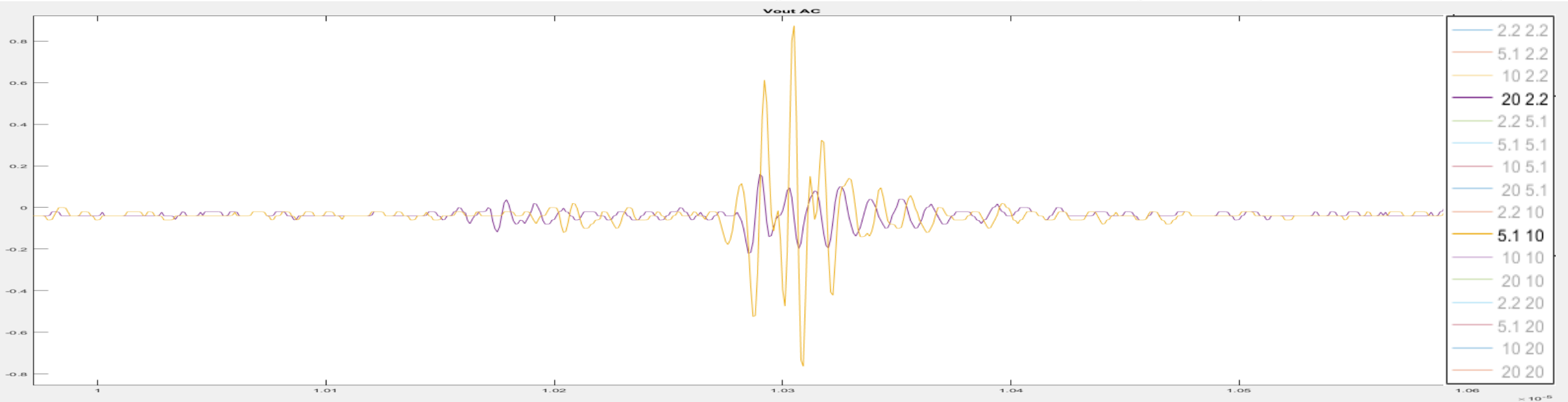
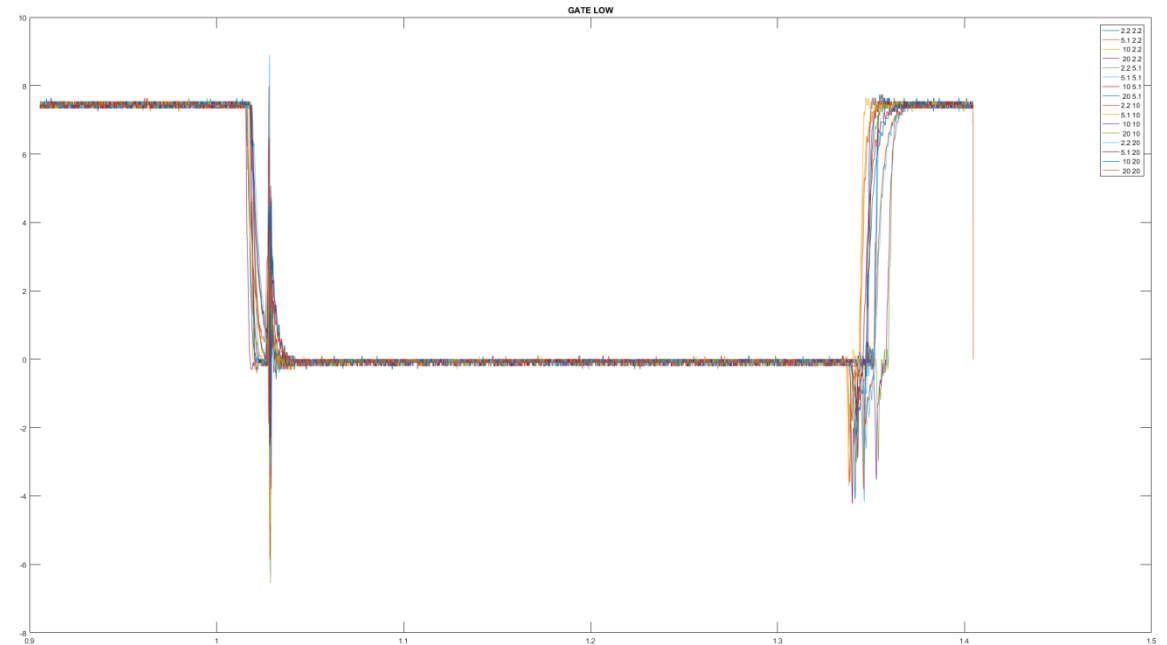
GATE RESISTOR

$R_{\text{GATE_HIGH}} = 20 \Omega$

$R_{\text{GATE_LOW}} = 2.21 \Omega$

TESTIRANJE (16 meritev!):

2Ω 5Ω 10Ω 20Ω



SNUBBER

- Izračun parazitne kapacitivnosti:

2x MOSFET :

C_{oss}	Output Capacitance	—	310	—
-----------	--------------------	---	-----	---

 pF

VEZJE : ~ 100 pF

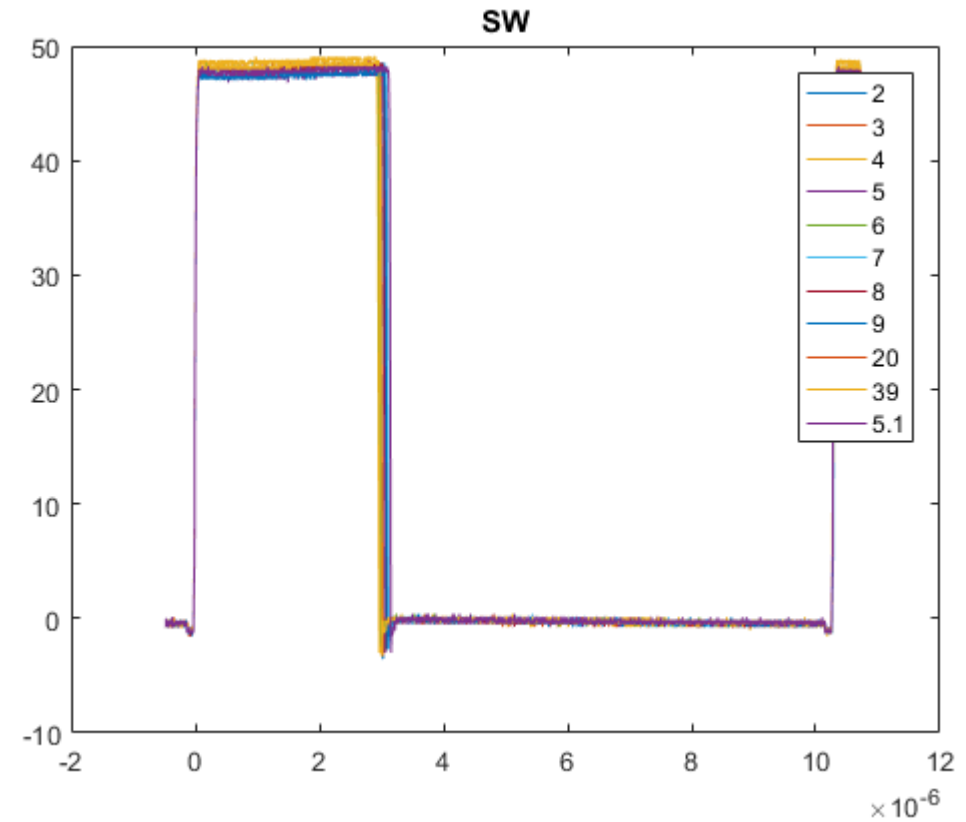
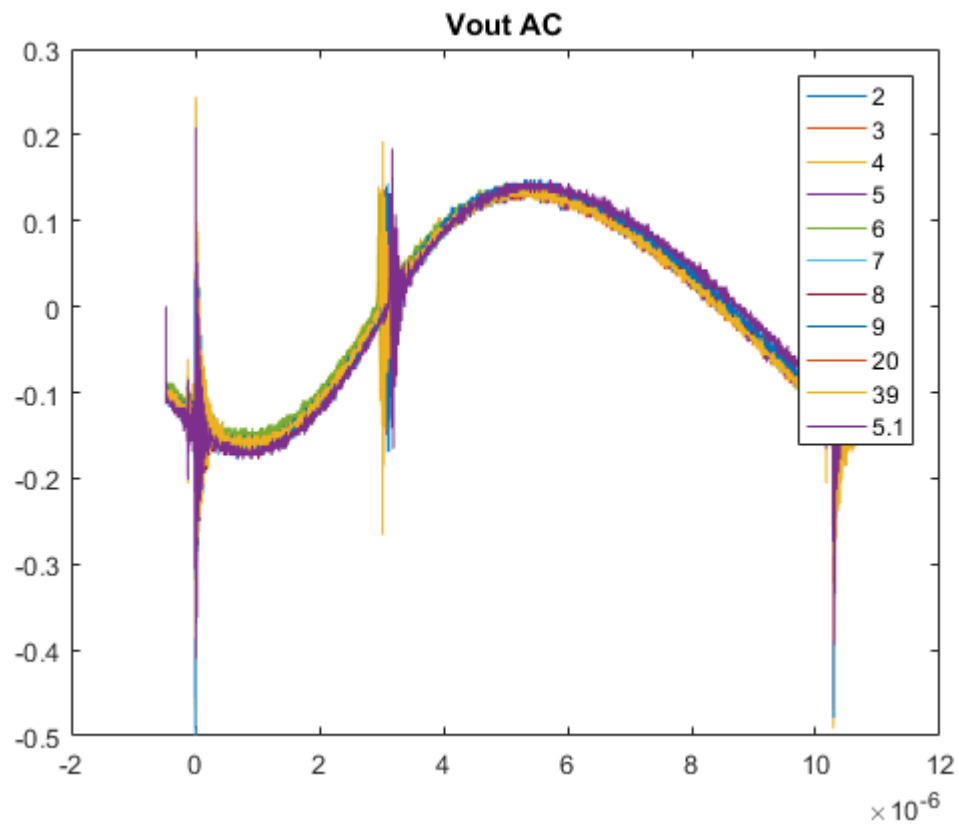
⇒ minimalna SNUBBER kapacitivnost 720 pF

⇒ uporabil 1.6 nF, NPO

- Izgube na uporu: $P_{diss} = C_s E_a^2 f_s = 1.6n \cdot 60^2 \cdot 100k = \sim 0.6 \text{ W}$
- Ohišje 2512 za upor (1-2W)

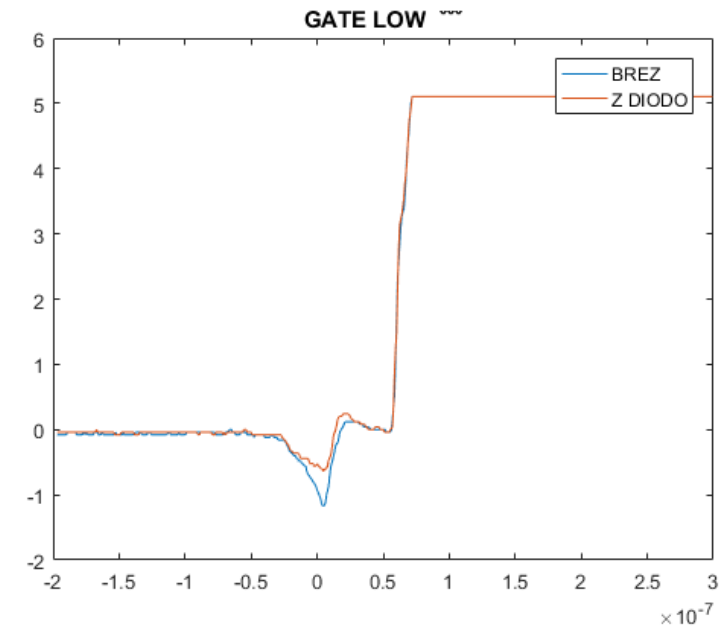
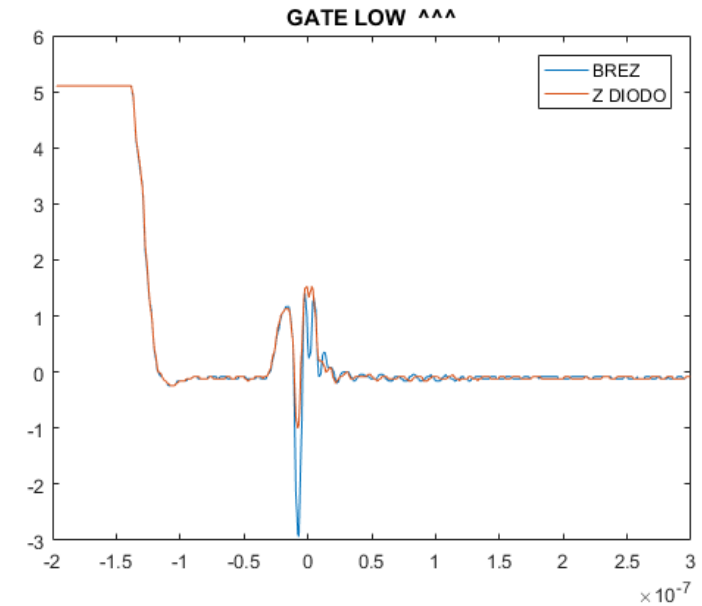
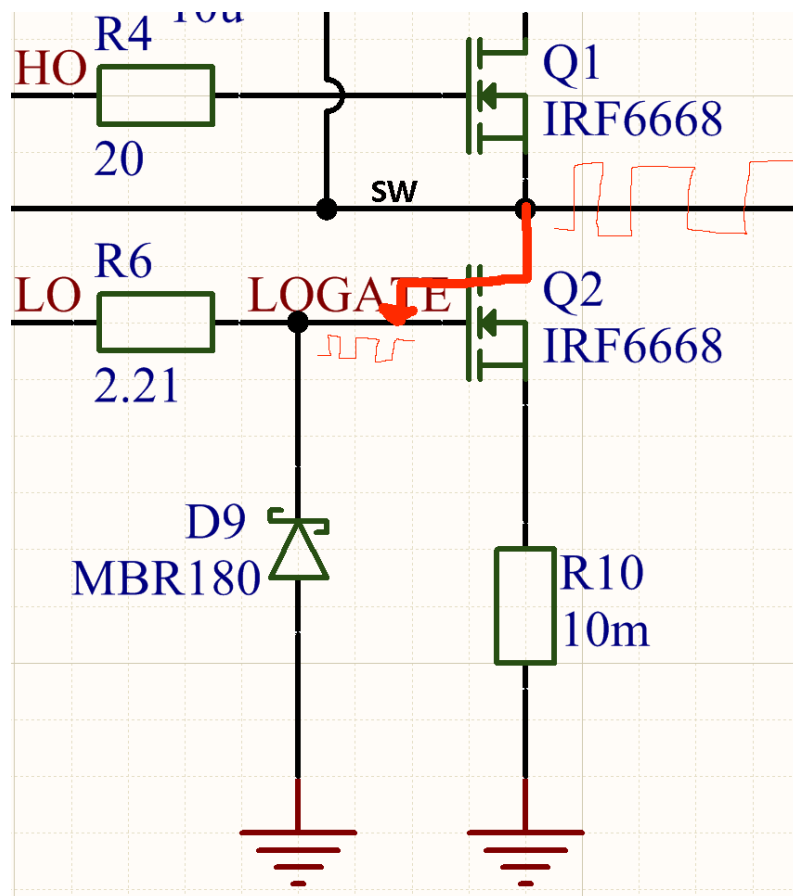
SNUBBER

- Optimizacija R za prenihaj (2 3 4 5 6 7 8 9 20 39) Ω



GATE DIODA HACK

- Couplanje SW točke v LOW_GATE!
- Rešitev DIODA :)

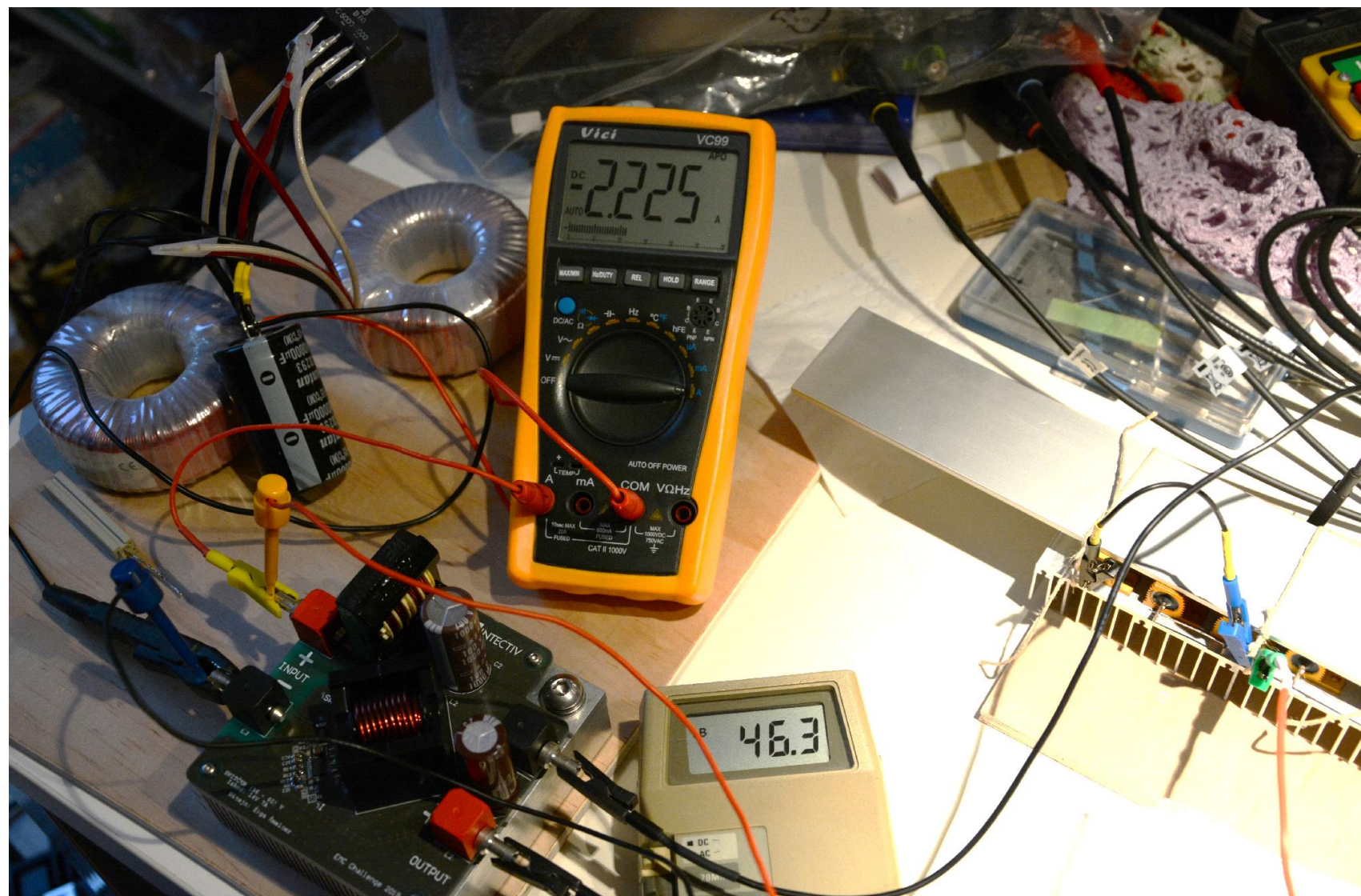


TRAJNOSTNO TESTIRANJE

2h na 100W

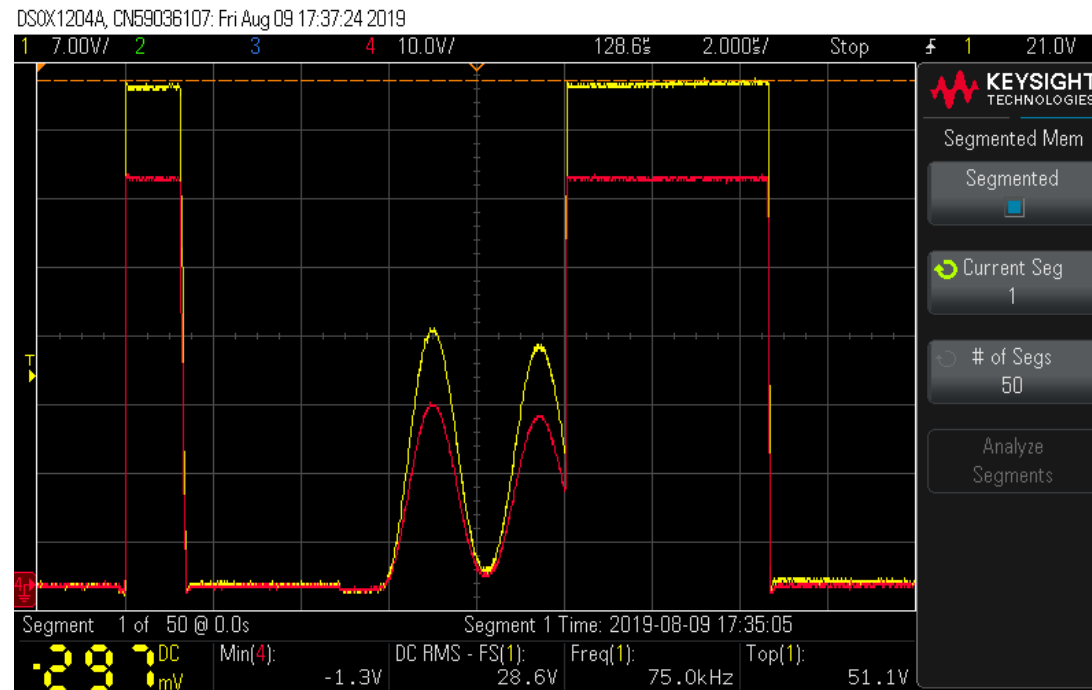
3*12V transformator

Izkoristek ~ 94 %



PROBLEMI

- Pozabil prispajkati HIGH_GATE upor
- 60V -> izhod !!!
- Prenihanja SW pri preklopih (DISCONTINUOUS NAČIN!!!)

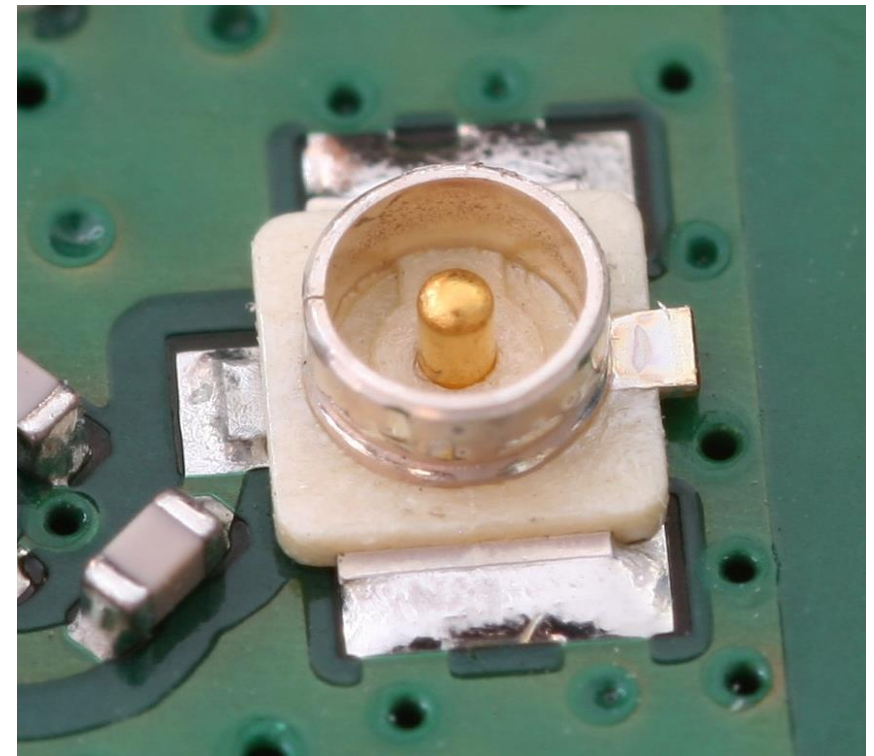


PROBLEMI

- Merjenje visoko frekvenčnih prenihajev



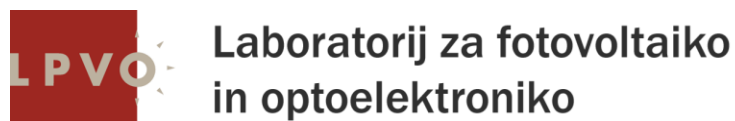
ANTENA!



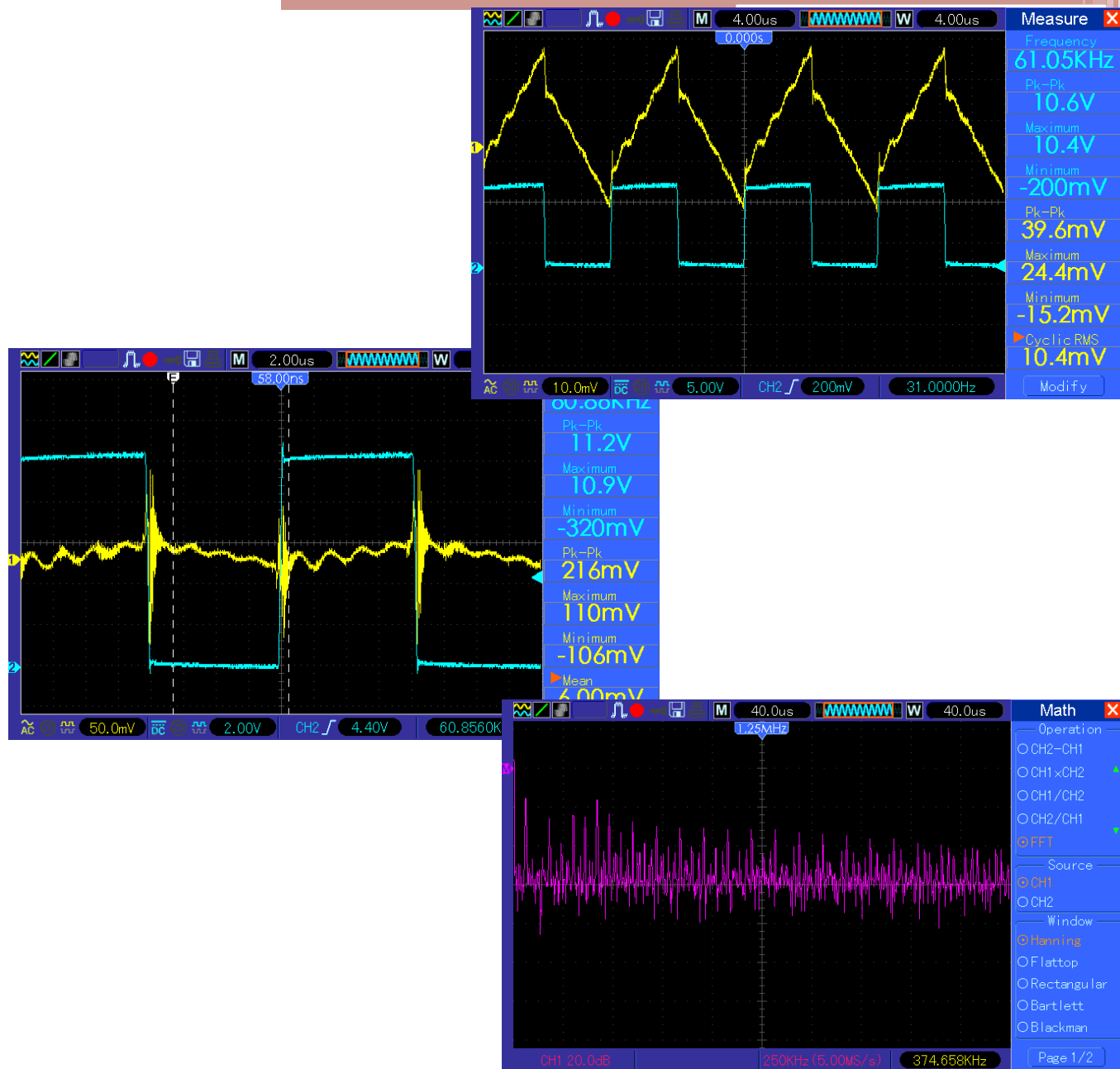
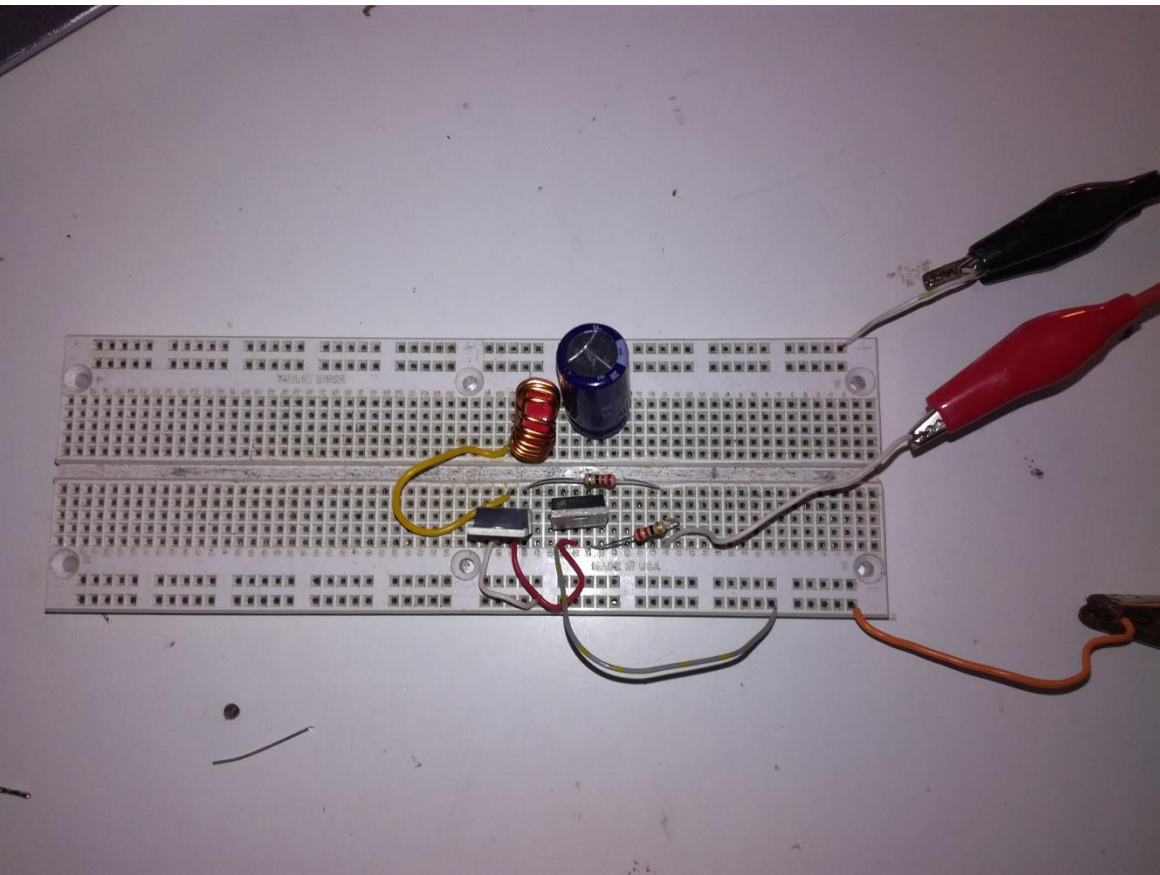
REŠITEV

Načrtovanje elektronike za **EMC**²

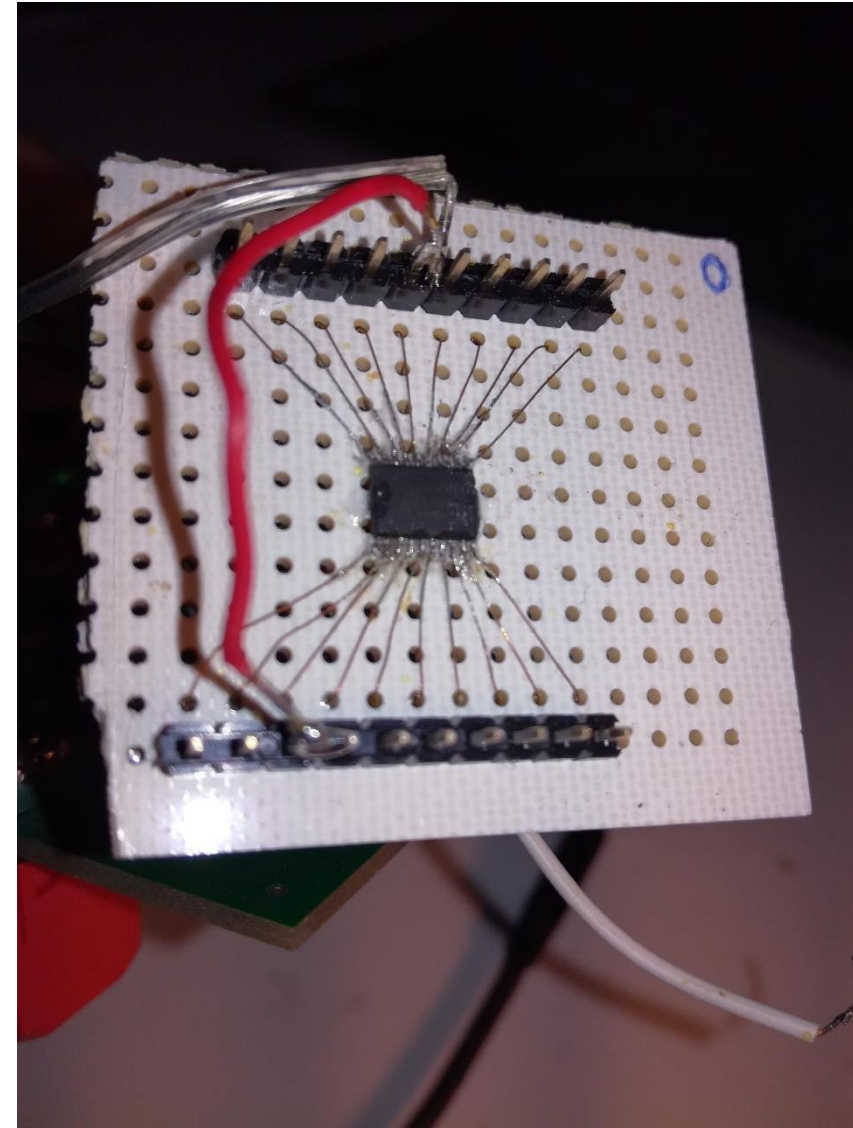
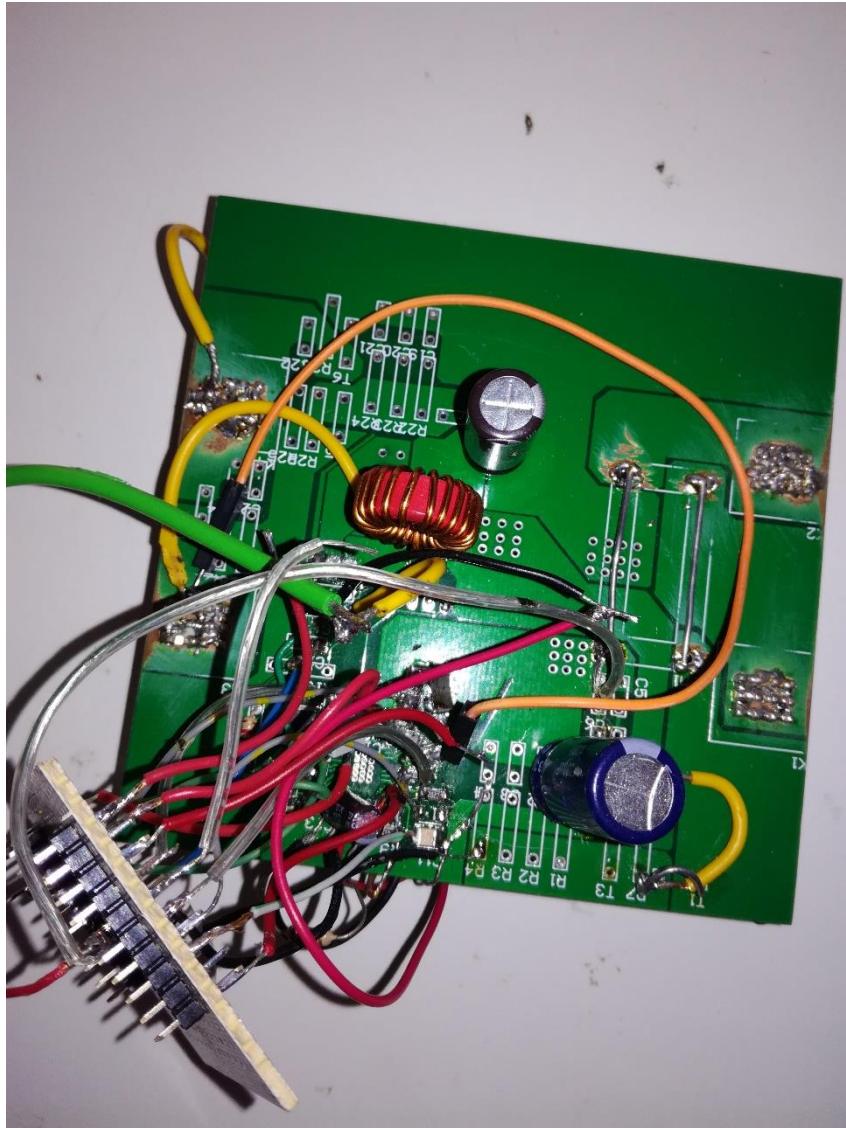
S03 Bernard Veršnjak



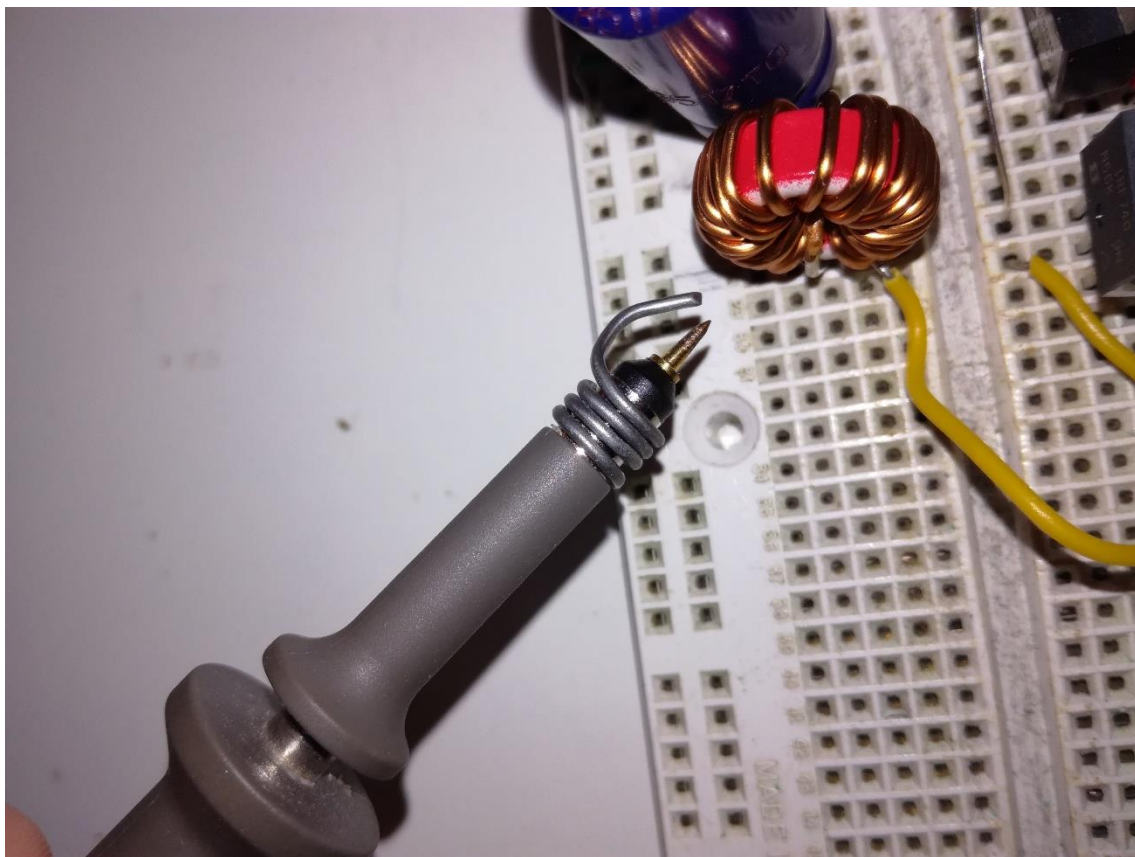
PRIPRAVE



... IN PRVI SPODRSLJAJ



MERJENJE



DIFERENCIALNE MOTNJE



SOFAZNE MOTNJE

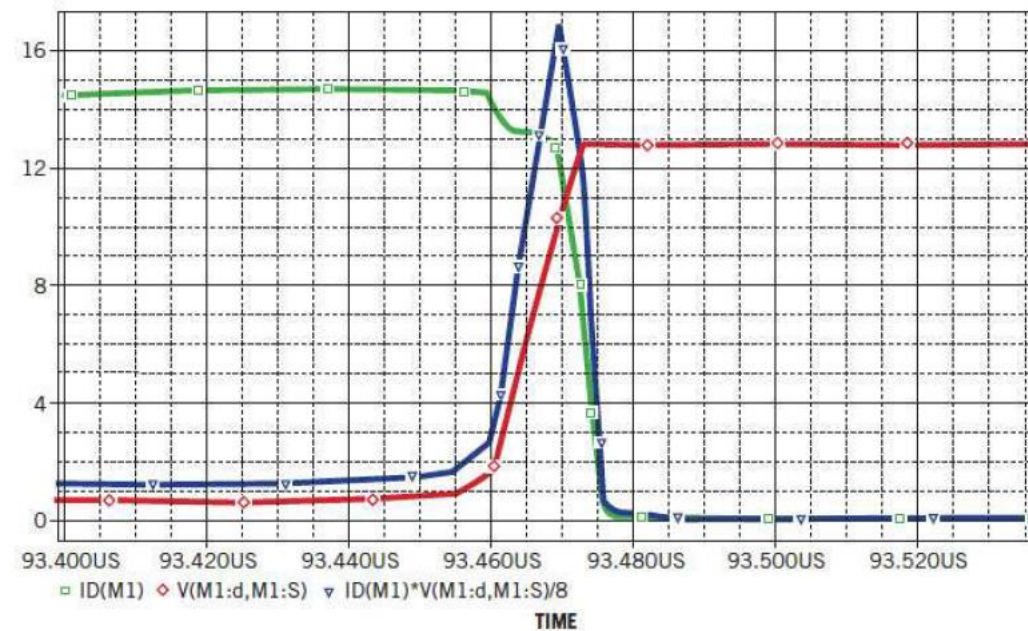
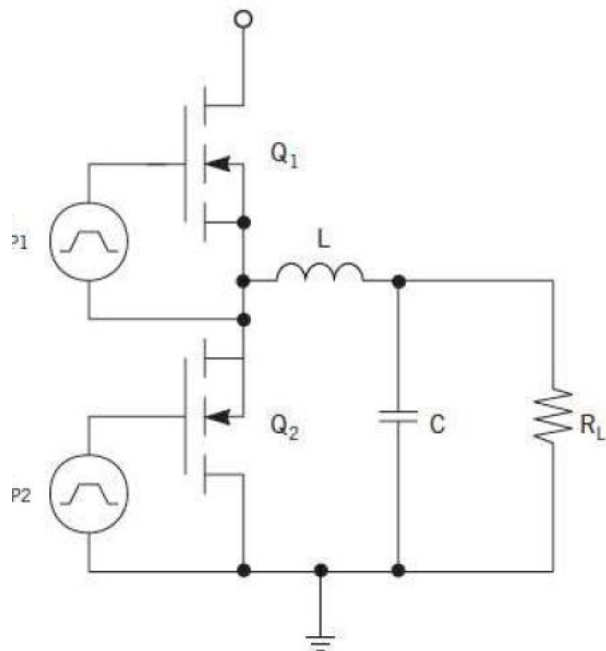
IZGUBE NA MOSFETU

$$P(Q_1) = I_{RMS}^2 R_{ON1} D +$$

$$f \left[Q_{G1} V_{G1} + \frac{1}{2} (t_r + t_f) I_{RMS} V_S \right]$$

$$P(Q_2) = I_{RMS}^2 R_{ON2} (1 - D) +$$

$$f \left[Q_{G2} V_{G2} + \frac{1}{2} (t_r + t_f) I_{RMS} V_D \right]$$



- MOČ
- TOK
- NAPETOST

IZBIRA MOSFETA

SPODNJI MOSFET – IRF3710

$$V_{DSS} = 100V$$

$$R_{DS(on)} = 23m\Omega$$

$$I_D = 57A$$

➤ PREVLADUJEJO PREVAJALNE IZGUBE

➤ Qg, tr in tf so stranskega pomena

➤ Pomemben je Ron, saj velja:

$$P = R_{on} \cdot I^2 \cdot (1 - D)$$

➤ Ocenjena izgubna moč pri največji obremenitvi: **6W**

Qg	Total Gate Charge	—	—	130	nC	ID = 28A VDS = 80V VGS = 10V, See Fig. 6 and 13
Qgs	Gate-to-Source Charge	—	—	26		
Qgd	Gate-to-Drain ("Miller") Charge	—	—	43		
td(on)	Turn-On Delay Time	—	12	—	ns	VDD = 50V ID = 28A RG = 2.5Ω VGS = 10V, See Fig. 10 ④
tr	Rise Time	—	58	—		
td(off)	Turn-Off Delay Time	—	45	—		
tf	Fall Time	—	47	—		

IZBIRA MOSFETA

ZGORNJI MOSFET – IRF540

PRODUCT SUMMARY	
V_{DS} (V)	100
$R_{DS(on)}$ (Ω)	$V_{GS} = 10\text{ V}$ 0.077
Q_g (Max.) (nC)	72
Q_{gs} (nC)	11
Q_{gd} (nC)	32
Configuration	Single

➤ PREVLADUJEJO STIKALNE IZGUBE

➤ $Q(g)$ mora biti čim manjši, zaradi

$$\frac{dV}{dt}$$

➤ T_r in T_f morata biti čim manjša

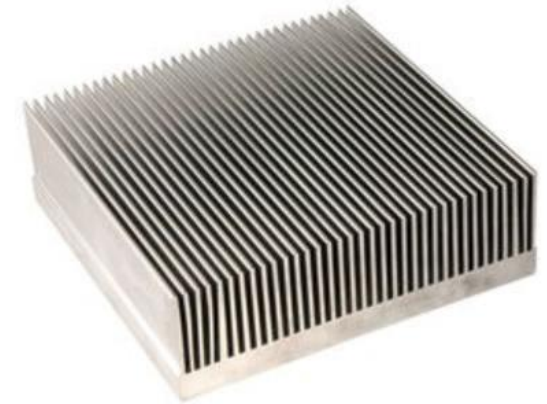
➤ R_{on} je stranskega pomena

➤ Ocenjena izgubna moč pri največji obremenitvi: **5.2W**

Turn-On Delay Time	$t_{d(on)}$	$V_{DD} = 50\text{ V}, I_D = 17\text{ A}$ $R_g = 9.1\ \Omega, R_D = 2.9\ \Omega, \text{ see fig. } 10^b$	-	11	-	ns
Rise Time	t_r		-	44	-	
Turn-Off Delay Time	$t_{d(off)}$		-	53	-	
Fall Time	t_f		-	43	-	

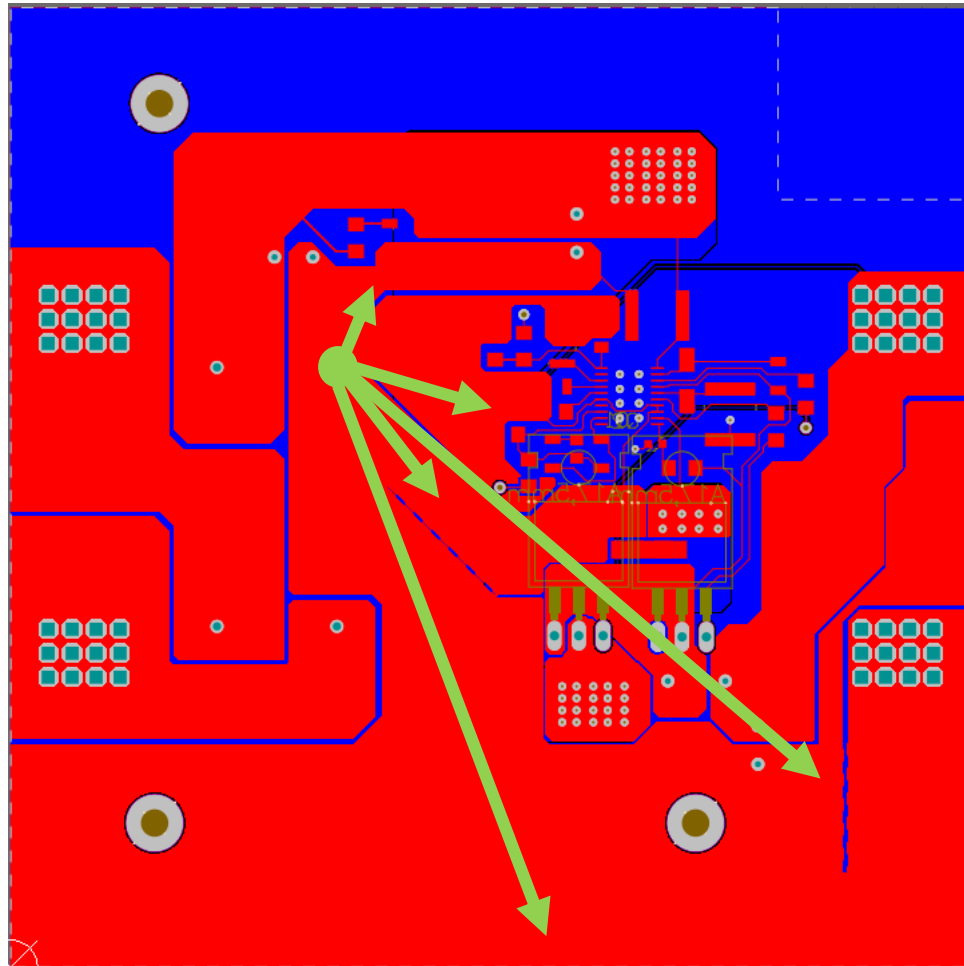
GRETJE HLADILNIKA

- Termalna upornost hladilnika: $0,12 \text{ }^{\circ}\text{C}/\text{W}$
- Termalna upornost IRF3710 ($R_{jc} + R_{cs}$): $1,25 \text{ }^{\circ}\text{C}/\text{W}$
- Termalna upornost IRF540 ($R_{jc} + R_{cs}$): $1,5 \text{ }^{\circ}\text{C}/\text{W}$
- Izgubna moč na IRF540: $5,2 \text{ W}$
- Izgubna moč na IRF3710: 6 W
- $\Delta T = 5,2\text{W} \cdot \left(1,5 \frac{^{\circ}\text{C}}{\text{W}} + 0,12 \frac{^{\circ}\text{C}}{\text{W}}\right) + 6\text{W} \cdot \left(1,25 \frac{^{\circ}\text{C}}{\text{W}} + 0,12 \frac{^{\circ}\text{C}}{\text{W}}\right) = \mathbf{16,6^{\circ}\text{C}}$

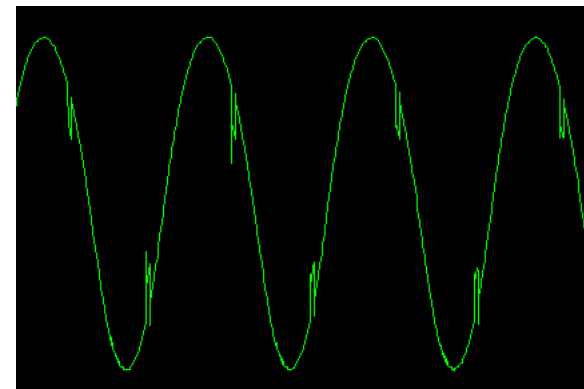
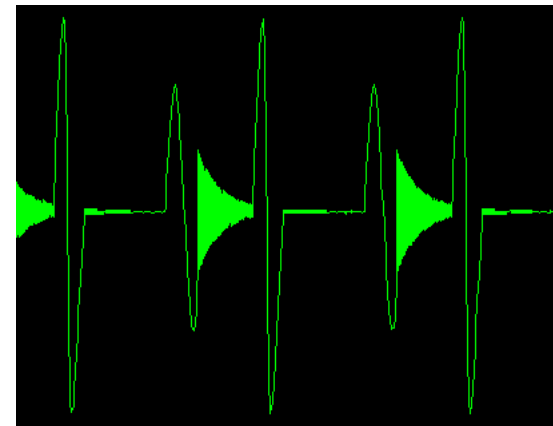


„STAR POINT GROUNDING“

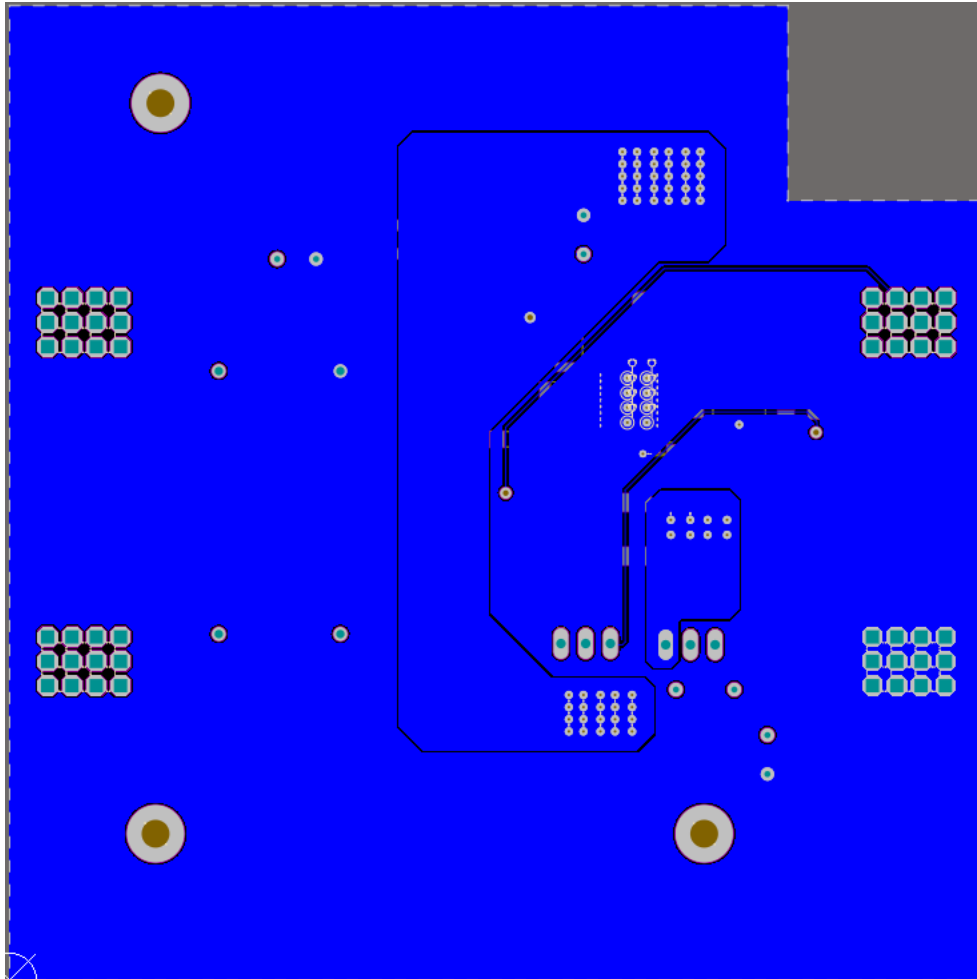
MASA NI PREVODNA POVRŠINA, AMPAK ENA SAMA TOČKA



- Previdnost pri povezovanju spodnjega MOSFETA in obeh filtrov k masi.

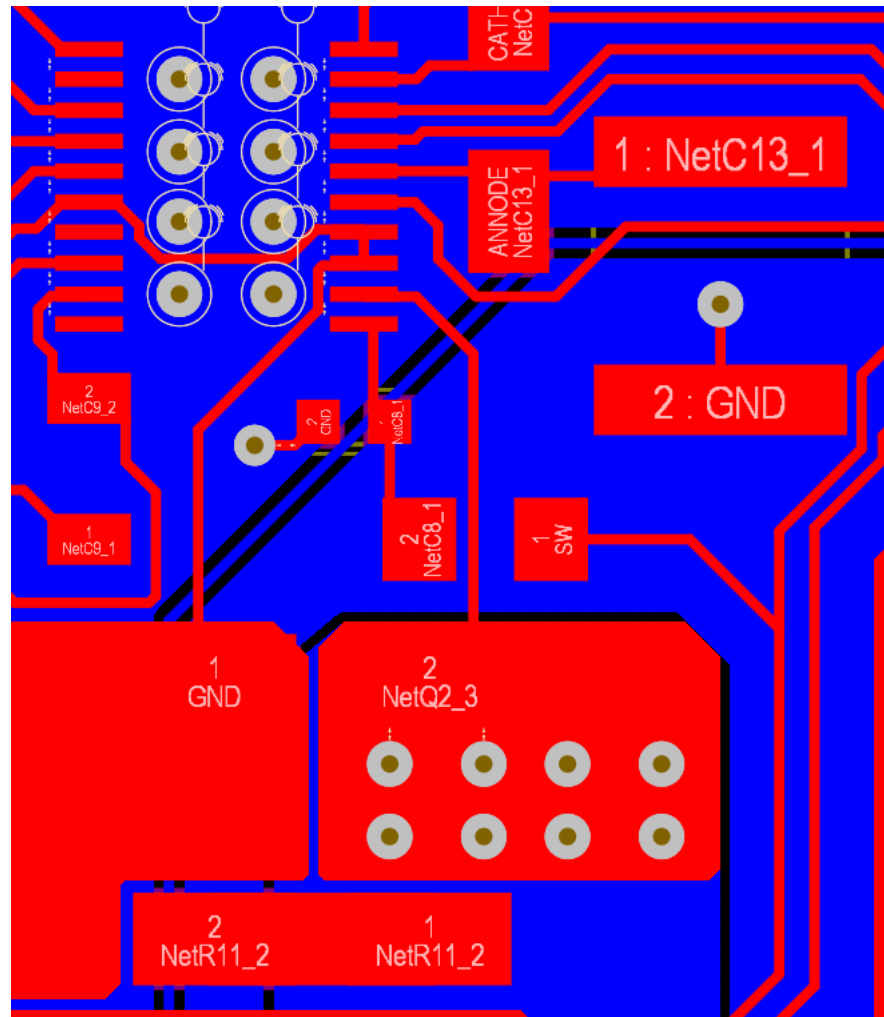


POVRATNA POVEZAVA



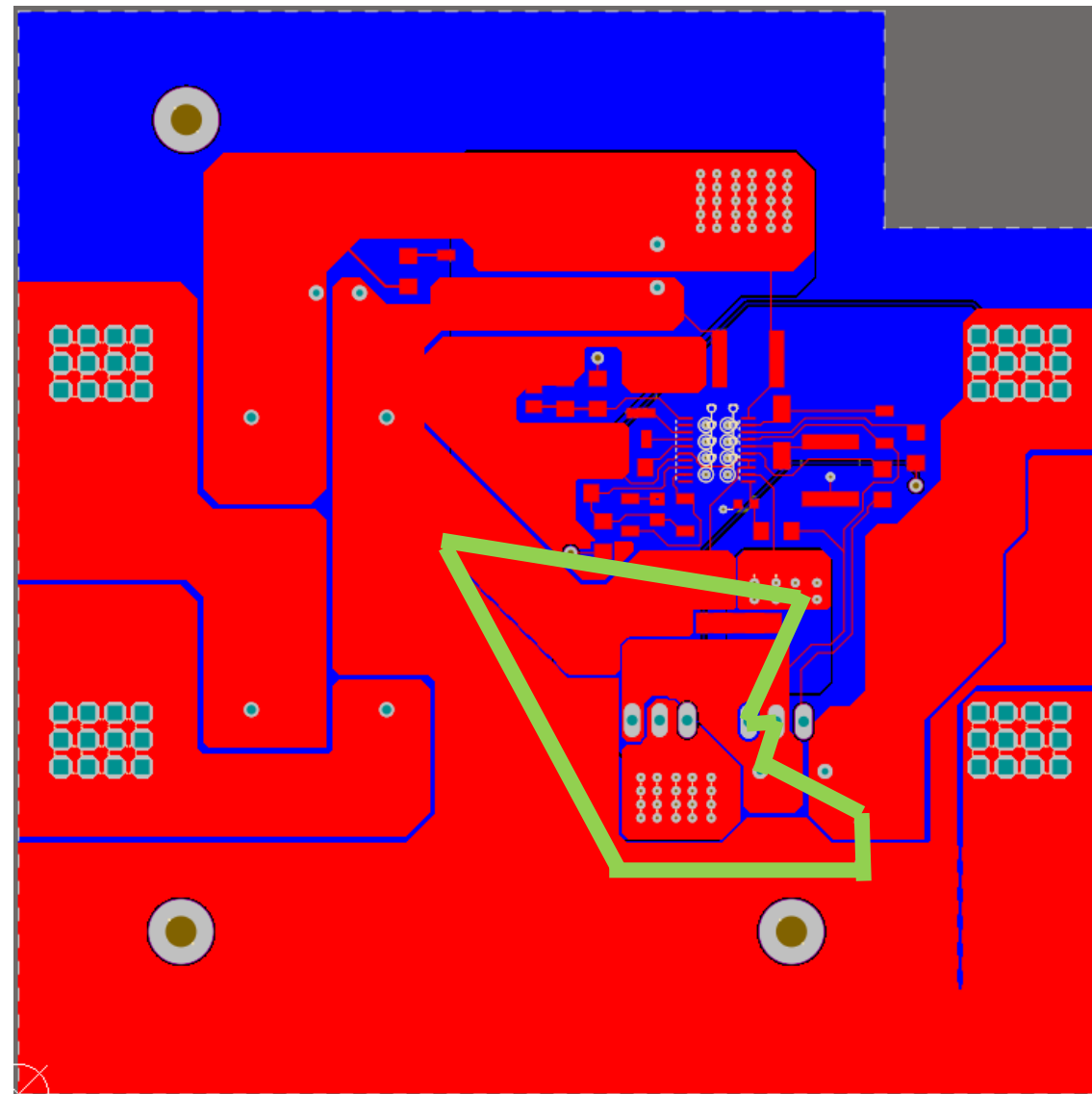
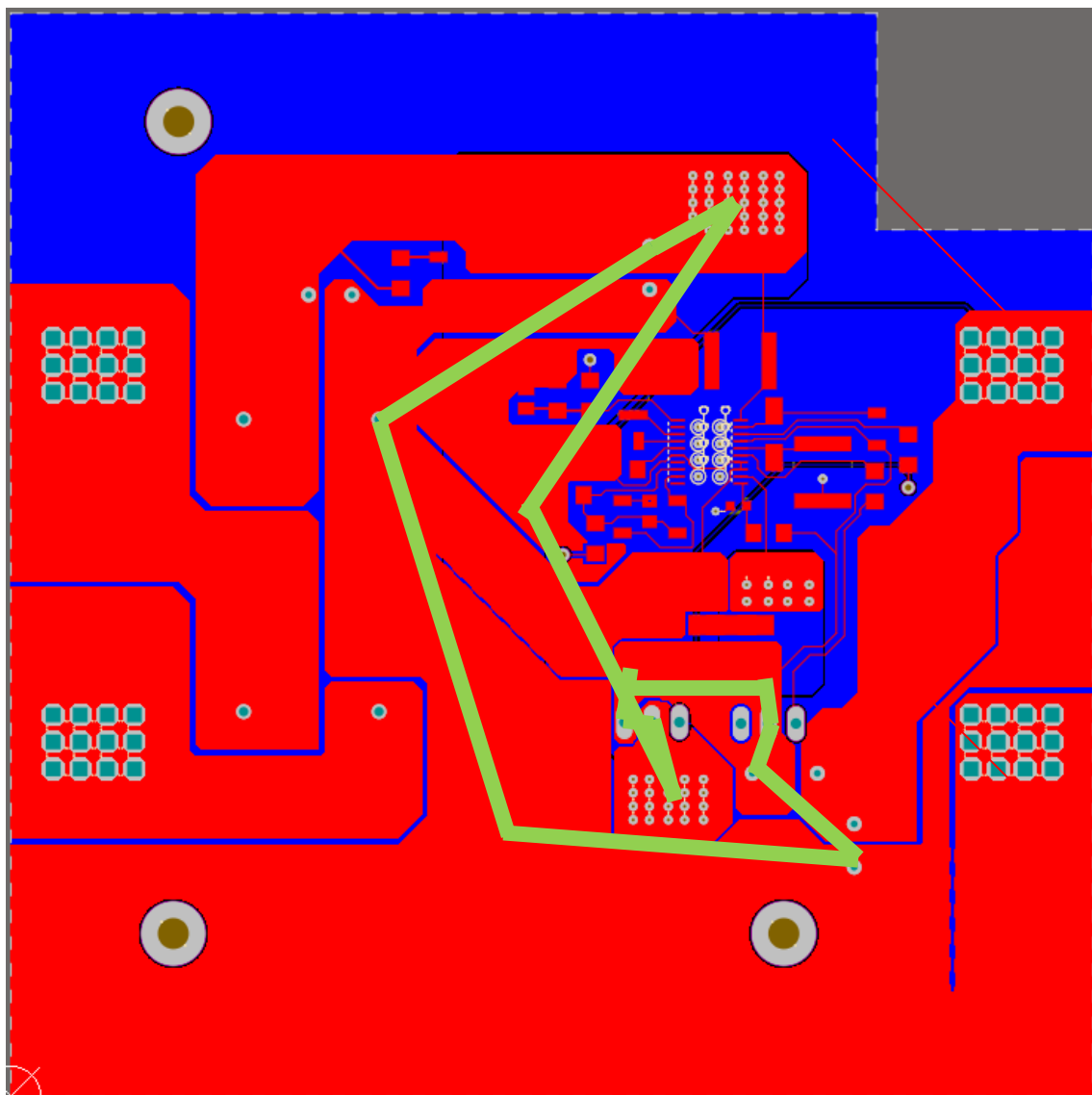
- Povezava mora iti daleč od mest z $\frac{dI}{dt}$ in $\frac{dV}{dt}$

„Current sense resistor“



- Povezava mora predstavljati čim manjšo impedanco
- Upornost bi lahko zmanjšal še bolje s poligonom

KRITIČNI ZANKI

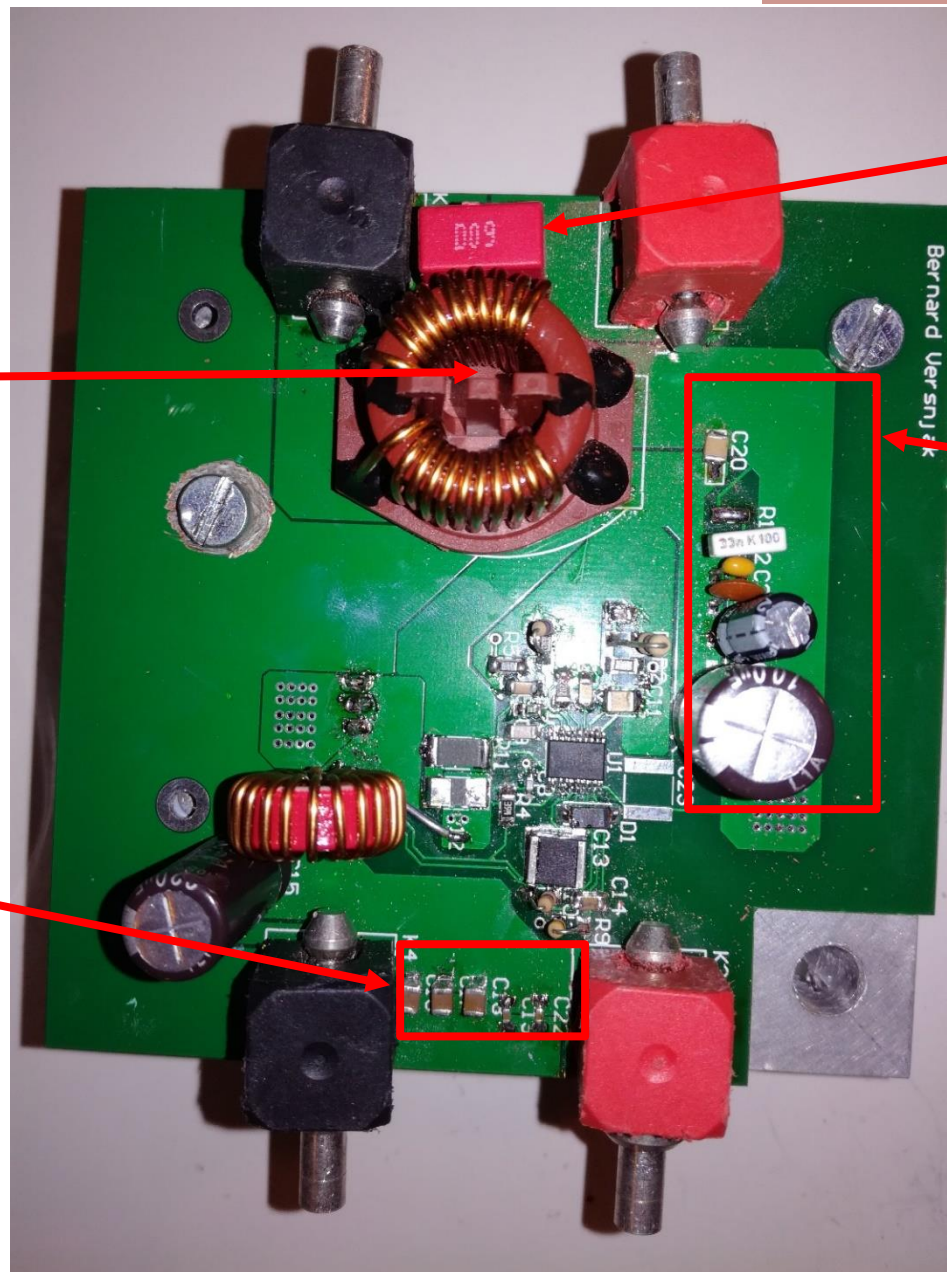


FILTRI

SOFAZNA
DUŠILKA 1mH

Serijski
kondenzatorji

- 10 μ F
- 10 μ F
- 10 μ F
- 1 μ F
- 1 μ F

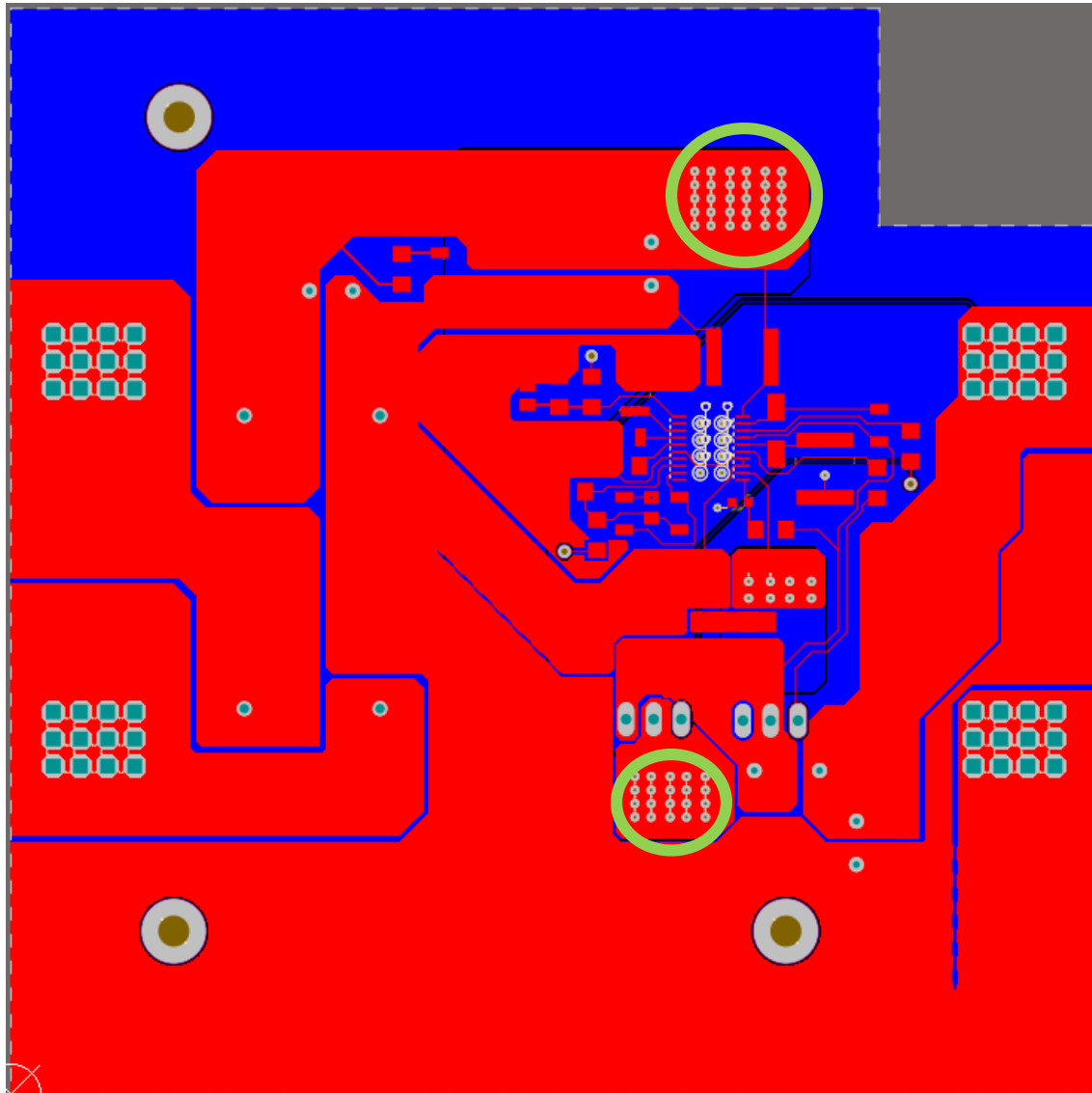


150n kondenzator

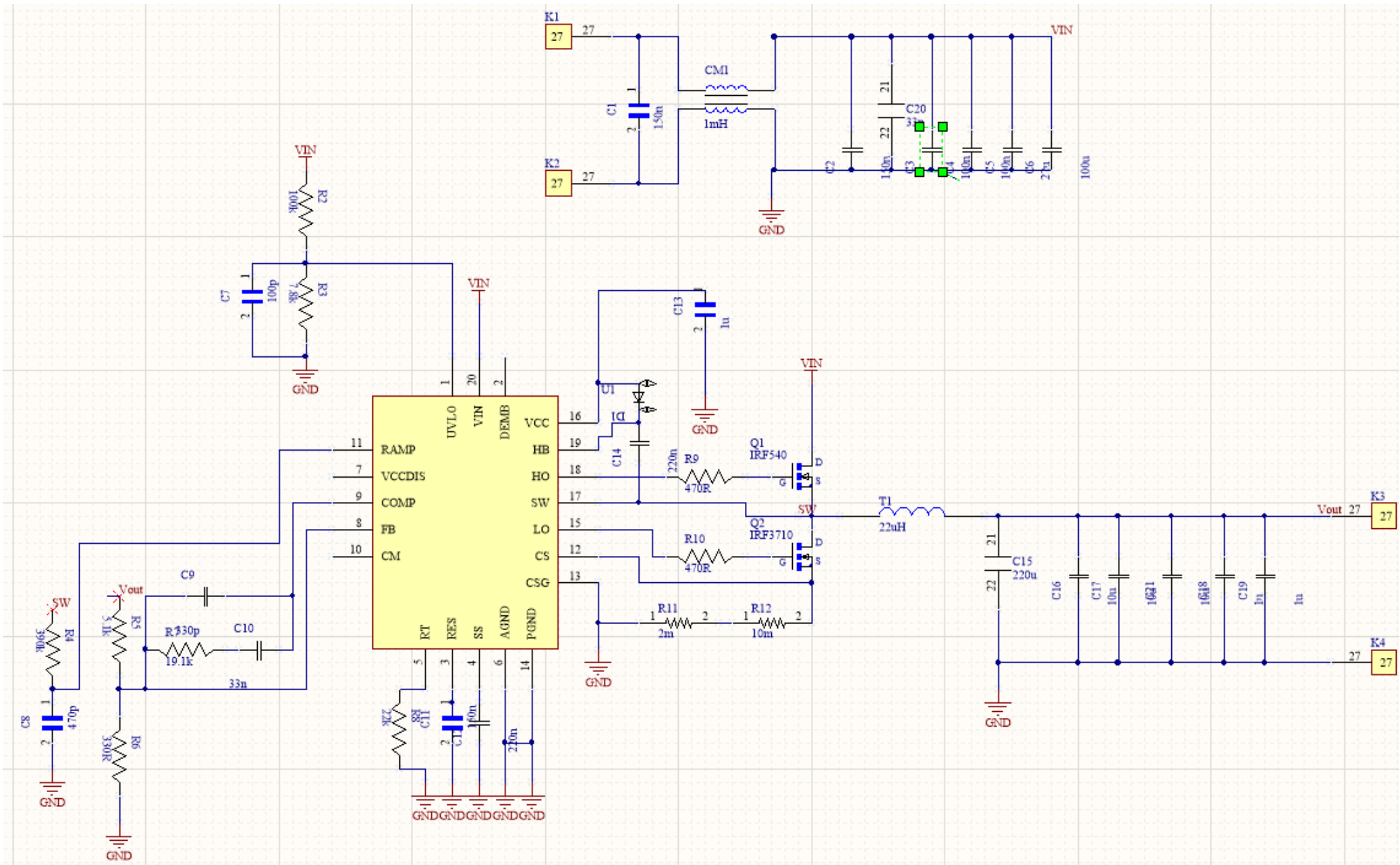
Serijski
kondenzatorji

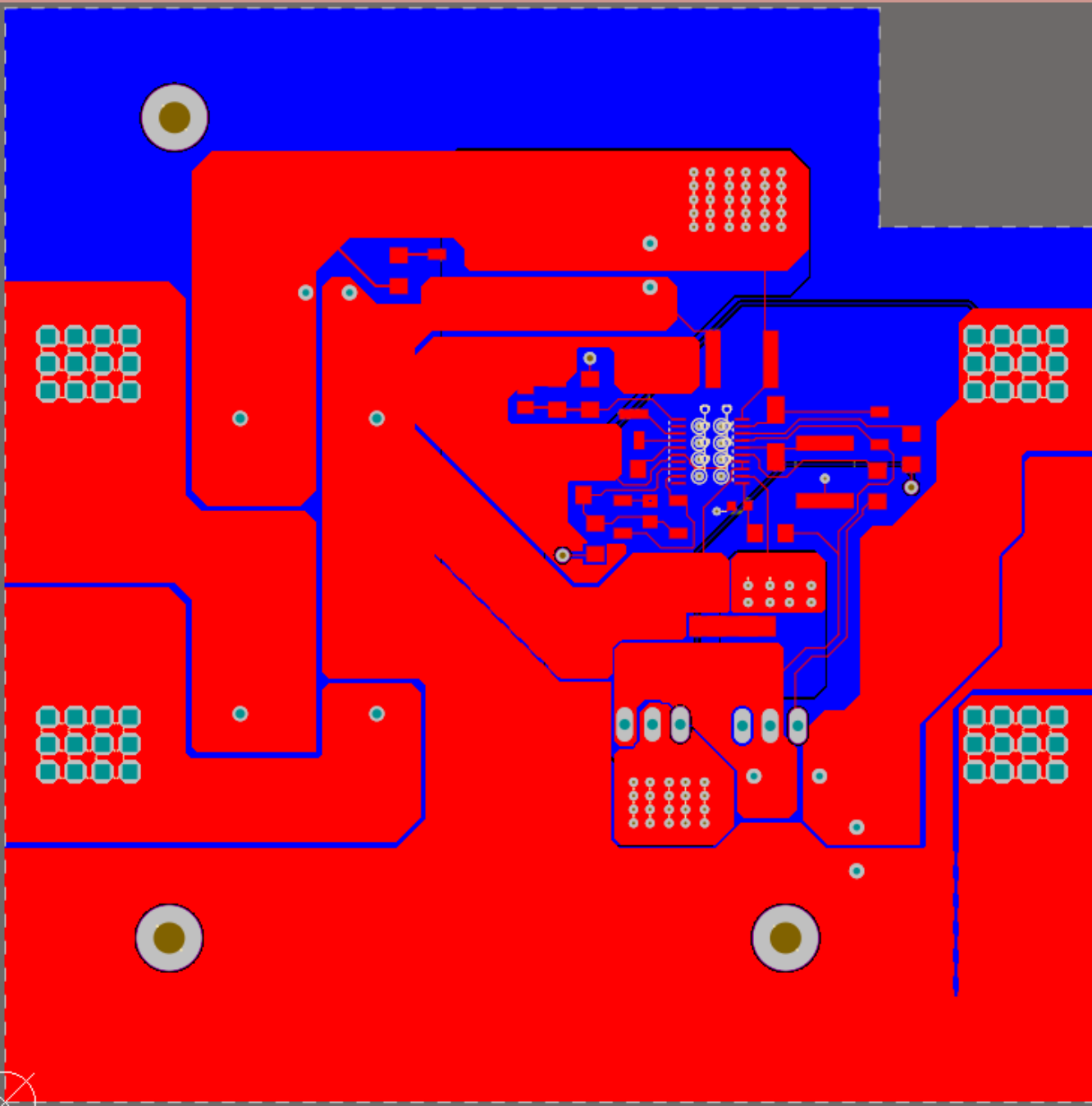
- 150n
- 33n
- 100n
- 100n
- 22 μ F
- 100 μ F

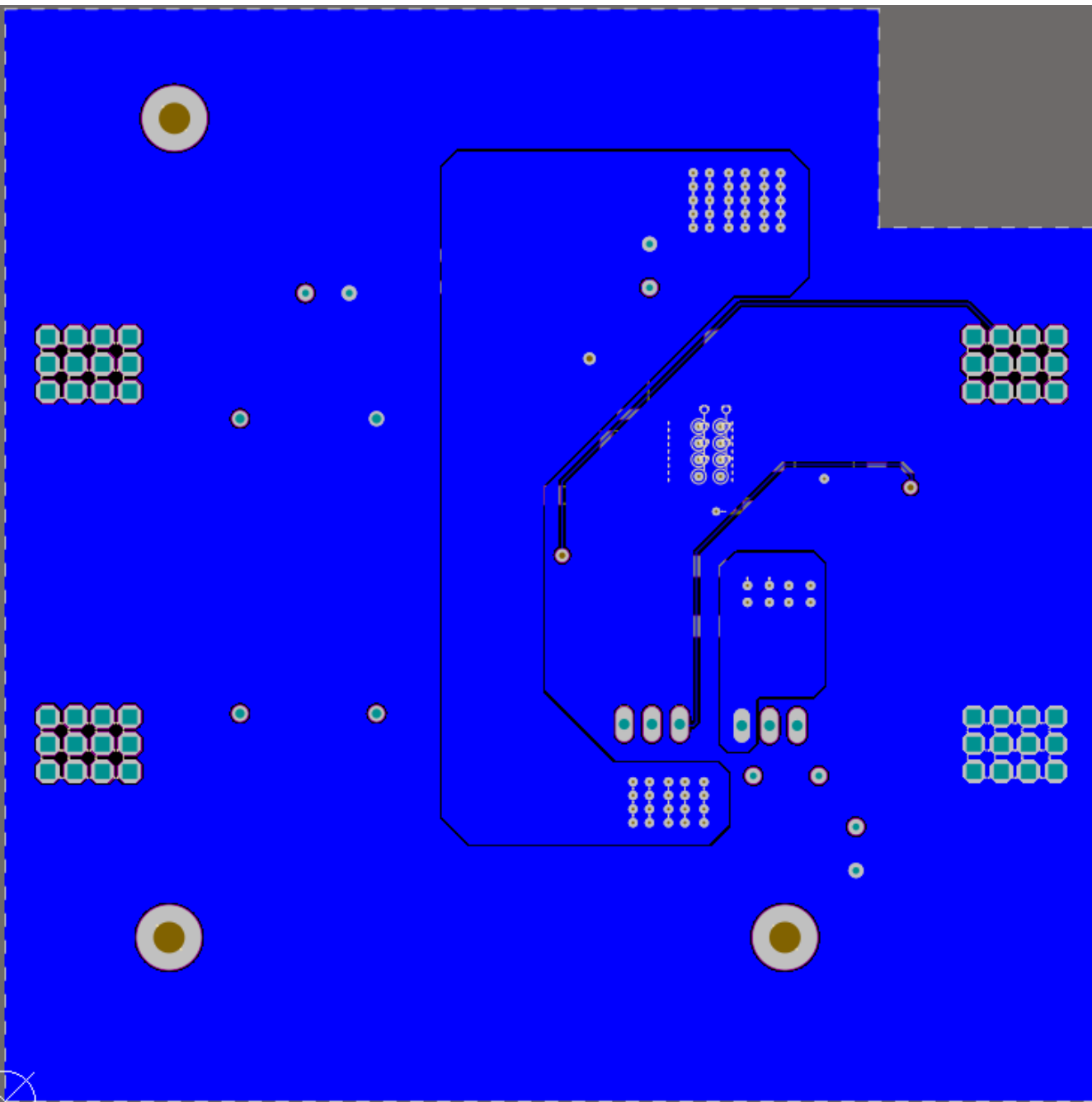
POTREBNE IZBOLJŠAVE



- Pri povezavah z visokimi tokovi se poskušamo izogibati uporabi skožnikov.
- Kritični zanki morata biti čim manjši.
- Upornost povezave z R_s mora biti čim manjša.
- Boljšo razporeditev elementov pri obeh filtrih.
- Večja kapacitivnost na izhodu.

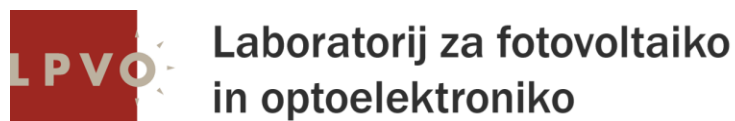






Načrtovanje elektronike za **EMC**²

S04 in S05 Jan Žagar



Izračuni

UVLO – Undervoltage Lockout

$$R_1 = 100k\Omega$$

$$U_{ENoutUVLO} = 1.25V$$

$$V_{in(max)} = 60V$$

$$V_{in(min)} = 36V$$

$$V_{in(off)} = 35V$$

$$\frac{R_2}{R_1} = \frac{U_{ENoutUVLO}}{V_{in(off)} - U_{ENoutUVLO}} \rightarrow R_2 = \frac{U_{ENoutUVLO}}{V_{in(off)} - U_{ENoutUVLO}} \cdot R_1$$

$$R_2 = 3,7k\Omega \approx 3,74k\Omega$$

Nad 0,4V in pod 1,25V bodo tranzistorji onemogočeni (standby mode).

Pod 0,4V je LM5117 v shutdown mode

Izračuni

Frekvenca delovanja notranjega oscilatorja

$$R_T = \frac{5,2 \cdot 10^9}{f_{SW}} - 948$$

$$f_{SW} = \frac{5,2 \cdot 10^9}{R_T} - 948$$

$$R_T = 10k\Omega$$

$$f_{SW} = \frac{5,2 \cdot 10^9}{10k\Omega} - 948 \cong 520kHz$$

Izračun močnostne tuljave

Izračuni

$$L_O = \frac{V_{out}}{I_{PP}(max) \cdot f_{SW}} \cdot \left(1 - \frac{V_{out}}{V_{in}}\right)$$

- valovitost toka (ripple current) sem si izbral, da bo 35% od nazivnega izhodnega tok ($I_{max} = 7A$).

$$I_{PP}(max) = 0.35 \cdot 7A = 2.45A$$

$$L_O|_{V_{in}=60V} = \frac{14V}{2.45A \cdot 520kHz} \cdot \left(1 - \frac{14V}{60V}\right) = 8,4\mu H \approx 8,2\mu H$$

ponovni izračun $I_{PP}(max)$ toka pri tuljavi z $8,2\mu H$

$$I_{pp(max)} = \frac{14V}{8,2\mu H \cdot 520kHz} \cdot \left(1 - \frac{14V}{60V}\right) = 2.5A$$

$$I_{pp(min)} = \frac{14V}{8,2\mu H \cdot 520kHz} \cdot \left(1 - \frac{14V}{36V}\right) = 2A$$

$$L_O|_{V_{in}=48V} = \frac{14V}{2.45A \cdot 520kHz} \cdot \left(1 - \frac{14V}{48V}\right) = 7,78\mu H$$

Izračuni

Izračun shunt upora – R_S

- Maksimalna zmožnost izhodni tok ($I_{OUT(max)}$) naj bo 20%-50% večji od nazivnega izhodnega toka v našem je ta tok 7A.
- Za moj primer sem si izbral 30% višji tok od 7A

$$I_{OUT(max)} = 1,3 \cdot 7A = 9,1A$$

$$V_{CS(TH)} = 120mV$$

$$K = 1$$

$$R_S = \frac{V_{CS(TH)}}{I_{OUT(max)} + \frac{V_{OUT} \cdot K}{f_{SW} \cdot L_O} - \frac{I_{pp(min)}}{2}} = \frac{0.12V}{9,1 + \frac{14V \cdot 1}{520kHz \cdot 8,2\mu H} - \frac{2}{2}}$$

$$= 10.5m\Omega \approx 10m\Omega$$

Izračuni

Trošenje moči na R_S upor

- $$P_{R_S} = \left(1 - \frac{V_{OUT}}{V_{in(max)}}\right) \cdot I_{out}^2 \cdot R_S = \left(1 - \frac{14V}{60V}\right) \cdot 7A^2 \cdot 10m\Omega = 0.375W$$

Izračuni

Izračun med izhodnim kratkim stikom je tok tuljave omejen:

$$t_{ON(min)} = 100ns - \text{minimum high side MOS ON time}$$

$$V_{CS(TH)} = 120mV$$

$$I_{lim_pk} = \frac{V_{CS(TH)}}{R_S} + \frac{V_{in(max)} \cdot t_{ON(min)}}{L_O} = \frac{0.12V}{10m\Omega} + \frac{60V \cdot 100ns}{8,2\mu H} = 12,7A$$

Izračuni

Izhodni napetostni delilnik R_{FB1} in R_{FB2}

$$V_{OUT} = 14V$$

$$R_{FB1} = 1k\Omega$$

$$\frac{R_{FB2}}{R_{FB1}} = \frac{V_{OUT}}{0,8V} - 1$$

$$\frac{R_{FB2}}{R_{FB1}} = 16,5$$

$$R_{FB2} = 16,5k\Omega$$

Izbor elementov za 2. vezje

- *Texas Instruments webench*
- Razlike:
 - Močnostna tuljava je sedaj $15\mu H$
 - Upor $R_{ramp} = 150k\Omega$ zato, da je $K = 1$
 - Kondenzator $C_{ramp} = 1nF$
 - Upor $R_{comp} = 30k\Omega$
 - Kondenzator $C_{comp} = 3,3nF$
 - Kondenzator $C_{HF} = 68pF$

Izbira tranzistorja

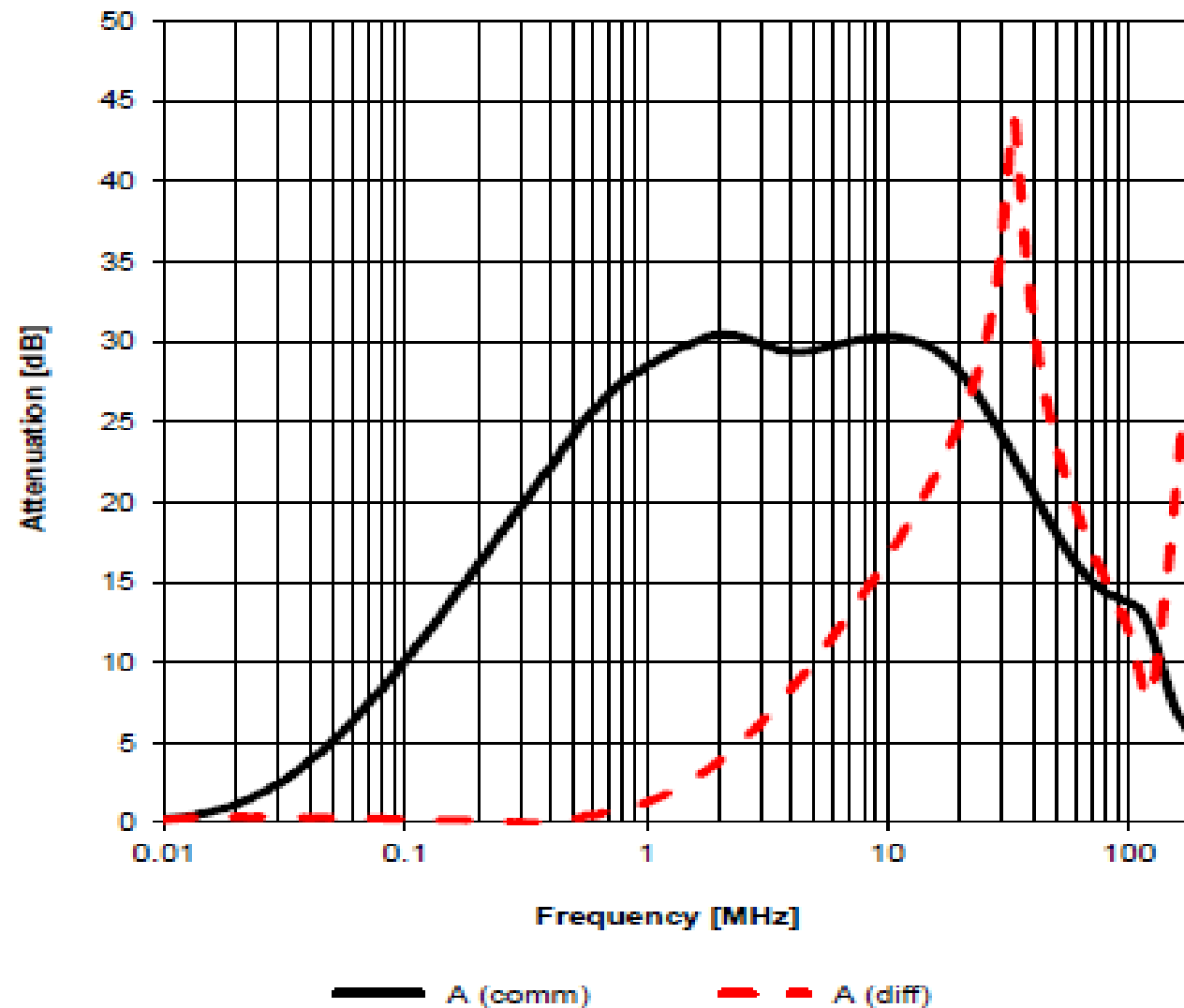
IRFB4610

Cenovno ugoden 0,95€/kos

- Aplikacije:
 - Za visoko učinkovite stikalne napajalnike
 - Za visokofrekvenčna vezja
- Tip paketa
 - TO-220
- Podatki
 - $Max V_{DS} = 100V$
 - $Max I_D = 73A$

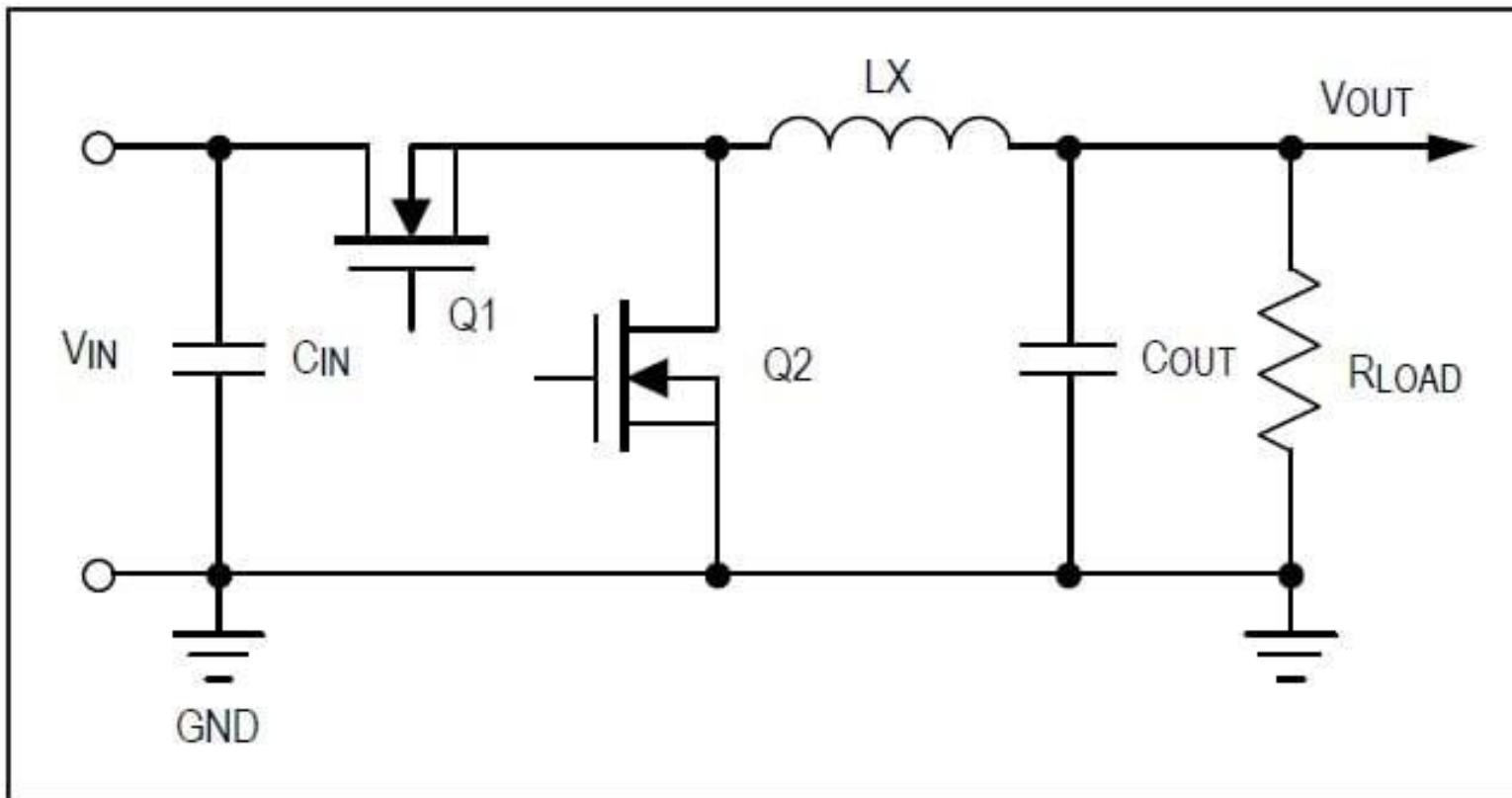


Izbor sofazne dušilke



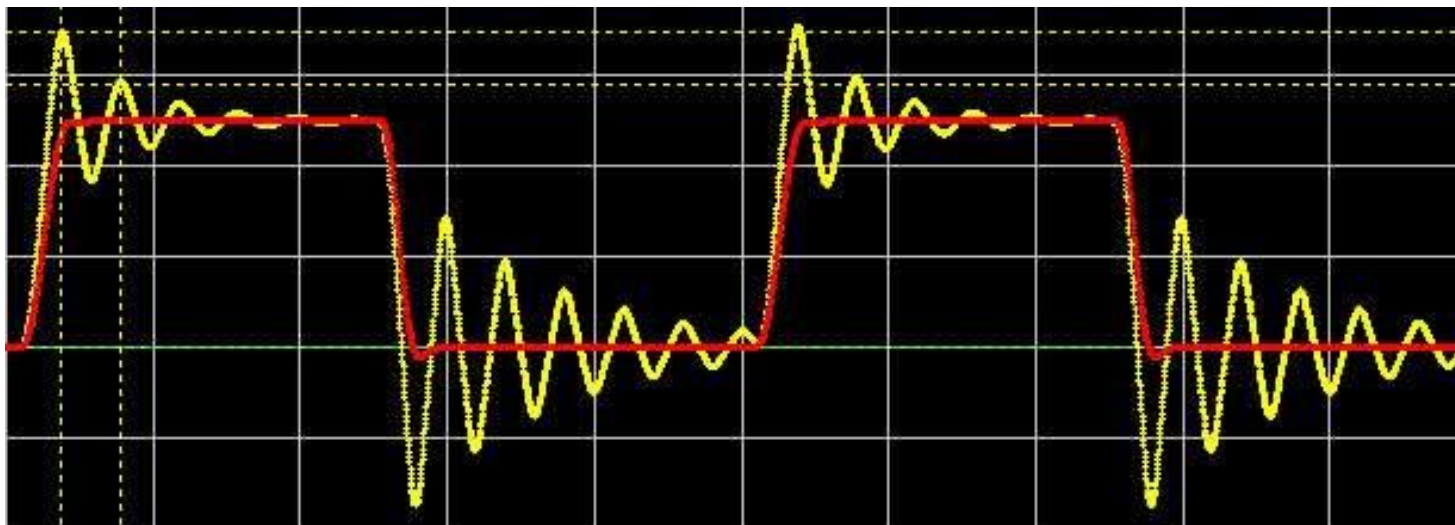
Postavitev elementov - zanki

- 2 zanki \rightarrow velik $\frac{di}{dt}$



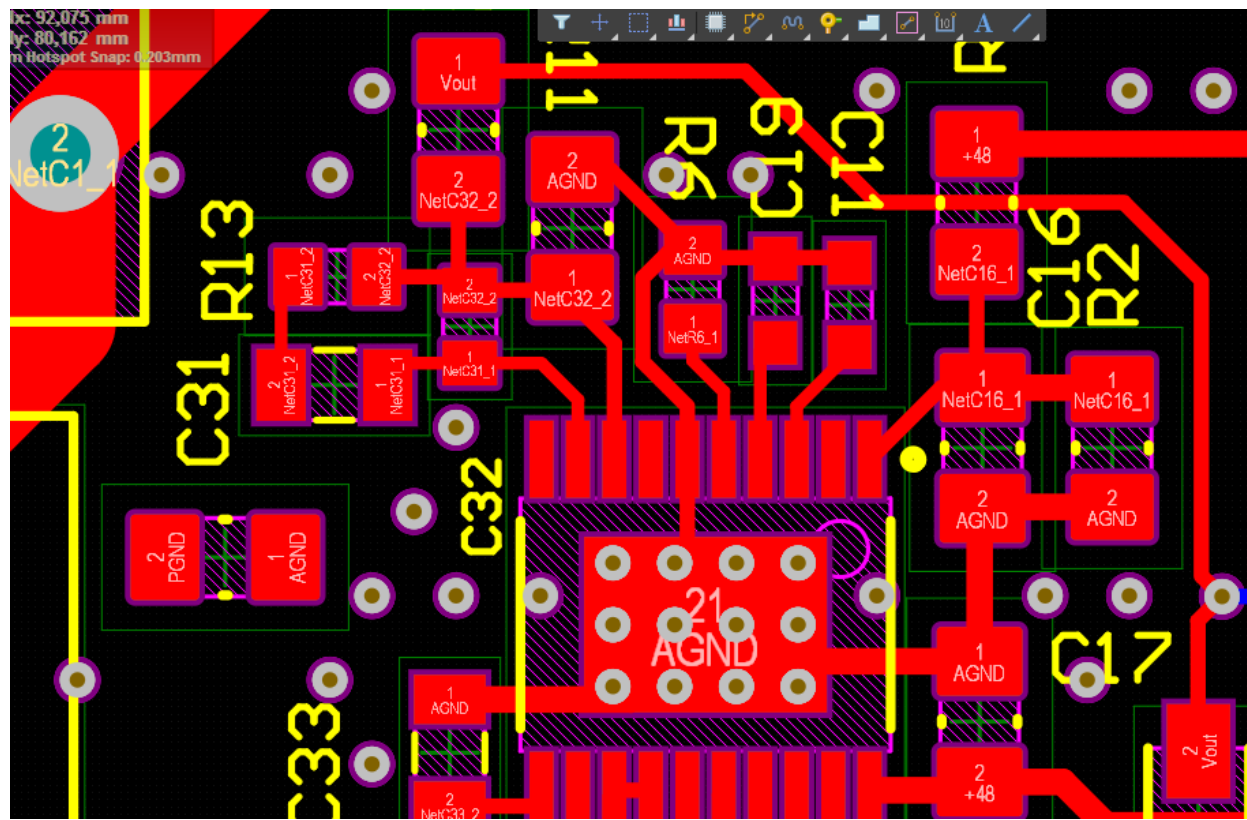
Postavitev elementov - RC snubber filter

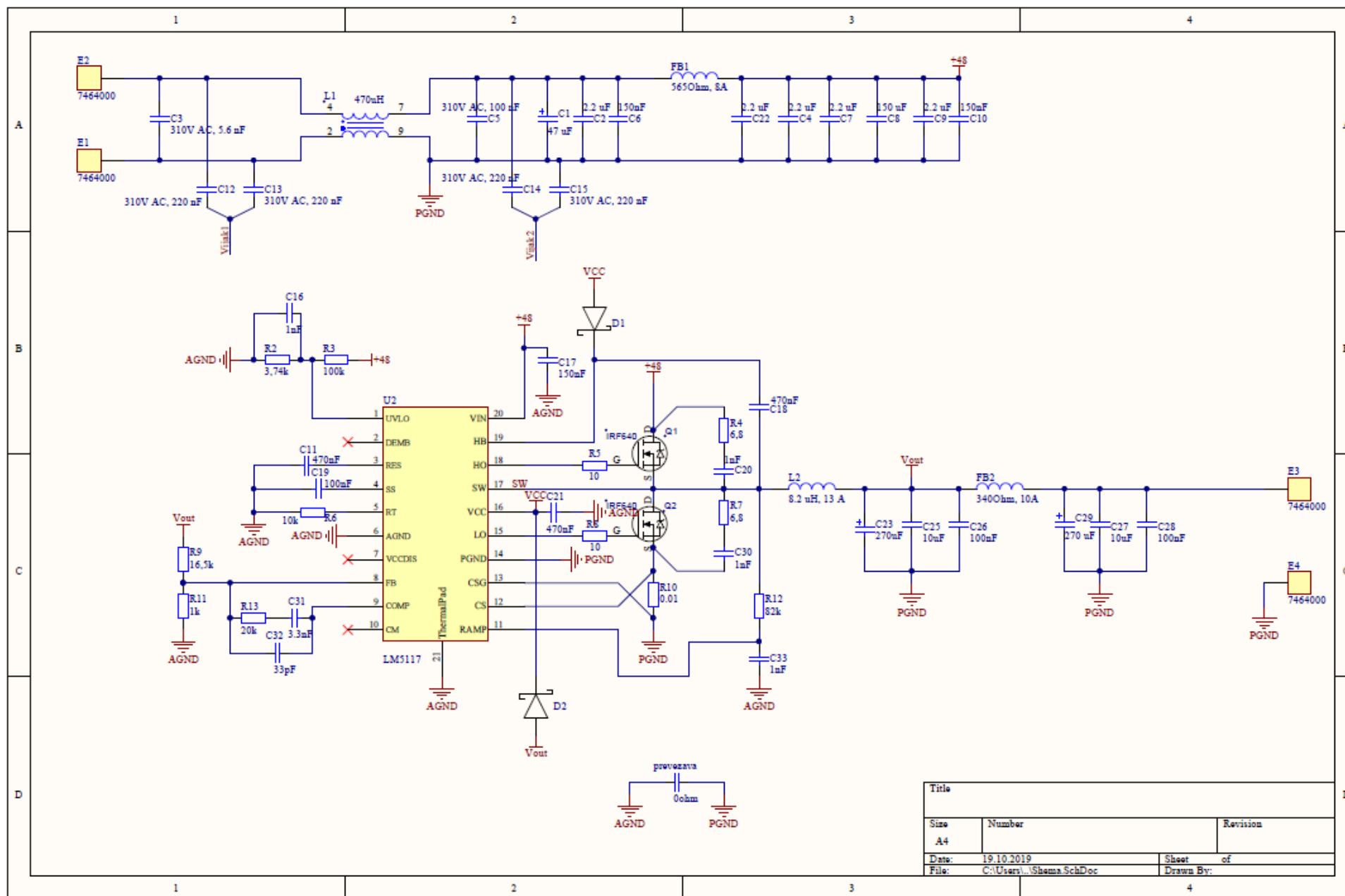
- $C_{snubber} = 1nF$
- $R_{snubber} = 6.8\Omega$

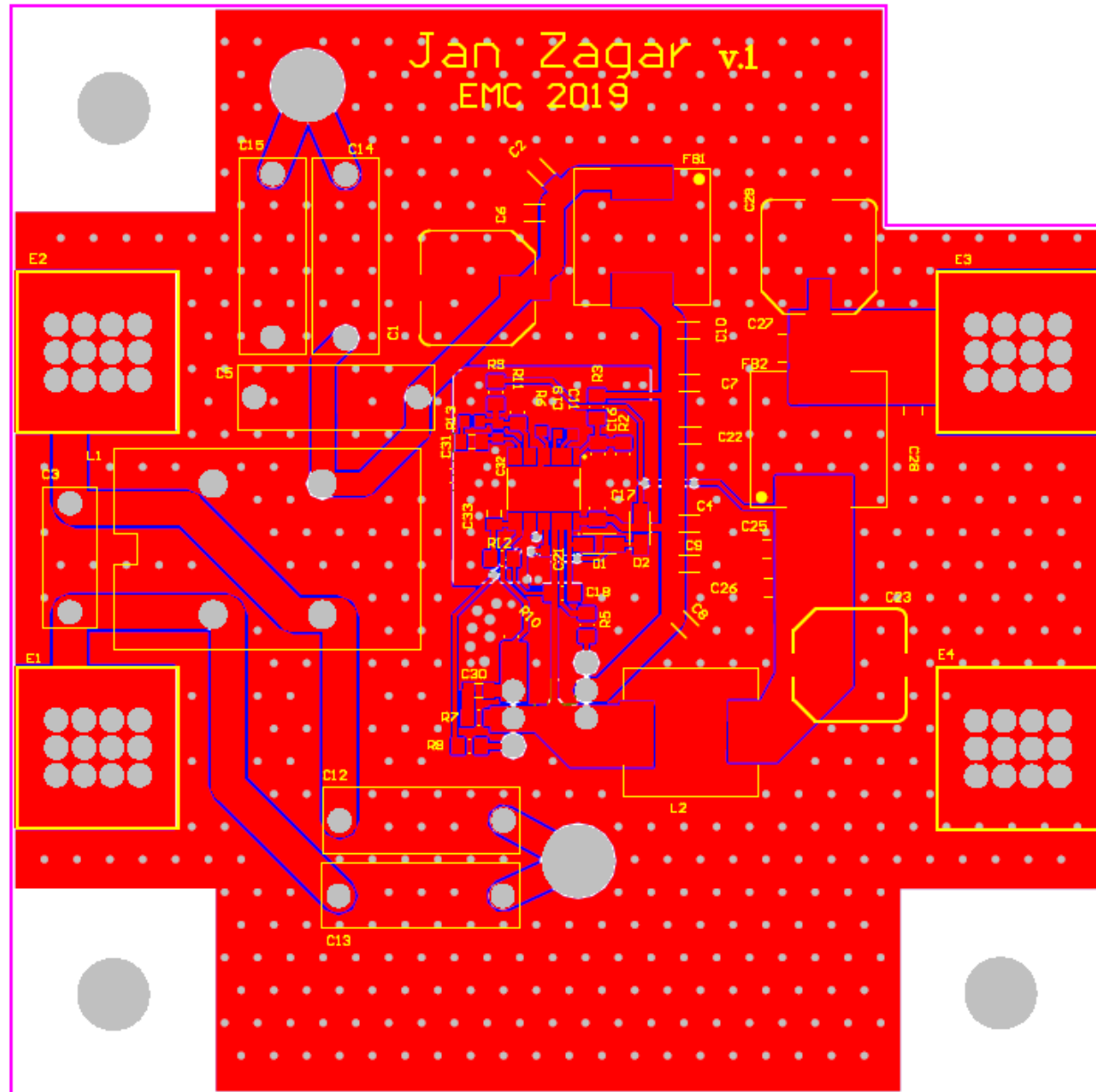


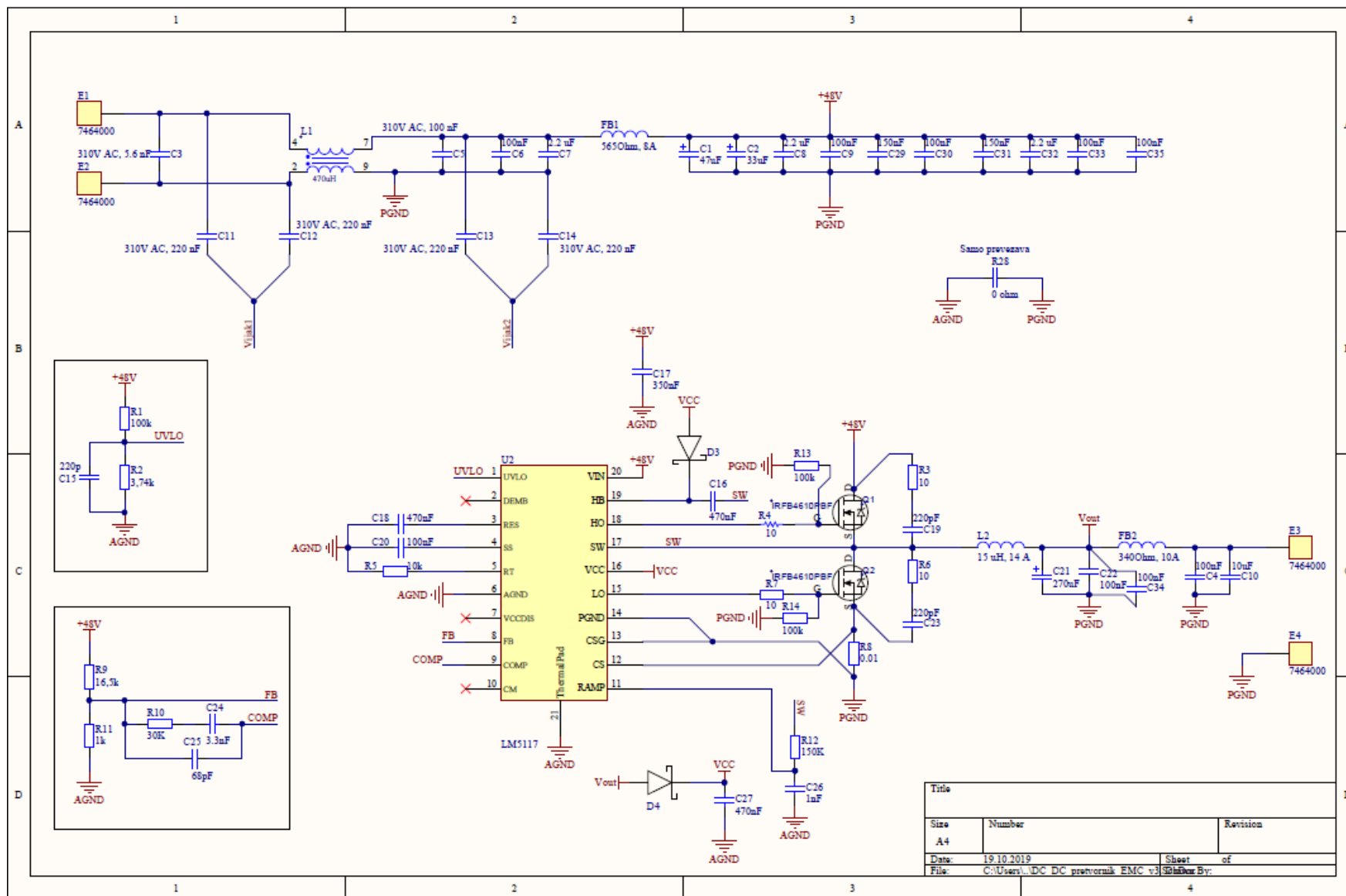
Postavitev elementov

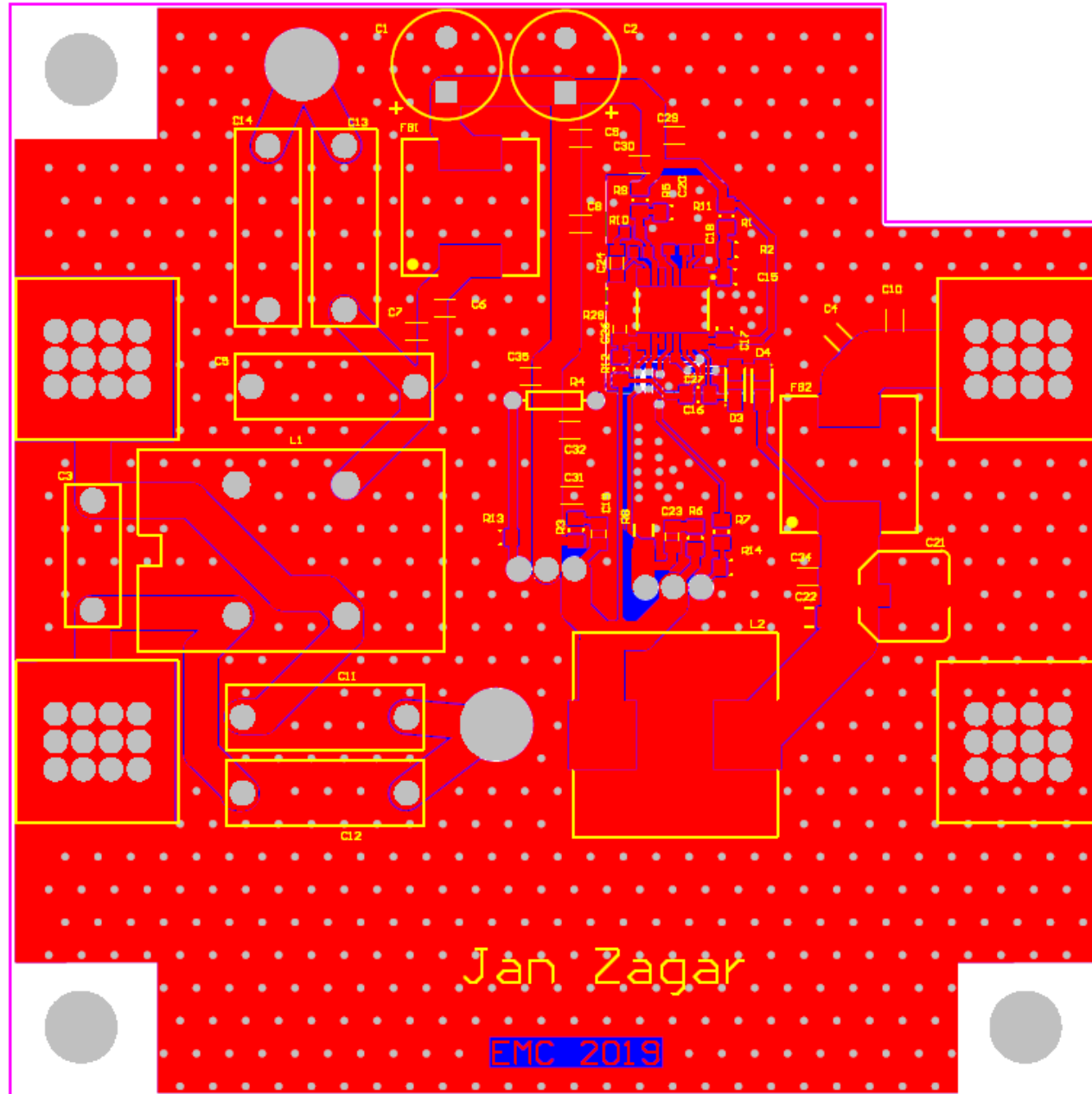
- Blokirni kondenzator C_{VCC}
- R_{UV} , R_T , R_{FB} , C_{SS} , C_{res} , C_{ramp} , ...
- Termične via za odvajanje toplote











Načrtovanje elektronike za **EMC**²

S06 Matjaž Janežič

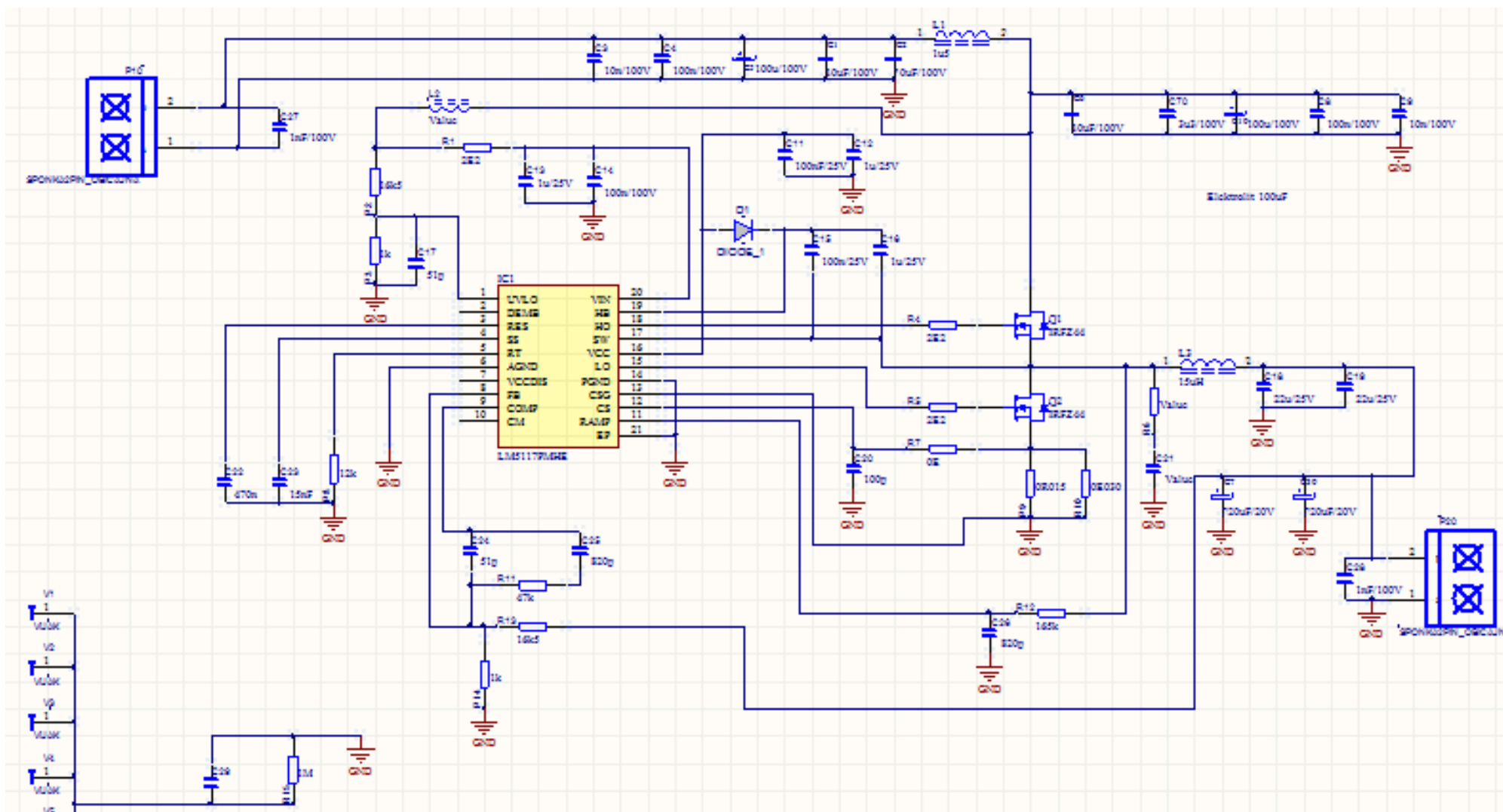


Načrtovanje

- Uporaben napajalnik za solarne sisteme iz 10S LiPO na nižjo napetost
- Malo večji tok (10 A)
- Izkoristek tudi vsaj 90 %
- Kasneje popravek za UVLO na 30..32 V
- EMC seveda, blizu je RF oprema!

- Preizkus layouta (brez zank!)

Shema

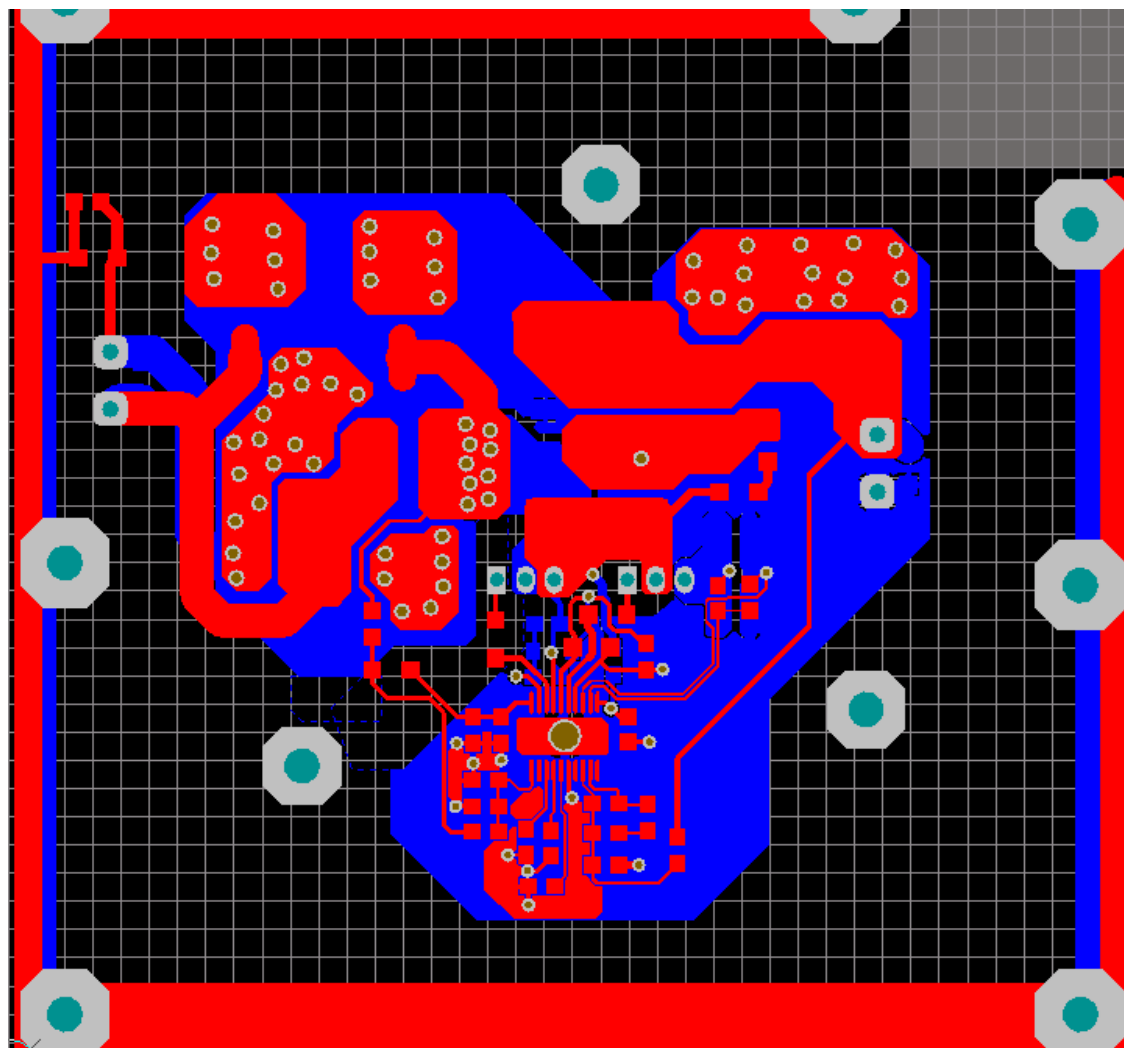


Komponente

- Varnostni faktor vsaj 1.5
- Webench, Spreadsheet
- Izkaže se, da je za dinamične izgube Q_g prva prioriteta
- R_{dson} ni tako kritičen

- Tok I_d vsaj za faktor 2 večji
- Klasično ohišje (SMD ni zaželen)
- Kondenzatorji!!! Problem, ker je zahtevana napetost 60 V -> komponente 100 V na vhodu, 25 V na izhodu
- Elektrolitski imajo majhen I_{ripple} !

Layout



Meritve

- prenehaj na stikalni točki 54 MHz
- Snubber 2,2 Ohm ter 4,7 nF

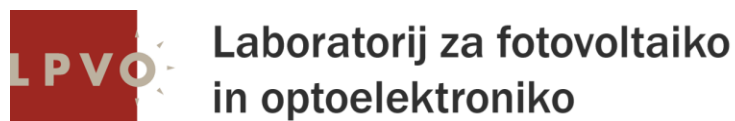
- Izkoristek okoli 91 % pri Iload 7 A

- Gretje IC-ja, potrebno bi bilo urediti njegovo napajanje
- Na izhodu vsaj še enkrat več keramike (Kompromis v designu, saj je cena visoka!)

- Hladilnik je lahko precej manjši

Načrtovanje elektronike za **EMC**²

S07 Jan Cvijanovič Hudoklin



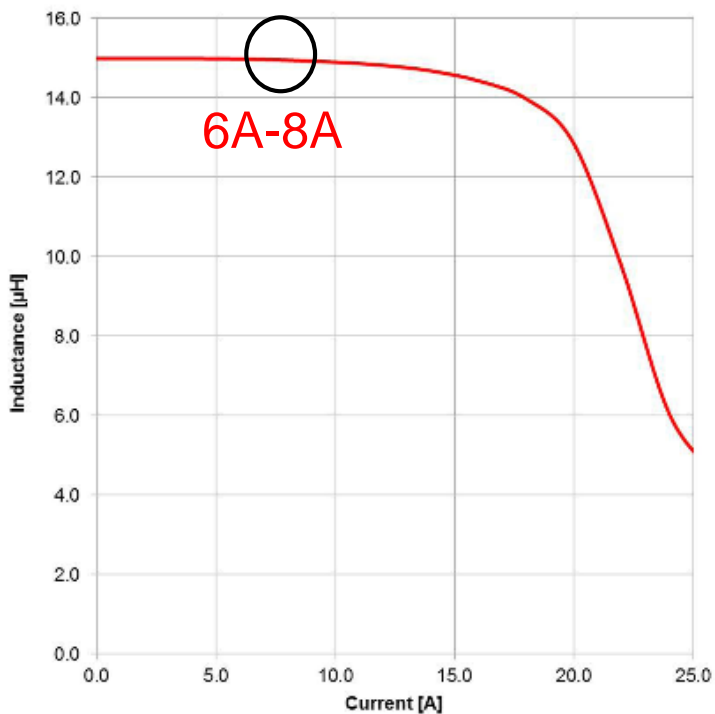
Izbira komponent

Ključne komponente

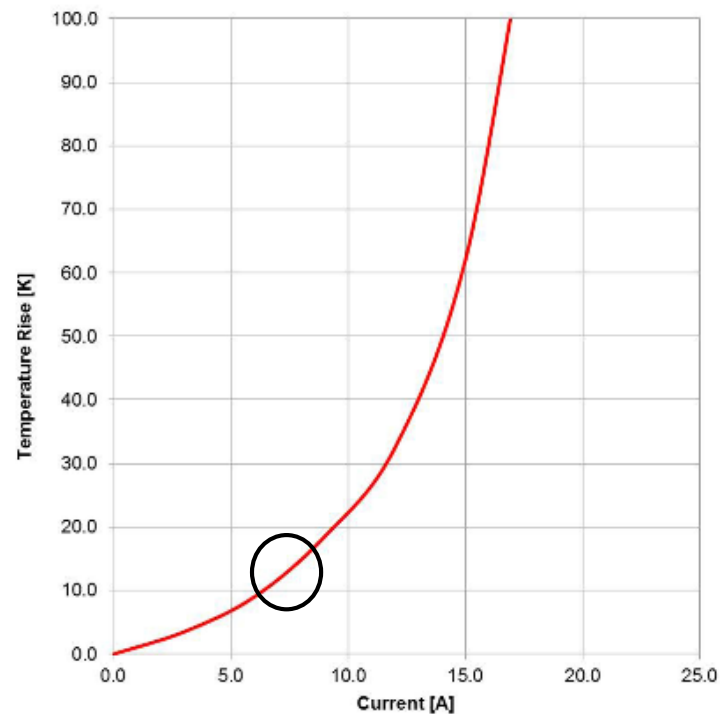
- Dušilka
- Tranzistorja
- Kondenzatorji (vrednosti, tipi)
- FB upori (tolerančni razred)
- Elementi filtra

Dušilka in Tranzistorja

F1 Typical Inductance vs. Current Characteristics:



F2 Typical Temperature Rise vs. Current Characteristics:



Properties	Test conditions		Value	Unit	Tol.
Inductance	100 kHz/ 10 mA	L	15	µH	± 15%
Rated current	$\Delta T = 50 \text{ K}$	I_R	14.0	A	max.
Saturation current	$ dL/dI < 30\%$	I_{sat}	21.0	A	typ.
DC Resistance	@ 20°C	R_{DC}	8.70	mΩ	±10%
Self resonant frequency		f_{res}	12.8	MHz	typ.



OptiMOS™ 5 Power-Transistor, 80 V

BSZ110N08NS5

1 Description

Features

- Ideal for high frequency switching and sync. rec.
- Optimized technology for DC/DC converters
- Excellent gate charge x $R_{DS(on)}$ product (FOM)
- Very low on-resistance $R_{DS(on)}$
- N-channel, normal level
- 100% avalanche tested
- Pb-free plating; RoHS compliant
- Qualified according to JEDEC¹⁾ for target applications
- Halogen-free according to IEC61249-2-21
- Higher solder joint reliability with enlarged source interconnection

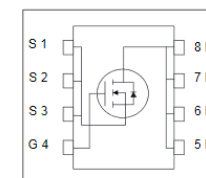
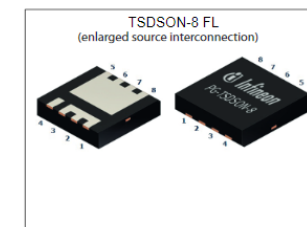


Table 1 Key Performance Parameters

Parameter	Value	Unit
V_{DS}	80	V
$R_{DS(on),max}$	11.0	mΩ
I_b	40	A
Q_{oss}	19	nC
$Q_g(0V..10V)$	15	nC



Vhodni in izhodni kondenzatorji

- MLCC kondenzatorji

$$C_{out} = \frac{D \times (1 - D) \times I_{out}}{V_{in_{rip}} \times f_{sw}} = \frac{0.4 \times (1 - 0.4) \times 7A}{200mV \times 400kHz} = 21\mu F$$

$$C_{out} = \frac{D \times (1 - D) \times \Delta I_{L_{pp}}}{V_{out_{rip}} \times f_{sw}} = \frac{0.23 \times (1 - 0.23) \times 2A}{20mV \times 400kHz} = 45\mu F$$

- AL polymer kondenzatorji

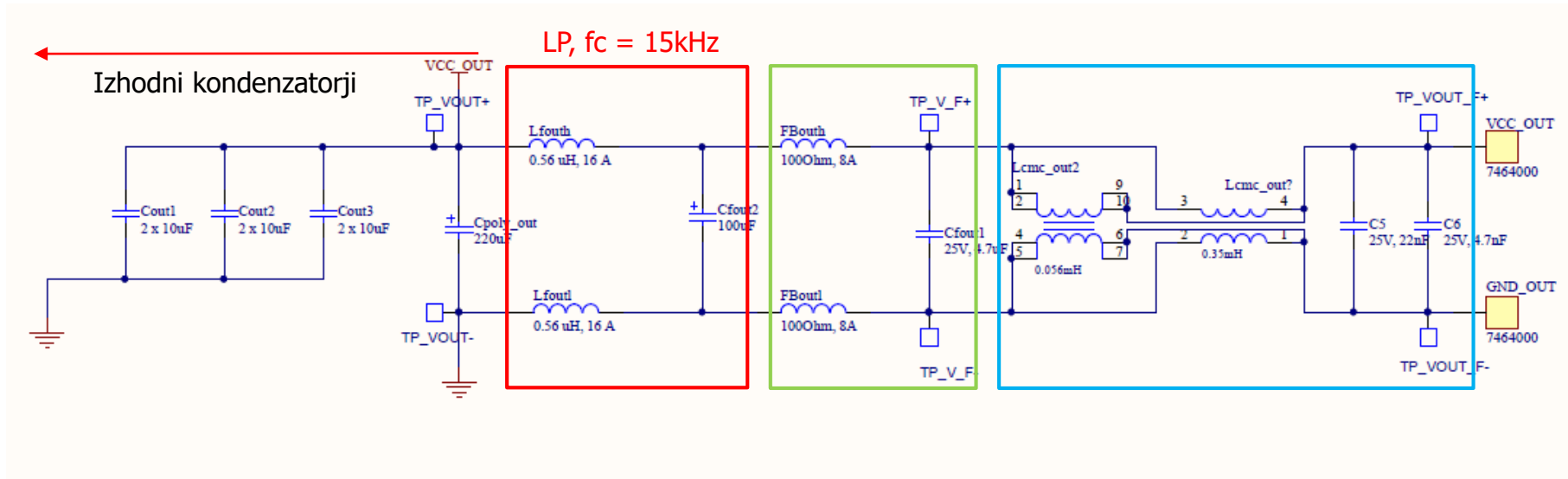
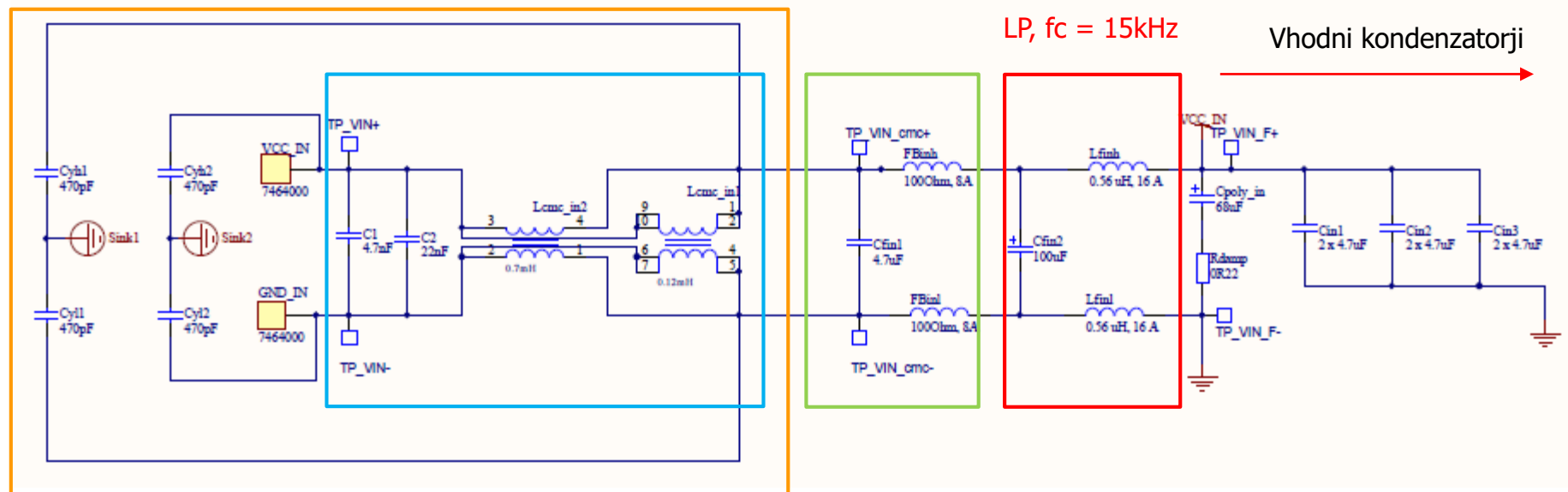
$$C_B \geq \frac{\frac{1}{2} \times I_{Step} \times D_{max} \times T_{R_PS}}{V_{IN_Tran}} - C_{CE_Total} \times (1 - Tol.)$$

D1 Electrical Properties:

Properties	Test conditions		Value	Unit	Tol.
Capacitance	0.25V; 120Hz	C	220	μF	± 20%
Rated voltage		U _R	25	V (DC)	max.
Leakage current	after 2 min.	I _{Leak}	1100	μA	max.
Dissipation factor	120 Hz	DF	10	%	typ.
ESR	100 kHz	R _{ESR}	15	mΩ	max.
Ripple current	100kHz @105°C	I _{ripple}	4800	mA	max.

Specifications	
Capacitance:	68 μF
Capacitance Tolerance:	20%
Voltage DC:	63 VDC, 72 VDC (Surge)
Temperature Range:	-55/+105C
Rated Temperature:	105C
Life:	2000 Hrs
Resistance:	30 mOhms (100kHz 20C)
Ripple Current:	2450 mAmps (100kHz 105C)
Leakage Current:	856 uA (2min 20C)
Impedance Ratio at -25C:	1.25
Impedance Ratio at -55C:	1.25
High Temperature Solder:	No

Načrtovanje filtrov



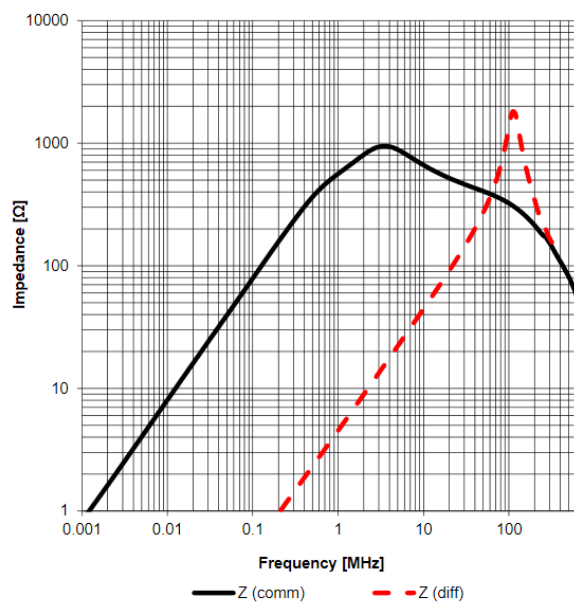
Sofazna dušilka in ferrite bead

Vhodna sofazna dušilka

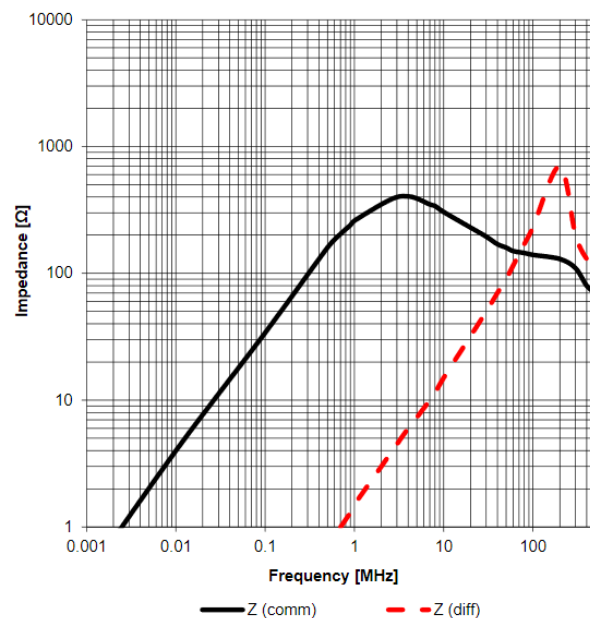
Izhodna sofazna dušilka

Ferrite beads

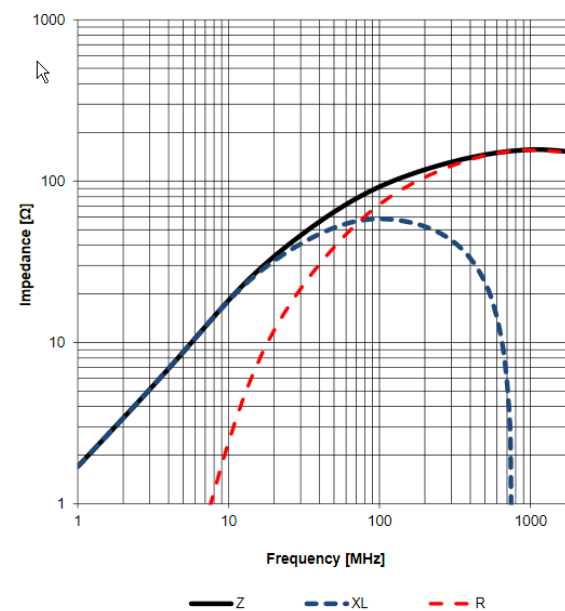
Typical Impedance Characteristics



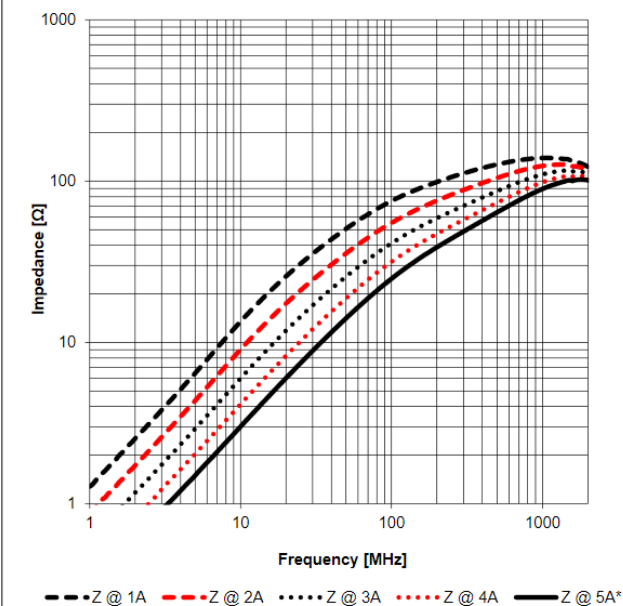
Typical Impedance Characteristics:



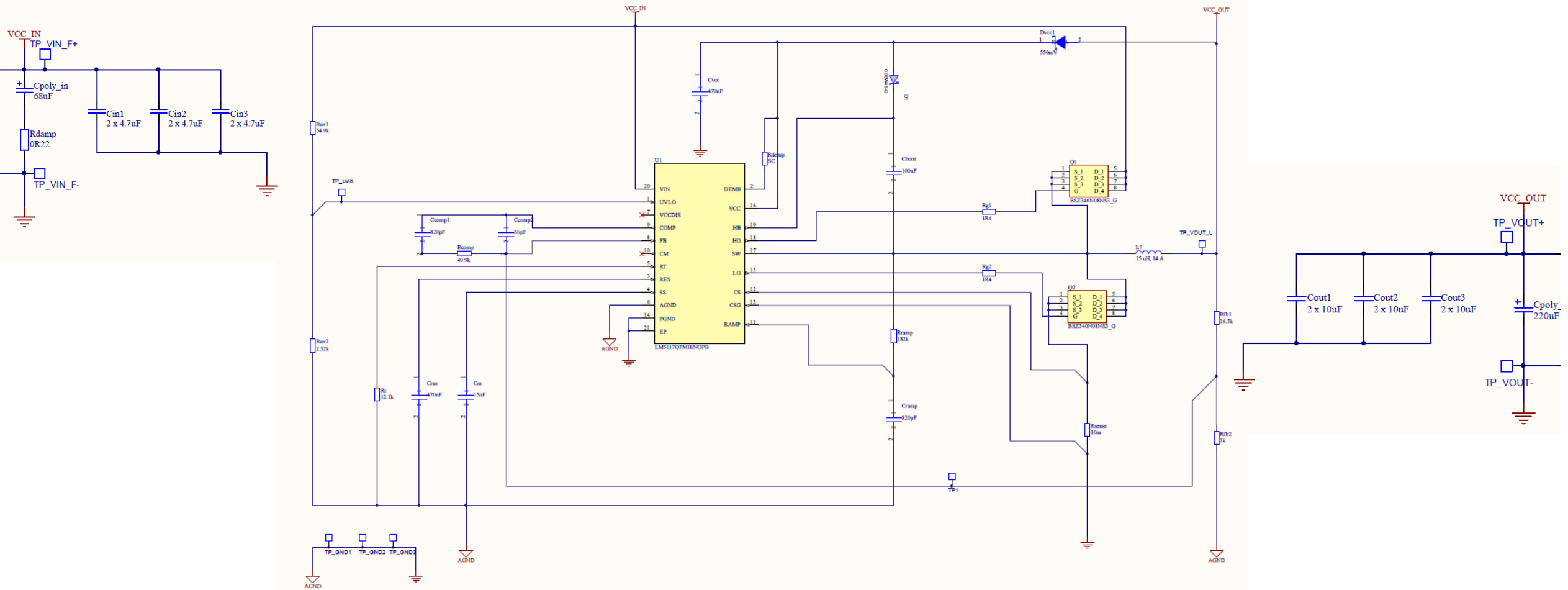
Typical Impedance Characteristics:



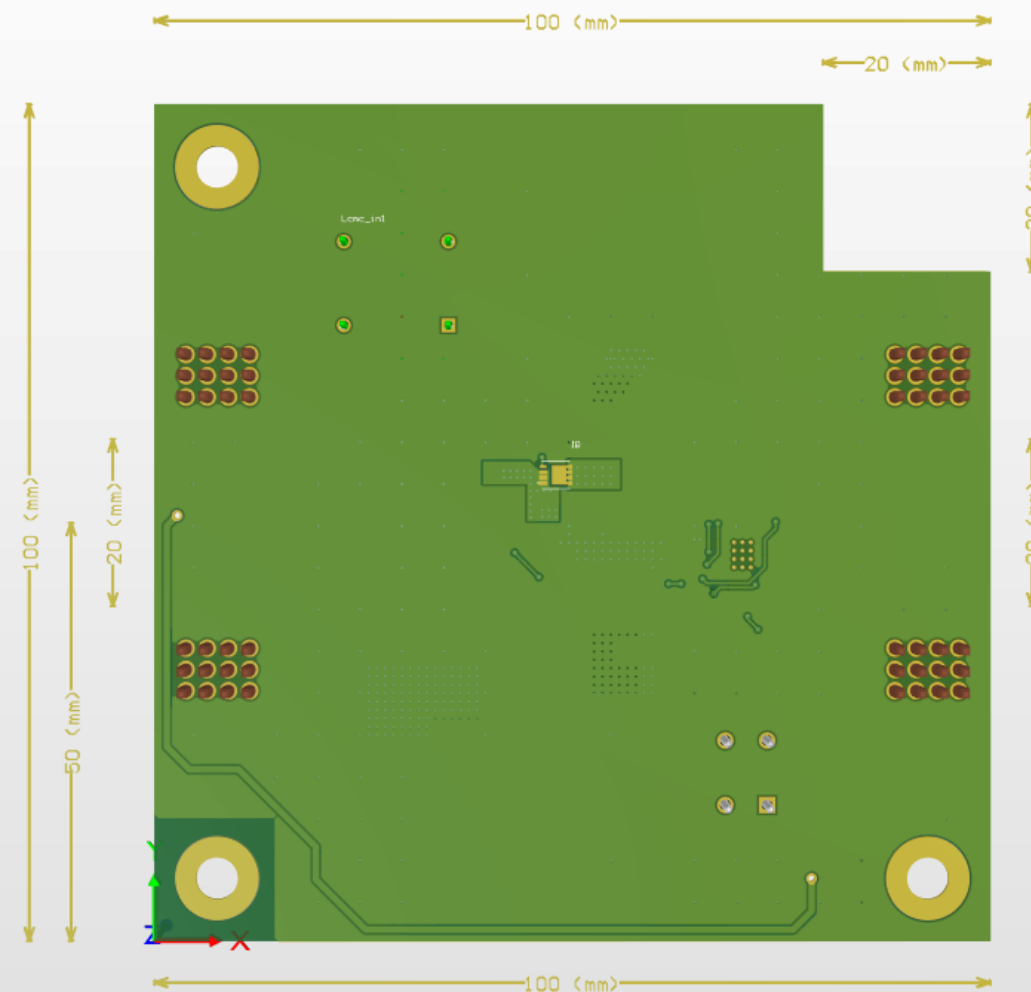
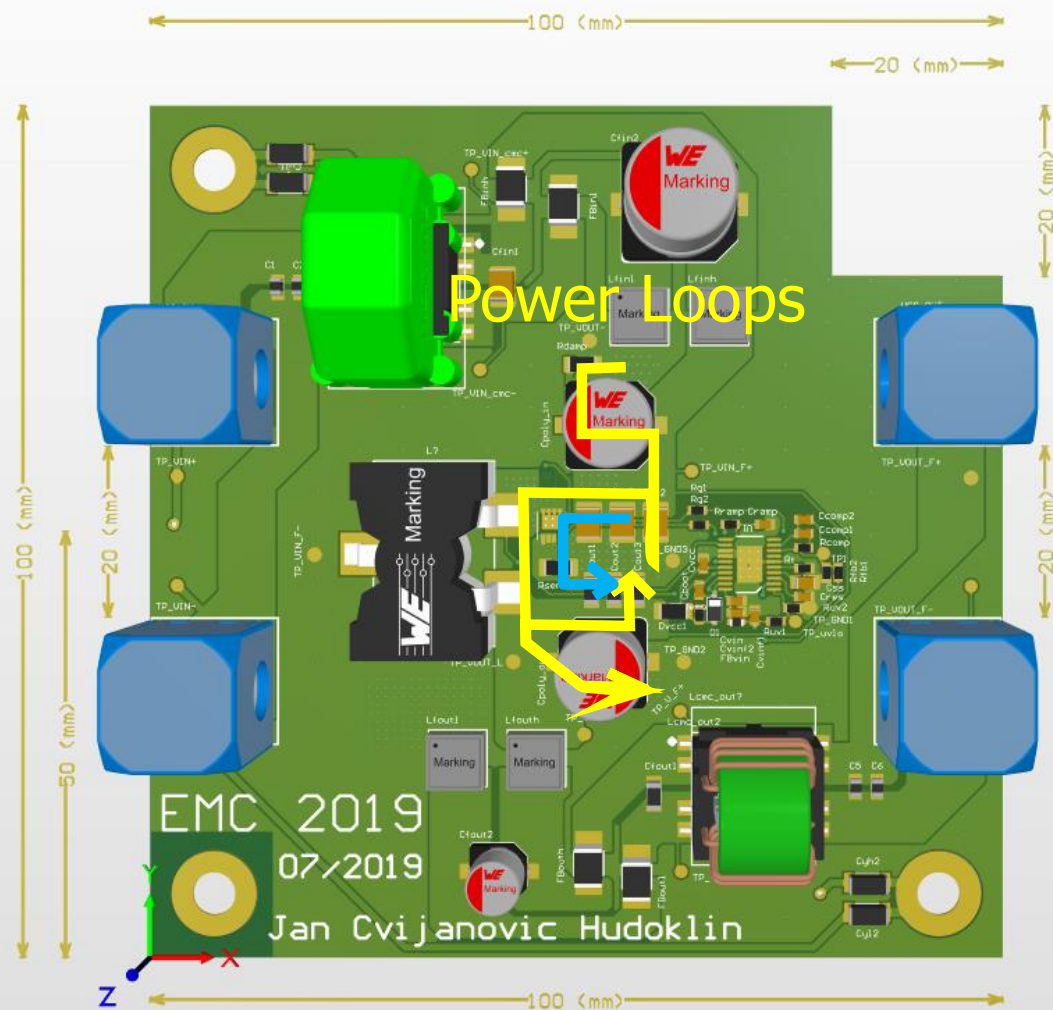
DC bias current:



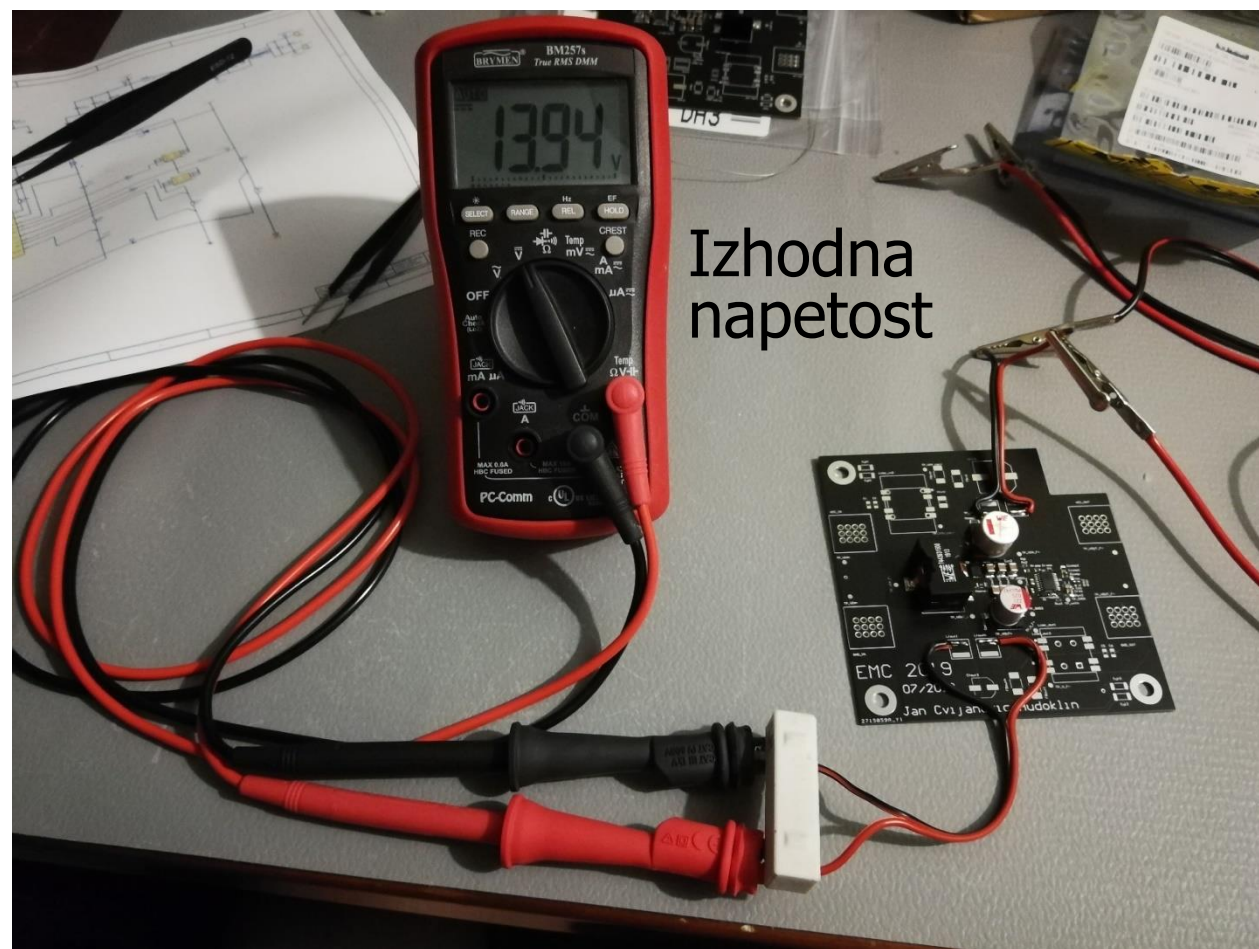
Shema

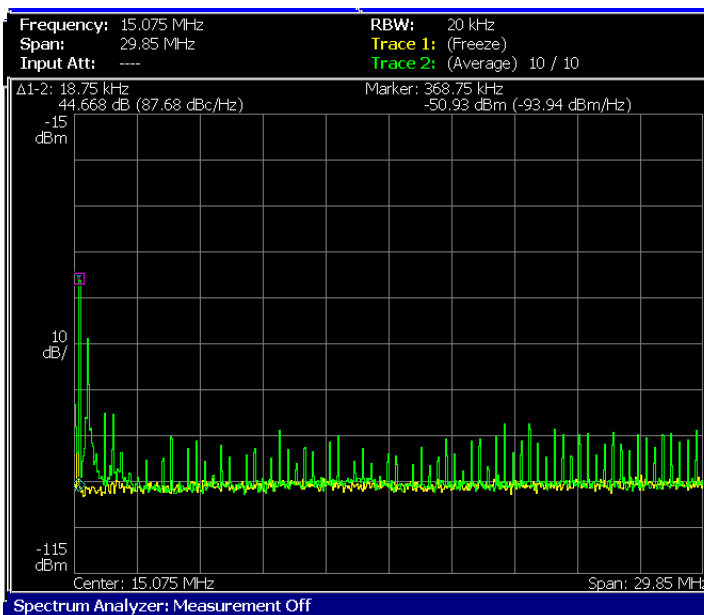


PCB Layout



Testiranje





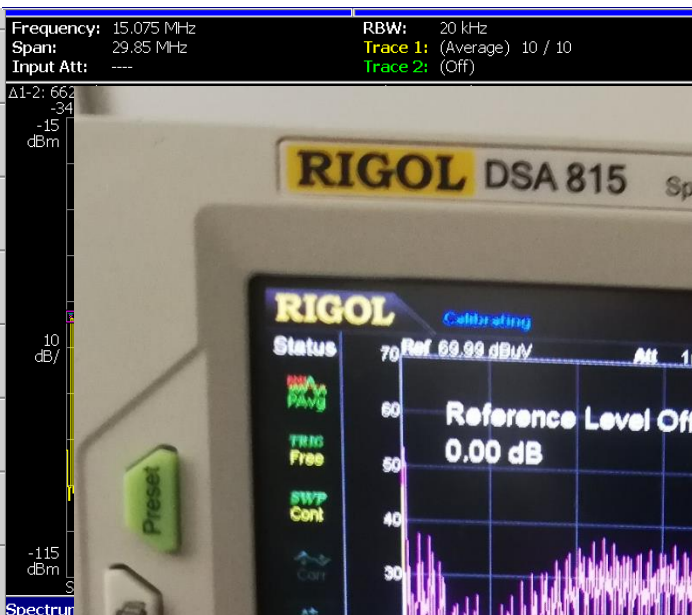
Cancel - Back

Save State

Save Trace 1

Save Trace 2

Save Correction



Cancel - Back

Save State



Cancel - Back

Save State



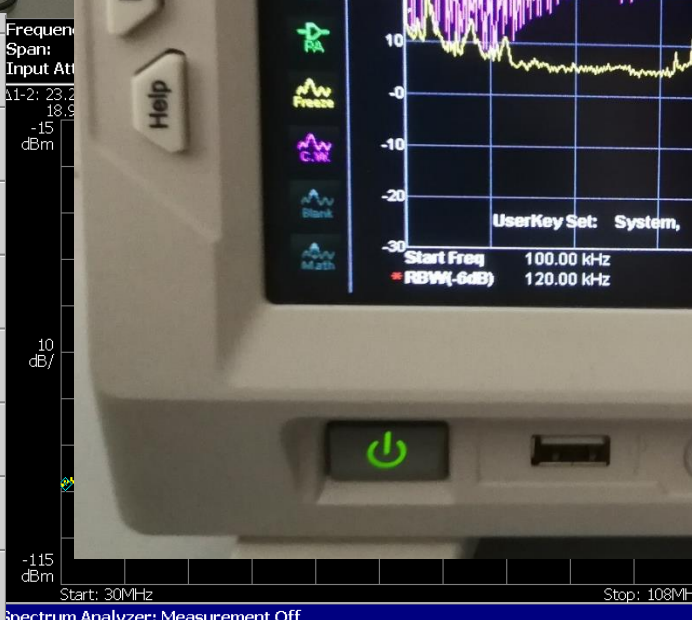
Cancel - Back

Save State

Save Trace 1

Save Trace 2

Save Correction



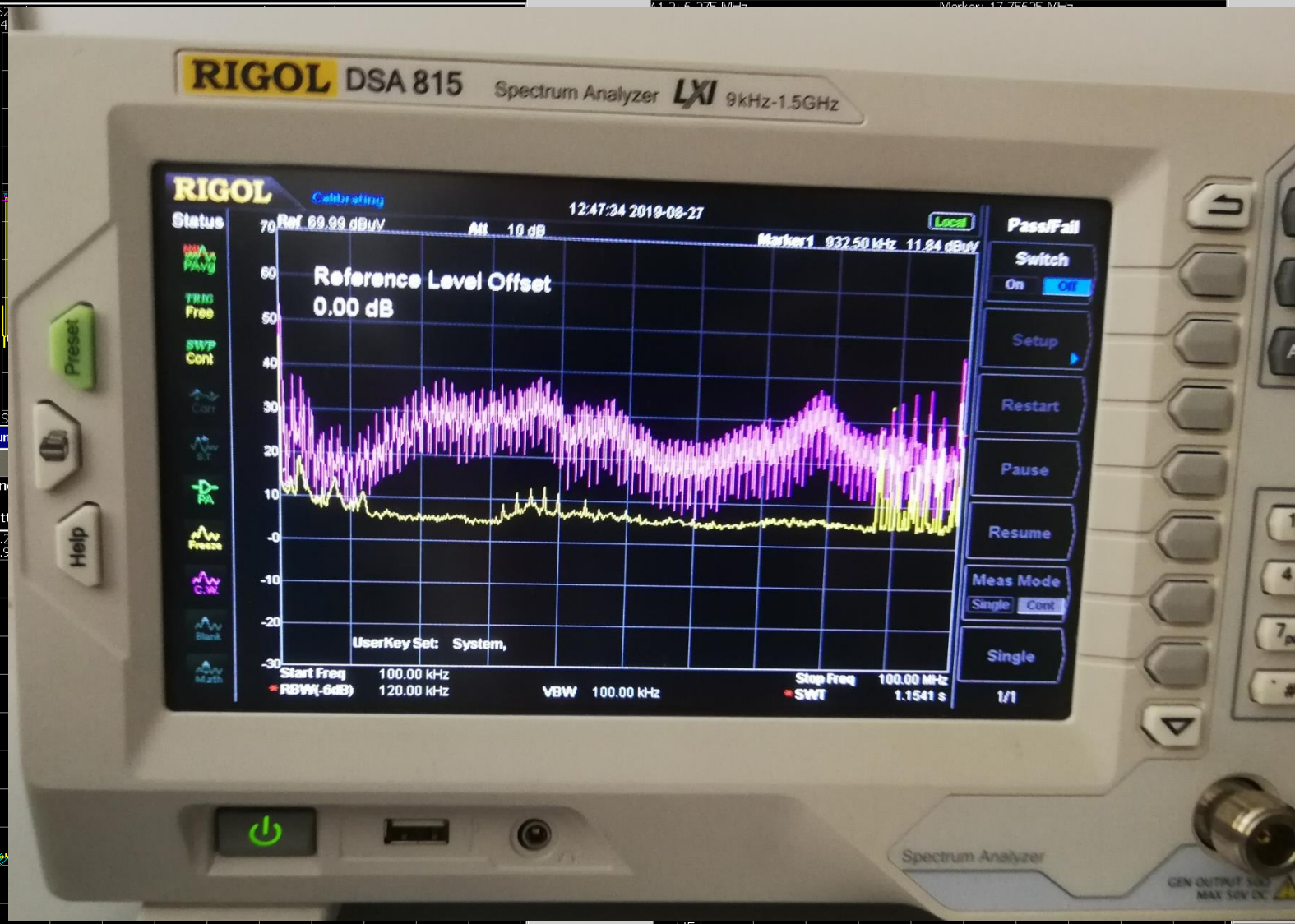
Cancel - Back

Save State



Cancel - Back

Save State

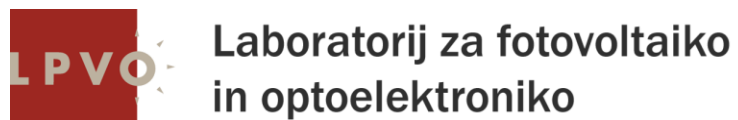


Možne izboljšave

- Odstranitev bakra na obeh slojih pri filtru in močnostni dušilki
- Dodaten filter pri napajanju Vin LM5117
- Povezovanje krmilne zanke vrat
- Cenovno optimizirati vezje

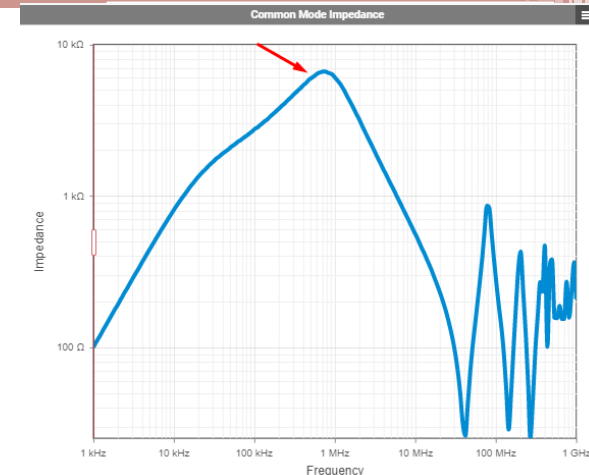
Načrtovanje elektronike za **EMC**²

S08 Martin Kregar in Blaž Okorn

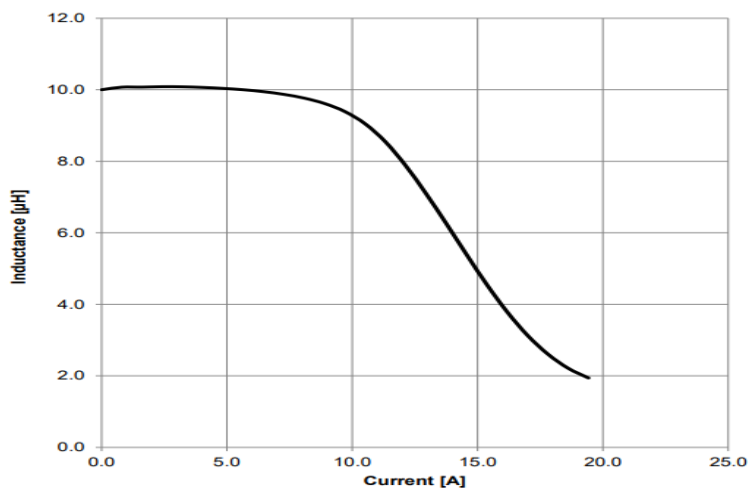


Izbor elementov

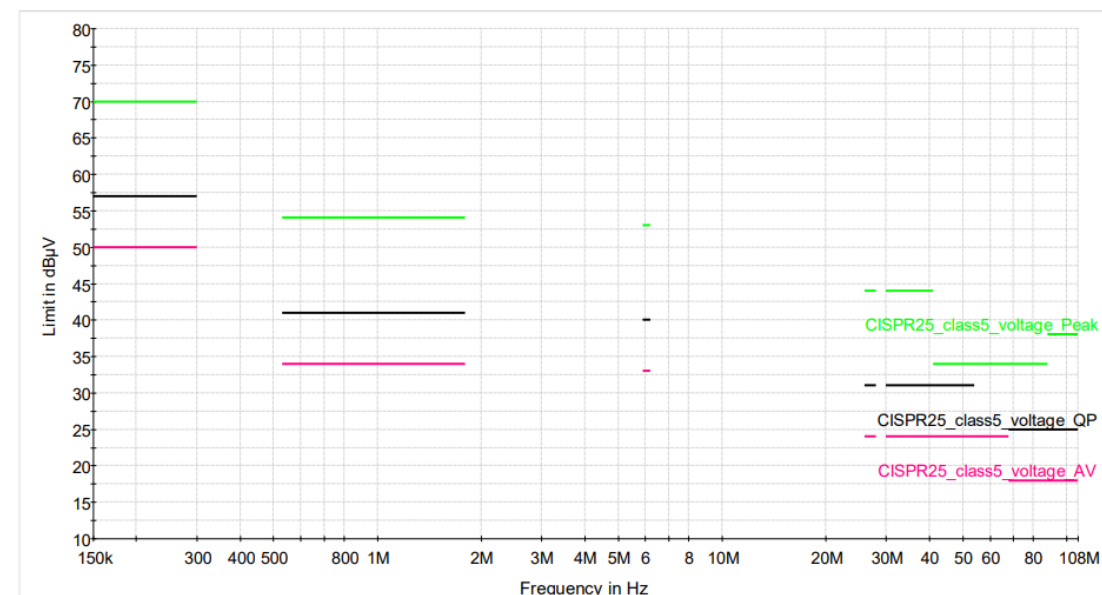
- Stikalna frekvenca delovanja 500 kHz,
- Induktivnost tuljave: $L_O = \frac{V_{OUT}}{I_{PP(MAX)} \times f_{SW}} \times \left(1 - \frac{V_{OUT}}{V_{IN(MAX)}}\right)$,
- Induktivnost tuljave 10 uH in maksimalen tok 7 A,
- Sofazna dušilka z vrhom slabljenja pri frekvenci 500 kHz,



Impedanca sofazne dušilke

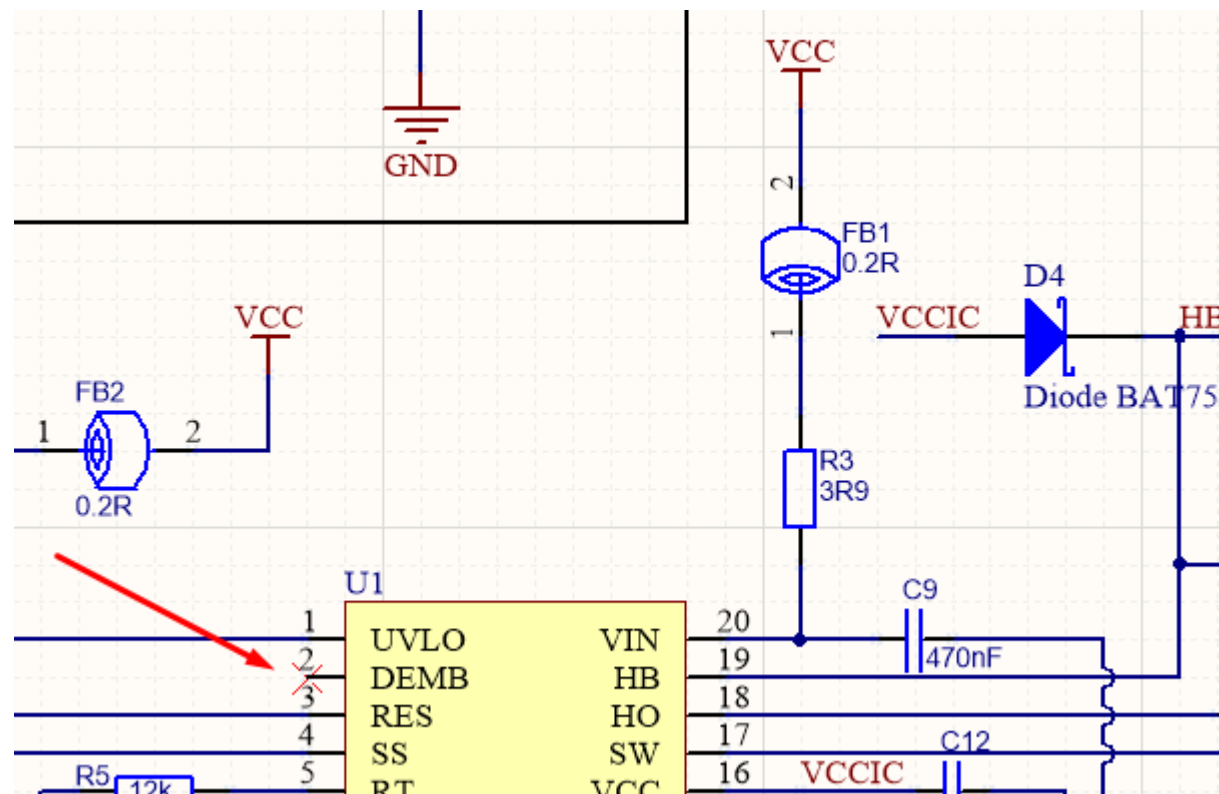


Induktivnost tuljave

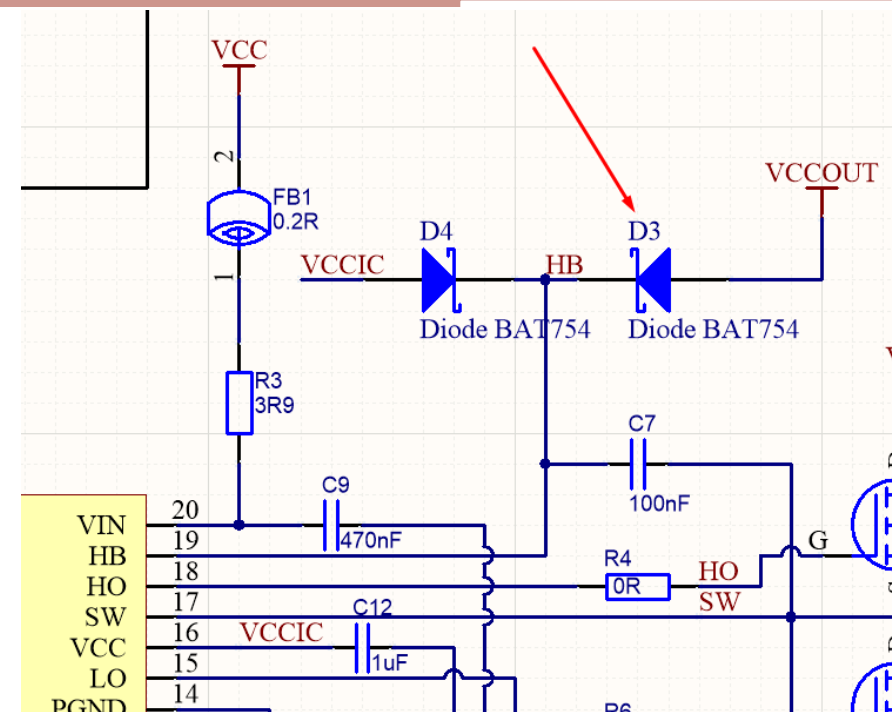


— CISPR25_class5_voltage_QP — CISPR25_class5_voltage_Peak — CISPR25_class5_voltage_AV

Napaki v shematiki

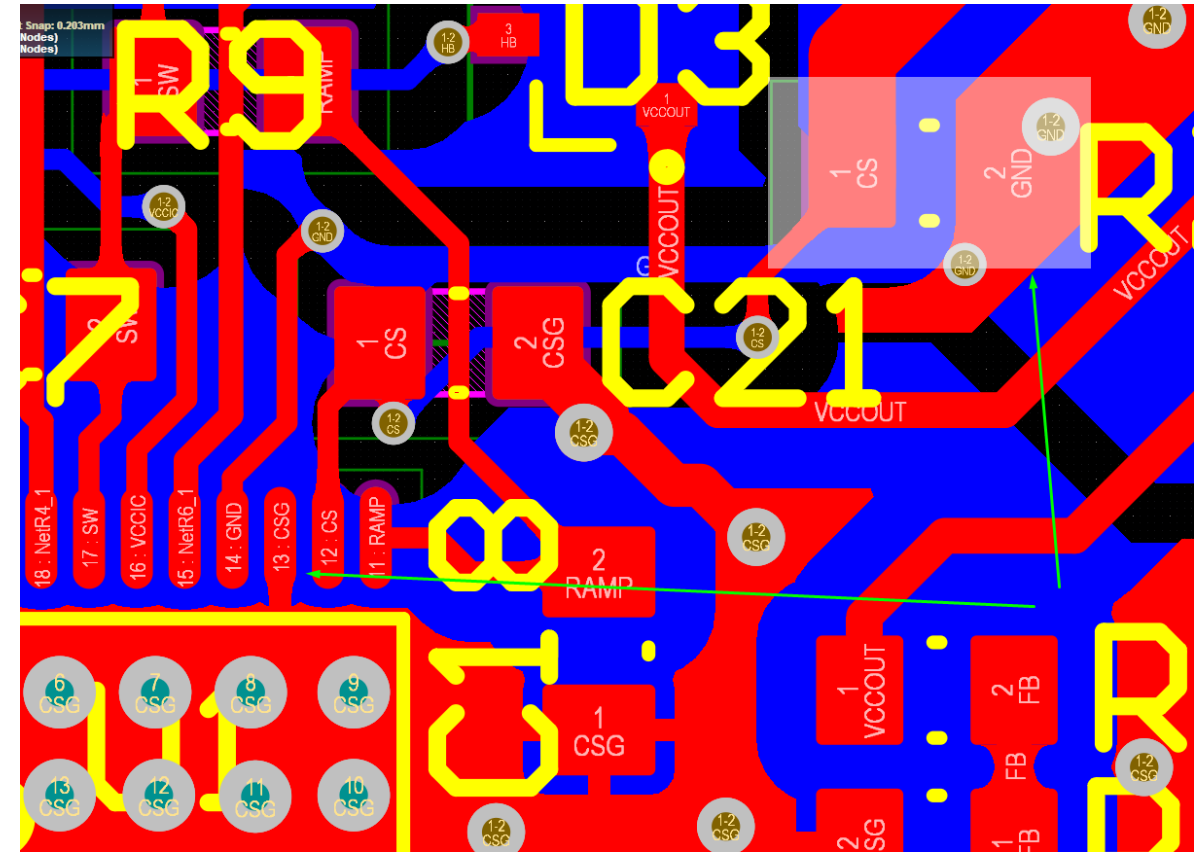


Nepovezan pin DEMB



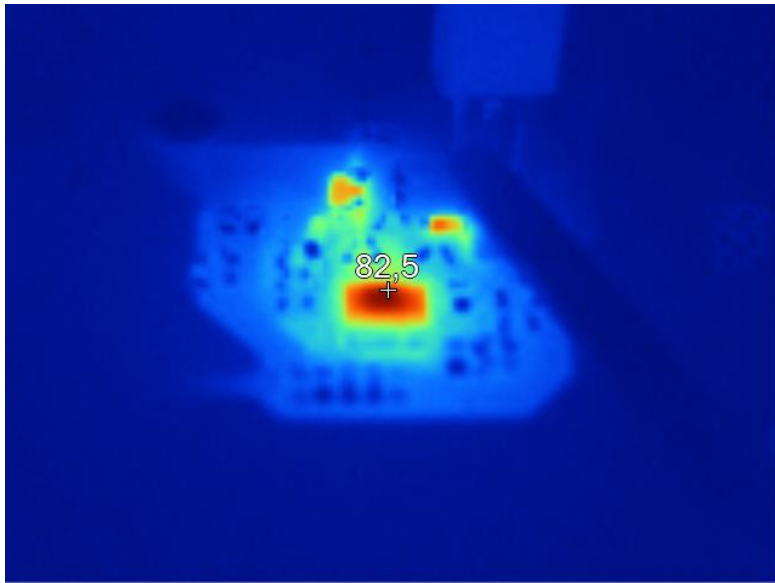
Napačna povezava diode D3

Napaka na PCB tiskanini

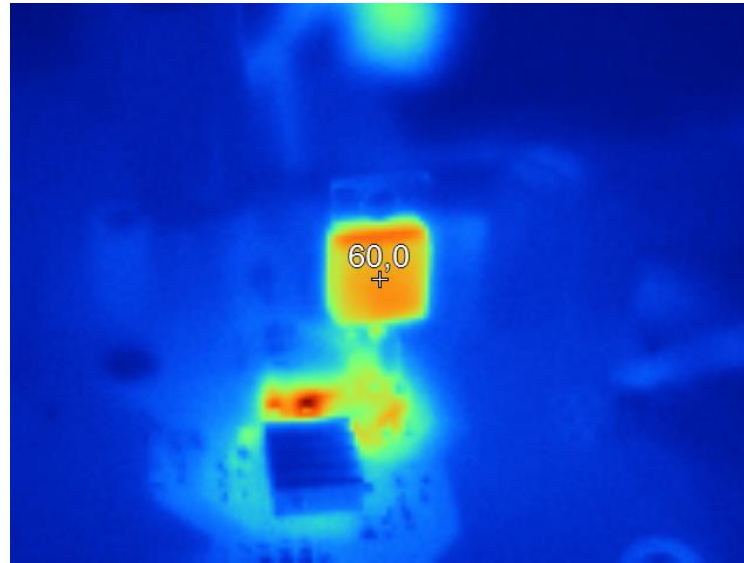


Neustrezna in predolga linija med CSG in GND merilnega upora

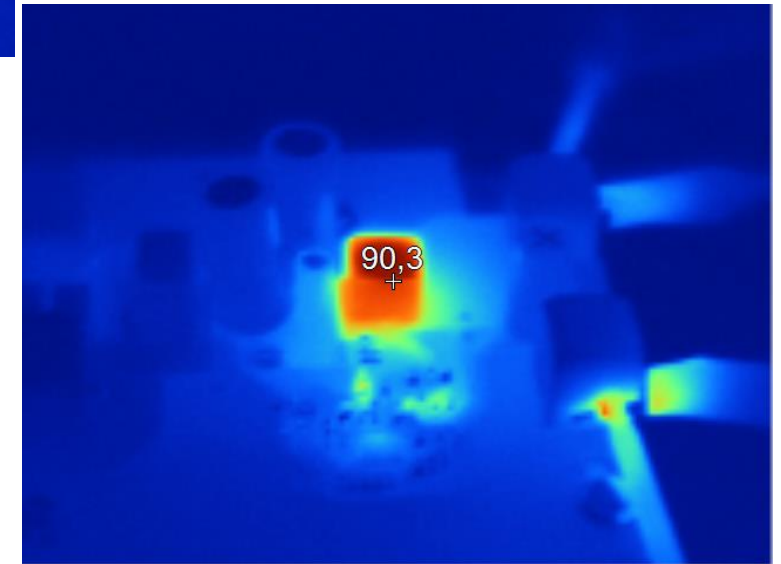
Testiranje



Temperatura switcherja pri izhodni moči 70 W



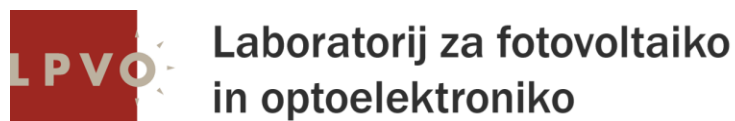
Temperatura tranzistorja pri izhodni moči 70 W



Temperatura tuljave pri izhodni moči 70 W

Načrtovanje elektronike za **EMC**²

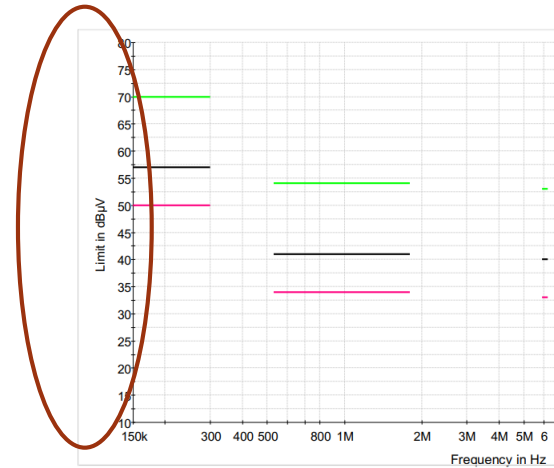
S09 Marko Remec



Ideja

- $2 * f_{sw} < 150kHz$

- $f_{sw} = 70kHz$



- $R_T = \frac{5,2 * 10^9}{f_{sw}} - 948 \rightarrow R_T = 73,2k\Omega \rightarrow f_{sw} = 70,130kHz$

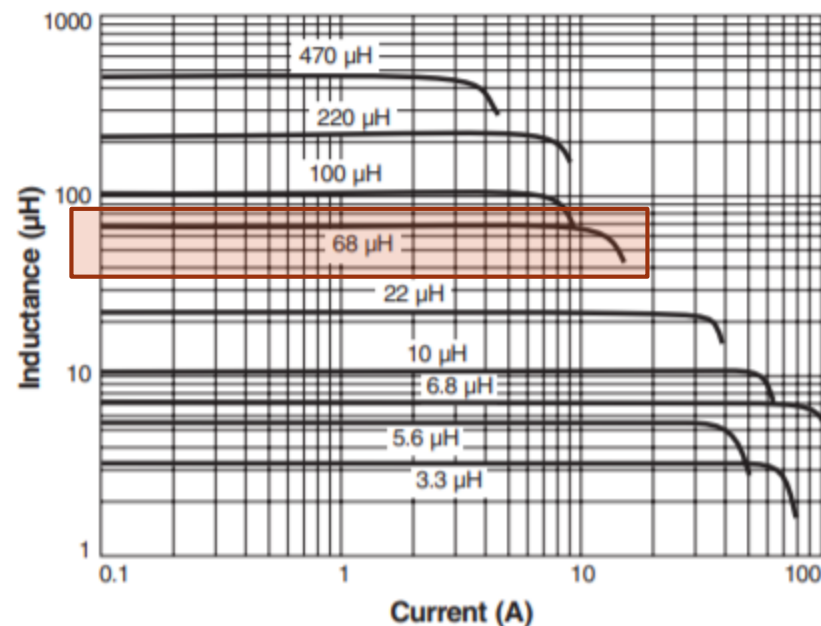
- $L_o = \frac{V_{out}}{I_{pp} * f_{sw}} * \left(1 - \frac{V_{out}}{V_{in}}\right) \rightarrow L_o = 68\mu H$

Dušilka

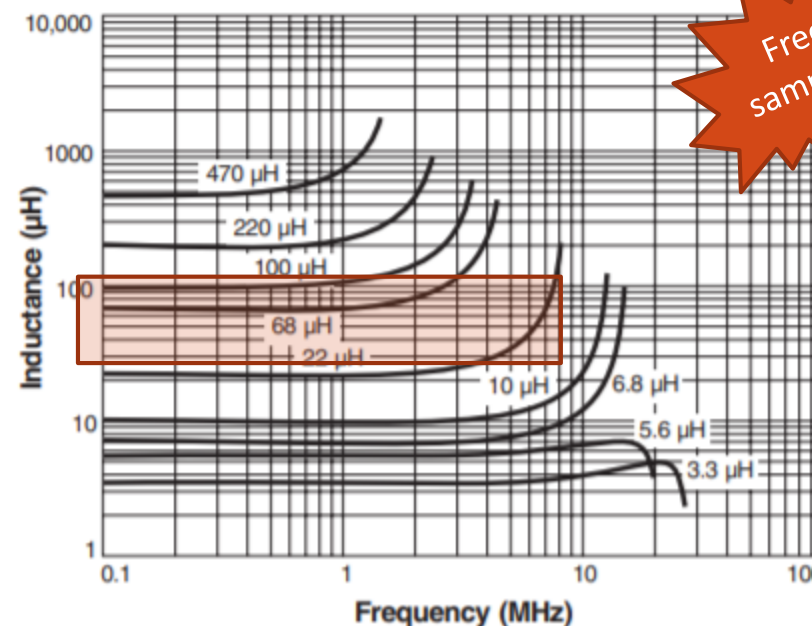
- Coilcraft AGP4233-683ME - $68\mu\text{H}$

Part number	Inductance ¹ $\pm 20\%$ (μH)	DCR (mOhms) ²		SRF typ (MHz)	Isat (A) ³			Irms (A) ⁴	
		nom	max		10% drop	20% drop	30% drop	20°C rise	40°C rise
AGP4233-683ME	68	2.80	2.95	6.4	10.6	12.2	13.0	24	34

Typical L vs Current



Typical L vs Frequency



Free samples!

Tranzistorja

- MOSFET high:
 - Majhen Q_g
 - IPP100N08N3GXXSA1
 - izgube $\approx 2W$
 - ohišje TO220
 - na hladilu



IPP100N08N3 G IPI100N08N3 G
IPB097N08N3 G

OptiMOS™ 3 Power-Transistor

Features

- Ideal for high frequency switching and sync. rec.
- Optimized technology for DC/DC converters
- Excellent gate charge x $R_{DS(on)}$ product (FOM)
- N-channel, normal level
- 100% avalanche tested
- Pb-free plating; RoHS compliant

Product Summary

V_{DS}	80	V
$R_{DS(on),max}$ (SMD)	9.7	mΩ
I_D	70	A

Gate Charge Characteristics⁵⁾

Gate to source charge	Q_{gs}	$V_{DD}=40\text{ V}, I_D=46\text{ A},$ $V_{GS}=0\text{ to }10\text{ V}$	-	9	-	nC
Gate to drain charge	Q_{gd}		-	5	-	
Switching charge	Q_{sw}		-	10	-	
Gate charge total	Q_g		-	26	35	
Gate plateau voltage	$V_{plateau}$		-	5.2	-	V
Output charge	Q_{oss}	$V_{DD}=40\text{ V}, V_{GS}=0\text{ V}$	-	35	47	nC

Tranzistorja

- MOSFET low:
 - Majhen $R_{DS(ON)}$
 - IPB031N08N5ATMA1
 - izgube $\approx 0.7W$
 - ohišje D2PAK
 - na tiskanini brez hladila



OptiMOS™ 5 Power-Transistor, 80 V

IPB031N08N5

1 Description

Features

- Ideal for high frequency switching and sync. rec.
- Excellent gate charge x $R_{DS(on)}$ product (FOM)
- Very low on-resistance $R_{DS(on)}$
- N-channel, normal level
- 100% avalanche tested
- Pb-free plating; RoHS compliant
- Qualified according to JEDEC¹ for target applications
- Halogen-free according to IEC61249-2-21

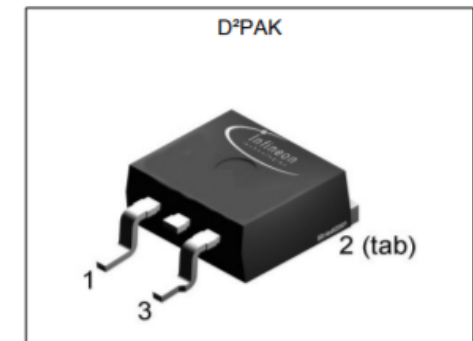
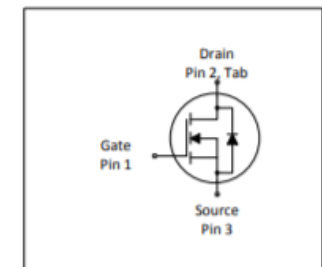
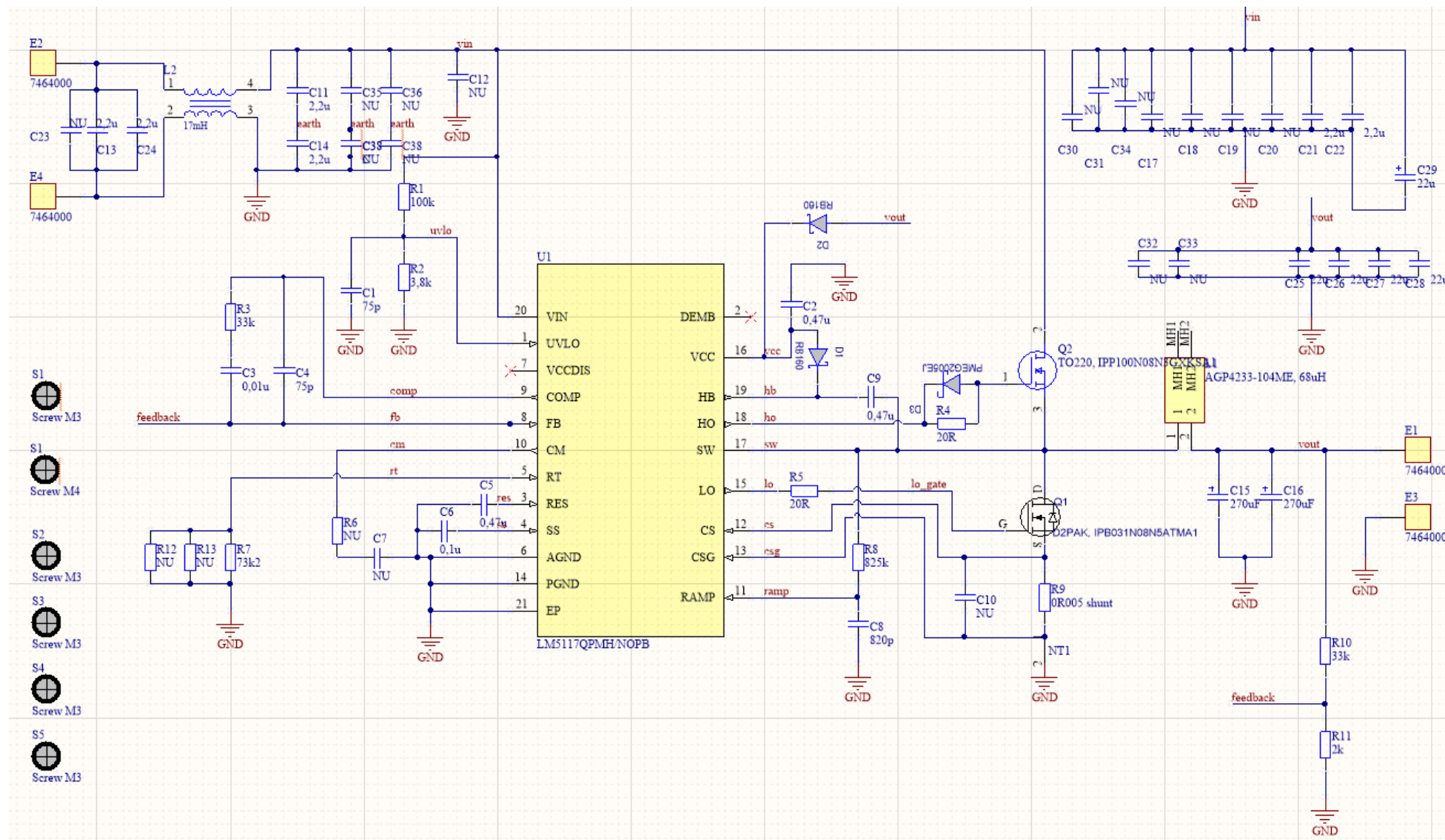


Table 1 Key Performance Parameters

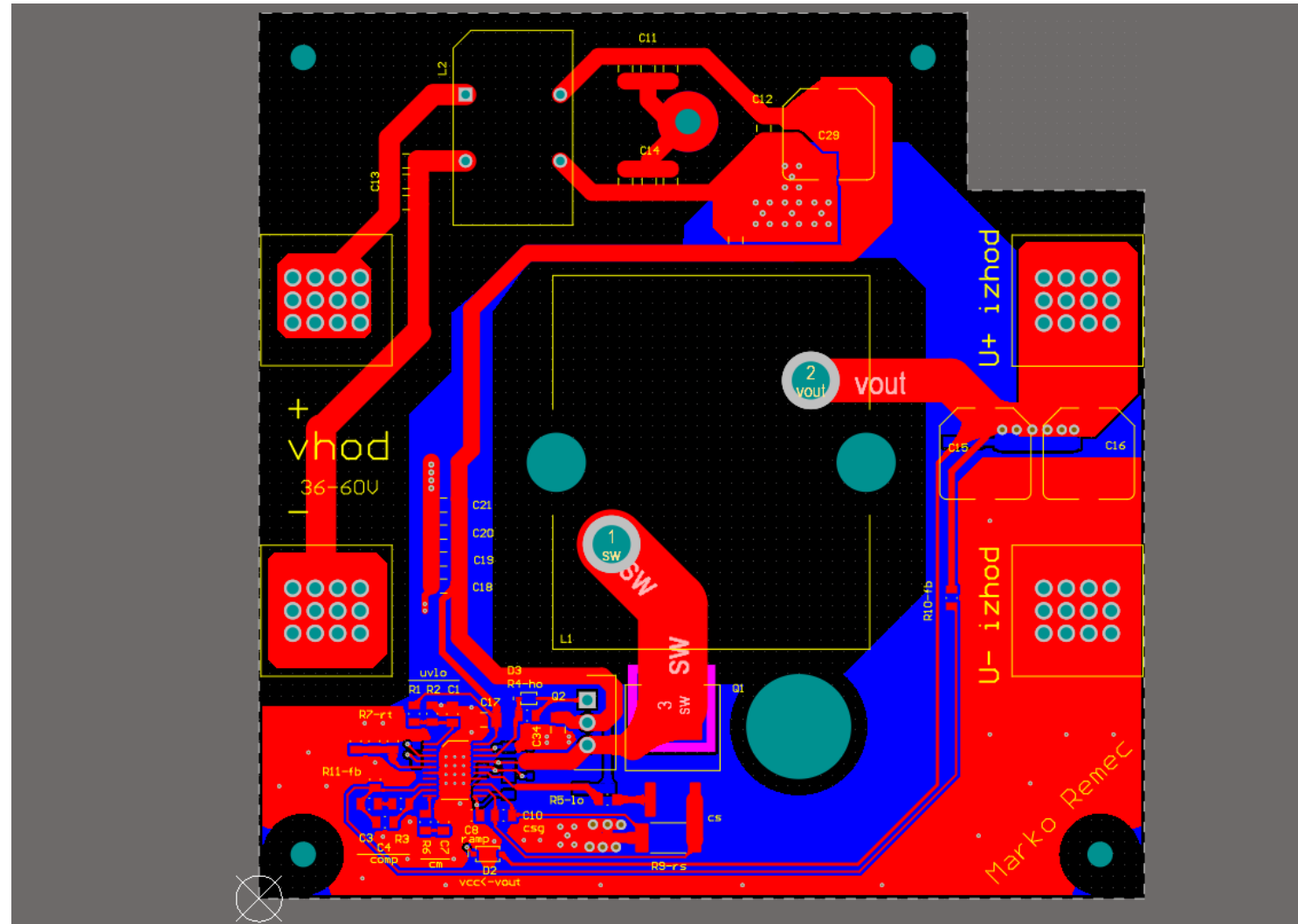
Parameter	Value	Unit
V_{DS}	80	V
$R_{DS(on),max}$	3.1	m Ω
I_D	120	A
Q_{oss}	82	nC
$Q_G(0V..10V)$	69	nC



SCH



PCB



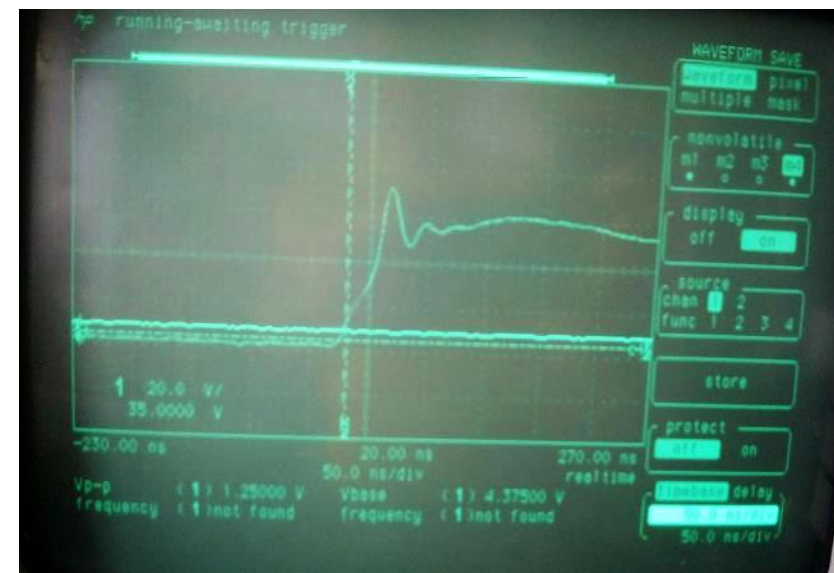
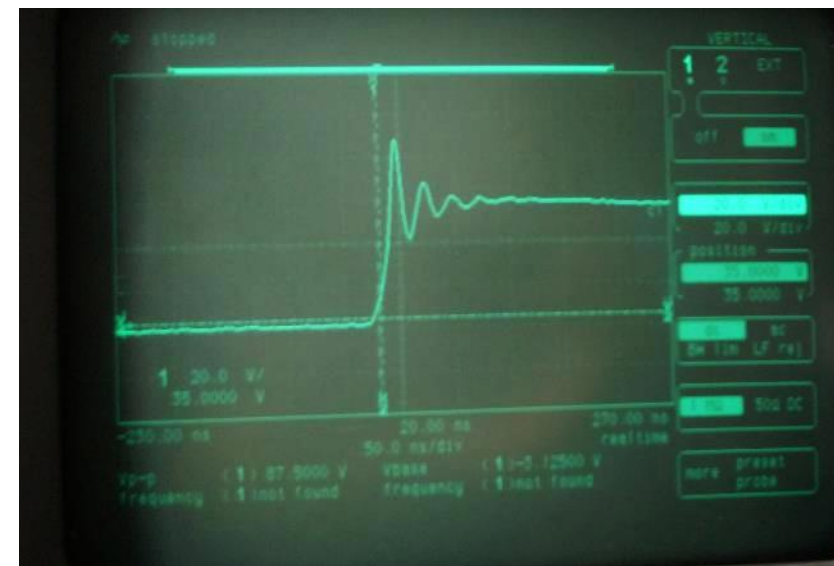
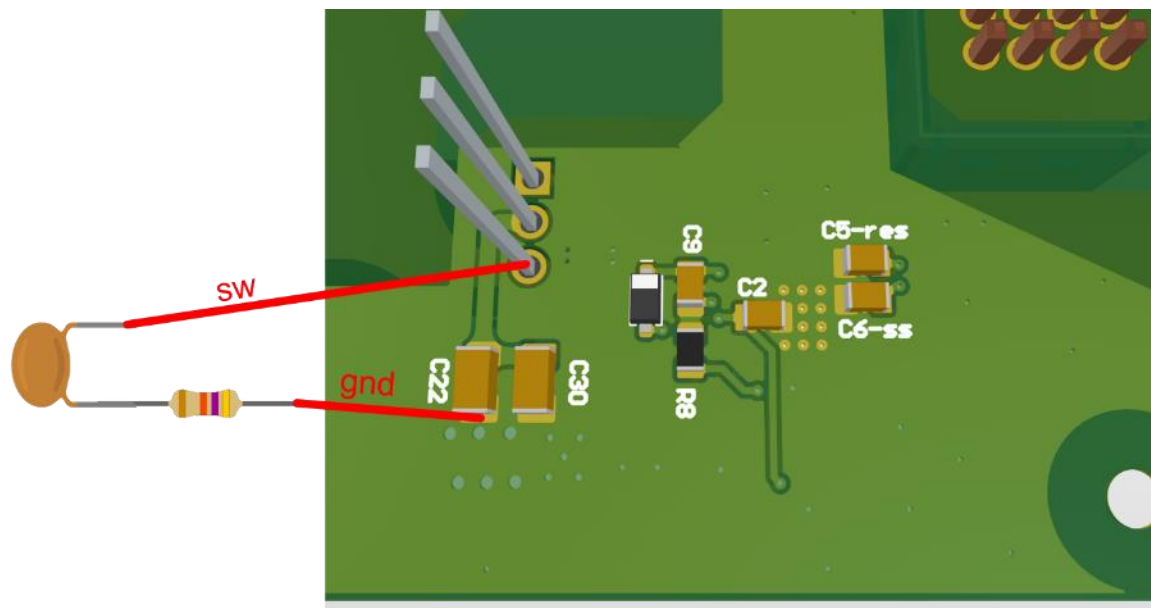
Moj napajalnik je lahko tudi zvočnik

- Napajalnik se prižge
 - Ko V_{in} ni previsoka
 - Pri majhnem izhodnem toku
- Tuljava piska
- → Feedback vezje ni dobro. → Debug.
- Po ponovnih izračunih in menjavah R in C v povratni zanki vezje deluje (tiho) tudi pri maksimalnem izhodnem toku.

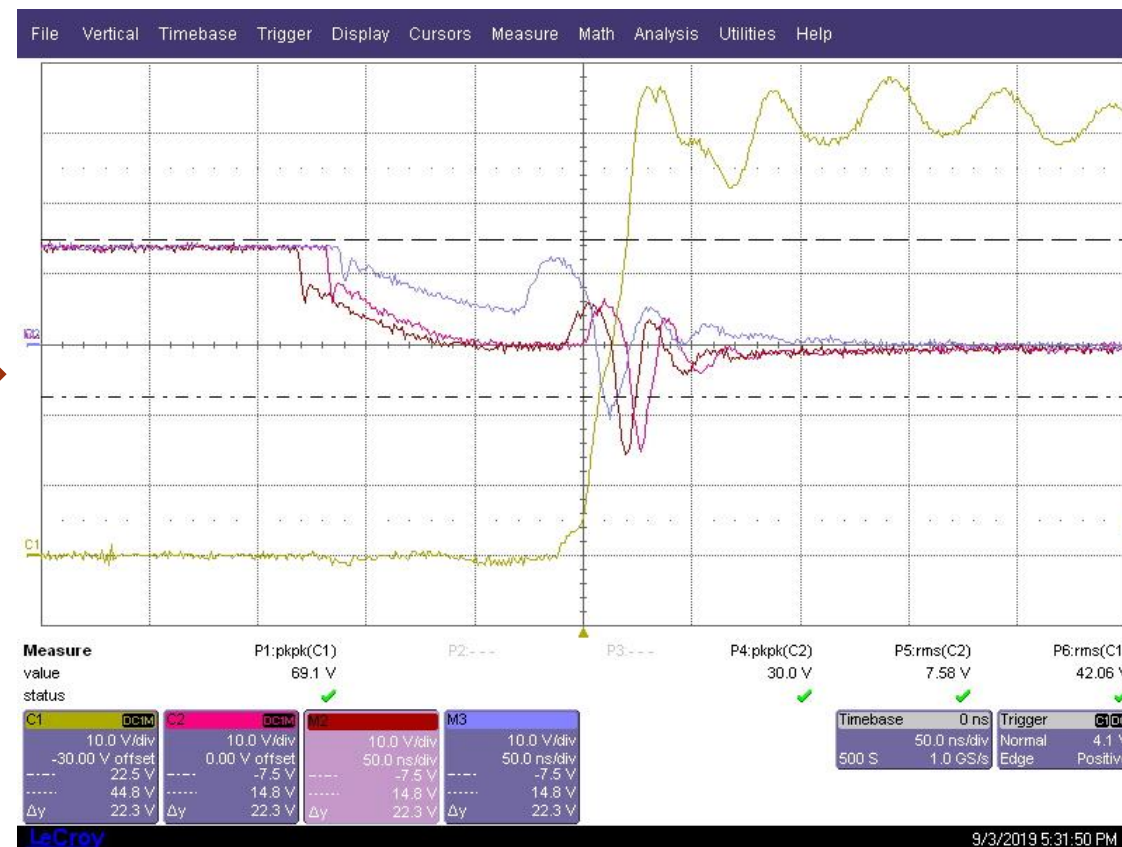


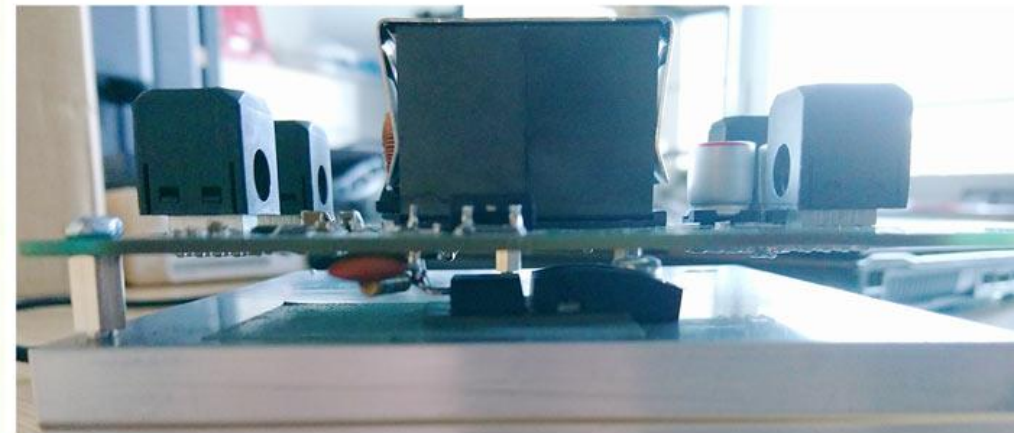
Snubber?

- Ups.



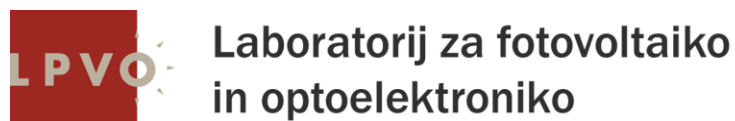
Različni R_{gate} + dioda





Načrtovanje elektronike za **EMC**²

S10 Gregor Pečar



Cilji

Izdelati pretvornik:

- Tapped inductor buck converter
- Spread spectrum buck converter
- Merjenje toka preko RdsOn
- Enostransko vezje izključno na spodnji strani
- Hlajenje preko PCB brez potrebe za hladilno telo
- Filtriranje na vhodu in izhodu do 1GHz

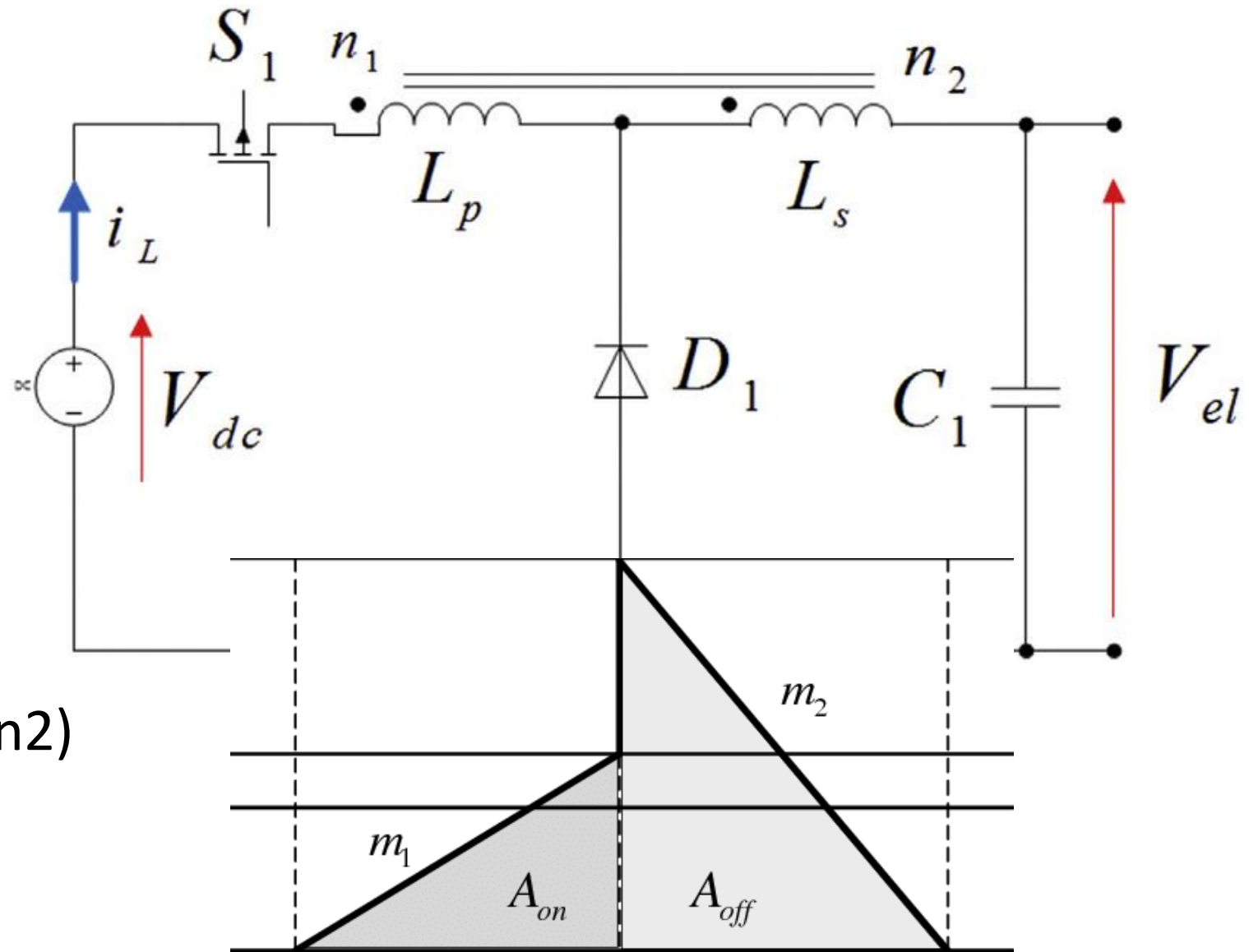
Tapped inductor buck converter

Prednosti:

- Višji izkoristek
- Manjši tok na vhodu
- Večji duty cycle

Slabosti:

- Višja obremenitev stikal
- Tok skozi D1 je večji
- (Skladno z razmerjem $n_1:n_2$)



Spread spectrum buck converter

Zakaj?

Emisije vezja so enake, vendar so razsejane po frekvenčnem spektru, ne dobimo špic, učinkovito znižamo nivo povzročenih motenj

Prednosti:

- Boljša EMC kompatibilnost
- Nižji stroški zaradi manj filtrirnih elementov, lahko tudi višji izkoristek, kjer se izognemo upornosti bakra v dušilkah

Slabosti:

- Težje filtriranje v določenih primerih, ker je sedaj spekter razsejan
- Nižji izkoristek naprave, ker se stalno spreminja delovna točka

Merjenje toka preko R_{dsOn}

Prednosti:

- Izognemo se merjenju preko uporovnega elementa, posledično nižje izgube
- Izgube v merilnem uporu so lahko večje kakor izgube v tranzistorju
- Boljše hlajenje tranzistorja, saj je termalna pot neposredna, ne greje se tudi upor

Slabosti:

- Upor duši motnje
- R_{dsOn} se spreminja s temperaturo in V_{gs}
- Povečana kompleksnost vezja

Enostransko vezje izključno na spodnji strani

Prednosti:

- Motnje sevajo samo na eno stran in „v tla“ (kar samo po sebi ne pomeni, da bodo manjše)

Slabosti:

- Nobene uporabe vij, potk, na drugi strani, da se izognemo emisijam
- Problem z višino in postavitvijo komponent
- Problem s hlajenjem komponent
- Problem s kapacitivnim spojem dušilke in hladila
- Vse SMT

Hlajenje preko PCB brez potrebe za hladilno telo

Prednosti:

- Odpade montažni material za hladilnik
- Nižji stroški proizvodnje in manj montaže, vrtanja itd.
- Manjši kapacitivni sklop med tranzistorjem in hladilnikom

Slabosti:

- Zahtevana površina za hlajenje je velika, baker pa je tenak
- Velika površina pomeni velik kapacitivni sklop
- Višja delovna temperatura zaradi slabšega hlajenja

Filtriranje na vhodu in izhodu do 1GHz

Prednosti:

- Zadoščanje delu EMC testiranj s filtriranjem emisij, ki se skurijo v dušilkah

Slabosti:

- Dušilke in kondenzatorji so strošek
- Filtriranje vhoda in izhoda je 2x strošek, kot če filtriramo samo vhod
- Za dobro filtriranje pri višjih frekvencah rabimo 2 tipa dušilk, saj zaradi parazitnih kapacitivnosti motnje prehajajo čez prvo toroidno dušilko
- Izjemne izgube zaradi upornosti bakra, posebno na izhodu
- Vprašljiva ekonomičnost, saj je izguba pik (x2 cene), skoraj tolikšna kakor te dušilke ponujajo filtracije (20-30dB)
- Špice (4V) še vedno pridejo čez

Kaj sem uspel narediti in ugotoviti

- Tapped inductor buck converter

S dušilko WE-DCT 744851470 se ni obnesel

Pregrevanje že pri minimalni obremenitvi

- Spread spectrum buck converter

LTC6908 – ni bil na zalogi

DS1090U-32+ - na zalogi vendar ni vgrajen, rešeno s 2x NPN avalanche oscilatorji na delu oscilatorja in Ramp generatorja

- Merjenje toka preko RdsOn

IR25750L – dela, teoretično, realno pa je popolni polom

Napetostna špica ob izklopu zgornjega in vklopu spodnjega tranzistorja sproži pretokovno zaščito



Kaj sem uspel narediti in ugotoviti

Enostransko vezje izključno na spodnji strani:

- Zahtevno, vendar izvedljivo, velik problem z zrcaljenjem, ker zgubiš orientacijo
- Hlajenje preko PCB brez potrebe za hladilno telo
Potrebno termično reševati s 0.8mm bakreno pločevino na obeh straneh. Rešeno, tranzistorji na 80C po 1h 110W obremenitve.
- Samo enostransko (pod tranzistorji) ni bilo zadostno, na drugi strani se je toplota odvajala skoraj točkovno

Filtriranje na vhodu in izhodu do 1GHz:

- Lahko, da je bilo uspešno. Sama postavitev bi lahko bila dosti boljša
- Dilema, ali začeti filtracijo s feritom ali s toroidom ?

Problemi

Kurjenje zgornjega driverja glavnega čipa (-2 kom)

- Premajhna induktivnost dušilke

Enormno gretje (120Win pri 100Wout, -1 kom zaradi stika)

- Premajhna induktivnost dušilke

Nestabilno delovanje (pri višjih Vin se vse skupaj ugasne, -1 kom, čip ok)

- Premajhna induktivnost dušilke in preobčutljiva merilna zanka

Motnje na Vin (4V špice)

- Premajhna induktivnost dušilke, konverter je deloval v DCM

Rešitve

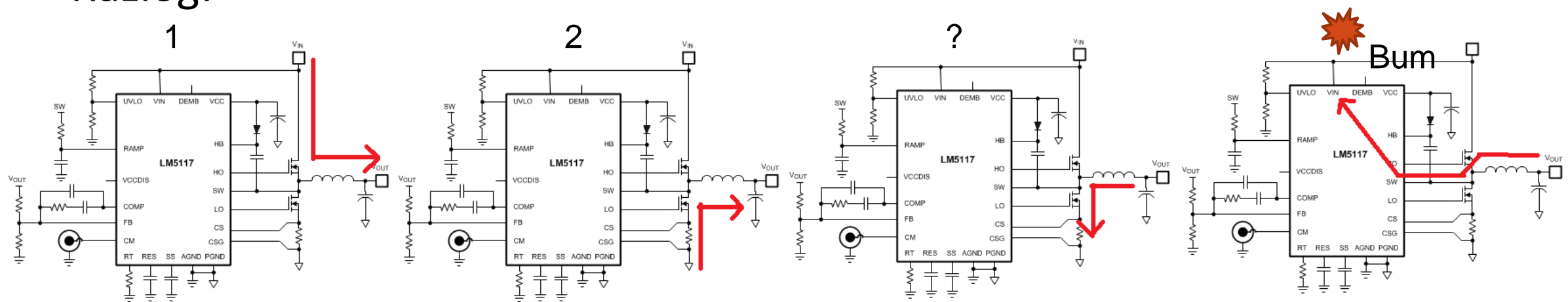
Kurjenje zgornjega driverja glavnega čipa

- Premajhna induktivnost dušilke

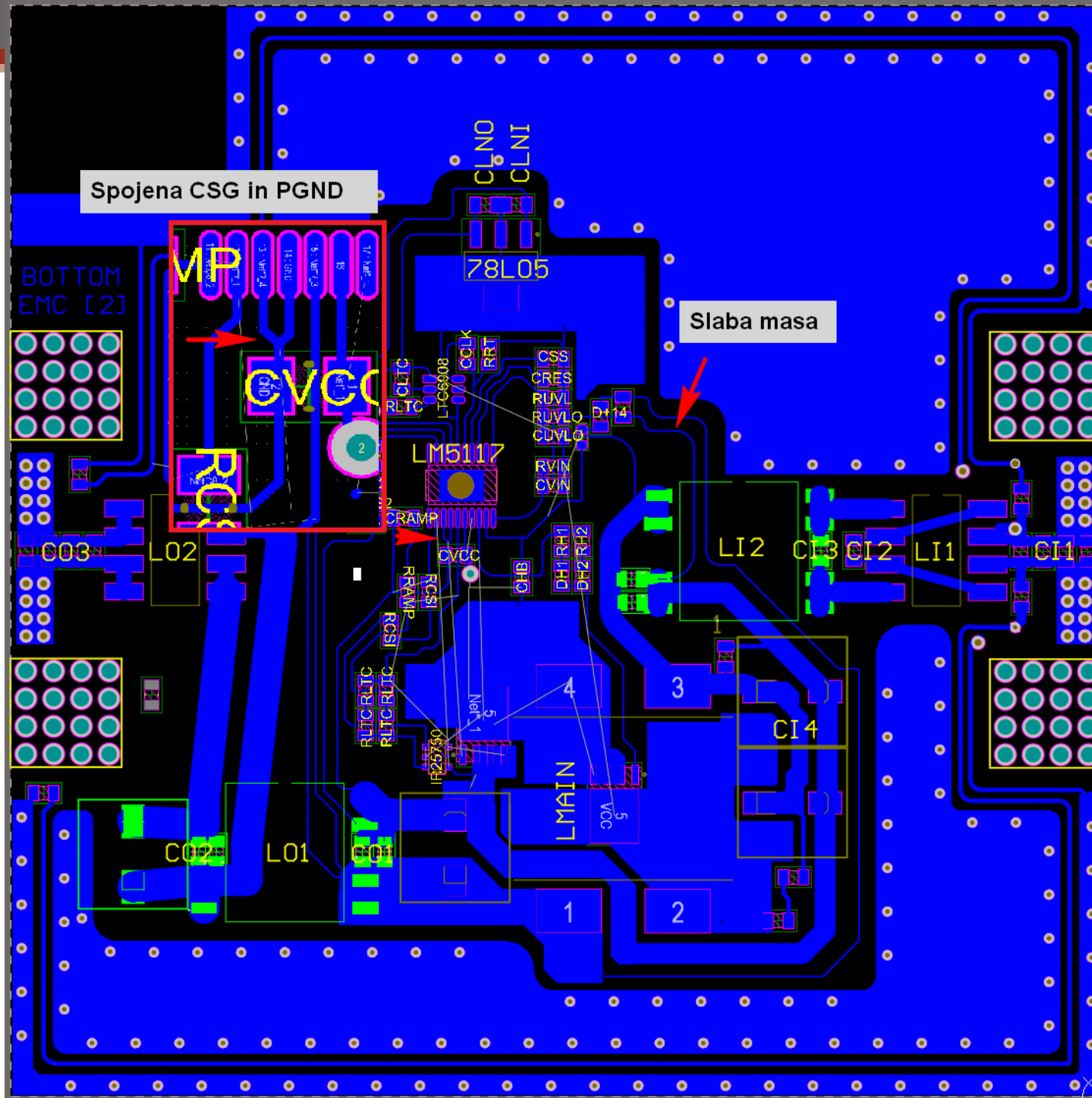
Rešitev, zamenjava z dušilko z večjim nazivnim tokom in realno induktivnostjo (+-20% !!!)

Dodane diode (za vsak primer) in RC snubber

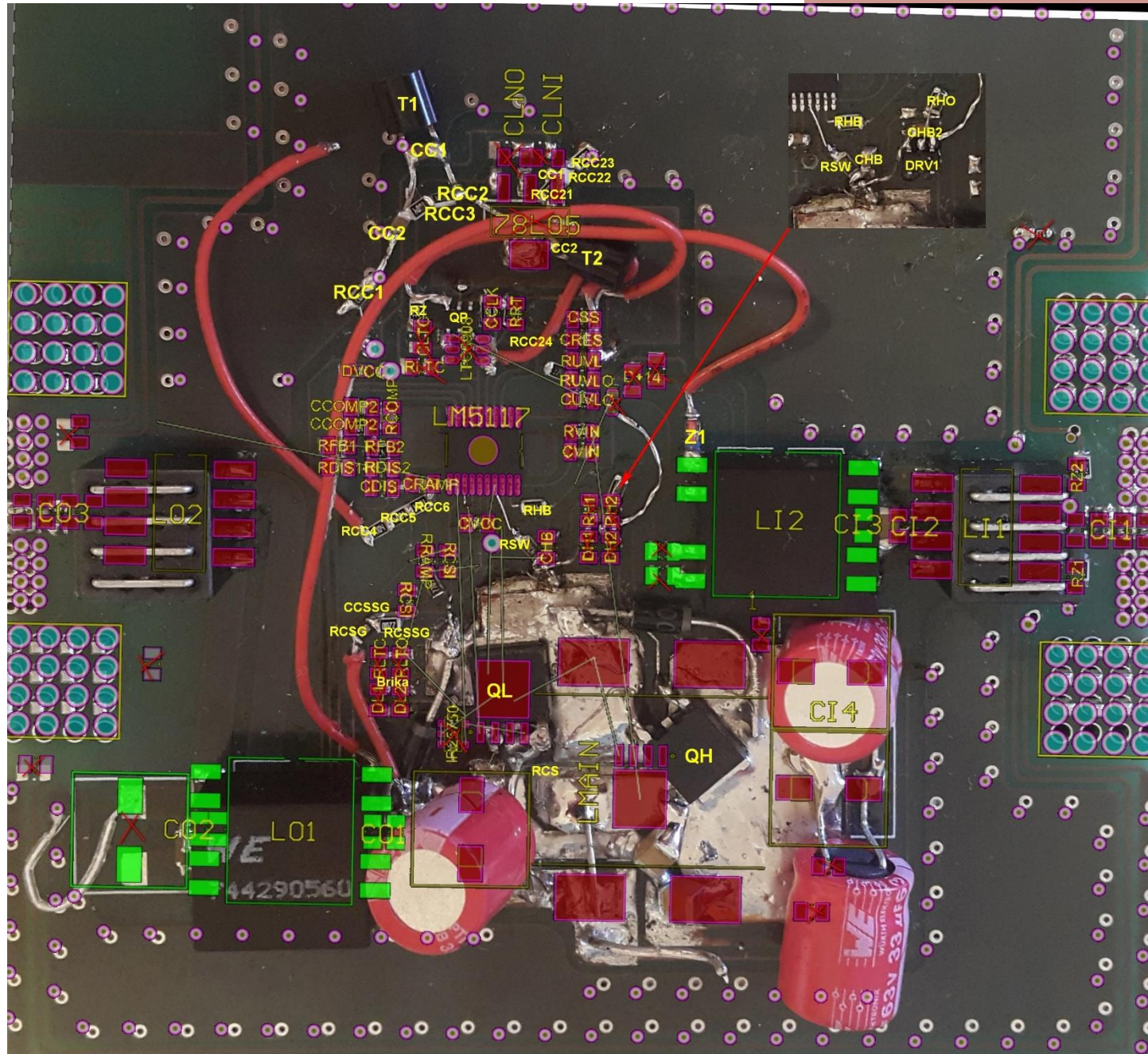
Razlog:



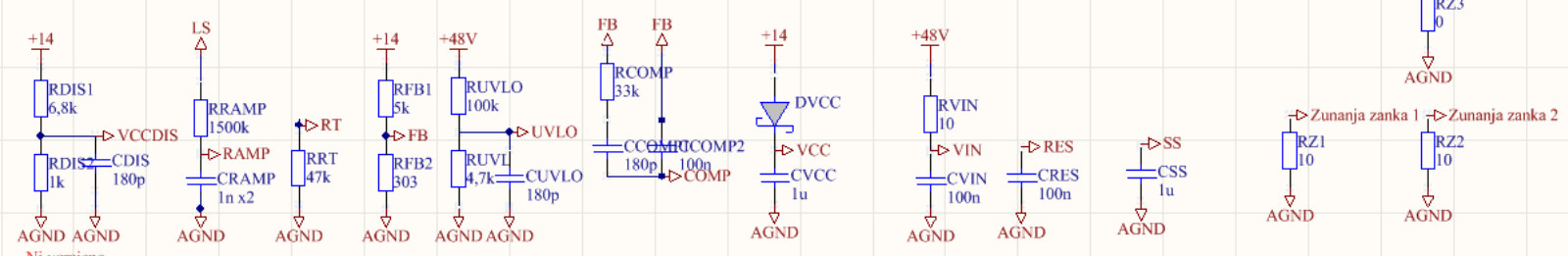
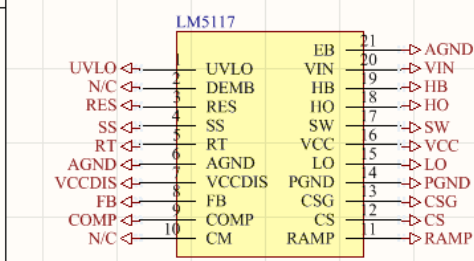
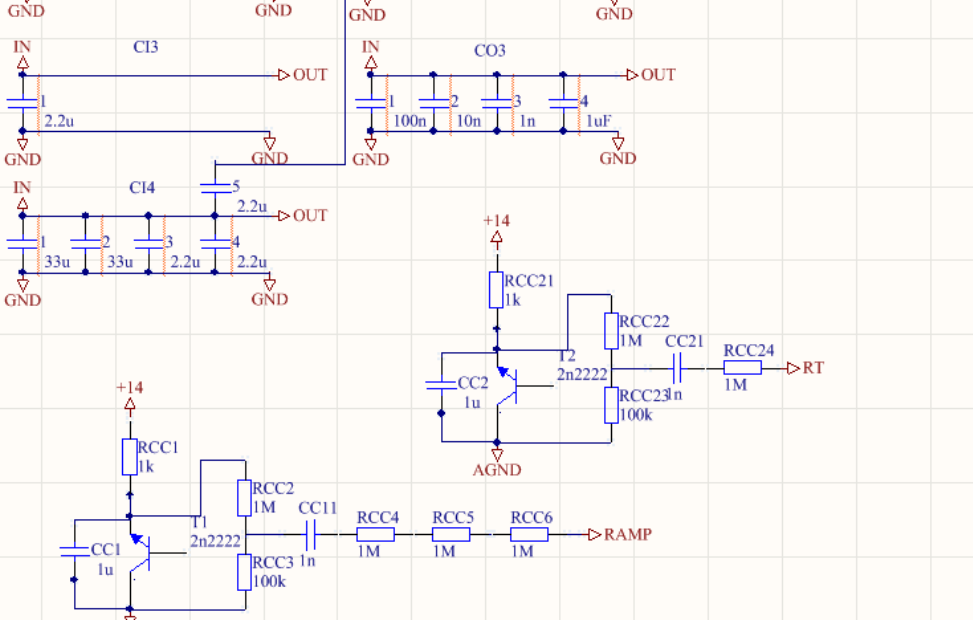
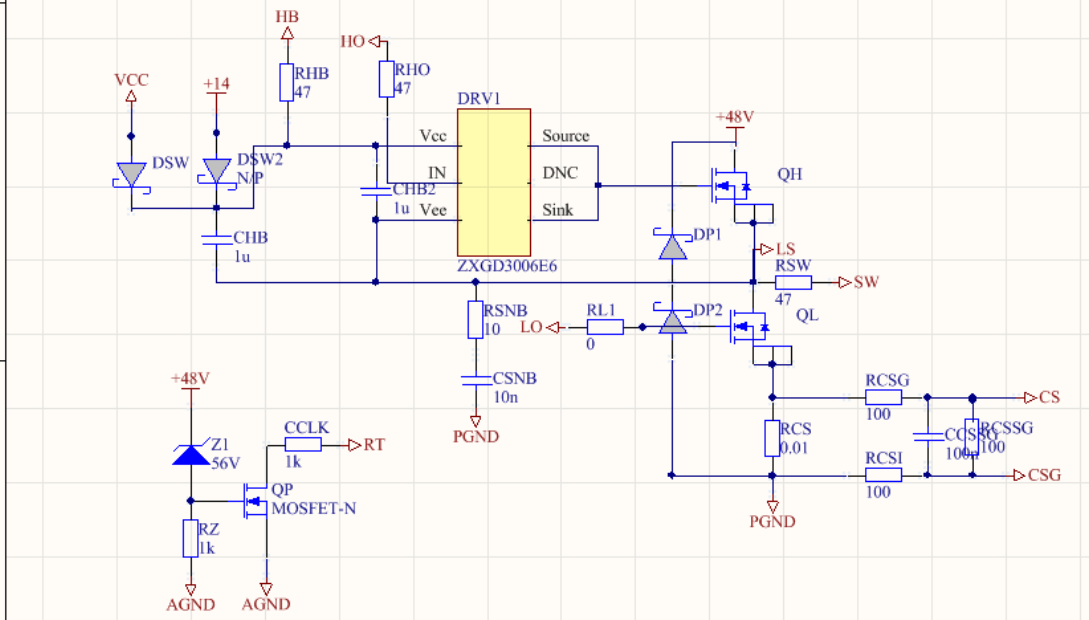
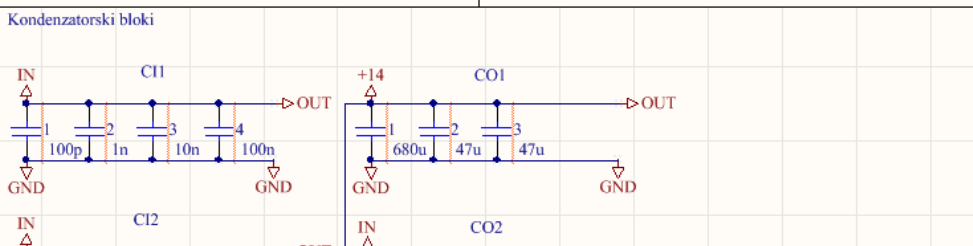
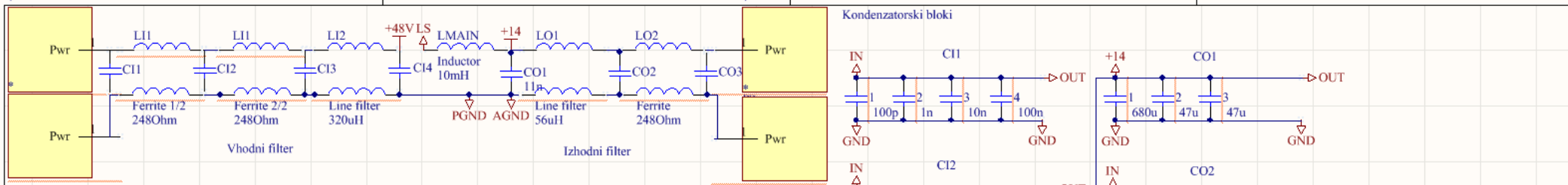
Napake



Overlay



S

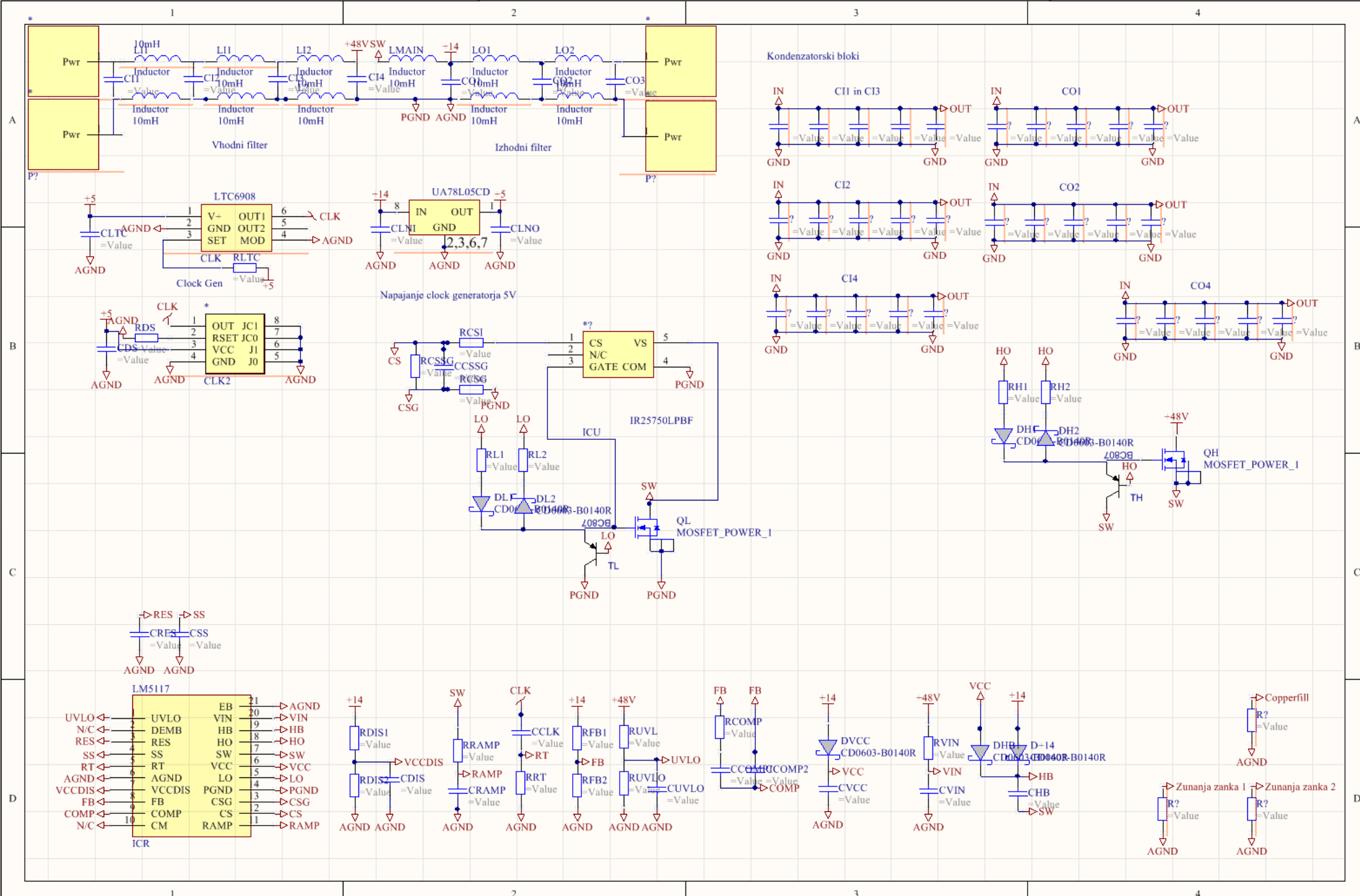


Ni vgrajeno

Zunanja zanka 1 Zunanja zanka 2

Copperfill

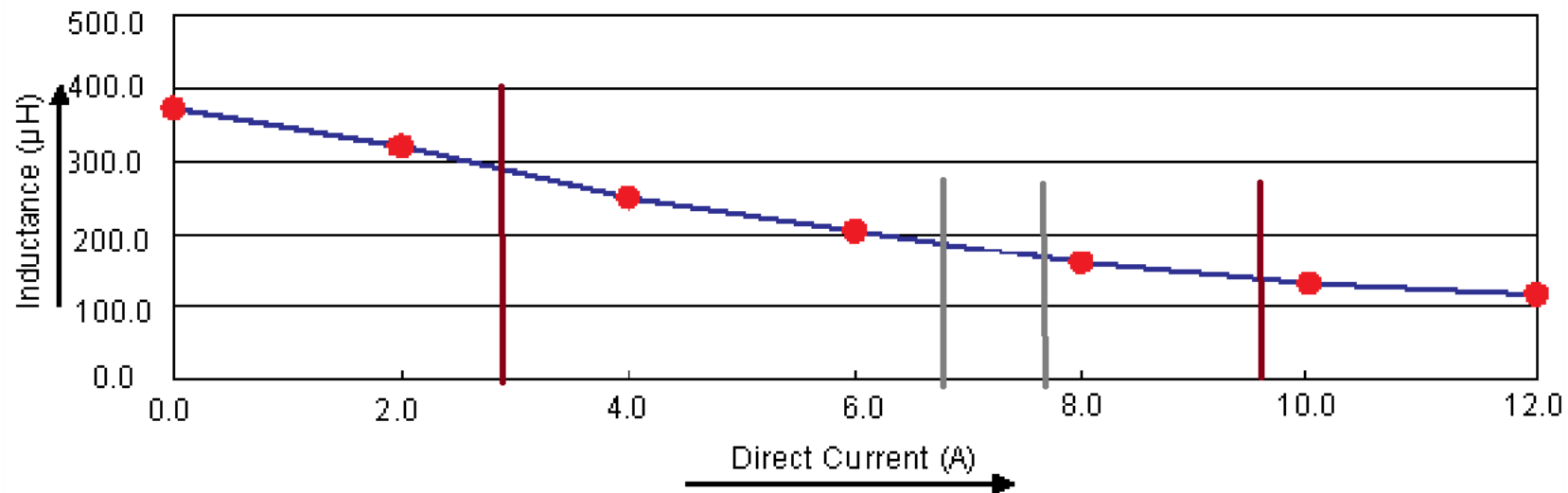
Sh



Katero vrednost izbrati za Ramp upor ?

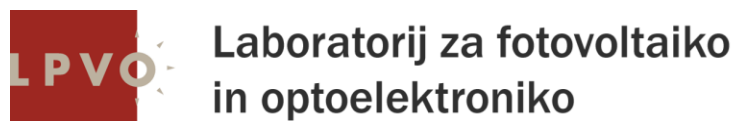
Electric Characteristics

RRamp ?



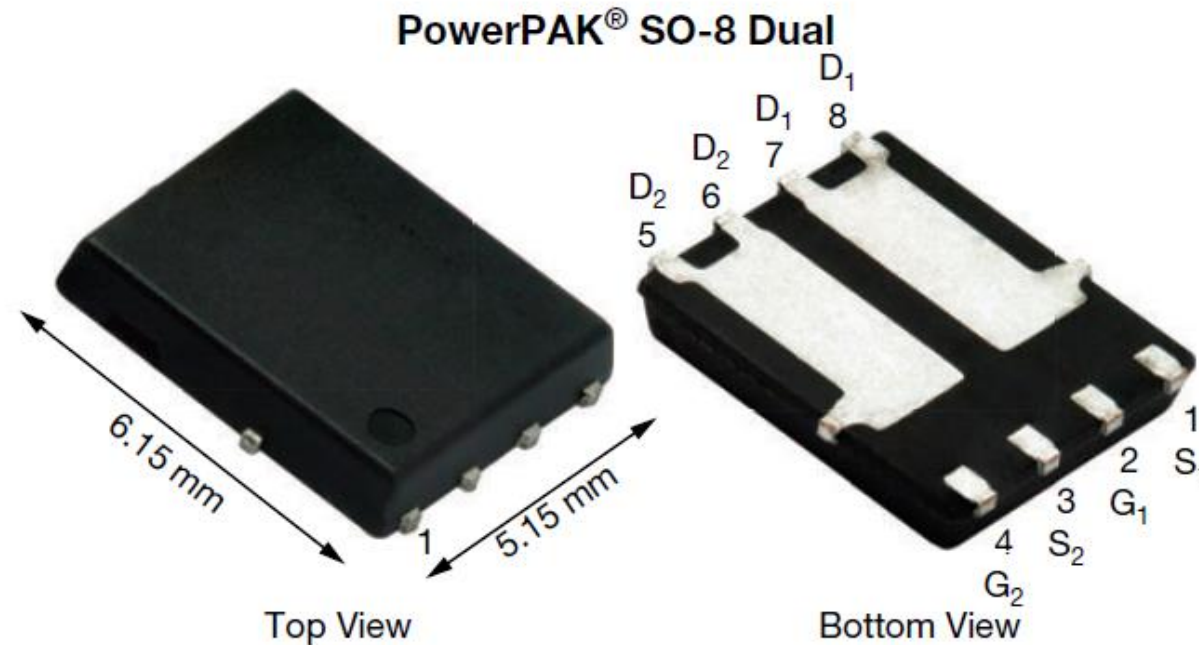
Načrtovanje elektronike za **EMC**²

Luka Pogačnik



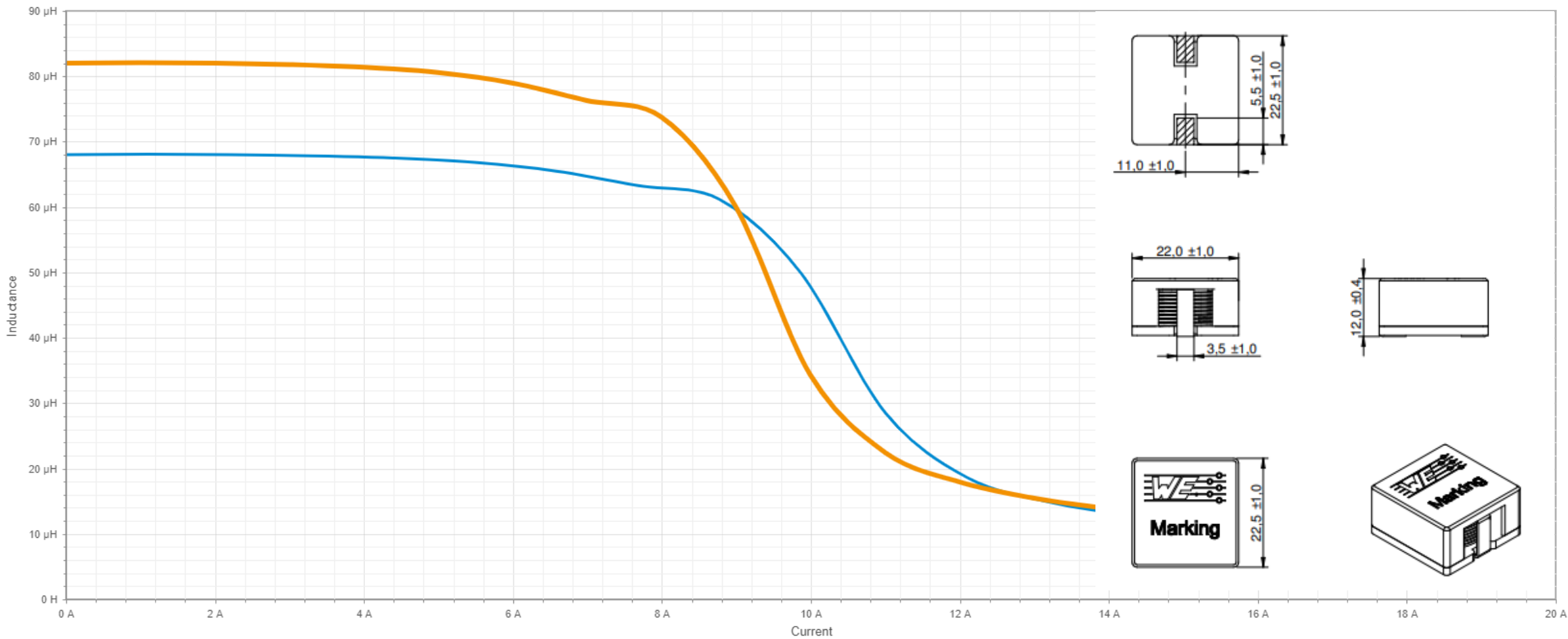
- f: 100 kHz
- L: 68 μ H
- M: Si7252DP

- I_{pp} : 1.58 - 1.46 - 1.26 [A]
- HS losses: 1.96 (DC: 0.82 + SW: 1.14) [W]
- LS losses: 1.55 (DC: 1.28 + SW: 0.27) [W]
- totla losses: 3.51 [W]



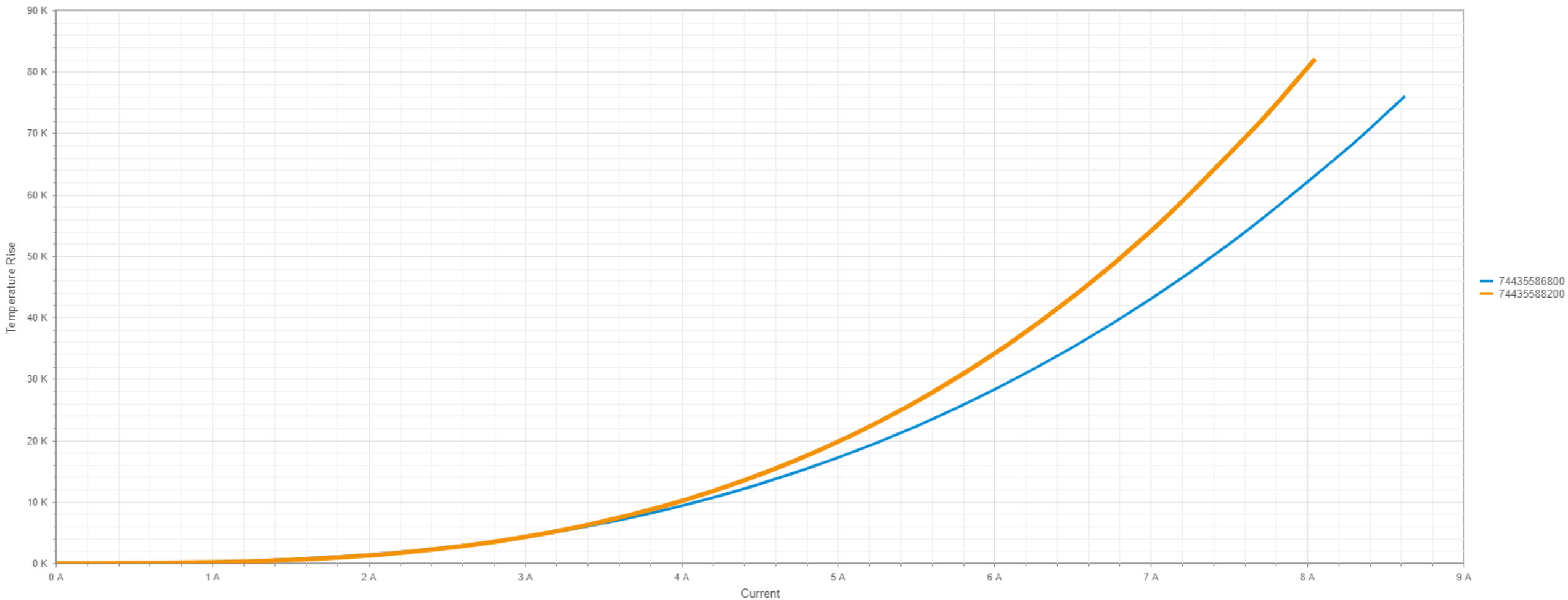
PRODUCT SUMMARY	
V_{DS} (V)	100
$R_{DS(on)}$ max. (Ω) at $V_{GS} = 10$ V	0.018
$R_{DS(on)}$ max. (Ω) at $V_{GS} = 7.5$ V	0.019
$R_{DS(on)}$ max. (Ω) at $V_{GS} = 6$ V	0.021
Q_g typ. (nC)	12.2
I_D (A)	36.7
Configuration	Dual

Inductance / DC Current (20.0°C)

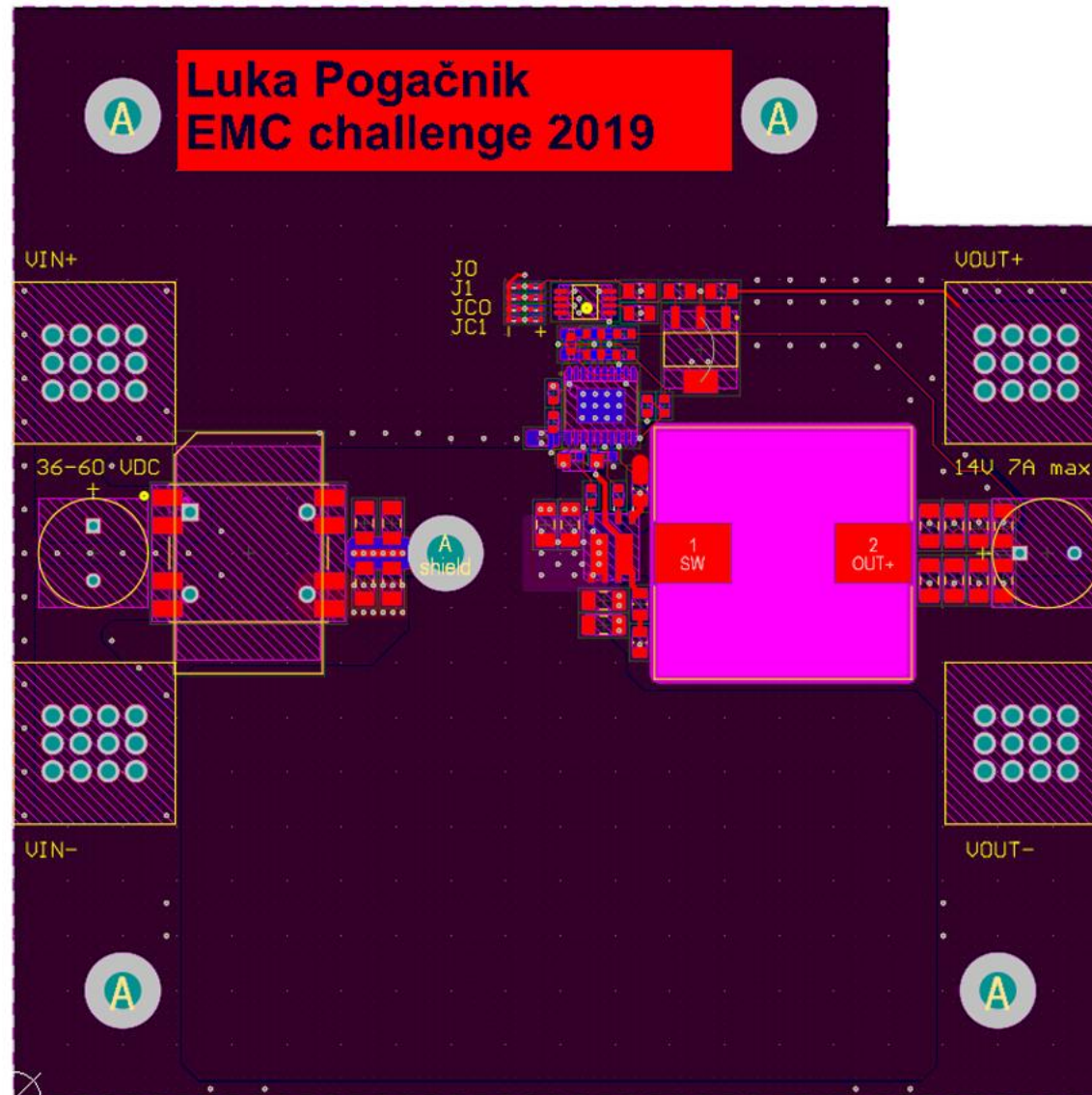


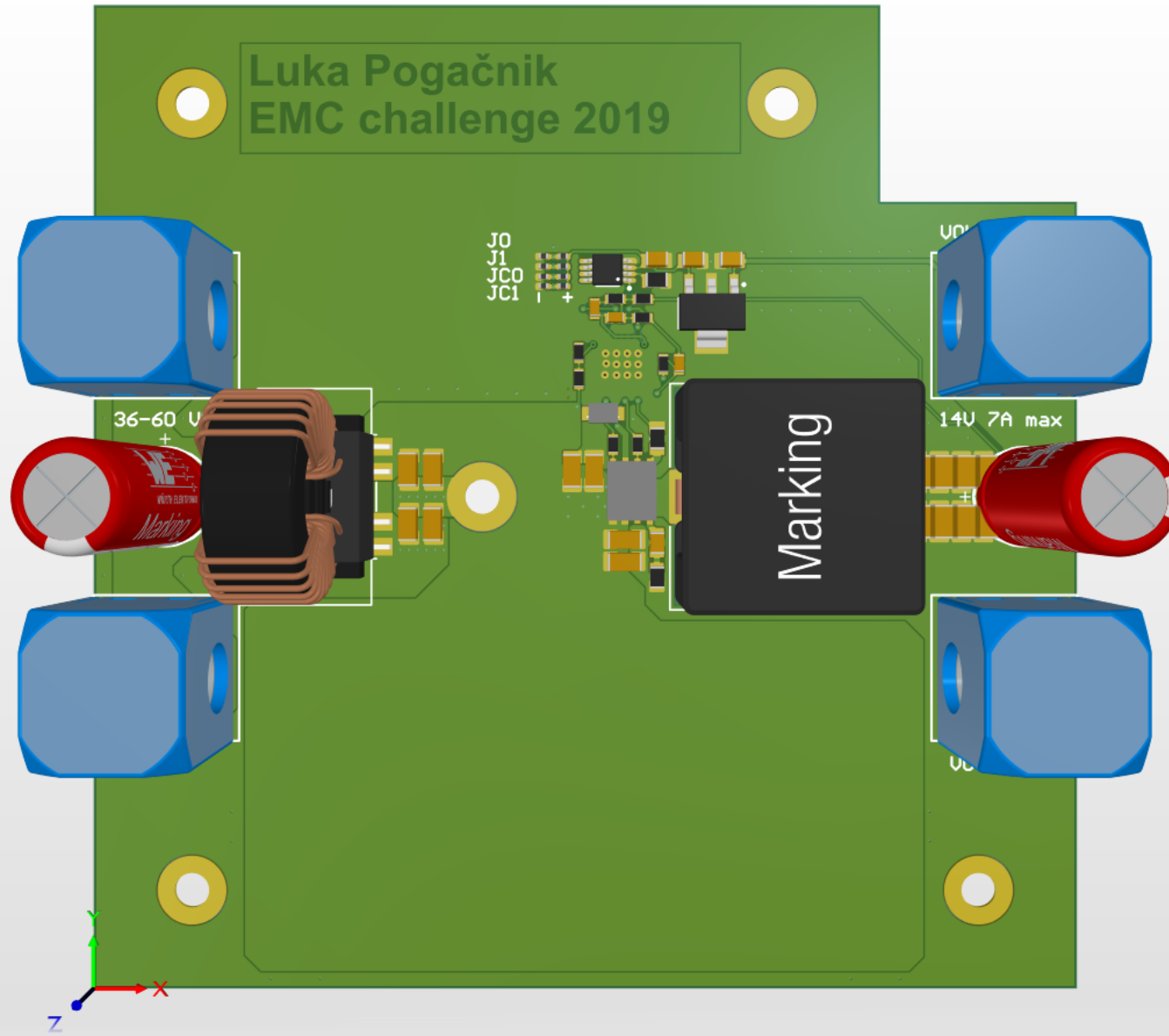
✓	74435588200	WE-HCI	2212	Single	82.0 µH	30.4 mΩ	7.00 A	8.50 A	5.00 MHz	22.5 mm	22.0 mm	12.4 mm	125°C	Shielded	1	x	MnZn	SMT
✓	74435586800	WE-HCI	2212	Single	68.0 µH	27.3 mΩ	7.50 A	9.50 A	5.80 MHz	22.5 mm	22.0 mm	12.4 mm	125°C	Shielded	1	x	MnZn	SMT

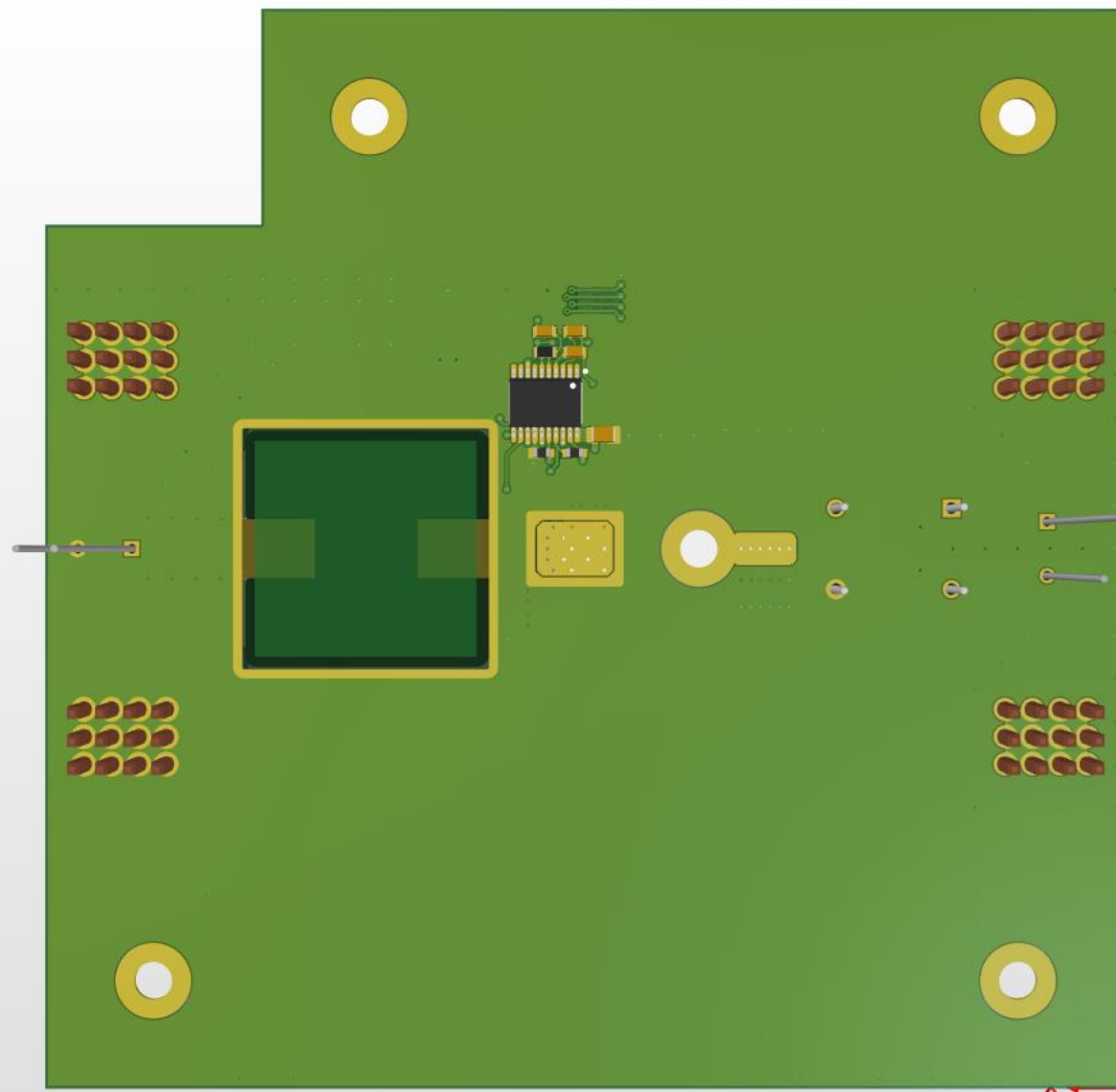
Temperature Rise / DC Current (20.0°C)



<input checked="" type="checkbox"/>	74435588200	WE-HCI	2212		Single	82.0 µH	30.4 mΩ	7.00 A	8.50 A	5.00 MHz	22.5 mm	22.0 mm	12.4 mm	125°C	Shielded	1	×	MnZn	SMT
<input checked="" type="checkbox"/>	74435586800	WE-HCI	2212		Single	68.0 µH	27.3 mΩ	7.50 A	9.50 A	5.80 MHz	22.5 mm	22.0 mm	12.4 mm	125°C	Shielded	1	×	MnZn	SMT







Vsak zna narest switcher

- doc. dr. Marko Jankovec

uvodno predavanje EMC delavnice 2019





Your PC ran into a problem and needs to restart. We're just collecting some error info, and then we'll restart for you.

20% complete



For more information about this issue and possible fixes, visit <https://www.windows.com/stopcode>

If you call a support person, give them this info:

Stop code: CRITICAL_PROCESS_DIED

Vsak zna narest switcher

- doc. dr. Marko Jankovec

uvodno predavanje EMC delavnice 2019

Glasujte za projekte

- <https://forms.gle/2xmfhwprNKmE7epr6>

