Načrtovanje elektronike za EMC² 2025

študentska delavnica in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

FORVIA

HELLA

INSTRUMENTATION TECHNOLOGIES

iskraemeco BY ELSEWEDY ELECTRIC

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AMITEH

GEMmotors

SIQ

Hella

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svet ELEKTRONIKE

AURORA

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Predstavitve konceptualnih rešitev

Izziv

0 % - 45%:

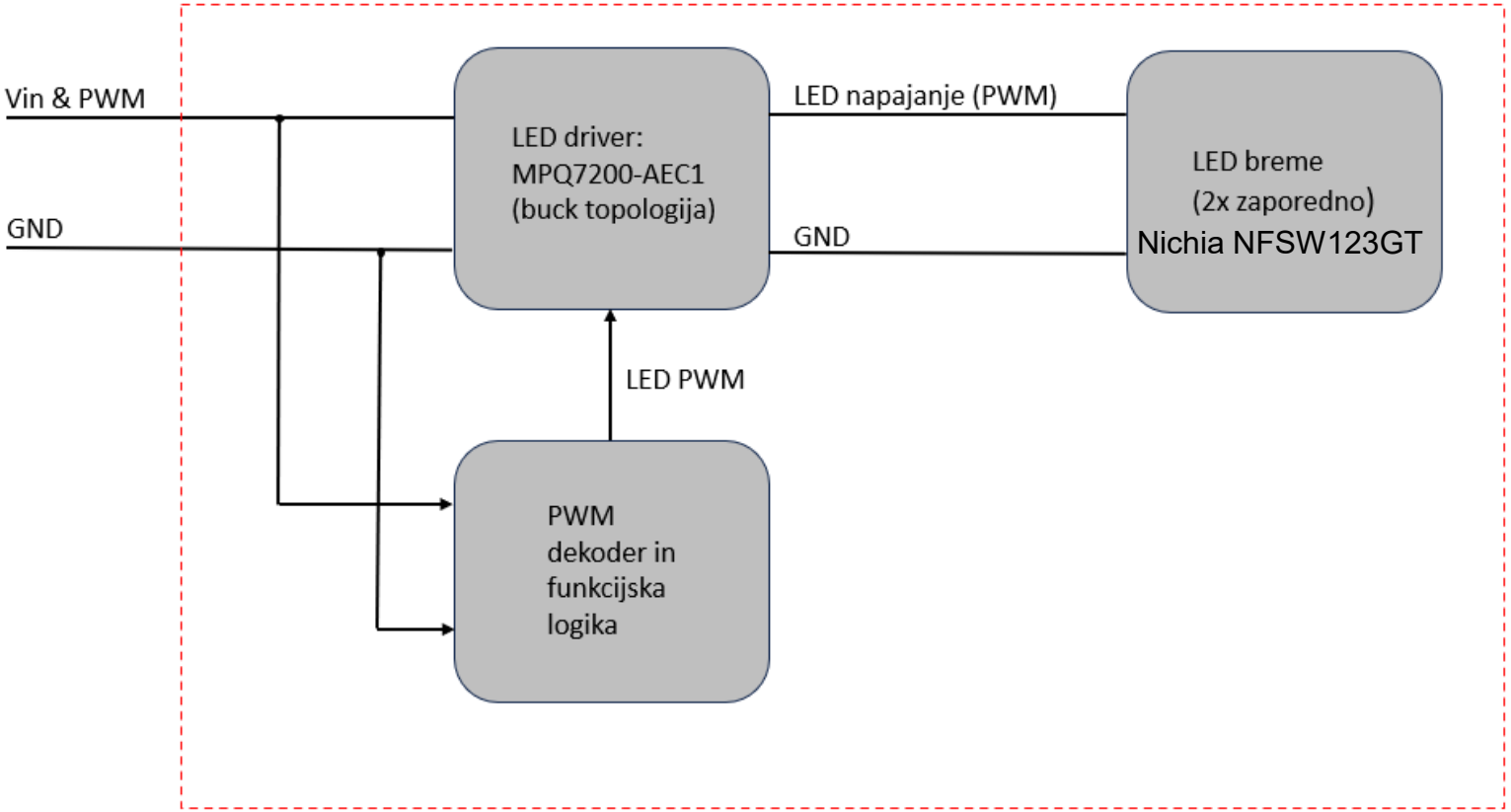
LED off

60 % - 80%:

LED 10%

95 % - 100%:

LED on



Možnosti krmiljenja MPQ7200A

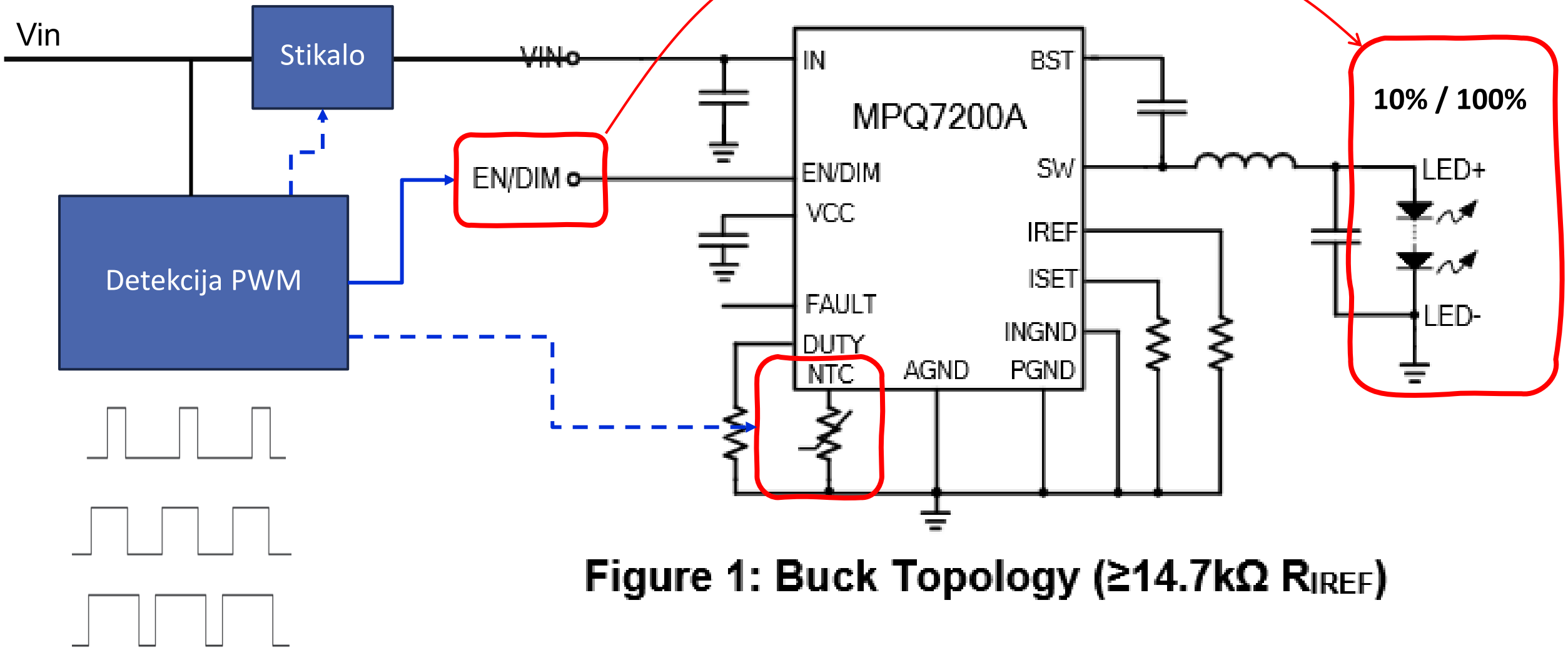
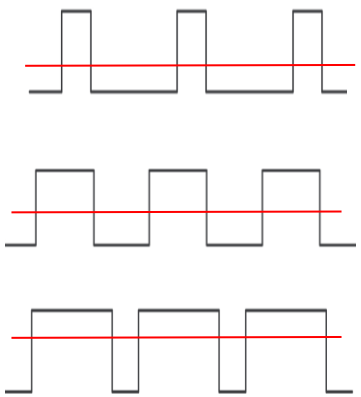
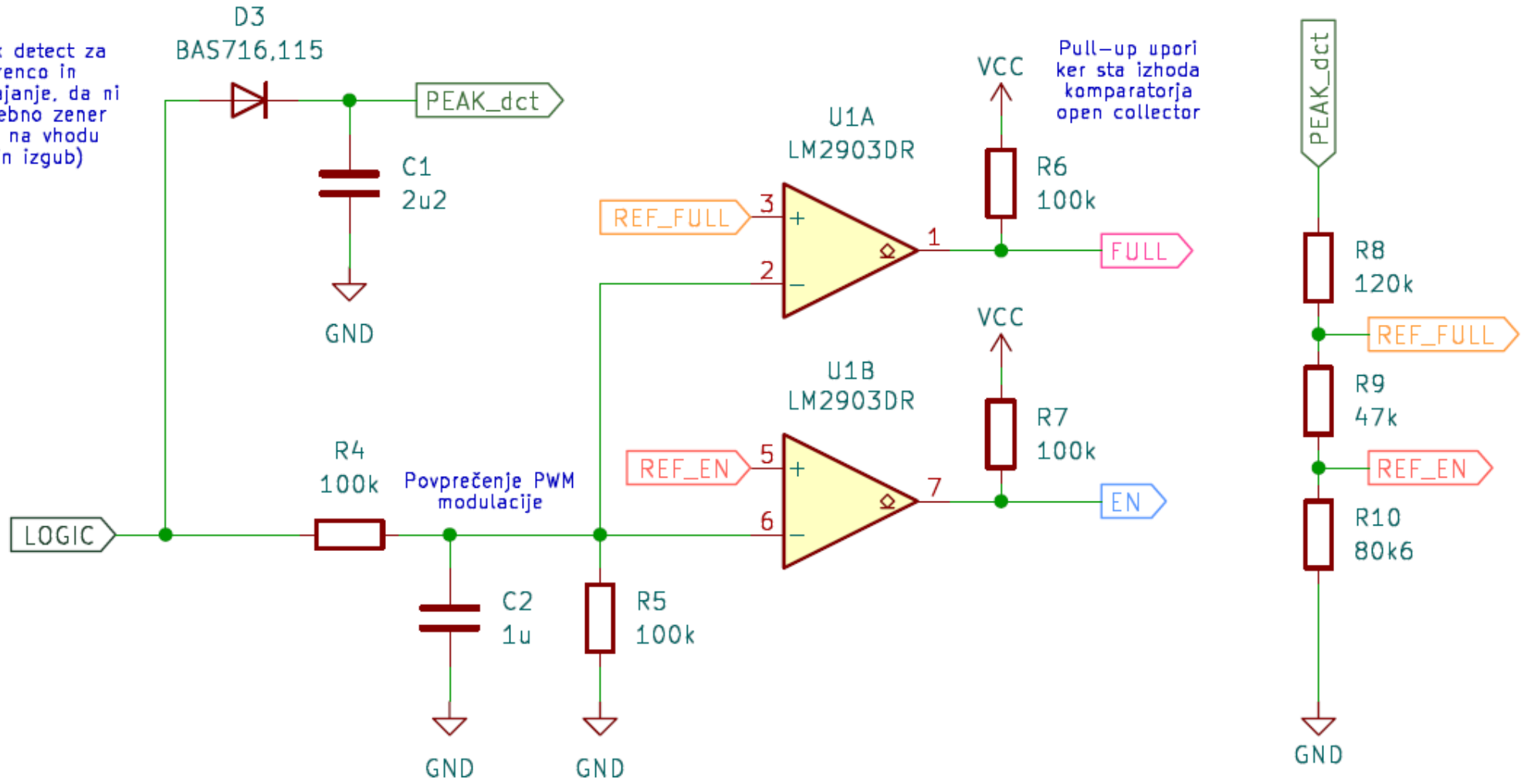


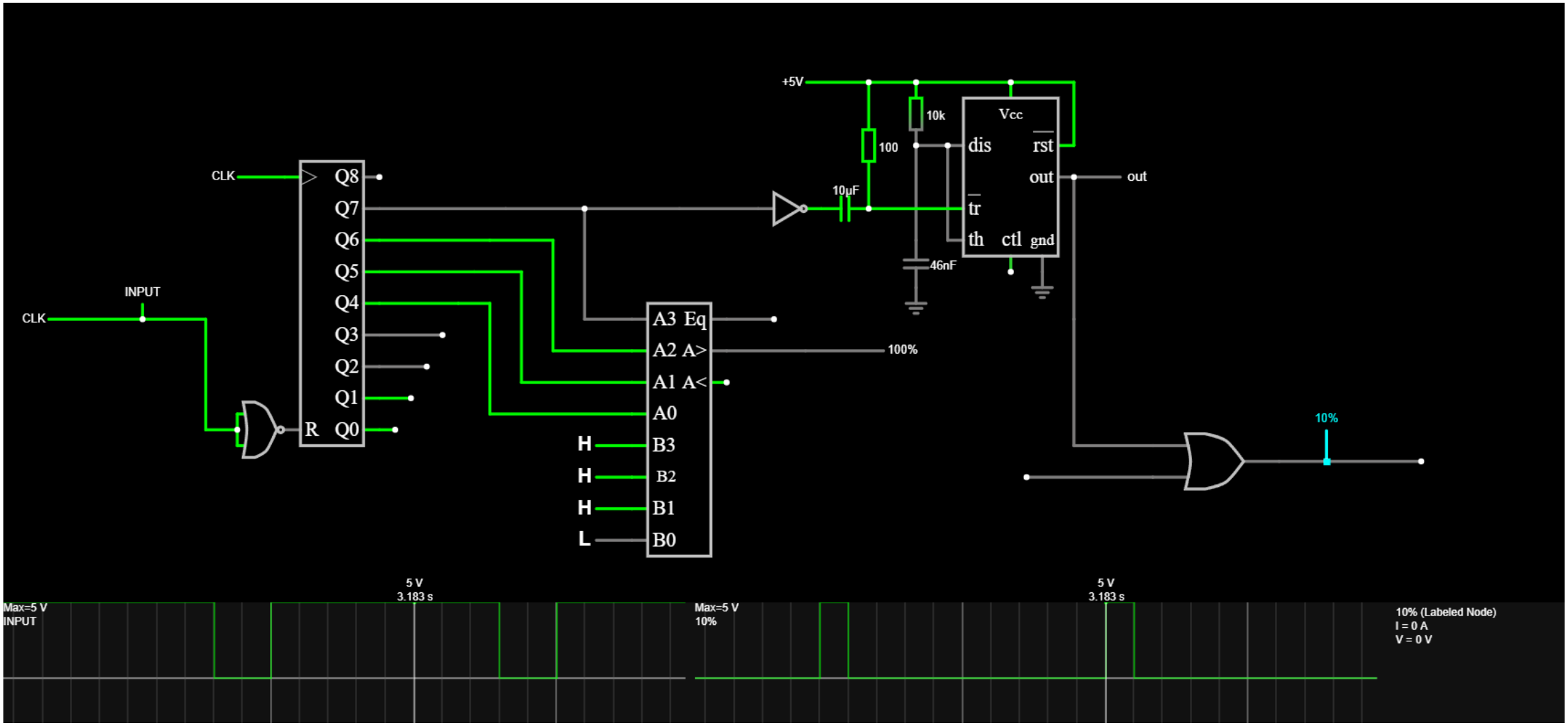
Figure 1: Buck Topology (≥14.7kΩ R_{IREF})

Detekcija PWM: Analogna z RC in primerjalniki

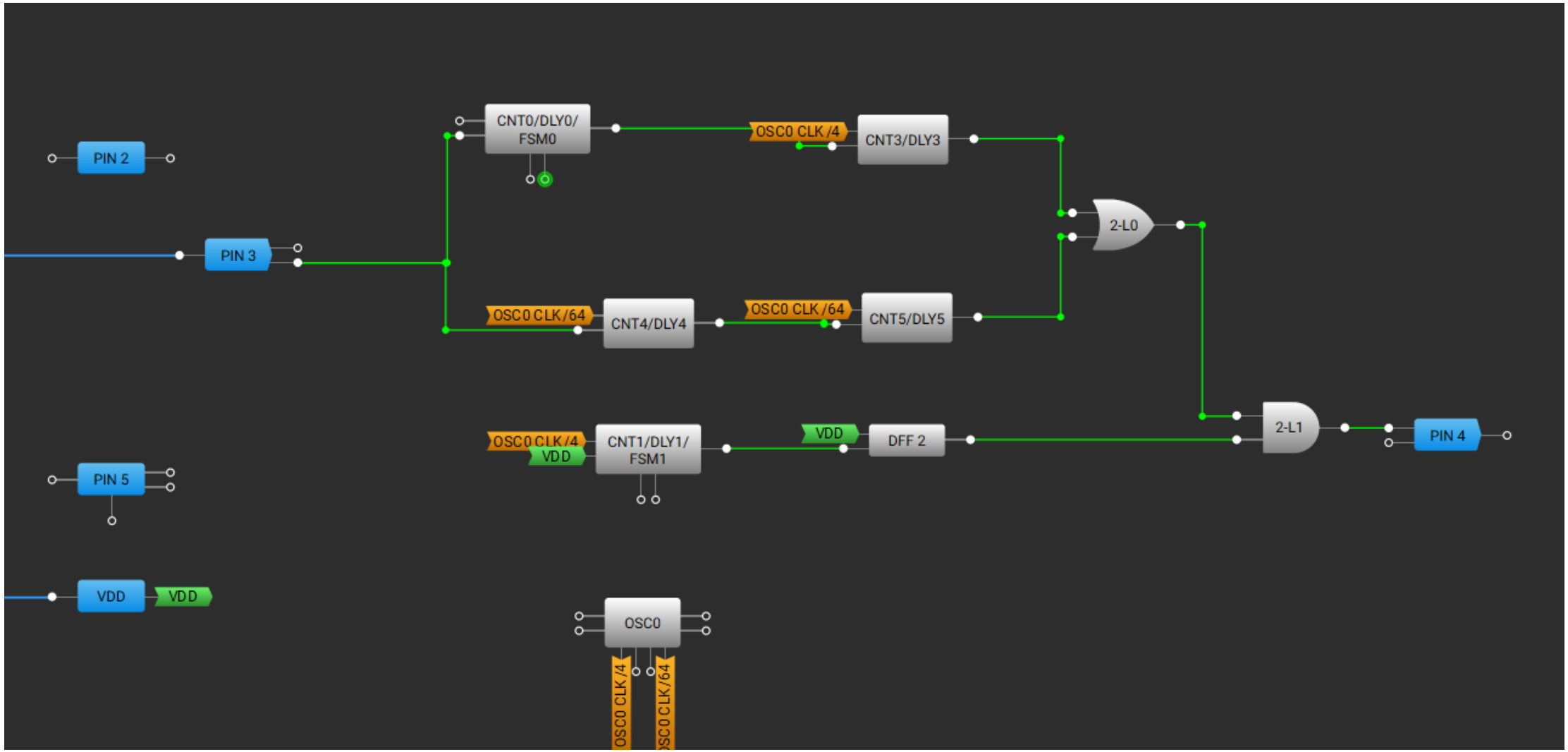




Detekcija PWM: Digitalna meritev časa z logiko



Detekcija PWM: Meritev časa z Renesas GreenPAK



Direktna generacija PWM za LED

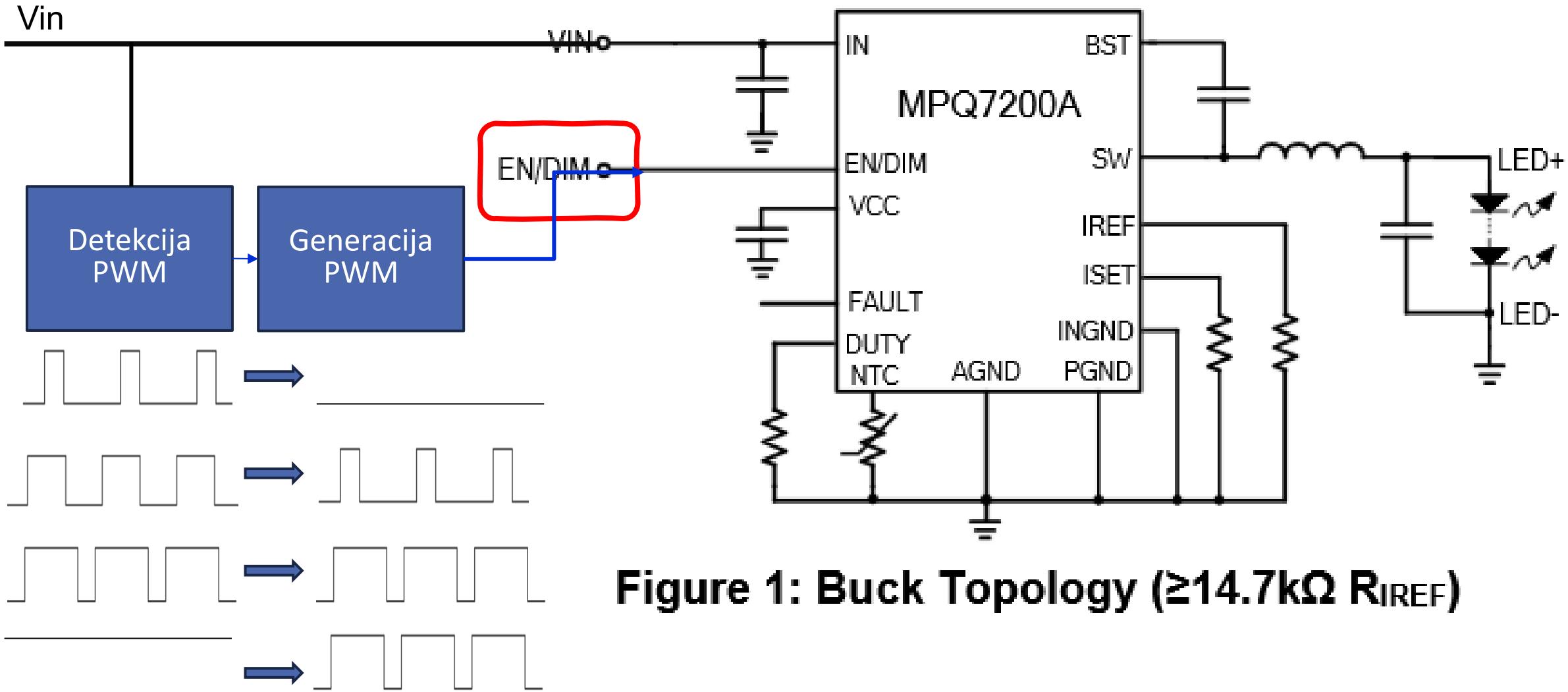
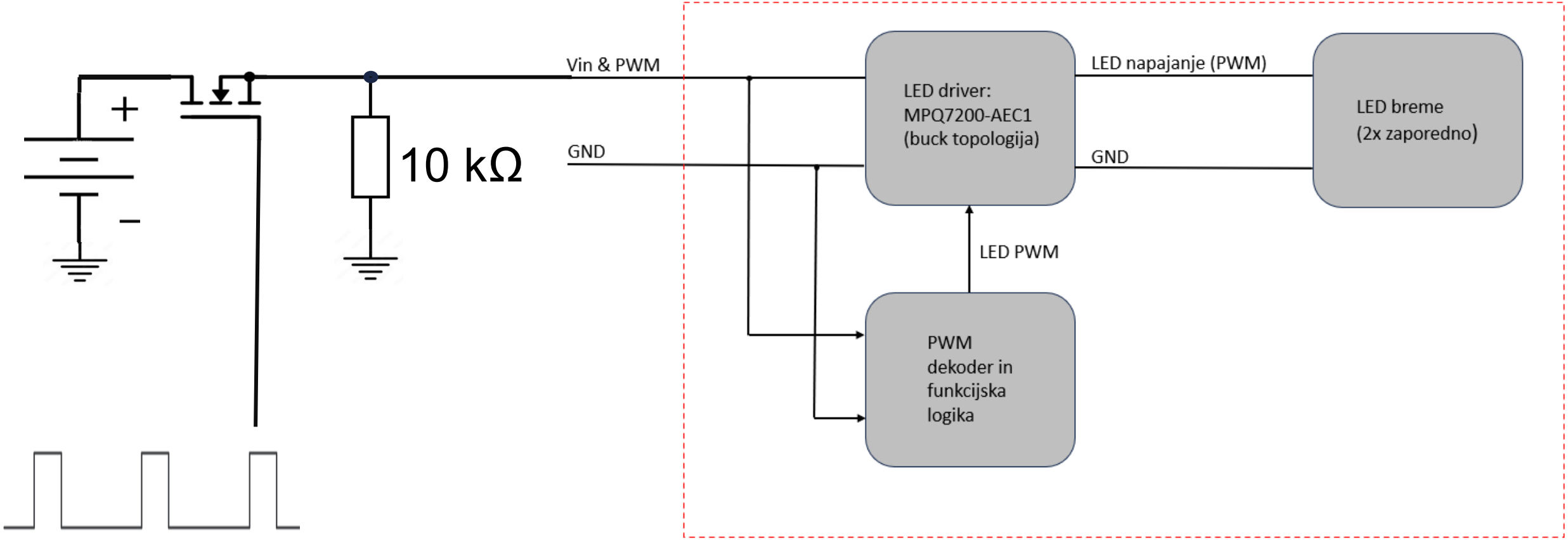
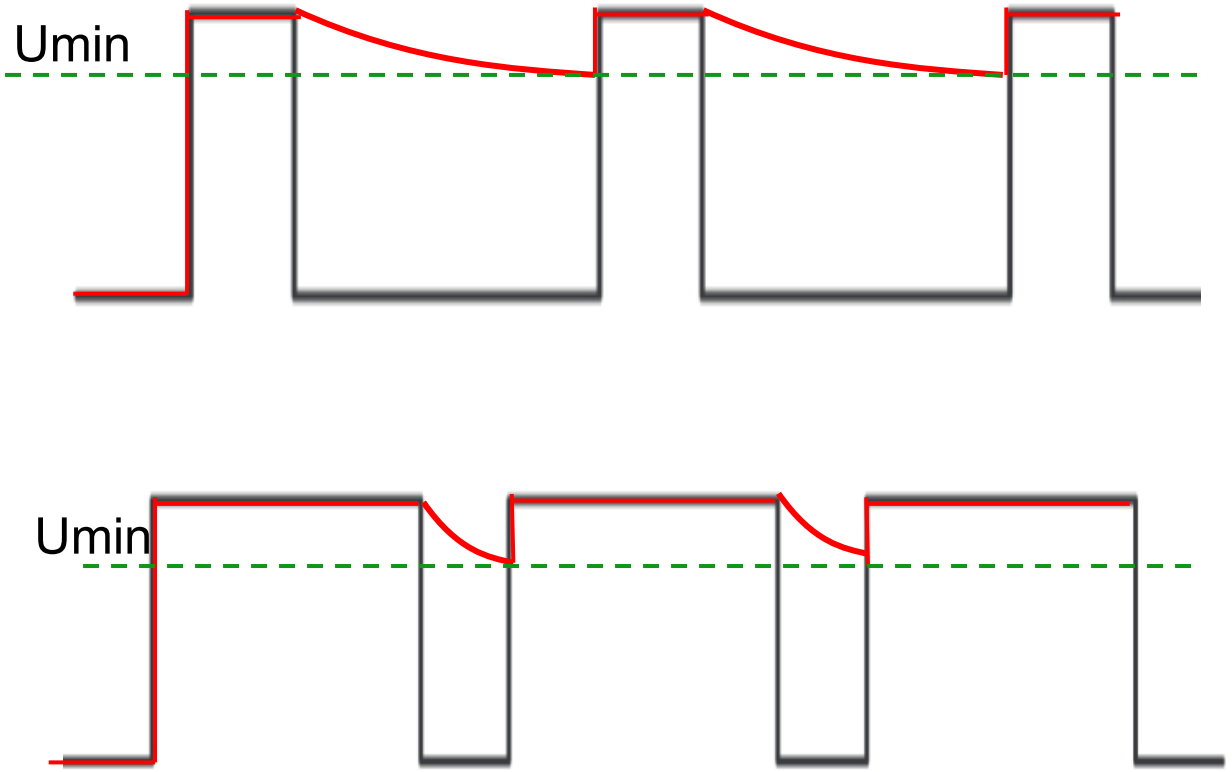


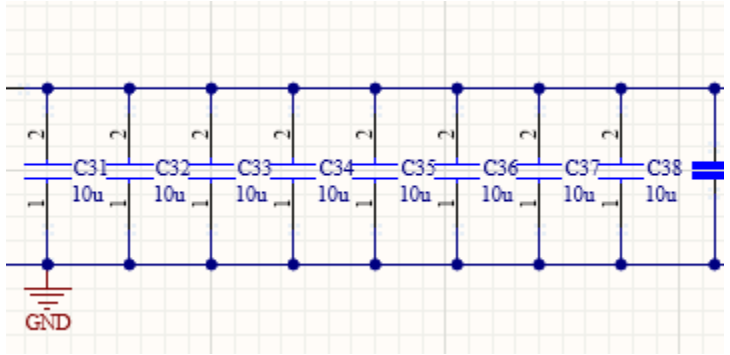
Figure 1: Buck Topology (≥14.7kΩ R_{IREF})

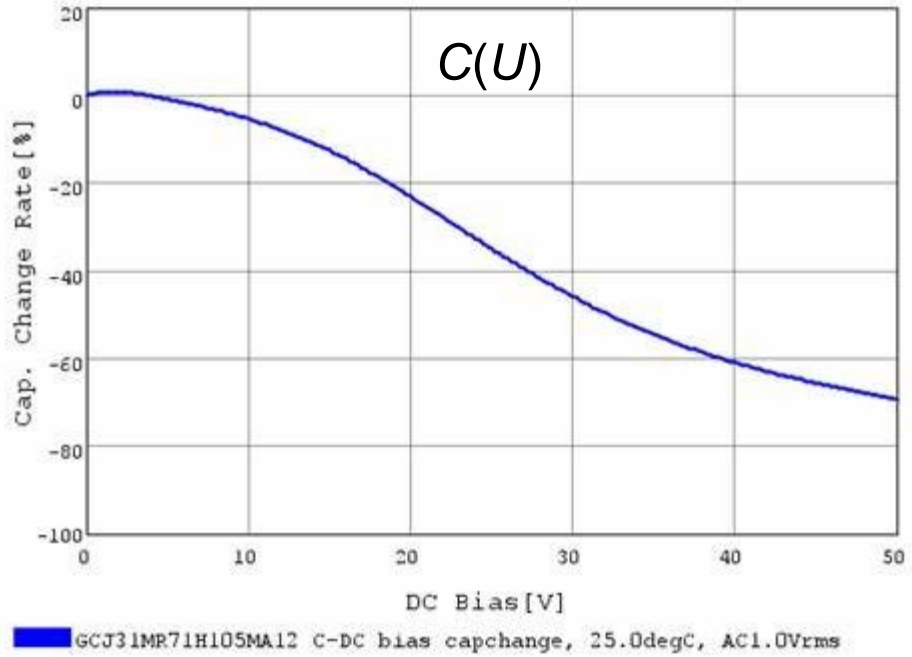
Prilagoditev na vir napajanja s PWM



Vhodna kapacitivna banka

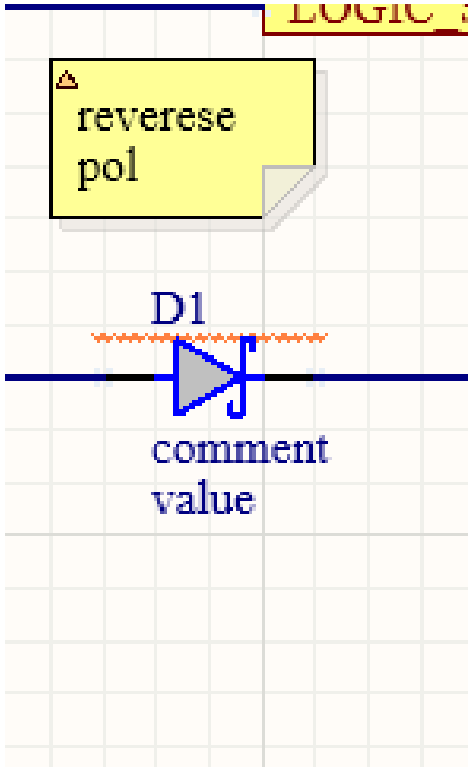




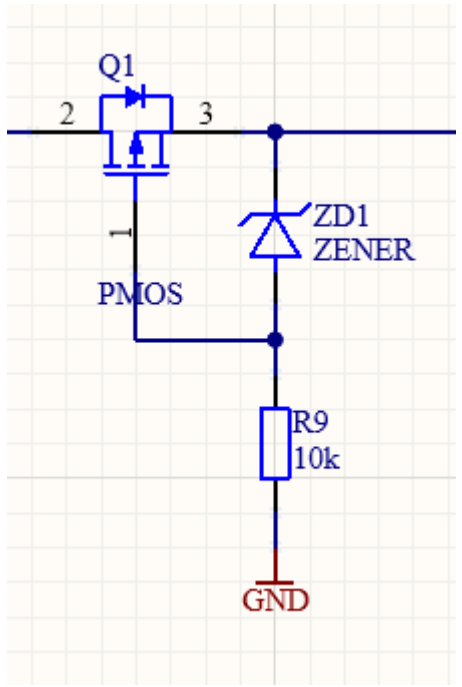


Zaščita pred obratno polariteto

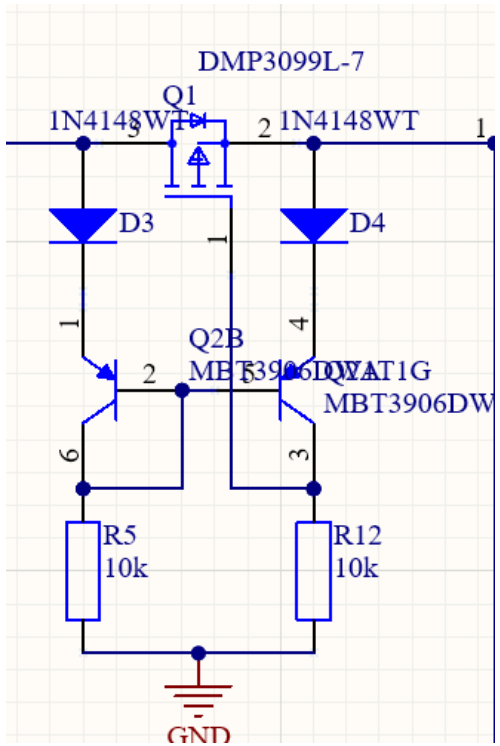
Za ziheraše



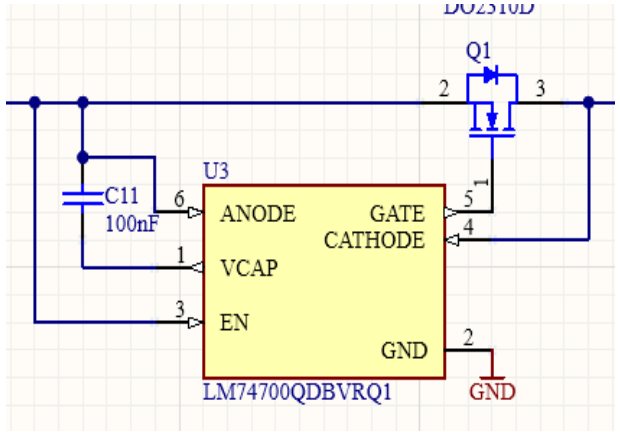
Za varčne



Za znajdljive



Za bogate



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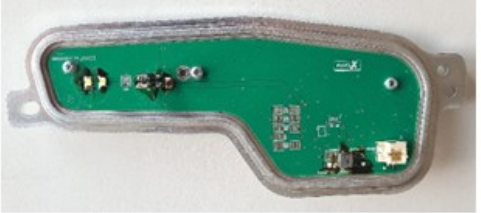
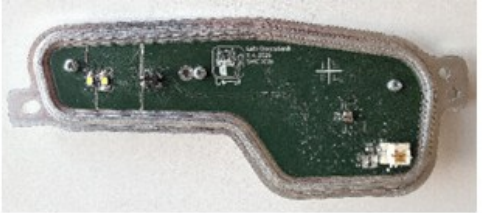
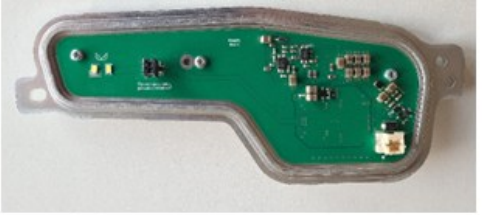
in optoelektroniko

Predstavitve projektov in rezultati

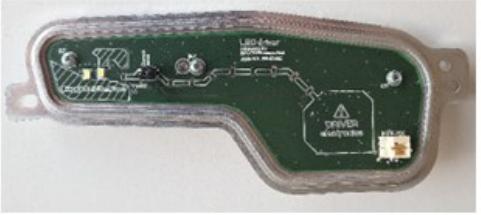
Oddani projekti

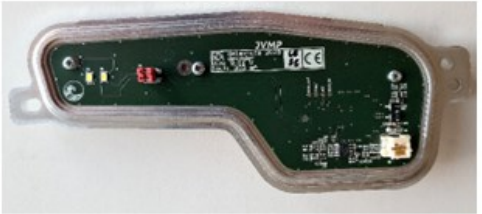

Debeljak


Domadenik

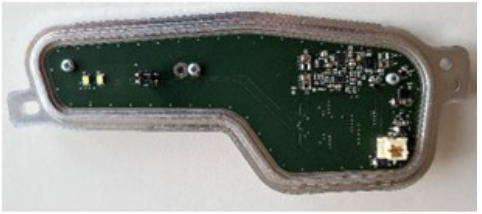

Krajnik


Peršolja


Leskovec


Meh Peer


Pavlin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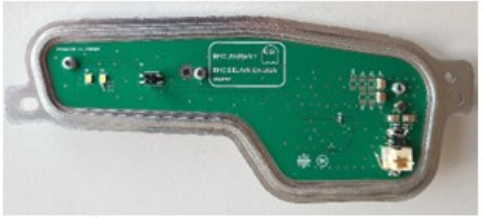
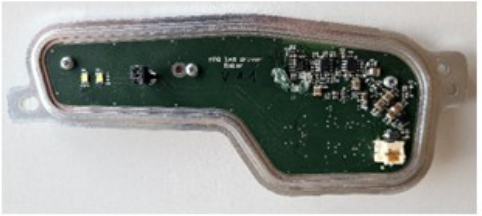
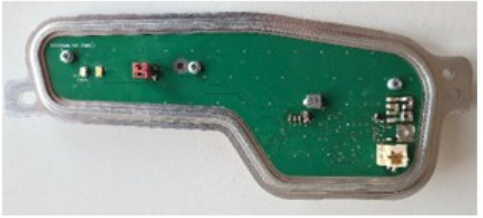
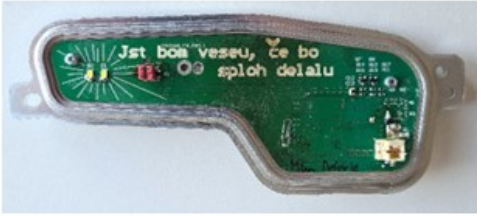
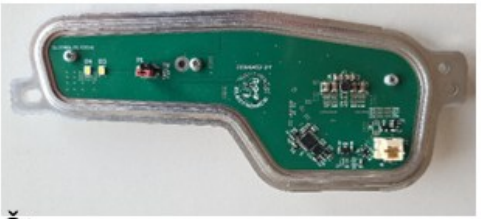

Papež

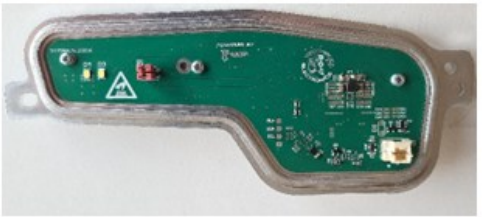

Rakar

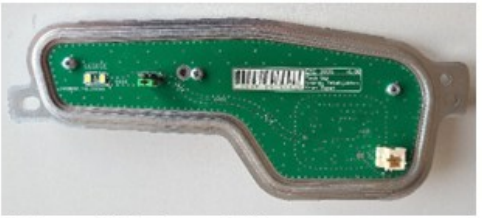

Kaurin



Peterle


Šturm


Pokovec/Zaplata


Zupet/Teleyukhin

Kavčič

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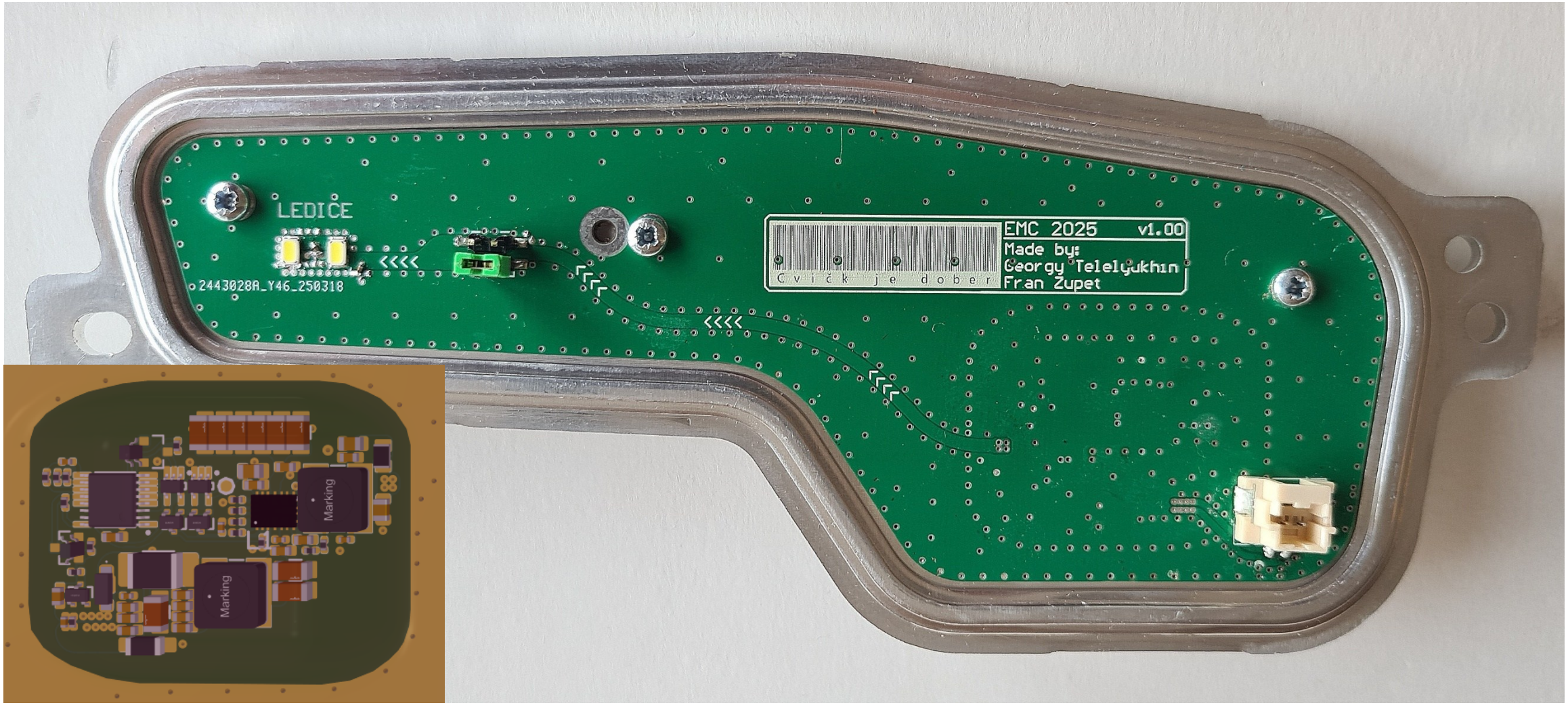
FE UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

Georgy Telelyukhin / Fran Zupet

2. letnik, VS-EL

Georgy Telelyukhin / Fran Zupet



Koncept rešitve

- Generali bomo **svoj PWM**
- Cena logike pod **20c**
- **Digitalna** logika, torej, večja **odpornost** na motnje?
- **Zanimiva** ne standardna rešitev, aka **NE komparator**
- Vse komponente **pod** hladilnikom

Shema logike

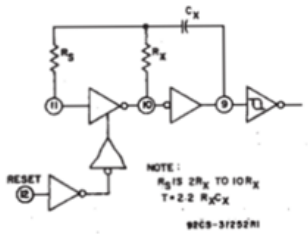


Fig. 12 – Typical RC circuit.

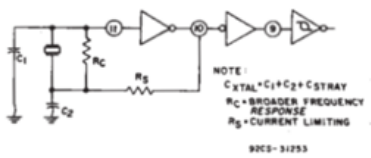
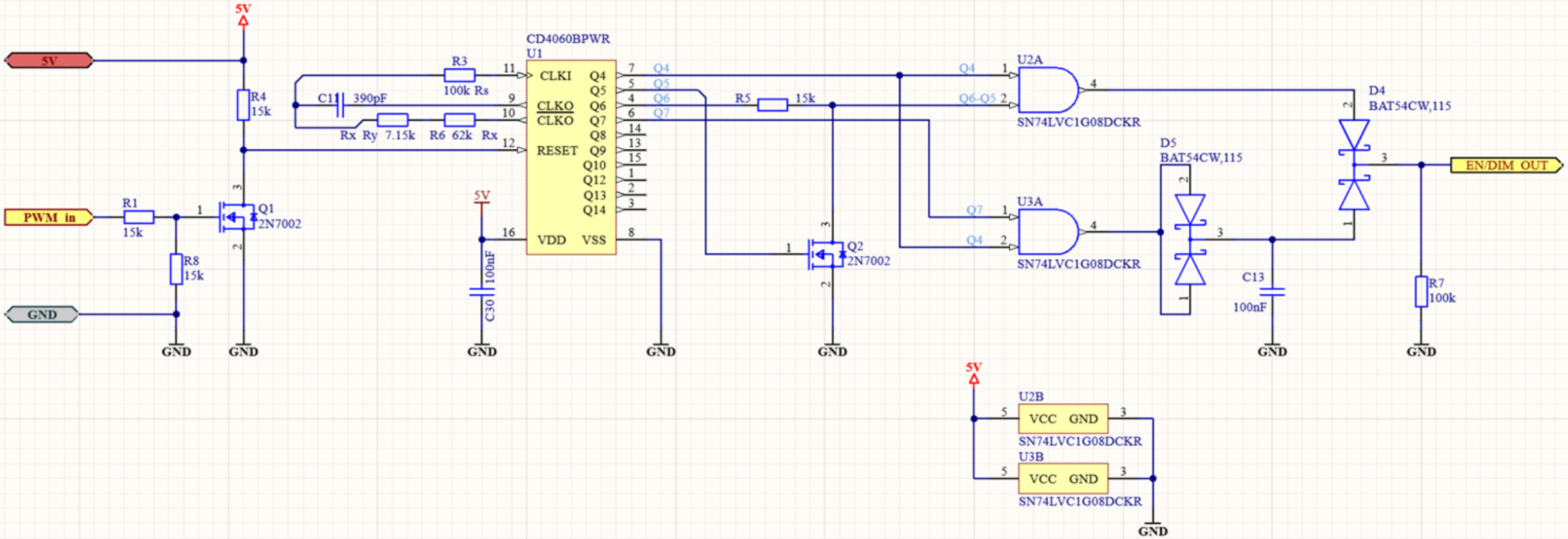
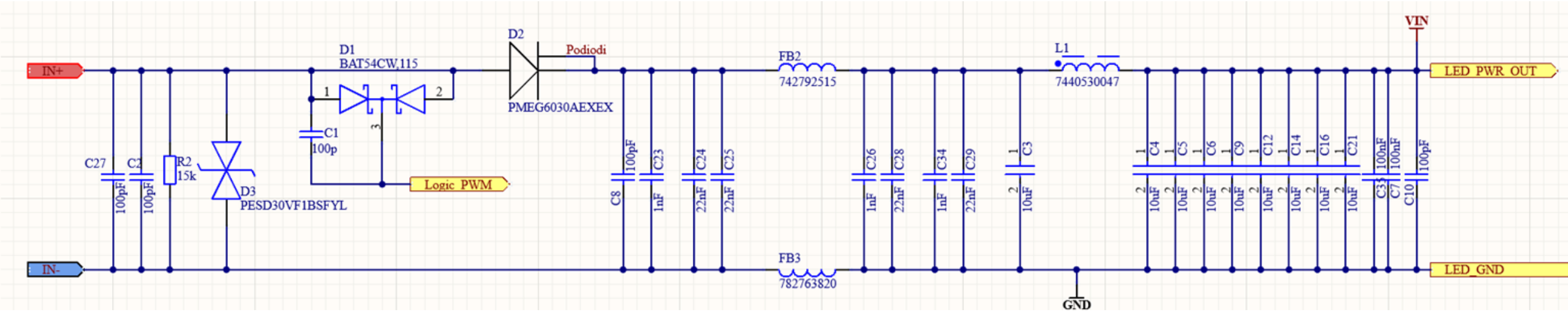


Fig. 13 – Typical crystal circuit.

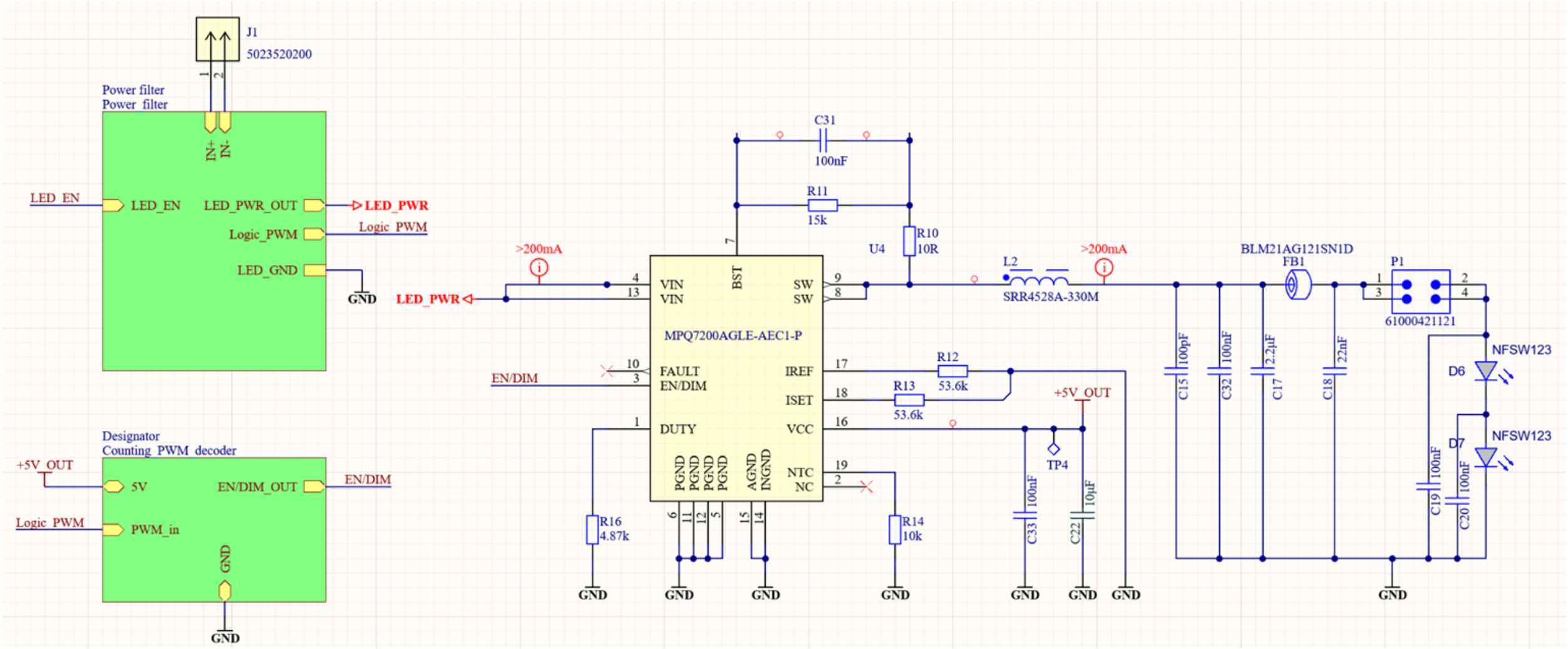
Binary counter oscilating with a Q4 friquency 1/10 of the PWM triggers pulses at 40 and 72 counts which results in one puls once at the 50% and once at the 90% 0f the PWM length. pulse at 90% is extended using a capacitor. This provides a reliable timing scheme as long as C3 and R6 are temperature stable.
R6 = 62k+10k or idk



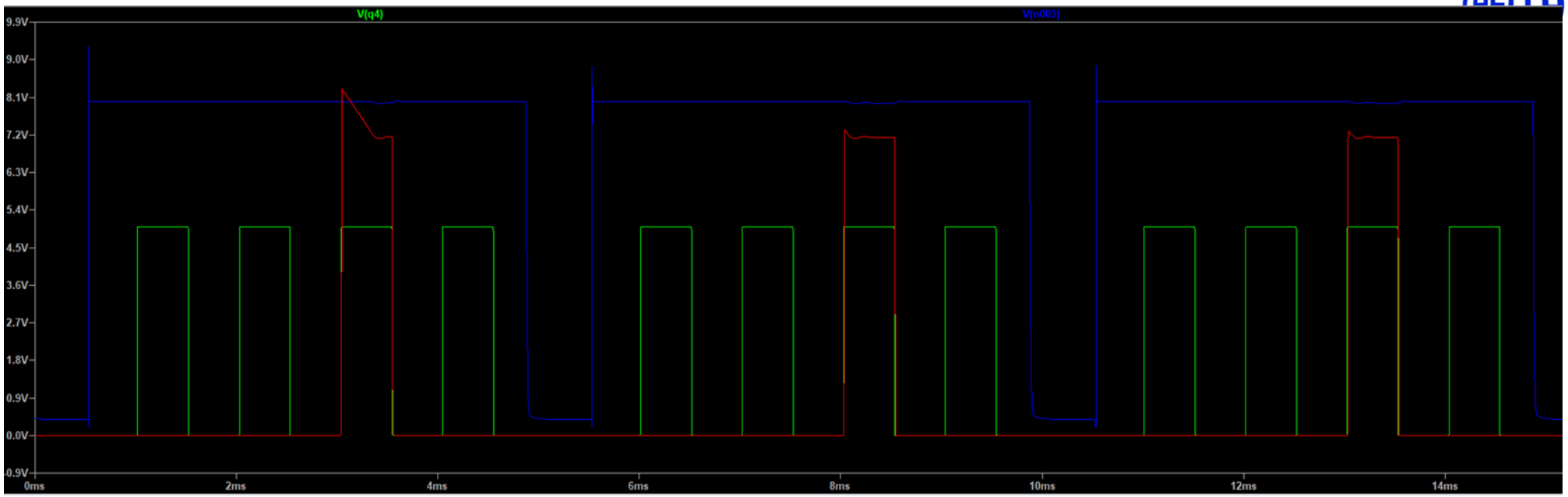
Shema Filtra



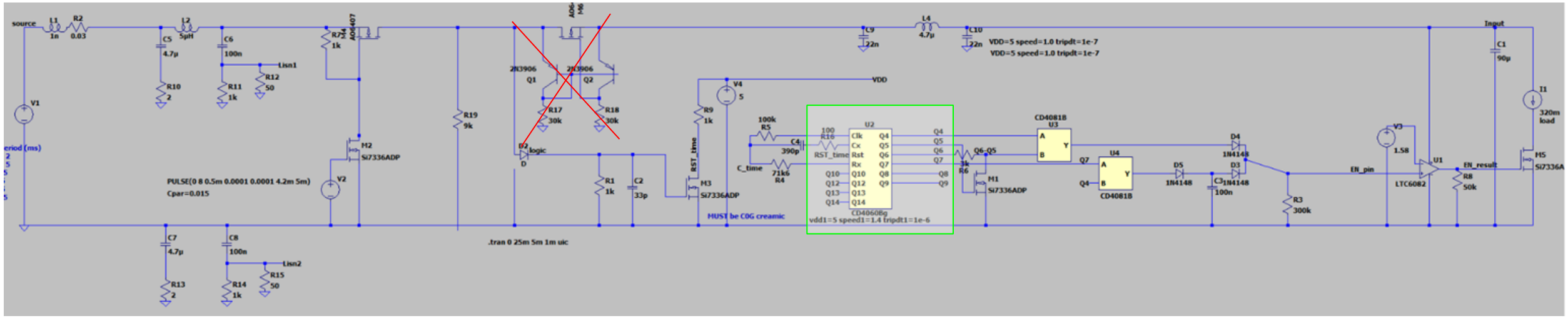
Celotna shema



Izračuni simulacije



Funkcionalna simulacija



friquency h	duty %	ON time(m	period (ms)
220,00	45,00	2,05	4,55
180,00	45,00	2,50	5,56
220,00	60,00	2,73	4,55
180,00	60,00	3,33	5,56
220,00	80,00	3,64	4,55
180,00	80,00	4,44	5,56
220,00	95,00	4,32	4,55
180,00	95,00	5,28	5,56
200,00	10,00	0,50	5,00
200,00	45,00	2,25	5,00
200,00	60,00	3,00	5,00
	80,00	4,00	5,00
	95,00	4,75	5,00

2,50	2,73	4,38
zagotovo ne gori	zagotovo sveti 60%	zagotovo gori 95%
do 45%	do 80%	po 87%

Rs value	Rx value [kOHM]	Cx value [nF]	Q4 [ms]	Q5 [ms]	Q6 [ms]	željeno	delta
143,21	71,61	0,390	0,50000	1,00000	2,00000	0,50000	0,0%
143,21	71,61	0,390	0,50000	1,00000	2,00000	0,50000	0,0%
143,21	71,61	0,390	0,50000	1,00000	2,00000	0,50000	0,0%
143,21	71,61	0,390	0,50000	1,00000	2,00000	0,50000	0,0%

q5 & q6 =50

Inductor calculation

	L [uH]	dI % shoul	I led	Uin	Uout
Max	55,69835	40	0,300	16	6,3
Min	19,52313	dL A	Iavg inductor	8	
Avg	37,61074	0,167	0,418		
Actual	33		Ipeak inductor		
			0,502		

Iset resistor [kOhm]

53,33333

Input capacitor

	Capacitor RMS curren	dUin	Cin
Max	0,150	0,001858155	0,000094
Min	0,123	0,001302624	
Avg	0,136	0,002	

Output capacitor

dUout	Cout	ESR
2,1516E-08	0,000002	0,5

Filters F is from 320-410-500kHz

410000

Power budget

85	minimalni izkoristek (zahteva)	
92	dejanski izkoristek konvertorja	padec na glavni diodi
		0,33 U
Pmax[W]	Psvičer	tok svičer	0,267842 I
2,223529	2,054348	0,267842	0,088388 P
P ledice	P dejanska	margin	
1,89	2,142736	0,080794	

Standard Capacitor Values (~10%)

10pF	100pF	1000pF	.010uF	.10uF	1.0uF	10uF
12pF	120pF	1200pF	.012uF	.12uF	1.2uF	
15pF	150pF	1500pF	.015uF	.15uF	1.5uF	
18pF	180pF	1800pF	.018uF	.18uF	1.8uF	
22pF	220pF	2200pF	.022uF	.22uF	2.2uF	22uF
27pF	270pF	2700pF	.027uF	.27uF	2.7uF	
33pF	330pF	3300pF	.033uF	.33uF	3.3uF	33uF
39pF	390pF	3900pF	.039uF	.39uF	3.9uF	
47pF	470pF	4700pF	.047uF	.47uF	4.7uF	47uF
56pF	560pF	5600pF	.056uF	.56uF	5.6uF	
68pF	680pF	6800pF	.068uF	.68uF	6.8uF	
82pF	820pF	8200pF	.082uF	.82uF	8.2uF	
0.082nF	0.82nF	8.2nF	82nF	820nF	8200nF	

Standard Resistor Values (~5%)

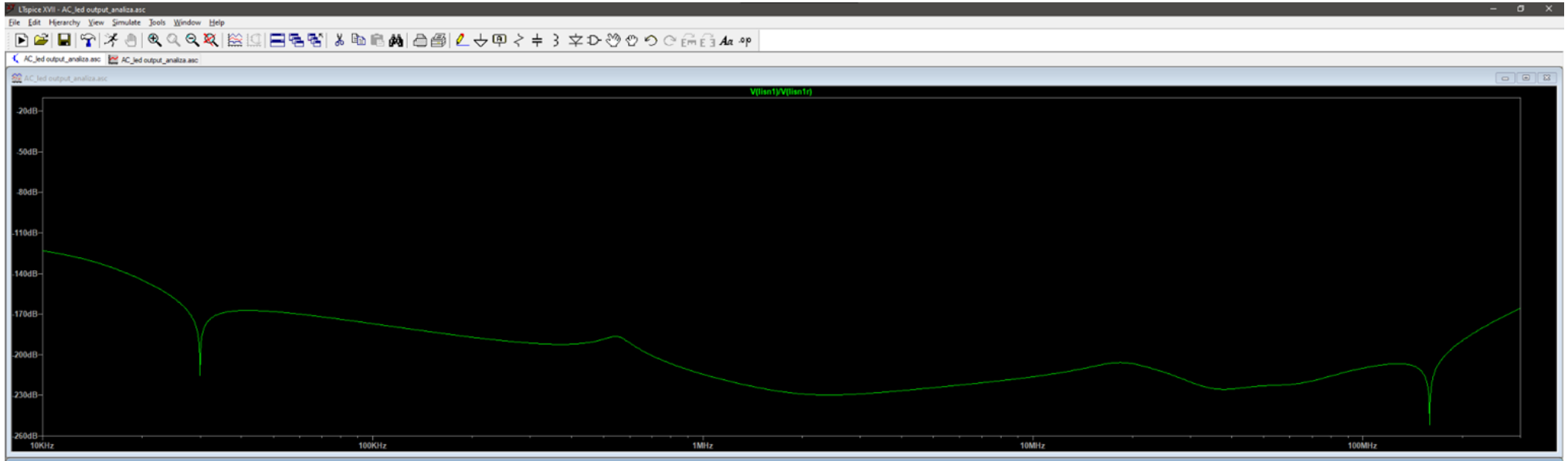
1	10	100	1.0K	10K	100K	1.0M
1.1	11	110	1.1K	11K	110K	1.1M
1.2	12	120	1.2K	12K	120K	1.2M
1.3	13	130	1.3K	13K	130K	1.3M
1.5	15	150	1.5K	15K	150K	1.5M
1.6	16	160	1.6K	16K	160K	1.6M
1.8	18	180	1.8K	18K	180K	1.8M
2	20	200	2.0K	20K	200K	2.0M
2.2	22	220	2.2K	22K	220K	2.2M
2.4	24	240	2.4K	24K	240K	2.4M
2.7	27	270	2.7K	27K	270K	2.7M
3	30	300	3.0K	30K	300K	3.0M
3.3	33	330	3.3K	33K	330K	3.3M
3.6	36	360	3.6K	36K	360K	3.6M
3.9	39	390	3.9K	39K	390K	3.9M
4.3	43	430	4.3K	43K	430K	4.3M
4.7	47	470	4.7K	47K	470K	4.7M
5.1	51	510	5.1K	51K	510K	5.1M
5.6	56	560	5.6K	56K	560K	5.6M
6.2	62	620	6.2K	62K	620K	6.2M
6.8	68	680	6.8K	68K	680K	6.8M
7.5	75	750	7.5K	75K	750K	7.5M
8.2	82	820	8.2K	82K	820K	8.2M
9.1	91	910	9.1K	91K	910K	9.1M

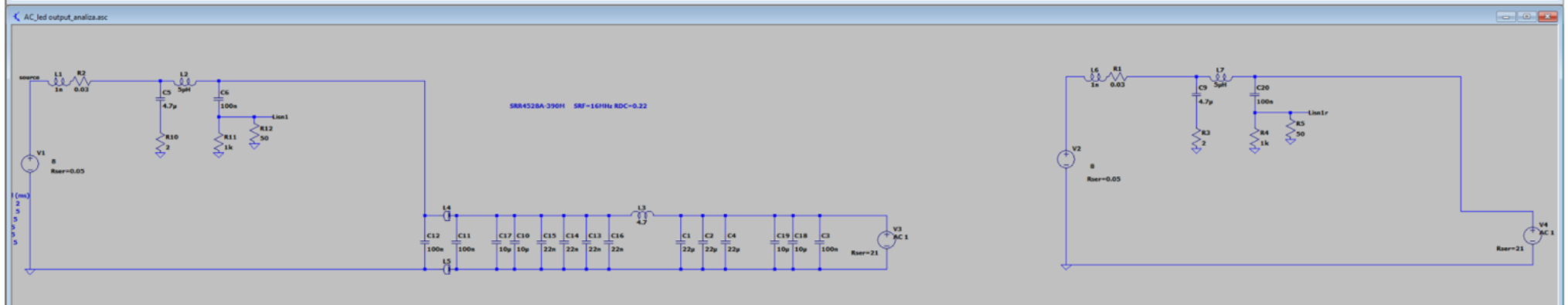
0	0	0	0	0	0	0	0	0		
1	0	0	0	0	0	0	0	1		
2	0	0	0	0	0	0	1	0		
3	0	0	0	0	0	0	1	1		
4	0	0	0	0	0	1	0	0		
5	0	0	0	0	0	1	0	1		
6	0	0	0	0	0	1	1	0		
7	0	0	0	0	0	1	1	1		
8	0	0	0	0	1	0	0	0		
9	0	0	0	0	1	0	0	1		
10	0	0	0	0	1	0	1	0		
11	0	0	0	0	1	0	1	1		
12	0	0	0	0	1	1	0	0		
13	0	0	0	0	1	1	0	1		
14	0	0	0	0	1	1	1	0		
15	0	0	0	0	1	1	1	1		
16	0	0	0	1	0	0	0	0		
17	0	0	0	1	0	0	0	1		
18	0	0	0	1	0	0	1	0		
19	0	0	0	1	0	0	1	1		
20	0	0	0	1	0	1	0	0		
21	0	0	0	1	0	1	0	1		
22	0	0	0	1	0	1	1	0		
23	0	0	0	1	0	1	1	1		
24	0	0	0	1	1	0	0	0		
25	0	0	0	1	1	0	0	1		
26	0	0	0	1	1	0	1	0		
27	0	0	0	1	1	0	1	1		
28	0	0	0	1	1	1	0	0		
29	0	0	0	1	1	1	0	1		
30	0	0	0	1	1	1	1	0		
31	0	0	0	1	1	1	1	1		
32	0	0	1	0	0	0	0	0		
33	0	0	1	0	0	0	0	1		
34	0	0	1	0	0	0	1	0		
35	0	0	1	0	0	0	1	1		
36	0	0	1	0	0	1	0	0		
37	0	0	1	0	0	1	0	1		
38	0	0	1	0	0	1	1	0		
39	0	0	1	0	0	1	1	1		
40	0	0	1	0	1	0	0	0	sveti	Q4 & Q6 & -Q5
41	0	0	1	0	1	0	0	1		
42	0	0	1	0	1	0	1	0		
43	0	0	1	0	1	0	1	1		
44	0	0	1	0	1	1	0	0		
45	0	0	1	0	1	1	0	1		
46	0	0	1	0	1	1	1	0		
47	0	0	1	0	1	1	1	1		
48	0	0	1	1	0	0	0	0		
49	0	0	1	1	0	0	0	1		
50	0	0	1	1	0	0	1	0		
51	0	0	1	1	0	0	1	1		
52	0	0	1	1	0	1	0	0		
53	0	0	1	1	0	1	0	1		
54	0	0	1	1	0	1	1	0		
55	0	0	1	1	0	1	1	1		
56	0	0	1	1	1	0	0	0		
57	0	0	1	1	1	0	0	1		
58	0	0	1	1	1	0	1	0		
59	0	0	1	1	1	0	1	1		
60	0	0	1	1	1	1	0	0		
61	0	0	1	1	1	1	0	1		
62	0	0	1	1	1	1	1	0		
63	0	0	1	1	1	1	1	1		
64	0	1	0	0	0	0	0	0		
65	0	1	0	0	0	0	0	1		
66	0	1	0	0	0	0	1	0		
67	0	1	0	0	0	0	1	1		
68	0	1	0	0	0	1	0	0		
69	0	1	0	0	0	1	0	1		
70	0	1	0	0	0	1	1	0		
71	0	1	0	0	0	1	1	1		
72	0	1	0	0	1	0	0	0	gori	Q4 & Q7

50%

90%

Izračuni, simulacije

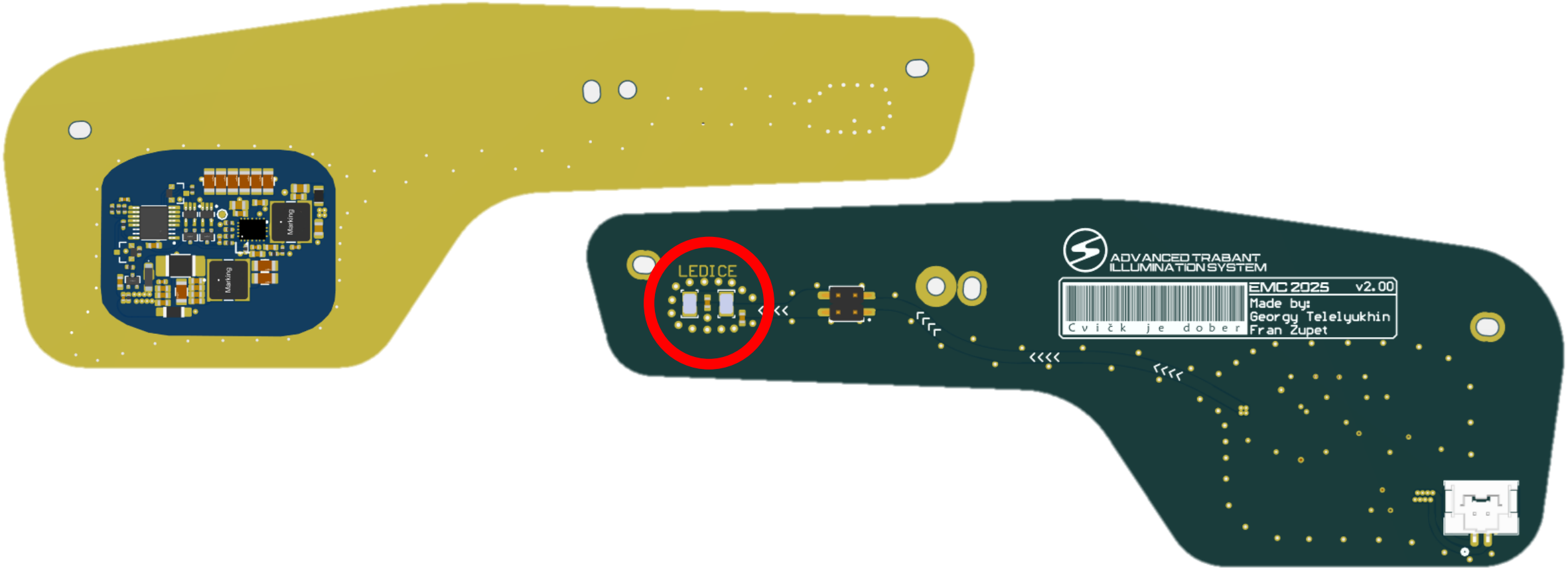




Filter iz referenčne sheme deluje zelo dobro

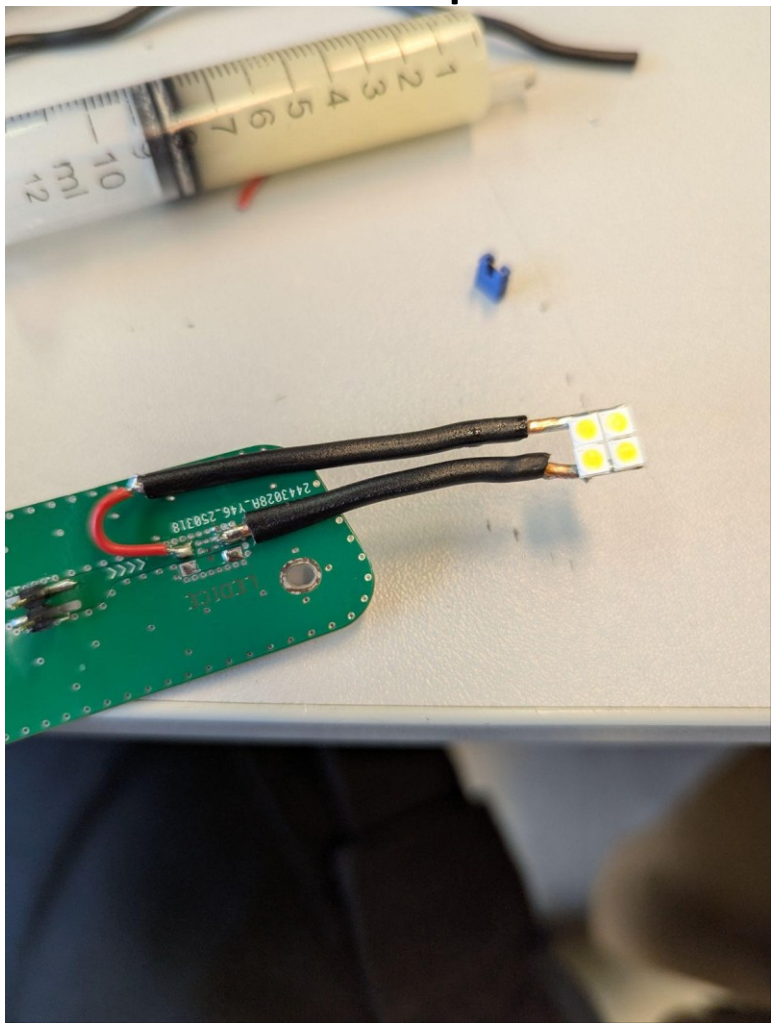
Načrtovanje tiskanega vezja

Vse komponente so na spodnji strani vezja pod aluminijastim ohišjem :)



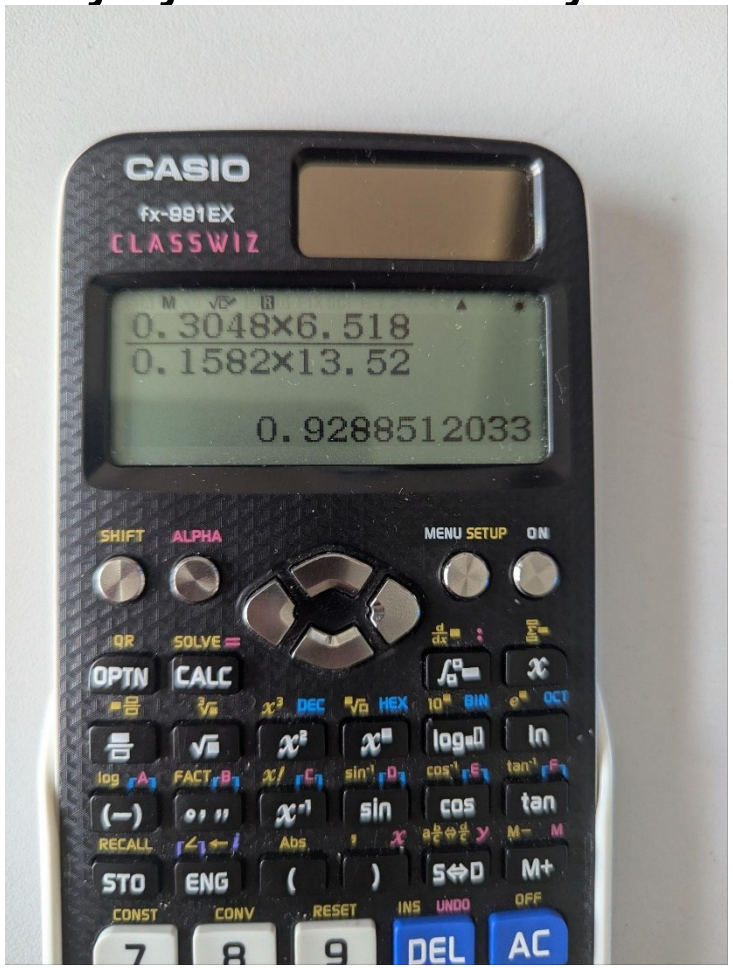
Načrtovanje tiskanega vezja

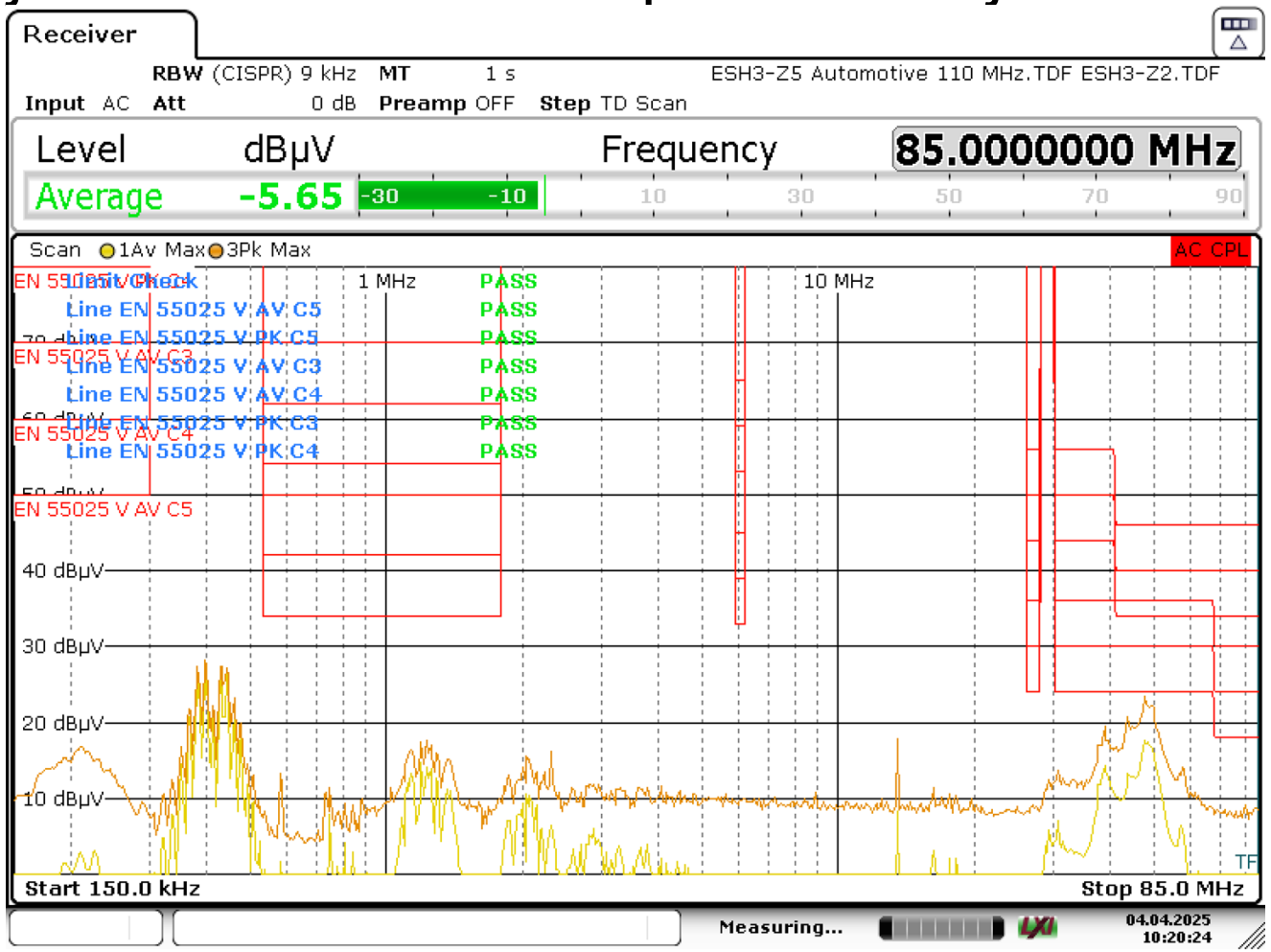
Vezje je bilo sestavljeno in je delalo že en mesec pred deadlajnom.



Načrtovanje tiskanega vezja

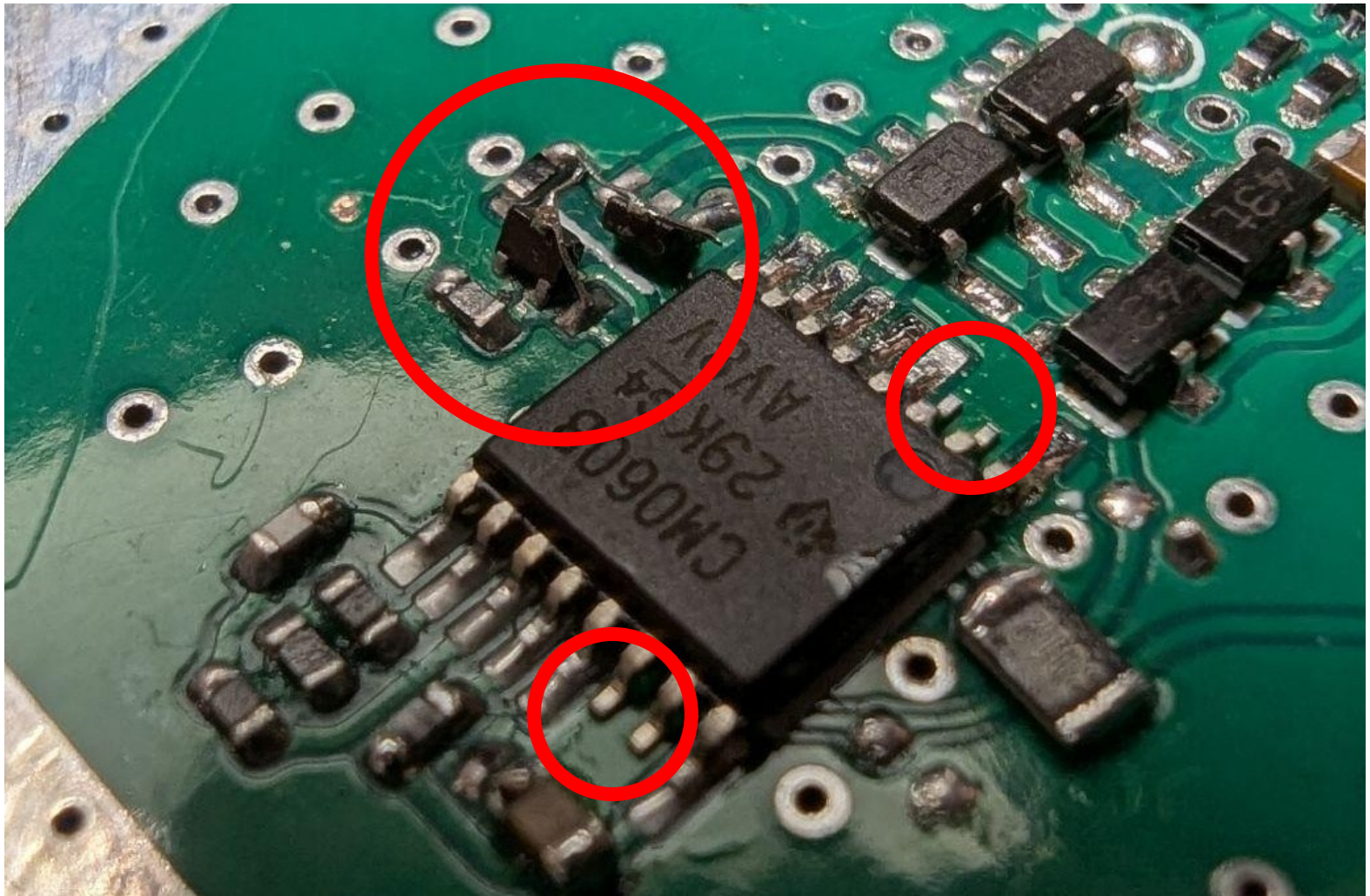
Vezje je bilo sestavljeno in je delalo že en mesec pred deadlajnom.



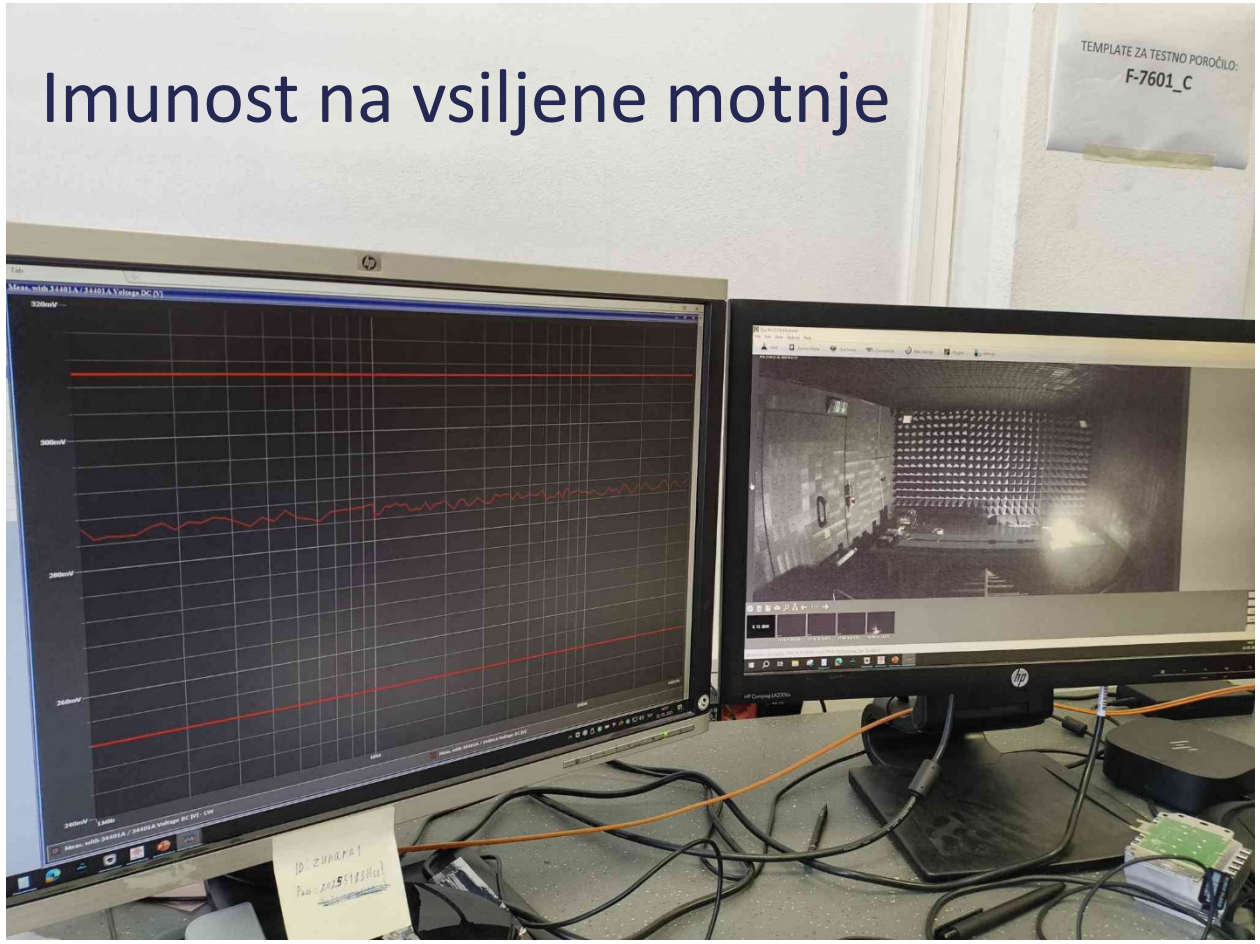


Načrtovanje tiskanega vezja

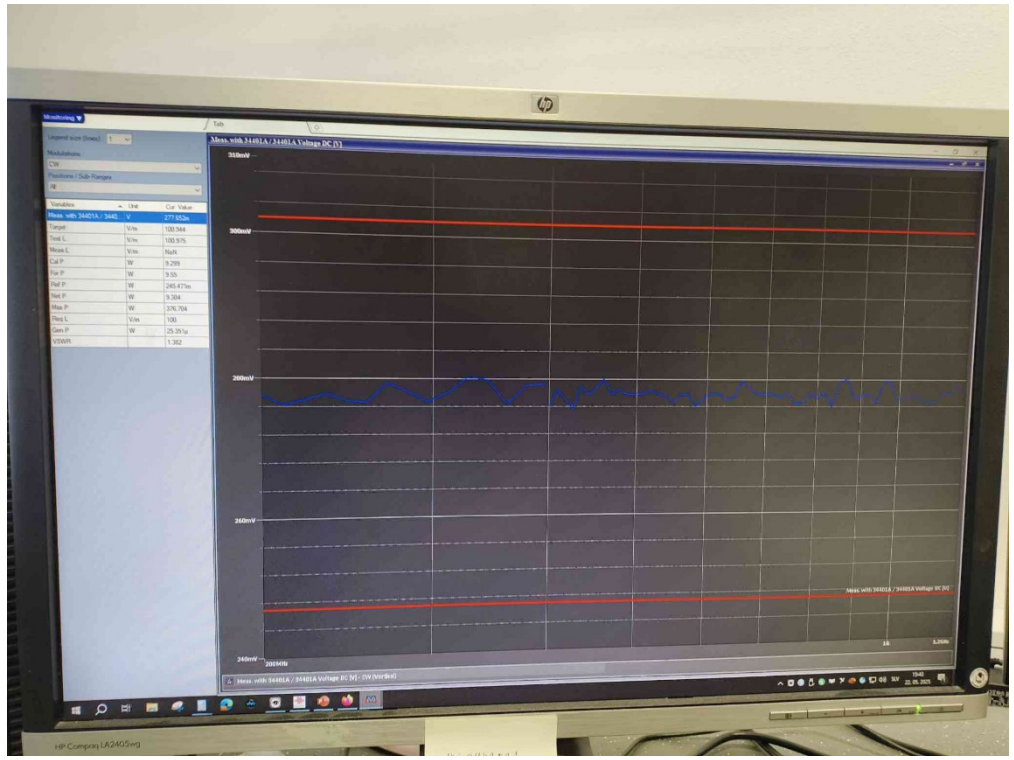
Vse komponente Lepo pašejo na svoj footprint :)



Meritve na HELLI



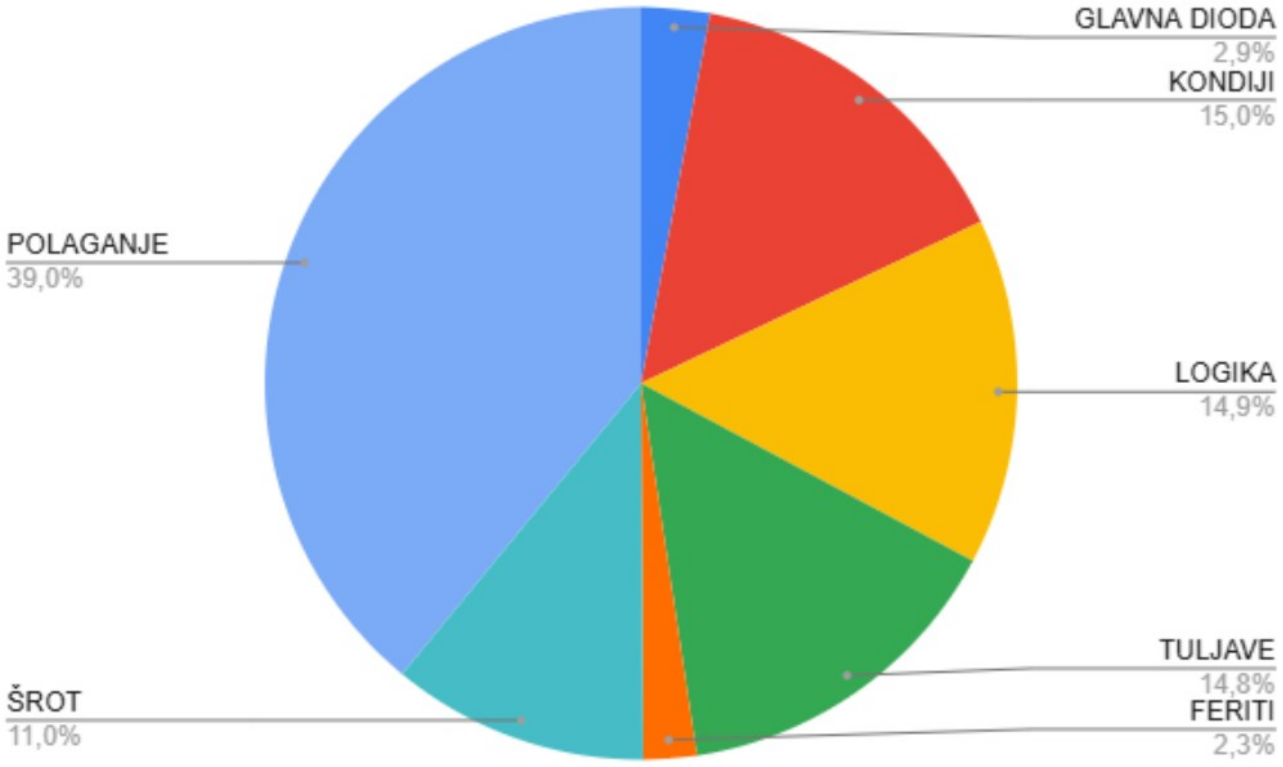
Imunost na sevalne motnje



Morebitni popravki

Polaganje je drago :[

Večja tuljava bi bila boljša glede učinkovitosti!



Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

Georgy Telelyukhin / Fran Zupet

Rezultati

Teleyukhin / Zupet – Funkcionalni in električni testi

Osnovna funkcionalnost ✓

PWM območje ✓

Napetostno območje ✓

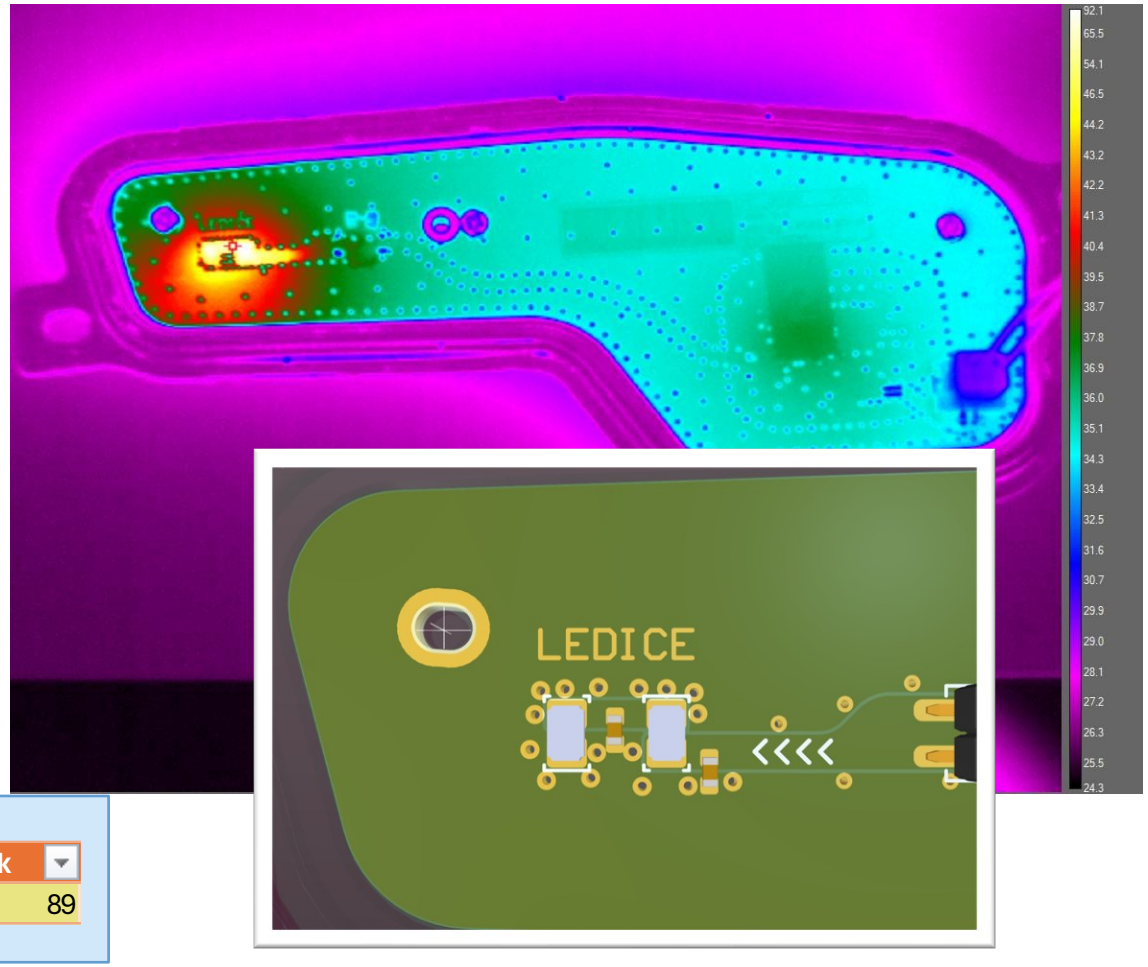
Temperaturno območje ✓

Obrnjena polariteta ✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	158	2.135	6.12	313	1.915	89

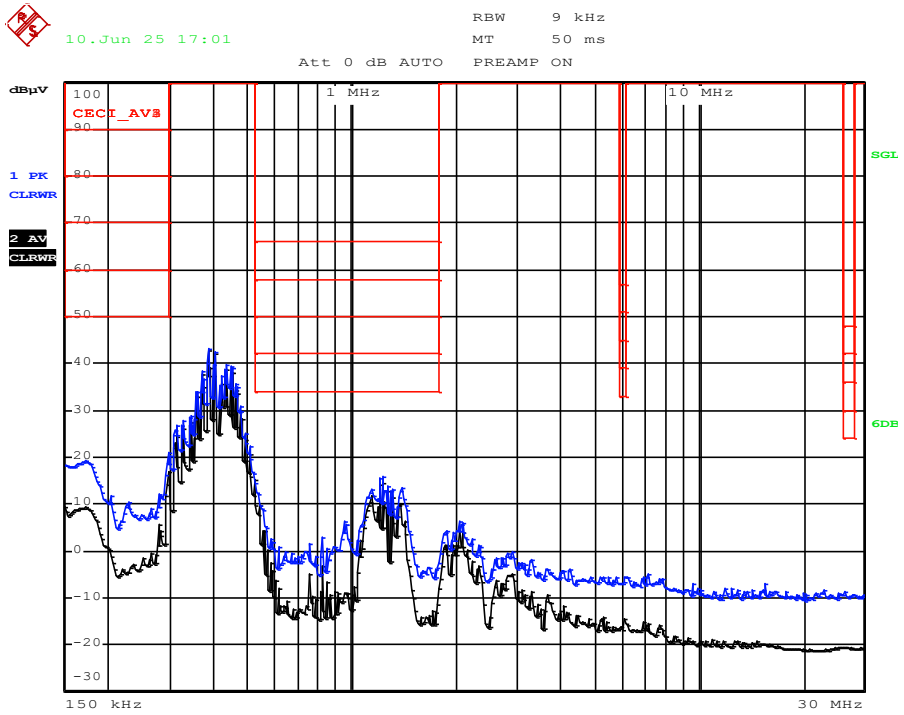
Temperaturna obremenitev: 66.81 °C



Teleyukhin / Zupet – EMC

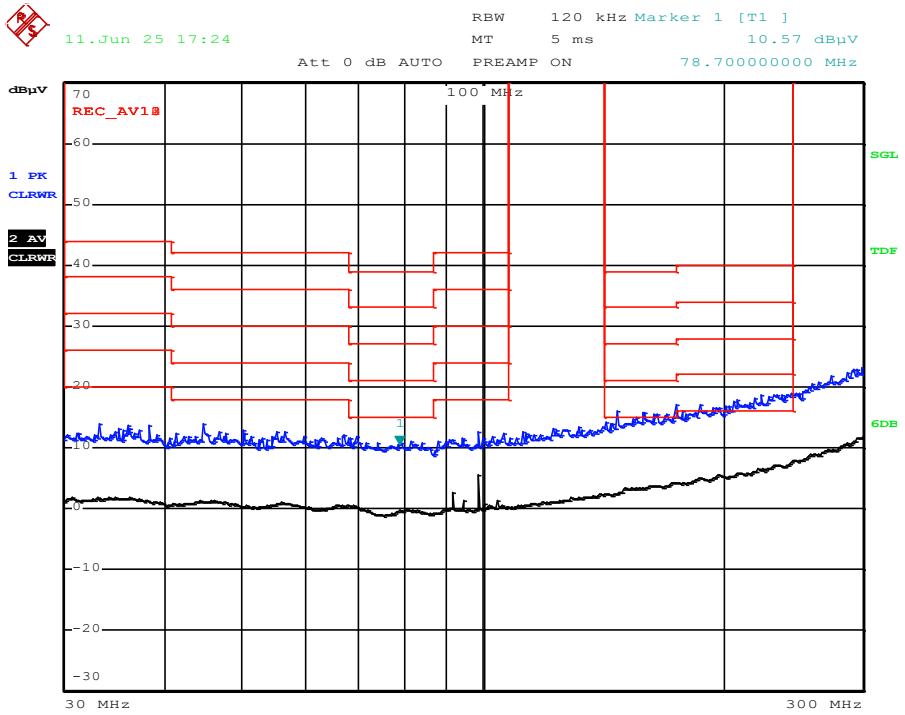
CE

5



RE

5



BCI

100 mA **A**

RI

100 V/m H+V **A**

Teleyukhin / Zupet – Cena

Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 10 000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vezje
0402-0603 <100nF	NA	NA	NA	NA	0.005 €	30	0.150 €
Bulk 22uF 16V 1210 X7R	**CS3225X7R226K160NRL**	**Samwha Capacitor**	**C2918510**	**LCSC**	**0.026 €**	**4**	**0.105 €**
5V rail 10uF 16V 1206 X7R	GRM31CR71C106KA12L	Murata Electronics	C97954	LCSC	0.013 €	5	0.064 €
Števec	CD4060BPWR	Texasa instruments	CD4060BPWR	Texasa instruments	0.046 €	1	0.046 €
AND vrata	SN74LVC1G08	Texasa instruments	SN74LVC1G08	Texasa instruments	0.046 €	2	0.092 €
Mosfeti	2N7002	Shikues	C42444380	LCSC	0.005 €	2	0.011 €
Glavna dioda	NSR1020MW2T3G	onsemi	NSR1020MW2T3G	MOUSER	0.036 €	1	0.036 €
Logična dioda	BAT54C-QR	Nexperia	BAT54C-QR	Arrow Electronics	0.009 €	3	0.027 €
Glavni ferrit	CBW321609U301	FENGHUA	EMICBW1206-301	Maritex	0.010 €	2	0.020 €
LED ferrit	BLM18PG121SN1D	MURATA	FE1768	RUTRONIK	0.006 €	1	0.006 €
Filter tuljava 4,7uH	**NR6028T4R7M**	**Taiyo Yuden**	**587-2100-2-ND**	**Digikey**	**0.086 €**	**1**	**0.086 €**
SW tuljava 33uH	**NRS6045T330MMGK**	**Taiyo Yuden**	**LMNRS6045T330MMGK**	**Onlinecomponents.com**	**0.085 €**	**1**	**0.085 €**

Št. komponent	Cena komponent	Cena polaganja	Skupaj
53	0.73 €	0.53 €	1.26 €

Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

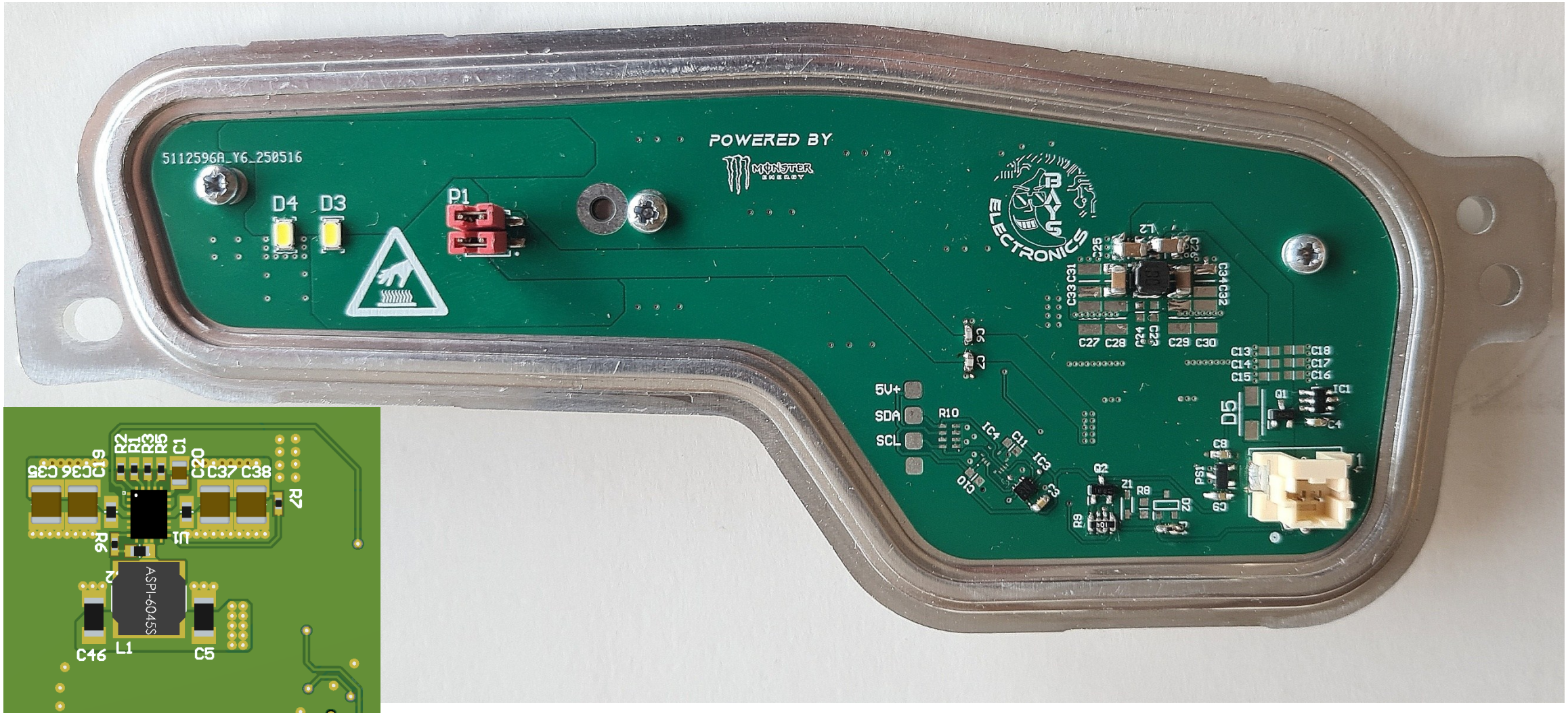
UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

Žiga Pokovec / Jakob Zaplata

2. letnik, VS-EL

Žiga Pokovec / Jakob Zaplata



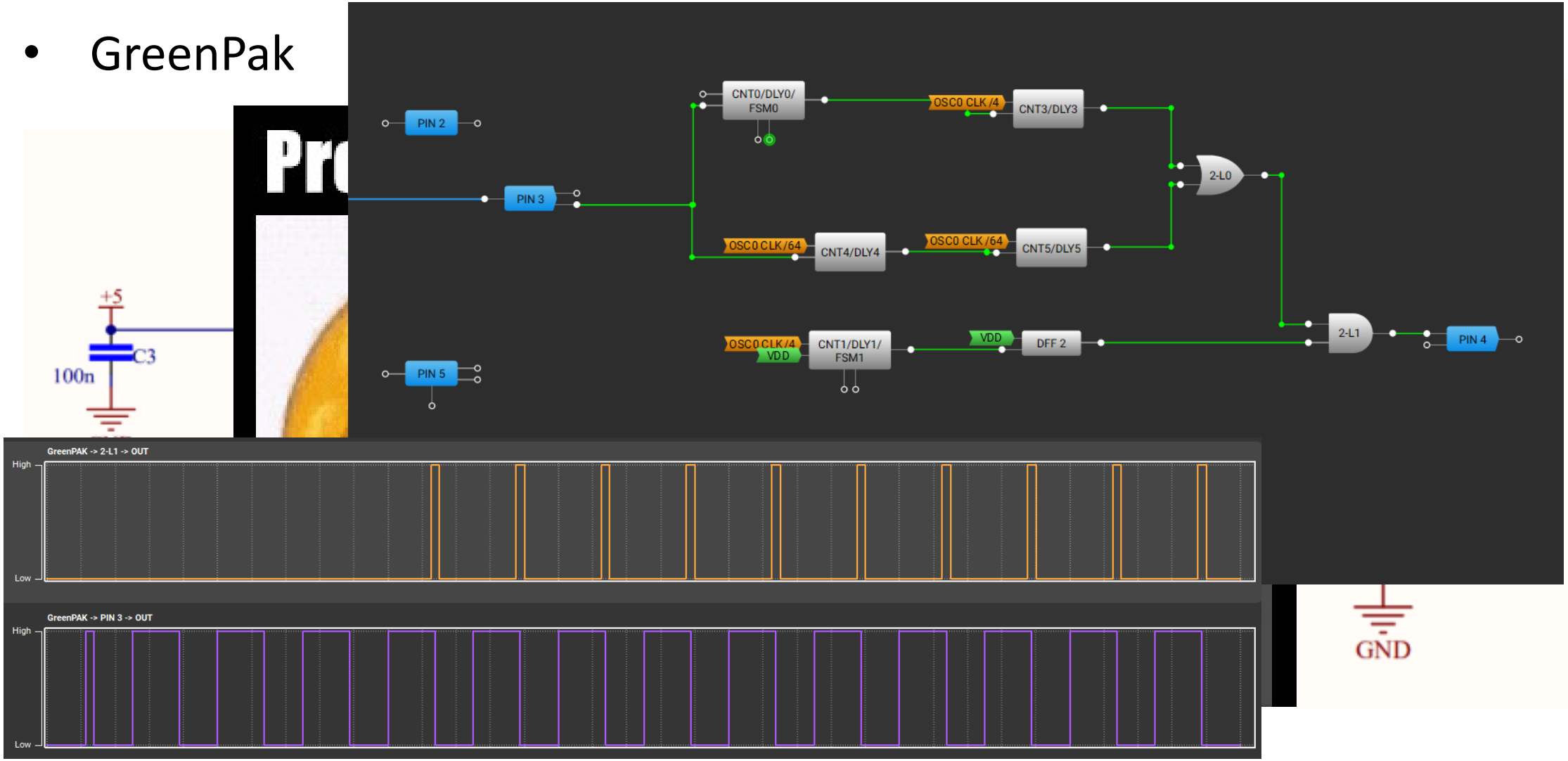
Question of logic

- Measuring time of pulse
- Comparing with certain value
- Depending on time of pulse – PWM: 0%, 10% or 100%

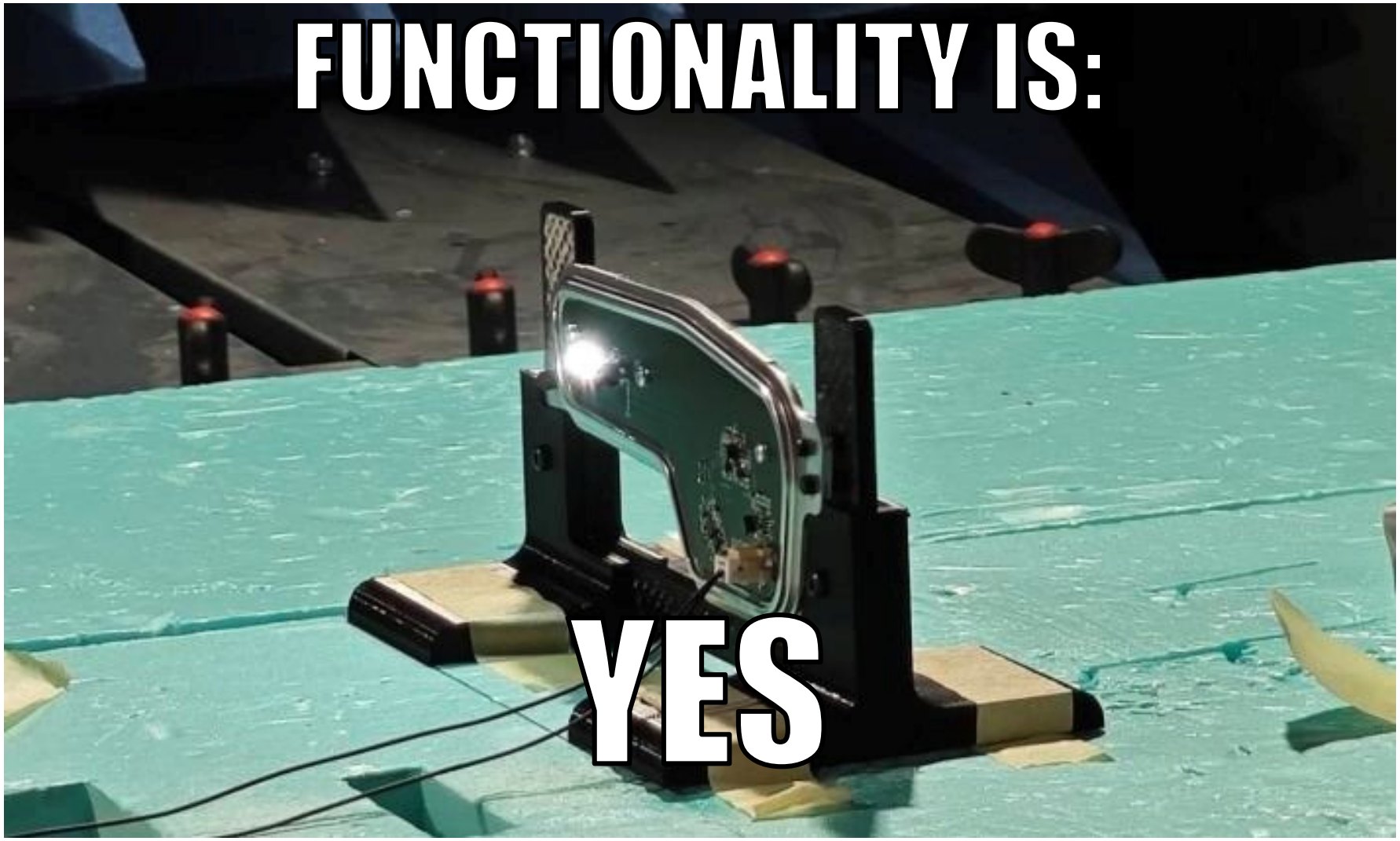
- 20ms delay on startup

Question of execution

- GreenPak

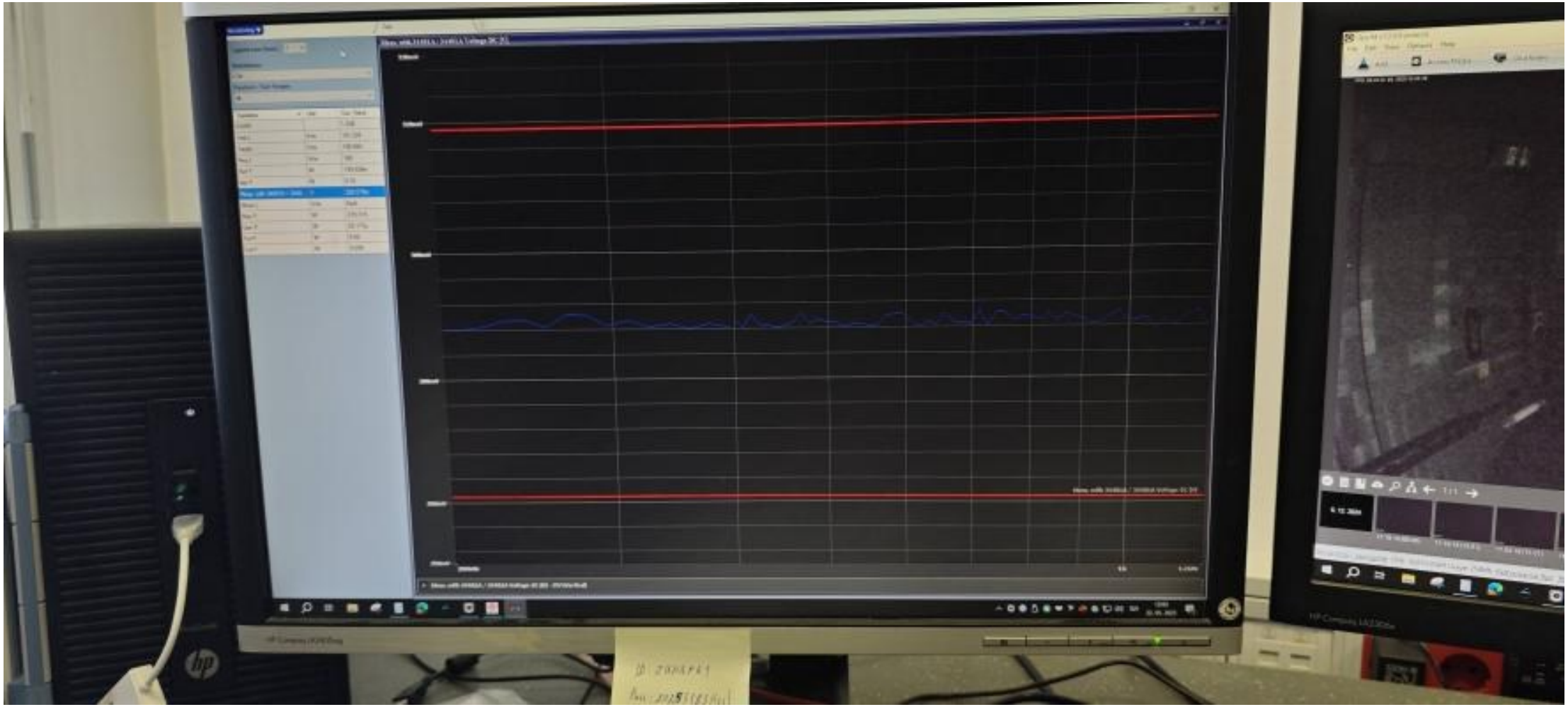


Question of functionality

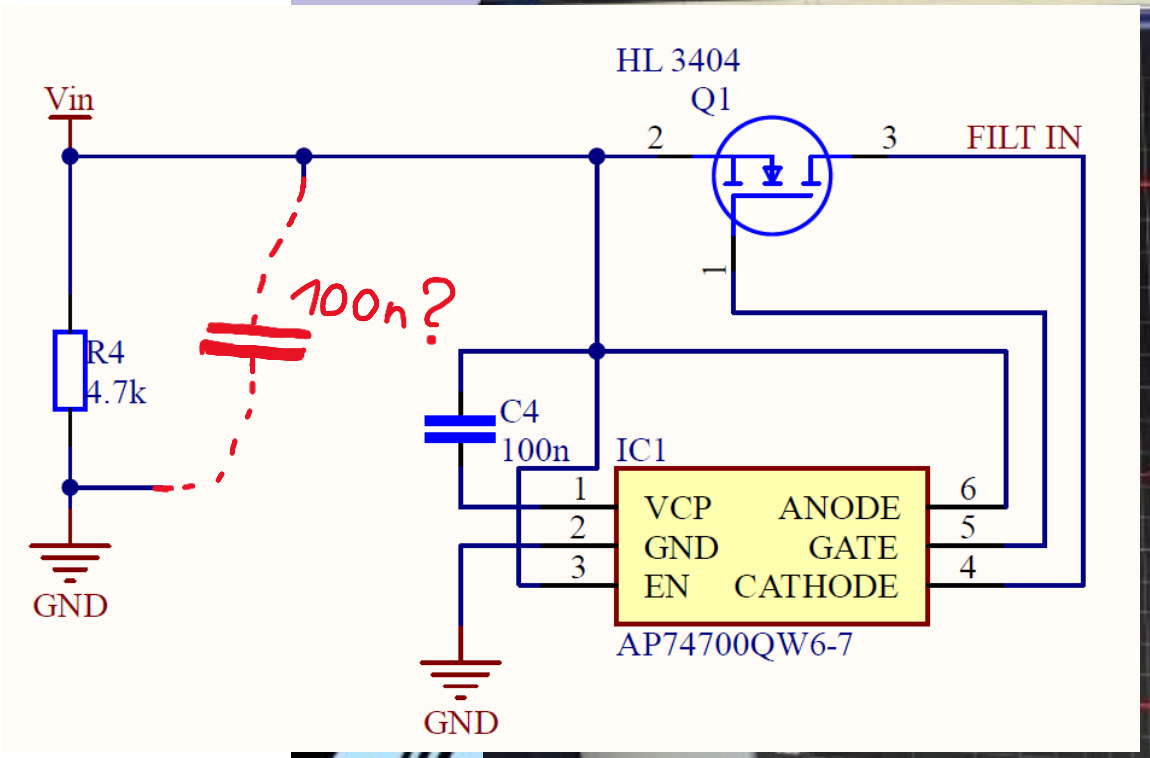


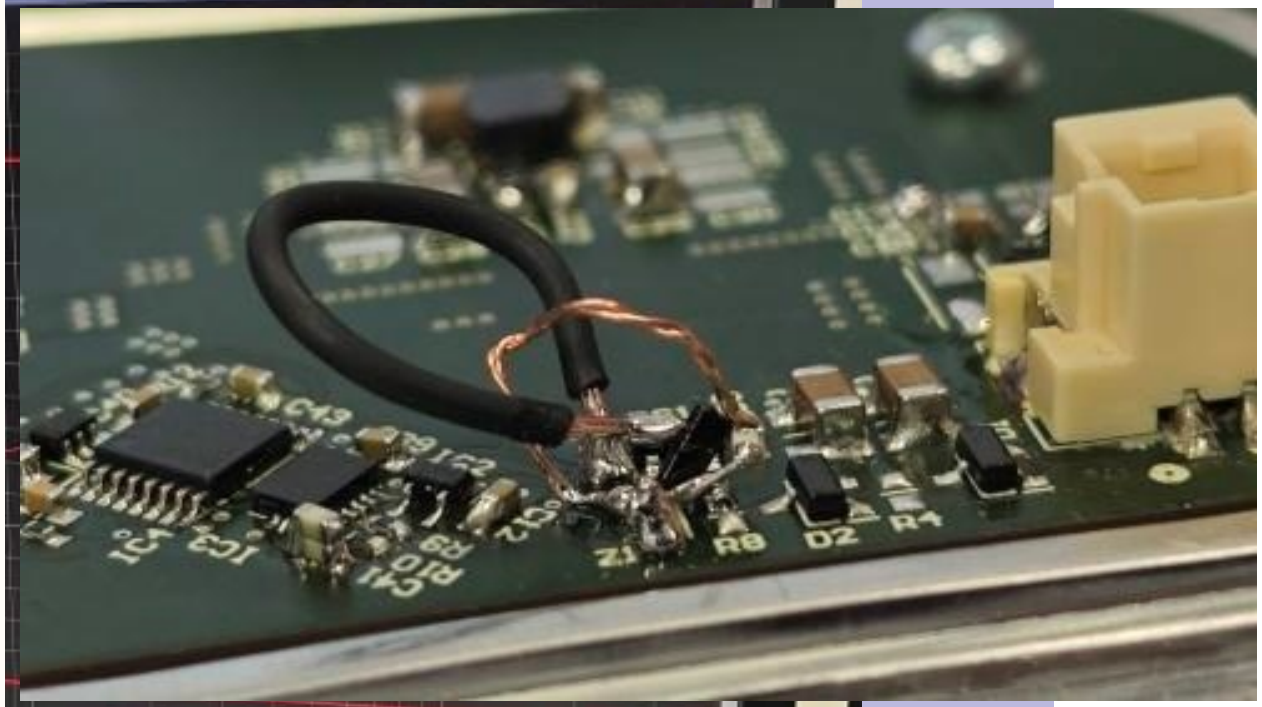
Question of EMC

Question of EMC: emissive interference



Question of EMC: conductive interference





Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

Žiga Pokovec / Jakob Zaplata

Rezultati

Pokovec / Zaplata – Funkcionalni in električni testi

Osnovna funkcionalnost ✓

PWM območje ✓

Napetostno območje ✓

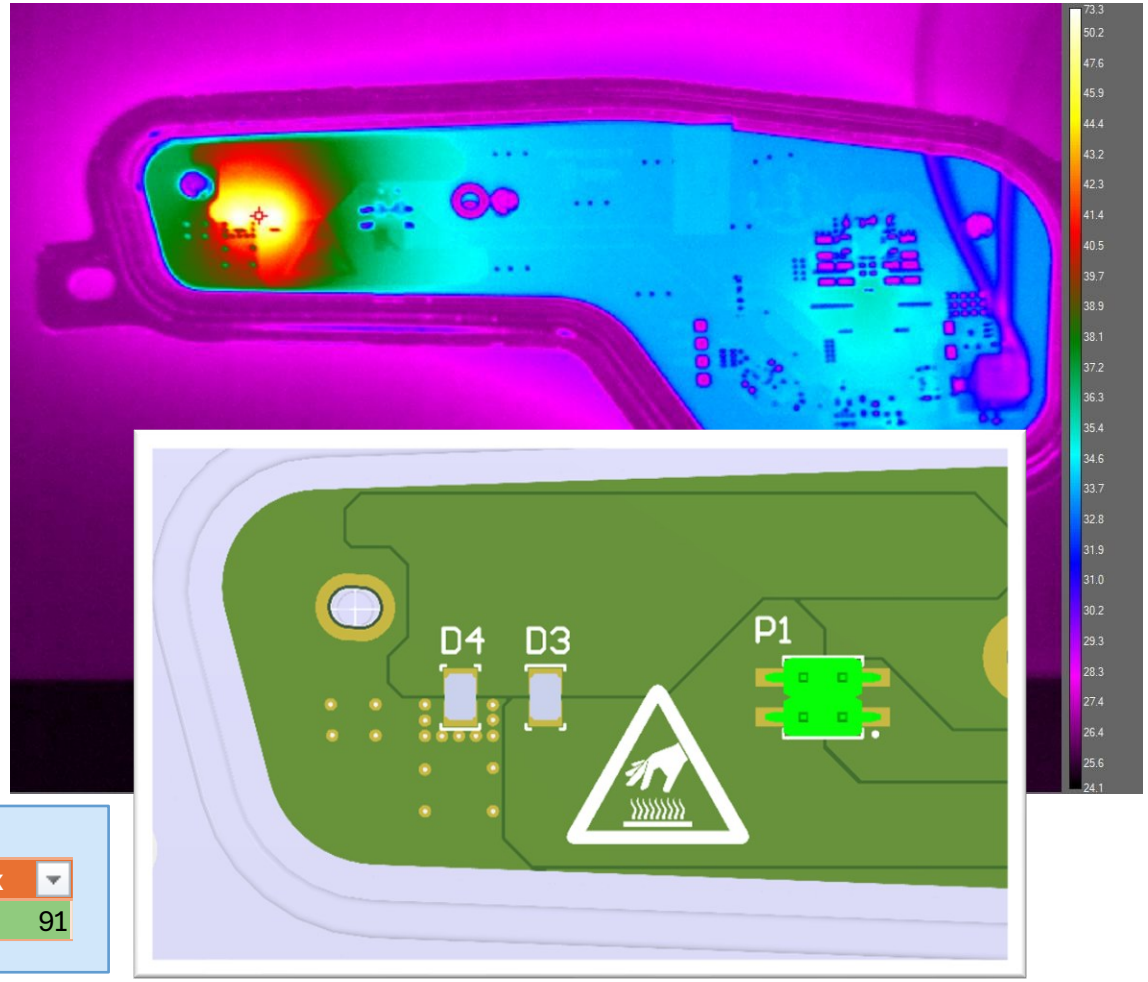
Temperaturno območje ✓

Obrnjena polariteta ✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	151	2.040	6.12	306	1.873	91

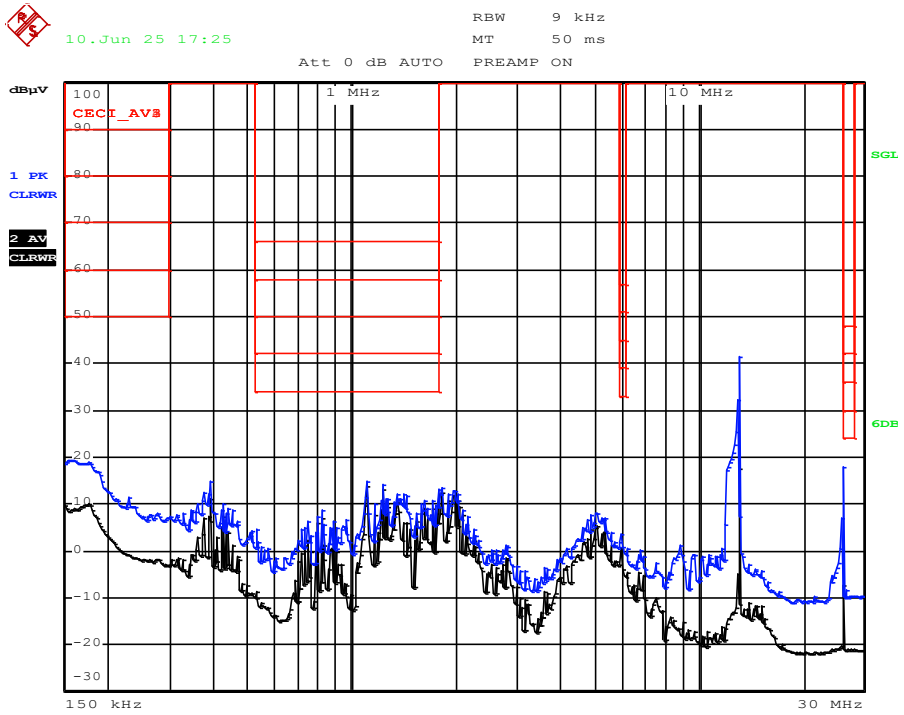
Temperaturna obremenitev: **50.36 °C**



Pokovec / Zaplata – EMC

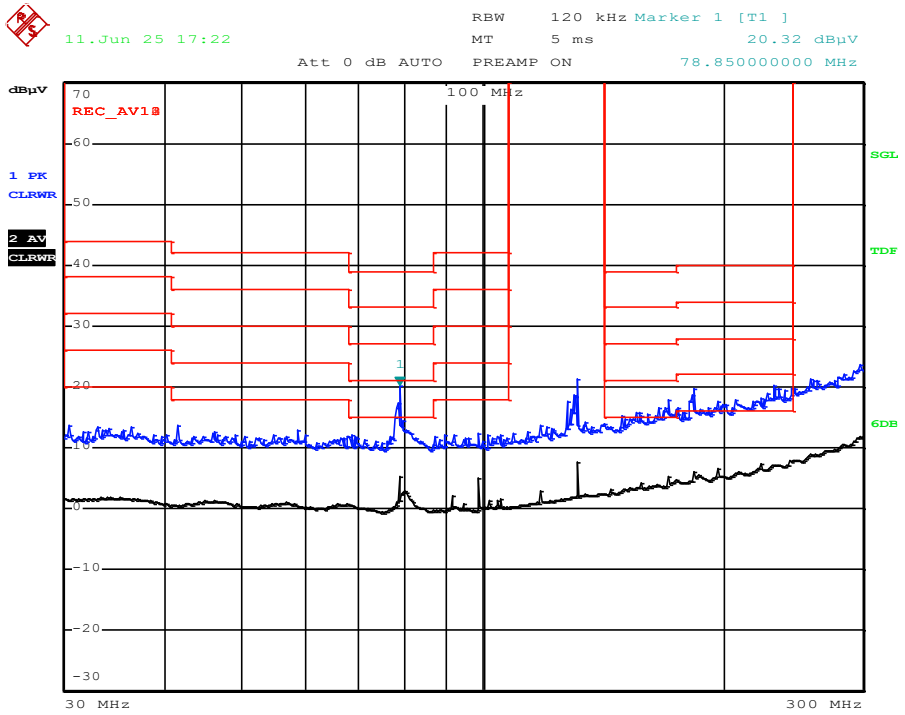
CE

5



RE

5



BCI

100 mA **A**

RI

100 V/m H+V **A**

Pokovec / Zaplata – Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 10000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vezje
C1	10u 0805 kondenzator	CL21B106KOQNNNE	Samsung	C95841	LCSC	0.012 €	1	0.012 €
C2, C4, C8, C9, C12, C19, C20, C39, C40, C43, C44, C45	100n 0603 kondenzator	NA	NA	NA	NA	0.005 €	12	0.060 €
C5, C46, C25, C26, C31, C33, C34, C36, C37, C38	**10u 1206 kondenzator**	**CL31B106KAHNNNE**	**Samsung**	**C14860**	**LCSC**	**0.016 €**	**10**	**0.160 €**
IC1	**Idealna dioda**	**AP74700QW6-7**	**Diodes Incorporated**	**AP74700QW6-7**	**Vertical**	**0.215 €**	**1**	**0.215 €**
L1	33uH glavna tuljava	CR6045-330M	Ceaiya	C7588812	LCSC	0.024 €	1	0.024 €
L2	10uH filterska tuljava	ZE ZNR4030ST100M	ZE	C42429195	LCSC	0.022 €	1	0.022 €
PS1	LDO 5V	MG78L05T3	Megain	C22396244	LCSC	0.010 €	1	0.010 €
Q1	N-channel MOS	HL 3404	HL	C19271467	LCSC	0.010 €	1	0.010 €
Q2	N-channel MOS	2N7002,215	Nexperia	C65189	LCSC	0.008 €	1	0.008 €
IC3	**Configurabilna matrika**	**SLG46536V**	**Renesas**	**SLG46536V**	**Renesas**	**0.406 €**	**1**	**0.406 €**
R9	Upor	CAY10-104J4LF	Bourns	652-CAY10-104J4LF	Mouser	0.006 €	1	0.006 €
C6, C7	1n 0603 kondenzator	NA	NA	NA	NA	0.005 €	2	0.010 €
R1	10k 0402 upor	NA	NA	NA	NA	0.005 €	1	0.005 €
R2, R4	4.87k 0402 upor	NA	NA	NA	NA	0.005 €	2	0.010 €
R3	53.6k 0402 upor	NA	NA	NA	NA	0.005 €	1	0.005 €
R4	10n 0603 kondenzator	NA	NA	NA	NA	0.005 €	1	0.005 €
R5	33k 0402 upor	NA	NA	NA	NA	0.005 €	1	0.005 €
R6	20R 0402 upor	NA	NA	NA	NA	0.005 €	1	0.005 €
R7	100k 0402 upor	NA	NA	NA	NA	0.005 €	1	0.005 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
41	0.98 €	0.41 €	1.39 €

Načrtovanje elektronike za EMC² 2025

študentska delavnica in tekmovanje

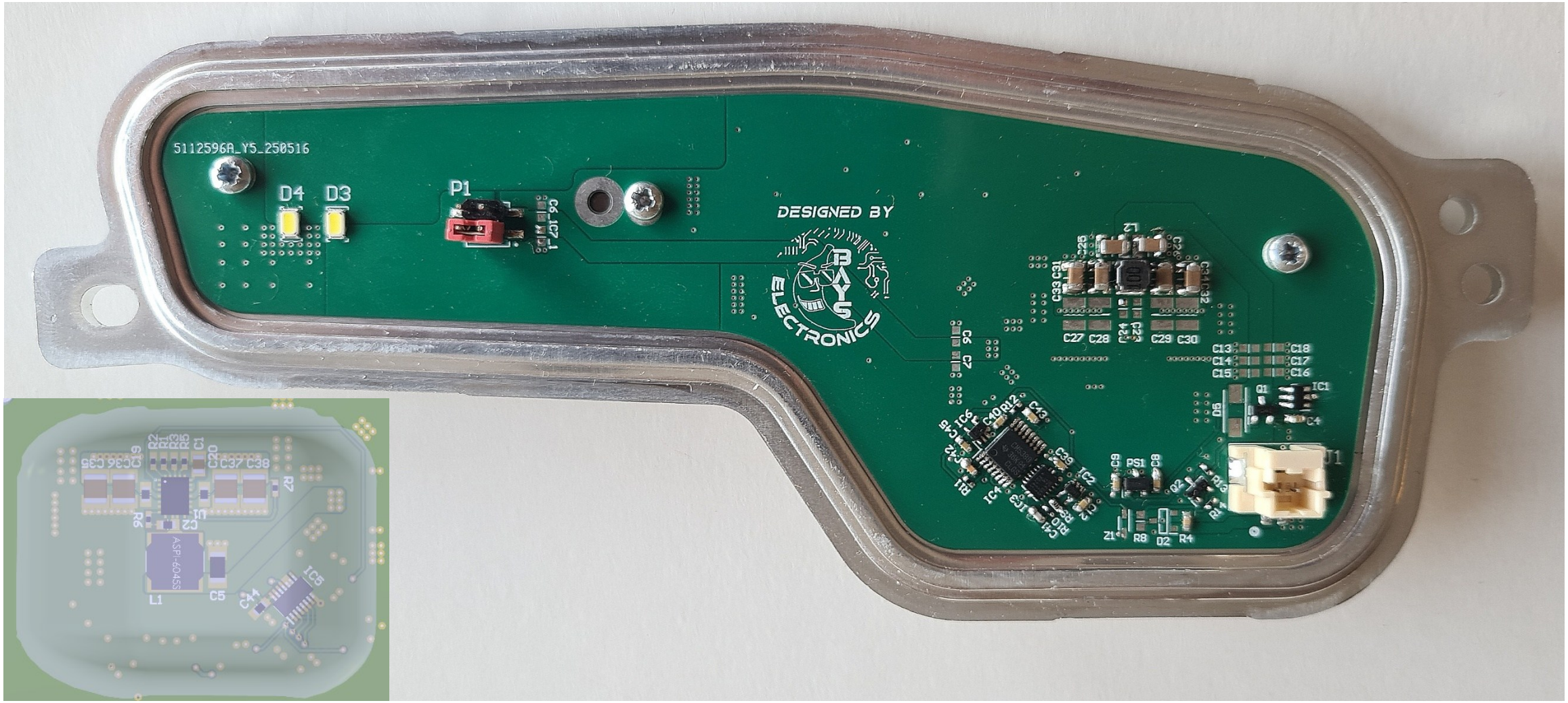
UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

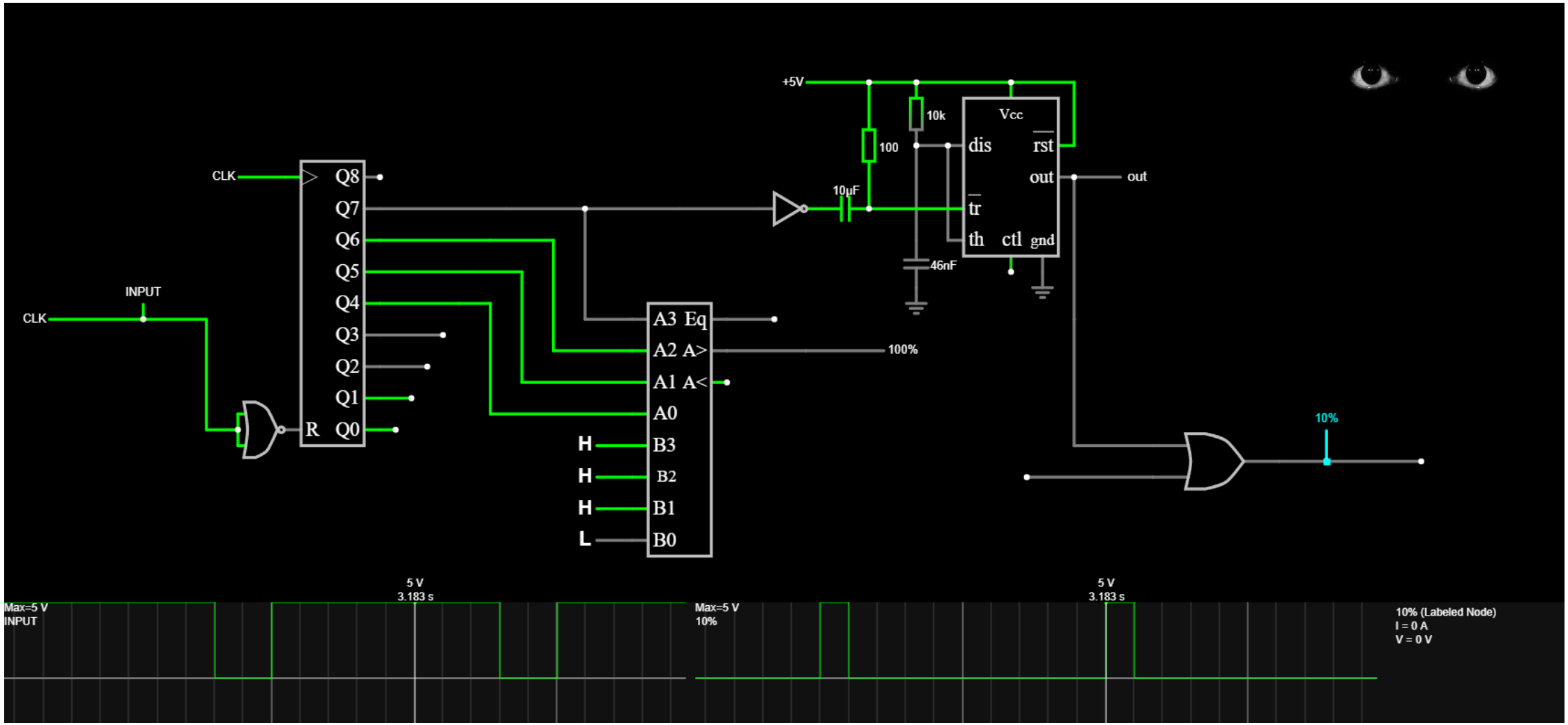
Aljaž Šturm

2. letnik, VS-EL

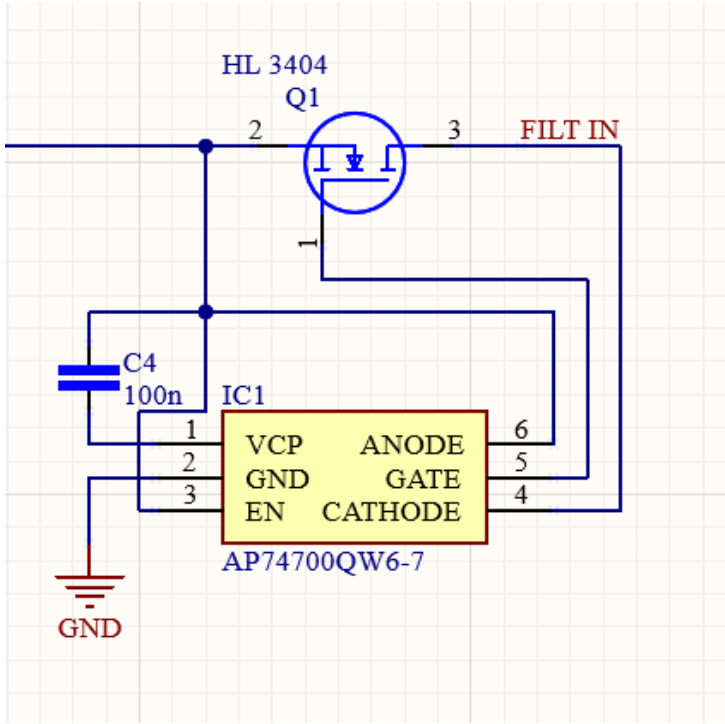
Aljaž Šturm

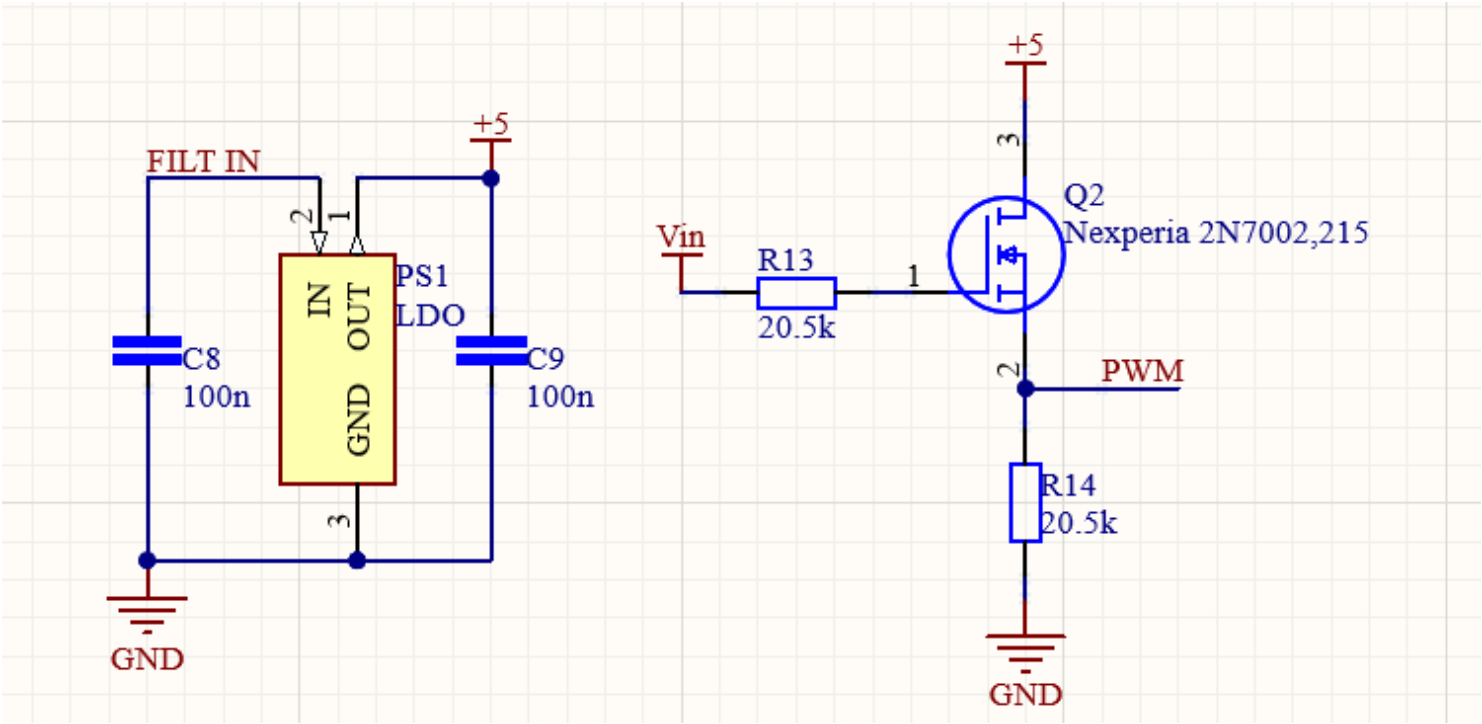


Simulacija koncepta

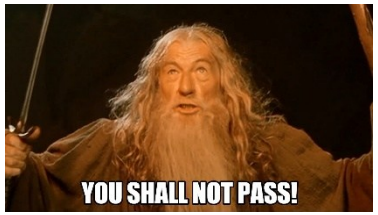


Zaščita pred obratno polariteto



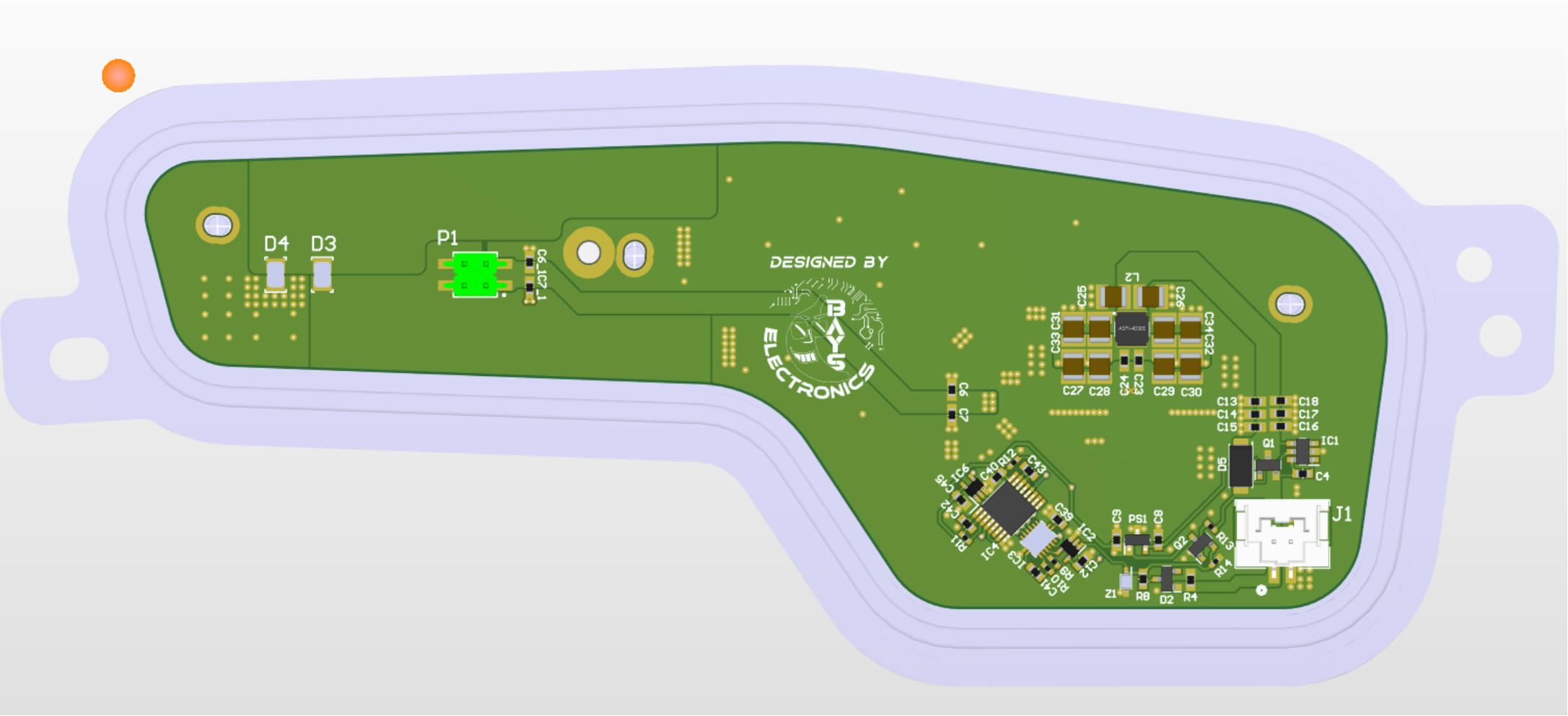


Draga idealna dioda (21c)

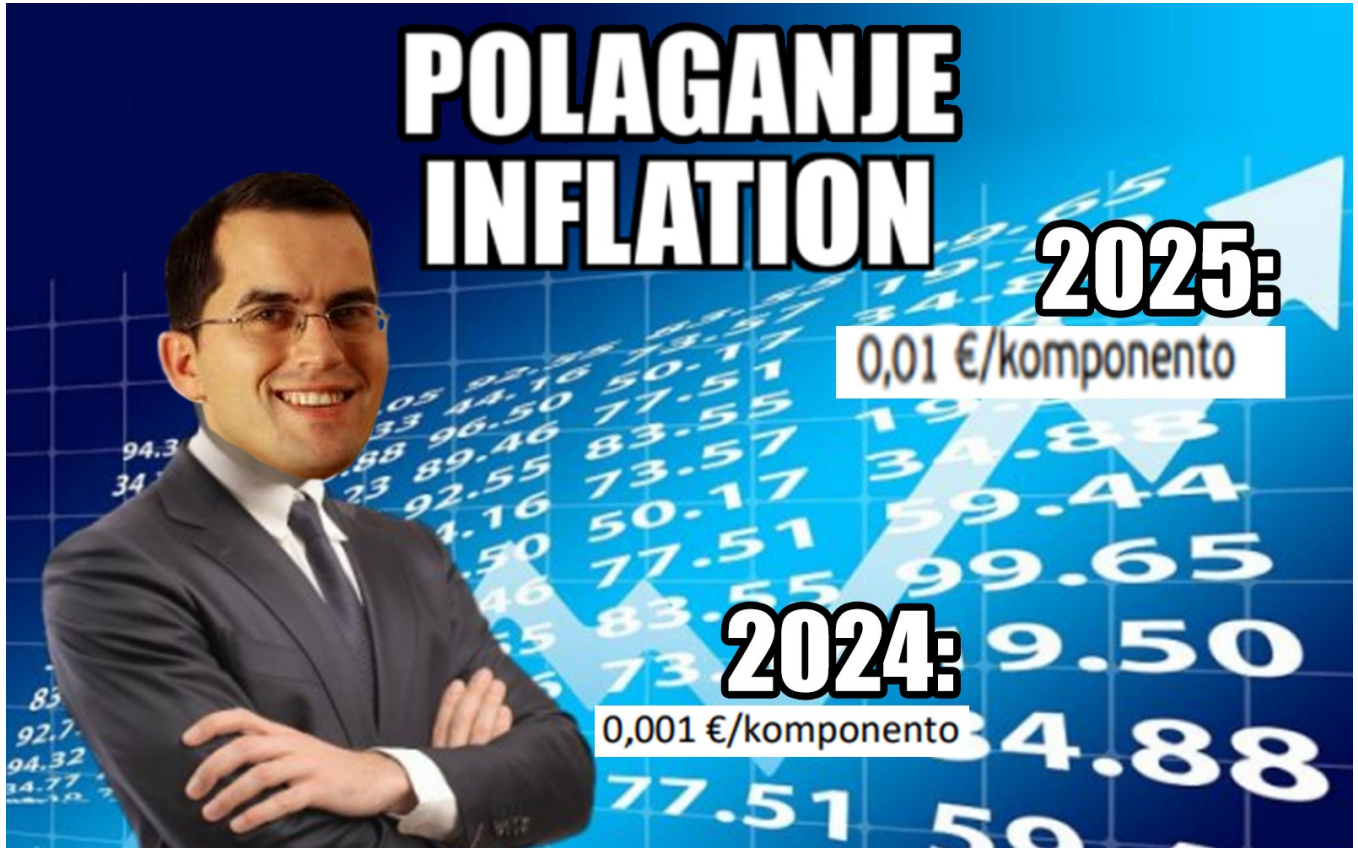


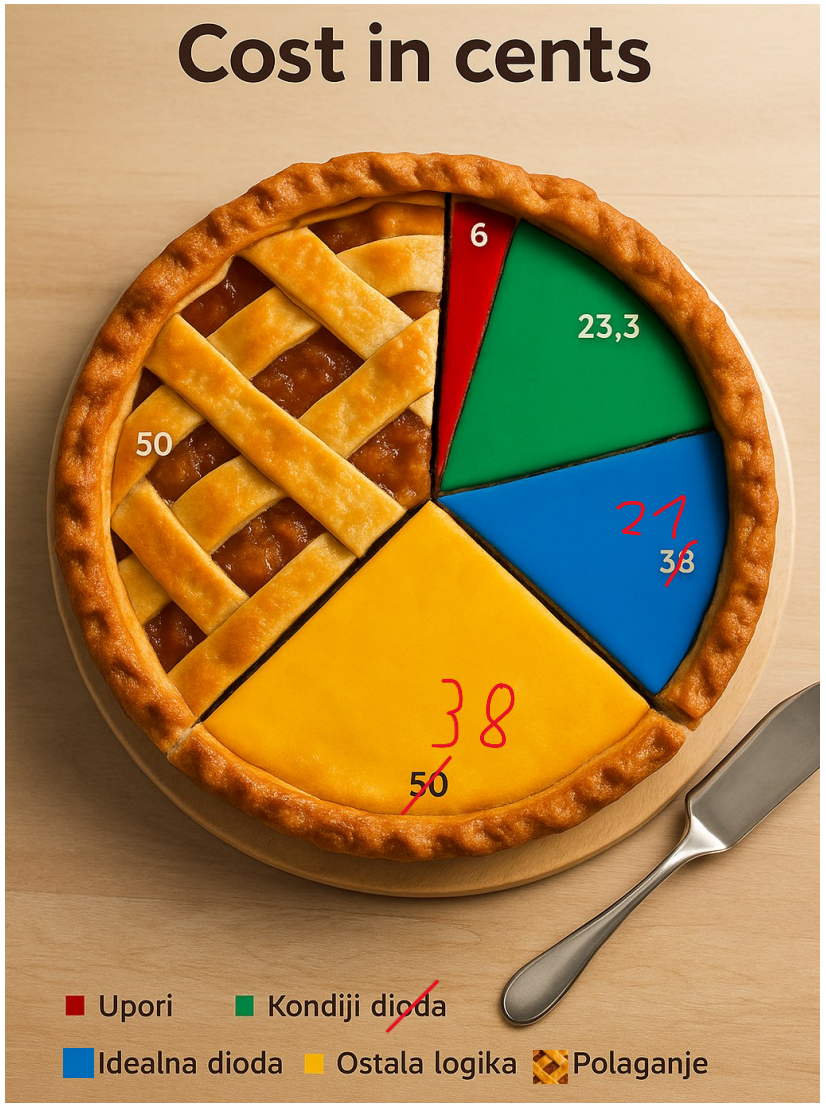
Rezanje pwm na 5V in zaščita pred obratno polariteto

PCB design


D4
D3
P1
DESIGNED BY
BAYS ELECTRONICS
L2
C25
C26
C31
C33
C34
C32
C27
C28
C24
C23
C29
C30
C13
C14
C15
C18
C17
C16
IC1
Q1
C4
J1
C9
PS1
C8
R13
R14
Z1
R8
D2
R4

Cost breakdown





Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

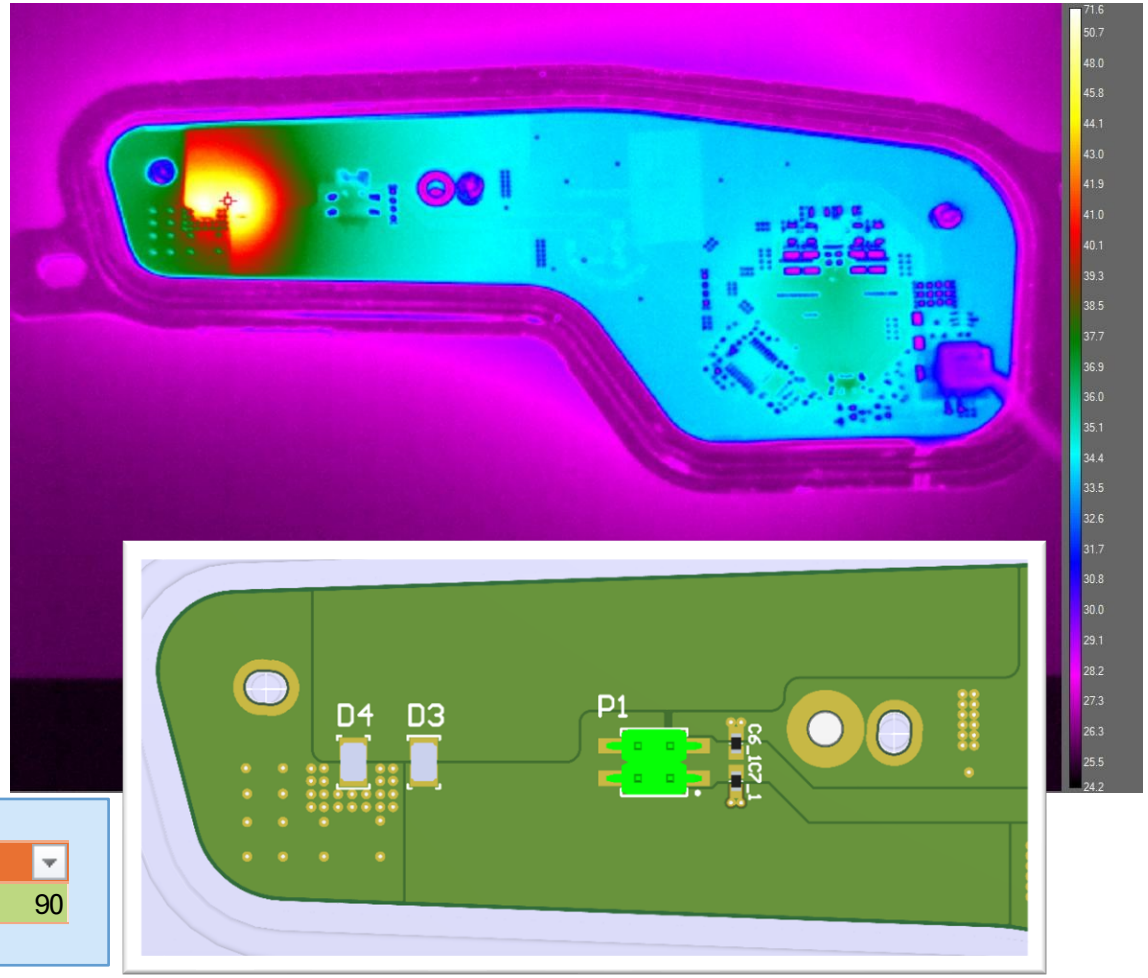
Aljaž Šturm

Rezultati

Aljaž Šturm– Funkcionalni in električni testi

Osnovna funkcionalnost	✓
PWM območje	✓
Napetostno območje	✓
Temperaturno območje	✓
Obrnjena polariteta	✓

Temperaturna obremenitev: **51.12 °C**



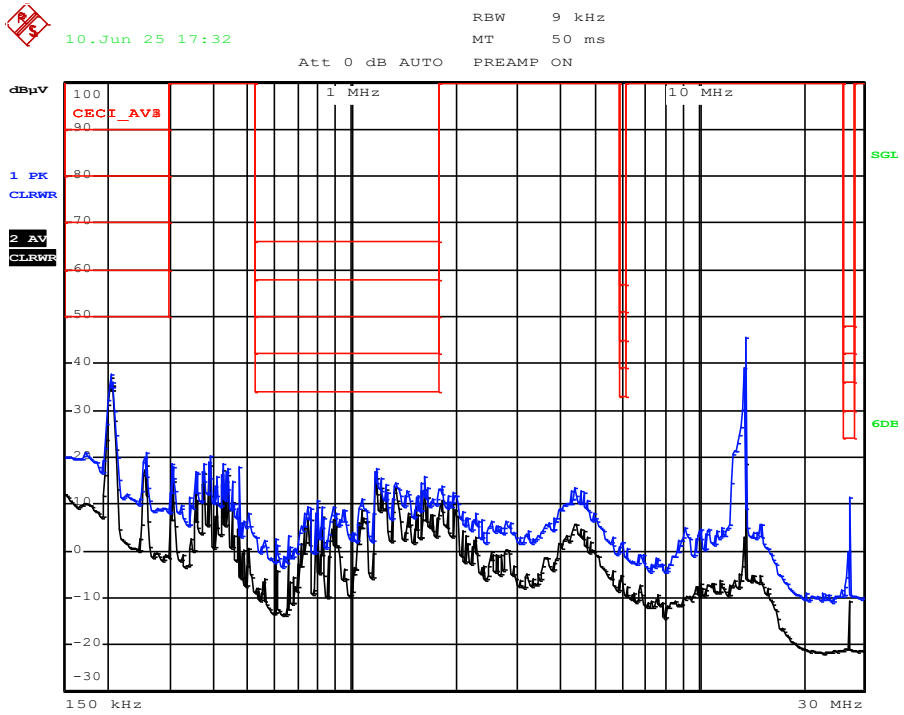
Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	153	2.067	6.18	304	1.877	90

Aljaž Šturm – EMC

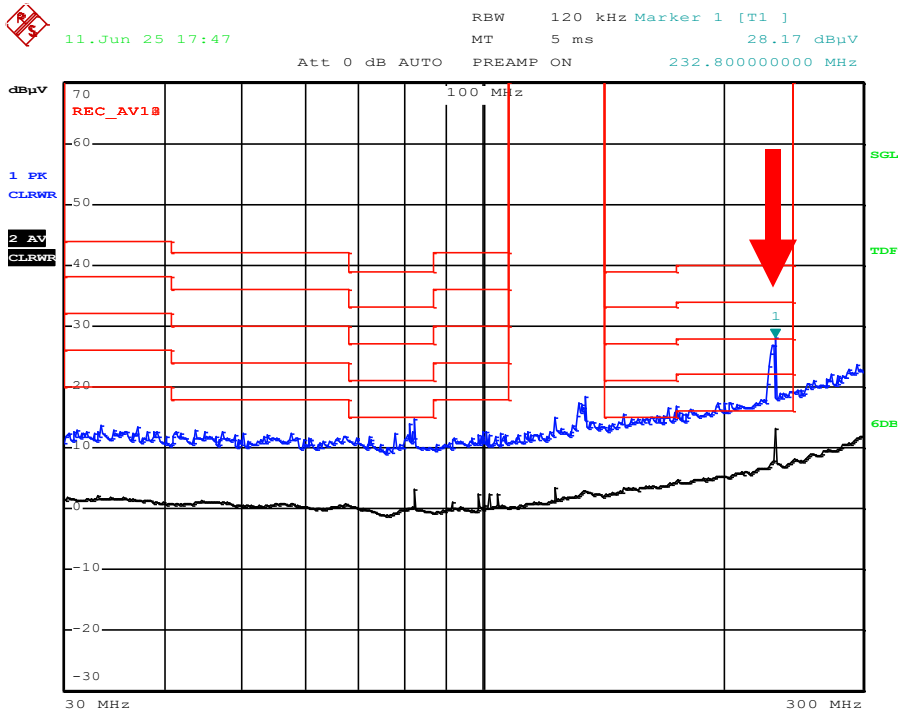
CE

5



RE

4



BCI

100 mA

A

RI

100 V/m
H+V 1 GHz

✕

60 V/m H+V

A

Aljaž Šturm - Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 10000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vezje
C1	10u 0805 kondenzator	CL21B106KOQNNNE	Samsung	C95841	LCSC	0.012 €	1	0.012 €
C2, C4, C8, C9, C12, C19, C20, C39, C40, C43, C44, C45	100n 0603 kondenzator	NA	NA	NA	NA	0.005 €	12	0.060 €
C5, C25, C26, C31, C32, C33, C34, C35, C36, C37, C38	**10u 1206 kondenzator**	**CL31B106KAHNNNE**	**Samsung**	**C14860**	**LCSC**	**0.013 €**	**11**	**0.147 €**
C41	680p 0603 kondenzator	NA	NA	NA	NA	0.005 €	1	0.005 €
C42	4.7n 0603 kondenzator	NA	NA	NA	NA	0.005 €	1	0.005 €
IC1	**Idealna dioda**	**AP74700QW6-7**	**Diodes Incorporated**	**AP74700QW6-7**	**Avnet**	**0.209 €**	**1**	**0.209 €**
IC2	NOR vrata	SN74AHC1G02DCKR	Texas Instruments	SN74AHC1G02DCKR	Texas Instruments	0.018 €	1	0.018 €
IC3	**Binary counter**	**74HC4060BQ,115**	**Nexperia**	**74HC4060BQ,115**	**Verical**	**0.104 €**	**1**	**0.104 €**
IC4	**Monostabilni multivibrator**	**CD74HC4538PWR**	**Texas Instruments**	**CD74HC4538PWR**	**Texas Instruments**	**0.122 €**	**1**	**0.122 €**
IC5	AND vrata	SN74HCS08DYYR	Texas Instruments	SN74HCS08DYYR	Texas Instruments	0.044 €	1	0.044 €
IC6	OR vrata	SN74AHC1G32DCKR	Texas Instruments	SN74AHC1G32DCKR	Texas Instruments	0.018 €	1	0.018 €
L1	33uH glavna tuljava	CR6045-330M	Ceaiya	C7588812	LCSC	0.024 €	1	0.024 €
L2	10uH filterska tuljava	ZE ZNR4030ST100M	ZE	C42429195	LCSC	0.022 €	1	0.022 €
PS1	LDO 5V	MG78L05T3	Megain	C22396244	LCSC	0.010 €	1	0.010 €
Q1	N-channel MOS	HL 3404	HL	C19271467	LCSC	0.010 €	1	0.010 €
Q2	N-channel MOS	2N7002,215	Nexperia	C65189	LCSC	0.008 €	1	0.008 €
R1	10k 0402 upor	NA	NA	NA	NA	0.005 €	1	0.005 €
R2	4.87k 0402 upor	NA	NA	NA	NA	0.005 €	1	0.005 €
R3	53.6k 0402 upor	NA	NA	NA	NA	0.005 €	1	0.005 €
R4	10n 0603 kondenzator	NA	NA	NA	NA	0.005 €	1	0.005 €
R5, R9	33k 0402 upor	NA	NA	NA	NA	0.005 €	2	0.010 €
R6	20R 0402 upor	NA	NA	NA	NA	0.005 €	1	0.005 €
R7	100k 0402 upor	NA	NA	NA	NA	0.005 €	1	0.005 €
R10	13k 0402 upor	NA	NA	NA	NA	0.005 €	1	0.005 €
R11, R12	105k 0402 upor	NA	NA	NA	NA	0.005 €	2	0.010 €
R13, R14	20.5k 0402 upor	NA	NA	NA	NA	0.005 €	2	0.010 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
50	0.88 €	0.50 €	1.38 €

Načrtovanje elektronike za EMC² 2025

študentska delavnica in tekmovanje

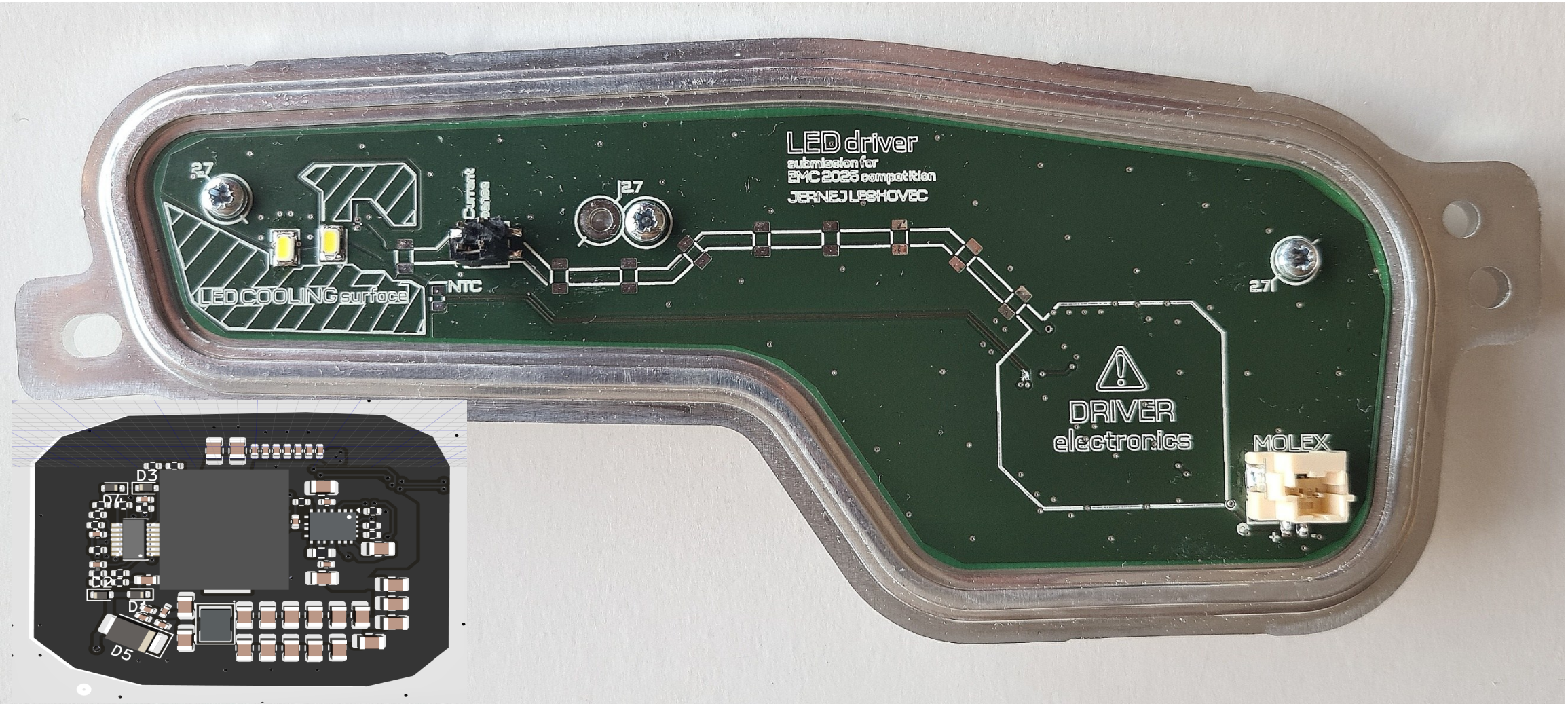
UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

Jernej Leskovec

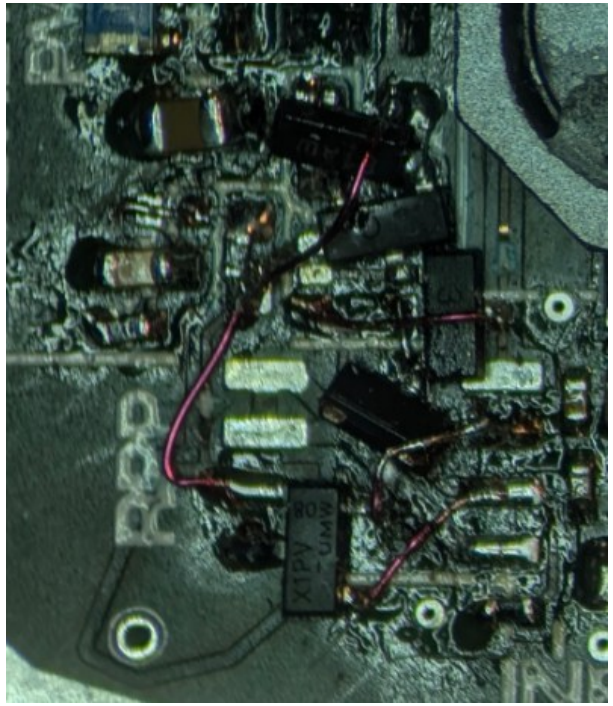
2. letnik, VS-EL

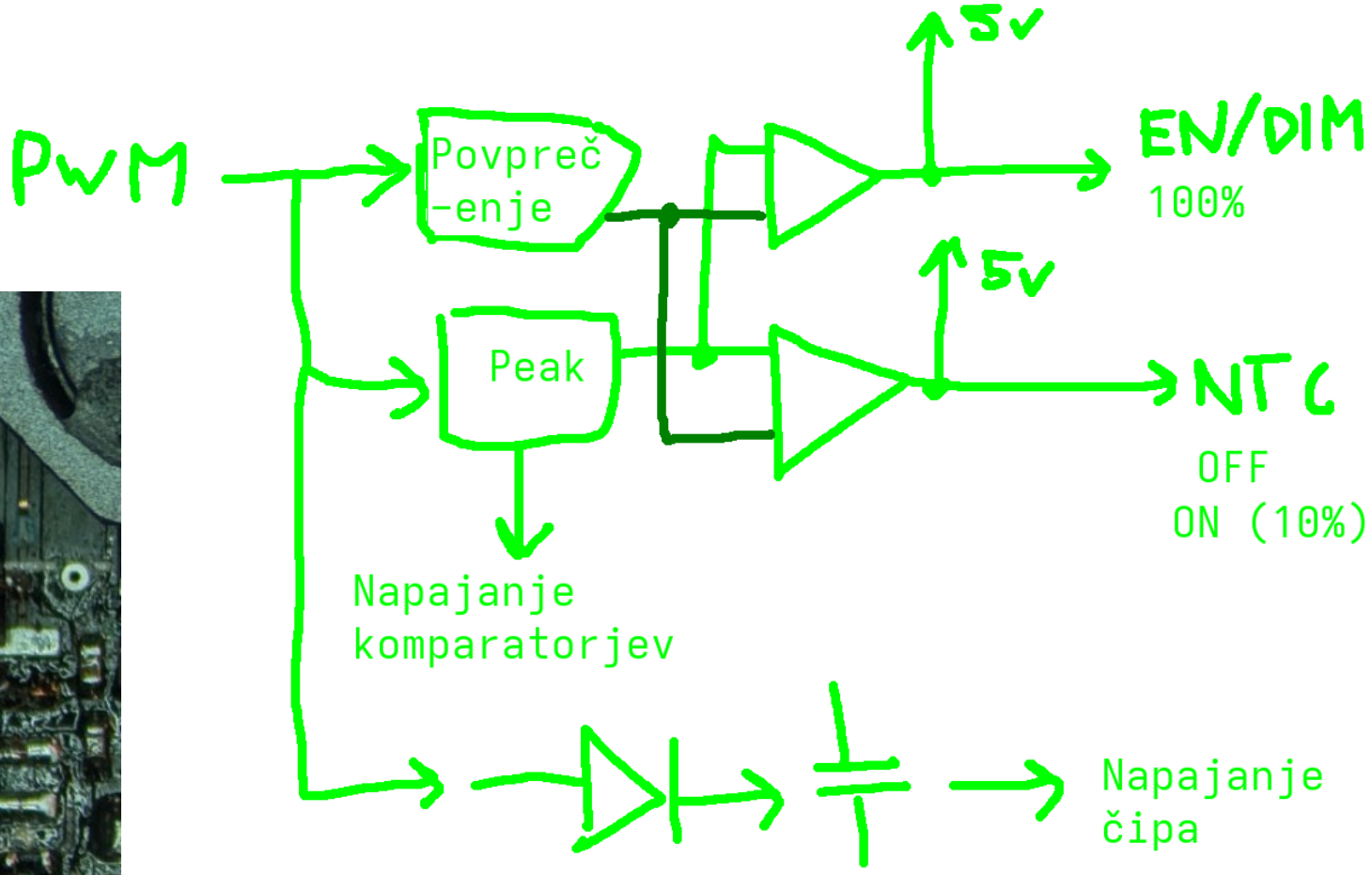
Jernej Leskovec



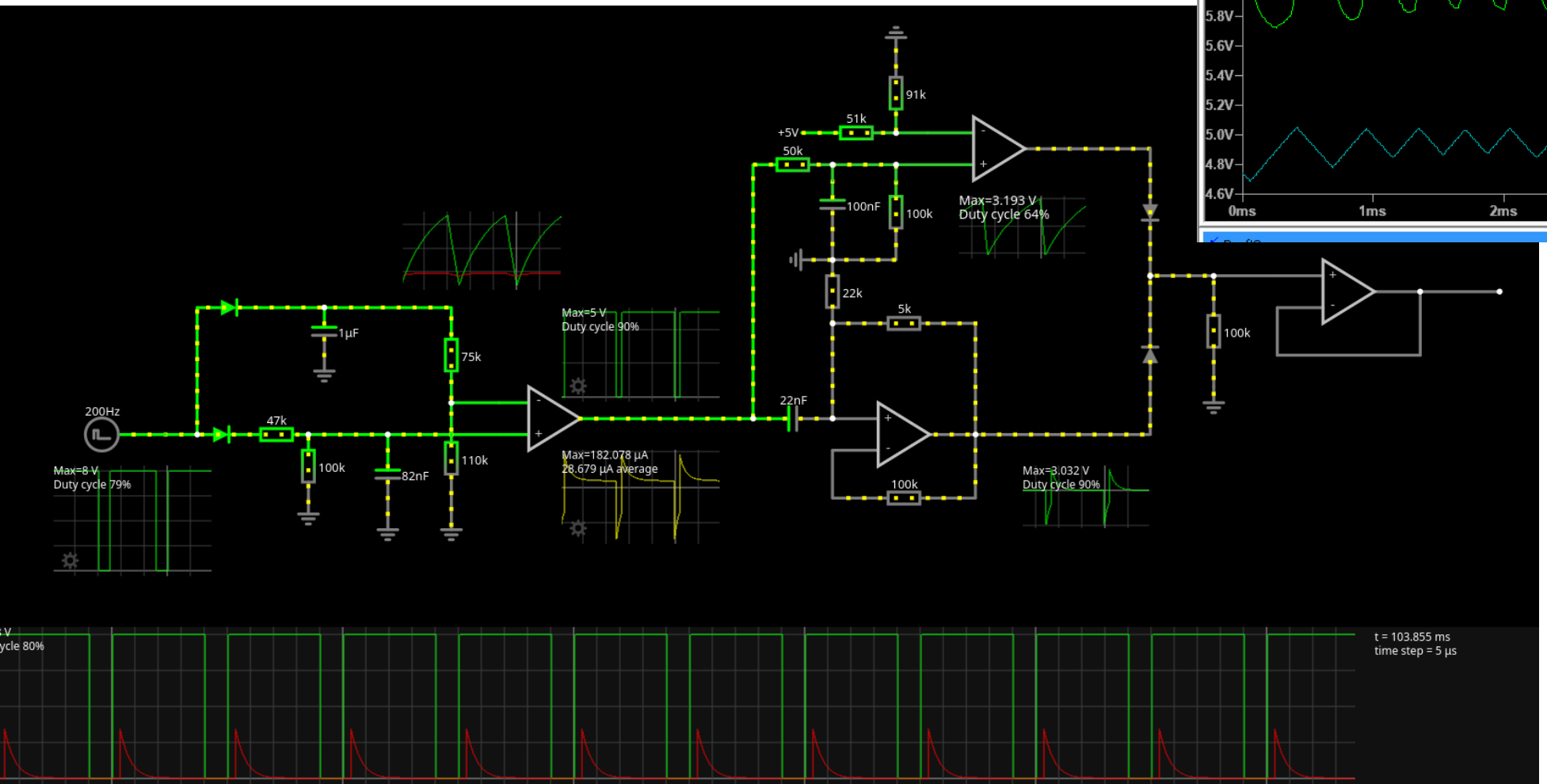
Koncept rešitve

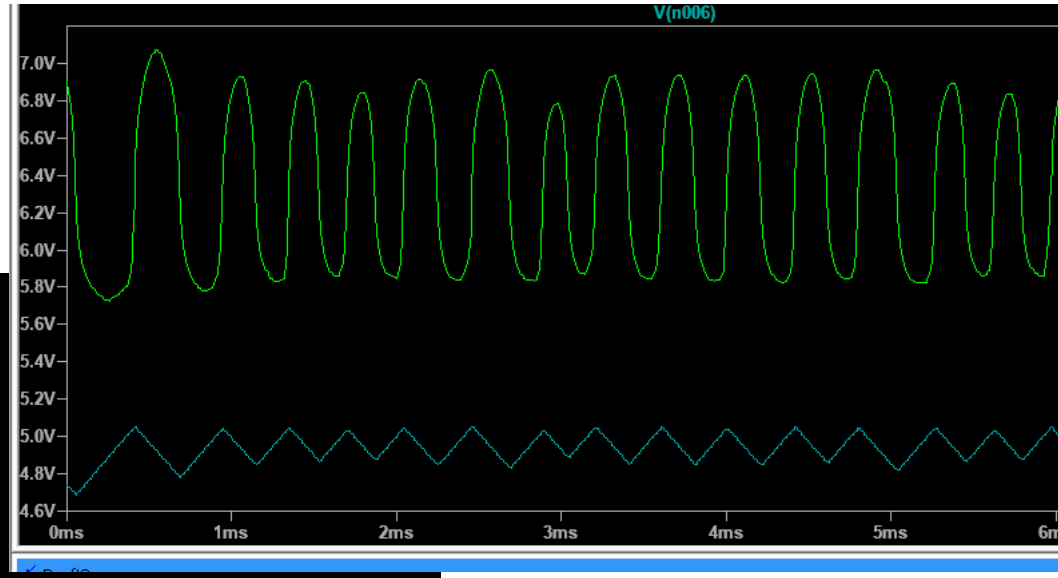
- Da dela dobro – Nevem še...
- Ne predrago – 1 🍦
- Čimbolj preprosto - ?
- Elegantno
  - uh oh





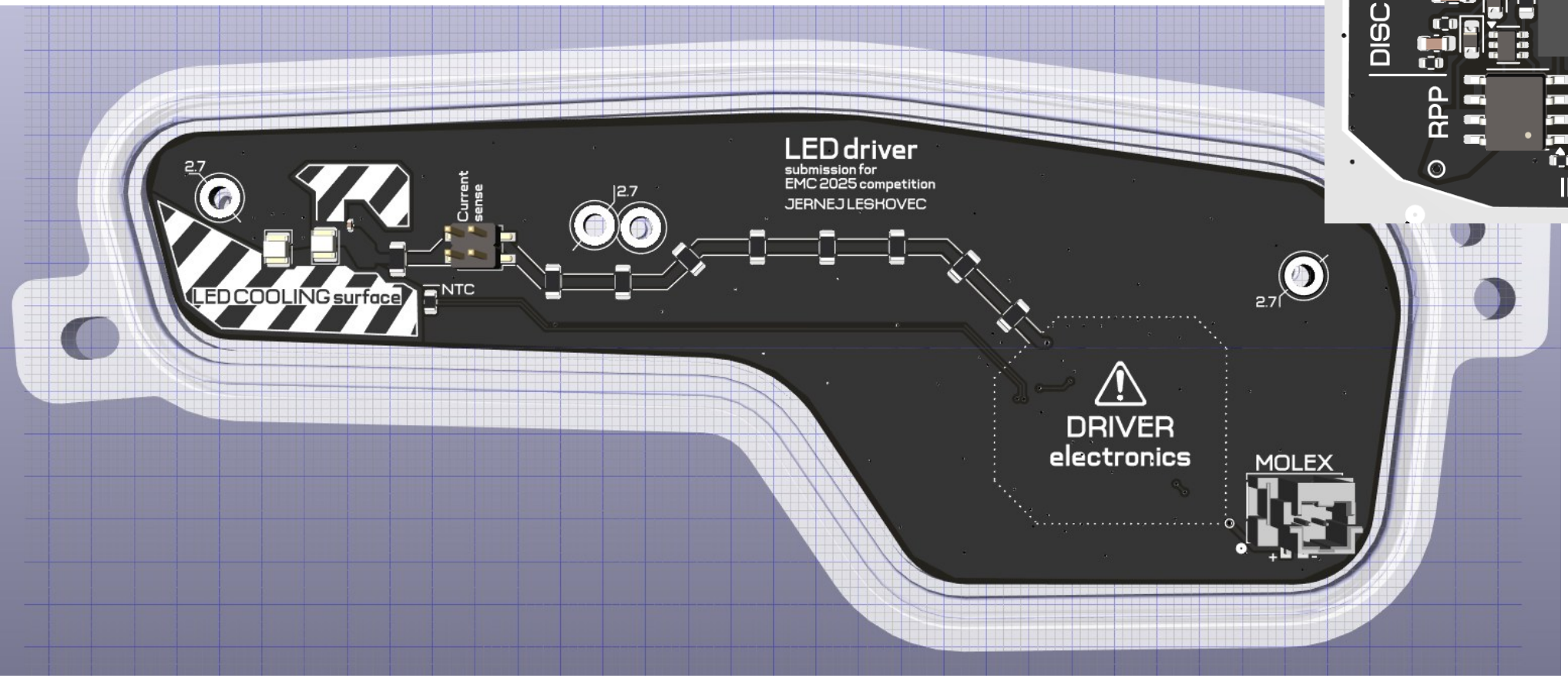
Izračuni, simulacije

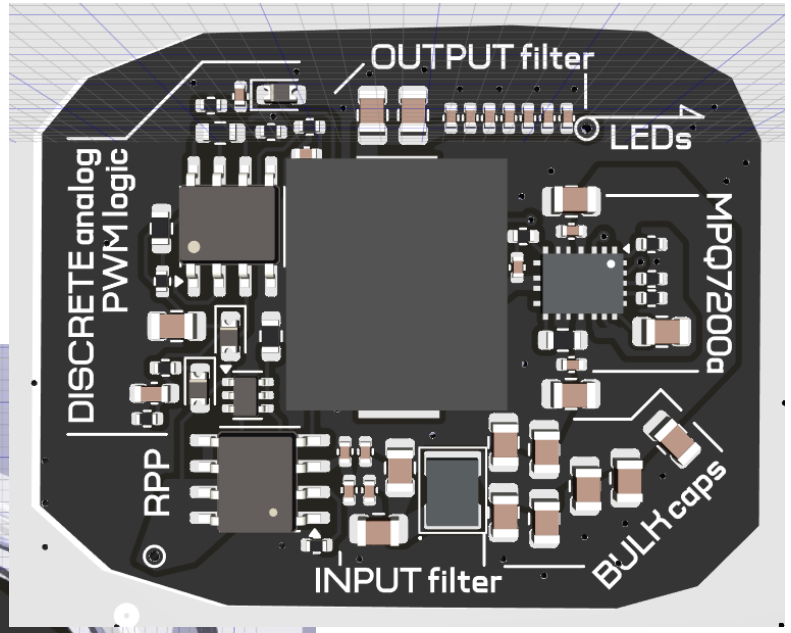




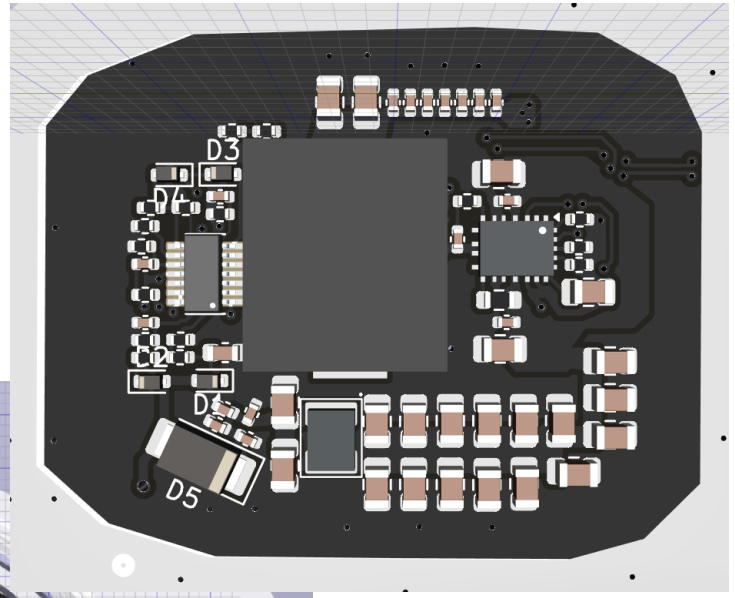
Načrtovanje tiskanega vezja

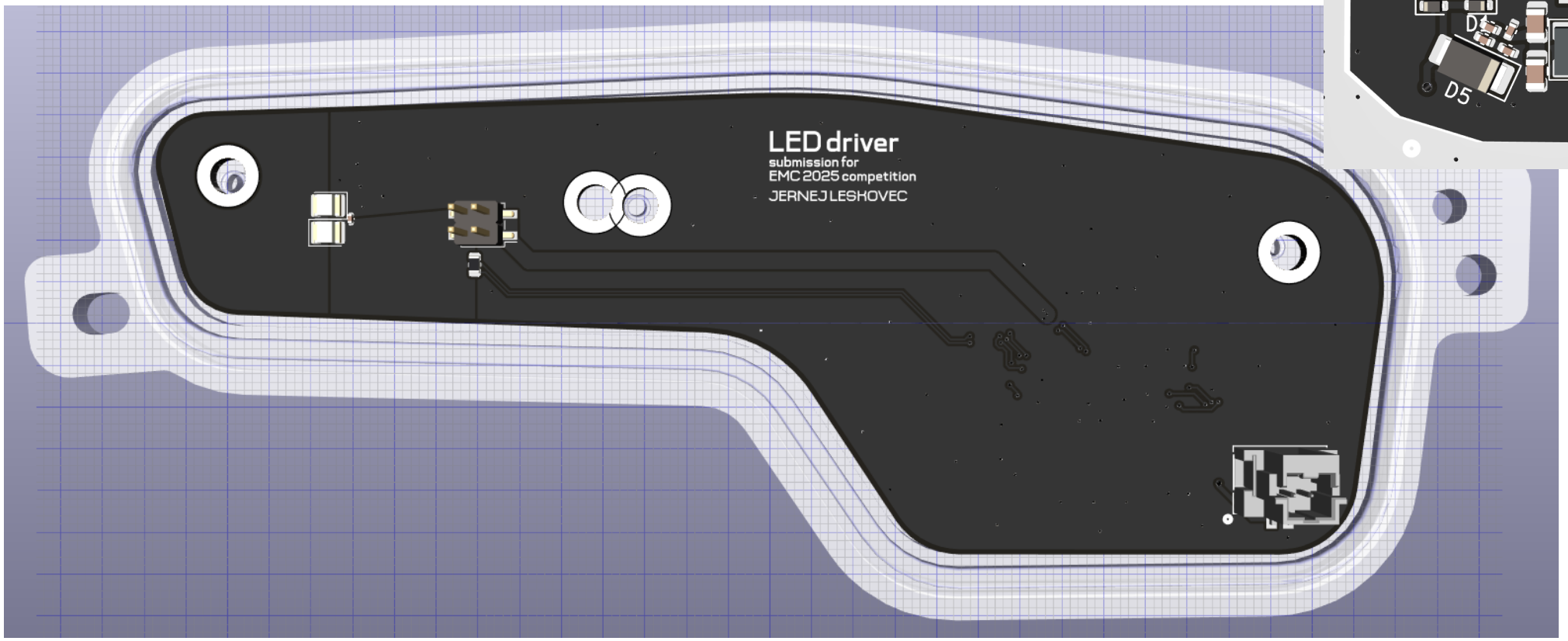
Verzija 1



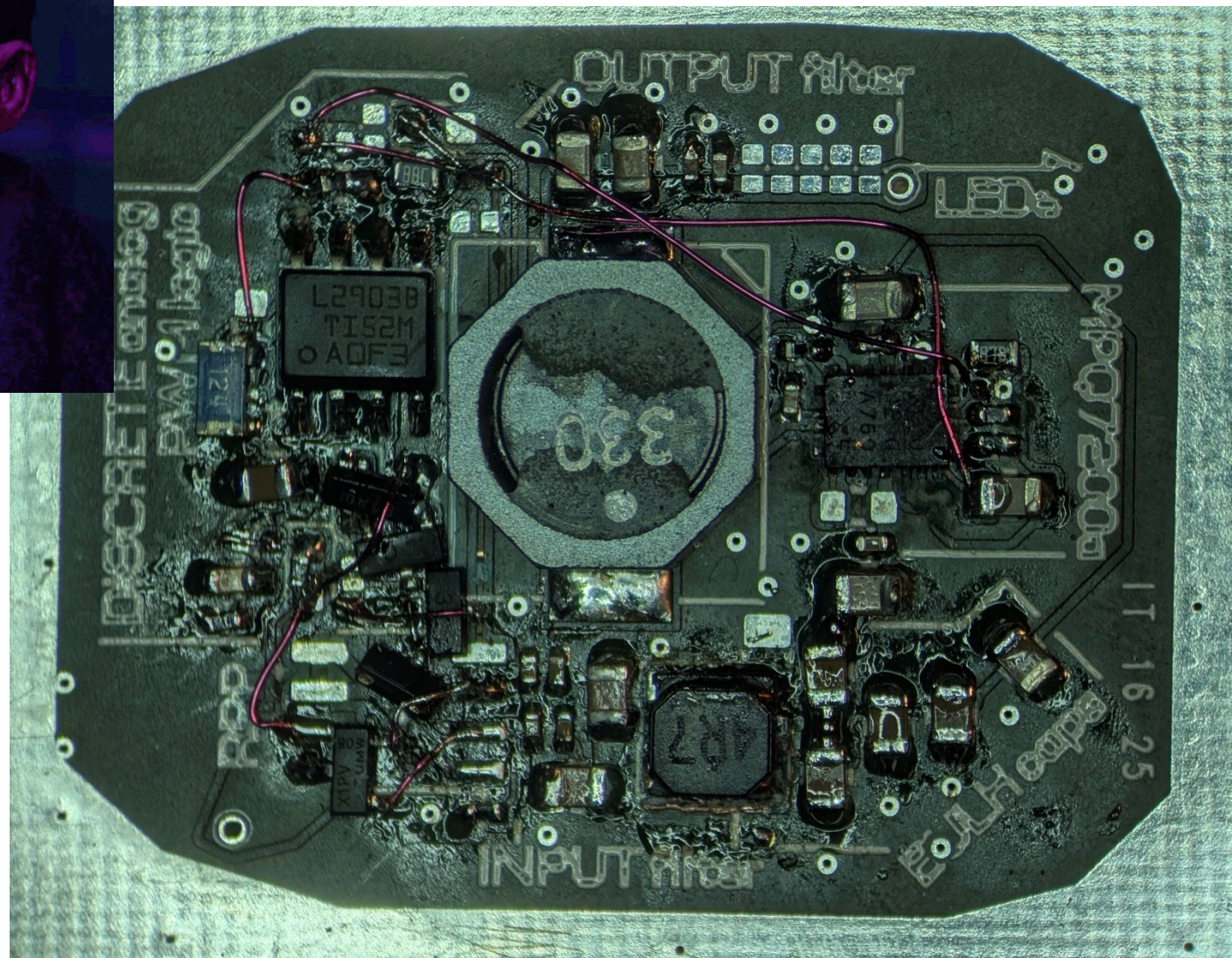


Verzija 2


D3
D4
D5

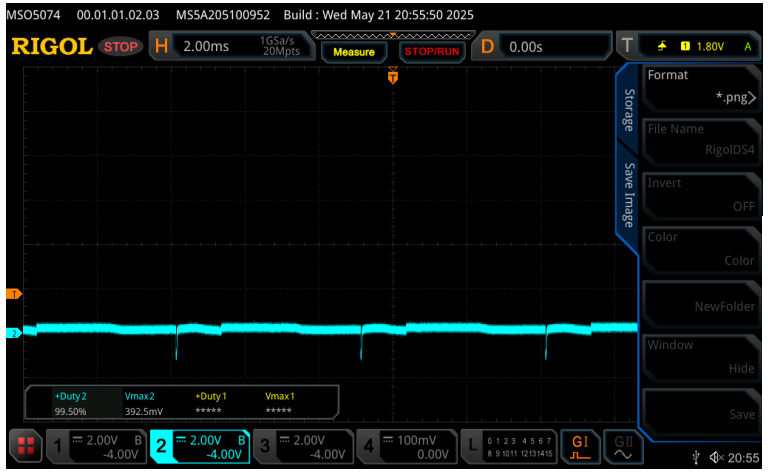

LED driver
submission for
EMC 2025 competition
JERNEJ LESHOVEC

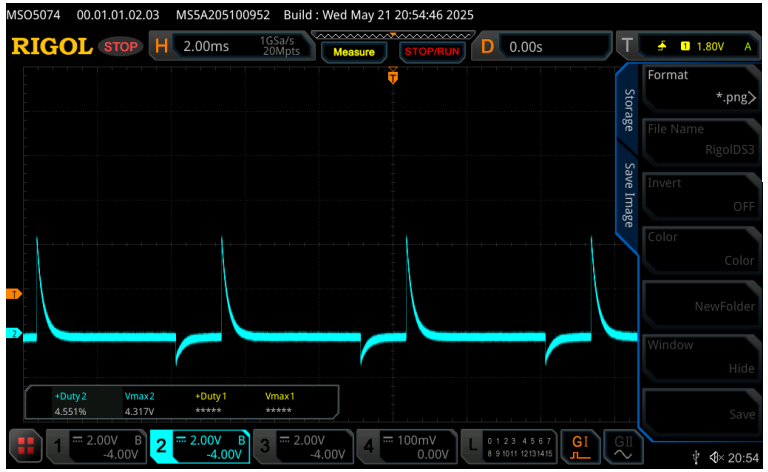
Verzija 5

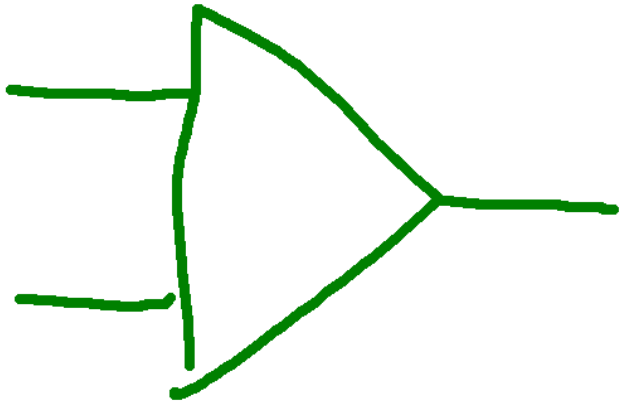


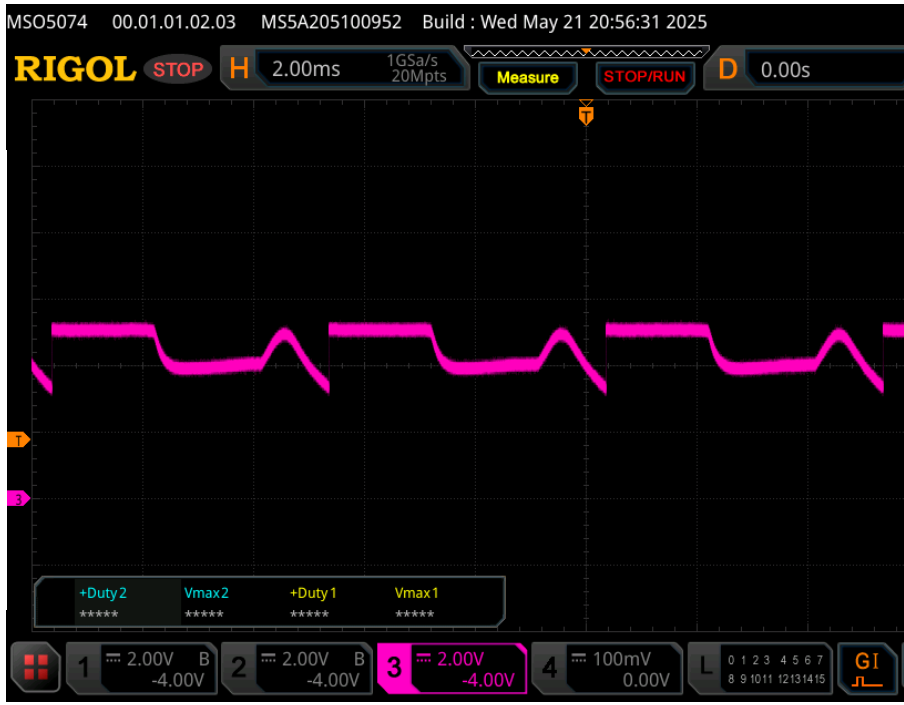
Preliminarne meritve

Verzija 2 kje je virtualni kratki stik :((



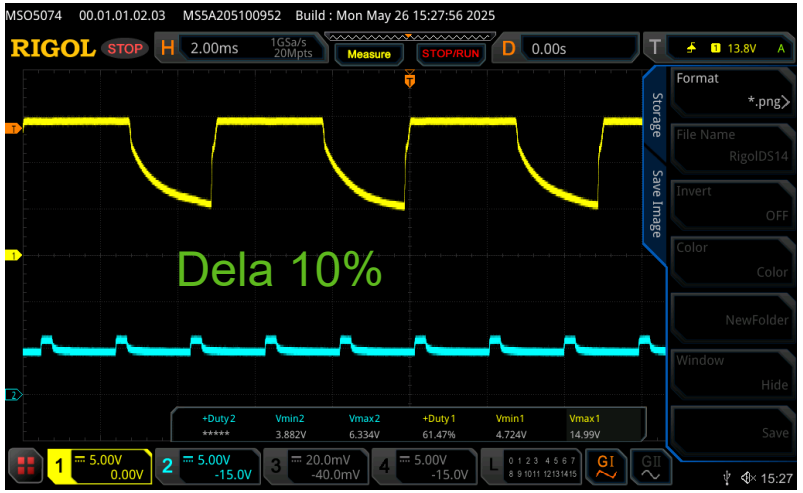




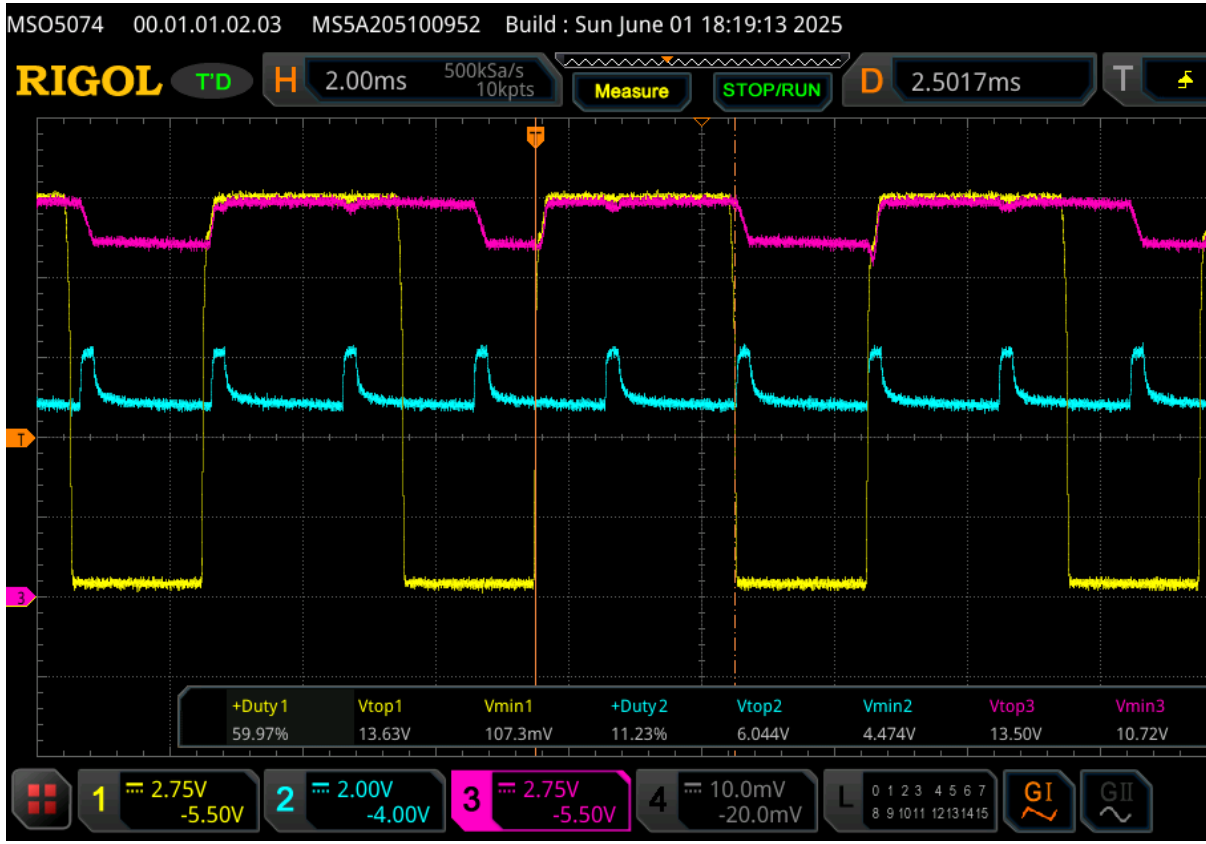


Preliminarne meritve

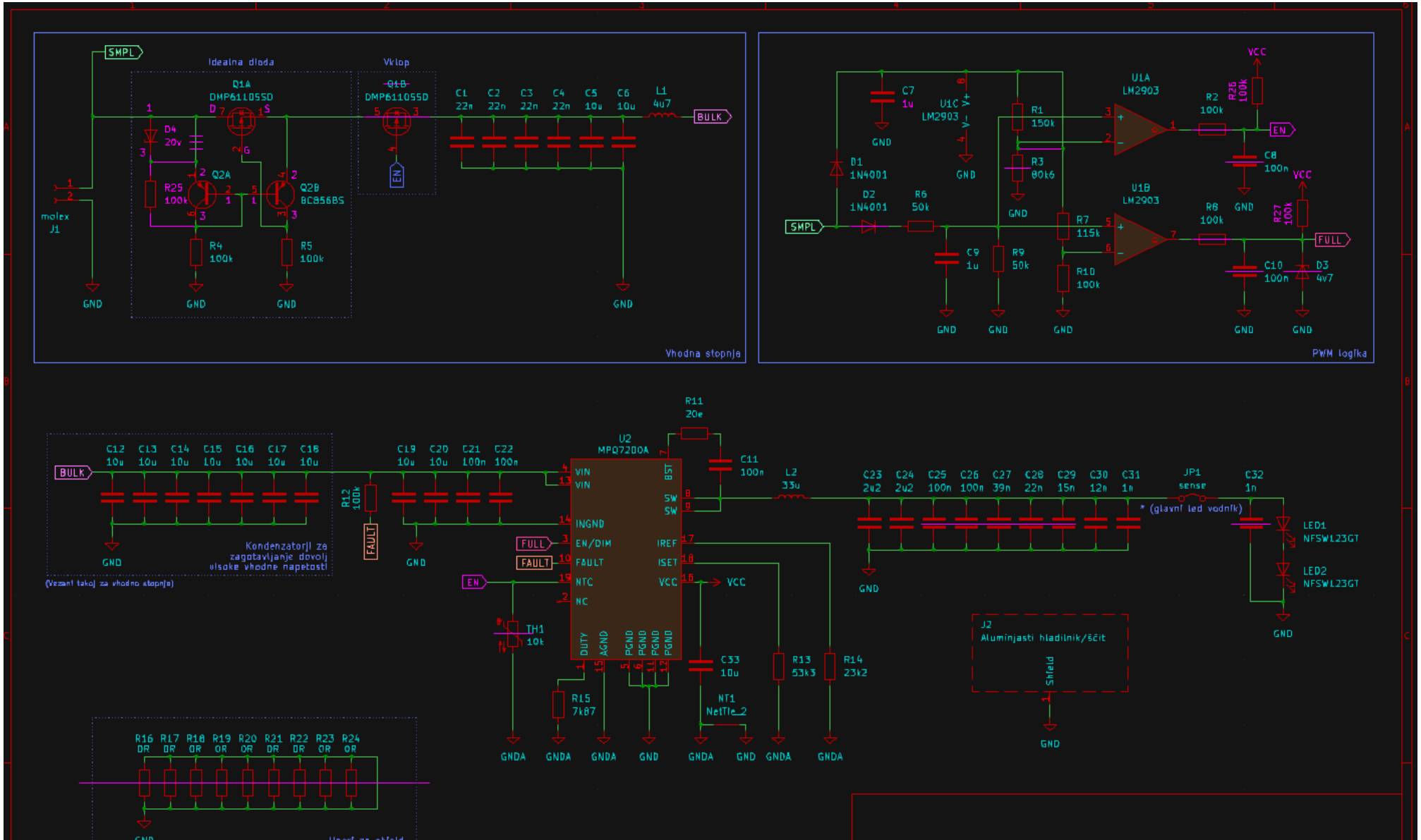
Verzija 2.2 (ps. DC 10V = DC)



Verzija 5



Morebitni popravki



Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko
in optoelektroniko

Jernej Leskovec

Rezultati

Jernej Leskovec – Funkcionalni in električni testi

Osnovna funkcionalnost ✓

PWM območje ✓

Napetostno območje ✓

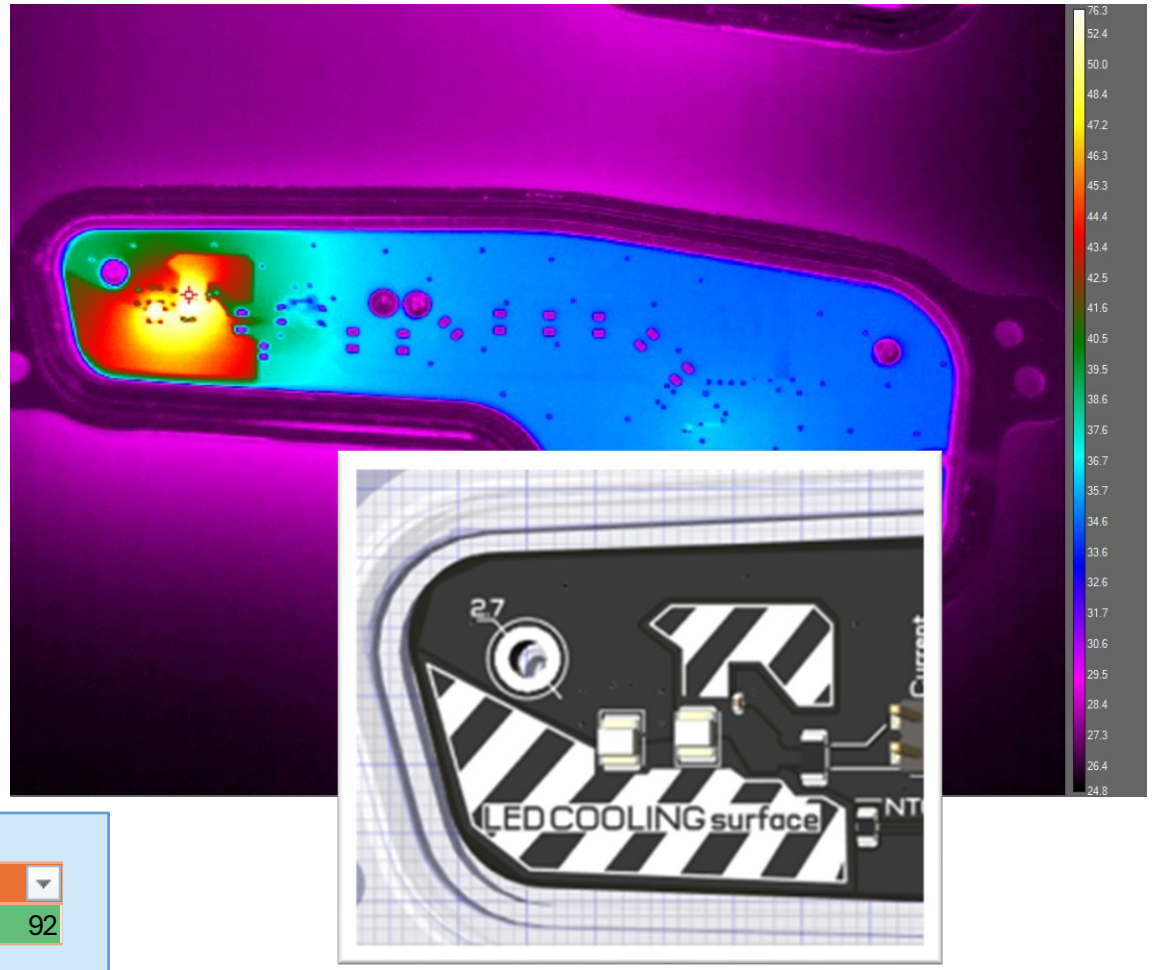
Temperaturno območje ✓

Obrnjena polariteta ✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	147	1.986	6.08	301	1.830	92

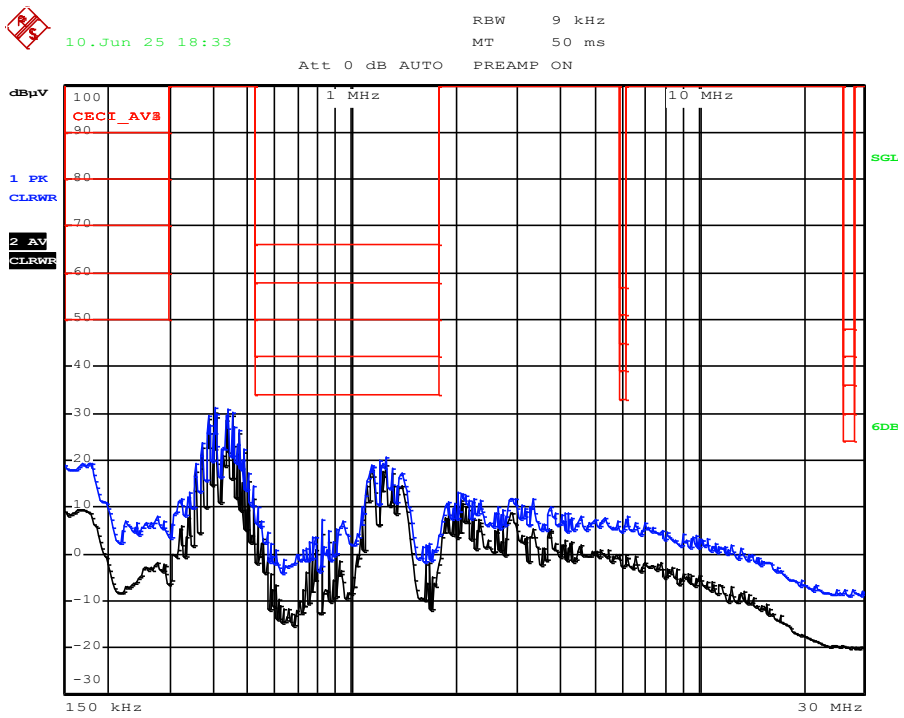
Temperaturna obremenitev: **54.25 °C**



Jernej Leskovec – EMC

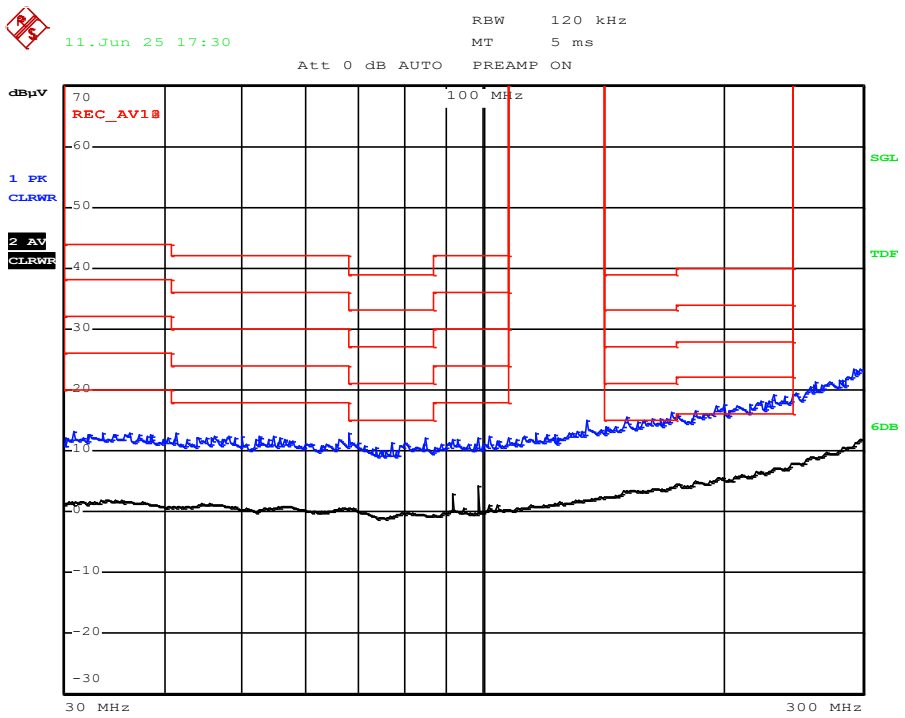
CE

5



RE

5



BCI

100 mA

B

318MHz, svetilnost se poveča za več kot 10%

RI

100 V/m V
1Ghz

60 V/m H+V

A

Jernej Leskovec - Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca (Mfr. No)	Proizvajalec (Mfr.)	Koda dobavitelja (SKU)	Dobavitelj	Cena/kos (za 10000)	Št. Kosov na vezje	Cena za št. kosov na vezje [$]
R1 – R14, C3, C25, C26, C4, C6, C8, C19, C20, C22	0402, 0603 komponente	NA	NA	NA	NA	0.005 €	23	0.115 €
C2	0603, 1u kondenzator	0603B105K250CT	Walsin	791-0603B105K250CT	Mouser	0.003 €	1	0.003 €
C1, C23, C24	0805, 2u2 kondenzator	CL21B225KAFNNNF	Samsung	KKK20356	Rutronik	0.010 €	3	0.029 €
C5, C7, C9-C12, C14-C18, C21	**0805, 10u kondenzator**	**CL21B106KAYQNNE**	**Samsung**	**C3039694**	**LCSC**	**0.027 €**	**12**	**0.326 €**
D3	Dioda	BAS716,115	Nexperia	C282366	LCSC	0.018 €	1	0.018 €
D1, D2	Zener 20V (idealna dioda)	SZMMBZ5250BLT1G	onsemi	863-SZMMBZ5250BLT1G	Mouser	0.018 €	2	0.037 €
L1	4u7 filterska tuljava	SRP3212A-4R7M	Bourns	652-SRP3212A-4R7M	Mouser	0.089 €	1	0.089 €
L2	**33uH glavna tuljava**	**SRU1048-330Y**	**Bourns**	**SRU1048-330Y**	**Avnet**	**0.283 €**	**1**	**0.283 €**
Q2	PMOS (idealna dioda)	AO3401A	Alpha & Omega	C15127	LCSC	0.026 €	1	0.026 €
Q1, Q3	PNP (idealna dioda)	BC856C	Diotec	637-BC856C	Mouser	0.011 €	2	0.021 €
U1	OC komparator	LM2903DR	Texas Instruments	C7549	LCSC	0.030 €	1	0.030 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
48	0.98 €	0.48 €	1.46 €

Načrtovanje elektronike za EMC² 2025

študentska delavnica in tekmovanje

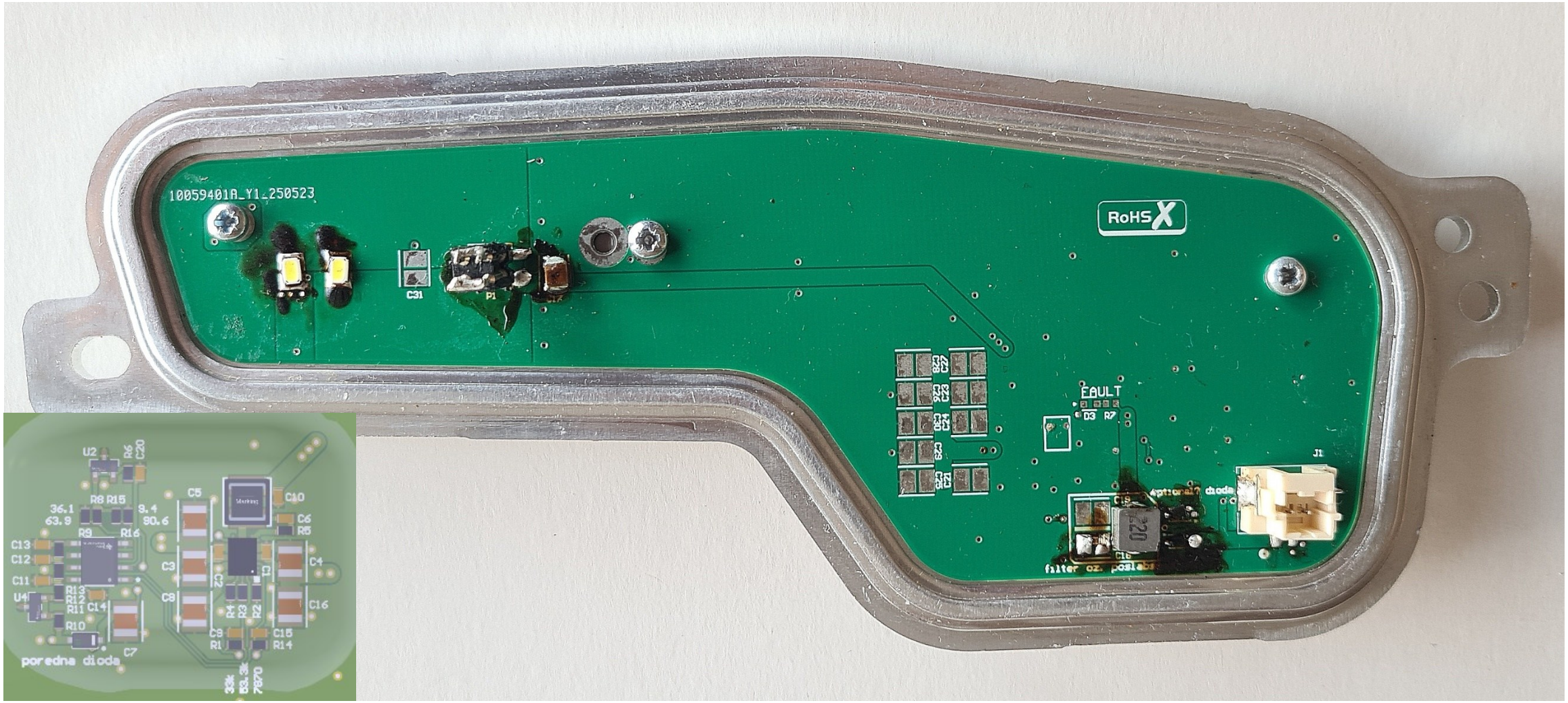
UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

Samo Debeljak

2. letnik, VS-EL

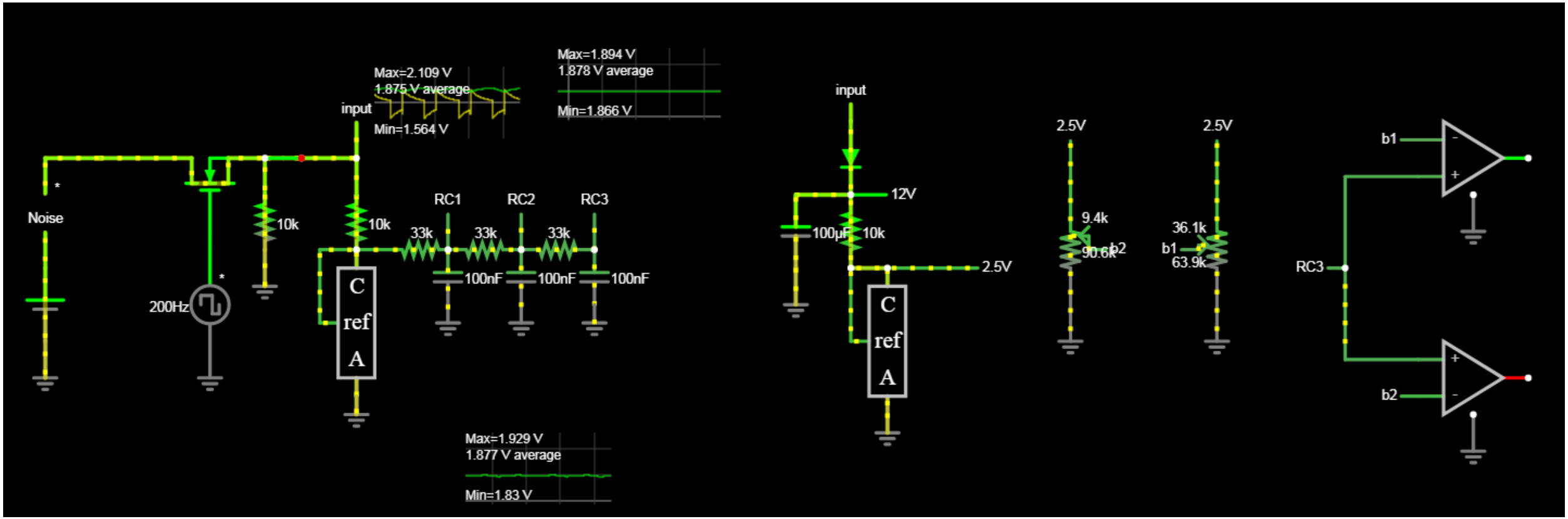
Samo Debeljak



Koncept rešitve

- Vse bo delal v prvo in bo šlo čez meritve in bo najbl pocen
- Bolj natančno:
  - RC povprečevalnik in dva komparatorja,
  - zravn pa ogromno kondenzatorjev da so tokovne špice znotraj toleranc pri 95%

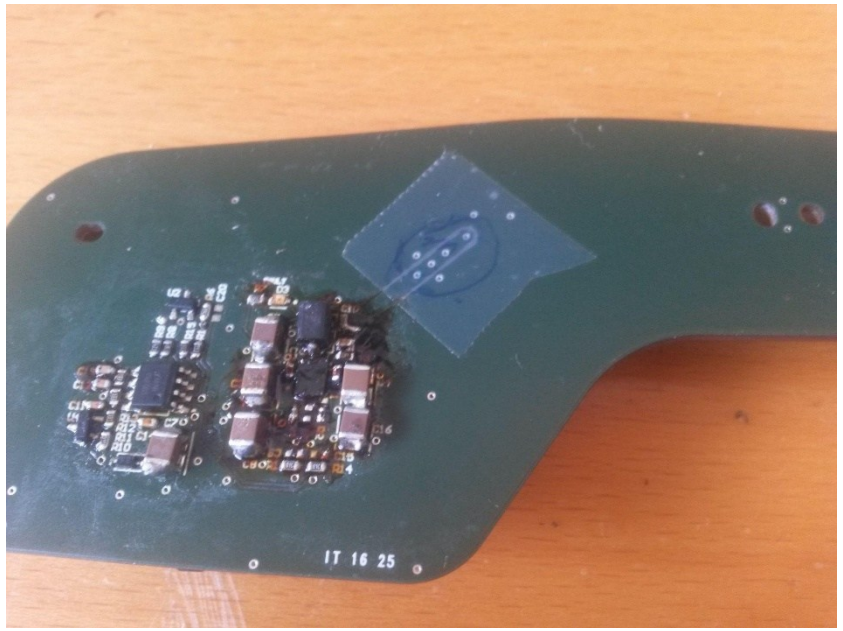
Izračuni, simulacije



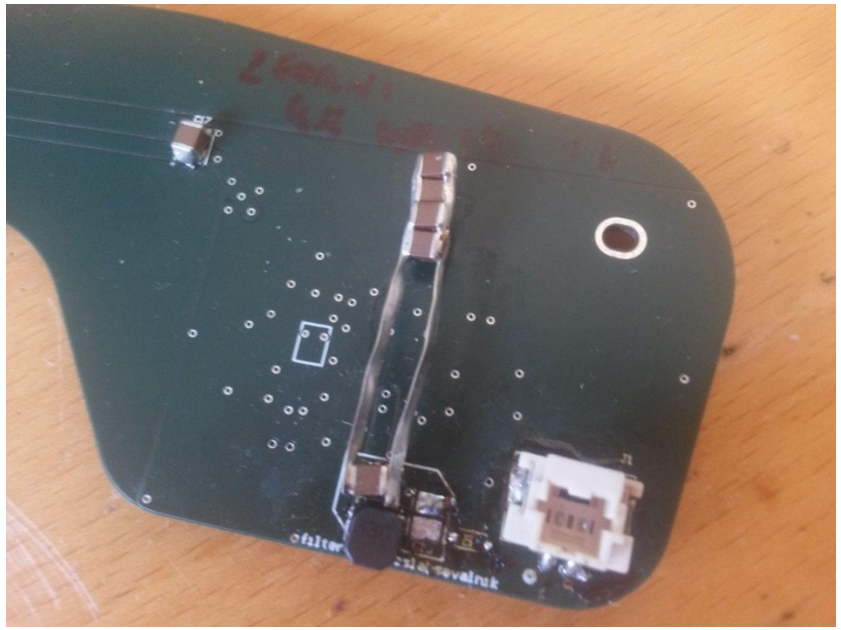
Adjustam potenciometre dokler ne preklop takrat kot bi moral

Načrtovanje tiskanega vezja

vie niso na masi

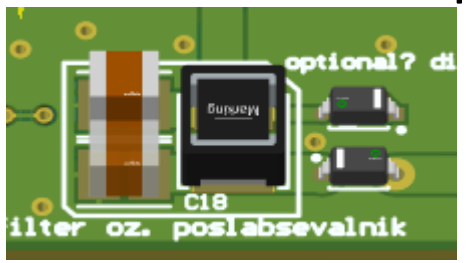


babilonski stolp

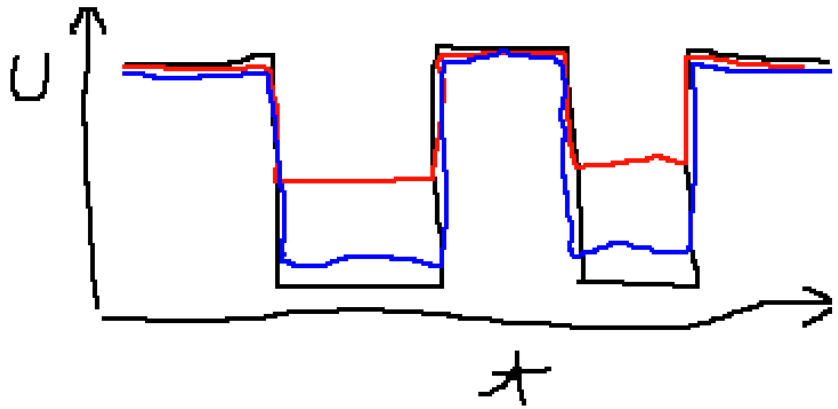


Preliminarne meritve

- Pri filtru rabiš input kondenzator, da tuljava ne nabije -40V nazaj na napajanje



Segrete kitajske diode preveč puščajo na 60C in pokvarijo PWM



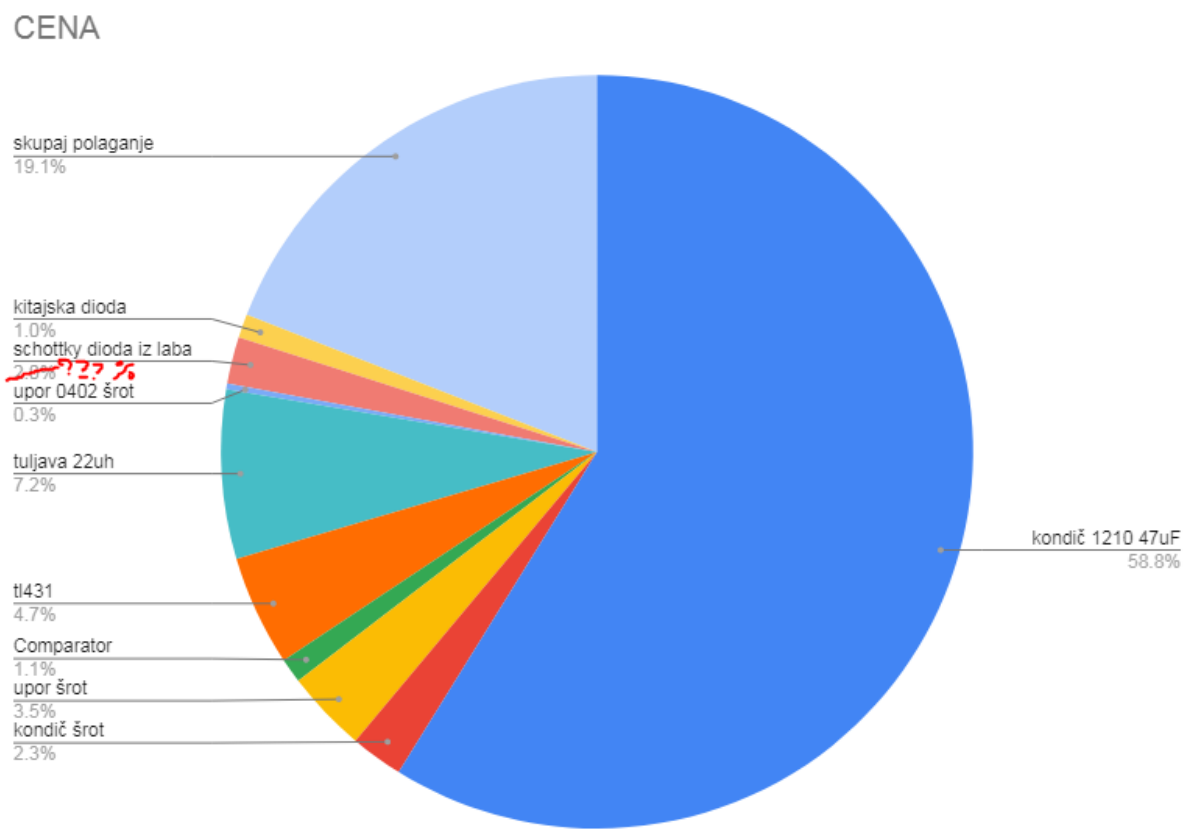
vezje ni prključeno
kitajske diode
neoznačene diode iz laba

- 10 voltni keramični kondenzatorji še ne eksplodirajo pri 70V

Morebitni popravki

Nespametna izbira diode

Kondenzatorji so dragi :(



Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

Samo Debeljak

Rezultati

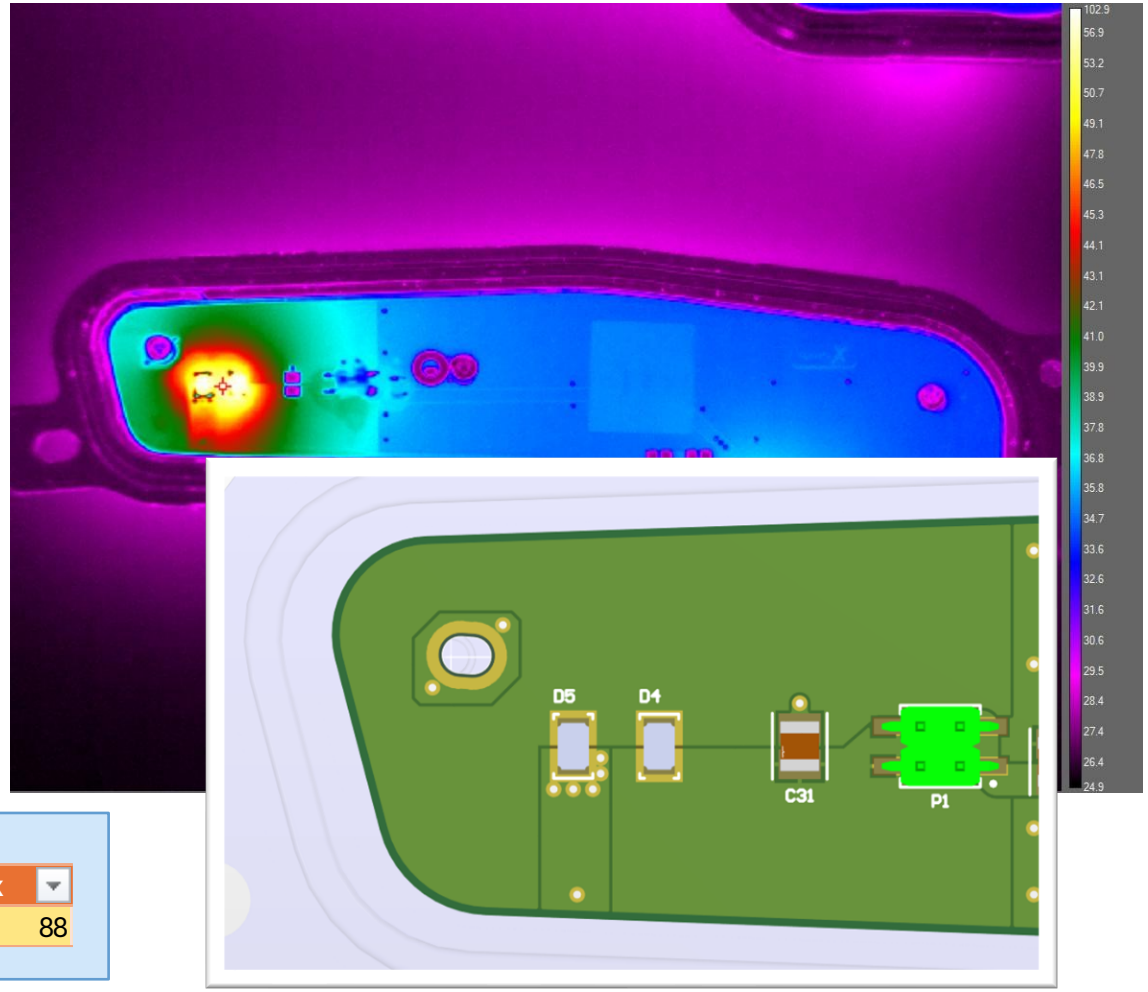
Samo Debeljak – Funkcionalni in električni testi

- Osnovna funkcionalnost ✓
- PWM območje ✓
- Napetostno območje ✓
- Temperaturno območje ✓
- Obrnjena polariteta ✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	153	2.067	6.10	301	1.836	88

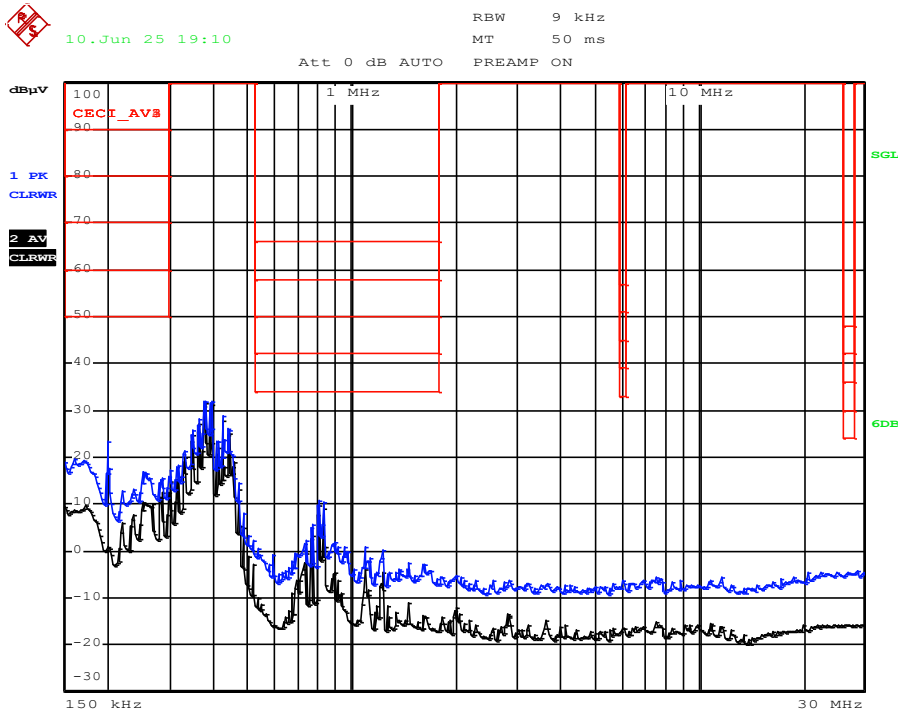
Temperaturna obremenitev: 56.15 °C



Samo Debeljak – EMC

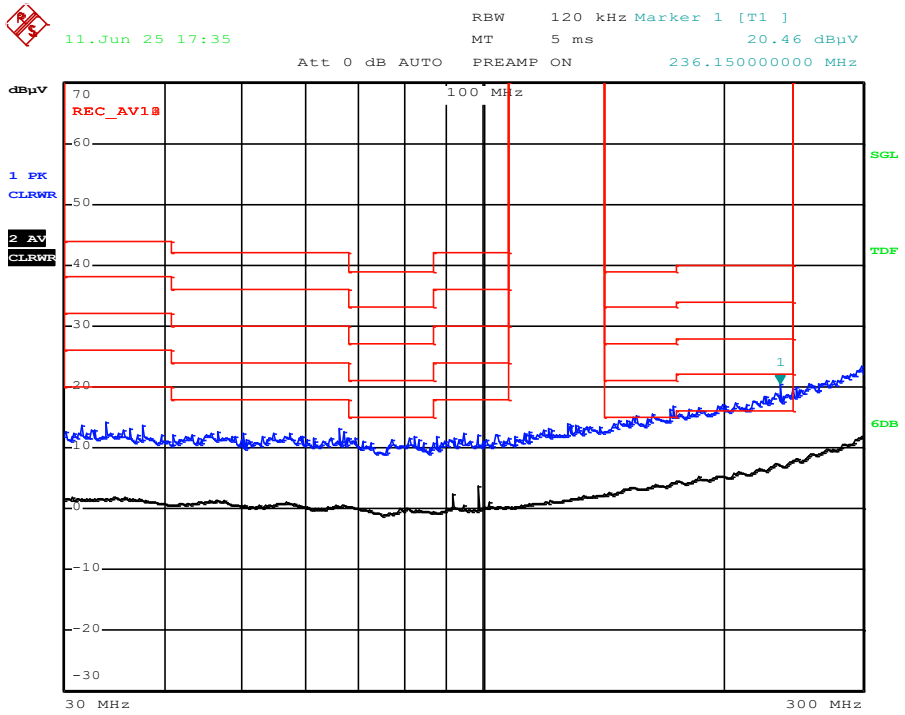
CE

5



RE

5



BCI

100 mA

C

Vezje skoraj ugasne, tudi na 60 mA ni znotraj 30%

RI

100 V/m H+V

A

Samo Debeljak – Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 10k vezij)	Št. Kosov na vezje	Cena za št. kosov na vetzje
c7 c8 c3 c5 c4 c16 c17	**kondič 1210 47uF**	**GRM32ER71A476K E15L**	**murata**	**C84494**	**lcsc**	**0.145 €**	**7**	**1.01 €**
c18 c11 c12 c13 c14 c1 c2 c10 c6	kondič 0603 100nF		šrot			0.005 €	9	0.05 €
r10 r11 r12 r13 r8 r9 r15 r16 r6 r1 r14 r2 r4 r5	upor 0603 1% razno		šrot			0.005 €	14	0.07 €
U3	Comparator open drain	LM393SR	COSINE	C25503982	lcsc	0.018 €	1	0.02 €
U2, U4	tl431	TL431IDBZR	texas instruments	C21235	lcsc	0.041 €	2	0.08 €
L1 L2	**tuljava 22uh od dolenjcev**	**mogoče SMMS0530-220M**			**mogoče lcsc**	**0.062 €**	**2**	**0.12 €**
r3	upor 0402 53.6k		šrot			0.005 €	1	0.01 €
D1	schottky dioda iz laba	nekaj podobnega CUS10S30,H3F	toshiba	C146335	lcsc	0.027 €	1	0.03 €
D6	schottky dioda	RB551VM-30TE-17	ROHM Semicon	C209640	lcsc	0.018 €	1	0.02 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
38	1.40 €	0.38 €	1.78 €

Načrtovanje elektronike za EMC² 2025

študentska delavnica in tekmovanje

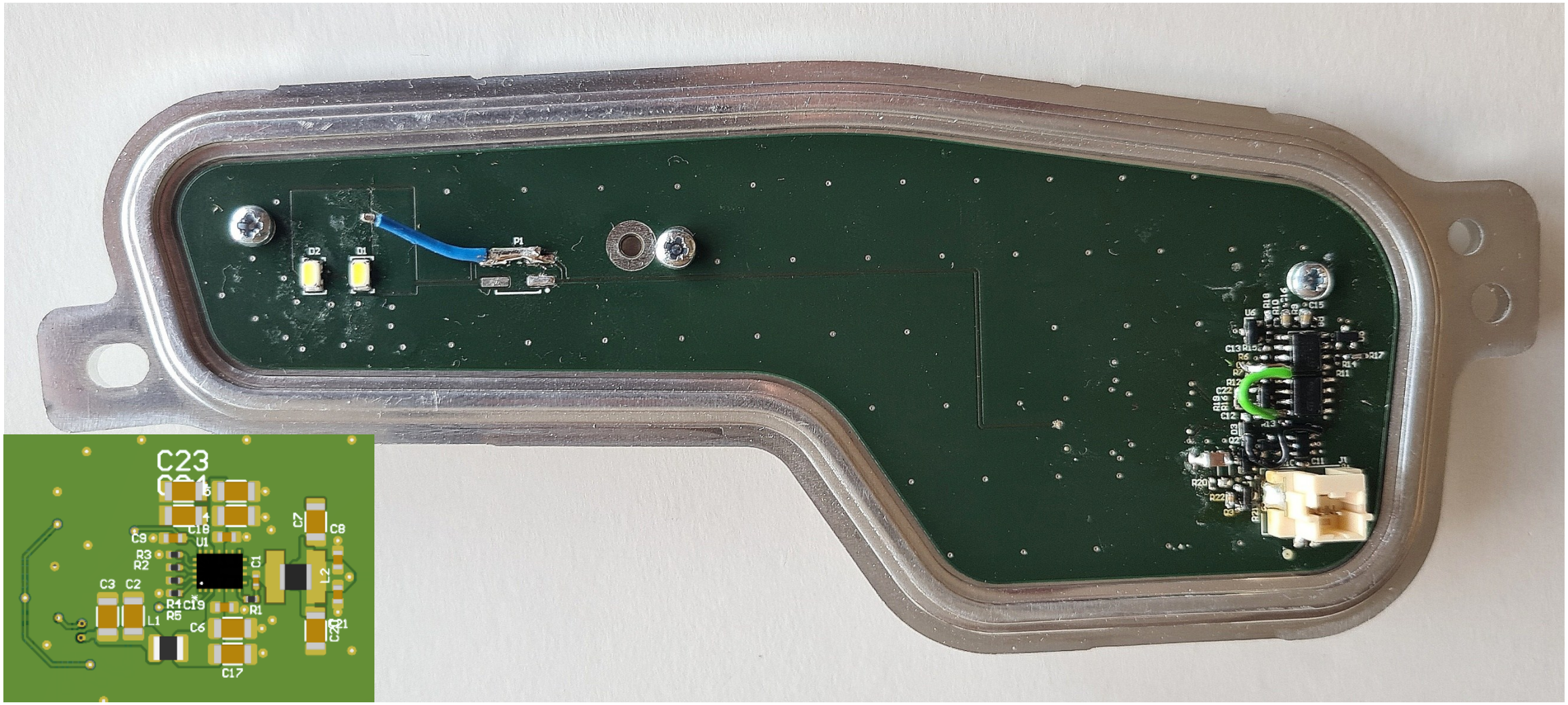
UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

Maj Pavlin

3. letnik, UN-EL

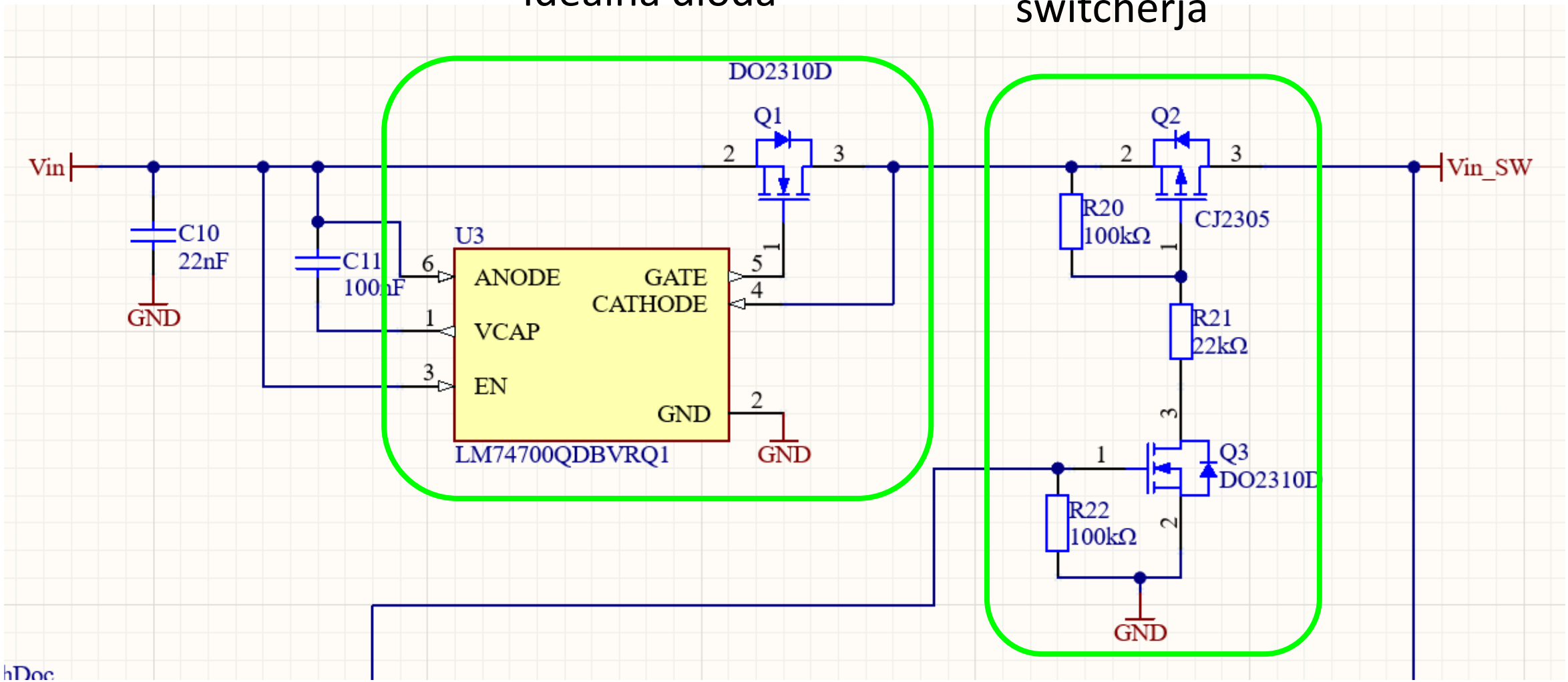
Maj Pavlin


D2
D1
P1
C23
C9
C18
U1
R3
R2
C3
C2
R4
C19
R5
L1
C6
C17
C1
R1
C7
C8
L2
C20
C21

Koncept rešitve

Idealna dioda

Stikalo za izklop switcherja

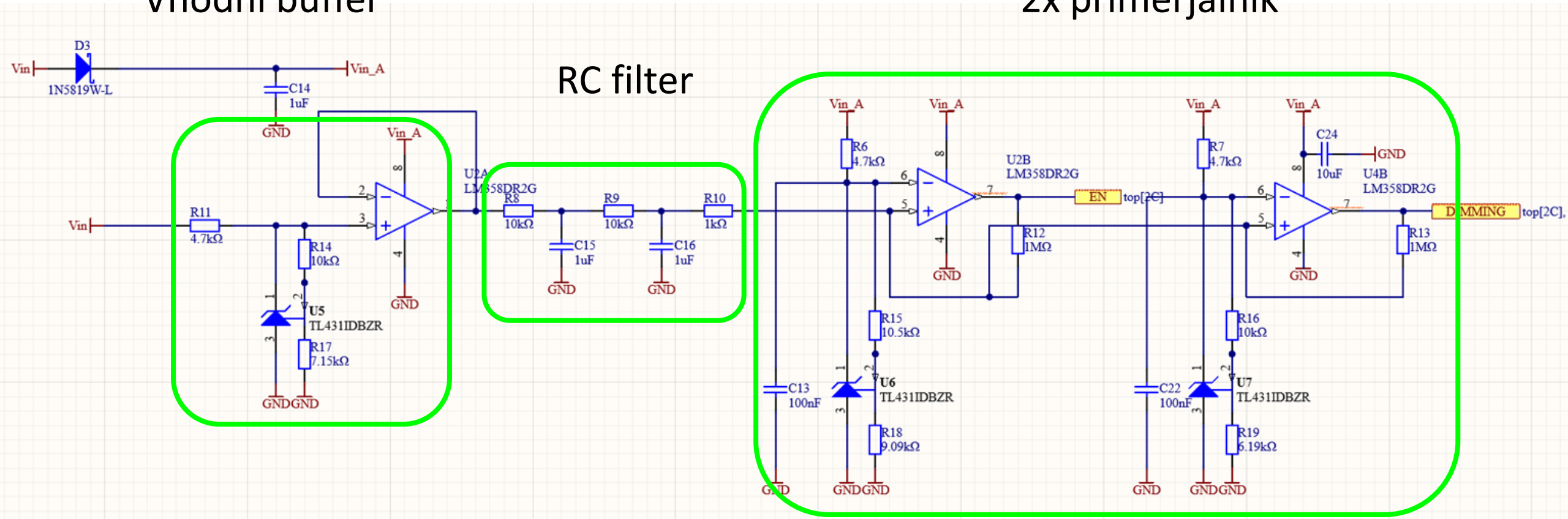


Koncept rešitve

Vhodni buffer

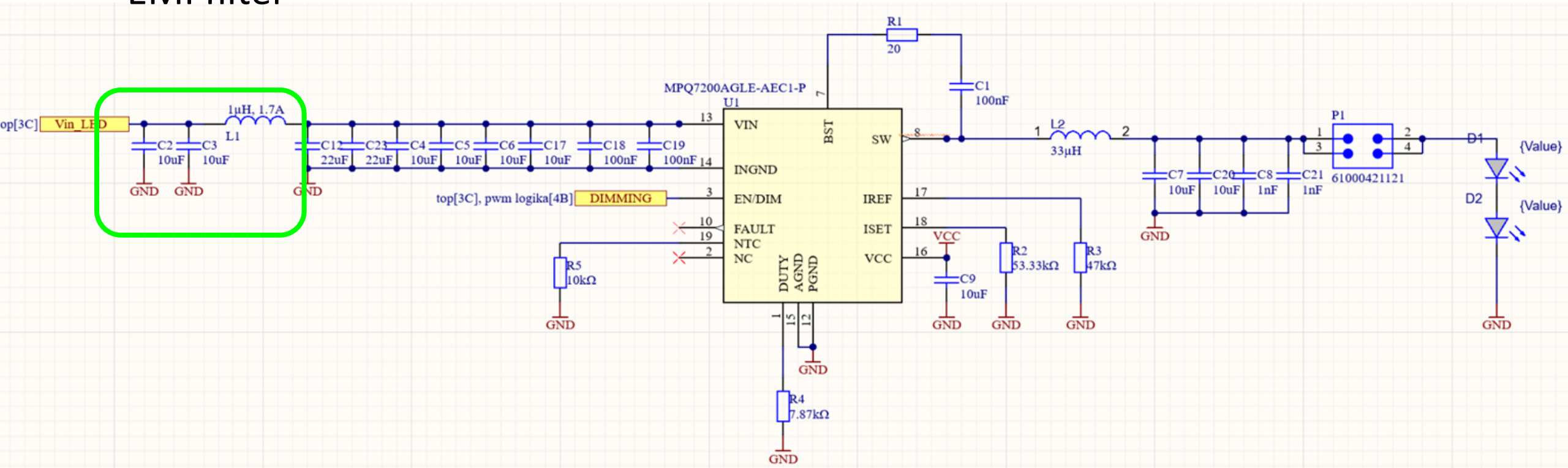
RC filter

2x primerjalnik

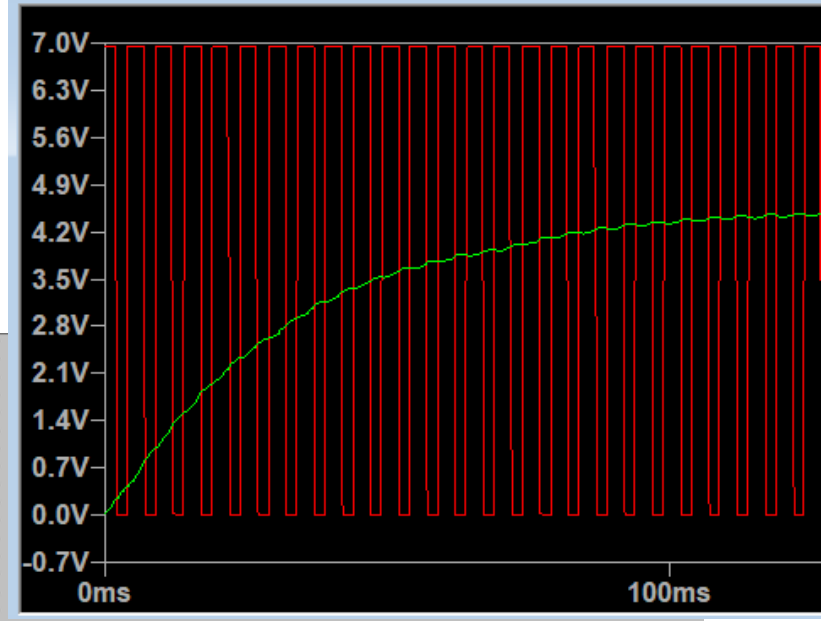


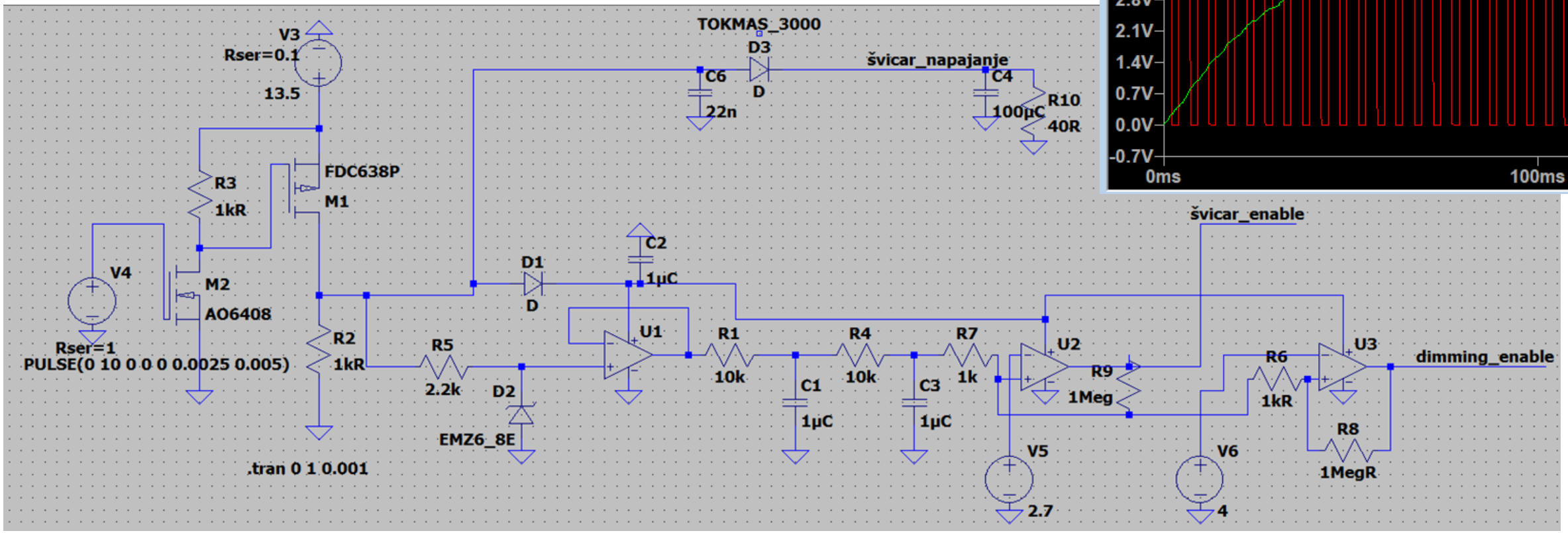
Koncept rešitve

EMI filter

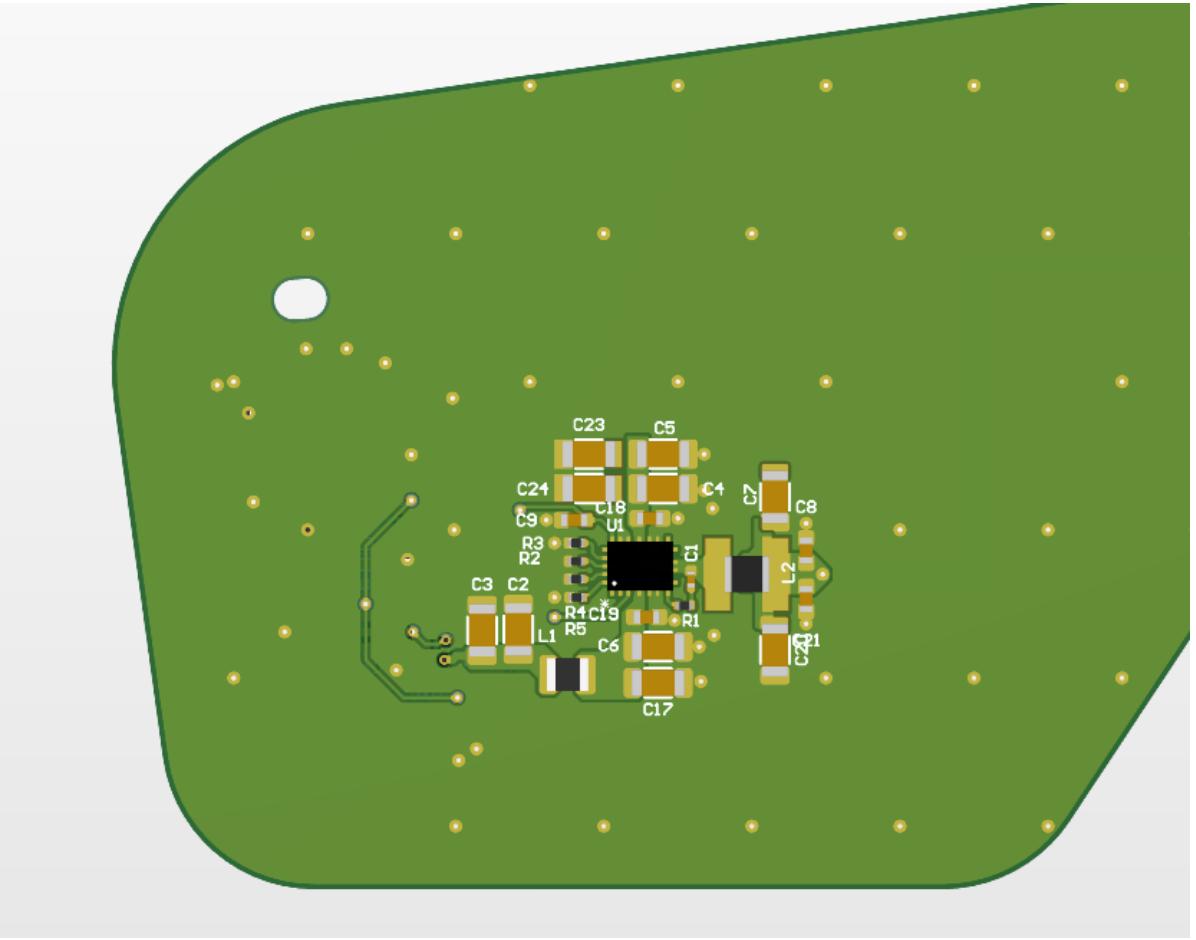


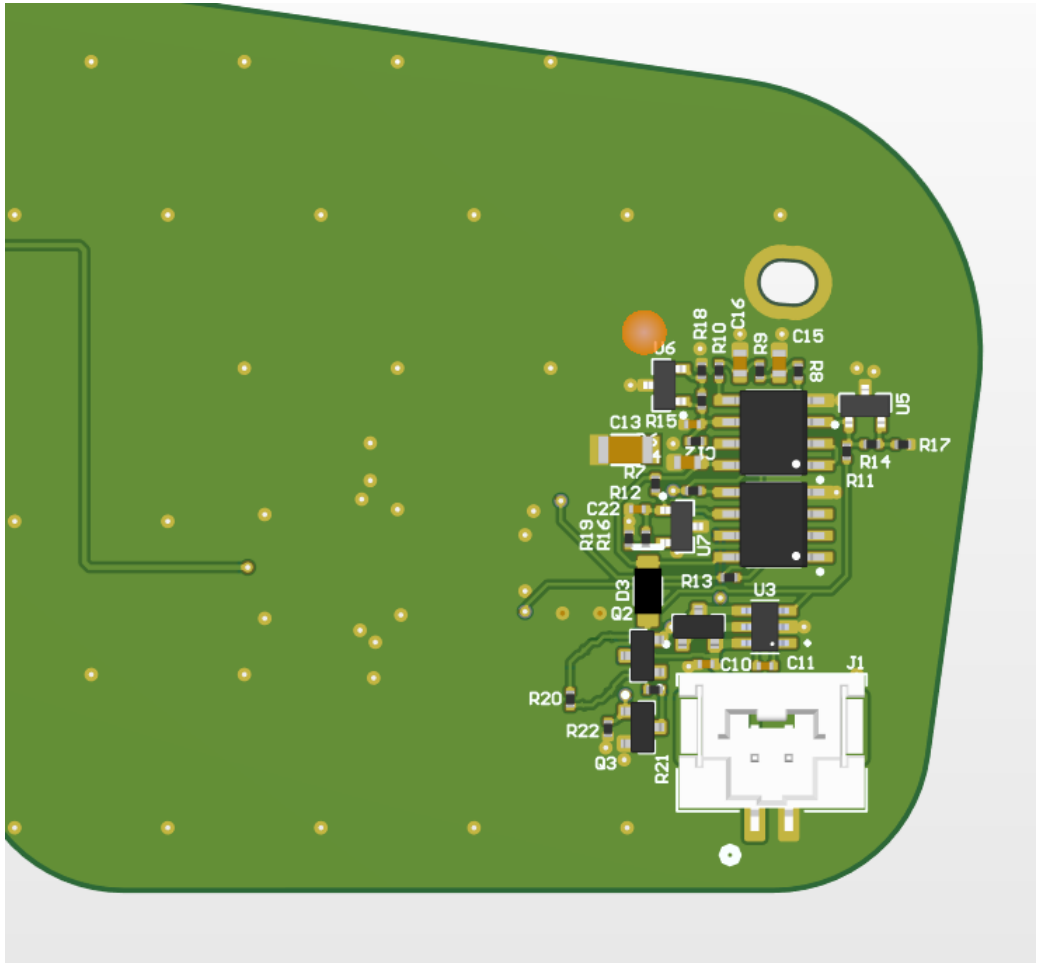
Izračuni, simulacije



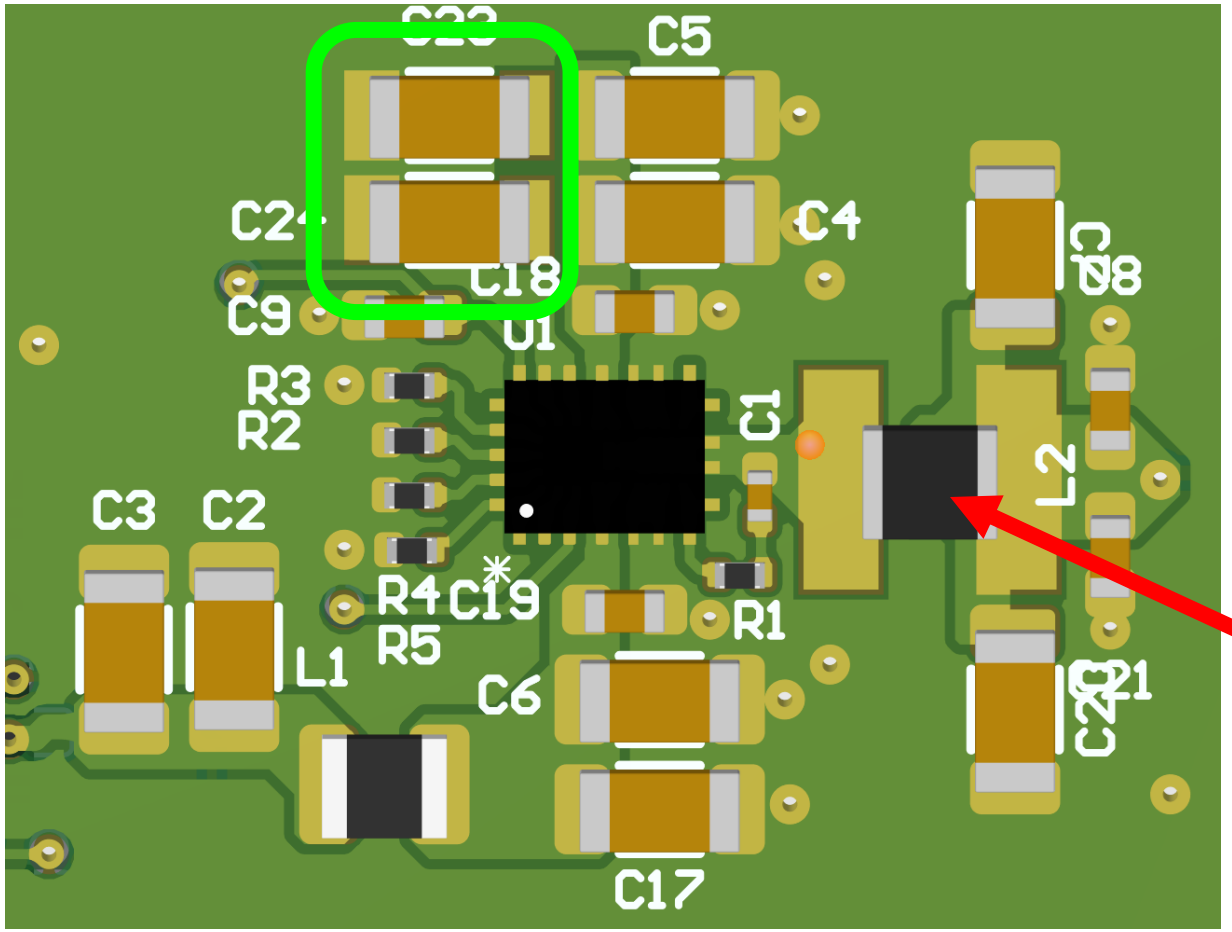


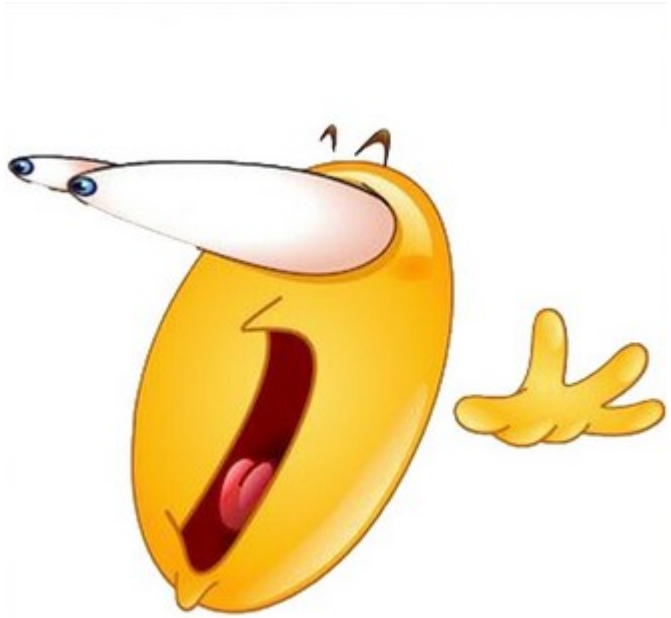
Načrtovanje tiskanega vezja





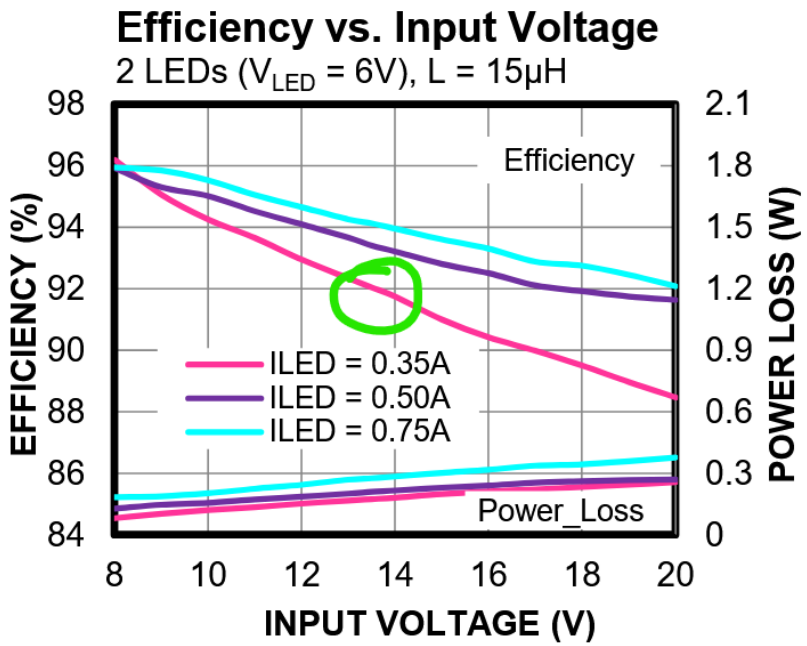
Načrtovanje tiskanega vezja

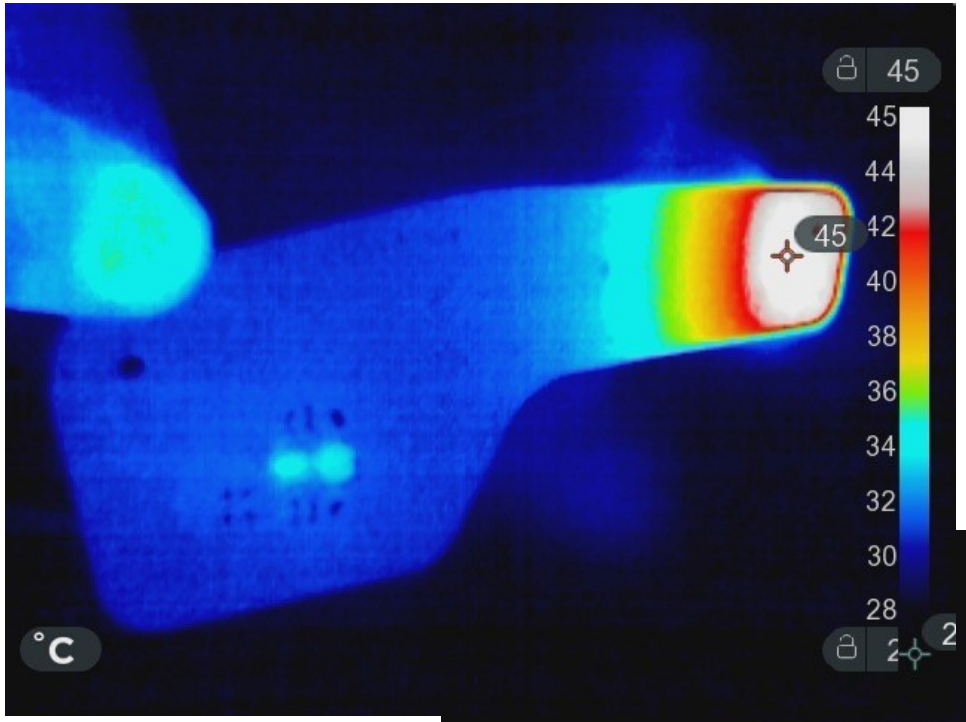


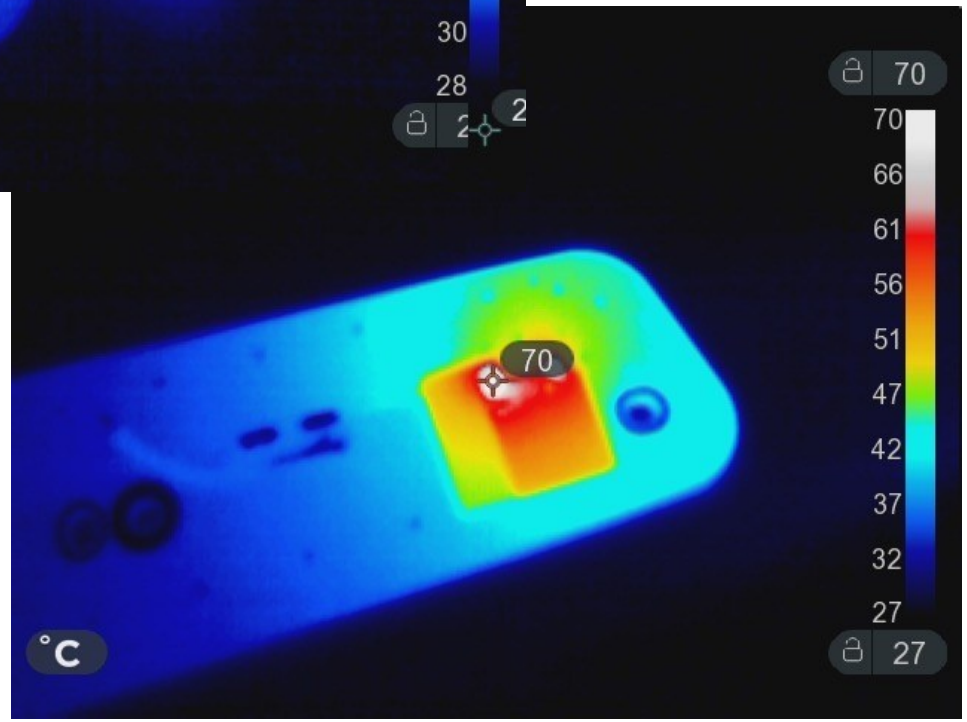


Preliminarne meritve

- Izmerjena eff. vezja: 88%
- Po datasheetu: 92%







Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

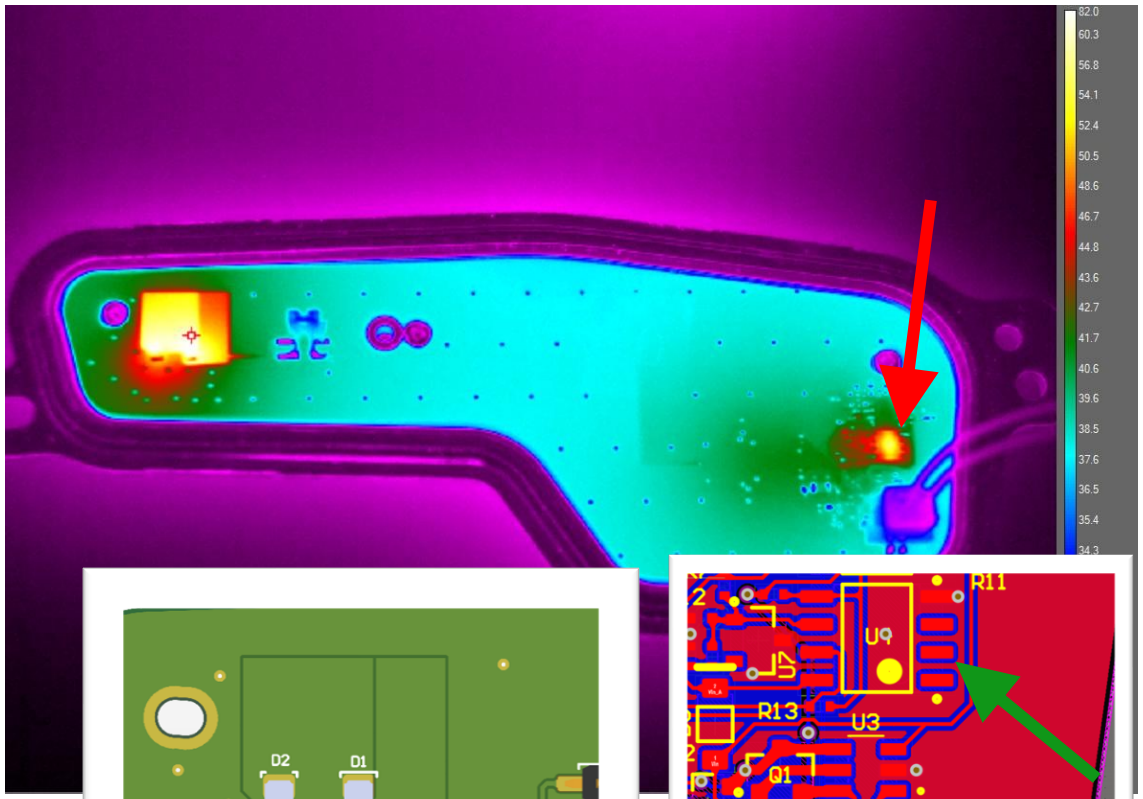
Maj Pavlin

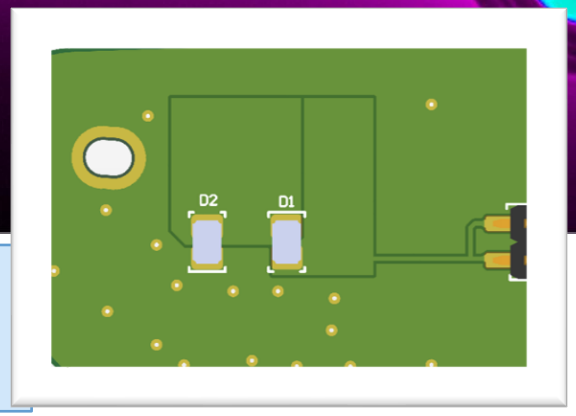
Rezultati

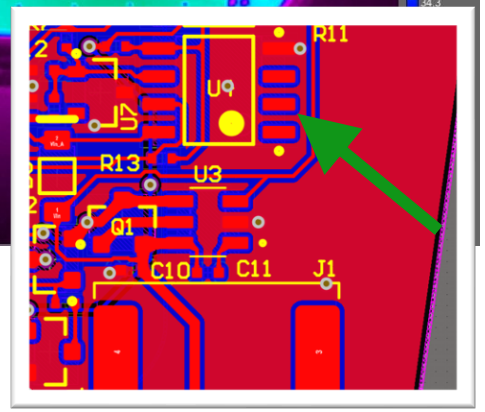
Maj Pavlin – Funkcionalni in električni testi

Osnovna funkcionalnost	✓
PWM območje	✓
Napetostno območje	✓
Temperaturno območje	✓
Obrnjena polariteta	✓

Temperaturna obremenitev: 61.90 °C







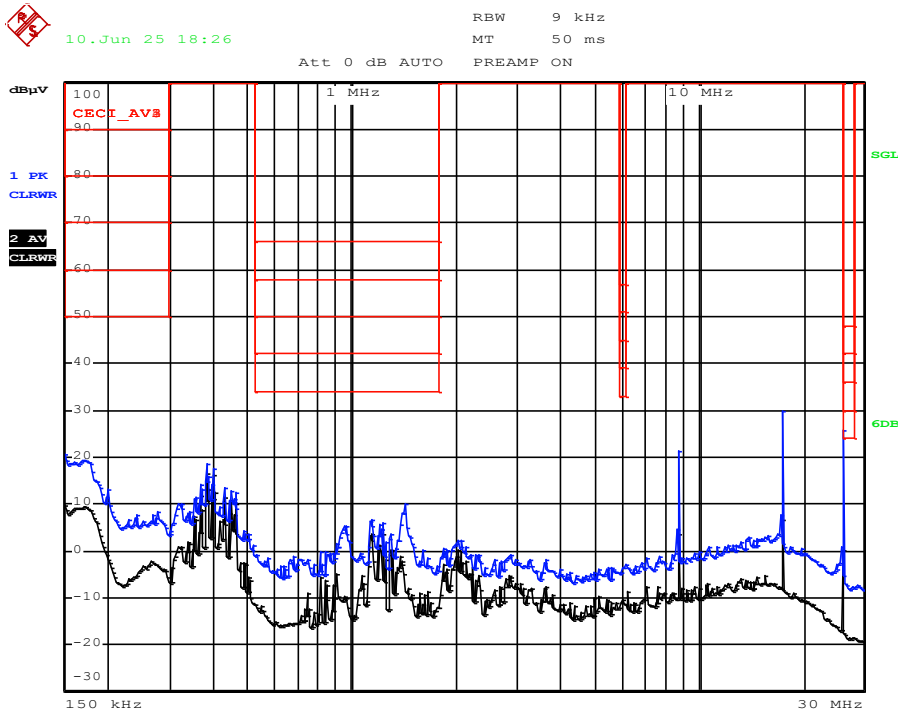
Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.5	187	2.525	6.12	301	1.843	73

Maj Pavlin – EMC

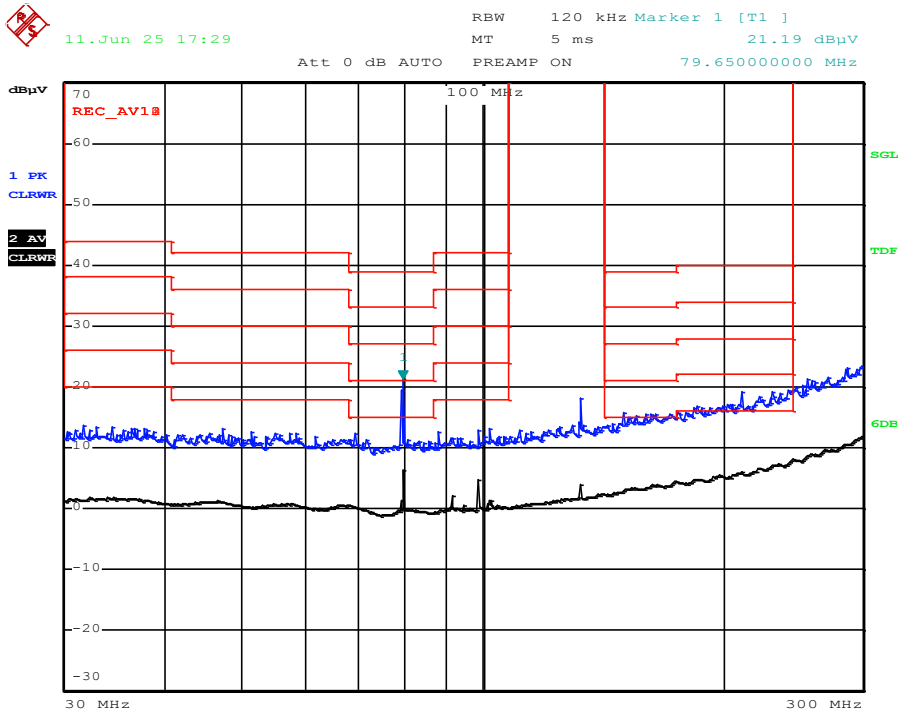
CE

5



RE

5



BCI

100 mA **A**

RI

100 V/m H+V **A**

Maj Pavlin – Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 1000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vetzje
ŠROT						€0.0050	28	€0.1400
C2, C3, C4, C5, C6, C7, C17, C20	**50V 10uF X7R ±10% 1206 Keramični kondenzator**	**CGA1206X7R106K500NT**	**HRE**	**C6119989**	**LCSC**	**€0.0186**	**9**	**€0.1674**
C9	10V 10uF X7R ±10% 0603 Keramični kondenzator	GRM188Z71A106KA73D	Murata Electronics	C2959727	LCSC	€0.0294	1	€0.0294
C14, C15, C16	25V 1uF X7R ±10% 0603 Keramični kondenzator	CGA0603X7R105K250JT	HRE	C7503503	LCSC	€0.0023	3	€0.0069
D3	40V 350mA SOD-123 Schottky Dioda	1N5819W-L	PIELENST	C41376455	LCSC	€0.0028	1	€0.0028
C12, C23	25V 22uF X7R ±10% 1210 Keramični kondenzator	CS3225X7R226K250NRL	Samwha Capacitor	C2918511	LCSC	€0.0384	2	€0.0768
L1	1.8A 1uH ±20% 1008 Ščitena tuljava	ANR252010T1R0M	APV	C6364750	LCSC	€0.0232	1	€0.0232
L2	830mA 33uH ±20% 5x5mm Tuljava	PSPNAQ5020-330M	PROD Tech	C436701	LCSC	€0.0265	1	€0.0265
Q1, Q3	60V 3A 1.5W 100mΩ MOSFET N-kanalni, SOT-23	DO2310D	DOINGTER	C41367407	LCSC	€0.0108	2	€0.0216
Q2	30V 4.2A 50mΩ 1.4W MOSFET P-kanalni, SOT-23	AO3401A	UMW(Youtai Semiconductor Co., Ltd.)	C347476	LCSC	€0.0131	1	€0.0131
U2, U4	Dual 200nA 0.6V/µs Operacijski ojačevalnik, SOIC-8	LM2904DT	STMicroelectronics	C105411	LCSC	€0.0323	2	€0.0646
U3	**SOT-23-6 ORing kontroler**	**LM74700QDBVRQ(TOKMAS)**	**Tokmas**	**C7589230**	**LCSC**	**€0.2800**	**1**	**€0.2800**
U5, U6, U7	2.5–36V 100mA Referenca napetosti, nastavljiva, SOT-23	LTL431ATLT1G	LRC	C83052	LCSC	€0.0178	3	€0.0534

Št. komponent	Cena komponent	Cena polaganja	Skupaj
55	0.91 €	0.55 €	1.46 €

Načrtovanje elektronike za EMC² 2025

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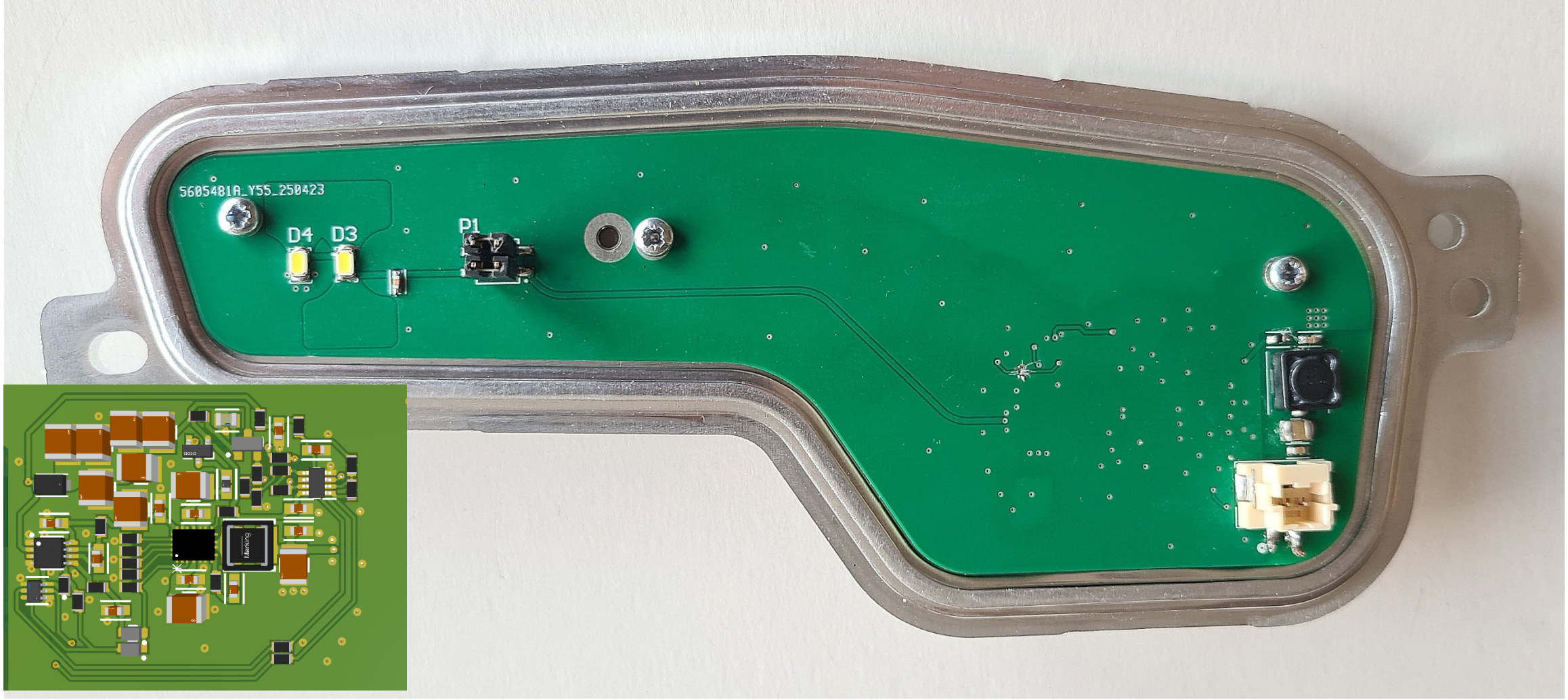
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

Luka Peršolja

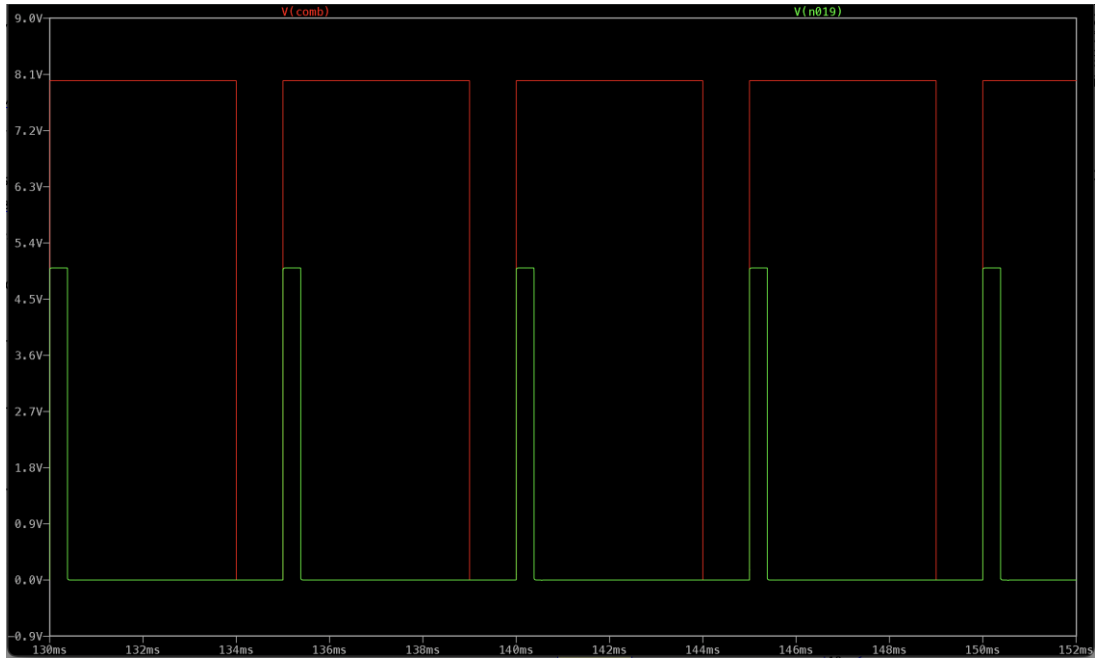
3. letnik, UNI-EL

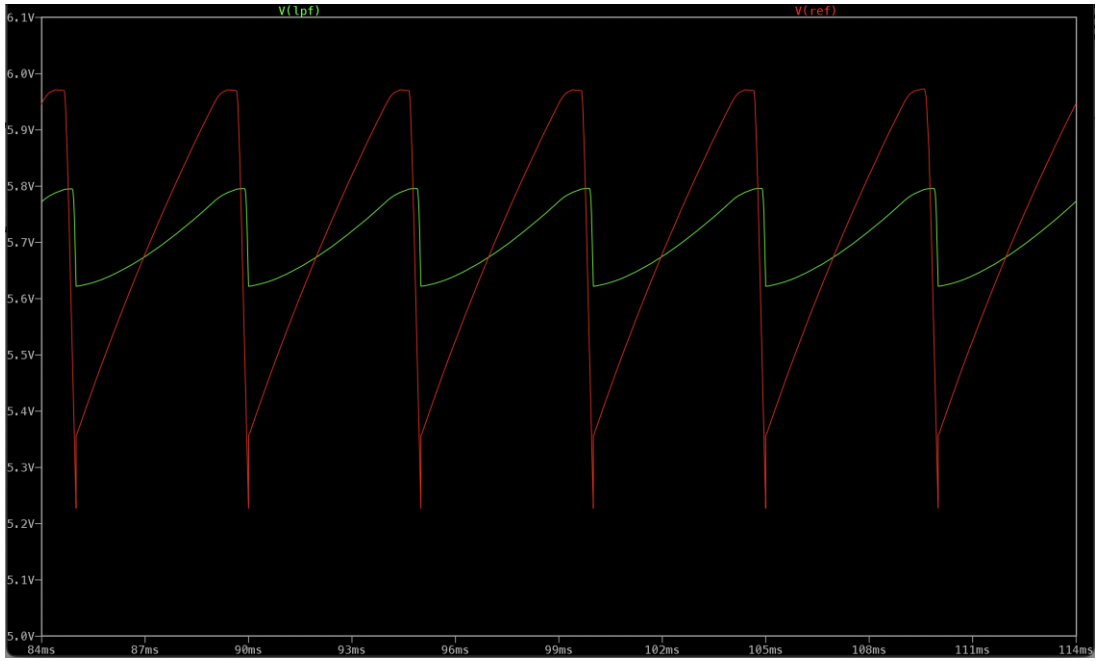
Luka Peršolja



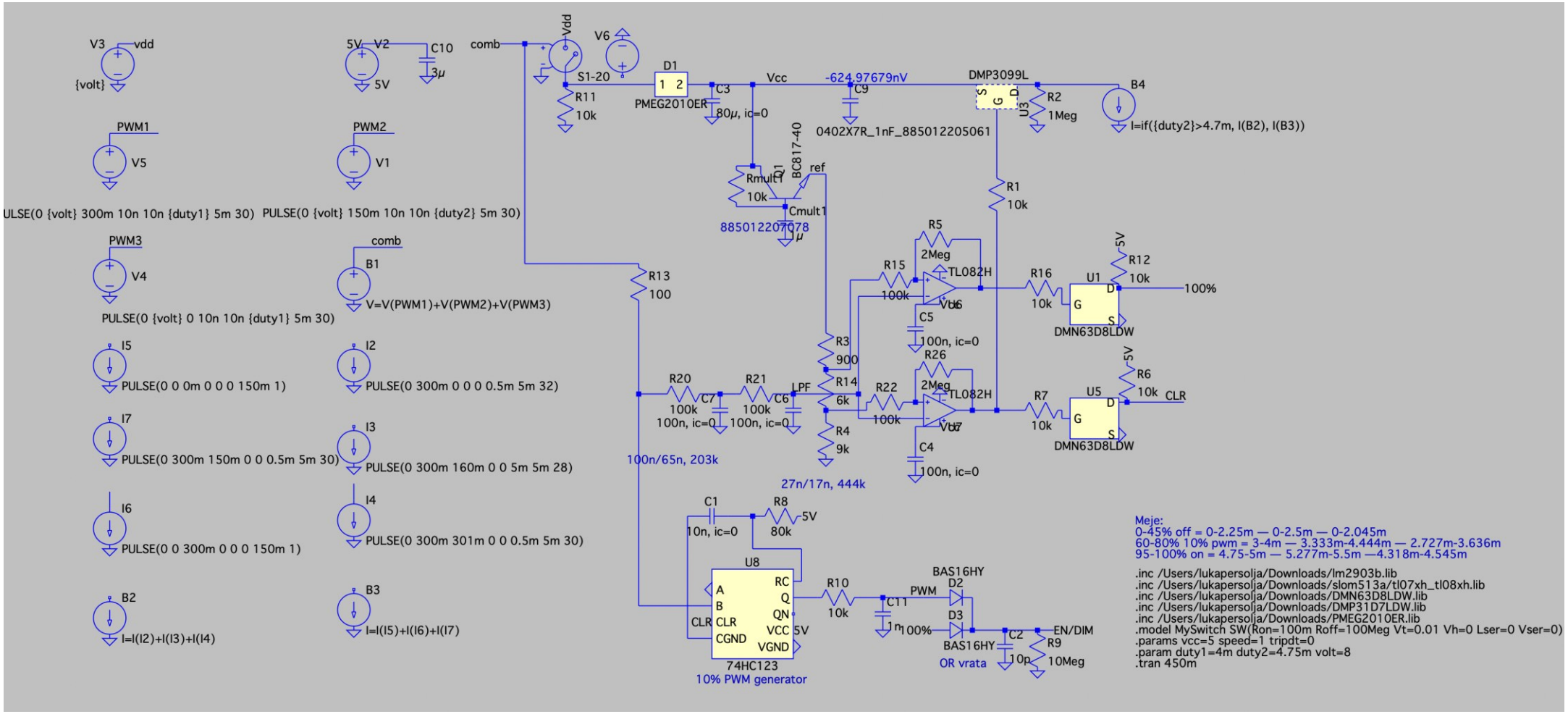
Koncept rešitve

- Sinhroni zunanji PWM -> manj kapacitivnosti
- Dekodiranje z LPF in komparatorji – najbolj preprosto
- Dimenzioniranje komponent





Izračuni, simulacije



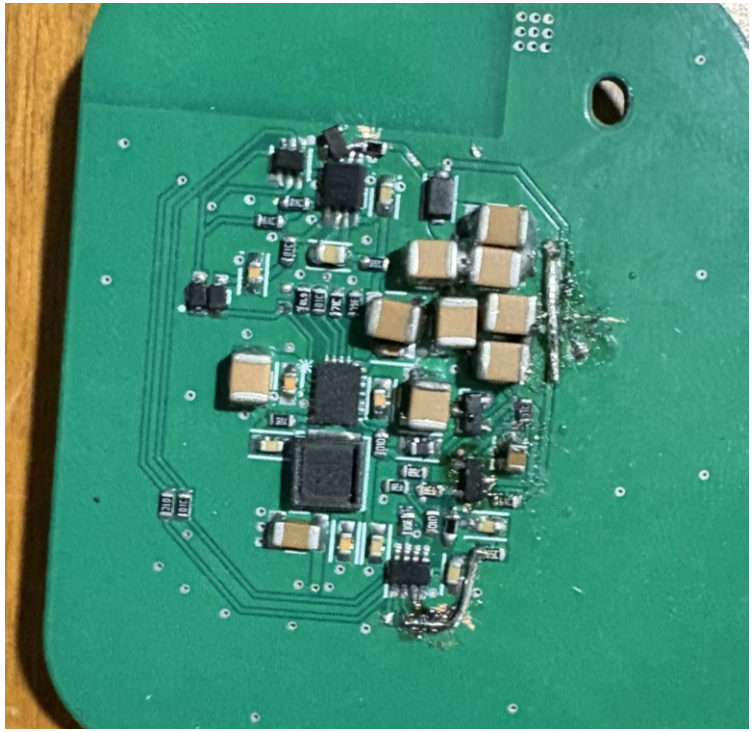
Načrtovanje tiskanega vezja

Načrtovanje tiskanega vezja

Napačna povratna vezava

Monostabilni multivibrator ima 5V vhod

(Pre)veliki kondenzatorji



Preliminarne meritve

Morebitni popravki

Drugačna detekcija – problem stabilnosti in izhodnih upornosti
Manj predimenzioniranja?

Načrtovanje elektronike za

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Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko
in optoelektroniko

Luka Peršolja

Rezultati

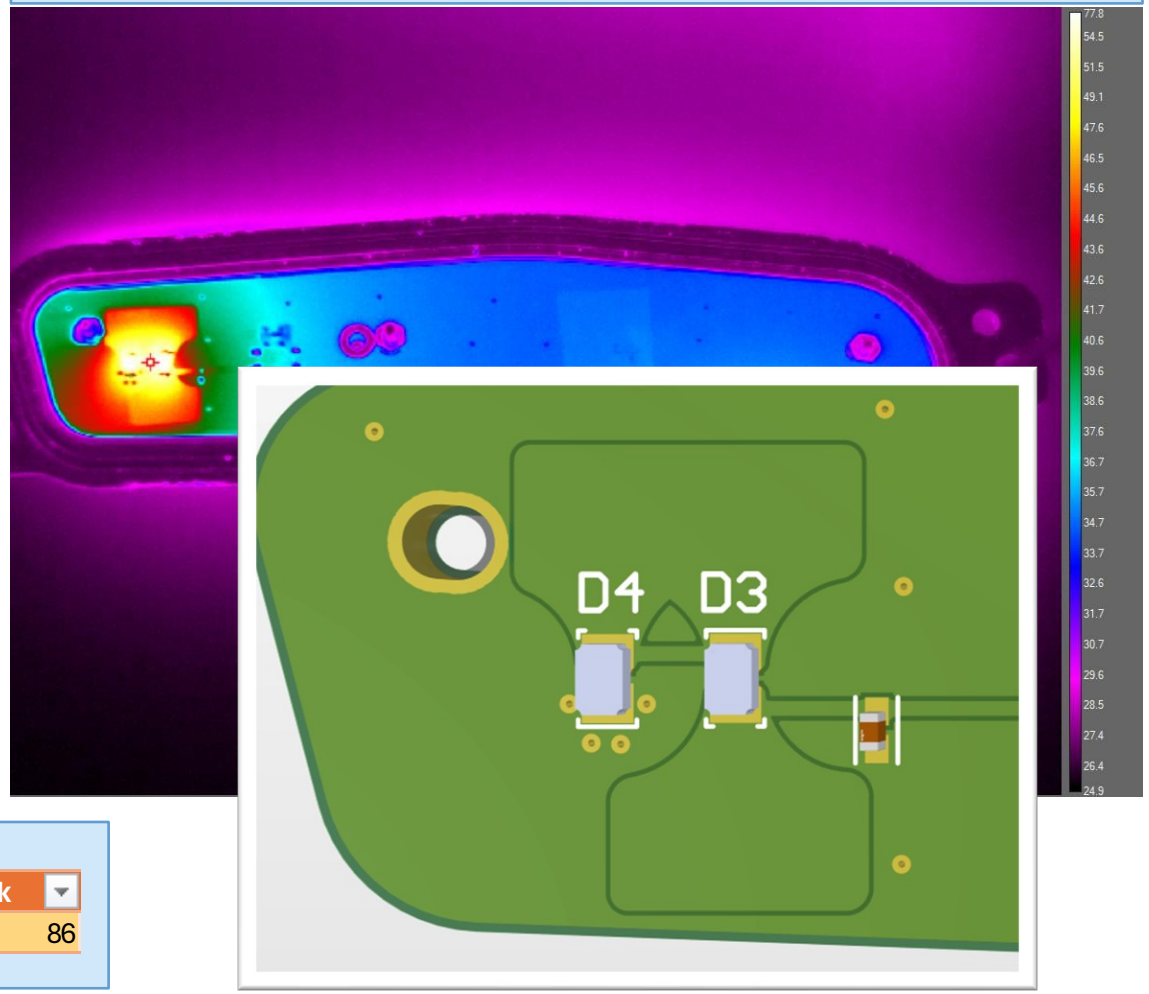
Luka Peršolja – Funkcionalni in električni testi

Osnovna funkcionalnost	PO mode ne deluje, DC=73%	✗
PWM območje	PO mode ne deluje, DC=73%	✗
Napetostno območje	PO mode ne deluje, DC=73%	✗
Temperaturno območje	PO mode ne deluje, DC=73%	✗
Obrnjena polariteta		✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	156	2.108	6.06	302	1.829	86

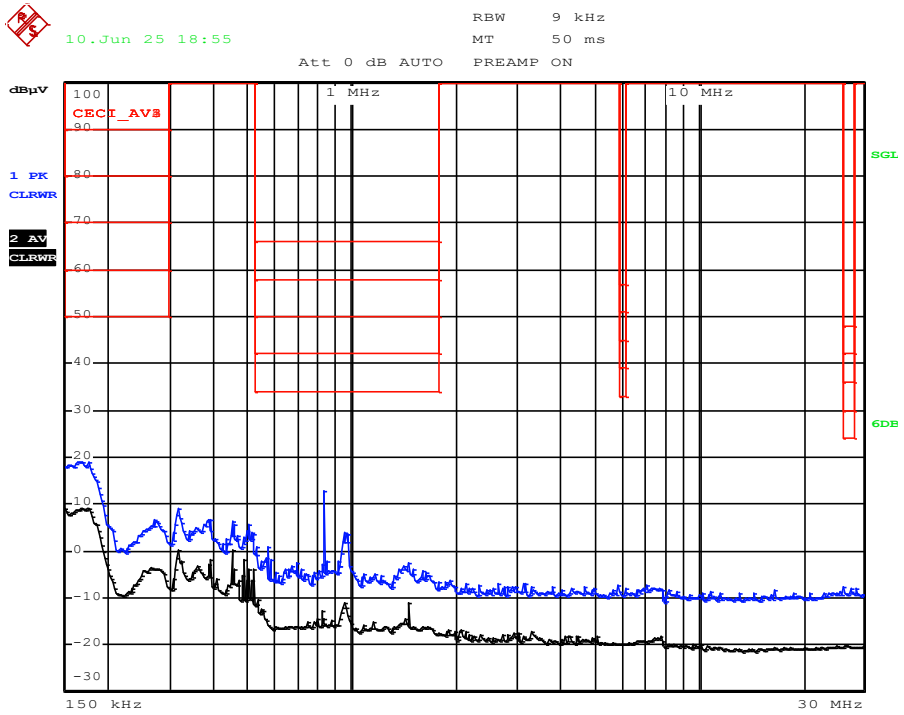
Temperaturna obremenitev: **57.76 °C**



Luka Peršolja – EMC

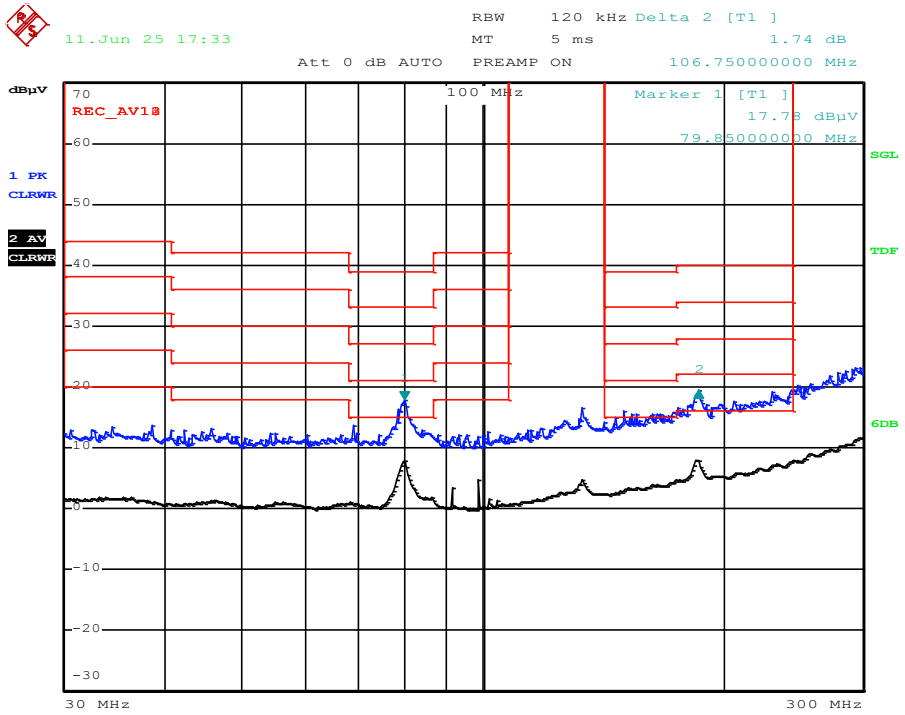
CE

5



RE

5



BCI

X

RI

X

Luka Peršolja - Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 10000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vezje
Lf1	**Tuljava 180uH**	**7447779218**	**Wurth Elektronik**	**7447779218**	**Wurth Elektronik**	**0.480 €**	**1**	**0.480 €**
Lf2-3	Ferrite bead	742863160	Wurth Elektronik	742863160	Wurth Elektronik	0.045 €	2	0.090 €
Cf2	Kondenzator 1uF 1210 50V	885012209047R	Wurth Elektronik	885012209047R	Wurth Elektronik	0.037 €	1	0.037 €
Cf1/Cf3/Cin9/10	Kondenzator 1nF 0603 50V	885012206083R	Wurth Elektronik	885012206083R	Wurth Elektronik	0.002 €	4	0.010 €
Cin1-8	**Kondenzator 10uF 50V**	**885012209073**	**Wurth Elektronik**	**885012209073**	**Wurth Elektronik**	**0.090 €**	**8**	**0.720 €**
Cmult1	Kondenzator 1uF 0805 25V	885012207078	Wurth Elektronik	885012207078	Wurth Elektronik	0.010 €	1	0.010 €
Lout1	**Tuljava 33uH**	**74406042330**	**Wurth Elektronik**	**74406042330**	**Wurth Elektronik**	**0.184 €**	**1**	**0.184 €**
Cout1	Kondenzator 4.7uF 1210 25V	885012208068	Wurth Elektronik	885012208068	Wurth Elektronik	0.043 €	1	0.043 €
Cvcc1	Kondenzator 4.7uF 1206 6.3V	885012208002	Wurth Elektronik	885012208002	Wurth Elektronik	0.047 €	1	0.047 €
M1	PFET	DMP3099L-13	Diodes Inc.	DMP3099L-13	Avnet	0.028 €	1	0.028 €
M2	Dvojni NFET	DMN63D8LDW-13	Diodes Inc.	DMP3099L-13	Avnet	0.023 €	1	0.023 €
D1	Schottky Dioda	PMEG2010ER,115	Nexperia	PMEG2010ER,115	Avnet	0.039 €	1	0.039 €
U3	Operacijski ojačevalnik	TL082HIDDFR	Texas Instruments	TL082HIDDFR	Texas Instruments	0.054 €	1	0.054 €
U2	Monostabilni multivibrator	SN74LVC1G123DCTR	Texas Instruments	SN74LVC1G123DCTR	Texas Instruments	0.114 €	1	0.114 €
Q1	NPN tranzistor	BC817-25,215	Nexperia	BC817-25,215	Avnet	0.009 €	1	0.009 €
D2/3	Signalna Dioda	SBAS16HT3G	OnSemi	2124344	Future Electronics	0.009 €	2	0.018 €
Rpwm1/Rup1-2/Rg1-3/Rmult1/Rntc1/Rclamp1	Upor 10k 0603 1%	RT0603FRD0710KL	Yageo			0.005 €	9	0.045 €
Rlp1	Upor 42.2k 0603 1%	RT0603FRE0742K2L	Yageo			0.005 €	1	0.005 €
Rlp2	Upor 75k 0603 1%	AC0603FR-0775KL	Yageo			0.005 €	1	0.005 €
Rgen1	Upor 80.6k 0603 1%	RT0603FRE0780K6L	Yageo			0.005 €	1	0.005 €
Rdiv1	Upor 909R 0603 1%	AC0603FR-07909RL	Yageo			0.005 €	1	0.005 €
Rdiv2	Upor 6.04k 0603 1%	RC0603FR-076K04L	Yageo			0.005 €	1	0.005 €
Rdiv3	Upor 9.09k 0603 1%	RT0603FRE079K09L	Yageo			0.005 €	1	0.005 €
Rin1-2/Rfault1	Upor 100k 0603 1%	AC0603FR-13100KL	Yageo			0.005 €	3	0.015 €
Rfb1-2	Upor 2M 0603 1%	AC0603FR-072ML	Yageo			0.005 €	2	0.010 €
Rduty1	Upor 4.87k 0603 1%	CR0603-FX-4871ELF	Bourns			0.005 €	1	0.005 €
Riset1	Upor 53.6k 0603 1%	RC0603FR-0753K6L	Yageo			0.005 €	1	0.005 €
Riref1	Upor 23.2k 0603 1%	RT0603FRE0723K2L	Yageo			0.005 €	1	0.005 €
Rbst1	Upor 20R 0603 1%	AC0603FR-0720RL	Yageo			0.005 €	1	0.005 €
Cvcc2/Cbypass1-2/Clp1-2/Cbst1	Kondenzator 100n 0603 25V	CL10B104KA8NNNL	Samsung Electro-Mechanics			0.005 €	6	0.030 €
Cpwm1/Cout2/Cled1	Kondenzator 1nF 0603 16V	885012206034	Wurth Elektronik			0.005 €	3	0.015 €
Cgen1	Kondenzator 10nF 0603 16V	885012206040	Wurth Elektronik			0.005 €	1	0.005 €
D4	Zener dioda 0603 5.1V	SZMMBZ5231BLT3G	OnSemi			0.005 €	1	0.005 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
63	1.60 €	0.63 €	2.23 €

Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

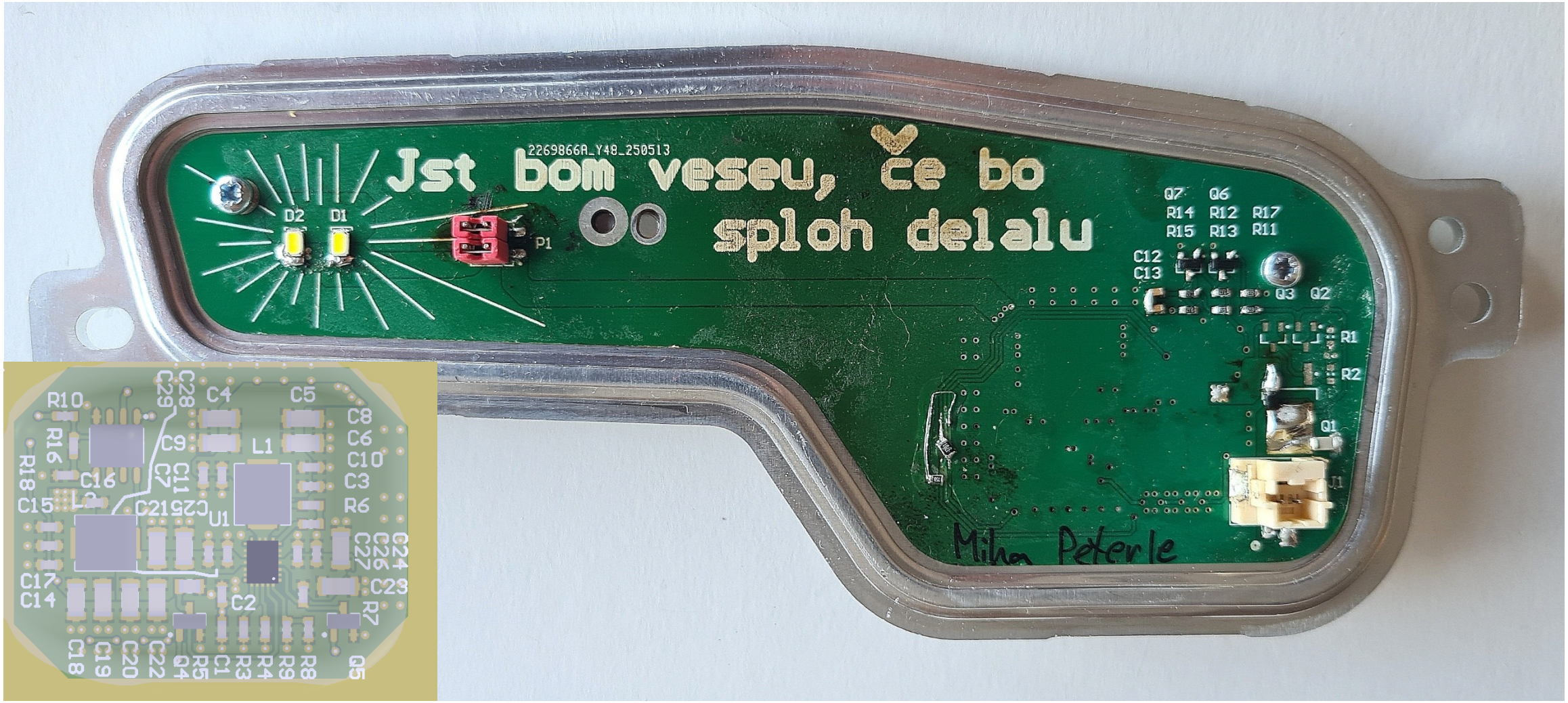
UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

Miha Peterle

1. letnik, MAG-EL

Miha Peterle

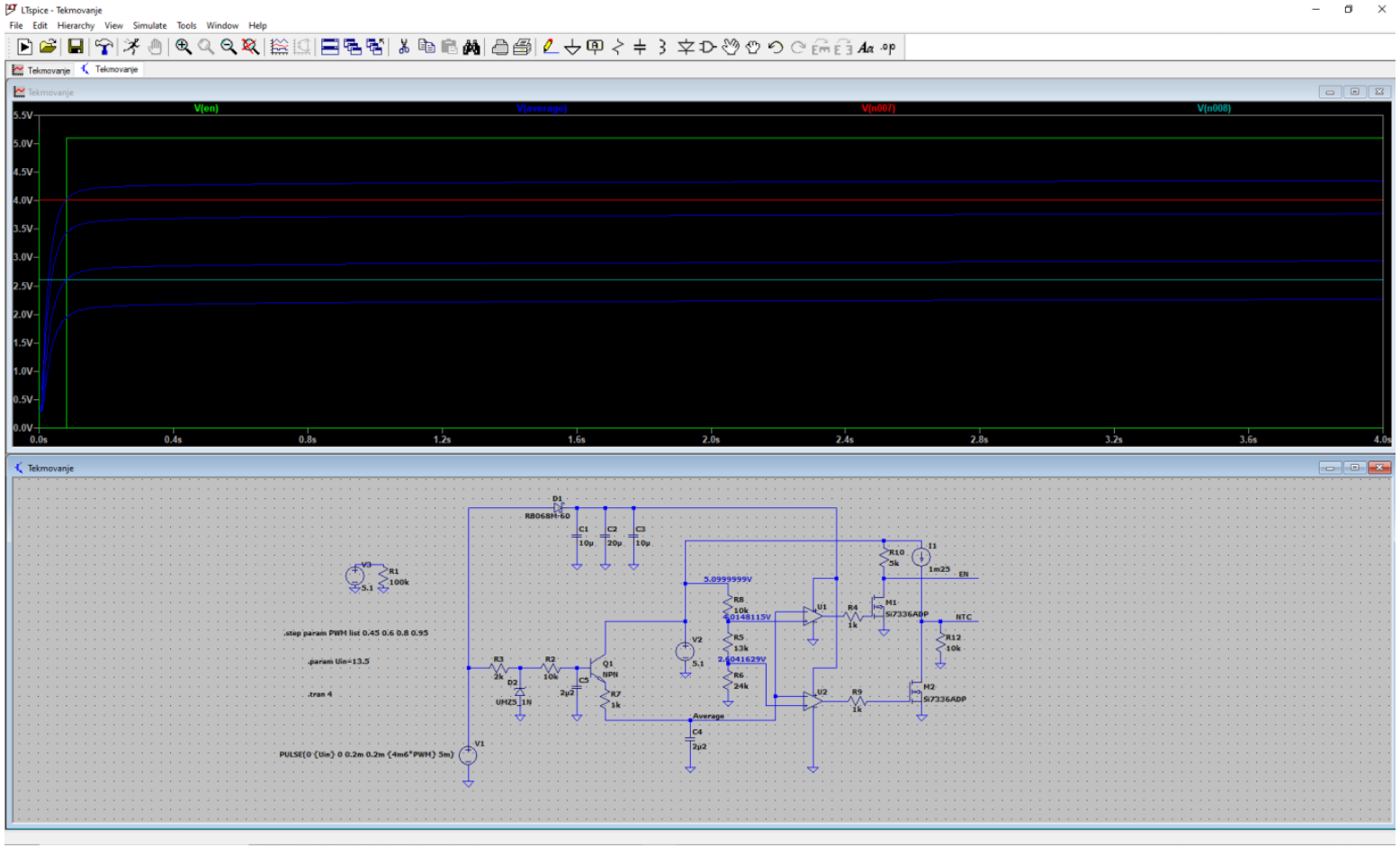


Koncept rešitve

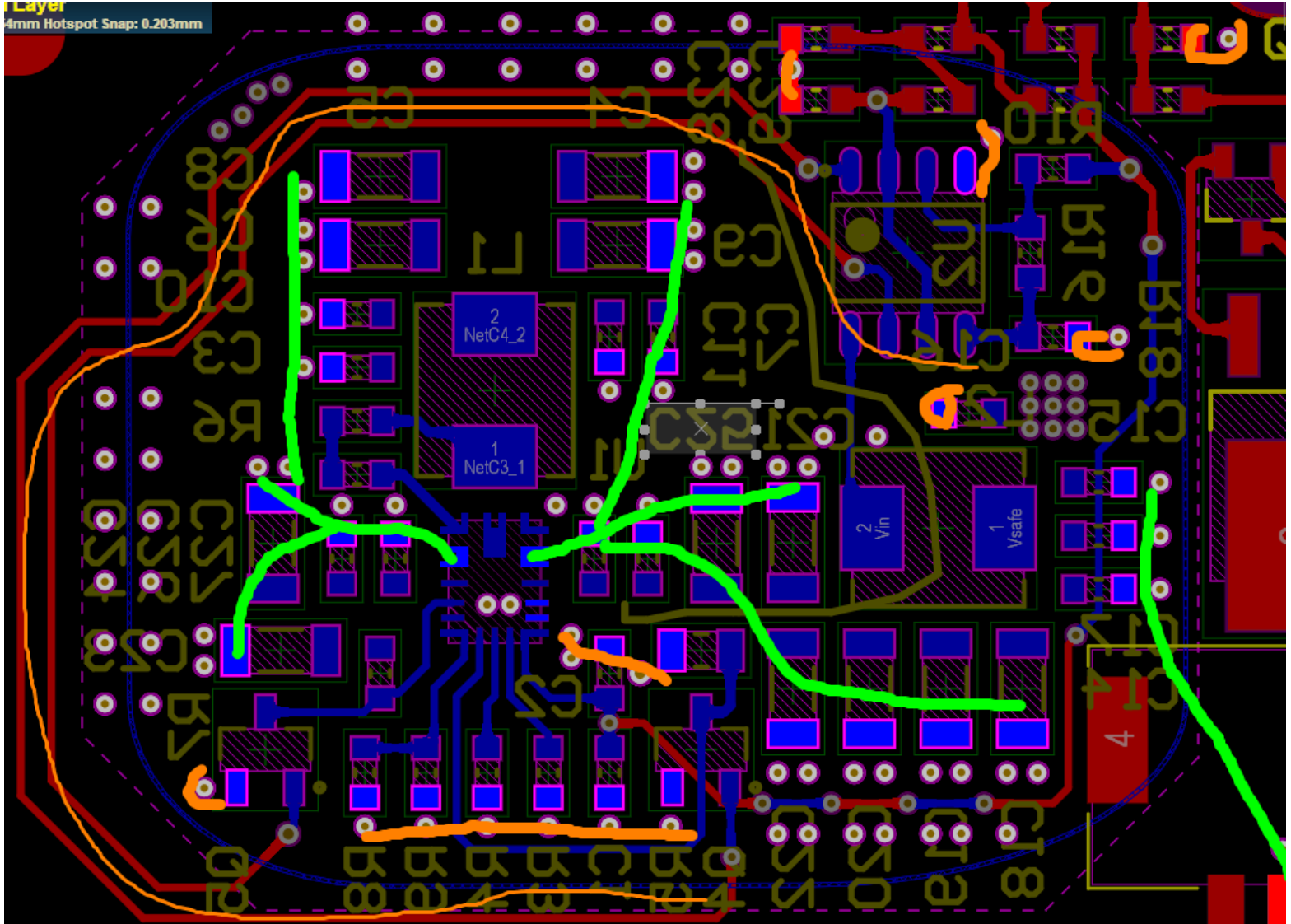
- Two-step dimming za enostavnost in nizke stroške
- RC filter za glajenje PWM, nizkocenovni opamp
- Zaščita pred napačno polariteto s Schottky diodo (kasneje)
- NTC za izklop, "enable" za 10 % svetilnost
- Preprostost zaradi lažjega debugiranja
- Uporaba interne reference DC-DC čipa

Izračuni, simulacije

U = R * I
ChatGPT



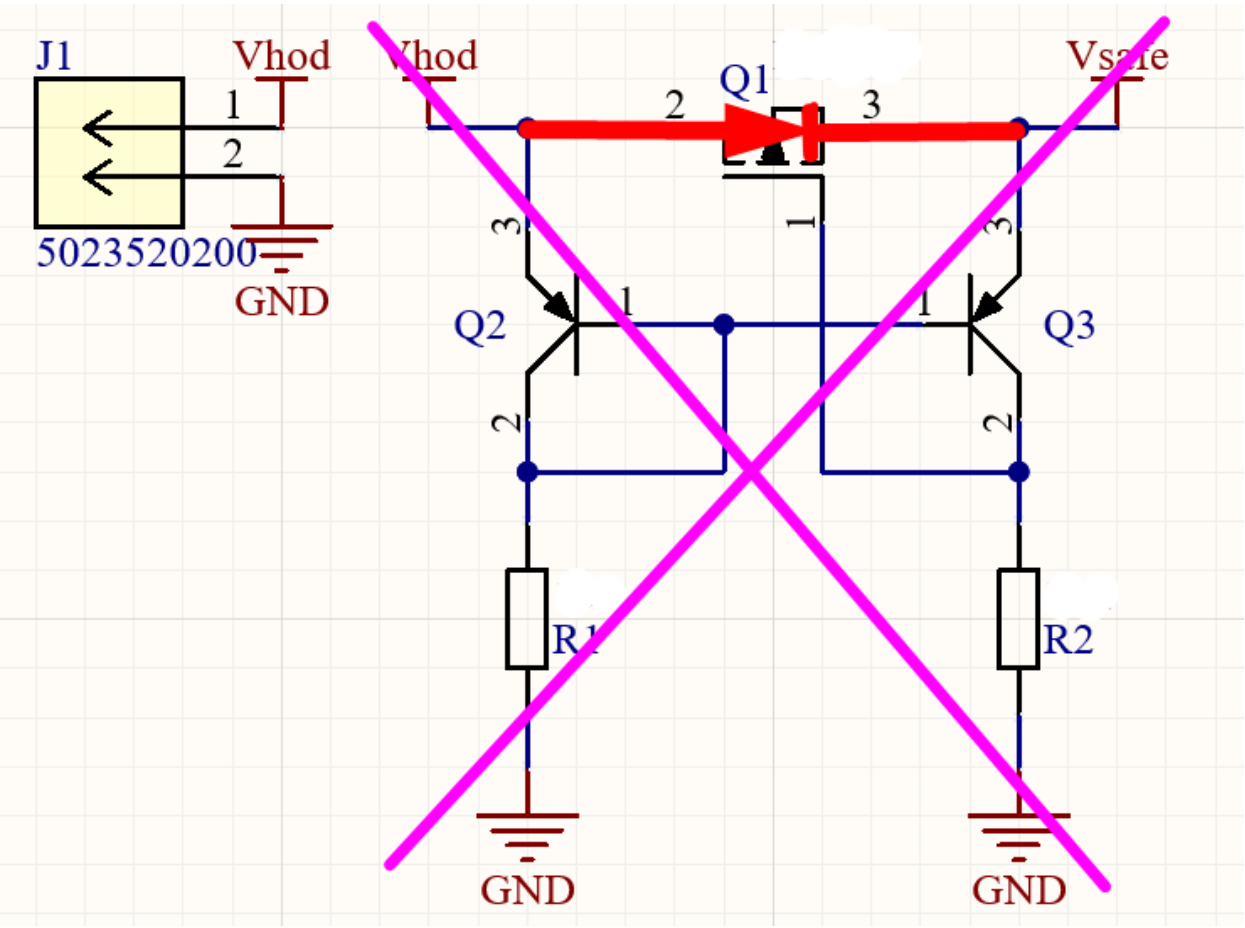
Načrtovanje tiskanega vezja



Preliminarne meritve

- Naključno nedelujoče vezje z oksidiranimi kontakti DC-DC čipa.
- Težave z vhodnjo stopnjo
- Klasični funkcijski generatorji delujejo v območju od 20 do 80% PWM?
  (mixed signal generator)

Morebitni popravki



Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

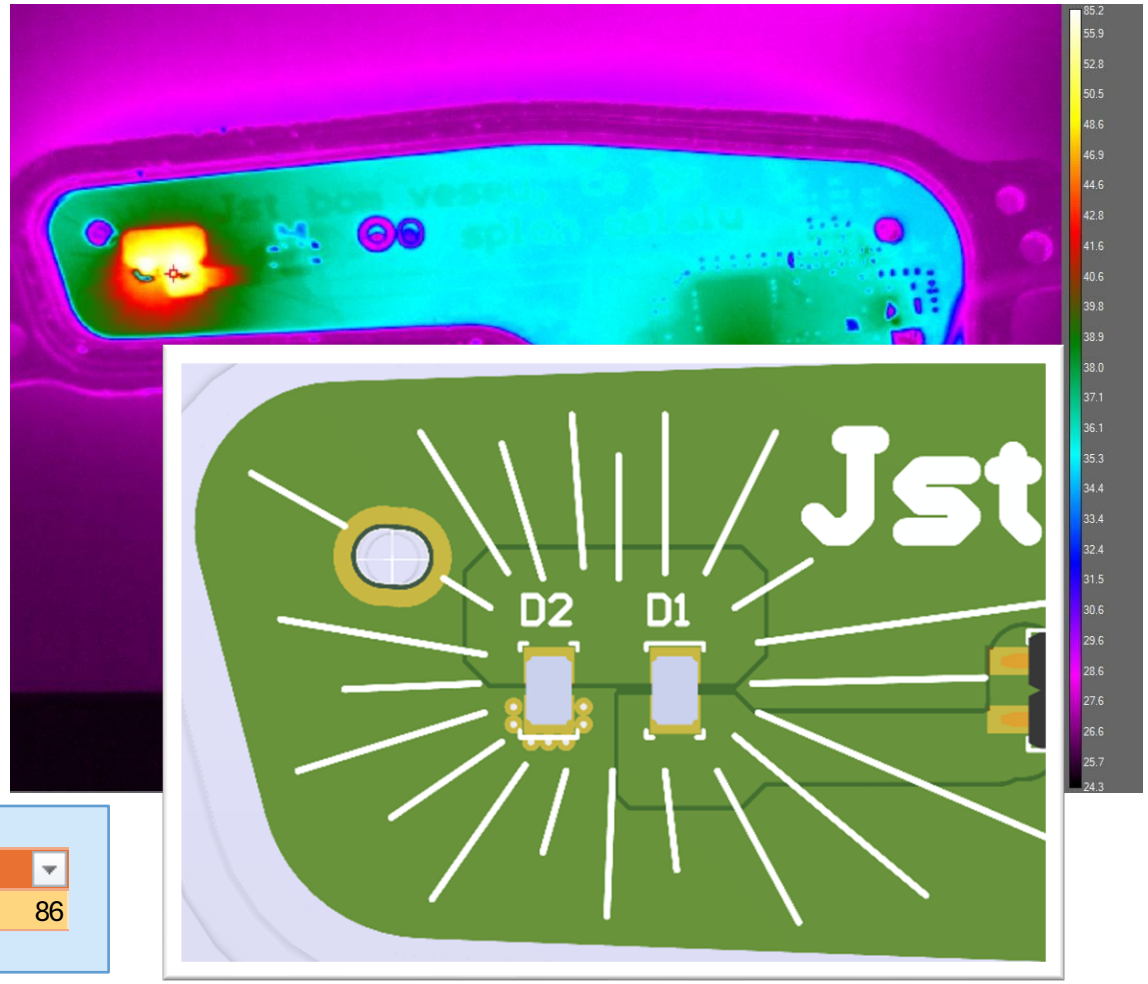
Miha Peterle

Rezultati

Miha Peterle – Funkcionalni in električni testi

Osnovna funkcionalnost	Odpovedala RP dioda ✗	✓
PWM območje		✓
Napetostno območje		✓
Temperaturno območje		✓
Obrnjena polariteta		✓

Temperaturna obremenitev: 58.00 °C



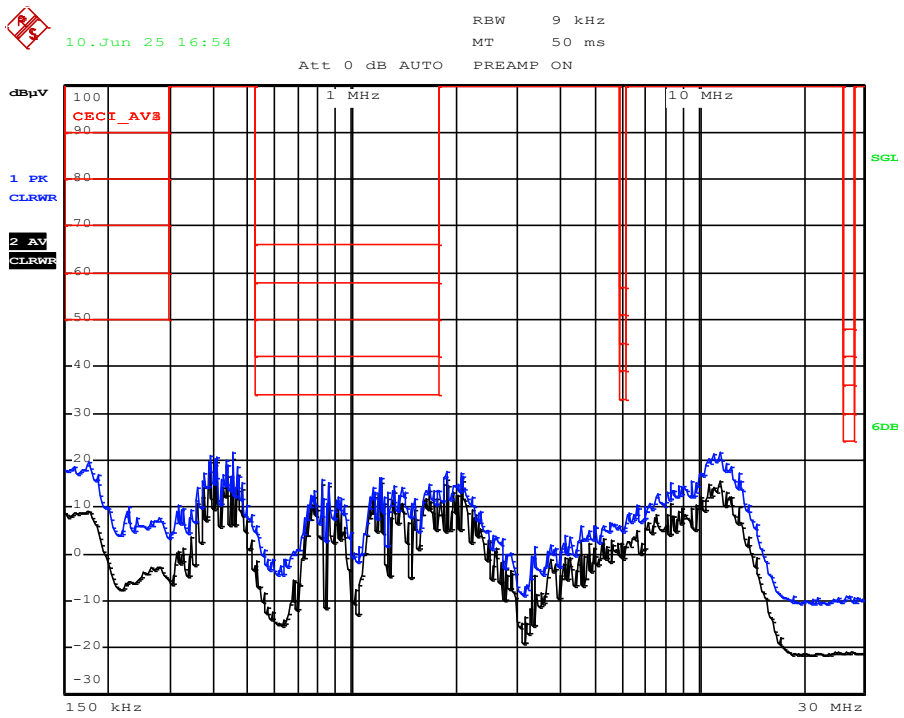
Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.54	164	2.221	6.12	314	1.920	86

Miha Peterle – EMC

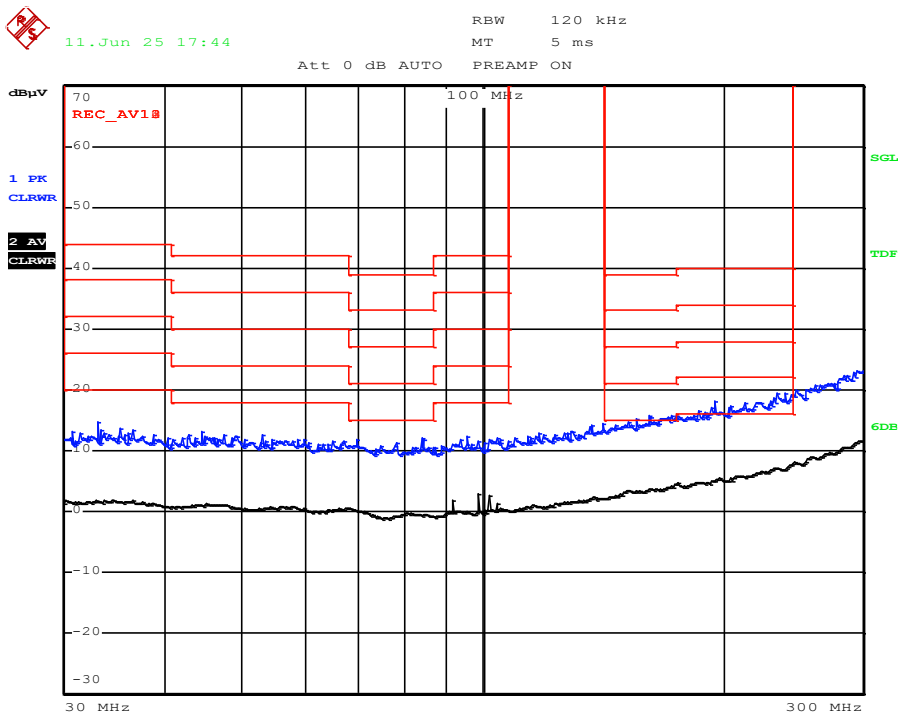
CE

5



RE

5



BCI

100 mA

A

RI

100 V/m H+V

A

Miha Peterle – Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 1000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vezje
C14-C17, C20-C25	10u,1206	CGA1206X7R106K250NT	HRE	C6119987	LCSC	0.012 €	10	0.220 €
Dvhodna	SOD-323FL	RB551VM-30TE-17	ROHM Semicon	C209640	LCSC	0.016 €	1	0.026 €
L2	SMD,4.7u 2.3A	SFE4018A-4R7M-F-HF	DDY	C5159668	LCSC	0.019 €	1	0.029 €
Cvhodni	1n,1206	NV1206B102K202CEDN	HUIJU	C710463	LCSC	0.004 €	1	0.014 €
C8-C11,C1	2u2,1206	TCC1206X7R225M250HT	CCTC	C5449010	LCSC	0.007 €	5	0.087 €
C19, C26-C27, C2-C5	100n,0603				LCSC	0.005 €	5	0.075 €
C28-C29	10n,0603				LCSC	0.005 €	4	0.060 €
C12,C13	2u2,0603	0603B225M100NT	FH	C47345168	LCSC	0.003 €	2	0.025 €
Q4-Q7	NMOS,SOT-32	L2N7002SLLT1G	LRC	C22446827	LCSC	0.003 €	4	0.051 €
U2	dual comparator	LM393DTR(XBLW)	XBLW	C18723572		0.017 €	1	0.027 €
R12-R15, R5, R7, R17	10k, 0603					0.005 €	7	0.105 €
R10	1k3, 0603					0.005 €	1	0.015 €
R18,R16	4k2, 0603					0.005 €	2	0.030 €
R11	1k,0604					0.005 €	1	0.015 €
R8	12k,0605					0.005 €	1	0.015 €
R6	20R,0606					0.005 €	1	0.015 €
R9	22k,0603					0.005 €	1	0.015 €
R4	51k,0604					0.005 €	1	0.015 €
R3	24k,0605					0.005 €	1	0.015 €
L1	22u,SMD,7.1x6.6mm	SL0630-220M	TECHFUSE	C22463825	LCSC	0.049 €	1	0.059 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
51	0.40 €	0.51 €	0.91 €

Načrtovanje elektronike za EMC² 2025

študentska delavnica in tekmovanje

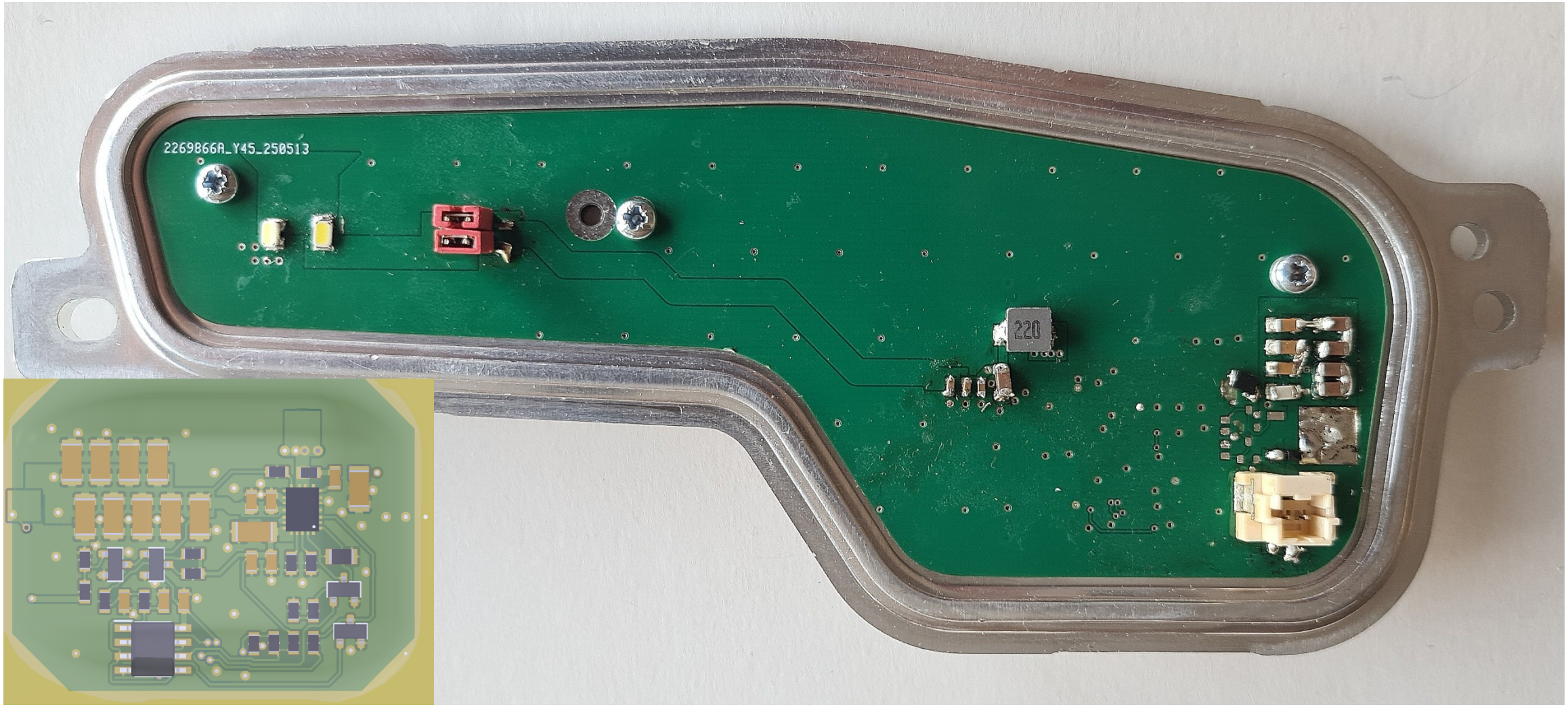
UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

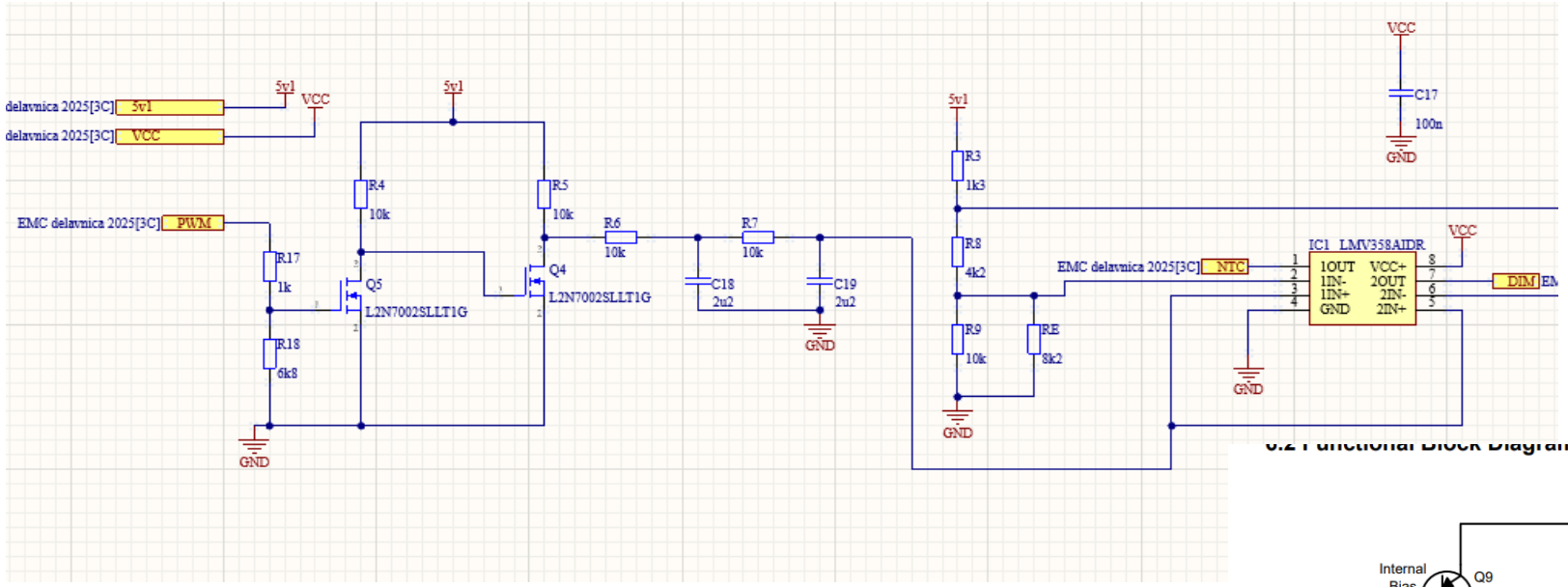
Simon Kaurin

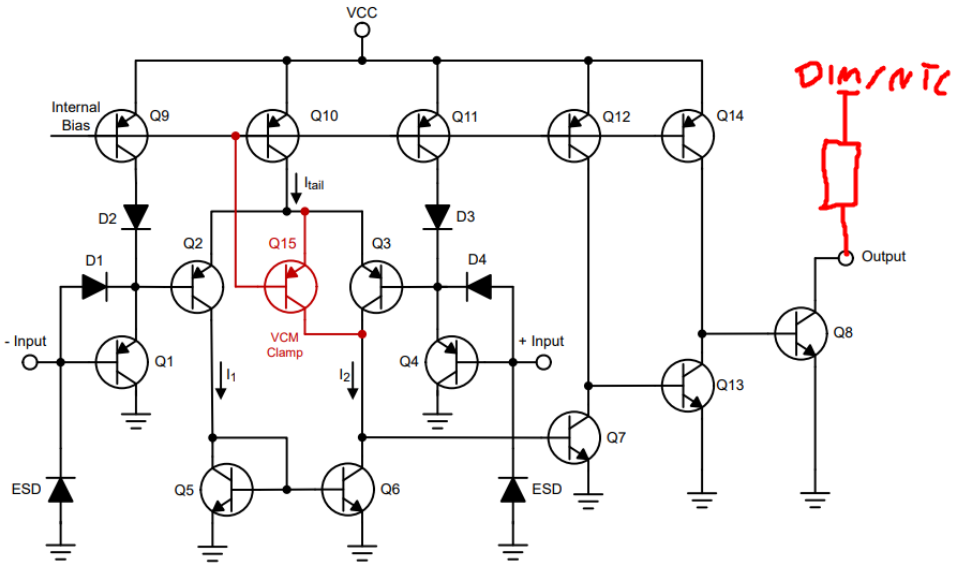
1. letnik, MAG-EL

Simon Kaurin

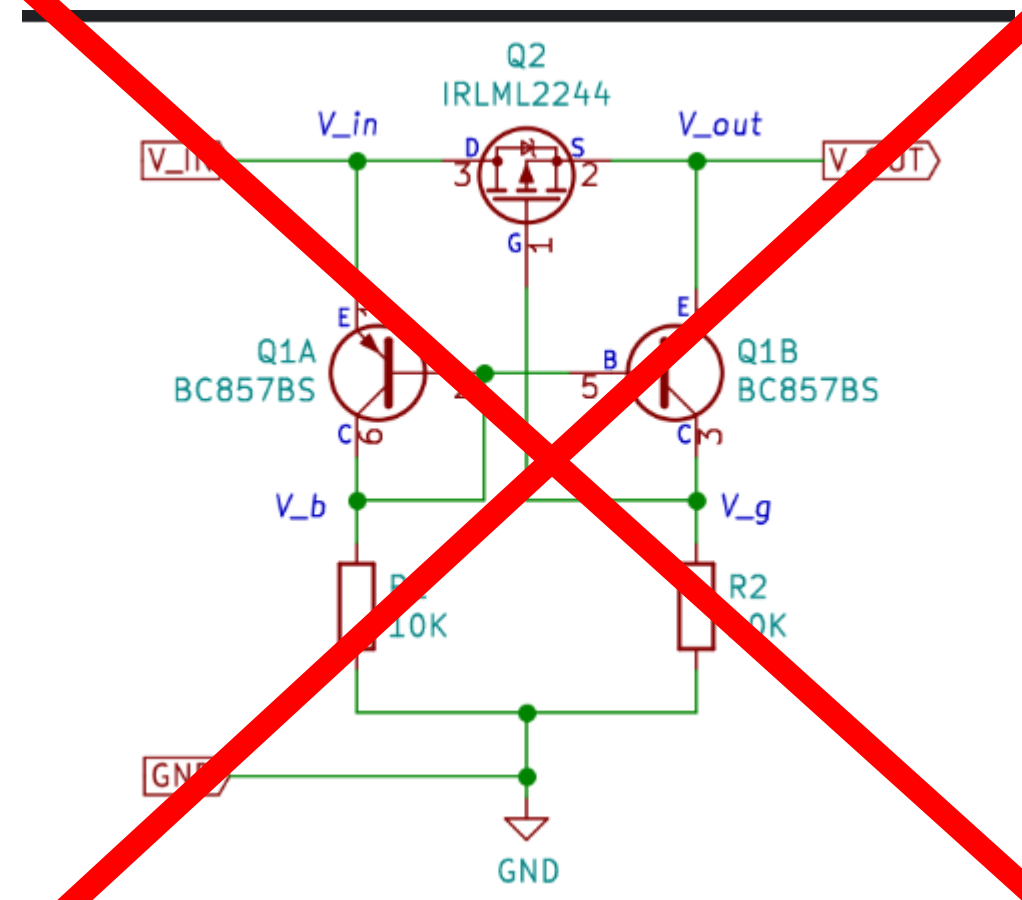


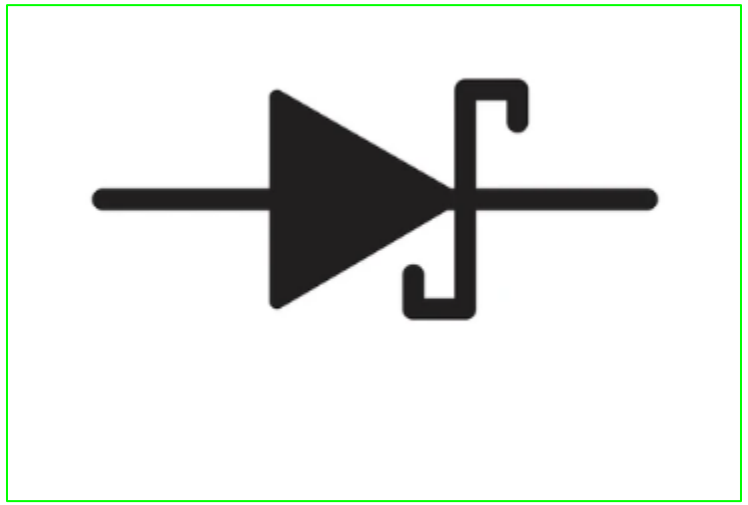
Koncept rešitve





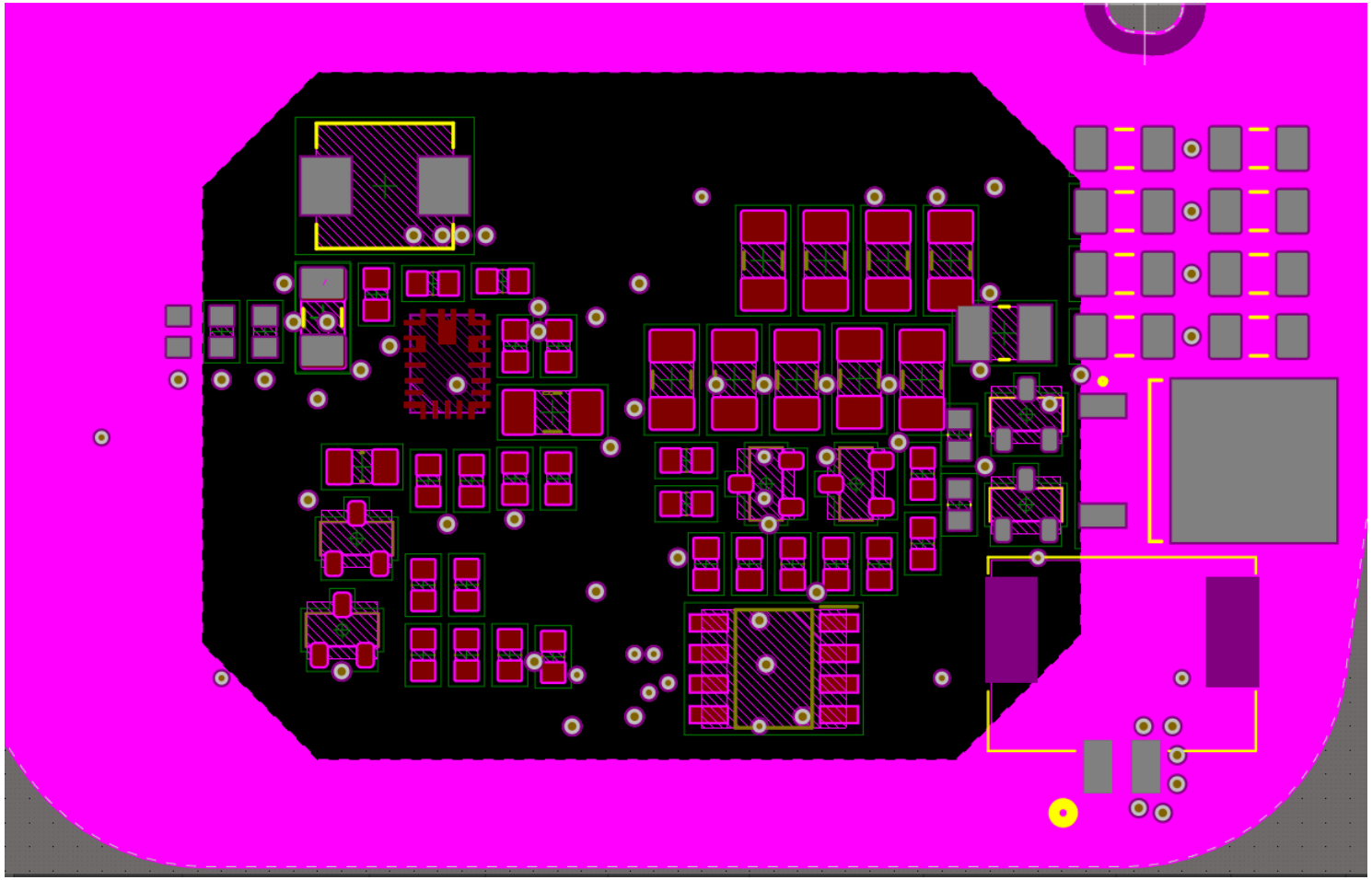
Izračuni, simulacije





Načrtovanje tiskanega vezja

- Tuljava je na zgornji strani kar ni optimalno zaradi sevalnih motenj



Preliminarne meritve

- Konduktivne motnje so na faksu šle čez :D

Morebitni popravki

- Nastavitev referenčnih uporov
- Idealna dioda zamenjana z Shottky diodo
- Uporabljen komparator namesto opampa

Načrtovanje elektronike za EMC² 2025

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UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

Simon Kaurin

Rezultati

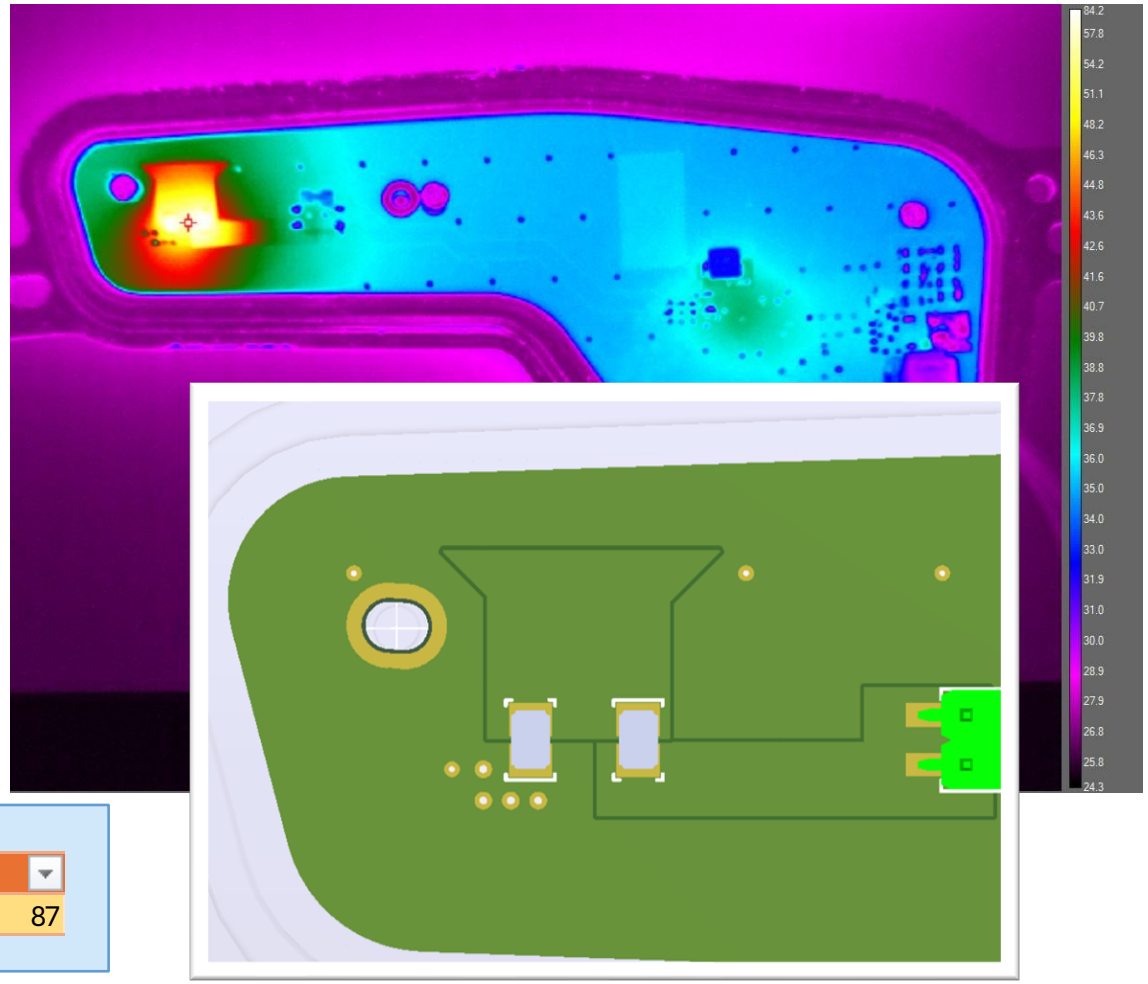
Simon Kaurin – Funkcionalni in električni testi

Osnovna funkcionalnost	Odpovedala RP dioda	✗ ✓
PWM območje	Kratek zvezen prehod med PO in DRL in obratno.	✓
Napetostno območje		✓
Temperaturno območje		✓
Obrnjena polariteta		✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.55	156	2.114	6.11	303	1.851	87

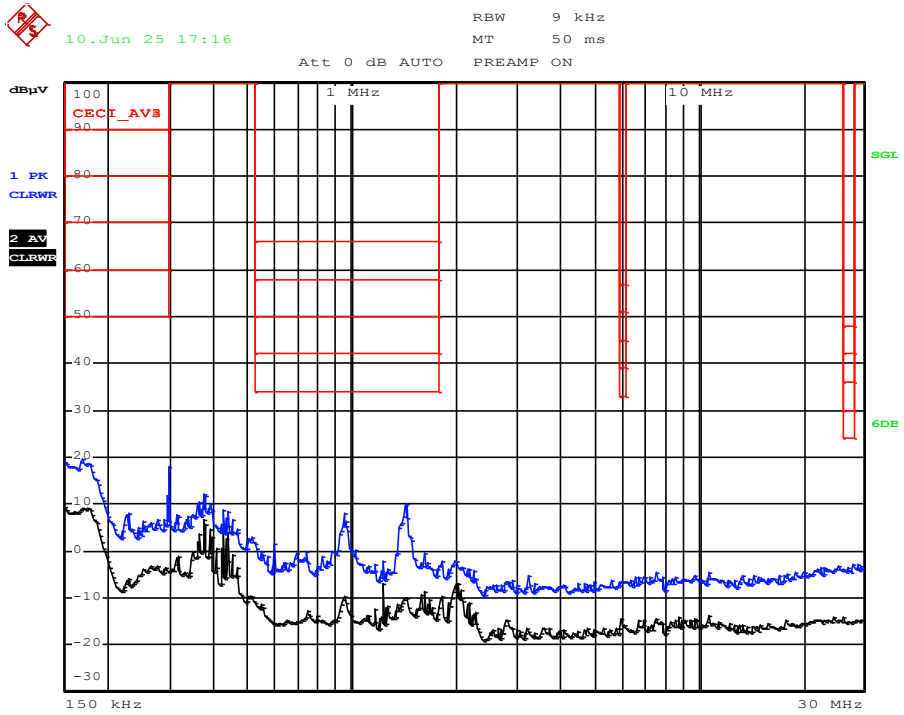
Temperaturna obremenitev: **58.24 °C**



Simon Kaurin – EMC

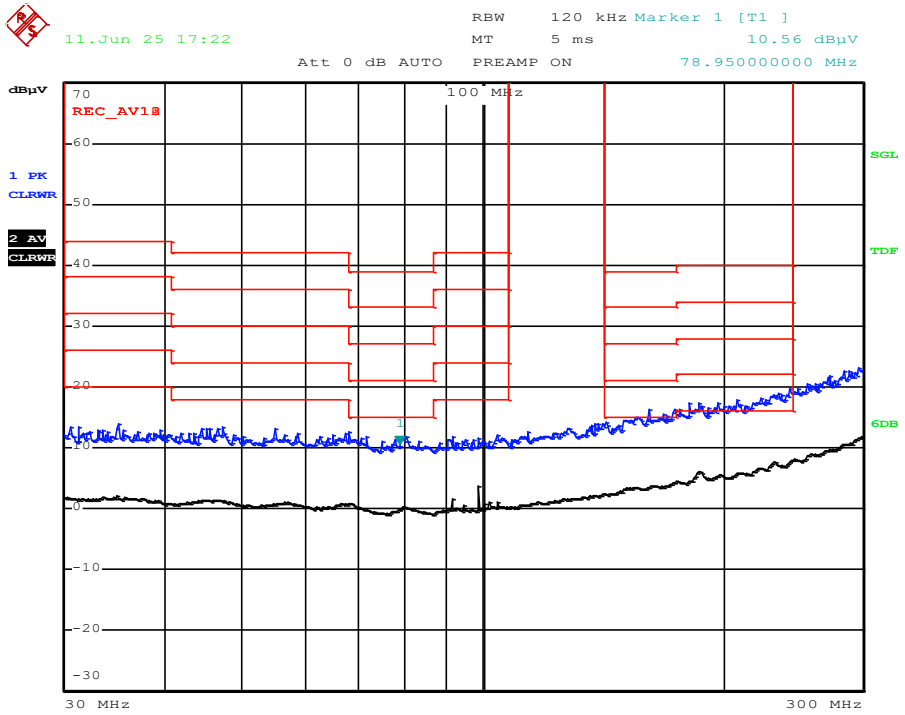
CE

5



RE

5



BCI

100 mA

C

Pri 20MHz se intenziteta poveča za več kot 30%

RI

100 V/m H+V

A

Simon Kaurin - Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 1000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vezje
C1-C7, C9-C14	10u,1206	CGA1206X7R106K250NT	HRE	C6119987	LCSC	0.012 €	13	0.286 €
D1	SOD-323FL	RB551VM-30TE-17	ROHM Semicon	C209640	LCSC	0.016 €	1	0.026 €
L1	SMD,1.3x1.8mm	WI0603LD4R7MST-TIA-HF	DDY	C5152010	LCSC	0.019 €	1	0.029 €
C8	1n,1206	NV1206B102K202CEDN	HUIJU	C710463	LCSC	0.004 €	1	0.014 €
C20,C27,C28,C23	2u2,1206	TCC1206X7R225M250HT	CCTC	C5449010	LCSC	0.007 €	4	0.069 €
C21,C26,C29,C24,C17	100n,0603				LCSC	0.005 €	5	0.075 €
C22,C29,C25,C30	10n,0603				LCSC	0.005 €	4	0.060 €
C31	1n,0603				LCSC	0.005 €	1	0.015 €
C18,C19	2u2,0603	0603B225M100NT	FH (Guangdong Fenghua Advanced Tech)	C47345168	LCSC	0.003 €	2	0.025 €
Q5,Q6	NMOS,SOT-32	L2N7002SLLT1G	LRC	C22446827	LCSC	0.003 €	2	0.025 €
IC1	dual comparator	LM393DTR(XBLW)	XBLW	C18723572		0.017 €	1	0.027 €
R4-R7,R9,R14,RNTC	10k, 0603					0.005 €	7	0.105 €
R3	1k3, 0603					0.005 €	1	0.015 €
R8,R10	4k2, 0603					0.005 €	2	0.030 €
RE	8k2,0603					0.005 €	1	0.015 €
R17	1k,0604					0.005 €	1	0.015 €
R18	6k8,0605					0.005 €	1	0.015 €
R16	20R,0606					0.005 €	1	0.015 €
R11	4k7,0603					0.005 €	1	0.015 €
R12	56k,0604					0.005 €	1	0.015 €
R13	24k,0605					0.005 €	1	0.015 €
R15	100k,0603					0.005 €	1	0.015 €
L2	22u,SMD,7.1x6.6mm	SL0630-220M	TECHFUSE	C22463825	LCSC	0.049 €	1	0.059 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
54	0.44 €	0.54 €	0.98 €

Načrtovanje elektronike za EMC² 2025

študentska delavnica in tekmovanje

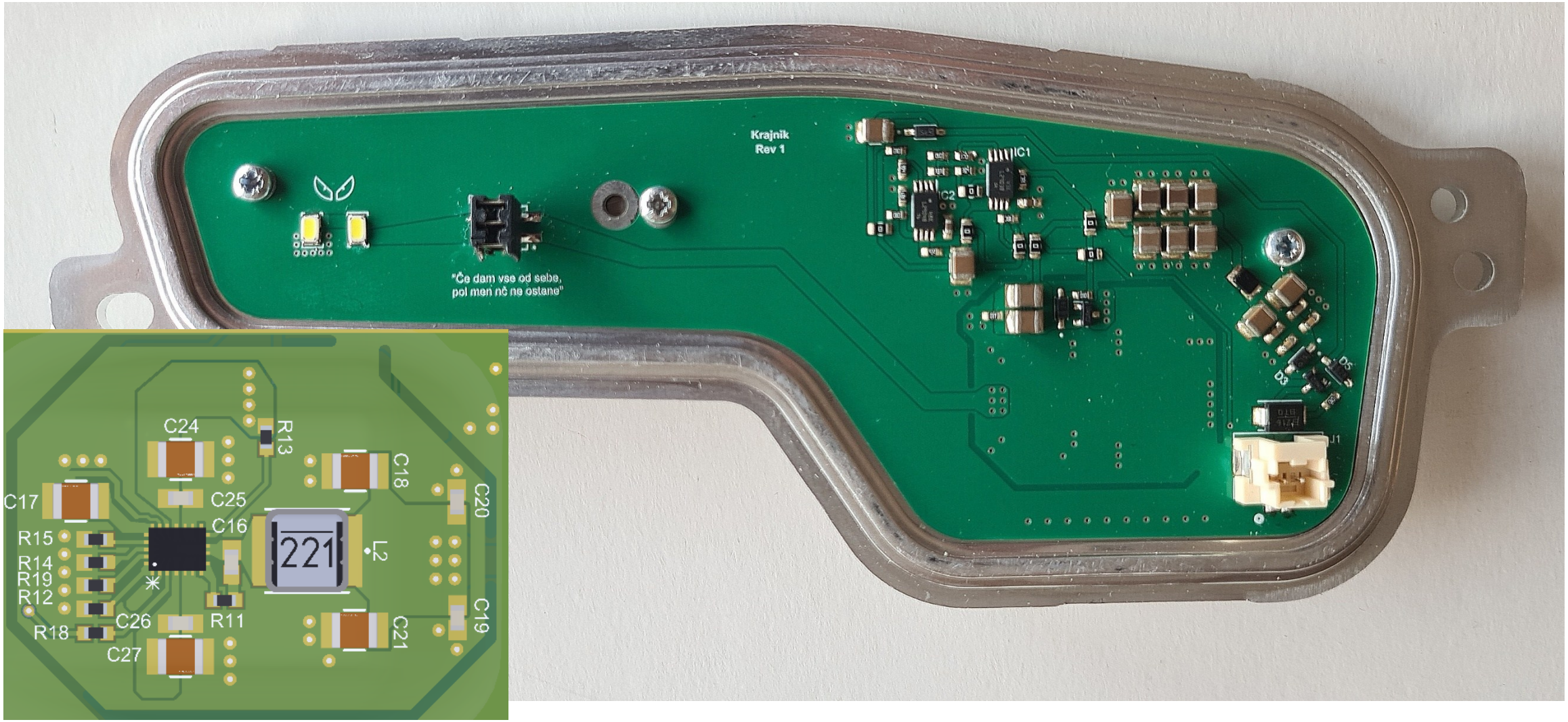
UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

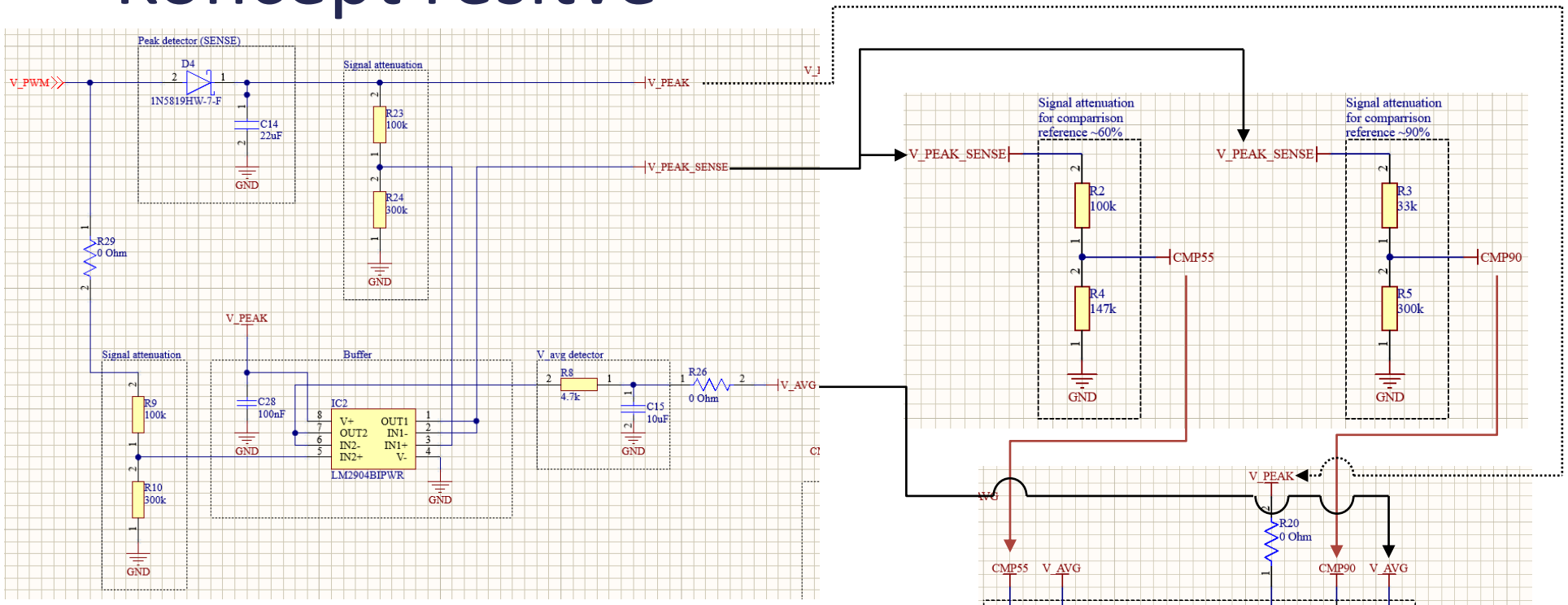
Blaž Krajnik

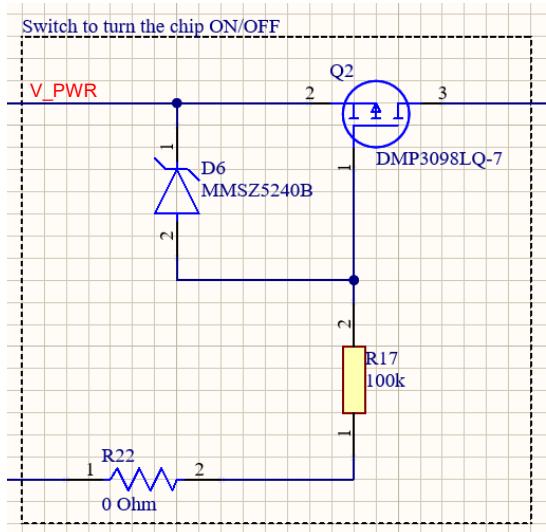
2. letnik, MAG-EL

Blaž Krajnik



Koncept rešitve





Izračuni, simulacije

Duty: 60%
2-Step Dimming

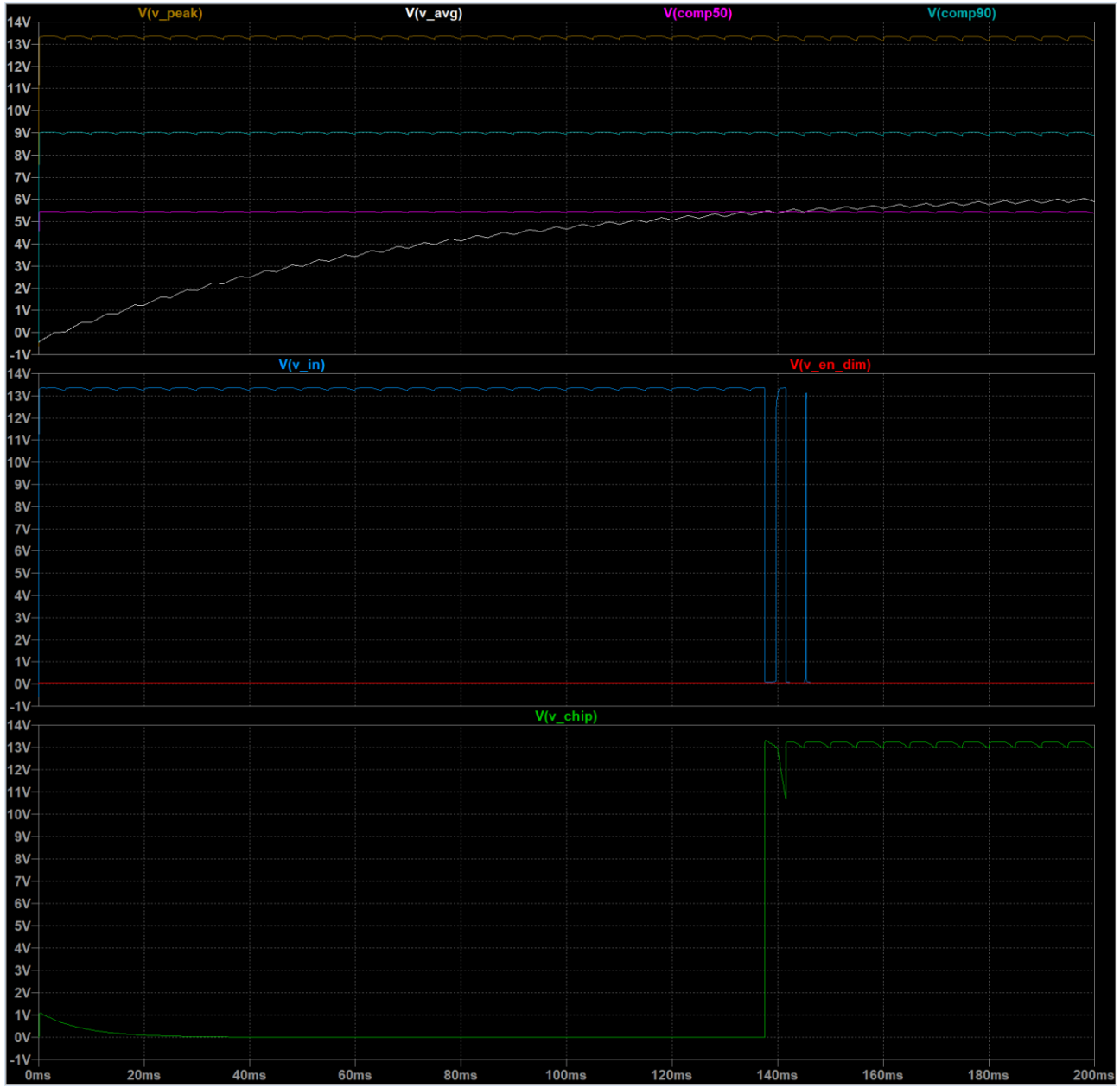
↓

EN/DIM pin = LOW

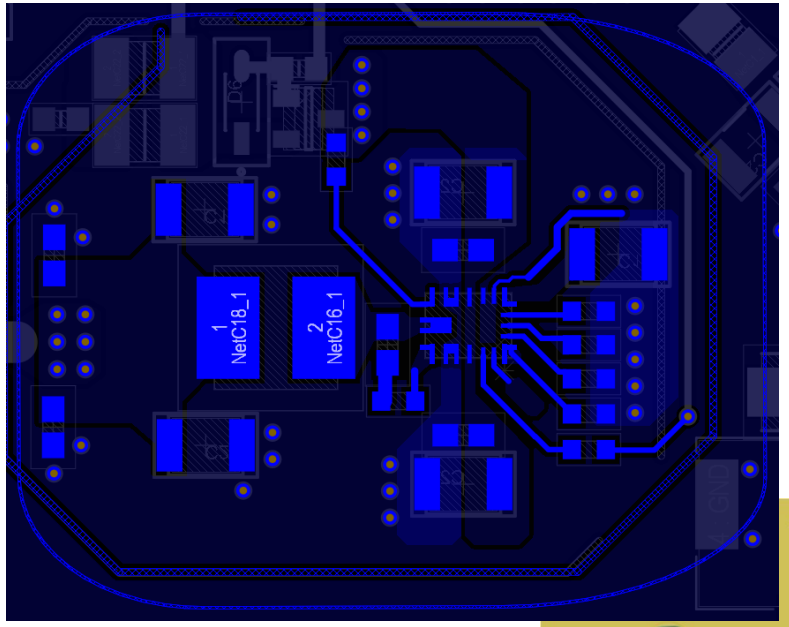
V_{IN} pin = HIGH

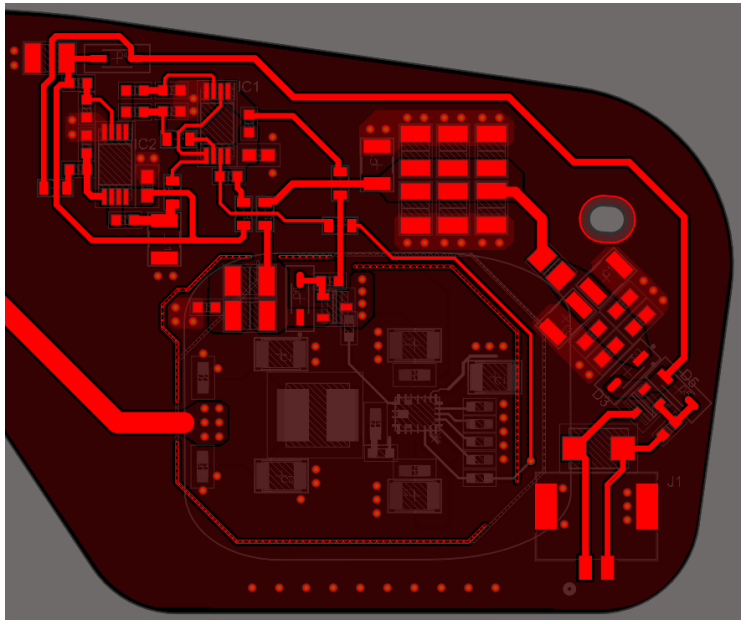
↓

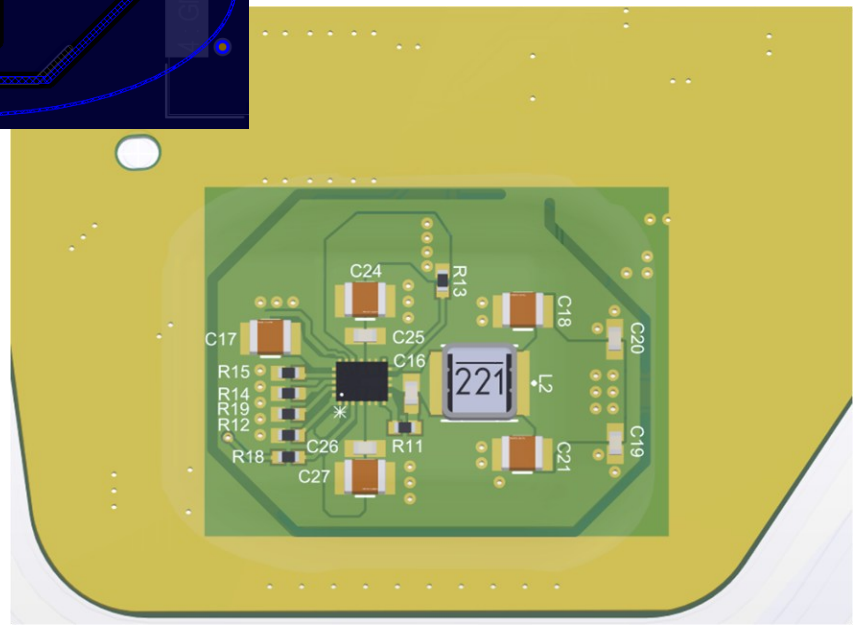
Vezje deluje pravilno?

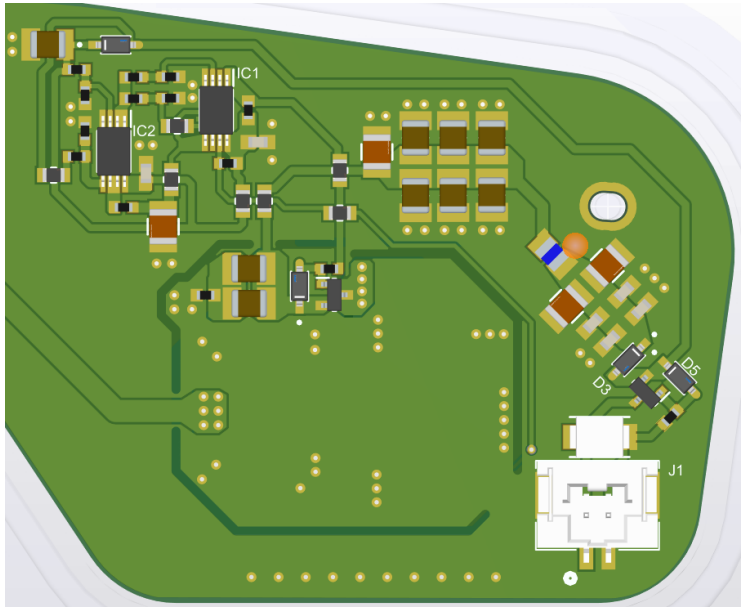


Načrtovanje tiskanega vezja

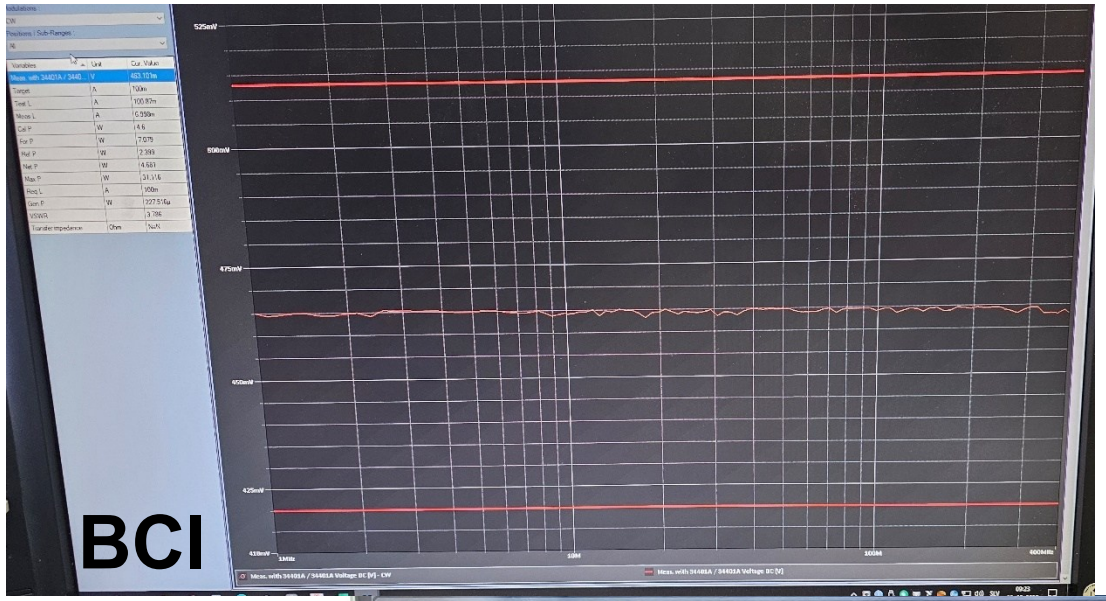


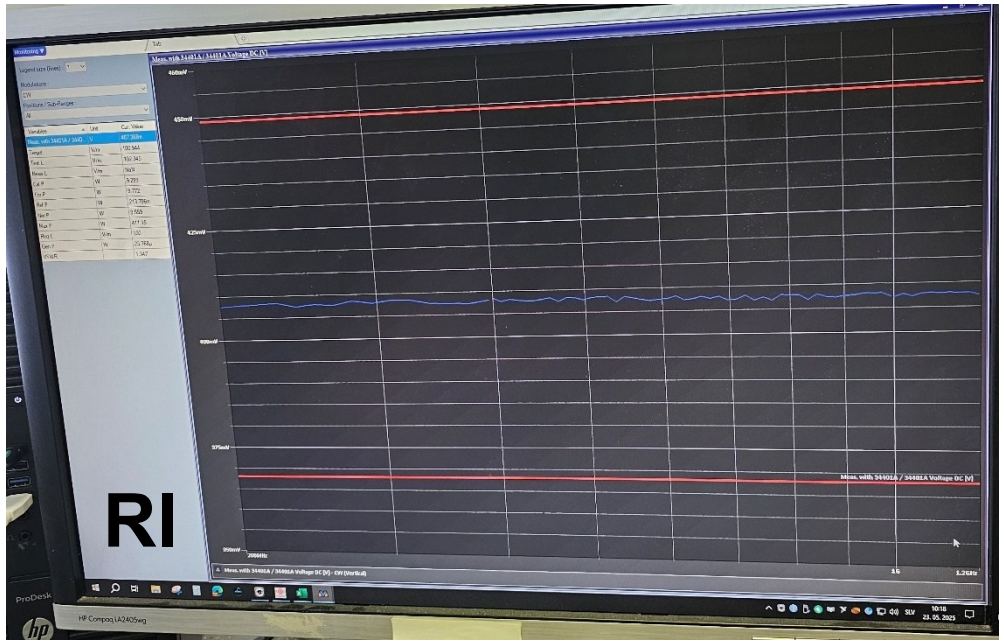


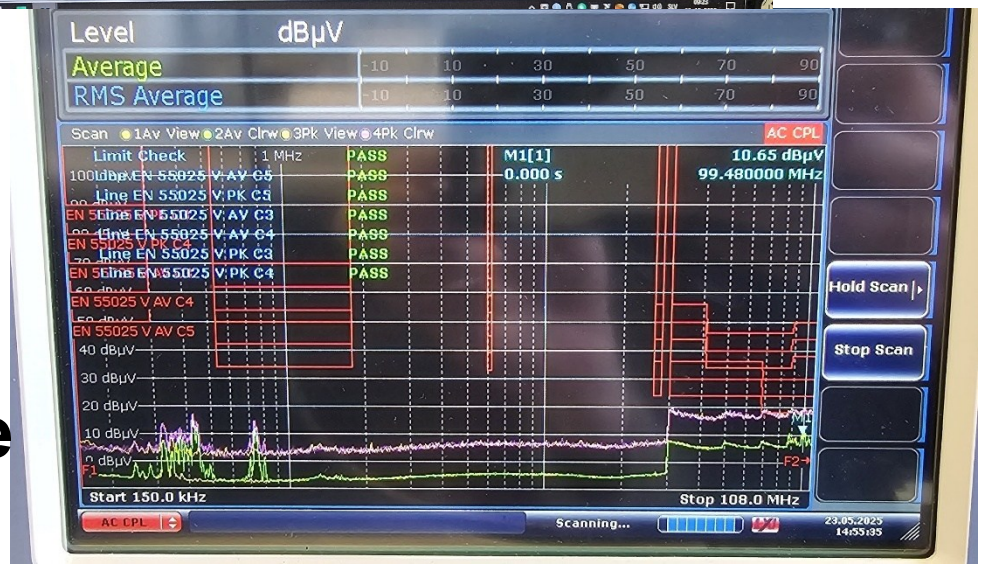


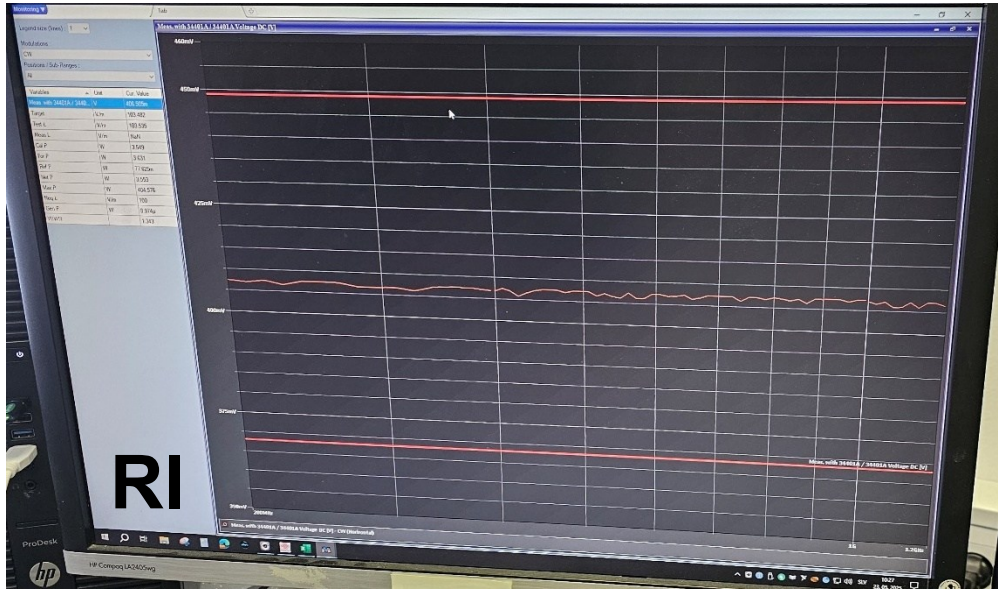


Preliminarne meritve



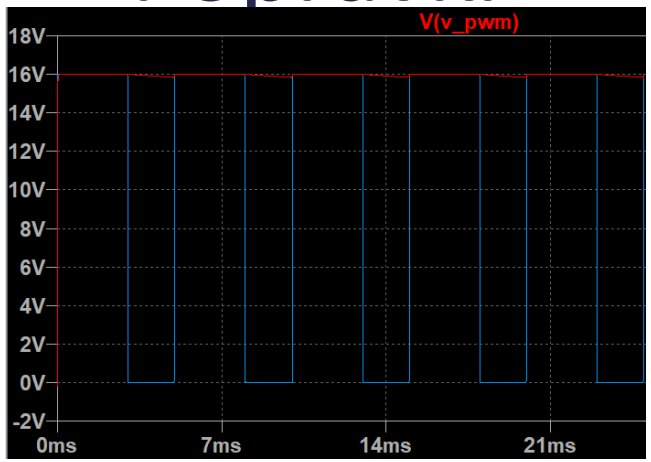


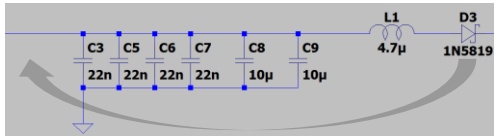


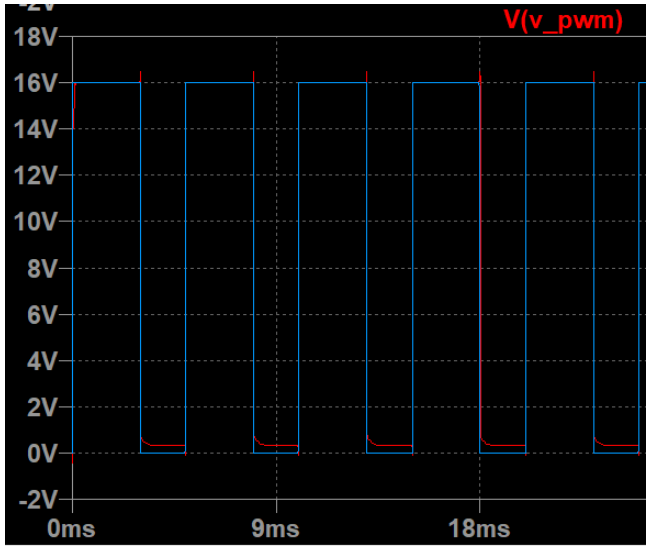


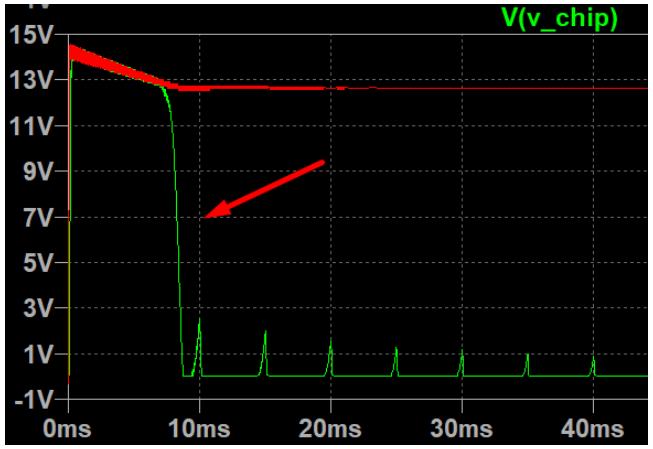
Prevodne emisije

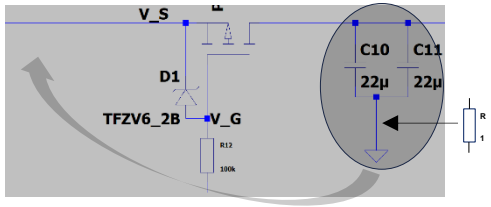
Popravki

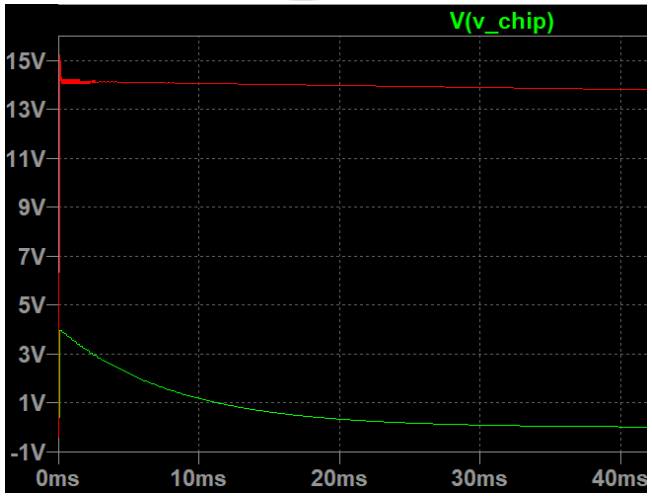


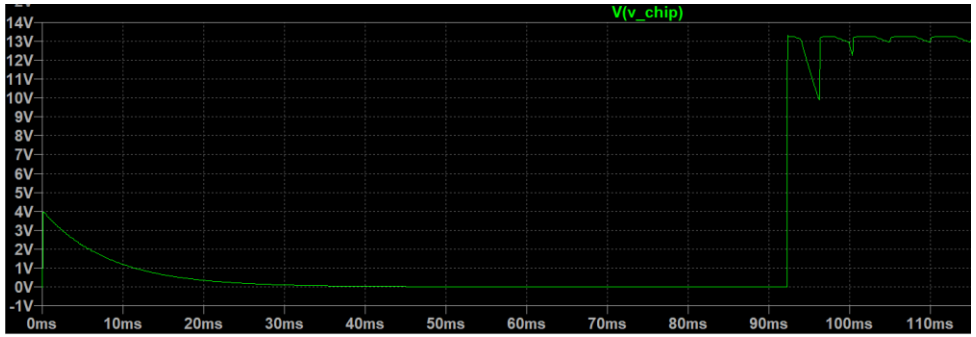






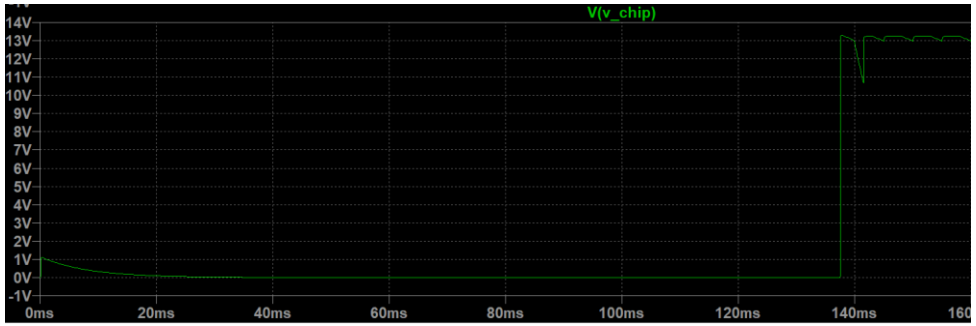






Logika in čip napajana z istim detektorjem vršne vrednosti

Logika in čip napajana z različnima detektorjema vršne vrednosti



Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

Blaž Krajnik

Rezultati

Blaž Krajnik – Funkcionalni in električni testi

Osnovna funkcionalnost ✓

PWM območje ✓

Napetostno območje ✓

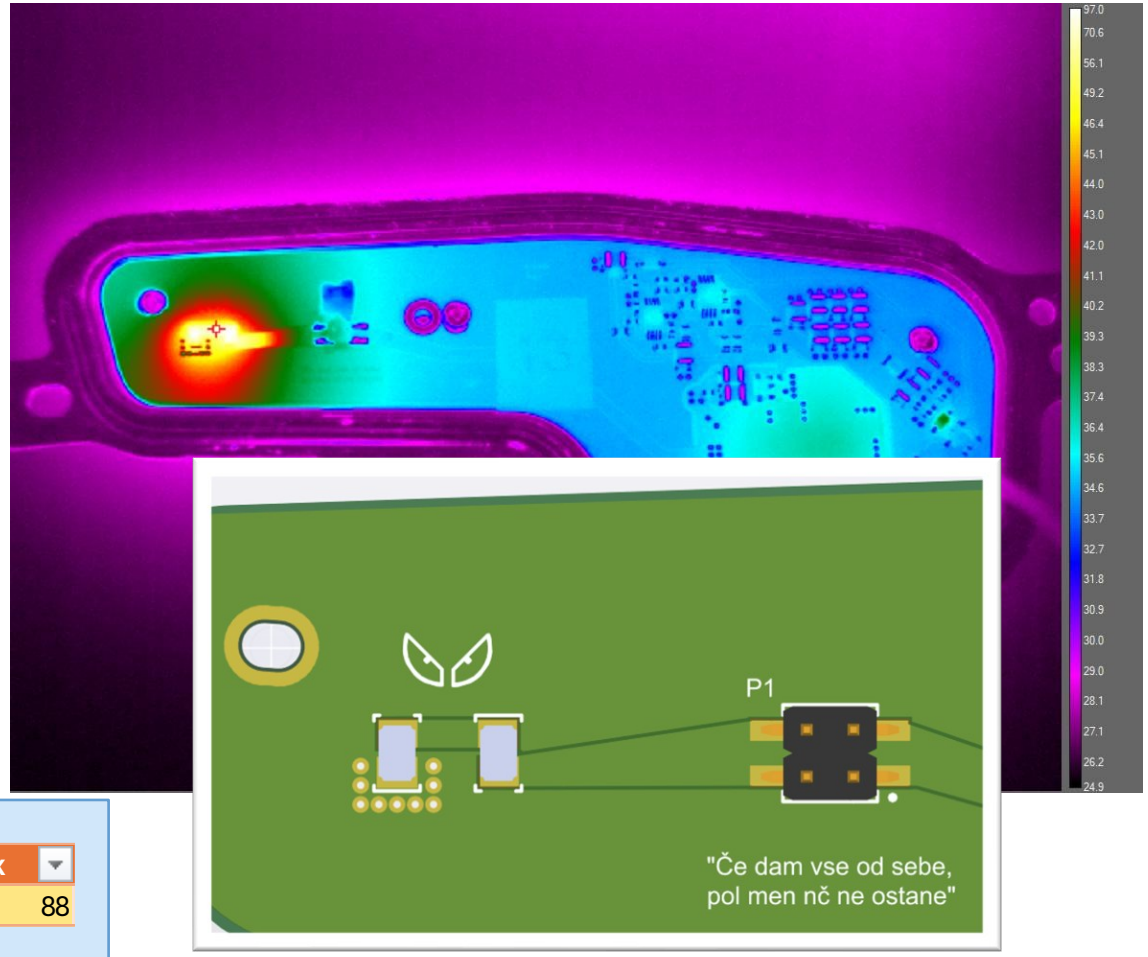
Temperaturno območje ✓

Obrnjena polariteta ✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	151	2.040	6.01	299	1.796	88

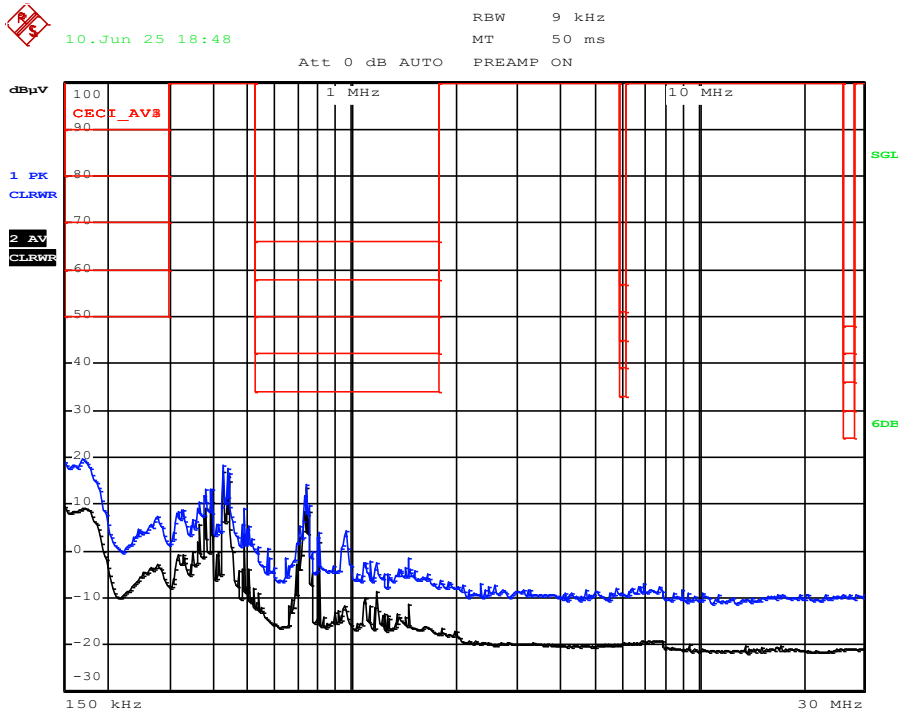
Temperaturna obremenitev: 72.06 °C



Blaž Krajnik – EMC

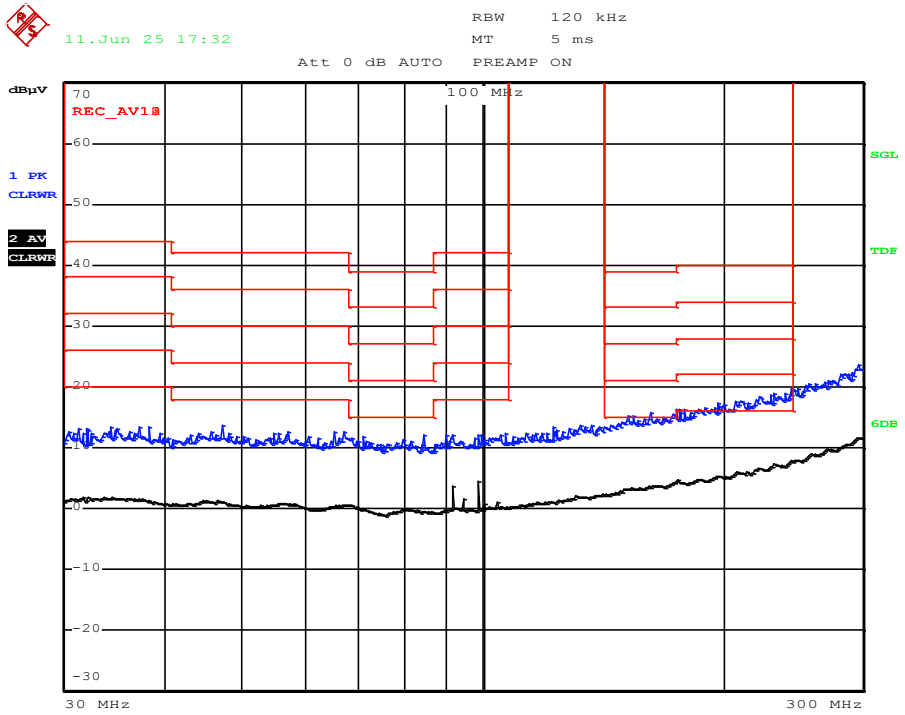
CE

5



RE

5



BCI

100 mA **A**

RI

100 V/m H+V **A**

Blaž Krajnik – Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 10000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vezje
C19, C20		GCM188R71E102KA37D	Murata	/	/	0.005 €	2	0.010 €
C3, C4, C5, C6		06035C223K4T2A	KYOCERA AVX	/	/	0.005 €	4	0.020 €
C16, C25, C26, C28, C29		TMK107B7104MAHT	TAIYO YUDEN	/	/	0.005 €	5	0.025 €
C18, C21		CC1210KKX7R8BB475	YAGEO	CC1210KKX7R8BB475	Ampacity Systems	0.046 €	2	0.092 €
C1, C2, C13, C15, C17, C24, C27		UMK325AB7106KM-P	TAIYO YUDEN	UMK325AB7106KM-P	Unikeyic	0.046 €	7	0.322 €
C7, C8, C9, C10, C11, C12, C14, C22, C23		**GCM32EC71E226KE36L**	**Murata**	**GCM32EC71E226KE36L**	**Rebound Electronics**	**0.170 €**	**9**	**1.530 €**
L1		AOTA-B252010S4R7MT	ABRACON	AOTA-B252010S4R7MT	Worldway Electronics	0.050 €	1	0.050 €
L2		**SRR5828A-220M**	**Bourns**	**6521-SRR5828A-220M**	**Mouser**	**0.397 €**	**1**	**0.397 €**
R20, R22, R25, R26, R27, R28, R29		RC0805FR-100RL	YAGEO	4125207	Future Electronics	0.002 €	7	0.014 €
R16		RC0603FR-131RL	YAGEO	/	/	0.005 €	1	0.005 €
R11		RC0603FR-1020RL	YAGEO	/	/	0.005 €	1	0.005 €
R8		AC0603FR-7W4K7L	YAGEO	/	/	0.005 €	1	0.005 €
R12		RC0603FR-077K87L	YAGEO	/	/	0.005 €	1	0.005 €
R19		RC0603FR-1010KL	YAGEO	/	/	0.005 €	1	0.005 €
R6, R7		RC0603FR-0715KL	YAGEO	/	/	0.005 €	2	0.010 €
R15		AC0603FR-0723K2L	YAGEO	/	/	0.005 €	1	0.005 €
R3		RC0603FR-1033KL	YAGEO	/	/	0.005 €	1	0.005 €
R14		AC0603FR-0753K6L	YAGEO	/	/	0.005 €	1	0.005 €
R1, R2, R9, R13, R17, R18, R23		RC0603FR-10100KL	YAGEO	/	/	0.005 €	7	0.035 €
R4		AC0603FR-07147KL	YAGEO	/	/	0.005 €	1	0.005 €
R5, R10, R24		RC0603FR-10300KL	YAGEO	/	/	0.005 €	3	0.015 €
IC1		LM2903BIPWR	Texas Instruments	LM2903BIPWR	Texas Instruments	0.042 €	1	0.042 €
IC2		LM2904BIPWR	Texas Instruments	LM2904BIPWR	Texas Instruments	0.036 €	1	0.036 €
D3, D4		1N5819HW-7-F	Diodes Incorporated	1N5819HW-7-F	Worldway Electronics	0.010 €	2	0.020 €
D5, D6		MMSZ5240B	Diotec Semiconductor	MMSZ5240B	Arrow Electronics	0.012 €	2	0.024 €
D7		SMBJ18CA-Q	Bourns	SMBJ18CAQ-13-F	Ampacity Systems	0.063 €	1	0.012 €
Q1, Q2		DMP3098LQ-7	Diodes Incorporated	DMP3098LQ-7	Fly-Wing Technology	0.028 €	2	0.056 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
68	2.76 €	0.68 €	3.44 €

Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

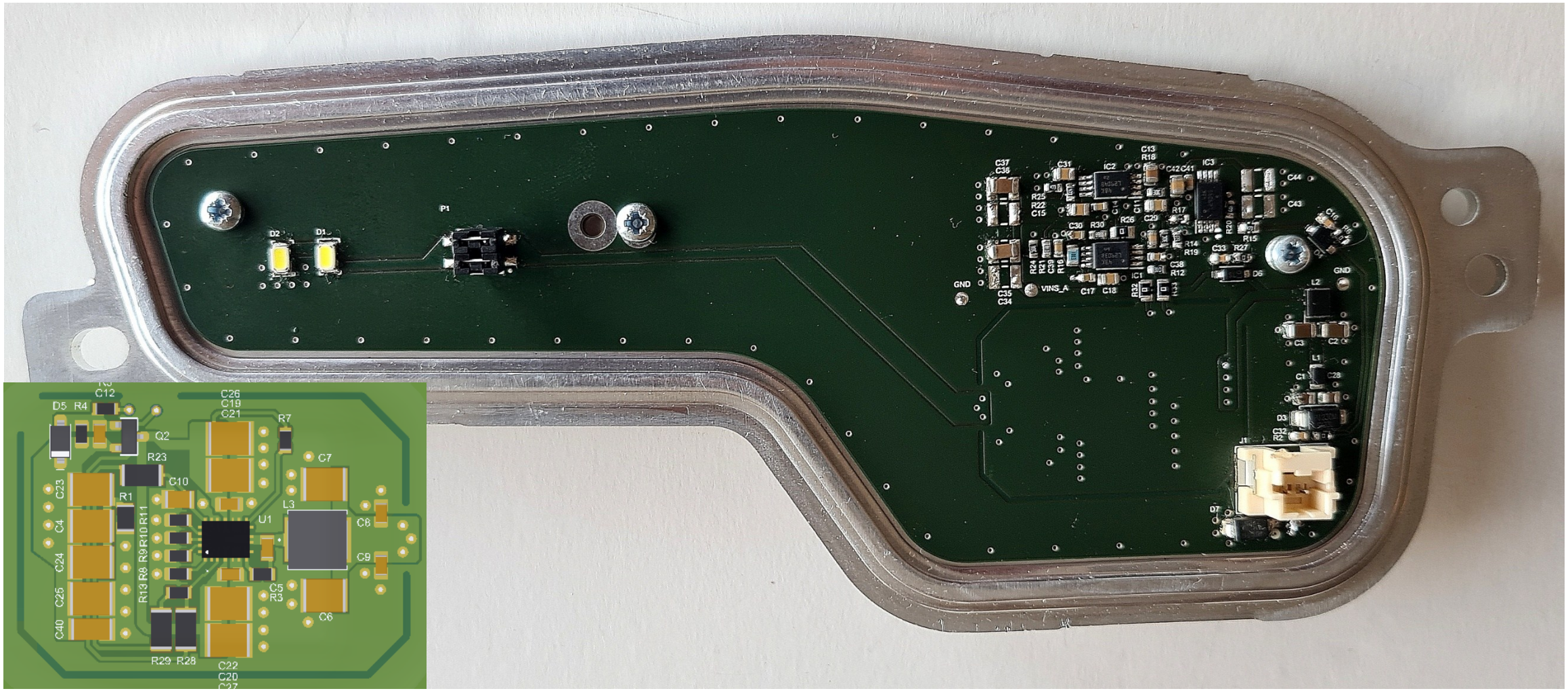
UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko
in optoelektroniko

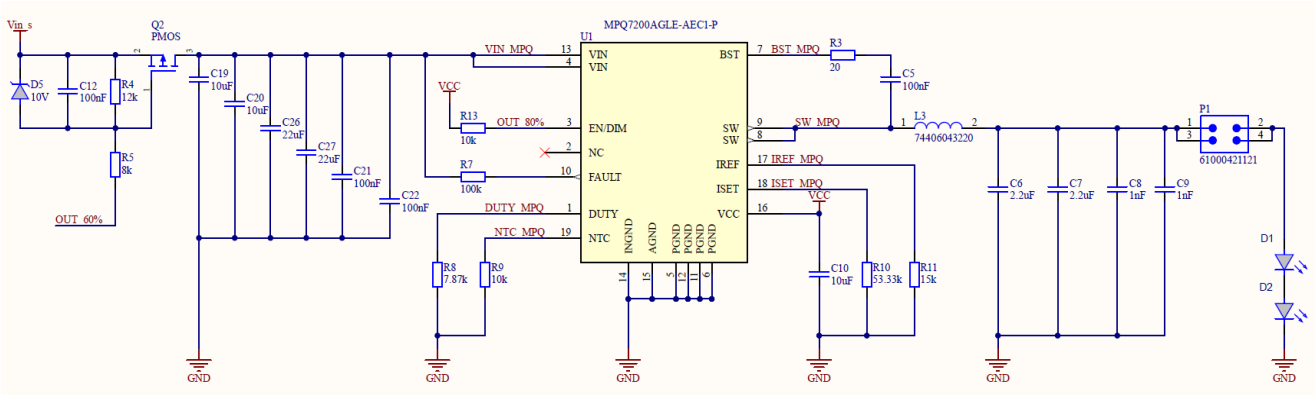
Tilen Plahuta

2. letnik, MAG-EL

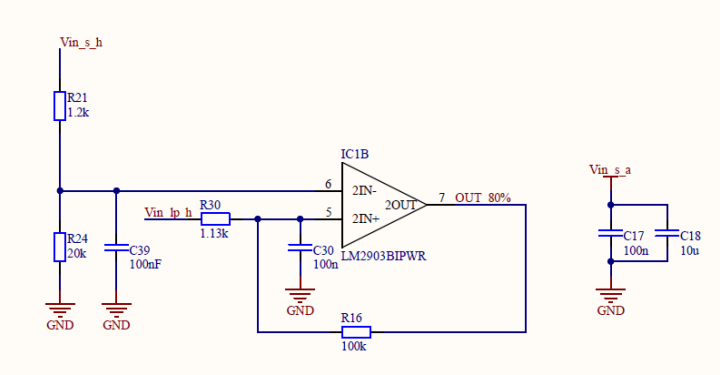
Tilen Plahuta

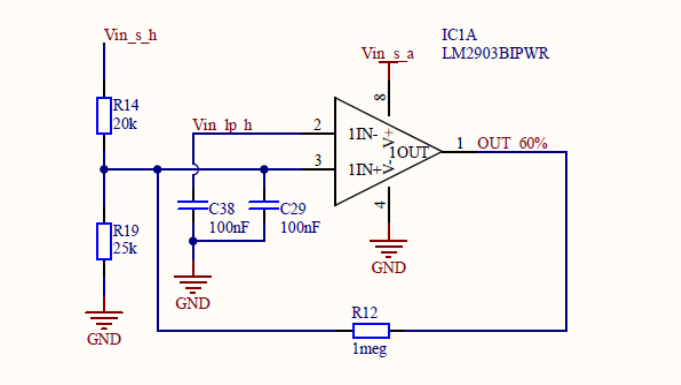


Koncept rešitve

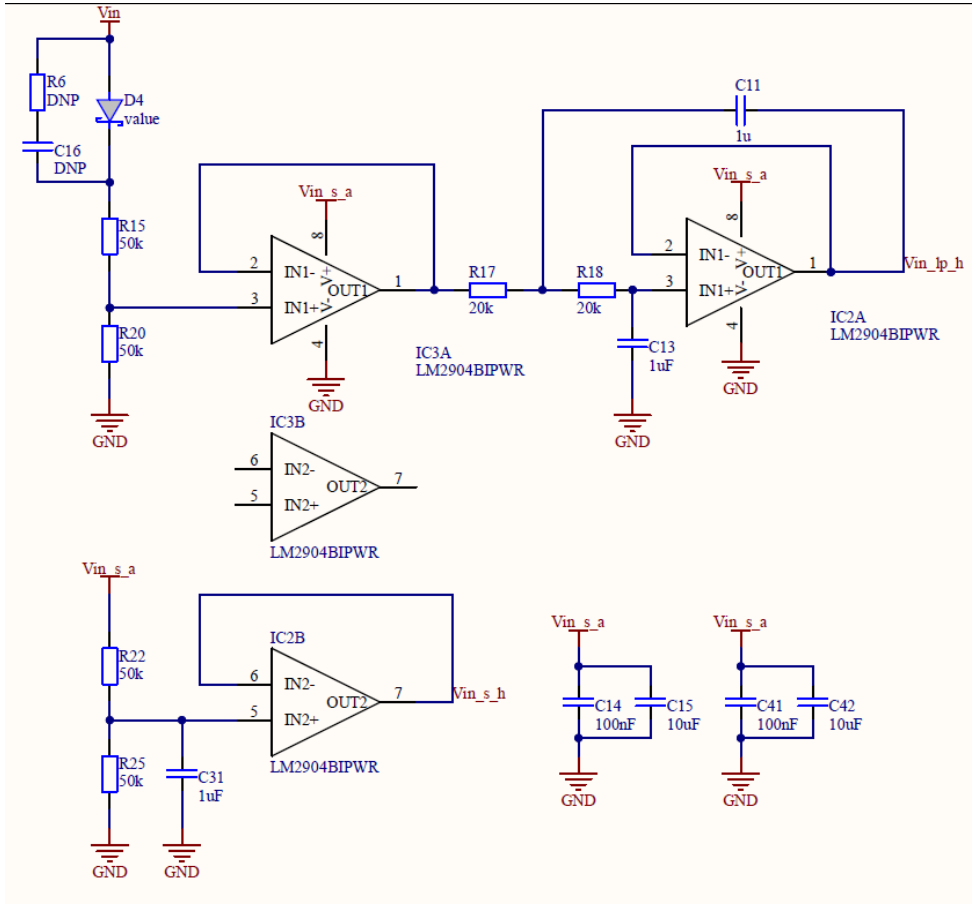


- PMOS za izklop čipa



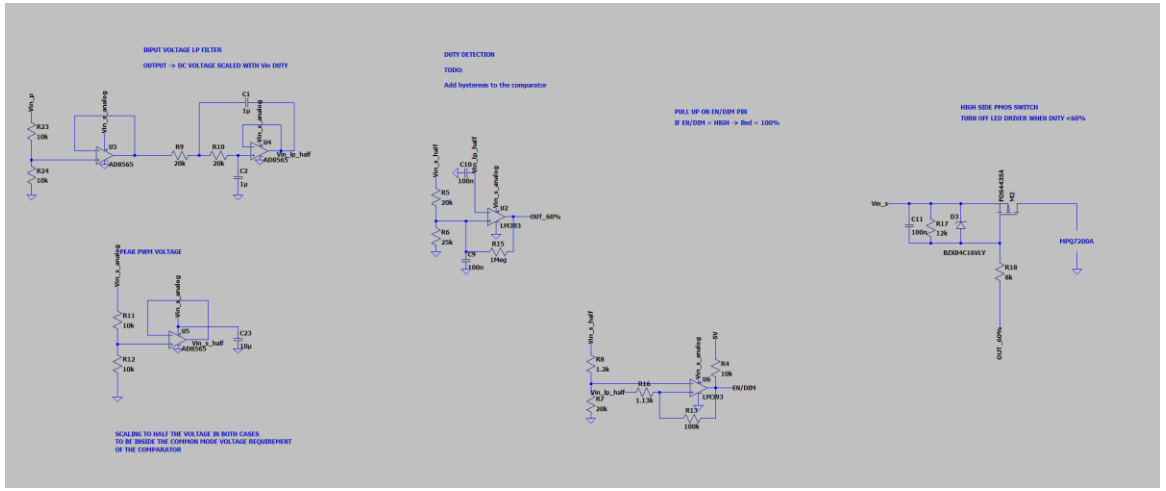


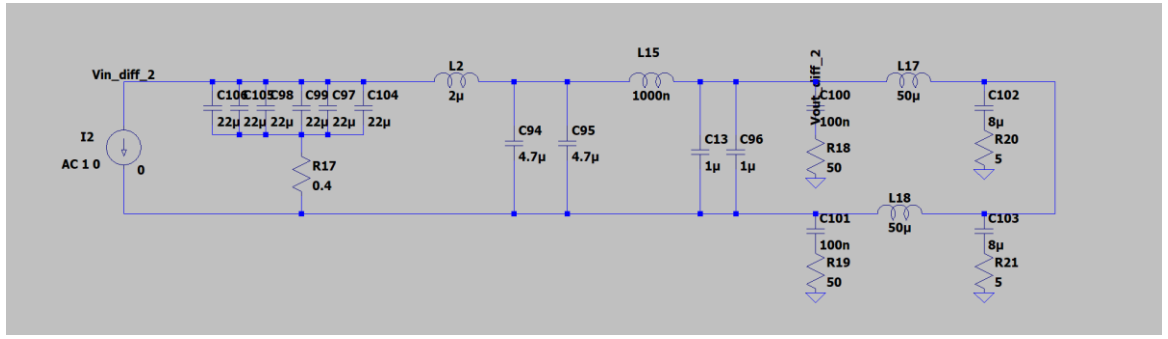
- Komparatorja za določitev stanja delovanja (10% ali 100%)

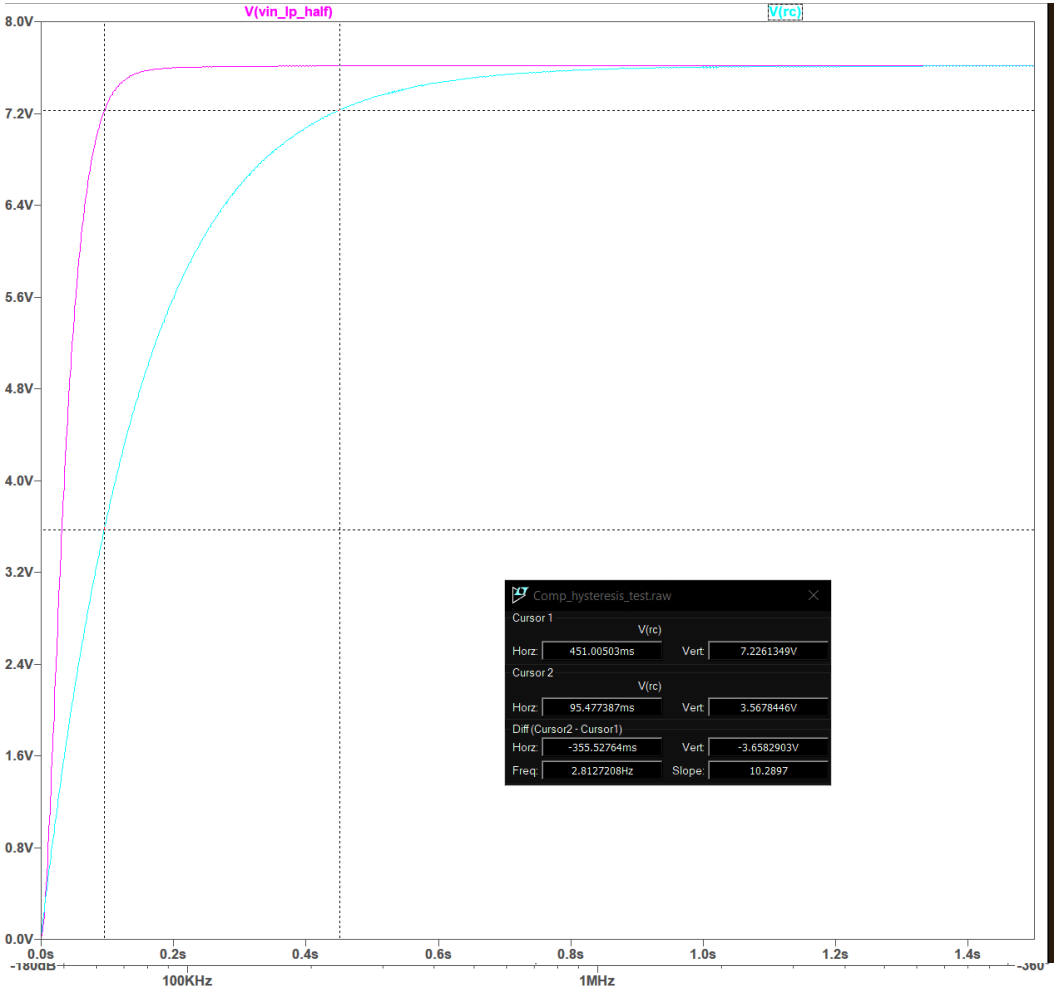


- Filter za pretvorbo DUTY v analogno vrednost

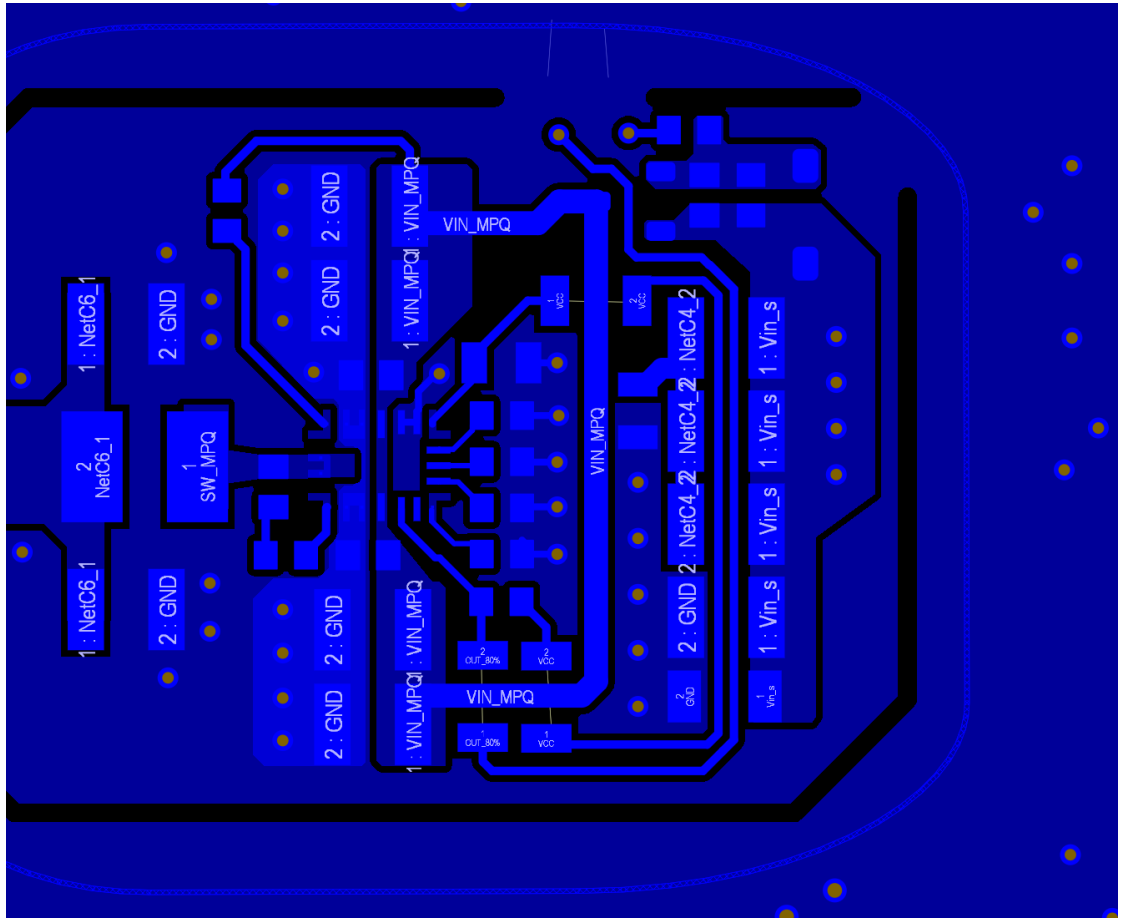
Izračuni, simulacije

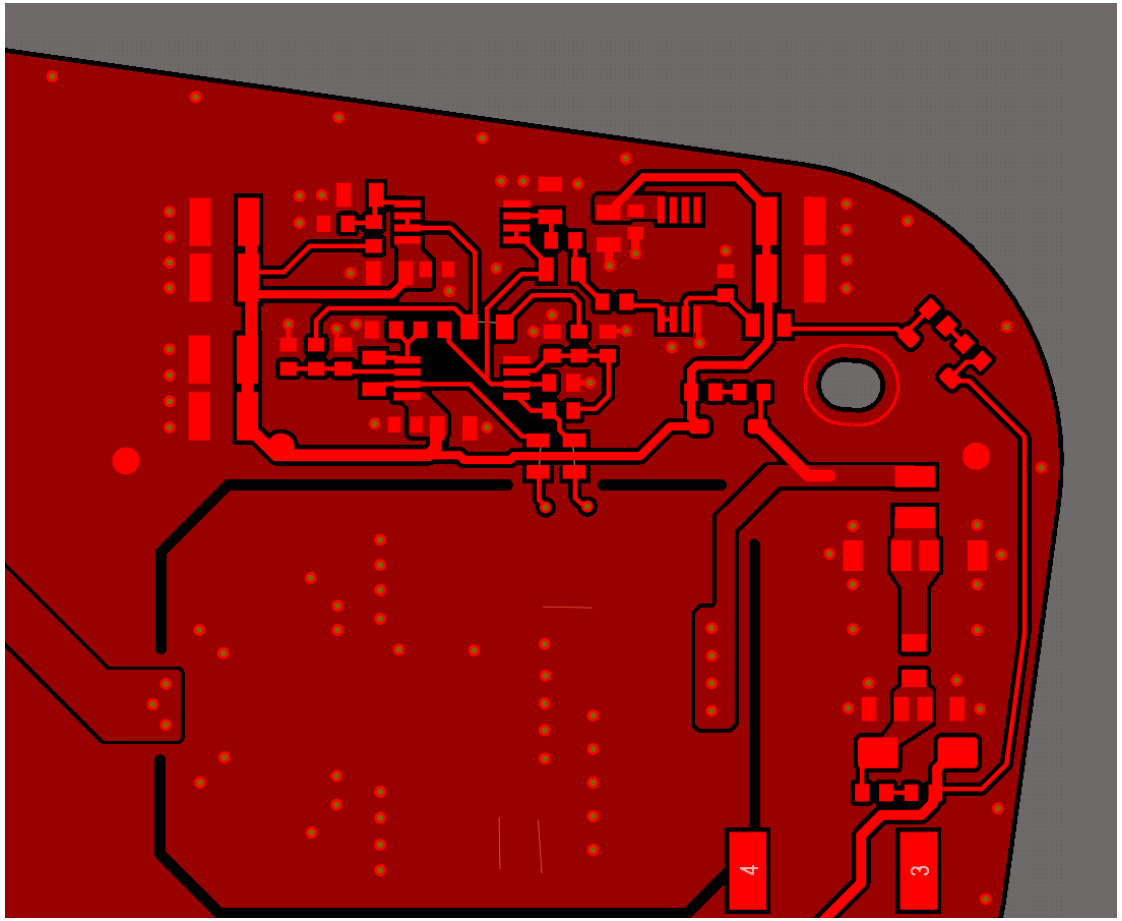




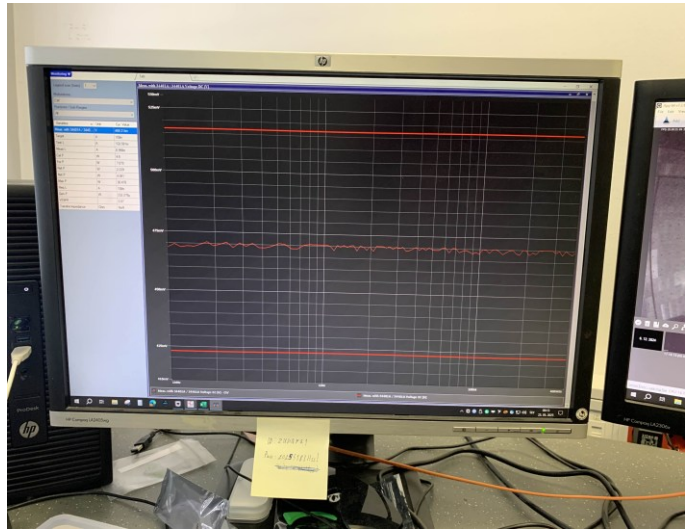


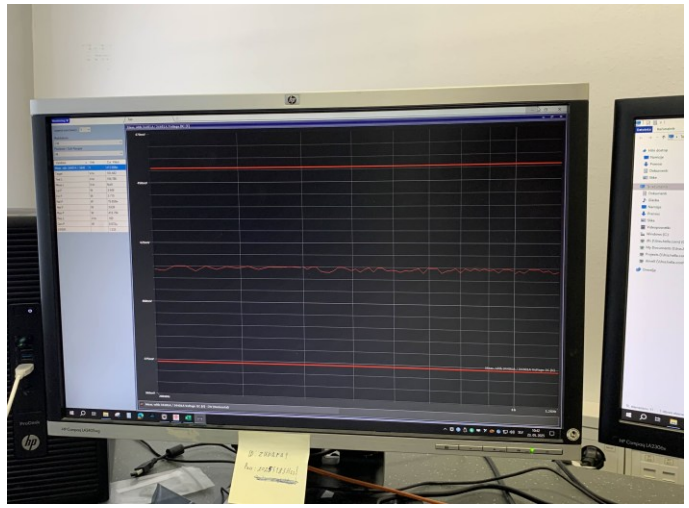
Načrtovanje tiskanega vezja





Preliminarne meritve





Morebitni popravki

- Cena
- Poenostavitev vezja

Texas Instruments		0.041	2	0.08 €	?q=lm2904bipwr&cu
Wurth		0.073	1	0.07 €	
Wurth		0.116	1	0.12 €	
Wurth		0.172	1	0.17 €	
Future Electronics		0.037	1	0.04 €	3SS314PEH6327XT
		0.005	20	0.10 €	
Mouser		0.0062	1	0.01 €	=RC0805FR-131RL
Mouser		0.012	1	0.01 €	s=sGAEpiMZZMvdG
Mouser		0.007	1	0.01 €	TTE1003F?qs=sGAE
Mouser		0.002	3	0.01 €	=sGAEpiMZZMvdGk
Mouser		0.004	3	0.01 €	-070RL?qs=sGAEpi
			81	2.47 €	
	81	0.01	0.81	3.28 €	
	st kos	polaganje na kos	cena polaganja	koncna cena	

Načrtovanje elektronike za

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Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko
in optoelektroniko

Tilen Plahuta

Rezultati

Tilen Plahuta – Funkcionalni in električni testi

Osnovna funkcionalnost ✓

PWM območje — Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne ✓

Napetostno območje — Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne ✓

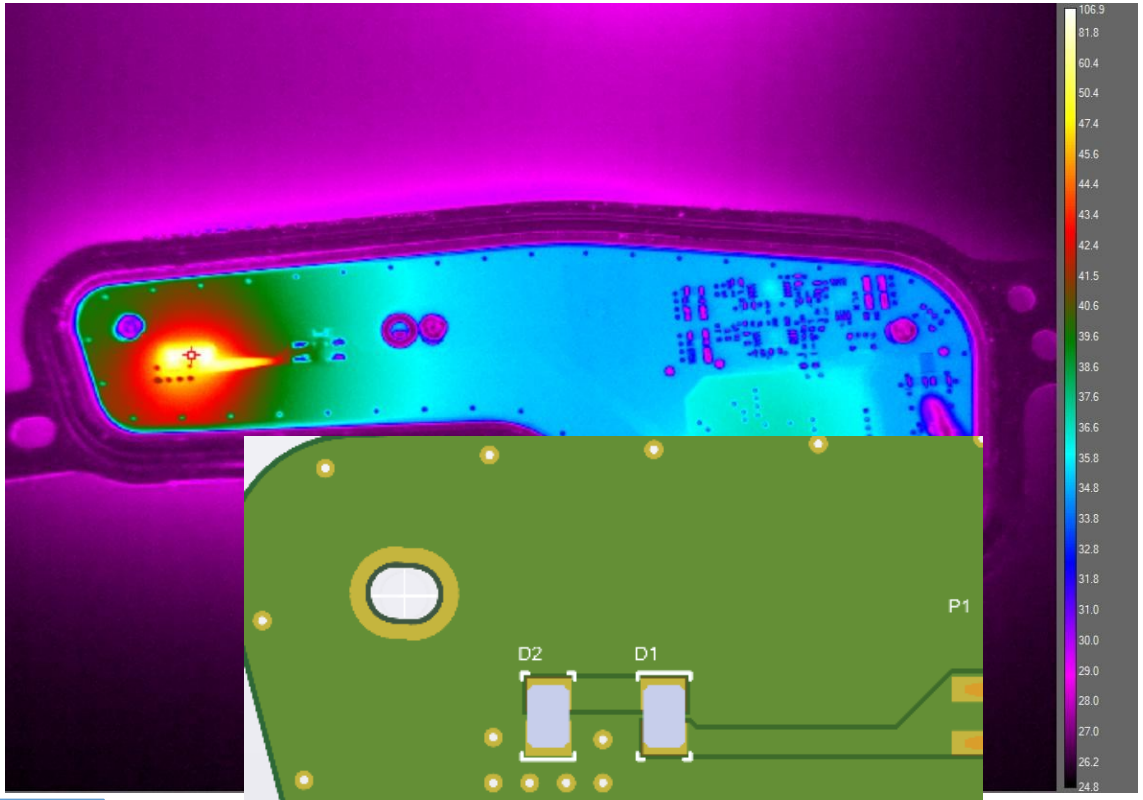
Temperaturno območje — Pri prvem pulzu na 45% utripne, za tem ugasne, Pri 60°C, 45%, vezje sveti v PO ✓

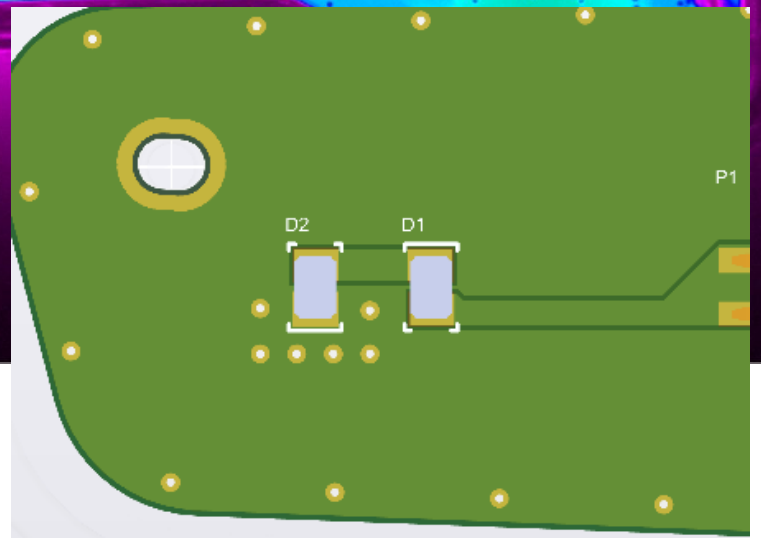
Obrnjena polariteta ✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	153	2.067	6.02	306	1.841	89

Temperaturna obremenitev: 86.39 °C

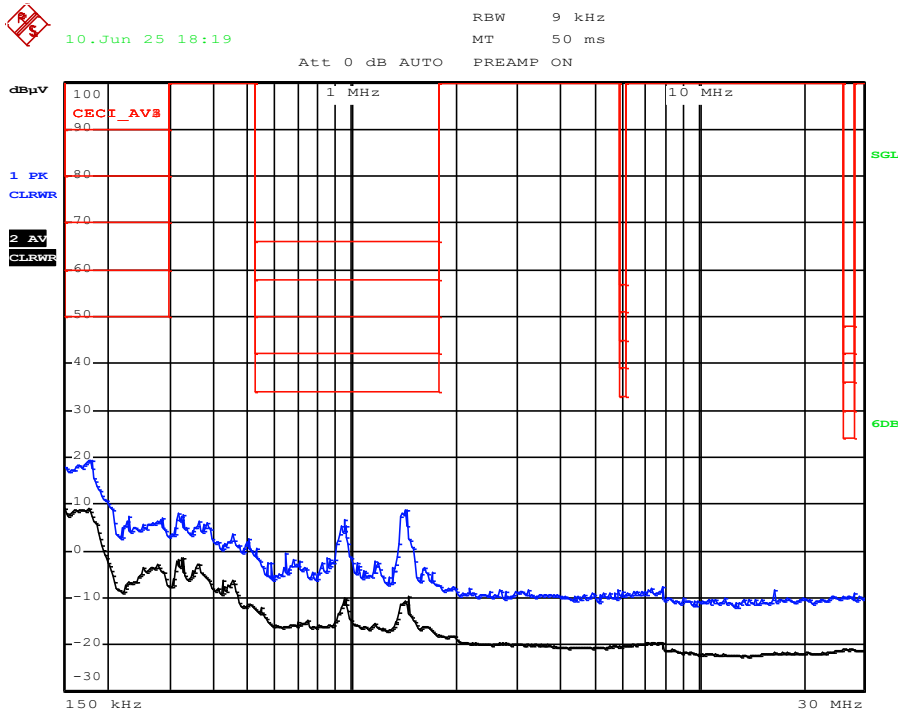




Tilen Plahuta – EMC

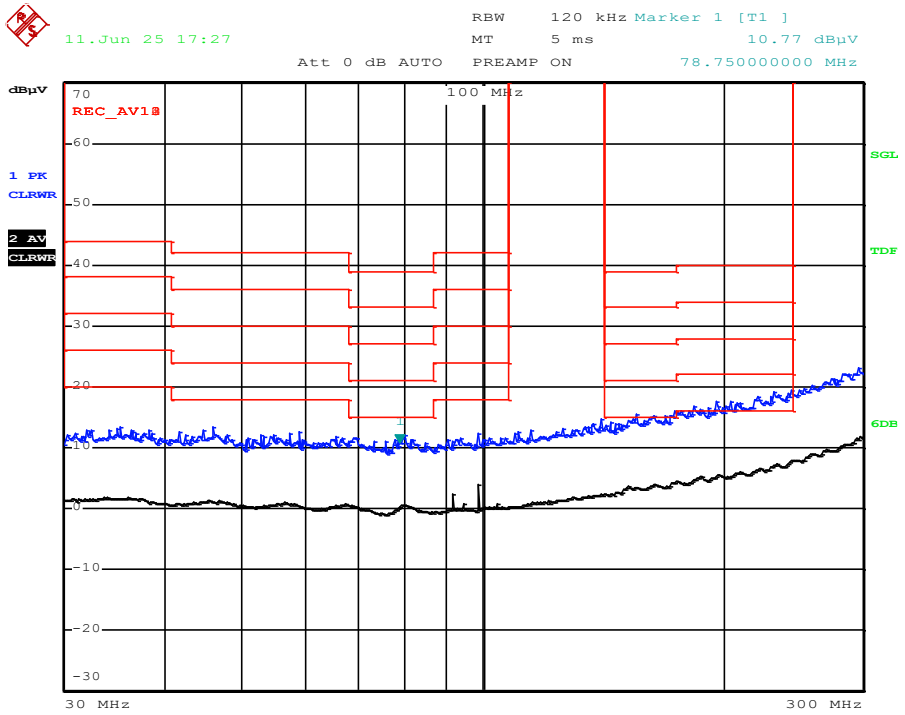
CE

5



RE

5



BCI

100 mA

A

RI

100 V/m H+V

A

Tilen Plahuta - Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Dobavitelj	Cena/kos (za 1000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vezje
C10	0805 10uF	GRM21BC71E106ME01L	Murata	Mouser	0.056	1	0.056 €
C1, C28, C13, C31, C11, C15, C42, C18	0805 1uF	GCM21BR71H105KA03L	Murata	Worldway electronics	0.014	8	0.112 €
C2, C3,C6, C7	4.7u 1206	GRM31CR71H475MA12L	Murata	Worldway electronics	0.026	4	0.104 €
C4, C23, C24, C25, C26, C27	**1210 22uF**	**GCM32EC71E226KE36L**	**Murata**	**Worldway electronics**	**0.18**	**6**	**1.080 €**
C14, C41, C17, C29, C38, C39, C30, C5, C12, C21, C22	0603 100nF	/	Wurth	Wurth	0.005	11	0.055 €
C8, C9, C16, C32,C33	0603 1nF	/	Wurth	Wurth	0.005	5	0.025 €
C19, C20	**1210 10uF**	**GCM32ER71E106KA42L**	**Murata**	**LCSC**	**0.072**	**2**	**0.144 €**
C40, C35, C37	1206 10uF	GRM31CR71E106KA12L	Murata	Worldway electronics	0.0088	3	0.026 €
D3	Schotky diode SMA	SX33L_R1_00001	Panjit	Mouser	0.055	1	0.055 €
D4, D6	SOD123 Schotky	B0520LWQ-7-F	Diodes Inc.	AVNET	0.03	2	0.060 €
D5	SOD123 Zener 10V	MMSZ5240BT1G	Onsemi	Future Electronics	0.011	1	0.011 €
D7	TVS DIODE 36VWM 58.1VC	SMAJ28CA	Bourns	Mosuer	0.075	1	0.075 €
IC1	LM2903BIPWR		Texas Instruments	Texas Instruments	0.048	1	0.048 €
IC2, IC3	LM2904BIPWR		Texas Instruments	Texas Instruments	0.041	2	0.082 €
L1	FIXED IND 1UH 1.8A 78 MOHM SMD	74479275210	Wurth	Wurth	0.073	1	0.073 €
L2	FIXED IND 2.2UH 2.1A 106MOHM SMD	74479299222	Wurth	Wurth	0.116	1	0.116 €
L3	**FIXED IND 22UH 1.23A 172MOHM SMD**	**74406043220**	**Wurth**	**Wurth**	**0.172**	**1**	**0.172 €**
Q2	Transistor PFET	BSS314PEH6327XTSA1	Infineon	Future Electronics	0.037	1	0.037 €
R3, R4, R5, R7, R8, R9, R13, R10, R11, R12, R14, R17, R18, R24, R19,R20, R22, R25, R21, R30	Resistor 0603 1%	/	/		0.005	20	0.100 €
R1	Resistor 0805 1%	RC0805FR-131RL	YAGEO	Mouser	0.0062	1	0.006 €
R15	Resistor 0805 1%	RT0805FRD0749K9L	YAGEO	Mouser	0.012	1	0.012 €
R16	Resistor 0805 1%	RK73H2ATTE1003F	KOA Speer	Mouser	0.007	1	0.007 €
R23, R28, R29	Resistor 1206 1%	1206W4F0000T5E	Royalohm	Mouser	0.002	3	0.006 €
R26, R32, R33	Resistor 0805 1%	AC0805FR-070RL	YAGEO	Mouser	0.004	3	0.012 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
81	2.47 €	0.81 €	3.28 €

Načrtovanje elektronike za EMC² 2025

študentska delavnica in tekmovanje

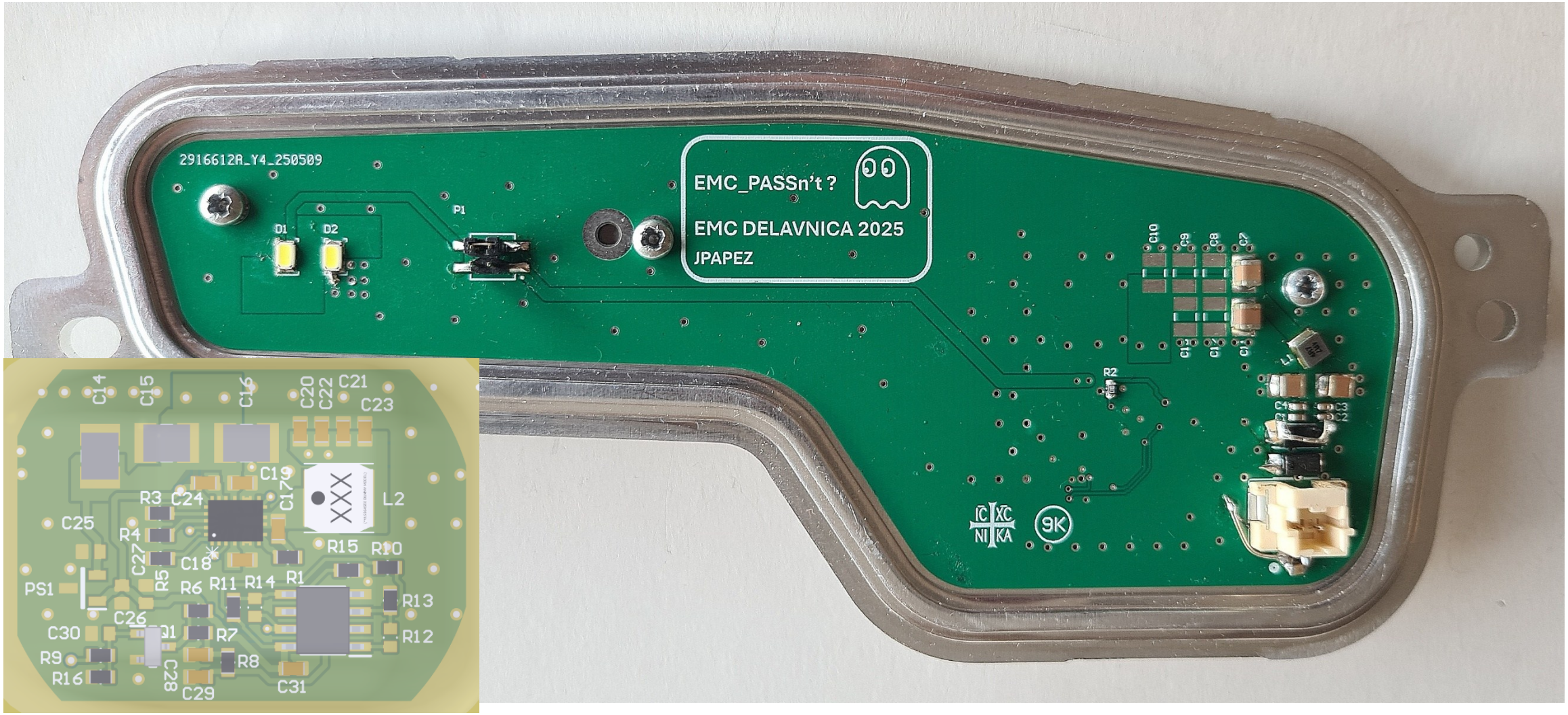
UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

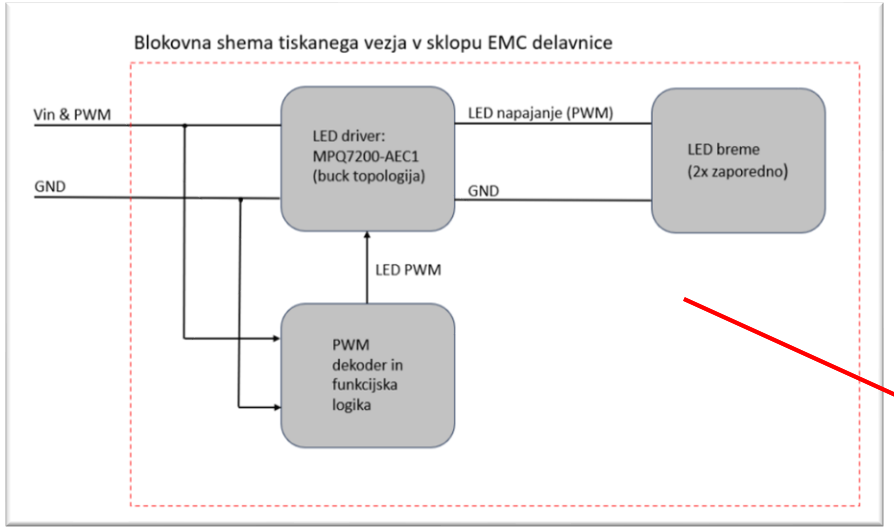
Jože Papež

2. letnik, MAG-EL

Jože Papež


2916612R_Y4_250509
D1
D2
P1
EMC_PASSn't ?
EMC DELAVNICA 2025
JPAPEZ
C10
C9
C8
C7
C13
C12
C11
L1
R2
C1
C3
C2
C14
C15
C16
C20
C22
C21
C23
C19
C17
R3
C24
L2
C25
R4
R15
R10
C27
C18
R5
R6
R11
R14
R1
PS1
R13
C26
D1
R7
R12
C30
R9
R8
R16
C28
C29
C31

Koncept rešitve



3 Načrtovalske zahteve

3.1 Funkcionalne zahteve:

Z uporabo MPQ7200A-AEC1 je treba izdelati DC/DC pretvornik za napajanje dveh zaporedno vezanih belih LED z izhodnim tokom 300 mA, ki mora delovati v navedenih temperaturnih in napetostnih pogojih, opisanih v poglavju 3.2. Poleg DC/DC pretvornika je treba načrtati tudi analogni vmesnik, ki vsebuje funkcijsko logiko, ki bo glede na napajalno napetost modulirano s PWM samostojno preklapljala med spodnjimi načini delovanja:

1. 0 % do 45 %: LED ne sveti (LED PWM = 0 %)
2. 60 % do 80 %: LED PWM = 10 % ± 3 % (7 % do 13 %)
3. 95 % do 100 %: LED PWM = 100 %

Pretvornik mora imeti zaščito proti napačni priključitvi napajalnih sponk.

3.2 Električne zahteve:

V spodnji tabeli so zbrane vse električne zahteve vezja.

Tabela 1: Seznam električnih zahtev

Lastnost	Vrednost	Opomba
Območje napajalne napetosti	8 V do 16 V	V tem področju mora pretvornik zagotavljati nazivni izhodni tok in ustrezno PWM krmiljenje LED.
Temperaturno območje delovanja tiskanine	−20 °C do +60 °C	V tem področju mora pretvornik zagotavljati nazivni izhodni tok in ustrezno PWM krmiljenje LED. Pri obeh temperaturah počakamo minimalno 10 min, da se temperatura elementov ustali.
Območje frekvence PWM napajalne	200 Hz ± 10 %	V tem področju mora pretvornik zagotavljati nazivni izhodni tok in ustrezno

PWM Dekoder za LED Nadzor

1. Pretvorba PWM v analogno vrednost:

- Uporabimo **RC filter** (R = 10 kΩ, C = 100 nF), ki pretvori PWM signal v **povprečno napetost** (DC), sorazmerno z **duty cycle** PWM signala.

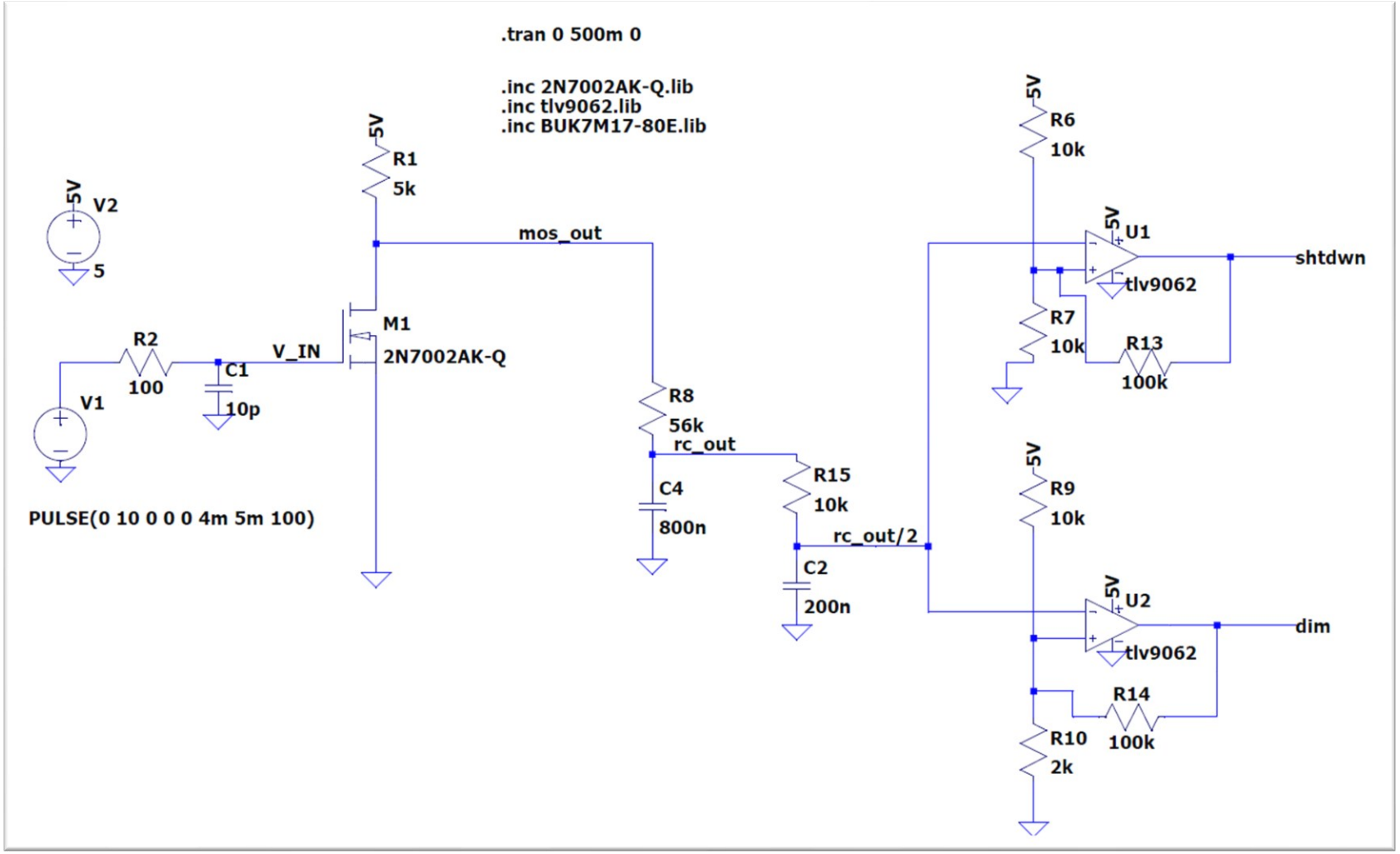
2. Komparatorji za odločanje:

- **Komparator 1**:
  - Odloči, ali je signal "ON" (≥ 45% duty cycle) ali "OFF" (≤ 45%).
- **Komparator 2**:
  - Odloči med **10% PWM (dim)** in **100% PWM (full)** glede na napetost iz RC filtra:
    - **3.0 V** za 10% PWM (dim).
    - **4.75 V** za 100% PWM (full).

3. Logika za LED:

- **LED OFF**: Če je PWM < 45 %.
- **LED Dim (10%)**: Če je PWM med 60 % in 80 %.
- **LED Full Brightness (100%)**: Če je PWM med 95 % in 100 %.

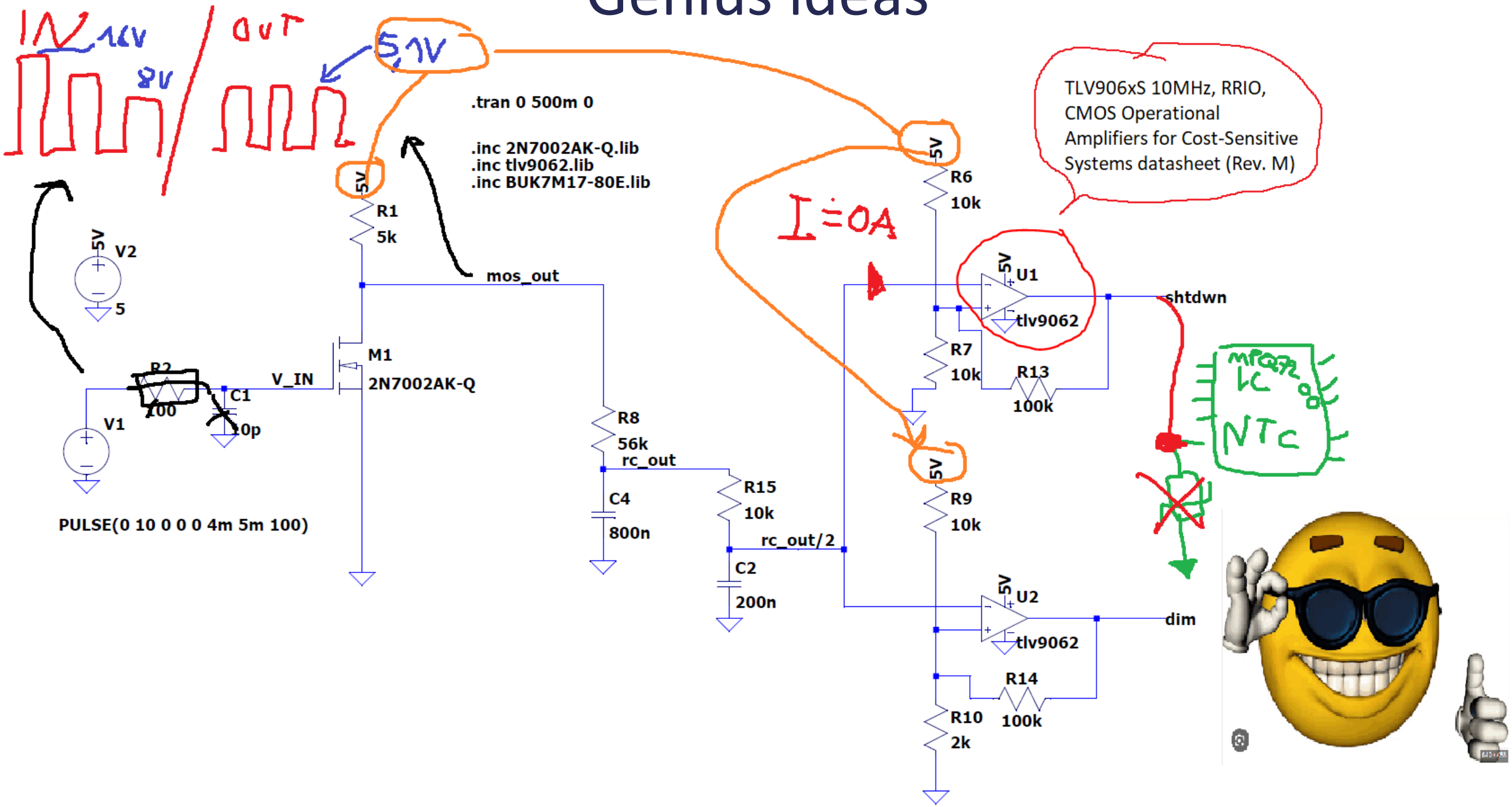
Simulacija


.tran 0 500m 0
.inc 2N7002AK-Q.lib
.inc tlv9062.lib
.inc BUK7M17-80E.lib
5V
R1
5k
V2
5
mos_out
M1
2N7002AK-Q
R2
100
C1
10p
V_IN
V1
PULSE(0 10 0 0 0 4m 5m 100)
R8
56k
rc_out
C4
800n
R15
10k
rc_out/2
C2
200n
R6
10k
U1
tlv9062
shtdwn
R7
10k
R13
100k
R9
10k
U2
tlv9062
dim
R14
100k
R10
2k

Rezultati simulacije

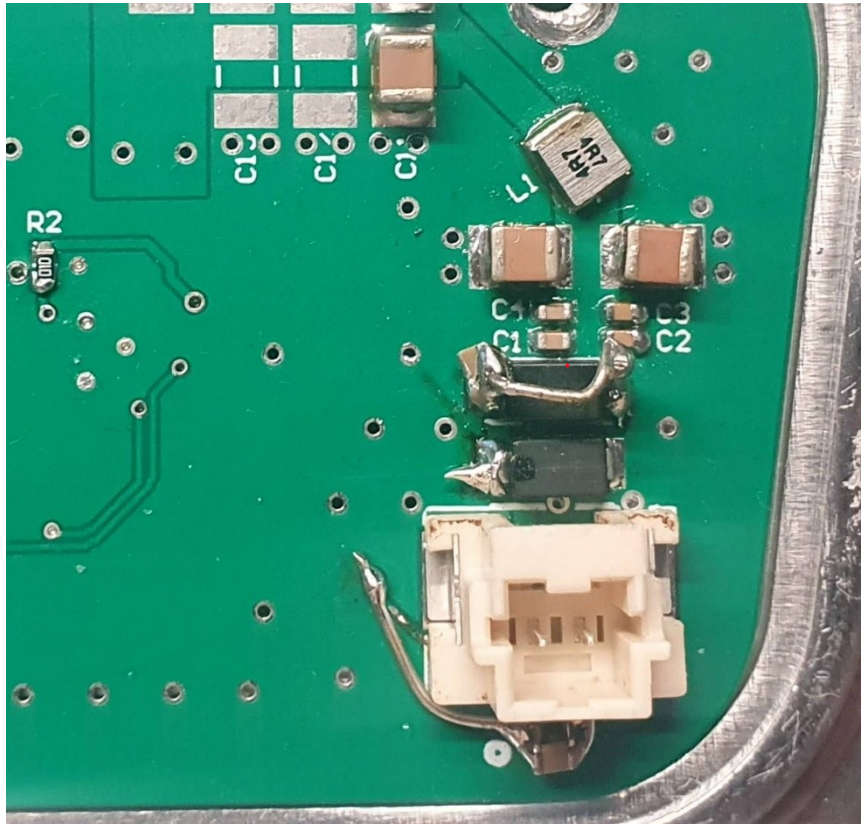
V simulaciji vse deluje.

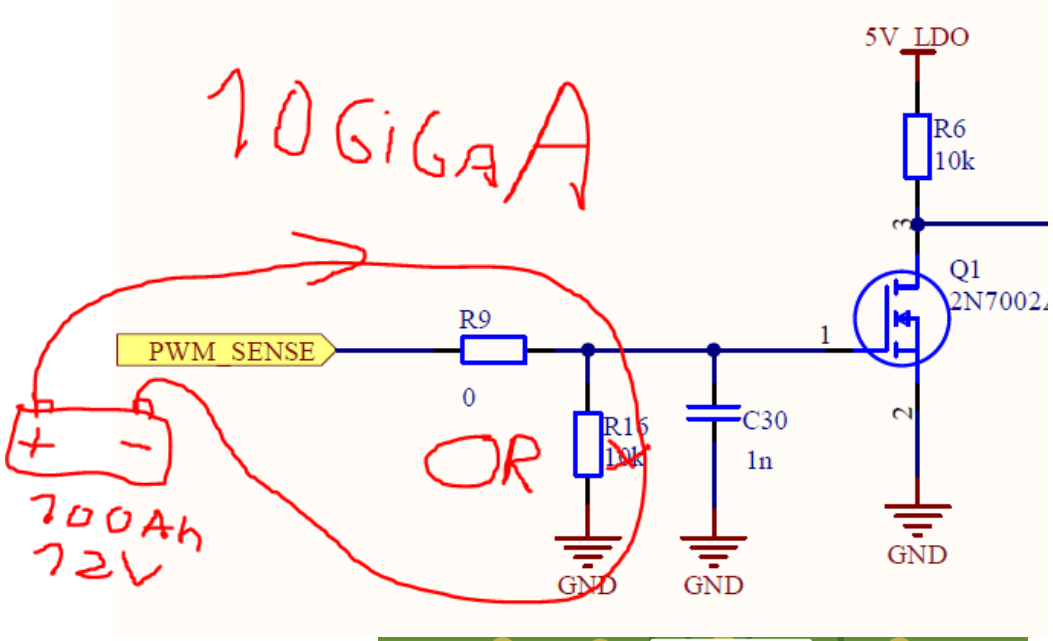
Genius ideas

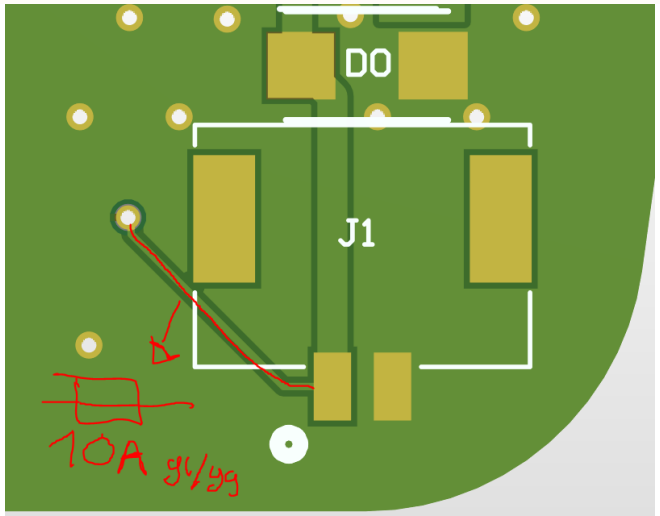


Preliminarne meritve - BCI

- Problem: failed BCI 5x
- Solution: Več kondenzatorjev







Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko
in optoelektroniko

Jože Papež

Rezultati

Jože Papež – Funkcionalni in električni testi

Osnovna funkcionalnost ✓

PWM območje — Pri 80% vezje preklaplja med DRL in PO, (utripa med 77 in 80%). Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne. ✓

Napetostno območje — Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne ✓

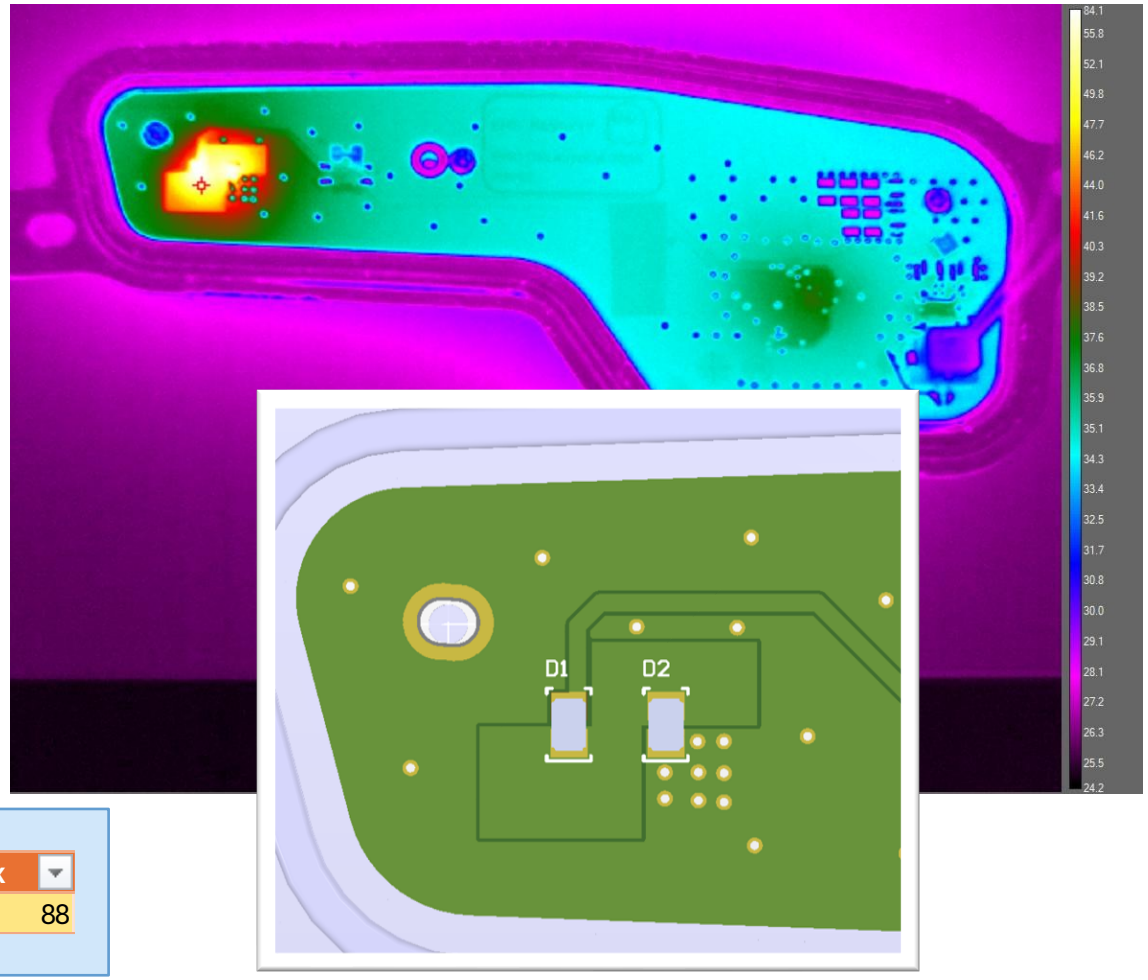
Temperaturno območje — Pri prvem pulzu na 45% utripne, za tem ugasne ✓

Obrnjena polariteta ✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	155	2.094	6.11	302	1.846	88

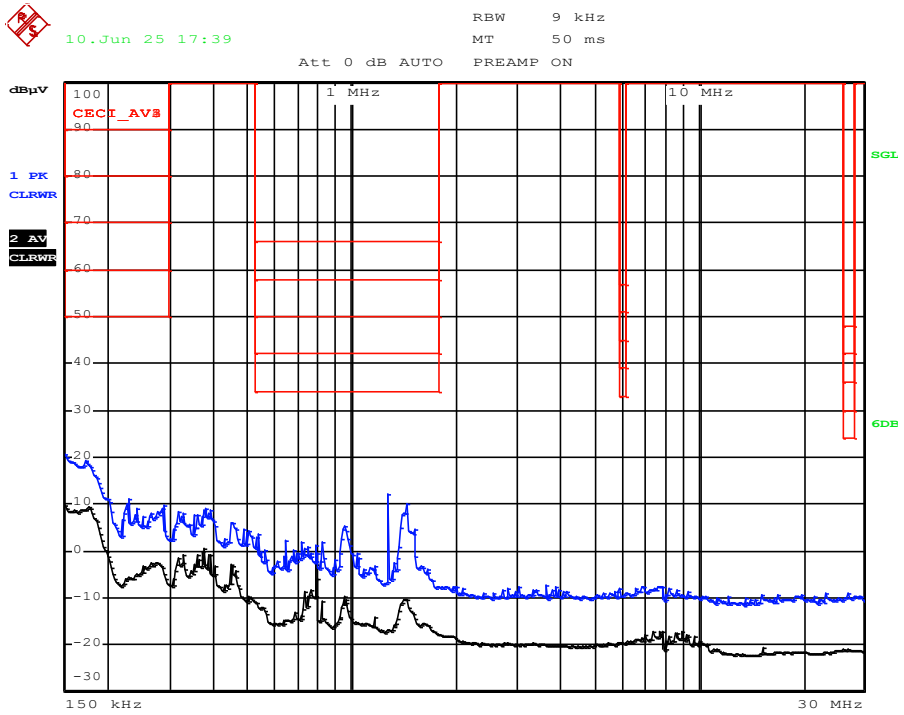
Temperaturna obremenitev: 74.59 °C



Jože Papež – EMC

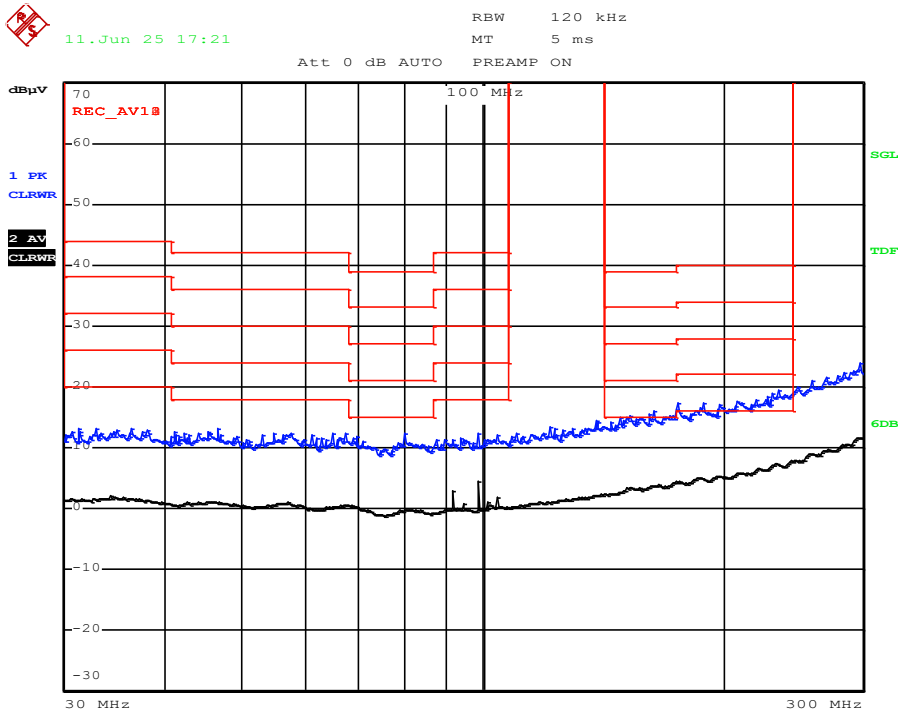
CE

5



RE

5



BCI

100 mA **A**

RI

100 V/m H+V **A**

Jože Papež - Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 10000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vezje
L1	**tuljava**	**74438335047**	**Wurth**		**Mouser**	**0.155 €**	**1**	**0.155 €**
CX1	kondenzator		N/A		N/A	0.005 €	1	0.005 €
CX2, CX3	kondenzator		N/A		N/A	0.005 €	2	0.010 €
CX4	kondenzator		N/A		N/A	0.005 €	1	0.005 €
D0	tvs dioda	P4SMA20CA	Vishay		Verical	0.032 €	1	0.032 €
D1	dioda	SS13	Dowo semi		LCSC	0.070 €	1	0.070 €
C1,C2,C3,C4	kondenzator		N/A		N/A	0.005 €	4	0.020 €
C5,C6,C7,C8	**kondenzator**	**12105C106K4Z2A**	**AVX**		**Ampacity Systems**	**0.110 €**	**4**	**0.440 €**
C9;C10,C11	**kondenzator**	**GCM32EC71E226KE36L**	**Murata**		**Rebound Electronics**	**0.169 €**	**3**	**0.507 €**
C17	kondenzator generic		N/A		N/A	0.005 €	1	0.005 €
C18,C19,C23,C31	kondenzator generic		N/A		N/A	0.005 €	4	0.020 €
IC1	opamp	TLV9062IDR	TI		Chipsmall limited	0.034 €	1	0.034 €
Q1	tranzistor	2N7002	Infineon		LCSC	0.005 €	1	0.005 €
C28,C29	kondenzator 800n	CC0603KRX7R7BB824	Yageo		Digikey	0.016 €	2	0.032 €
C20,C21,C22	kondenzator 1uF	0603DC105KAT2A	Kyocera AVX		easev	0.019 €	3	0.057 €
C24	kondenzator 10uF	GRM188Z71A106KA73D	Kyocera AVX		Yic international	0.007 €	1	0.007 €
R1-R11,R13,R15,R16	upor generic	RC0603FR	Yageo		Mouser	0.002 €	14	0.028 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
45	1.28 €	0.45 €	1.73 €

Načrtovanje elektronike za EMC² 2025

študentska delavnica in tekmovanje

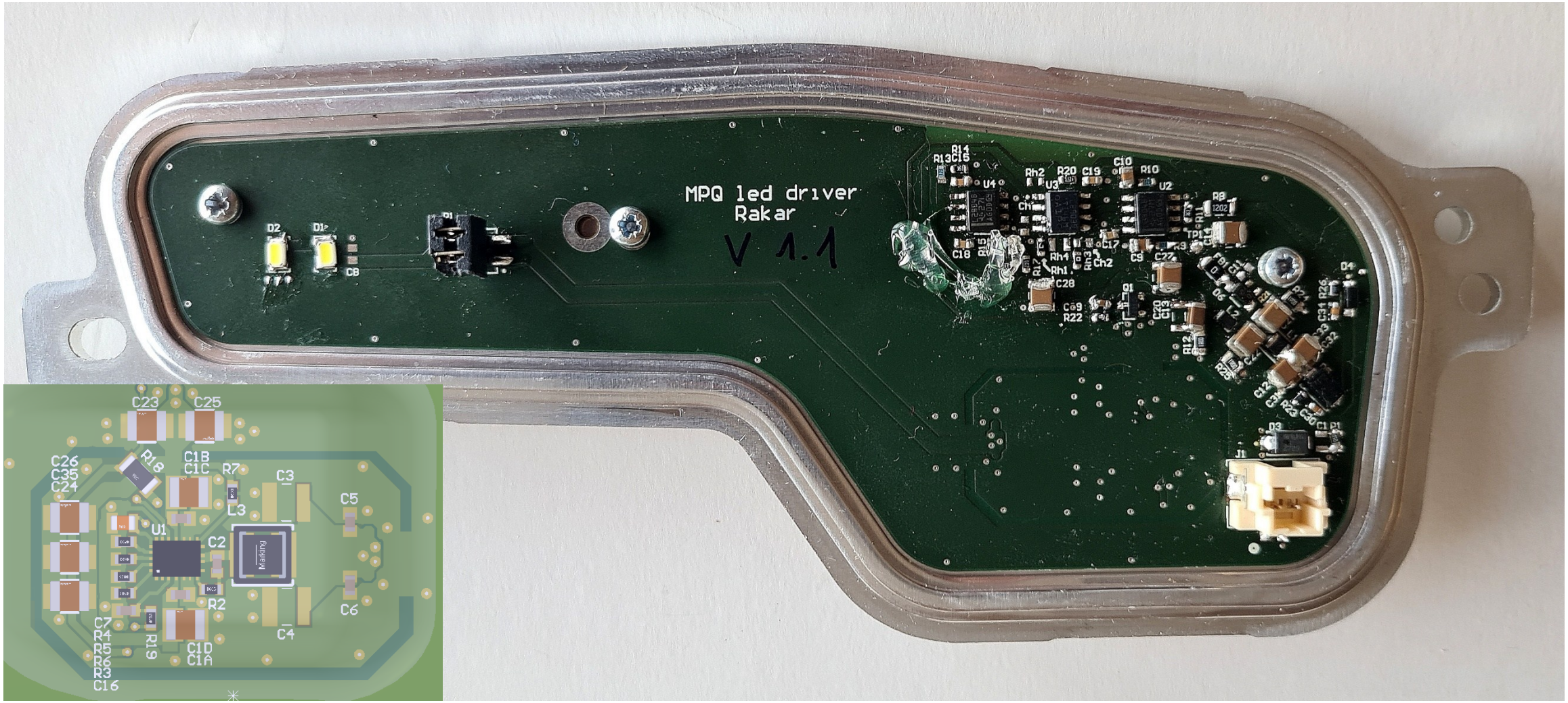
UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

Jan Rakar

2. letnik, MAG-EL

Jan Rakar

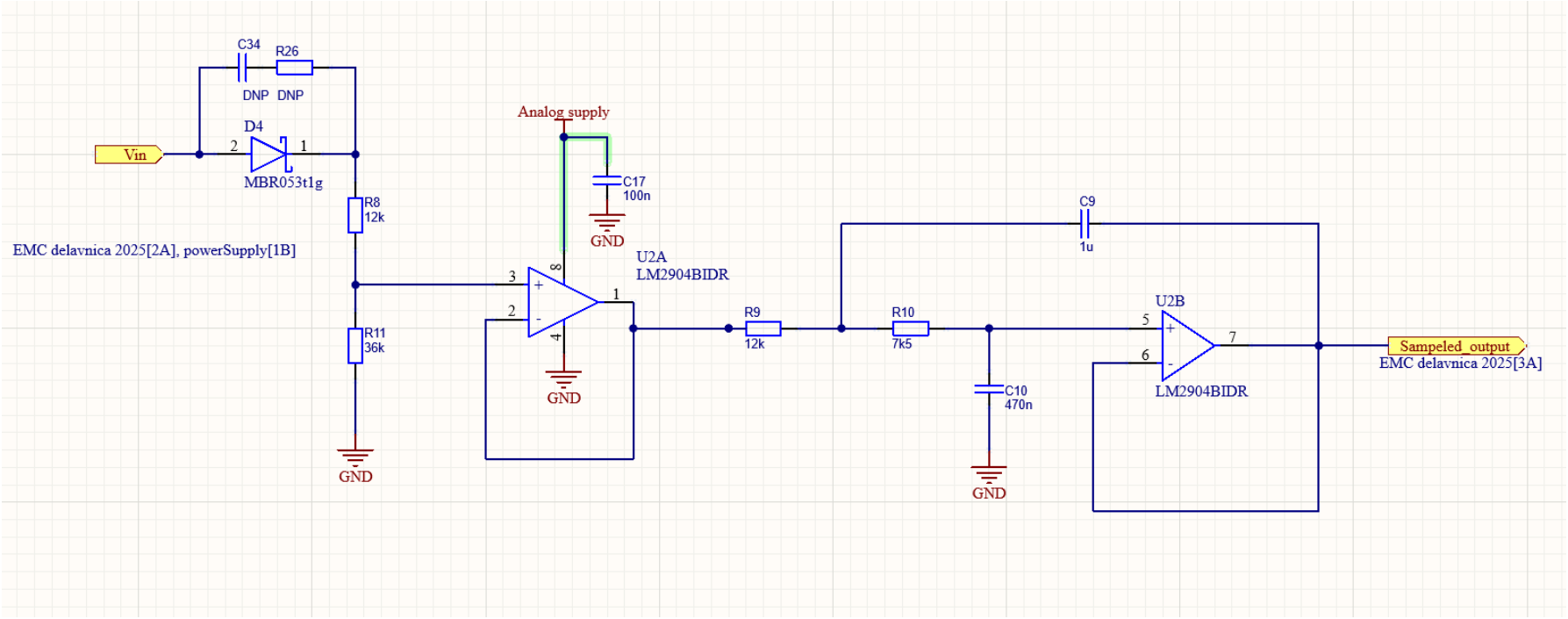


Koncept rešitve

- Two step dimming
- Duty < 45% izklopi gonilnik s pmos stikalom
- Aktiven filter za pretvorbo v analogni signal
- Komparatorji za preklope

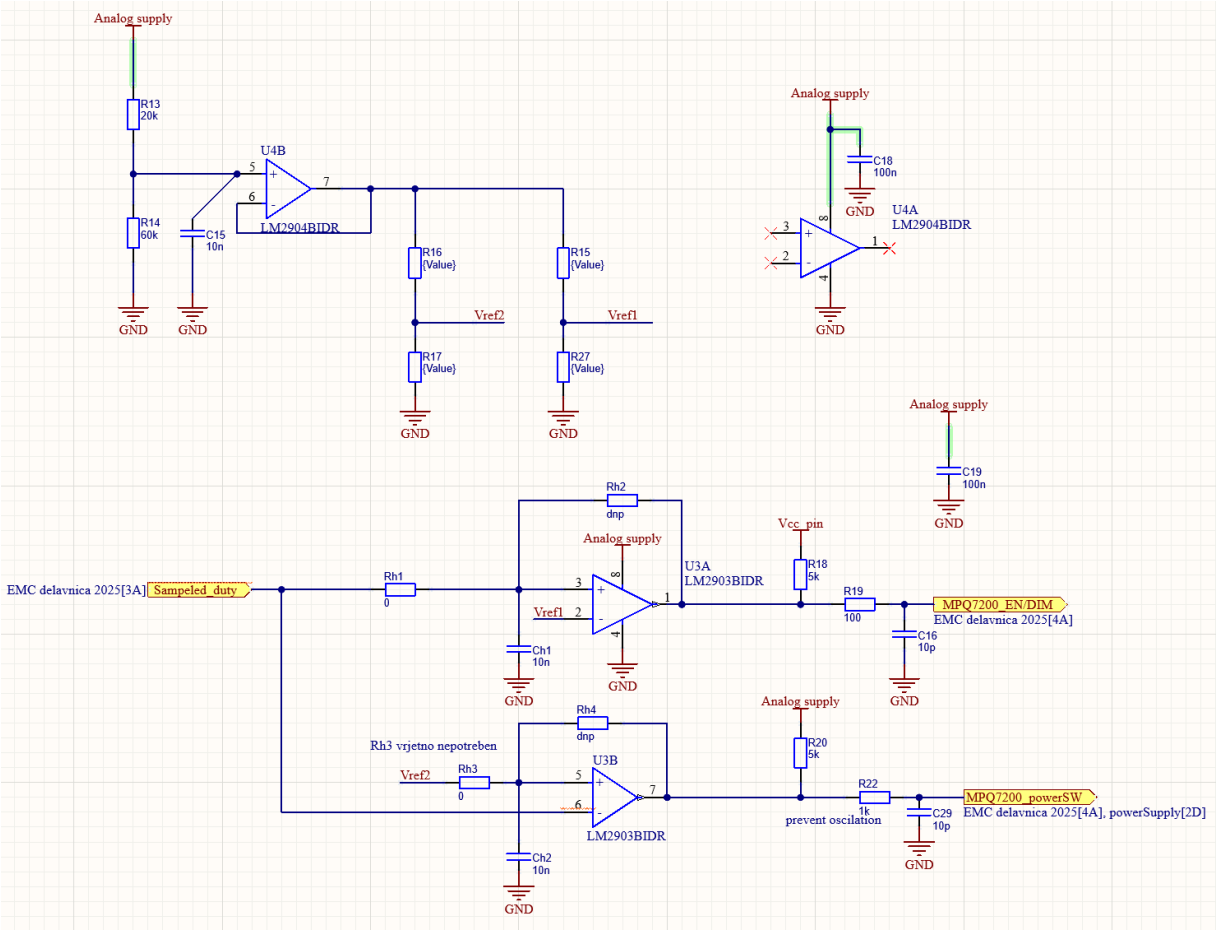
Koncept rešitve

- Pwm vzorčenje -> aktiven filter + buffer



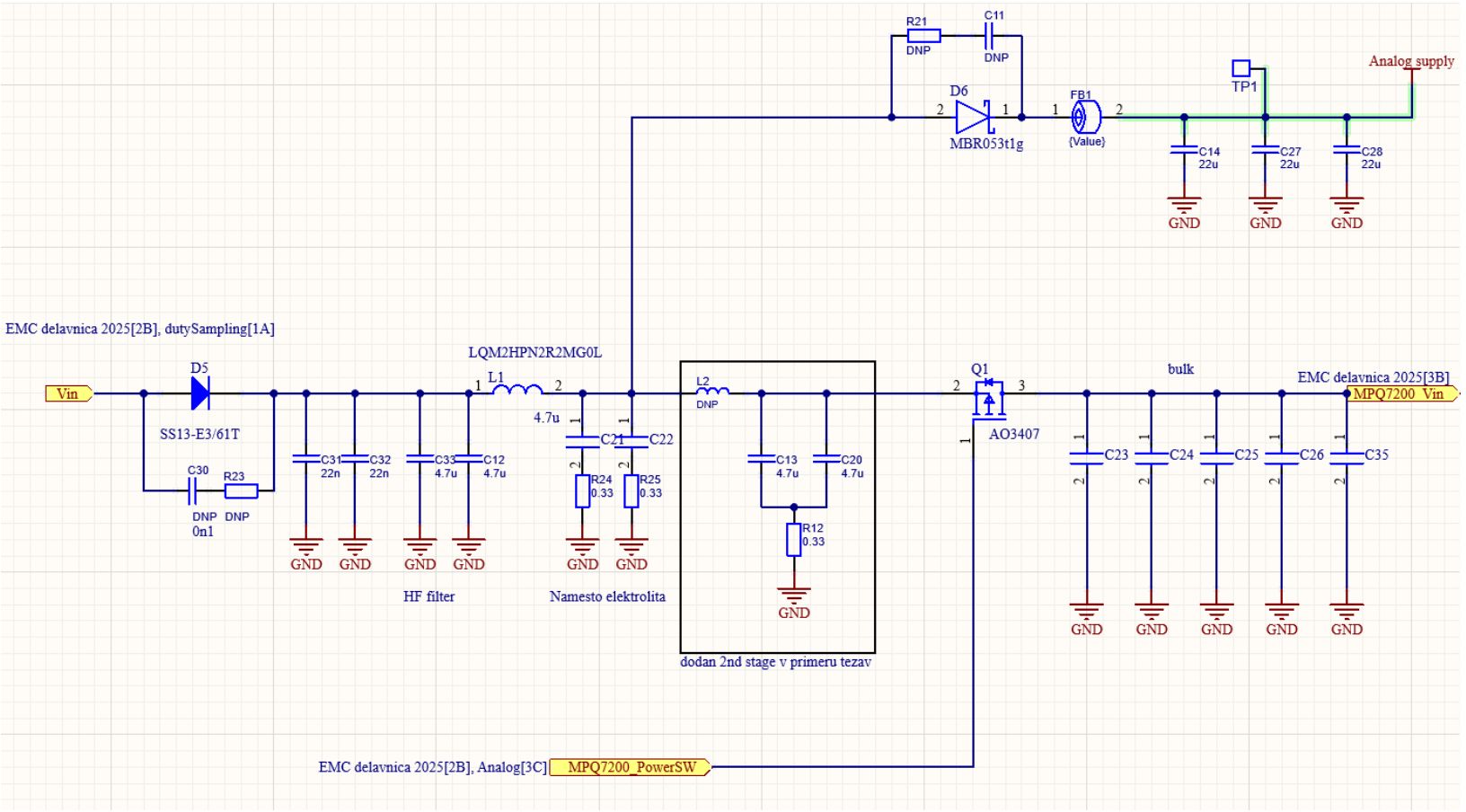
Koncept rešitve

- Pretvorjen PWM signal primerjam z referenčnimi napetostmi
- Komparatorja na podlagi tega preklopita izhodni tok ali izklopita LED gonilnik.

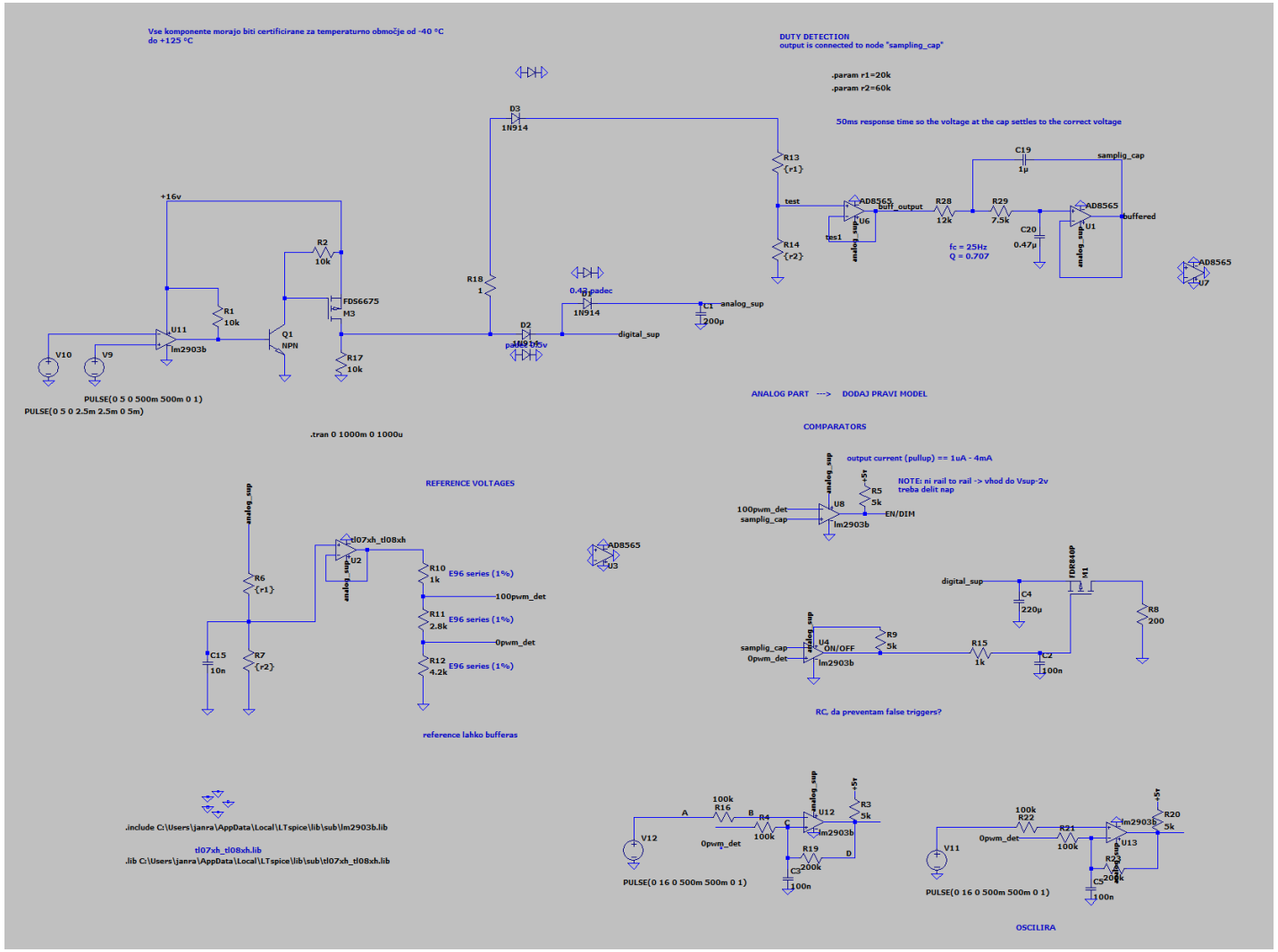


Koncept rešitve

- Še slikica EMI filtra in pmos stikala ☺

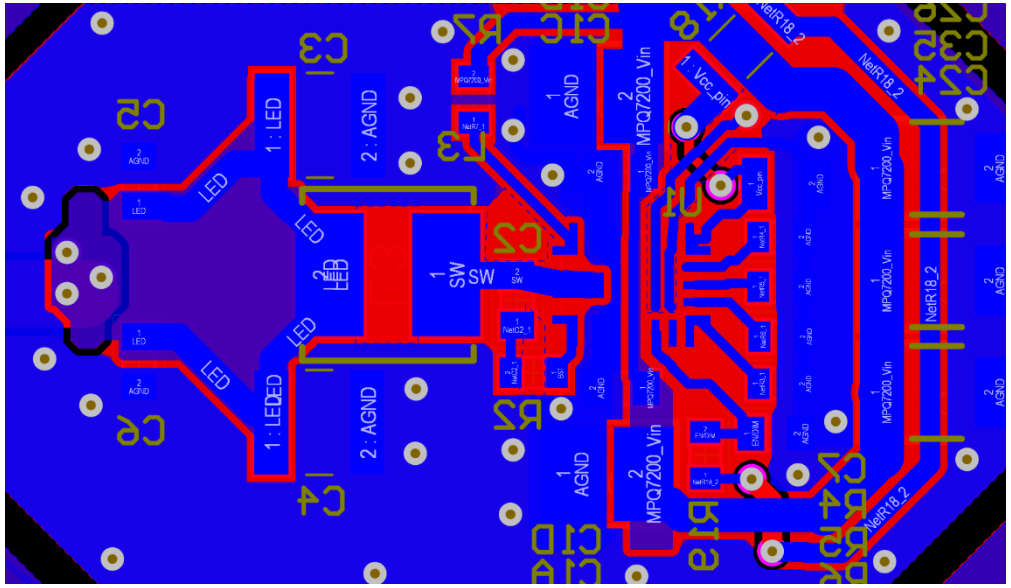


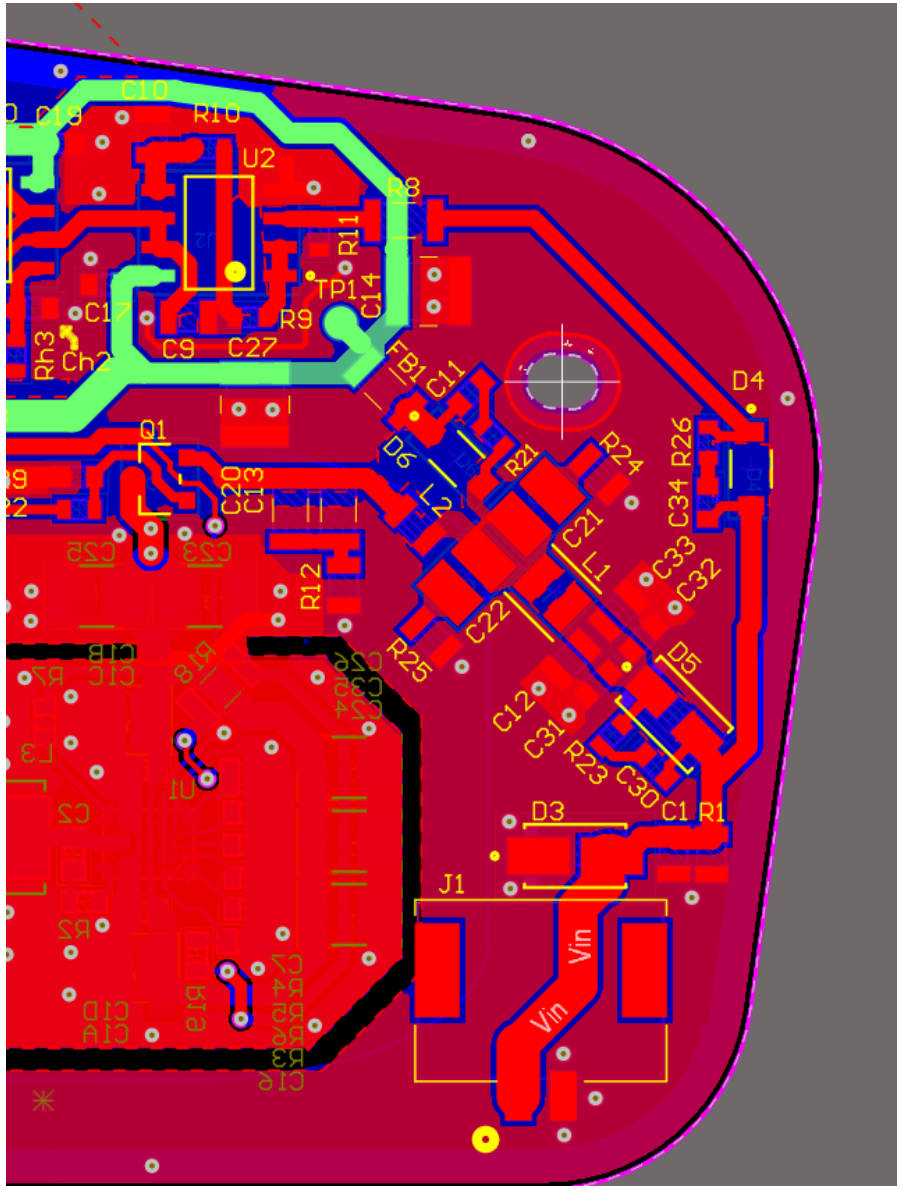
Some LT spice



Načrtovanje tiskanega vezja

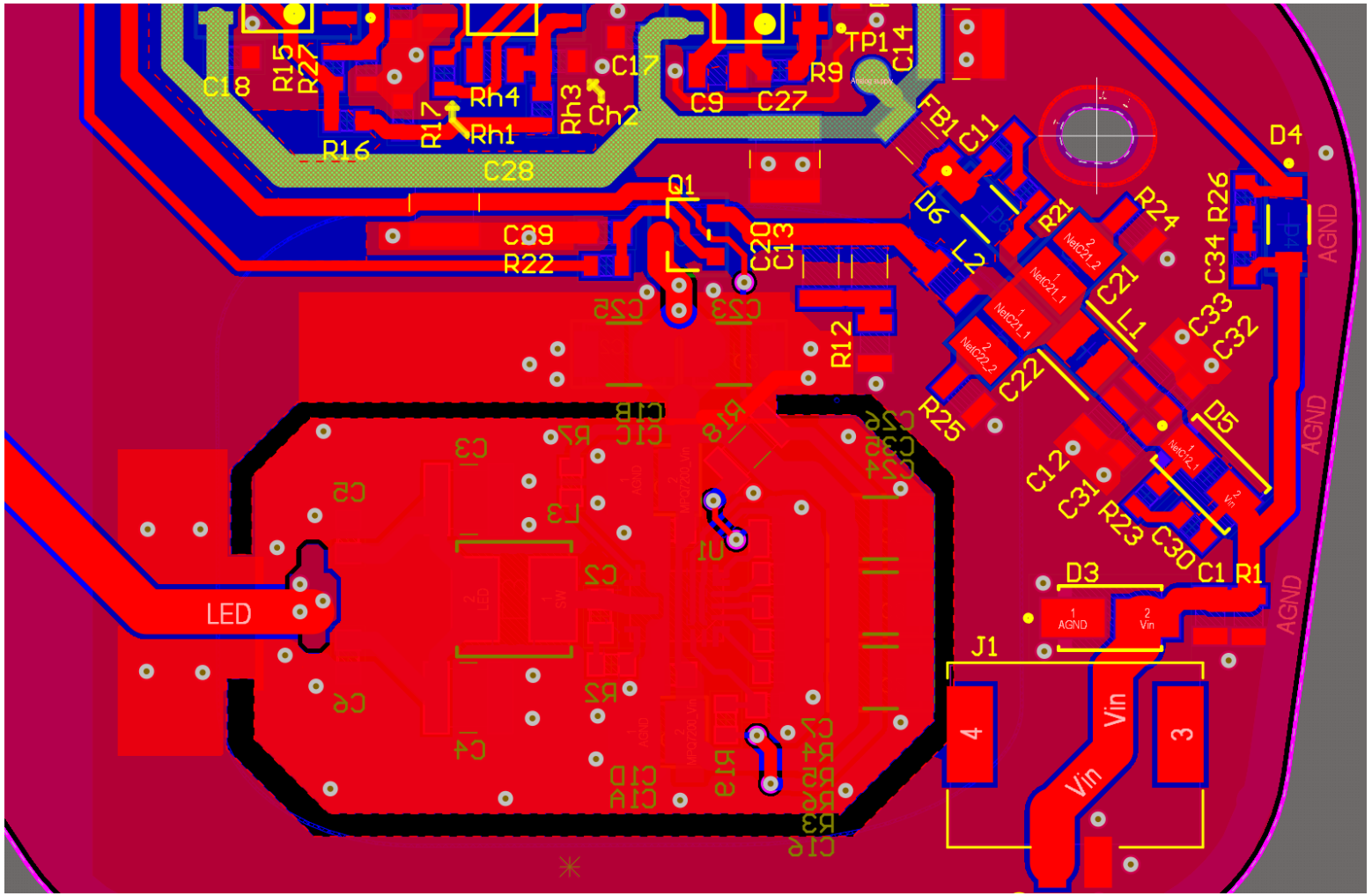
- Postavitev EMI filtra čim bližje vhodnemu napajalnemu konektorju
- Gonilnik na spodnji strani v luknji
- Majhno preklopno vozlišče





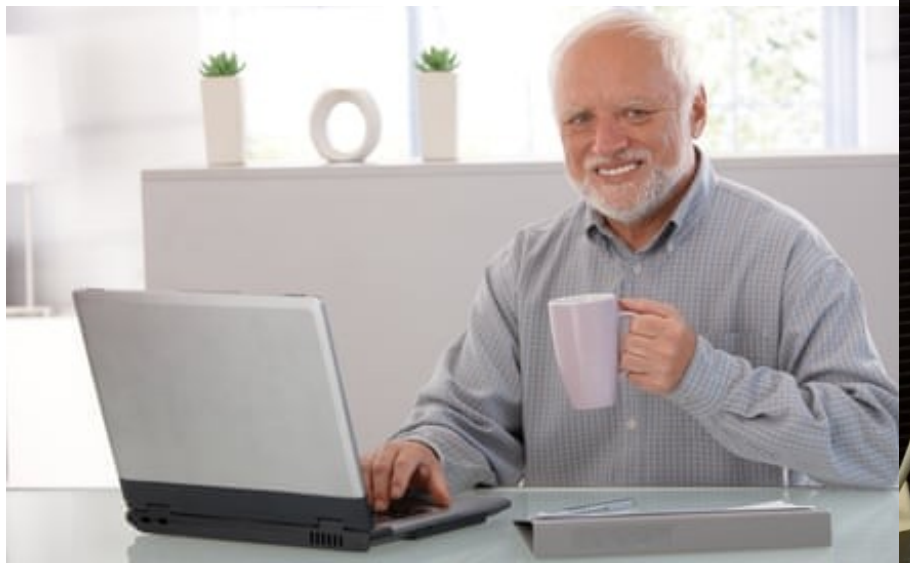
Načrtovanje tiskanega vezja

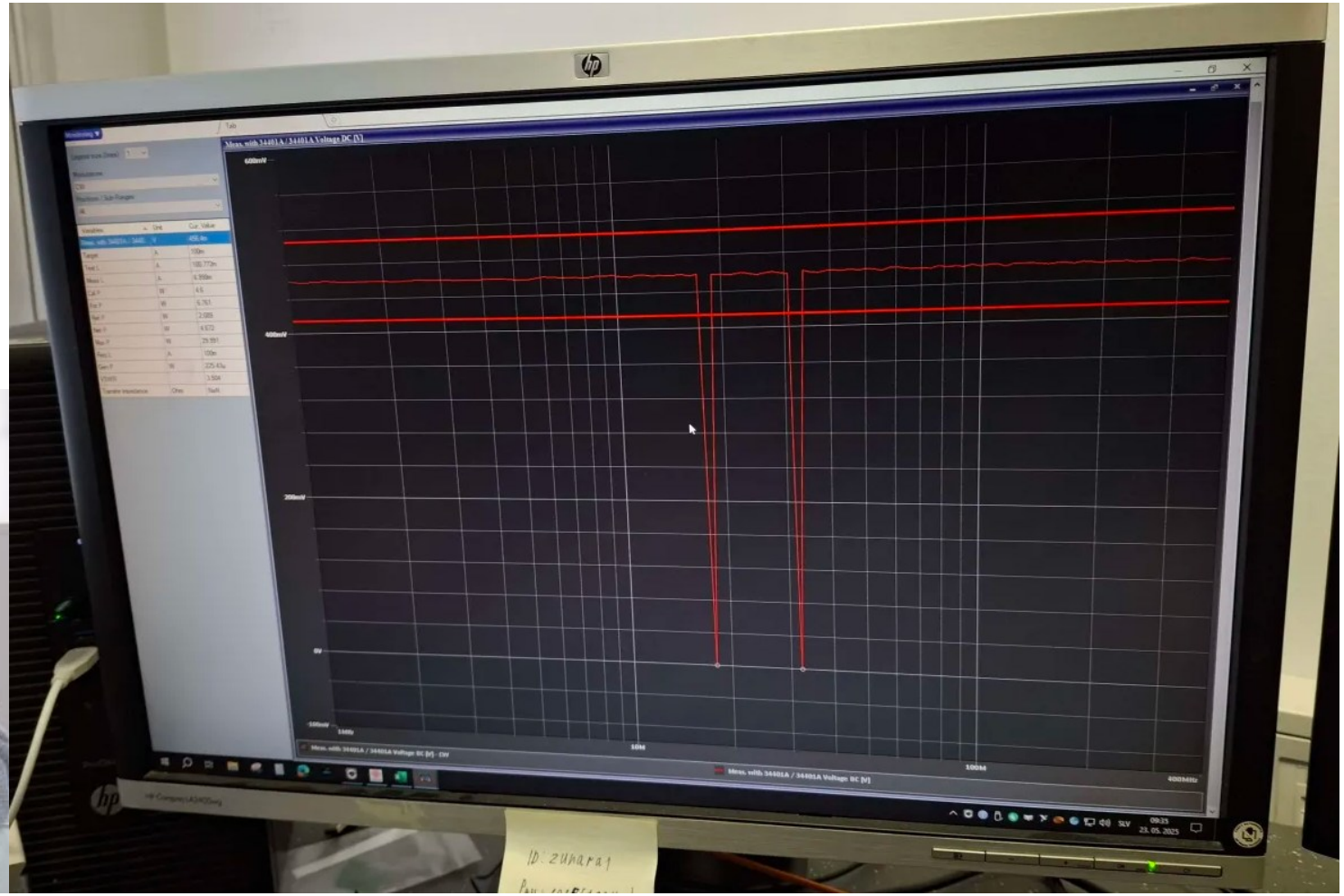
- Ločitev GND linij gonilnika in preostalega vezja



Preliminarne meritve

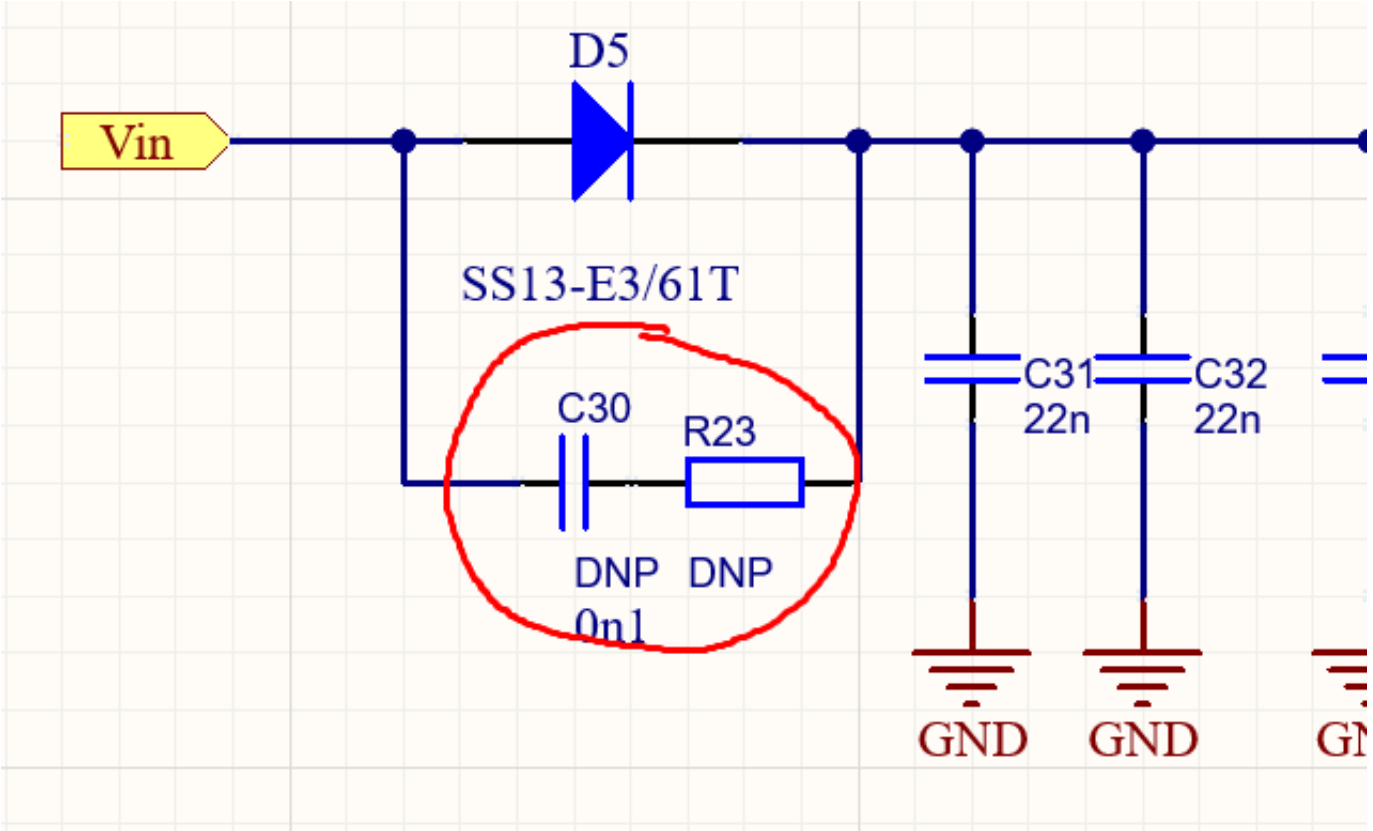
- Težave z BCI





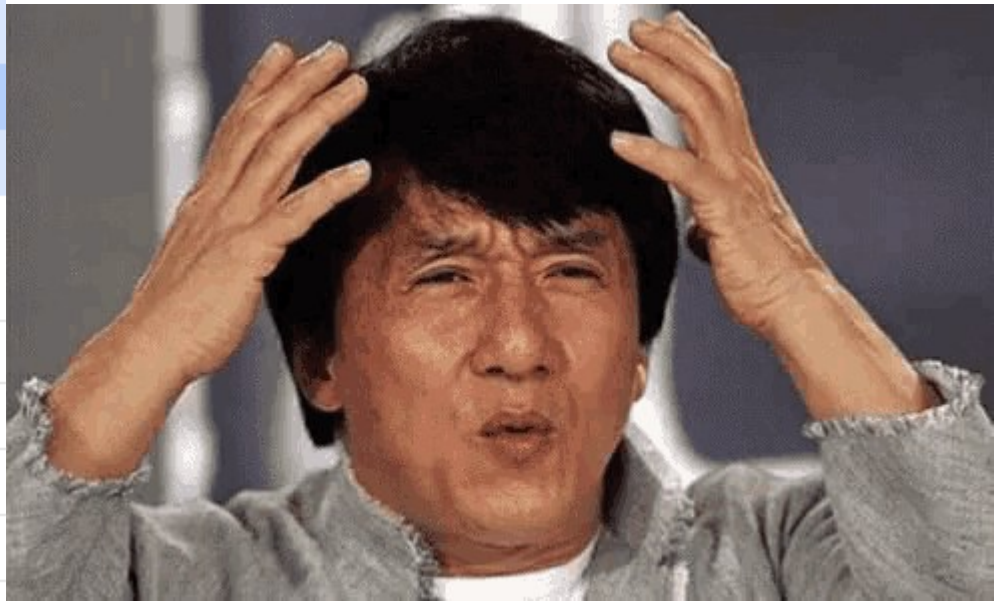
Preliminarne meritve

- Rešitev



Cena vezja

0	0
2	0.078
1	0.051
71	2.6202
0.01	0.71
Cena komponent s polaganjem	**3.3302**



Morebitni popravki

- Popravki
  - Zmanjšanje števila komponent
  - Implementacija histereze, ki bi preprečila oscilacije na meji preklopa

- Kaj sem se na delavnici naučil
  - Nekaj razumevanja o konceptih in testih, ki se jih za validacijo vezij opravlja

Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

Jan Rakar

Rezultati

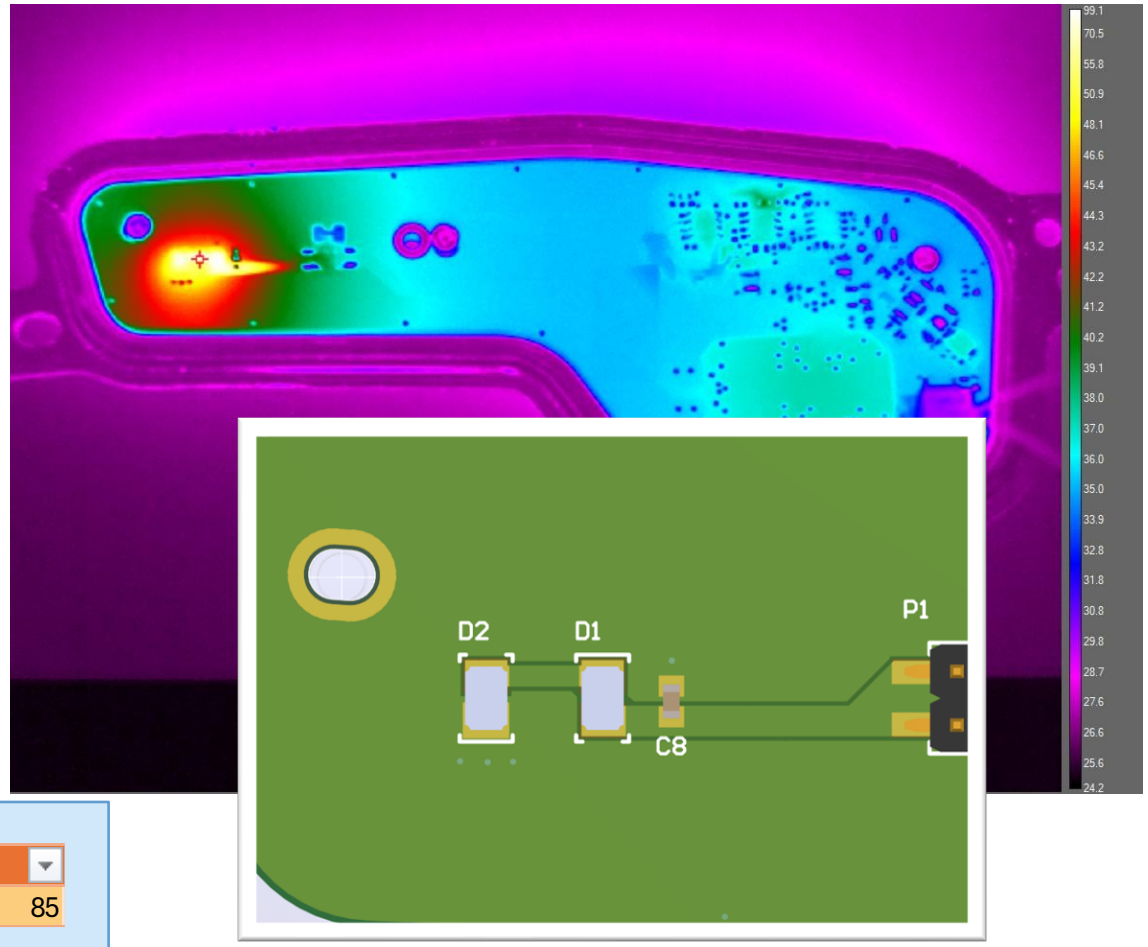
Jan Rakar – Funkcionalni in električni testi

Osnovna funkcionalnost		✓
PWM območje	Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	✓
Napetostno območje	Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	✓
Temperaturno območje	Pri prvem pulzu na 45% utripne, za tem ugasne	✓
Obrnjena polariteta		✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	158	2.135	6.07	302	1.833	85

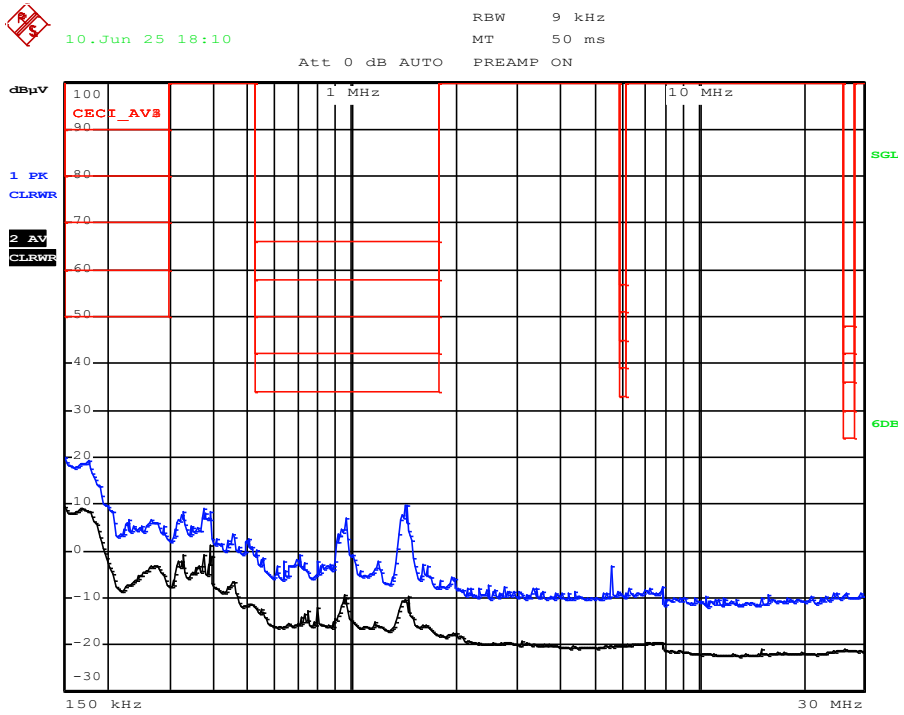
Temperaturna obremenitev: 74.59 °C



Jan Rakar – EMC

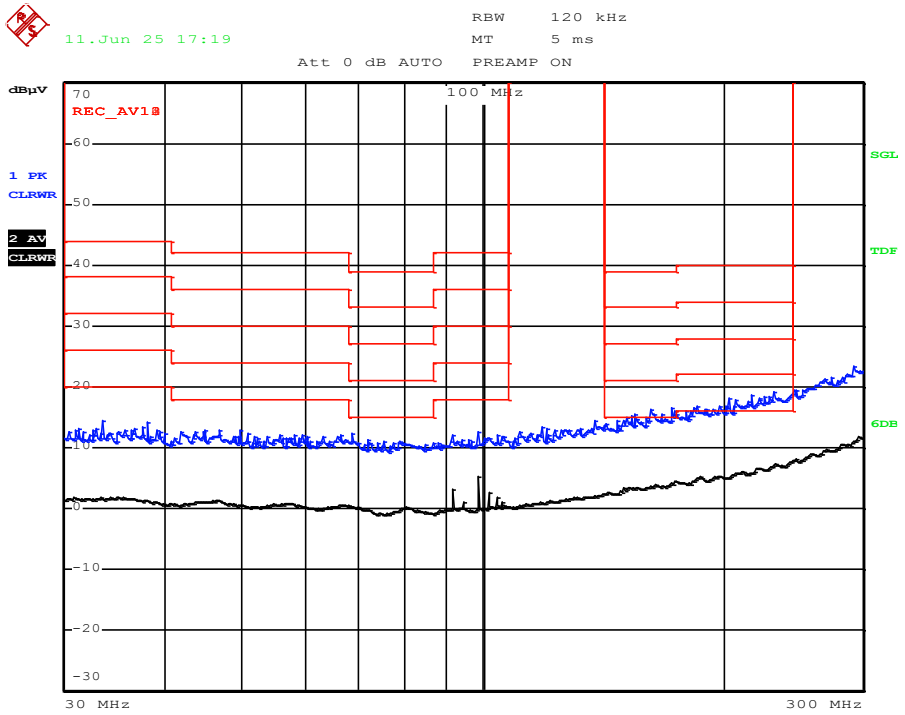
CE

5



RE

5



BCI

100 mA **A**

RI

100 V/m H+V **A**

Jan Rakar – Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 10000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vezje
C15, C30, C34, C31, C32, C29, C18, C19, C17, C5, C6, C1C, C1D, C16, C2	0603 <= 100n	/	/	/	/	0,005	15	0.075 €
C1A, C1B, C25, C23, C24, C26, C35	**22uF 1210**	**GCM32EC71E226KE36L**	**Murata**	**GCM32EC71E226KE36L-4172714**	**Worldway Electronics**	**0.175 €**	**7**	**1.225 €**
C21, C22	VHODNI FILTER (10u) -1210	UMK325AB7106KM-P	Taiyo Yuden	UMK325AB7106KM-P	Unikeyic	0.045 €	2	0.090 €
C3, C4	4.7uF 1206	8.85012E+11	Wurth	/	/	0.043 €	2	0.086 €
R1, R23, R26, R10, R11, R9, R14, R27, , R3, R4, R5, R6, R2, R7, R22, R13, R16, R17, R19,R20	resistor 0603 1%	/	/	/	/	0.005 €	20	0.100 €
C7	0805 10uF	GRM21BC71E106ME01L	Murata	81-GRM21B71E106ME01L	Mouser	0.052 €	1	0.052 €
C9, C10	0805 1u	0603DC105KAT2A	Kyocera	0603DC105KAT2A	Bettlink	0.042 €	2	0.084 €
C13	2ND STAGE FILT	8.85012E+11	Wurth	/	/	0.043 €	1	0.043 €
C12, , C33	VHODNI FILTER 10uF	UMK325AB7106KM-P	Taiyo Yuden	UMK325AB7106KM-P	Unikeyic	0.045 €	2	0.090 €
C14, C27, C28	**10uF - 1210**	**UMK325AB7106KM-P**	**Taiyo Yuden**	**UMK325AB7106KM-P**	**Unikeyic**	**0.045 €**	**3**	**0.135 €**
D3	TVS	SMAJ28CA	Bourns	SMAJ28CA	Component Stockers USA	0.009 €	1	0.009 €
D4, D6	Schootky diode	MBR0530T1G	onsemi	MBR0530T1G-32877	Worldway Electronics	0.008 €	2	0.022 €
D5	Schootky diode 1A	SS13E3/61T	Vishay		Worldway Electronics	0.026 €	1	0.026 €
L1	1ND STAGE TULJAVA	SRP2512A-4R7M	Bourns	428-71-12004320	Bettlink	0.140 €	0	0.140 €
L2	2ND STAGE TULJAVA 1uH	74479275210	Wurth	/	Wurth	0.073 €	1	0.073 €
L3	**IZHODNA TULJAVA 22uH**	**74406043220**	**Wurth**	**/**	**Wurth**	**0.172 €**	**1**	**0.172 €**
Q1	MOSFET P-CH 30V 2.6A SOT23	AO3409	Alpha & Omega Semiconductor	AO3409-2716469	worldwayelec	0.035 €	1	0.035 €
R8,	resistor 1206	CRGCQ1206F12K	TE Connectivity	CRGCQ1206F12K	Mouser	0.008 €	1	0.008 €
R18	resistor 1206	CRGCQ1206F12K	TE Connectivity	CRGCQ1206F12K	Mouser	0.008 €	1	0.008 €
R24, R25	Damp res 0805	RC0805FR-131RL	YAGEO	603-RC0805FR-131RL	Mouser	0.006 €	2	0.012 €
R12,	Damp res 2nd stage 0805	RC0805FR-131RL	YAGEO	603-RC0805FR-131RL	Mouser	0.006 €	1	0.006 €
U2, U4	LM2904BIDR OP. AMP	595-LM2904BIDR	Texas Instruments	LM2904BIDR	Texas Instruments	0.039 €	2	0.078 €
U3	LM2903BIDR COMPARATOR	296-LM2903BIDRCT-ND	Texas Instruments	LM2903BIDR	Texas Instruments	0.045 €	1	0.051 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
71	2.62 €	0.71 €	3.33 €

Načrtovanje elektronike za EMC² 2025

študentska delavnica in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko in optoelektroniko

Luka Kavčič

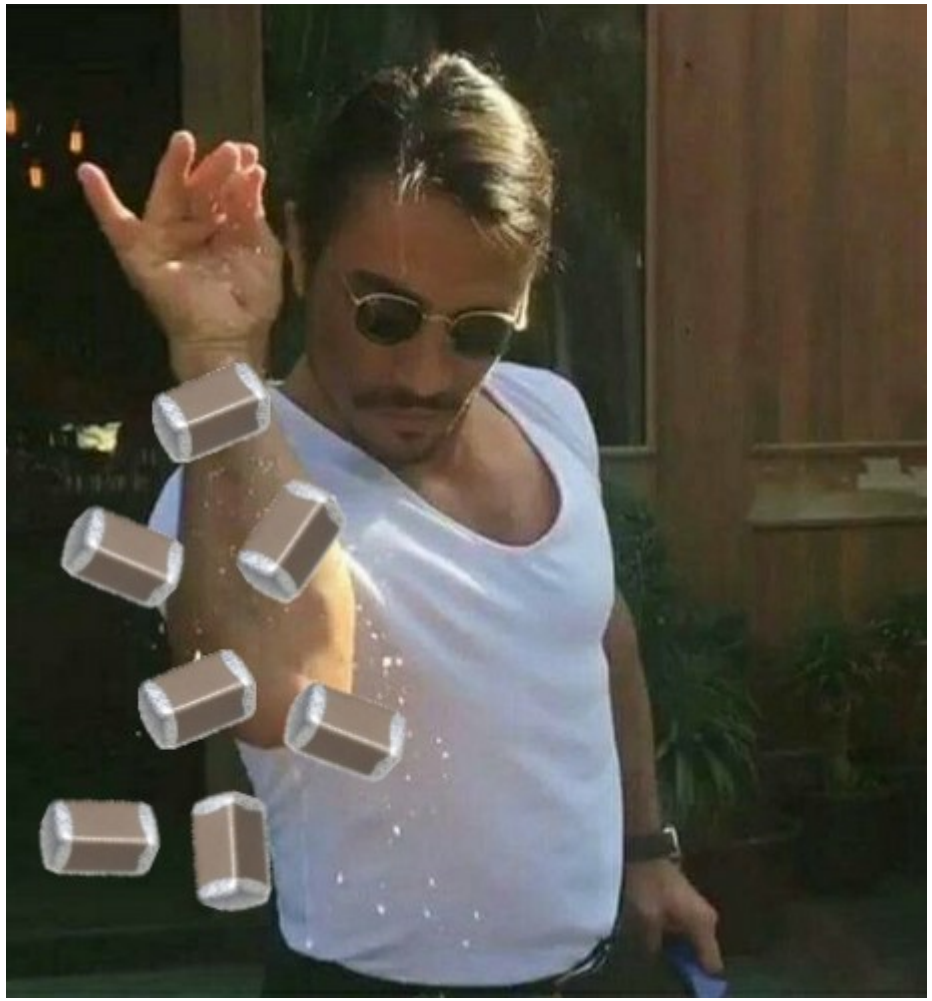
Absolvent, MAG-EL

Luka Kavčič

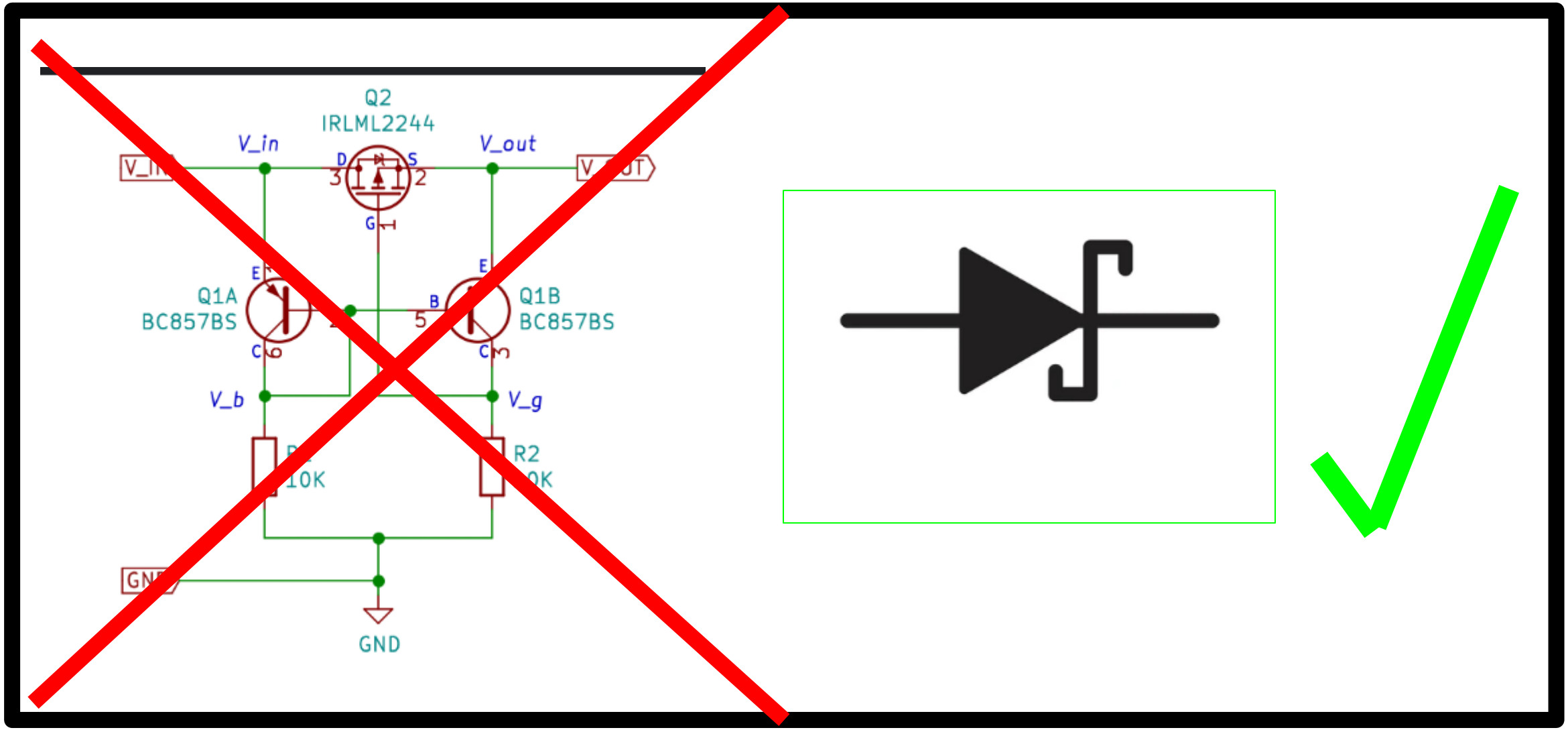

Let there be light!
D2
D1
D1
Maybe even there
Please not there
C17
C18
L2
C19
C20
C12
L1
C3
C4
C9
C6
C1
C2
R8
R9
R7
IC1
R4
R3
R2
U1
R11
R10
R1
RN1
C11
C5
C23
C8
C21
C22
C14
C16
C13
C15
Q2
Q1
R12
R5
C7
R6
J1

Koncept rešitve

- Izkoristit MPQ7200A:
  - Two-Step Dimming
  - NTC pin = EN pin
  - Vcc 5V, 10mA
- Samsung CL31B106KAHNNNE



Koncept rešitve



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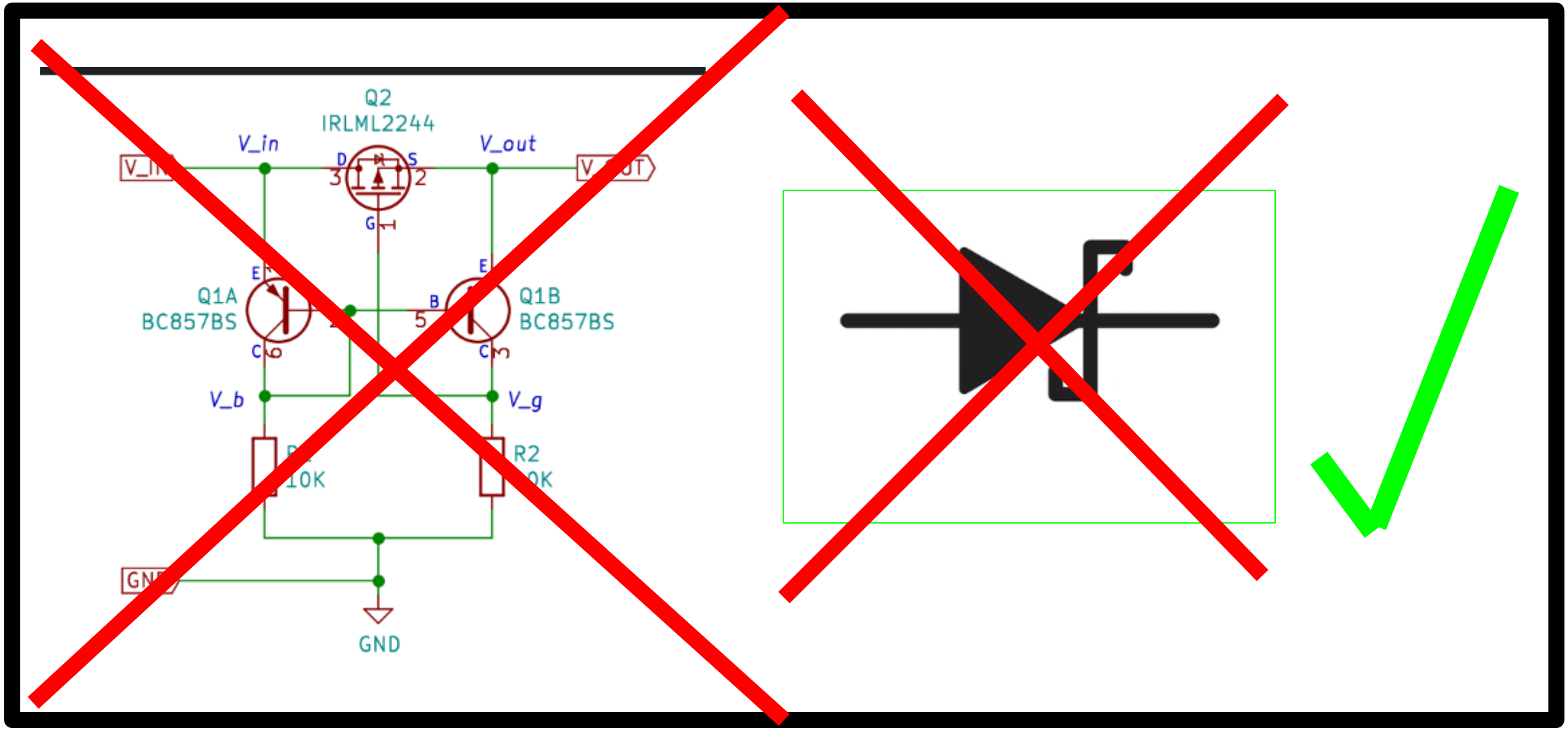
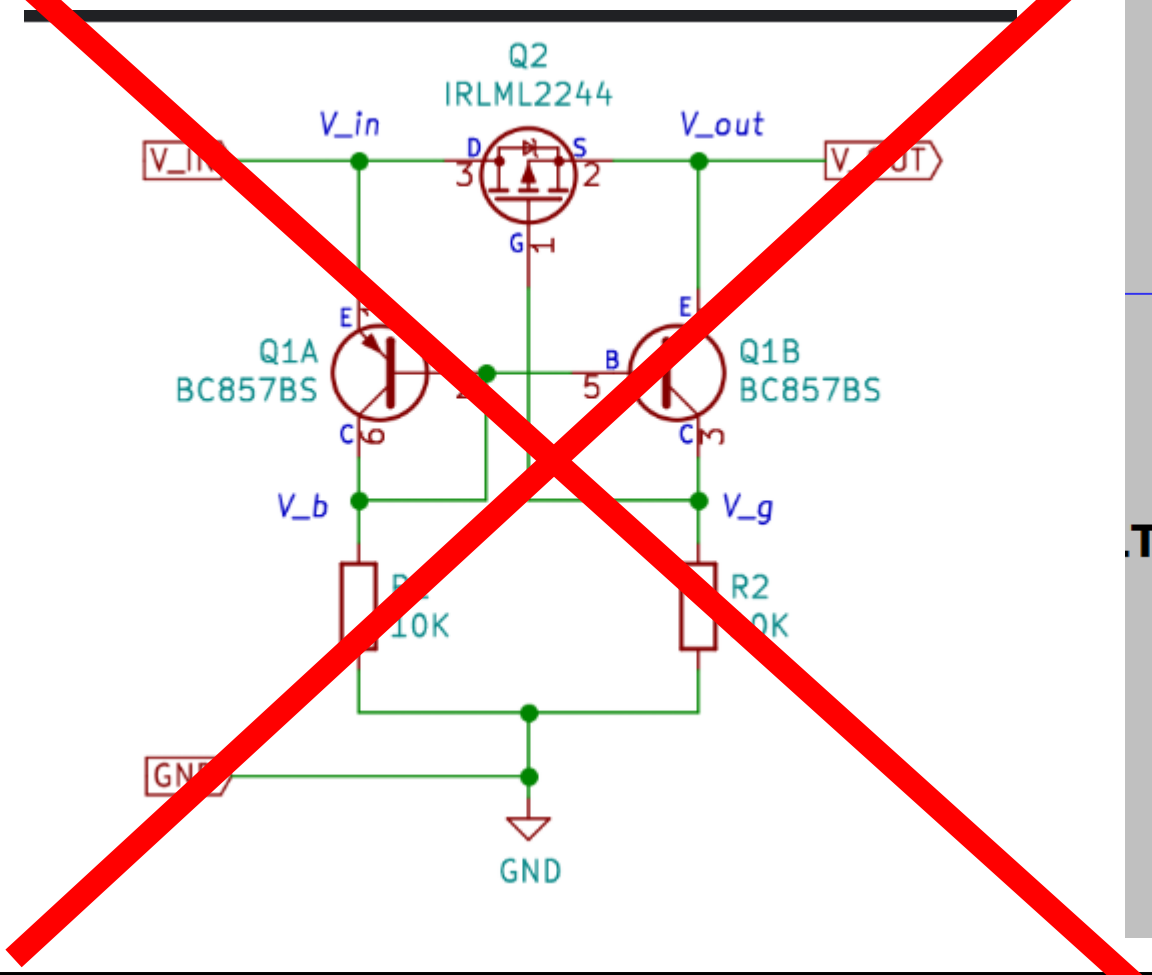
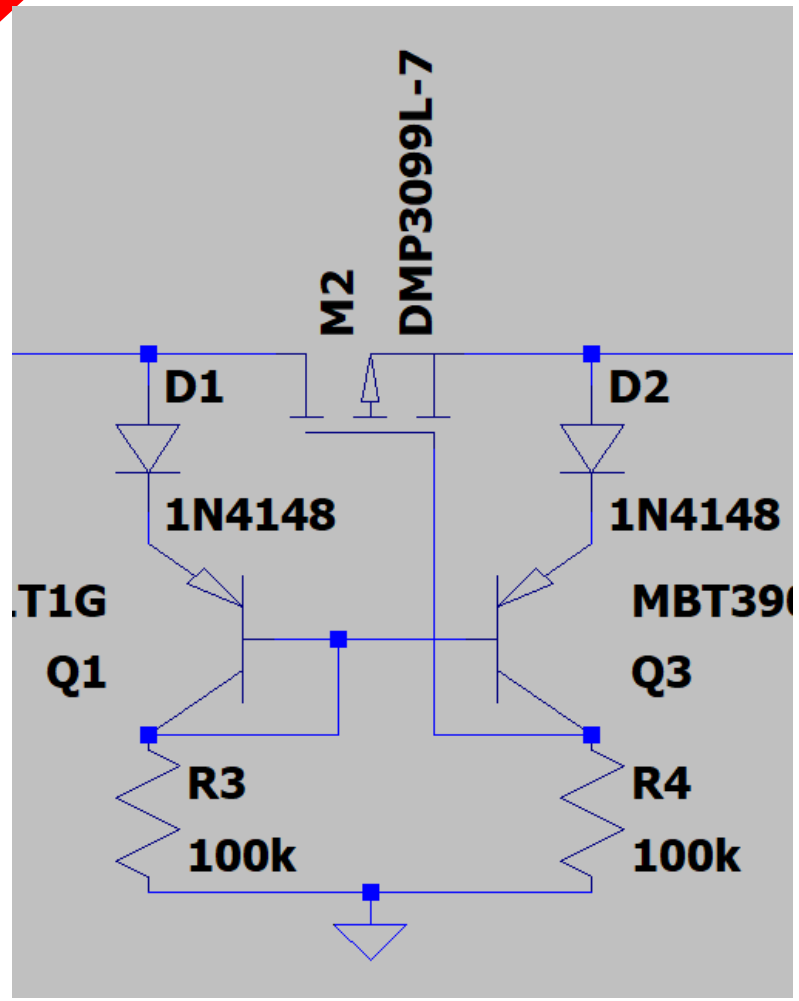
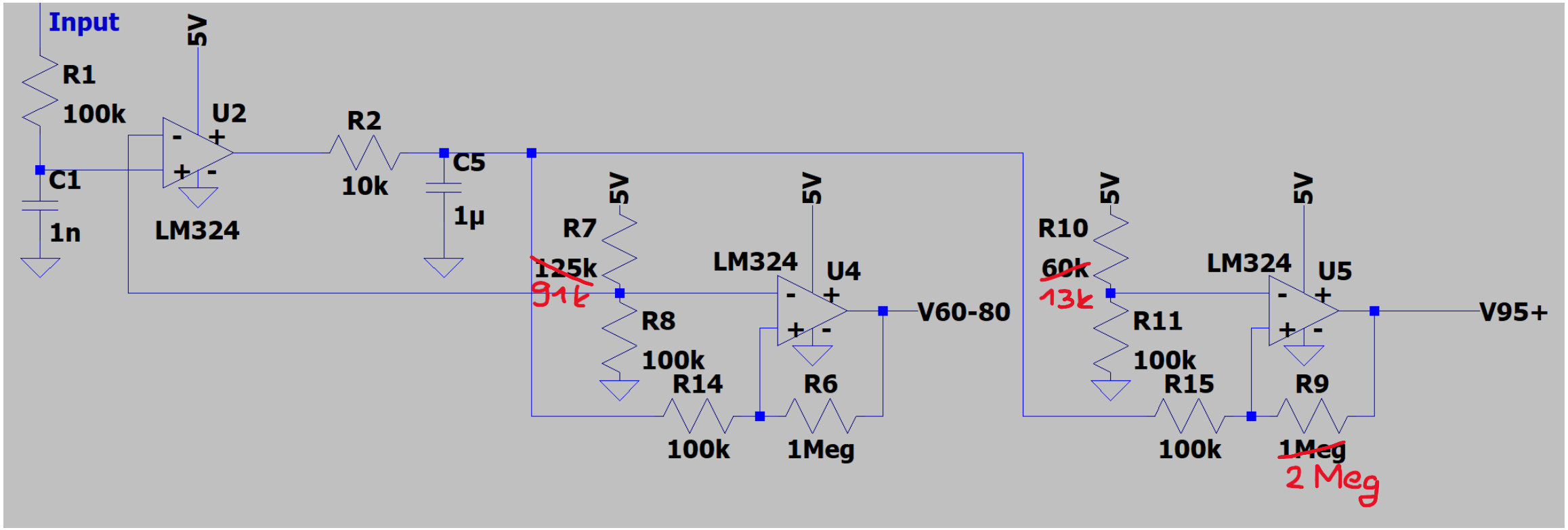


Koncept rešitve

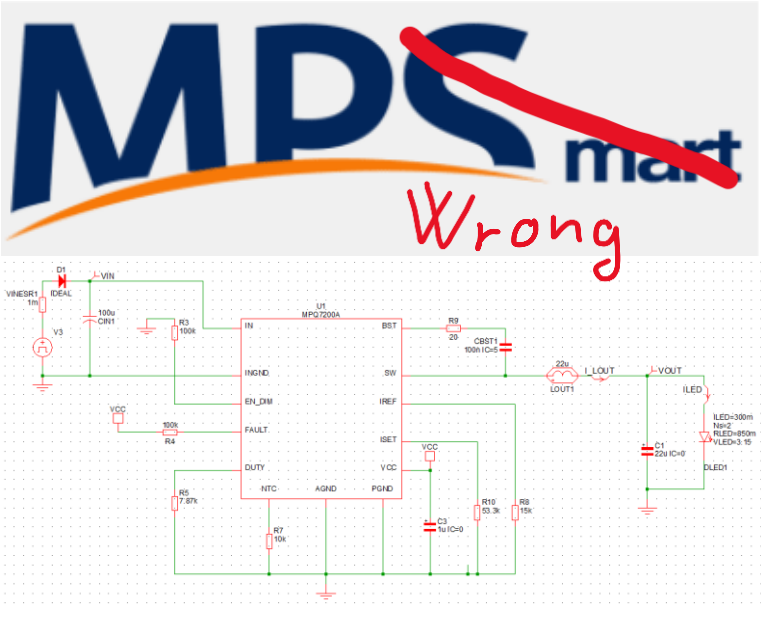


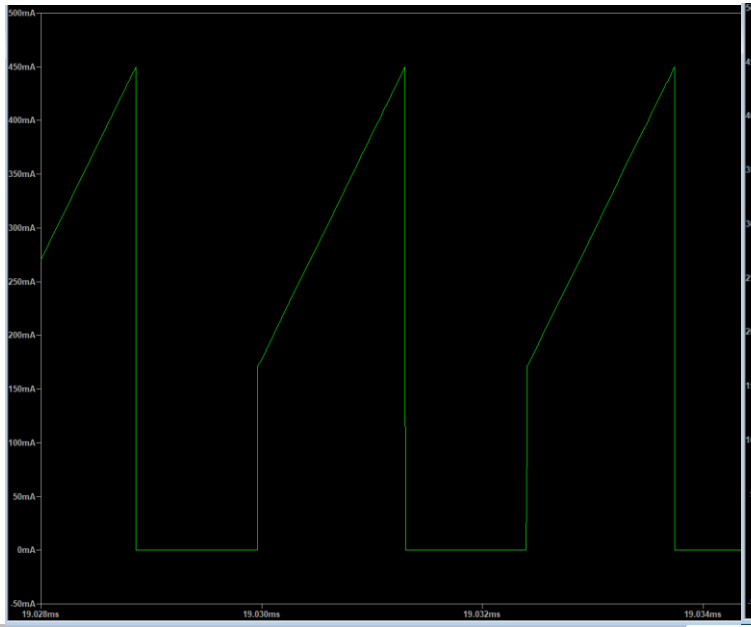


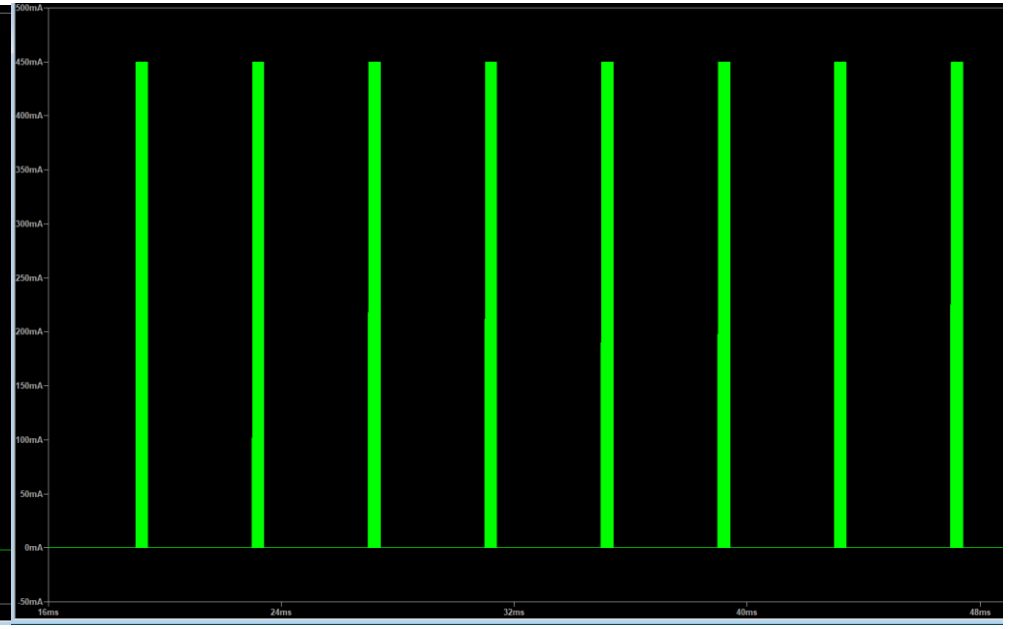
Izračuni, simulacije

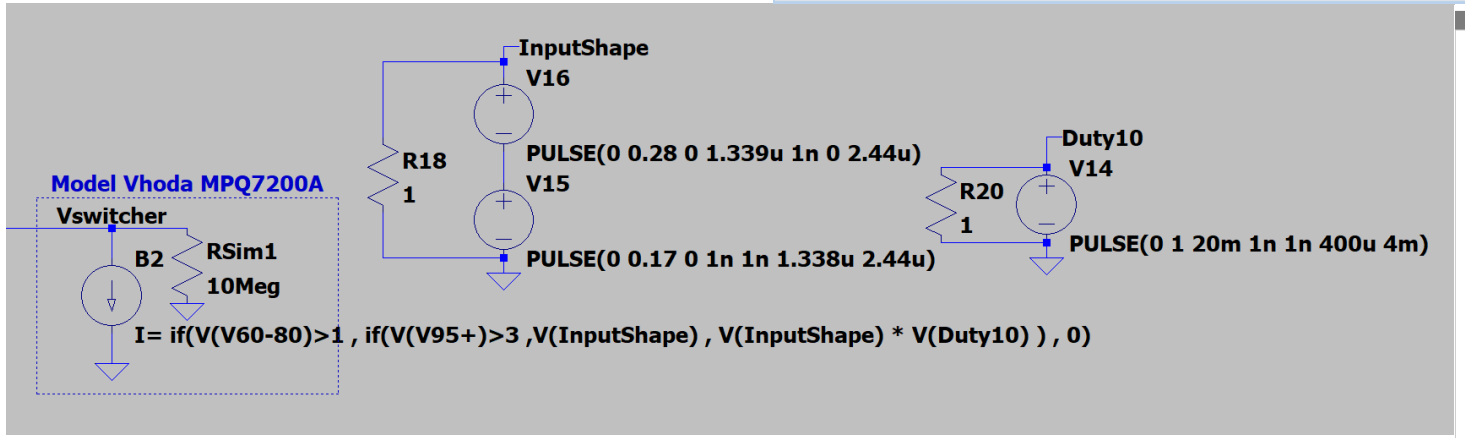


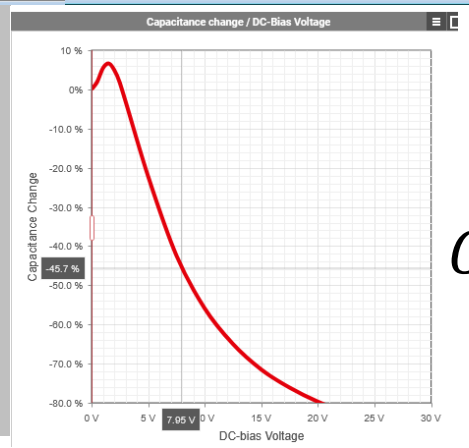
Izračuni, simulacije









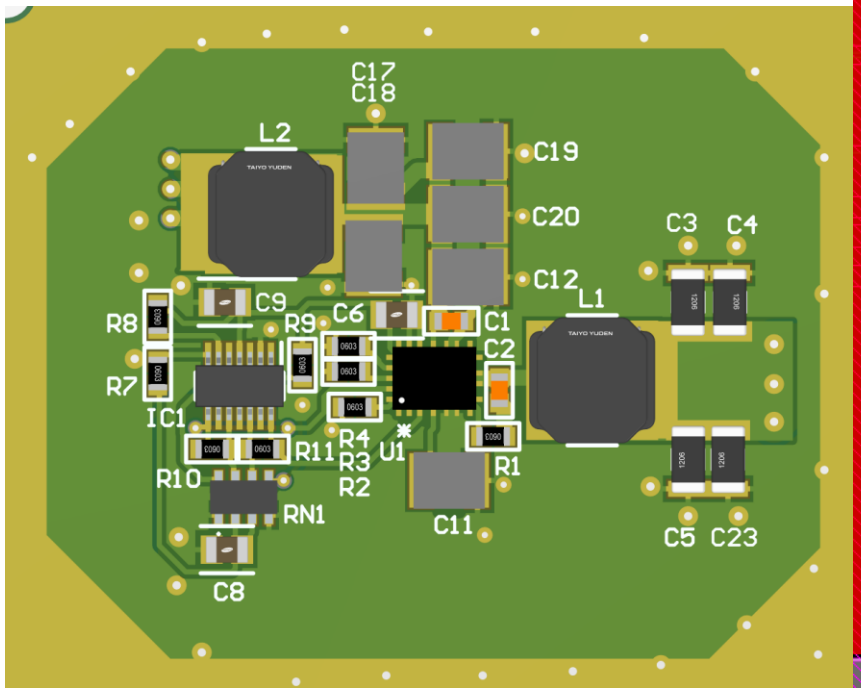


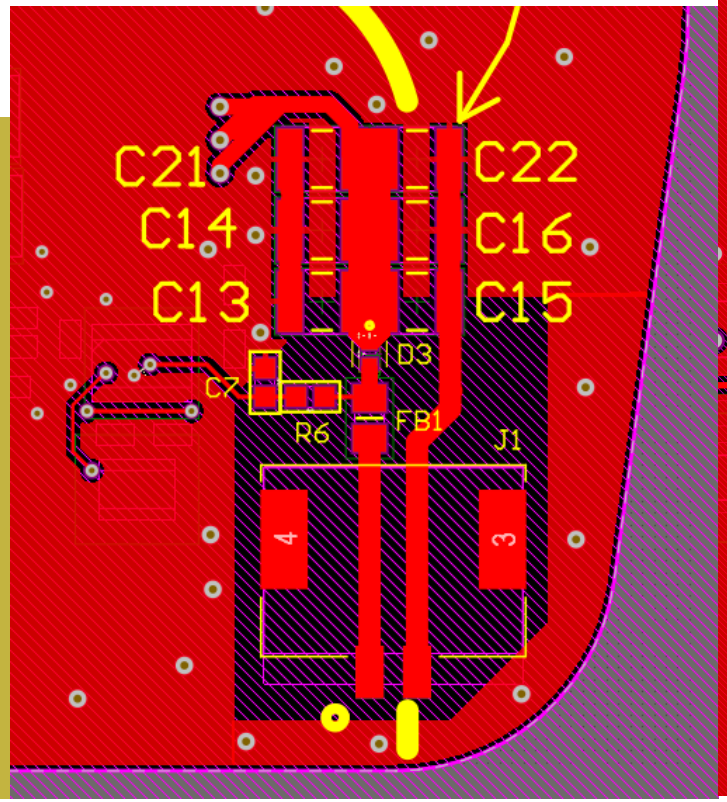
$$I_{avg} = 276\ mA, Q_{10\%} = 138$$
$$\Delta V = 2\ V, C_{in} = 70\ \mu F$$

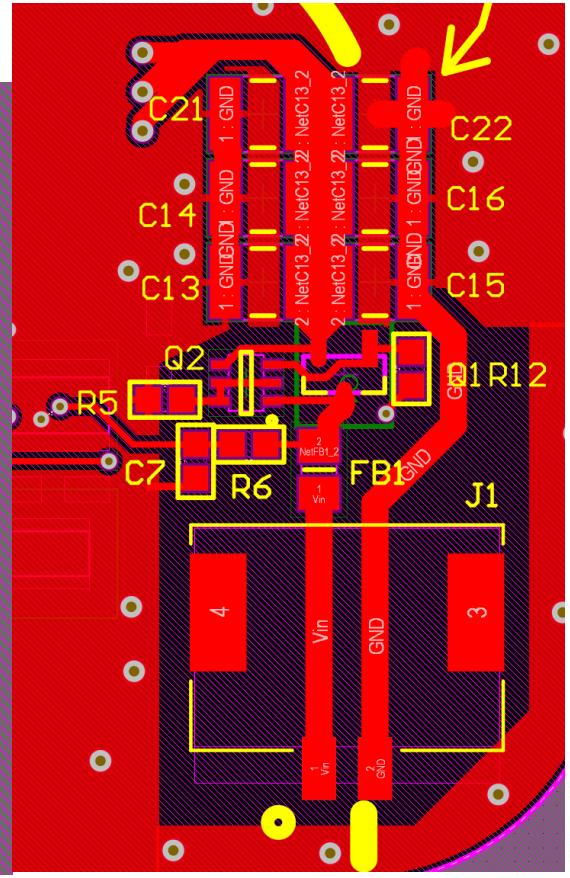
$$C_{real} = 120\ \mu F \pm 10\ \mu F$$

Načrtovanje tiskanega vezja

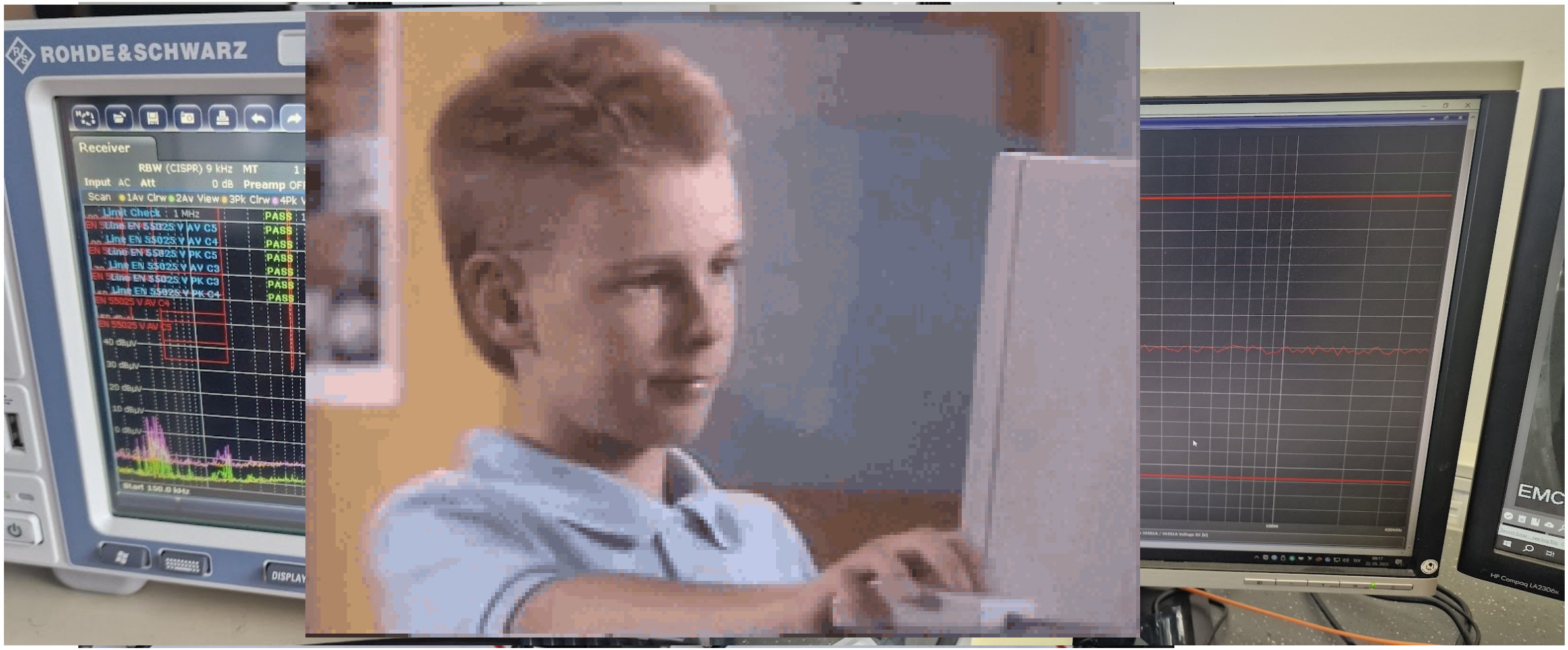
- Kar nastane noter ostane noter
- Kar pride od zunaj ostane zunaj







Preliminarne meritve



Morebitni popravki

- Ne

Načrtovanje elektronike za

EMC² 2025

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in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

Laboratorij za fotovoltaiko
in optoelektroniko

Luka Kavčič

Rezultati

Luka Kavčič – Funkcionalni in električni testi

Osnovna funkcionalnost ✓

PWM območje Kratek zvezen prehod med PO in DRL in obratno. ✓

Napetostno območje ✓

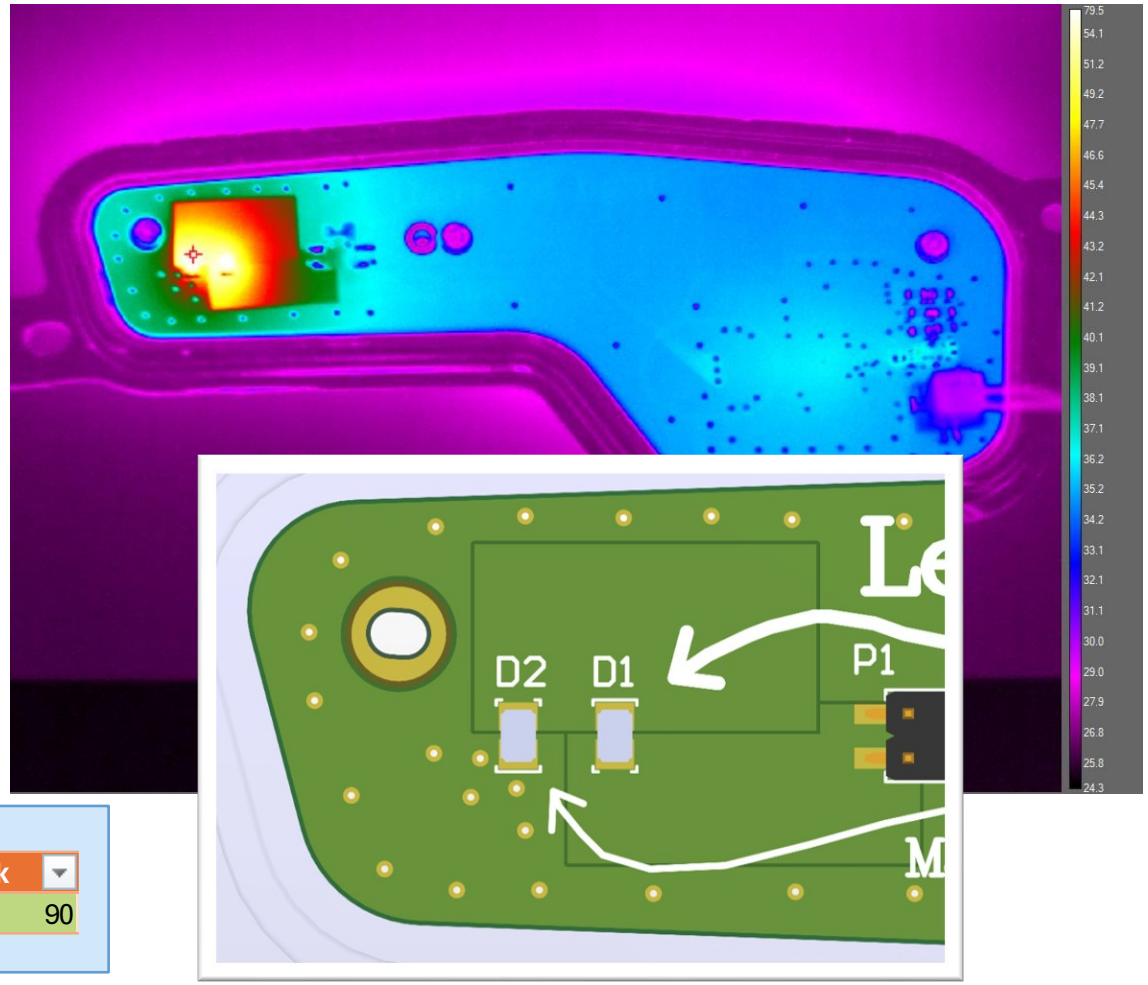
Temperaturno območje ✓

Obrnjena polariteta ✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	155	2.094	6.17	307	1.894	90

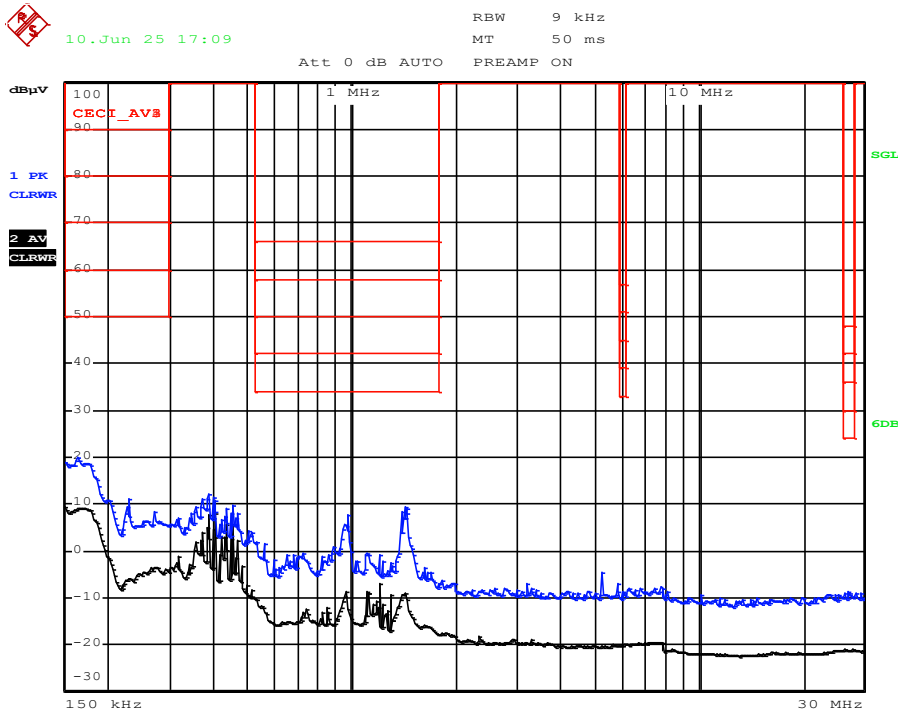
Temperaturna obremenitev: **54.81 °C**



Luka Kavčič – EMC

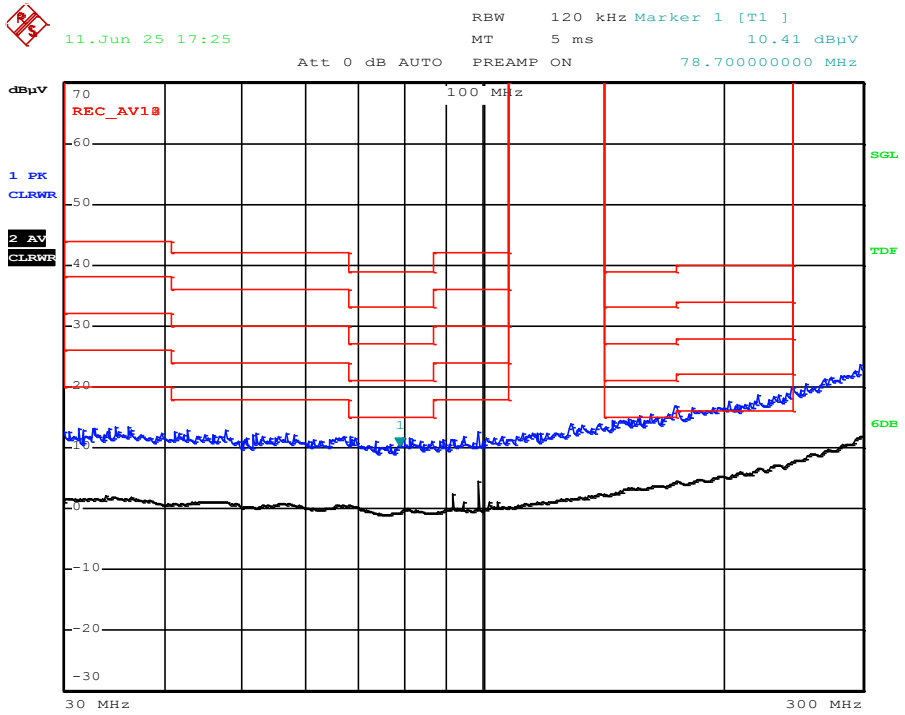
CE

5



RE

5



BCI

100 mA **A**

RI

100 V/m H+V **A**

Luka Kavčič - Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 10 000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vetzje
IC1	OpAmp	LM324LVIDYYR	TI	LM324LVIDYYR	TI	0.049 €	1	0.049 €
C13, C14, C15, C16, C21, C22, C11, C12, C17, C18, C19, C20, C6, C8, C3	**Capacitor**	**CL31B106KAHNNNE**	**Samsung**	**C14860**	**LCSC**	**0.013 €**	**15**	**0.195 €**
FB1	Ferit	FBMJ2125HS420-T	TAIYO YUDEN	963-FBMJ2125HS420-T	Arrow	0.021 €	1	0.021 €
L1	**Tuljava**	**NRS6028T220MMGJV**	**TAIYO YUDEN**	**NRS6028T220MMGJV**	**Avnet**	**0.102 €**	**1**	**0.102 €**
RN1	Resistor network	MNR14E0APJ104	ROHM Semicon	C308568	LCSC	0.008 €	1	0.008 €
Q1	MOSFET	DO3407B	DOINGTER	C41384538	LCSC	0.010 €	1	0.010 €
Q2	BJT	MMDT2907A	Slkor	C5122540	LCSC	0.024 €	1	0.024 €
D3, D4	Dioda	1N4148WT	onsemi	C232841	LCSC	0.008 €	2	0.016 €
L2	Tuljava	CD43-4R7M	HanElectricity	C42931114	LCSC	0.017 €	1	0.017 €
R3	0402 Upor					0.005 €	1	0.005 €
C7, C2	0603 Kondenzator					0.005 €	2	0.010 €
R5, R12, R6, R2, R4,R7, R8, R9, R10, R11, R1	0603 Upor					0.005 €	11	0.055 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
38	0.51 €	0.38 €	0.89 €

Načrtovanje elektronike za

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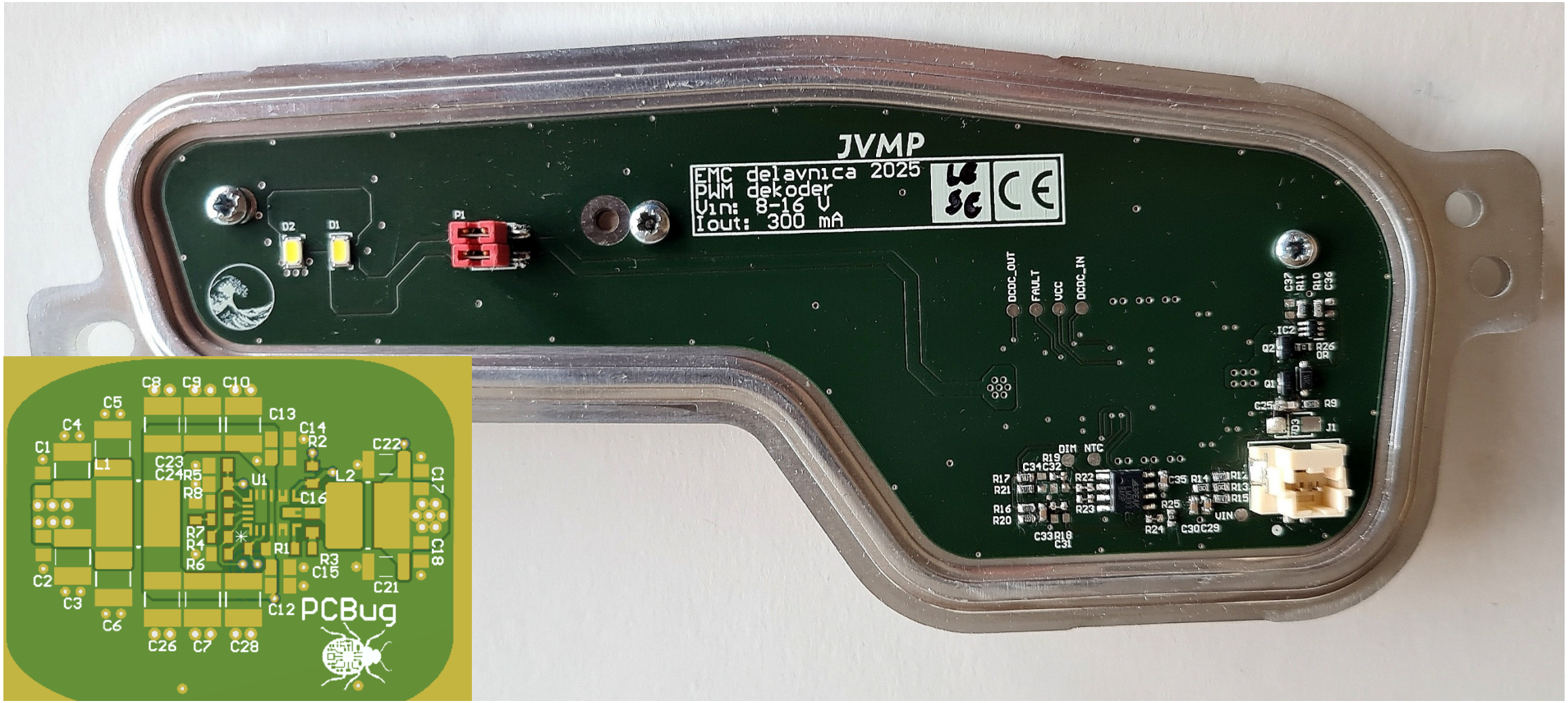
Laboratorij za fotovoltaiko
in optoelektroniko

Jaša Vid Meh Peer

1. letnik, DR-EL

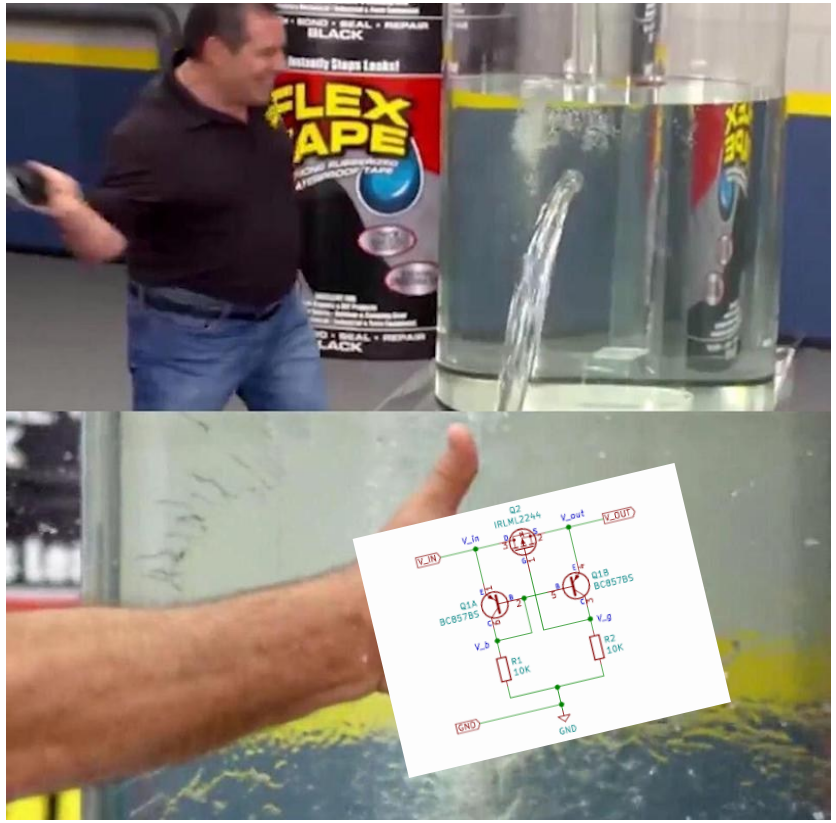
Jaša vid Meh Peer



Koncept rešitve - Napajanje

- Preprečitev kvarjenja signala

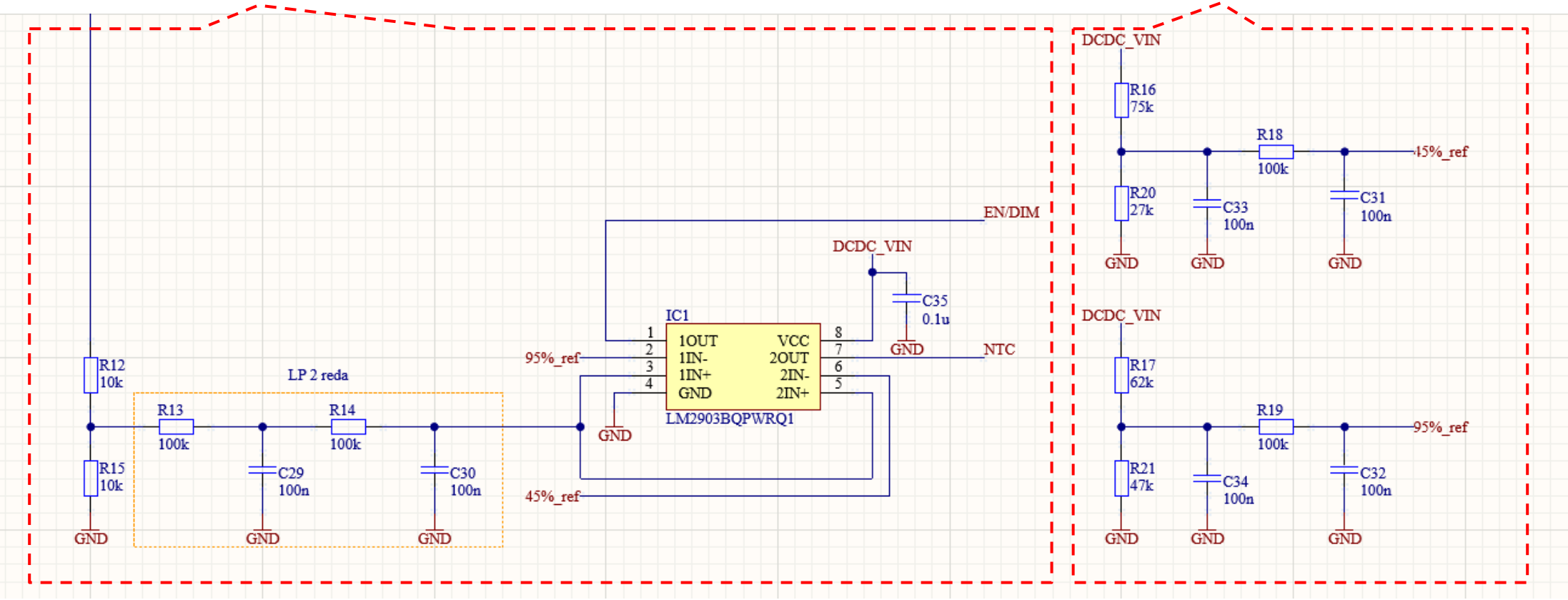
Konstantna napetost



Koncept rešitve – Dekodiranje PWM

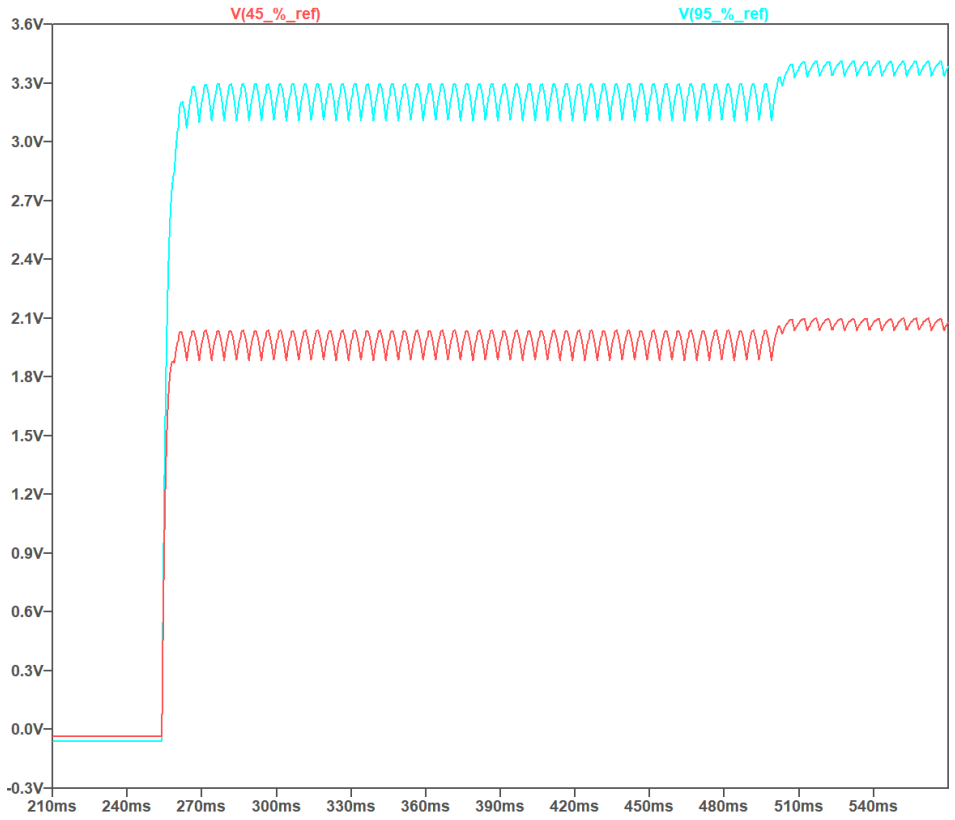
Signal: PWM -> Uporovni delilnik -> LP

- Reference: Napajanje -> Uporovni delilnik -> LP



Simulacije

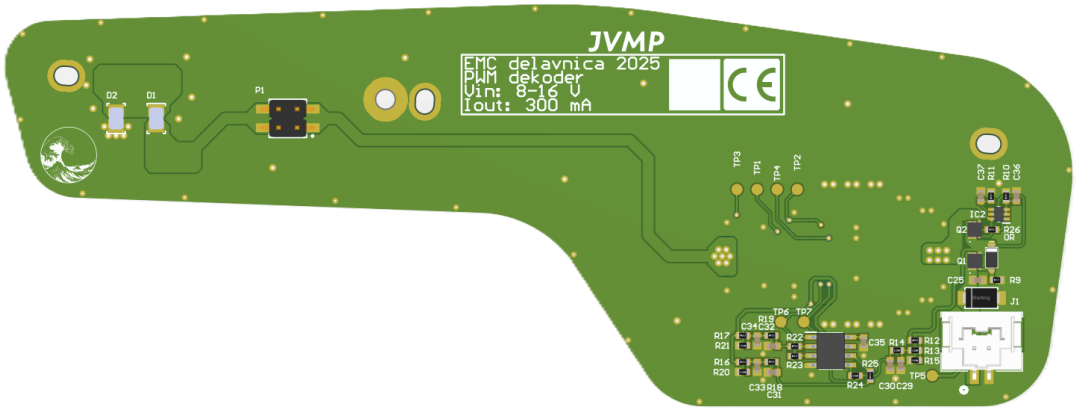
Vin = 8 V, Duty = 10 %



Načrtovanje tiskanega vezja

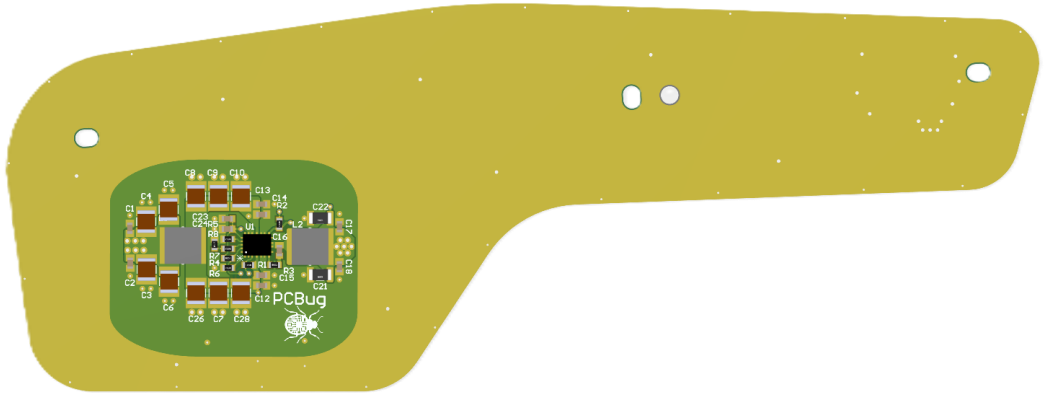
Top side

- Bottom side



Dimming in turn off logika

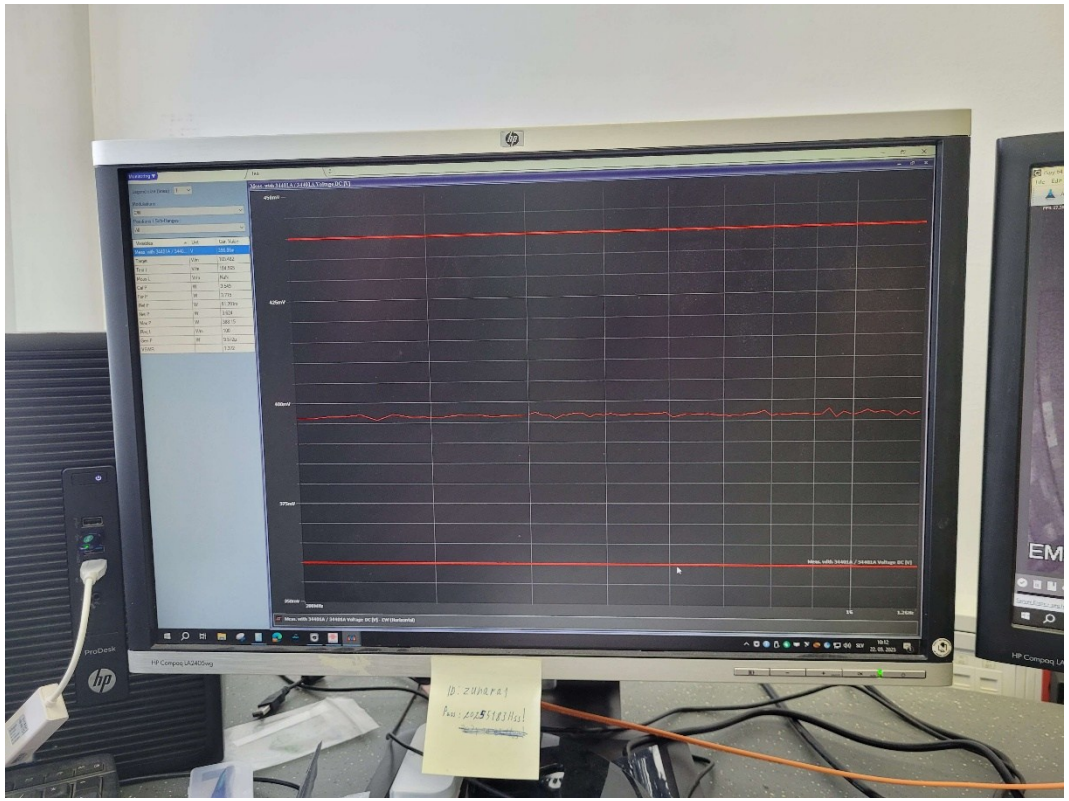
- Stikalni pretvornik

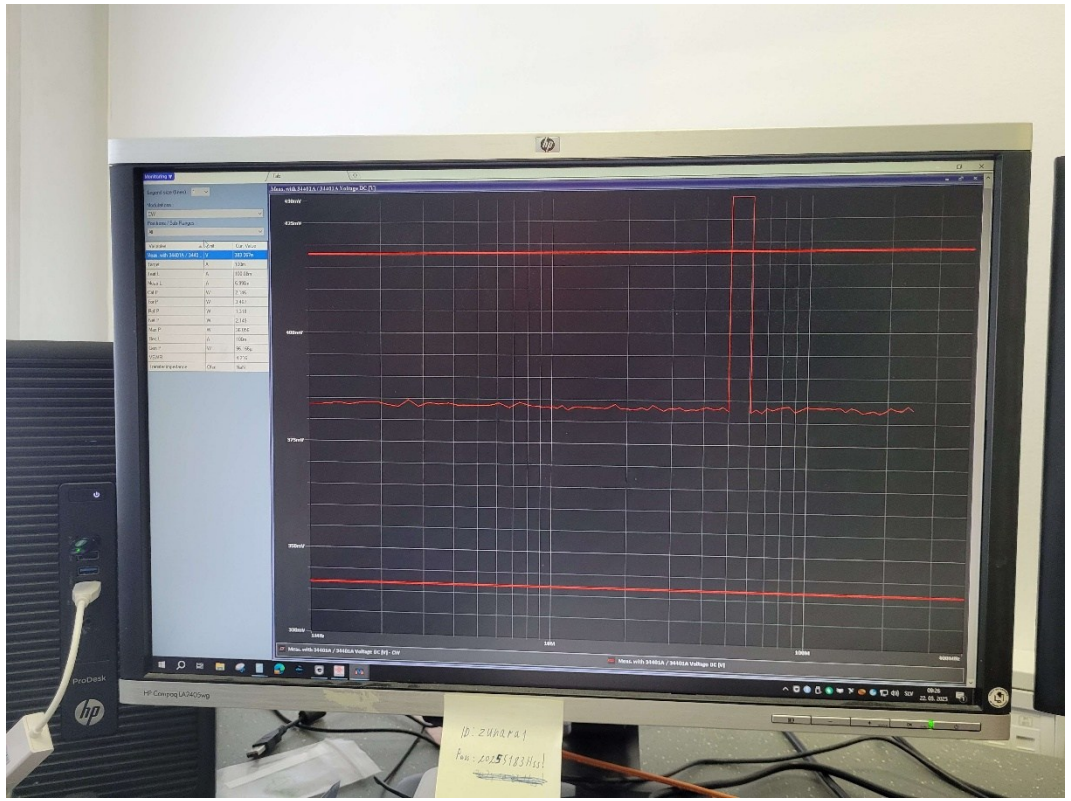


Preliminarne meritve

Imunost na elektromagnetno sevanje (RI)

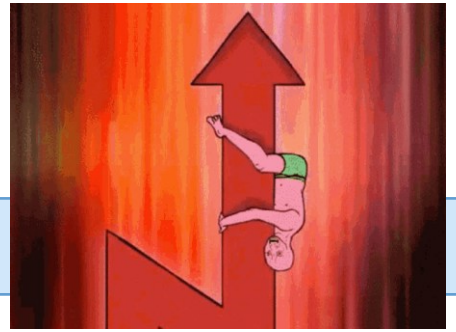
- Imunost na vsiljene tokove (BCI)



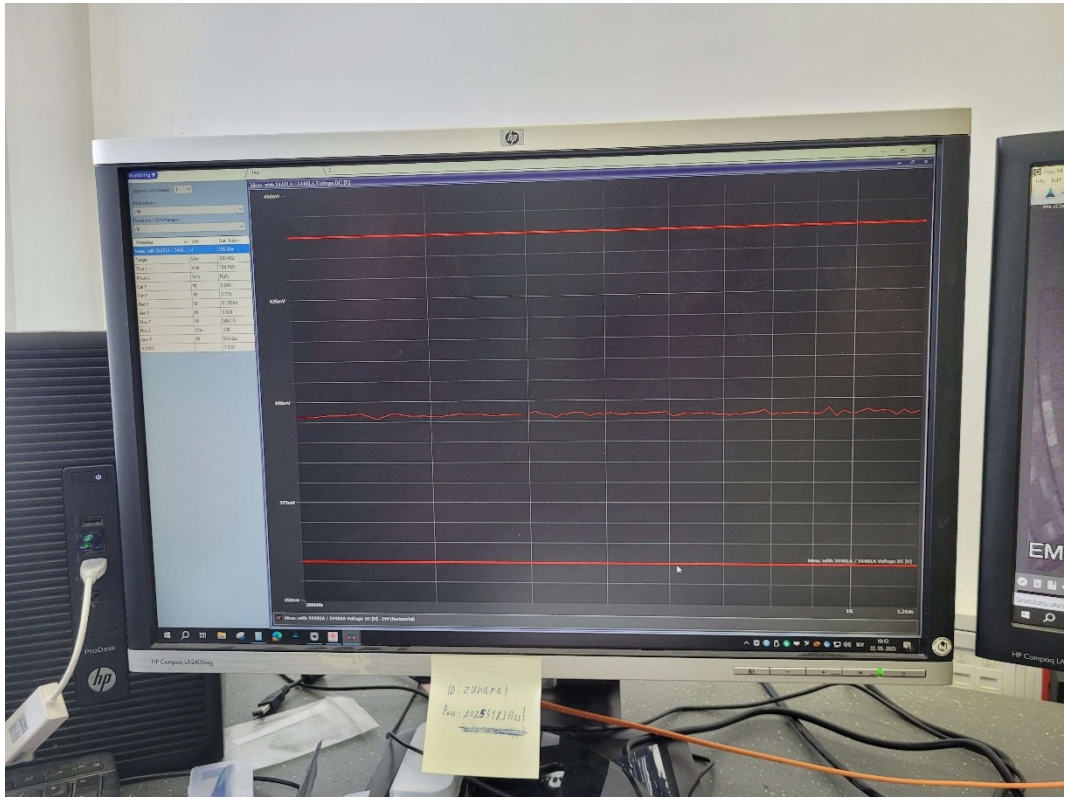


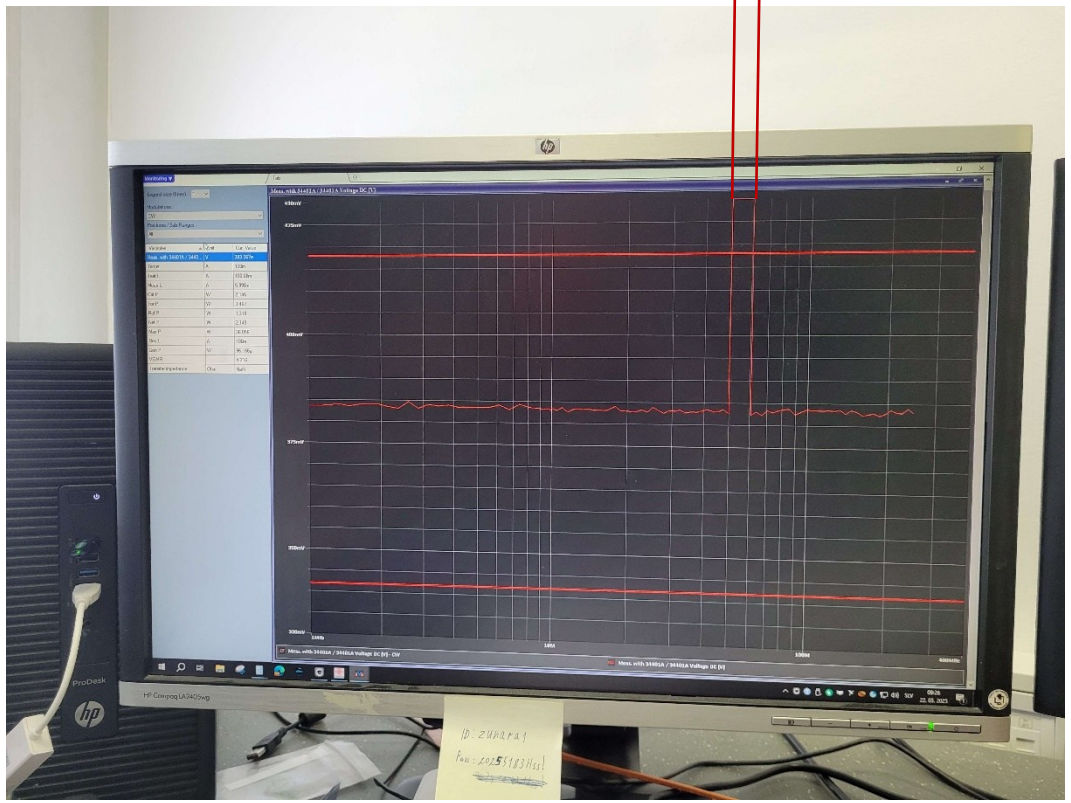
Preliminarne meritve

Imunost na elektromagnetno sevanje (RI)



- Imunost na vsiljene tokove (BCI)





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Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

Jaša Vid Meh Peer

Rezultati

Jaša Vid Meh Peer – Funkcionalni in električni testi

Osnovna funkcionalnost ✓

PWM območje ✓

Napetostno območje Sveti pri 16V 45% (nad 14,5V) ✓

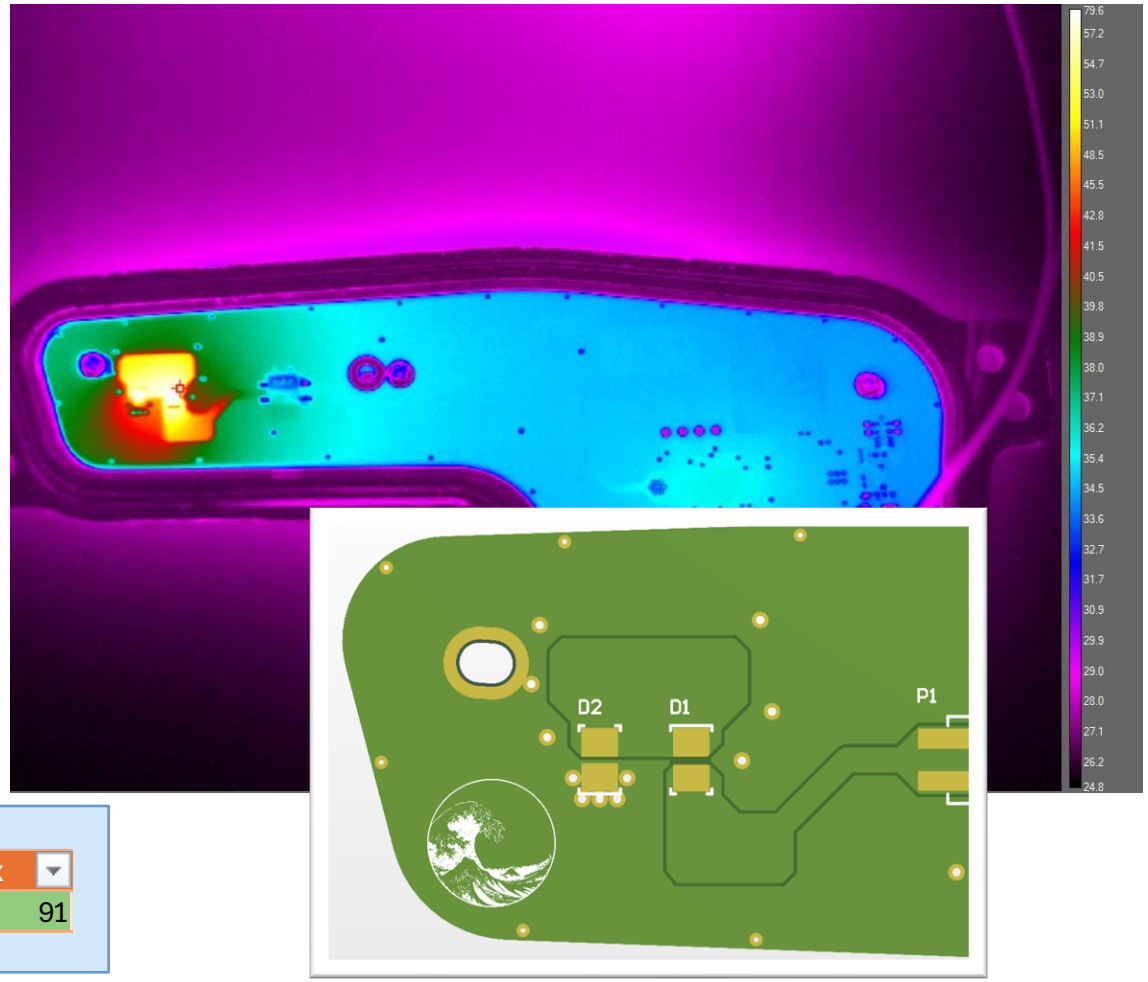
Temperaturno območje ✓

Obrnjena polariteta ✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	152	2.054	6.11	308	1.880	91

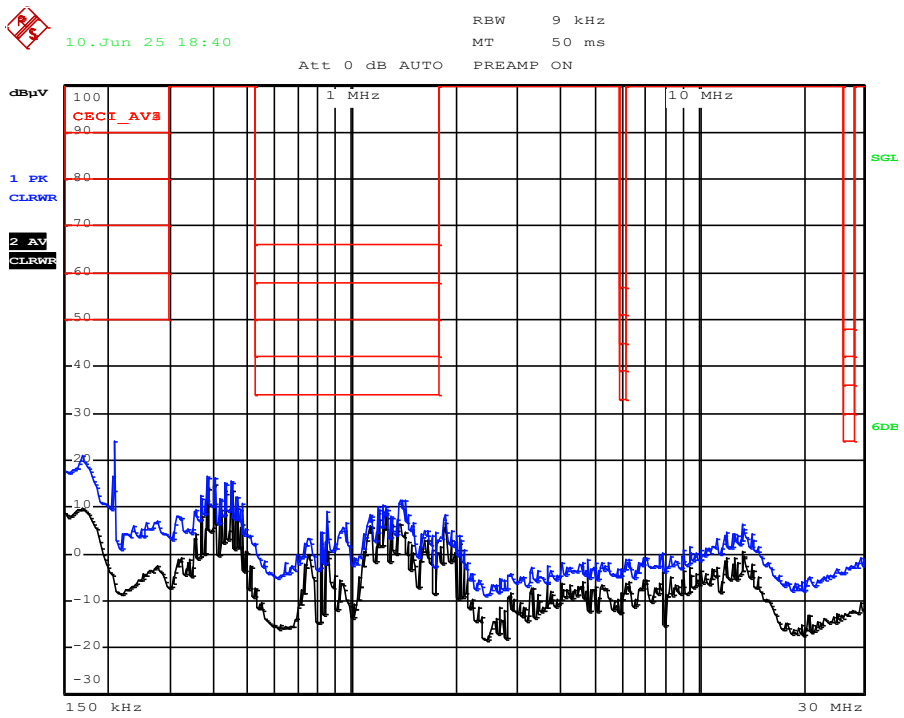
Temperaturna obremenitev: 57.90 °C



Jaša Vid Meh Peer – EMC

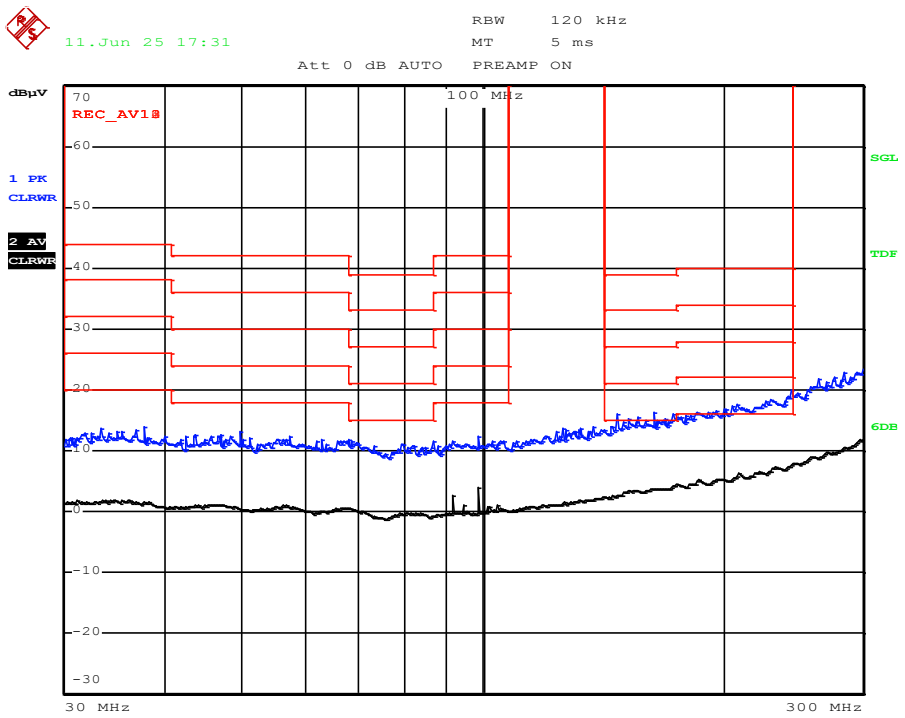
CE

5



RE

5



BCI

60 mA

A

Pri 60 MHz se vklopi DRL

RI

100 V/m H+V

A

Jaša Vid Meh Peer – Cena

Oznaka elementa na shemi	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (za 10000 vezij)	Št. Kosov na vezje	Cena za št. kosov na vezje
C3, C4, C10, C28	Capacitor 10 u 25 V	CS3225X7R106K250NRK	Samwha Capacitor	C2918497	LCSC	0.024 €	4	0.094 €
C5, C6, C7, C8, C9, C26	**Capacitor 22 u 25 V**	**CS3225X7R226K250NRL**	**Samwha Capacitor**	**C2918511**	**LCSC**	**0.038 €**	**6**	**0.230 €**
C21, C22	Capacitor 2.2 u 16 V	CC1206KKX7R7BB225	YAGEO	C107183	LCSC	0.015 €	2	0.029 €
C23	Capacitor 10 u 10 V	CGA0603X7R106K100JT	HRE	C22399626	LCSC	0.027 €	1	0.027 €
FB1	Feritte bead 0805	FBMJ2125HS420-T	TAIYO YUDEN	963-FBMJ2125HS420-T	Mouser	0.025 €	1	0.025 €
IC1	LM2903 comparator	LM2903A-SR	3PEAK	C7496686	LCSC	0.035 €	1	0.035 €
IC2	MMDT3906-7-F double PNP	MMDT3906	TECH PUBLIC	C7603391	LCSC	0.010 €	1	0.010 €
L1	L 4.7 u	CD43-4R7M	HanElectricity	C42931114	LCSC	0.015 €	1	0.015 €
L2	L 33 u	CY54-33UH	SHOU HAN	C2929433	LCSC	0.023 €	1	0.023 €
Q1, Q2	MOSFET	3401H	GOFORD	C3151755	LCSC	0.009 €	2	0.019 €
ZD1	Zener diode	BZT52C16	DOWO	C7544544	LCSC	0.006 €	1	0.006 €
C1-C25	**Capacitor < 100 nF 0603**					**0.005 €**	**15**	**0.075 €**
R1-R26	**Resistor 0603**					**0.005 €**	**21**	**0.105 €**

Št. komponent	Cena komponent	Cena polaganja	Skupaj
57	0.69 €	0.57 €	1.26 €

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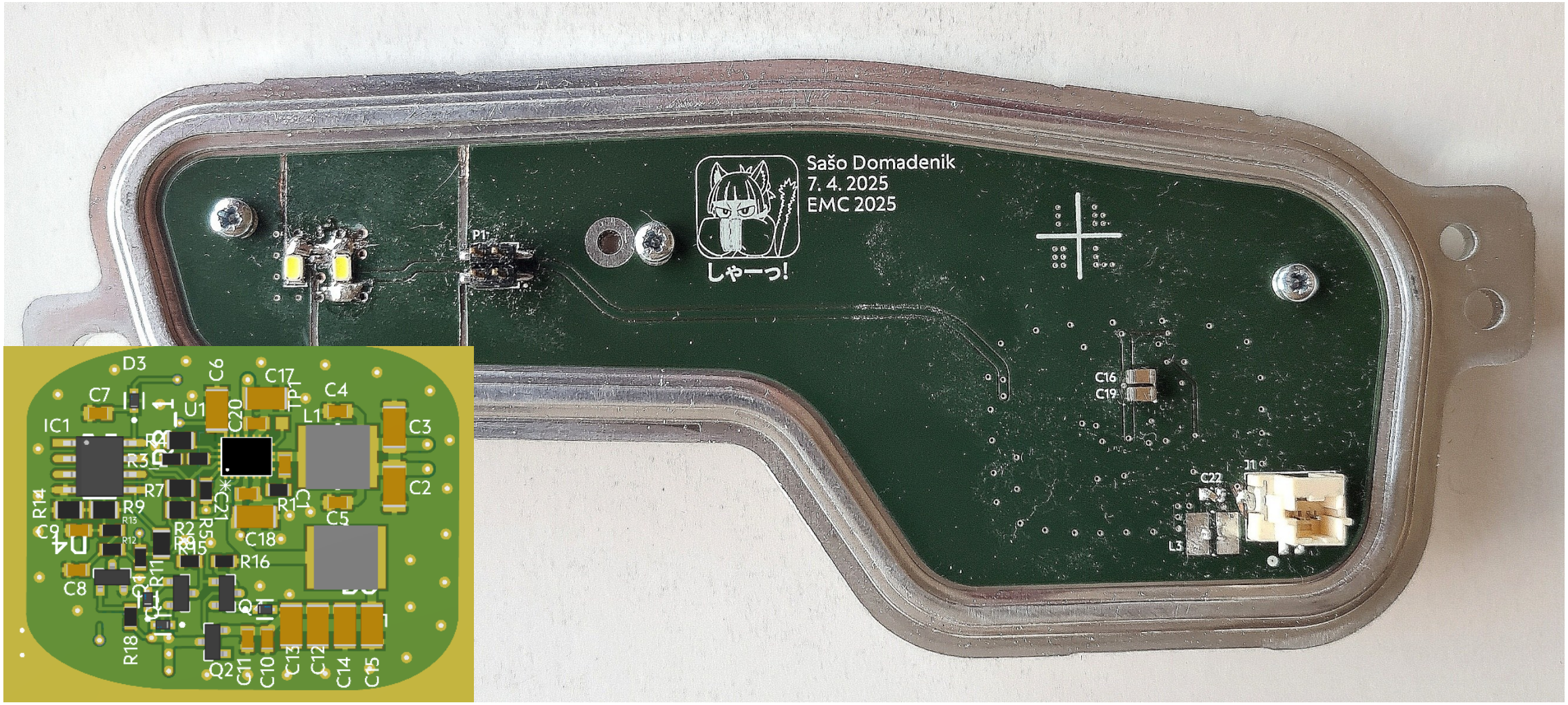
in optoelektroniko

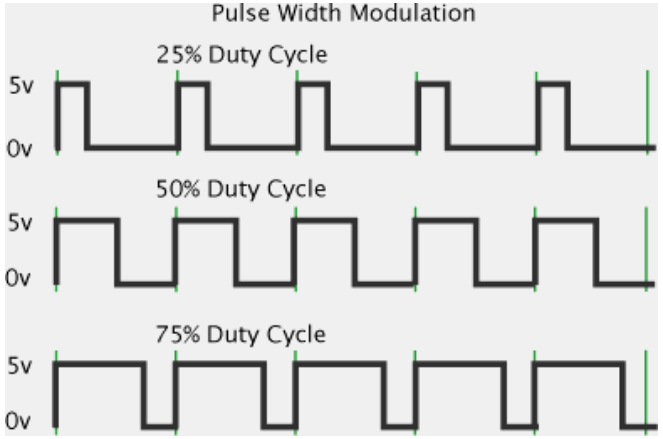
Sašo Domadenik

1. letnik, DR-EL

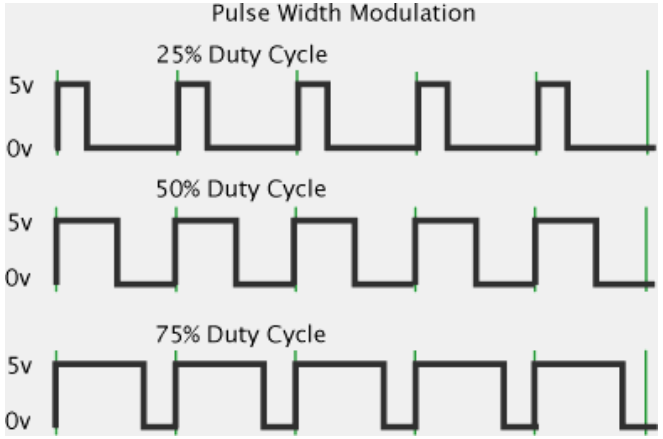
Sašo Domadenik



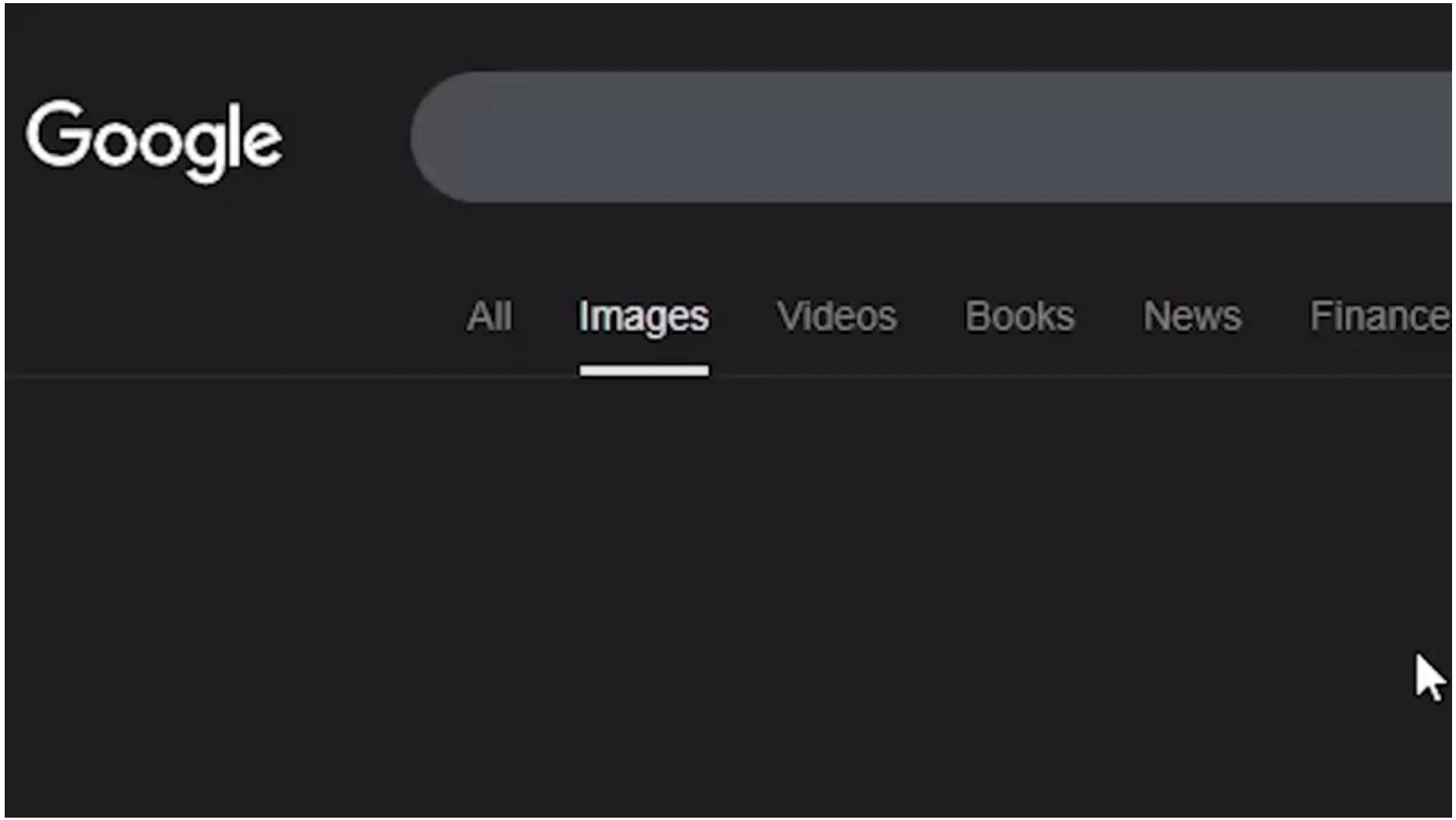
Kako napajati čip iz PWM?



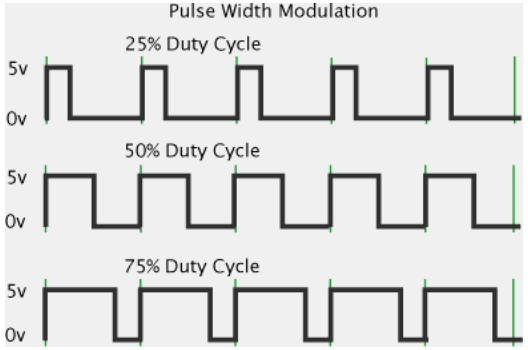
Kako napajati čip iz PWM?

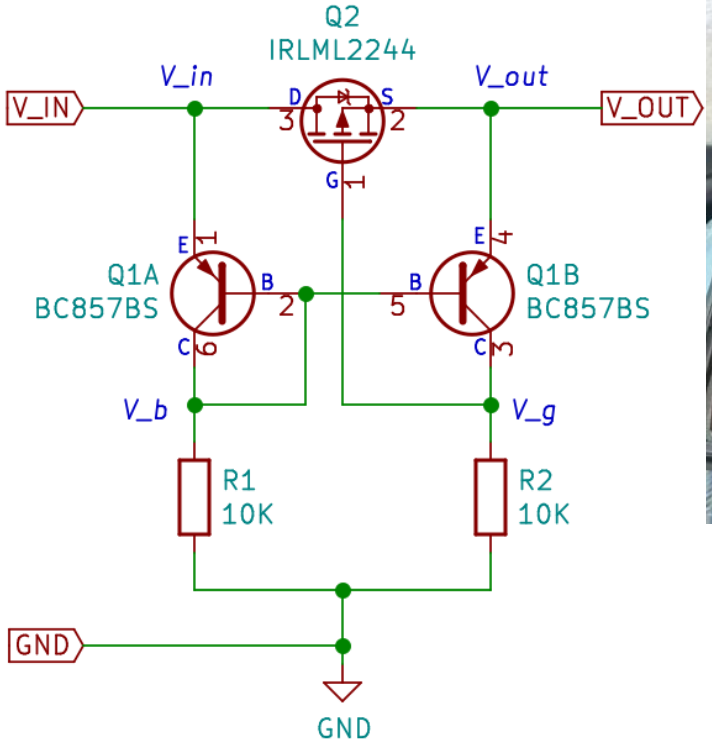


Kako napajati čip iz PWM?

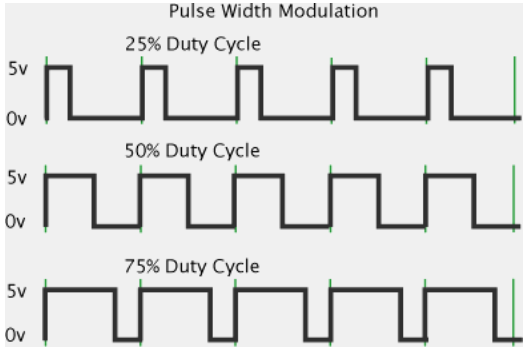


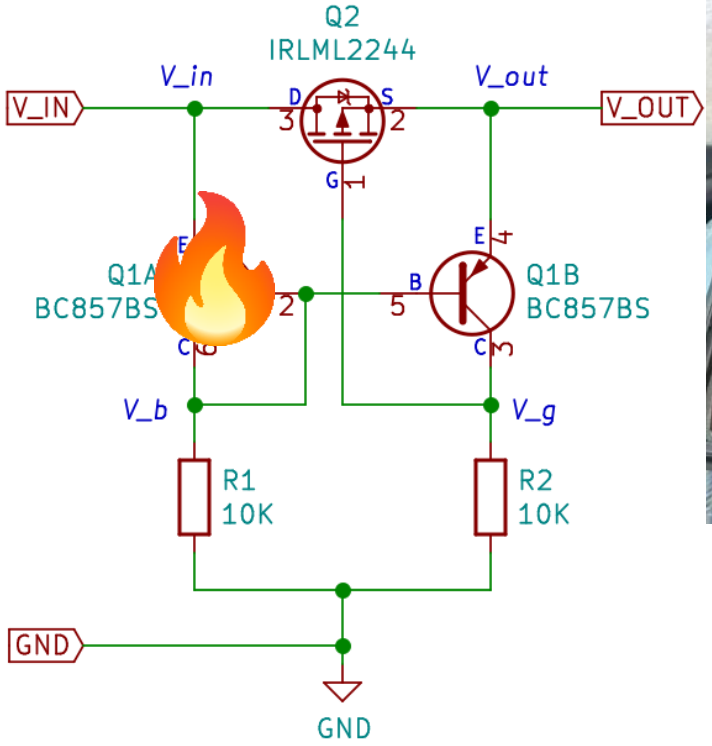
Kako napajati čip iz PWM?



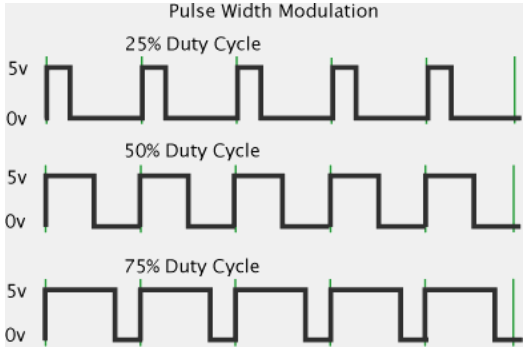


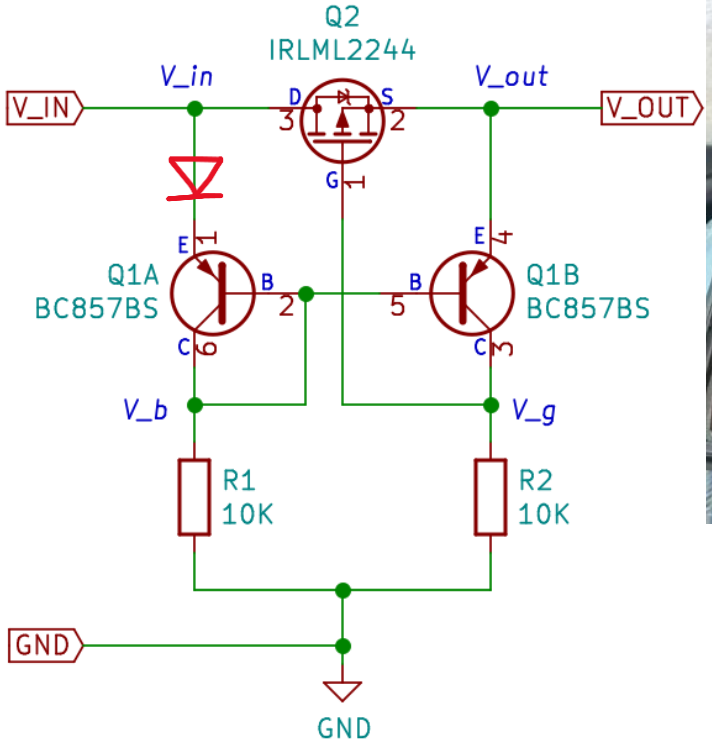
Kako napajati čip iz PWM?



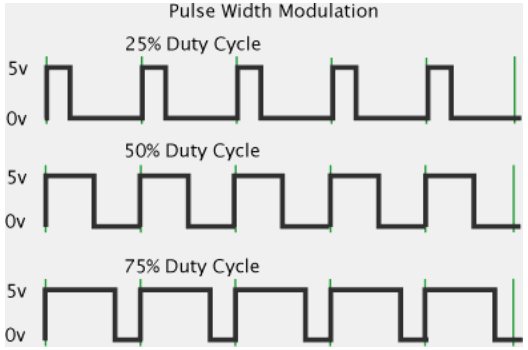


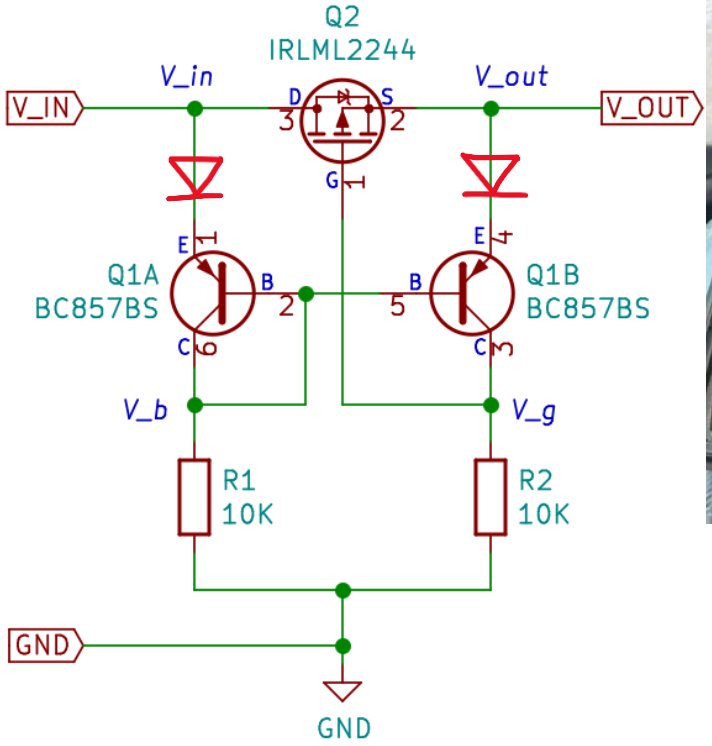
Kako napajati čip iz PWM?



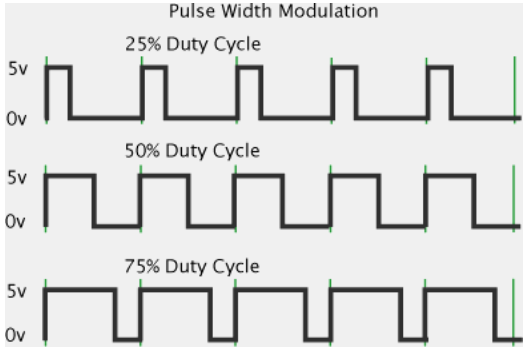


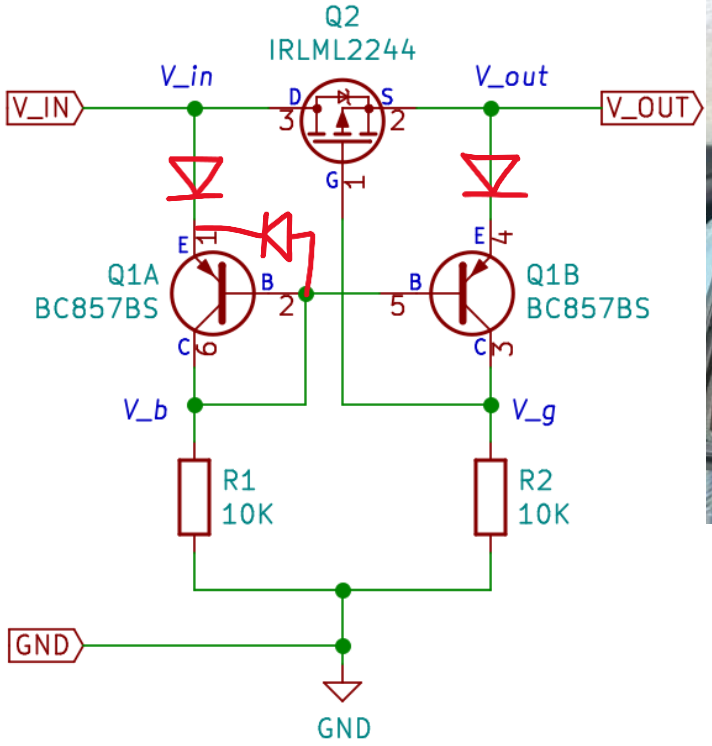
Kako napajati čip iz PWM?



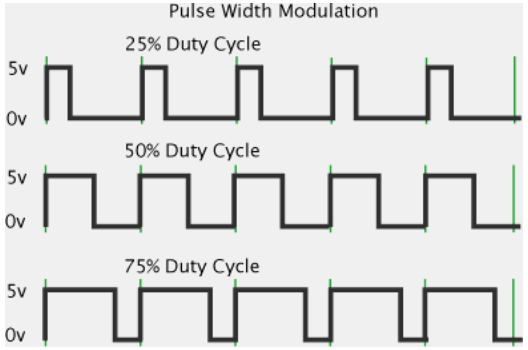


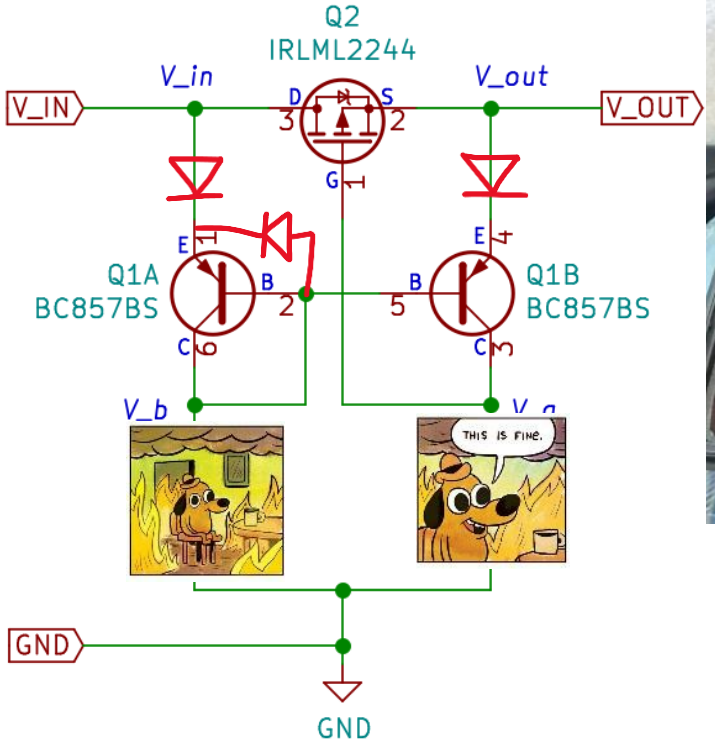
Kako napajati čip iz PWM?



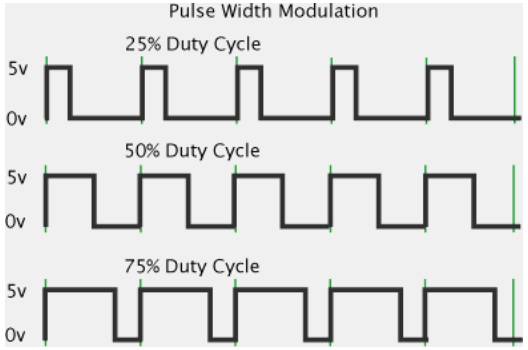


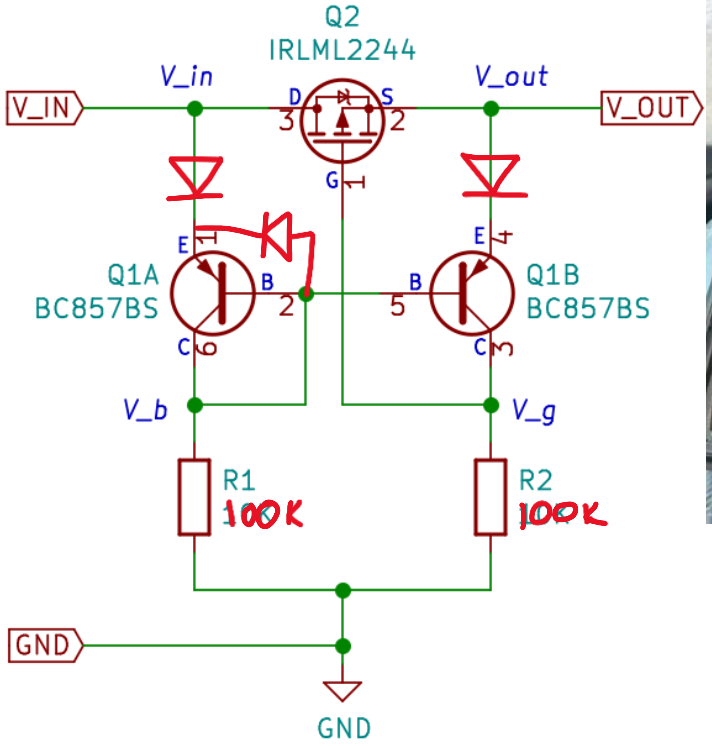
Kako napajati čip iz PWM?



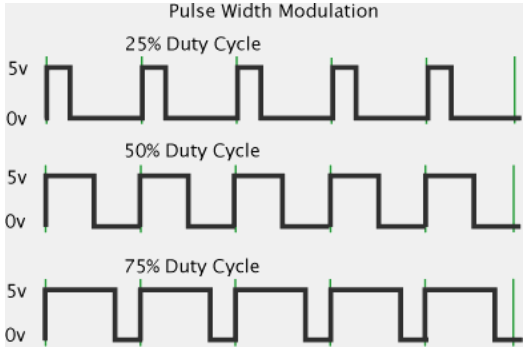


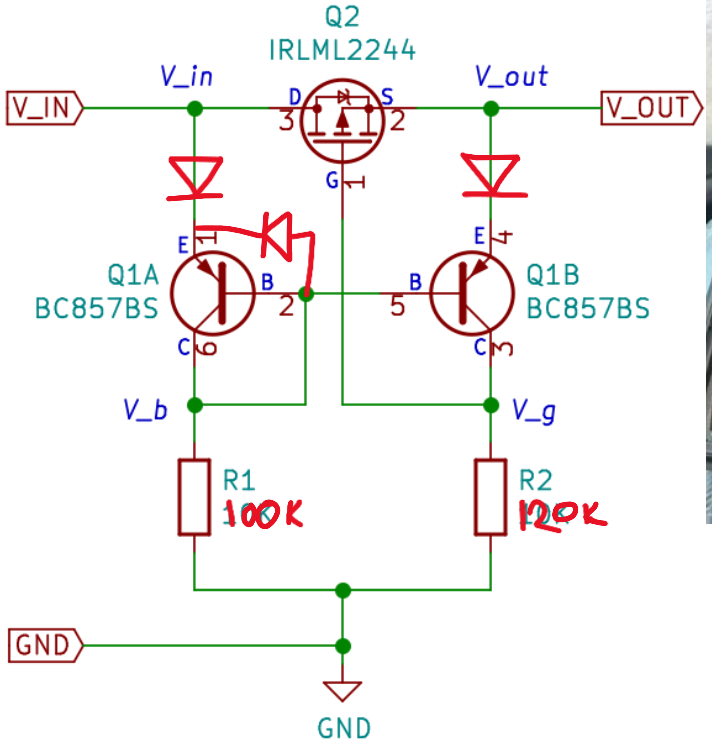
Kako napajati čip iz PWM?



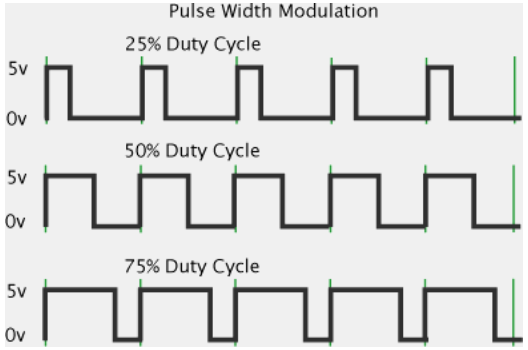


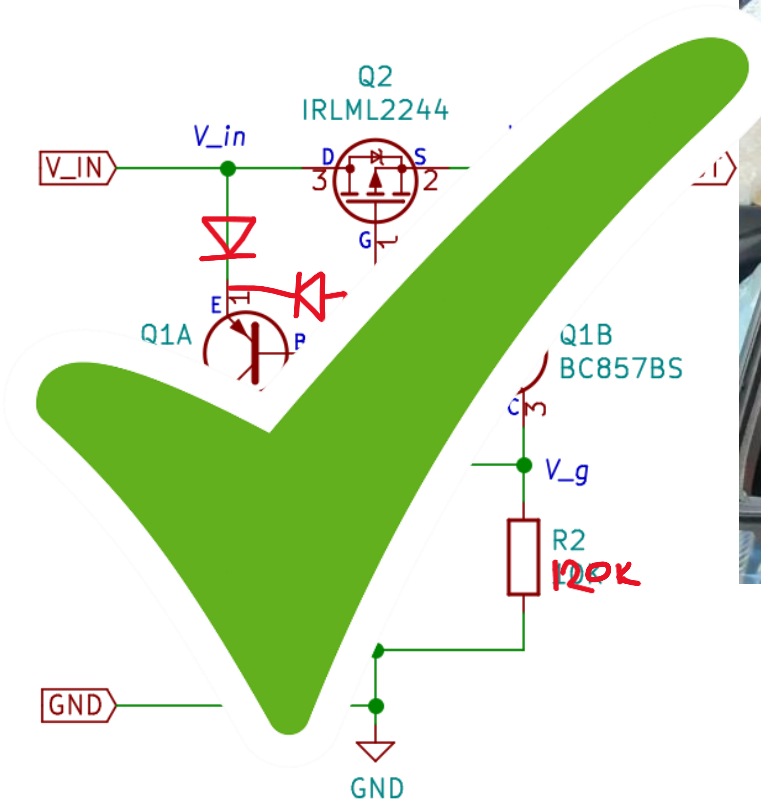
Kako napajati čip iz PWM?





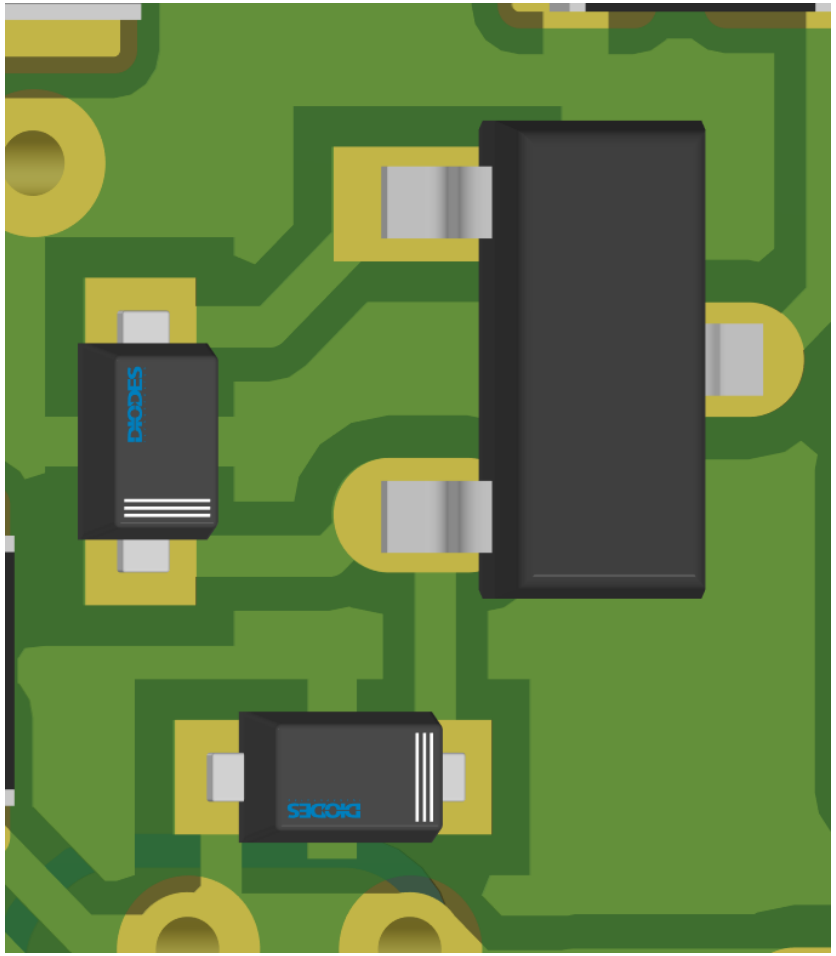
Kako napajati čip iz PWM?





PCB že oddan!

- 1N4148WT



Kako preklapljati stanja?

- Dimming

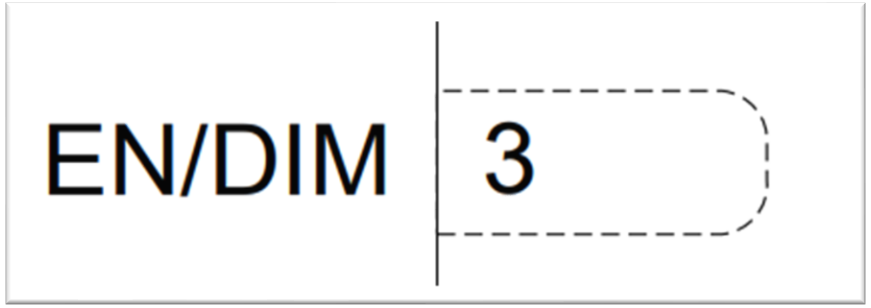
- Turn off

Kako izklopiti LEDice?

- EN Pin

Kako izklopiti LEDice?

- ~~EN Pin~~



Kako izklopiti LEDice?

- ~~EN Pin~~
- Odklopi LEDice

Kako izklopiti LEDice?

- ~~EN Pin~~
- ~~Odklopi LEDice~~

FAULT

Kako izklopiti LEDice?

- ~~EN Pin~~
- ~~Odklopi LEDice~~
- Kratkostiči LEDice

Kako izklopiti LEDice?

- ~~EN Pin~~
- ~~Odklopi LEDice~~
- ~~Kratkostiči LEDice~~

FAULT

Kako izklopiti LEDice?

- ~~EN Pin~~
- ~~Odklopi LEDice~~
- ~~Kratkostiči LEDice~~
- Kratkostiči VCC

Kako izklopiti LEDice?

- ~~EN Pin~~
- ~~Odklopi LEDice~~
- ~~Kratkostiči LEDice~~
- Kratkostiči VCC

MAYBE???

Kako izklopiti LEDice?

- ~~EN Pin~~
- ~~Odklopi LEDice~~
- ~~Kratkostiči LEDice~~
- ~~Kratkostiči VCC~~

MAYBE???

Kako izklopiti LEDice?

- ~~EN Pin~~
- ~~Odklopi LEDice~~
- ~~Kratkostiči LEDice~~
- ~~Kratkostiči VCC~~
- NTC Thermal Shutdown

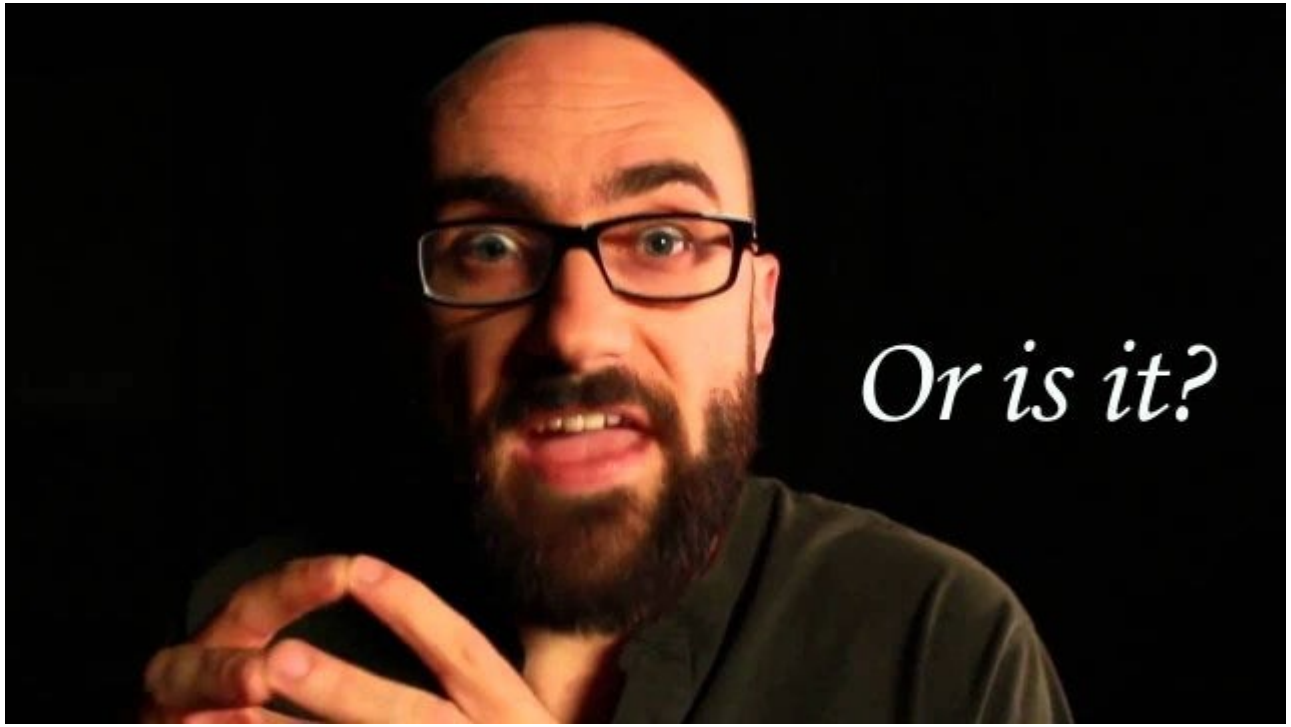
Kako izklopiti LEDice?

- ~~EN Pin~~
- ~~Odklopi LEDice~~
- ~~Kratkostiči LEDice~~
- ~~Kratkostiči VCC~~
- ~~NTC Thermal Shutdown~~

FAULT

Kako izklopiti LEDice?

- ~~EN Pin~~
- ~~Odklopi LEDice~~
- ~~Kratkostiči LEDice~~
- ~~Kratkostiči VCC~~
- NTC Thermal Shutdown



Kako izklopiti LEDice?

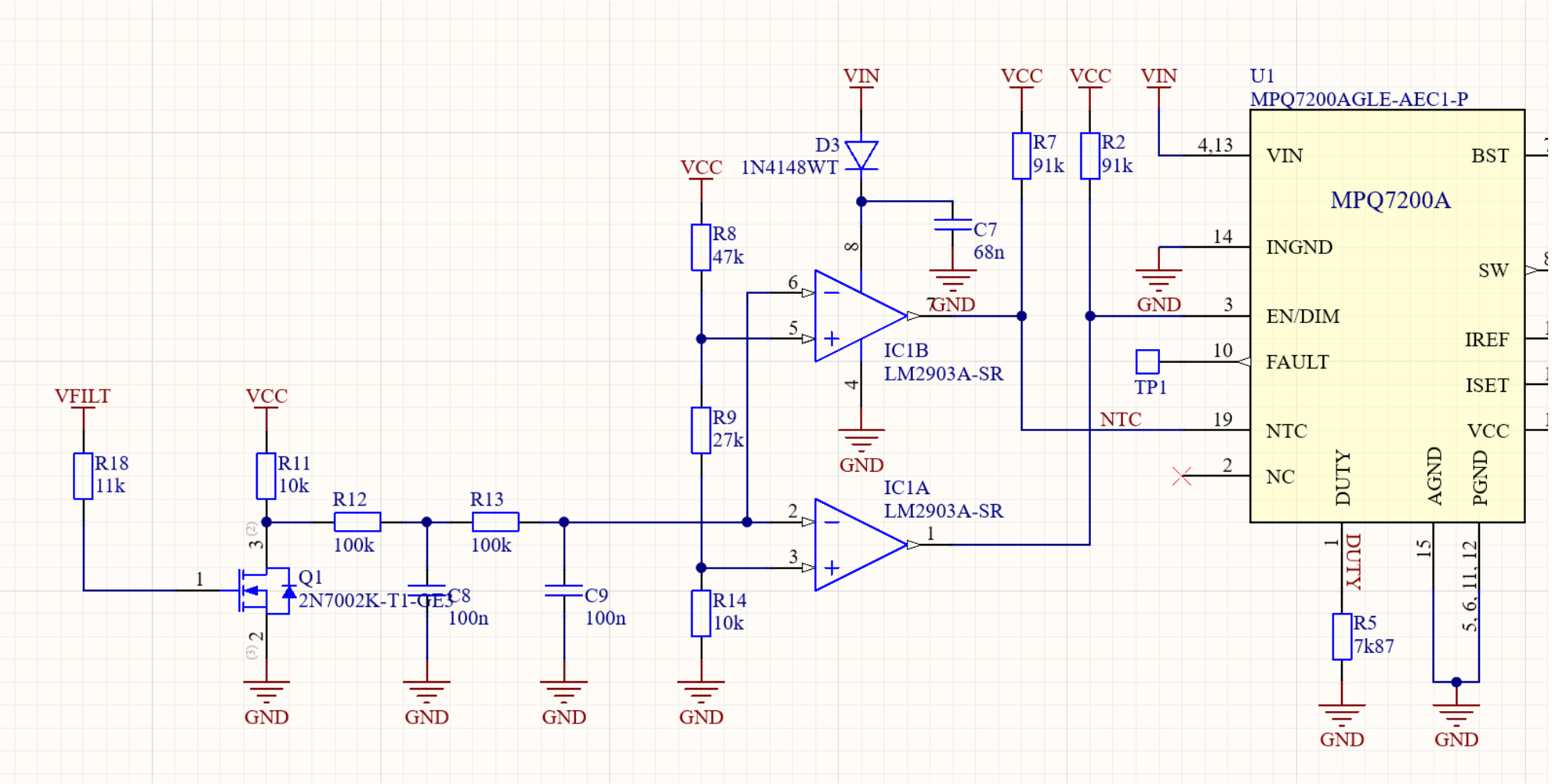
- ~~EN Pin~~
- ~~Odklopi LEDice~~
- ~~Kratkostiči LEDice~~
- ~~Kratkostiči VCC~~
- NTC Thermal Shutdown

```
> "thermal shutdown" == "thermal shutdown"
<· false
```

Kako izklopiti LEDice?

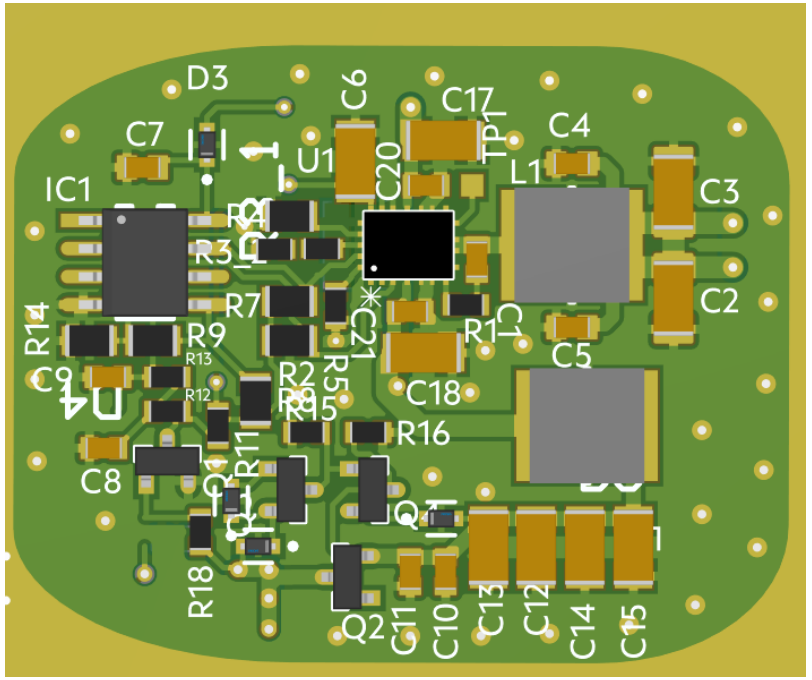
- ~~EN Pin~~
- ~~Odklopi LEDice~~
- ~~Kratkostiči LEDice~~
- ~~Kratkostiči VCC~~
- NTC Thermal Shutdown

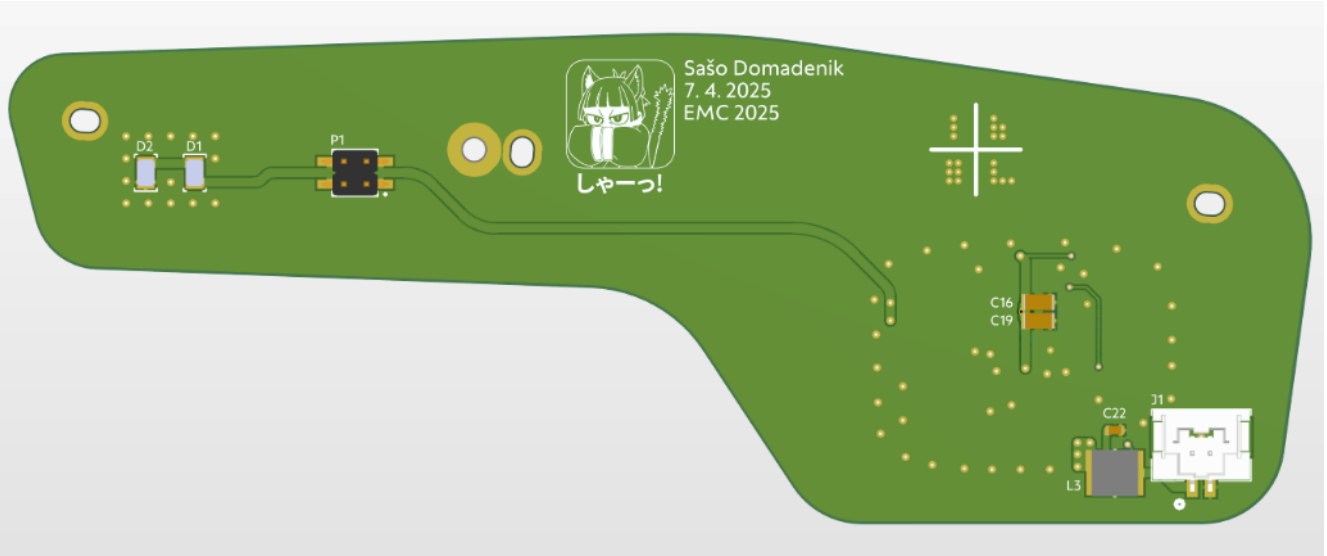
Kako izklopiti LEDice?



Načrtovanje tiskanega vezja

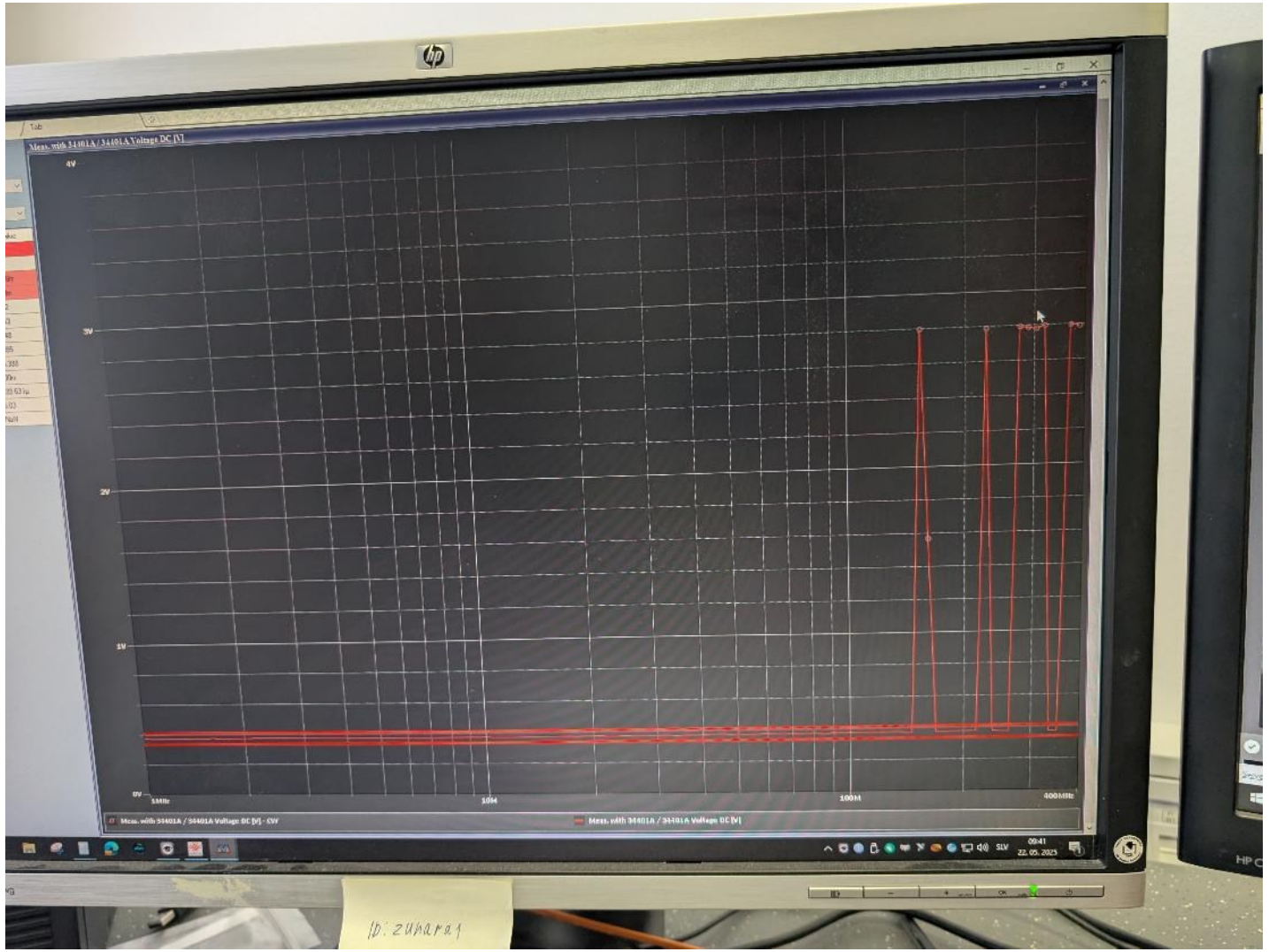
- Skoraj vse komponente na spodnji strani





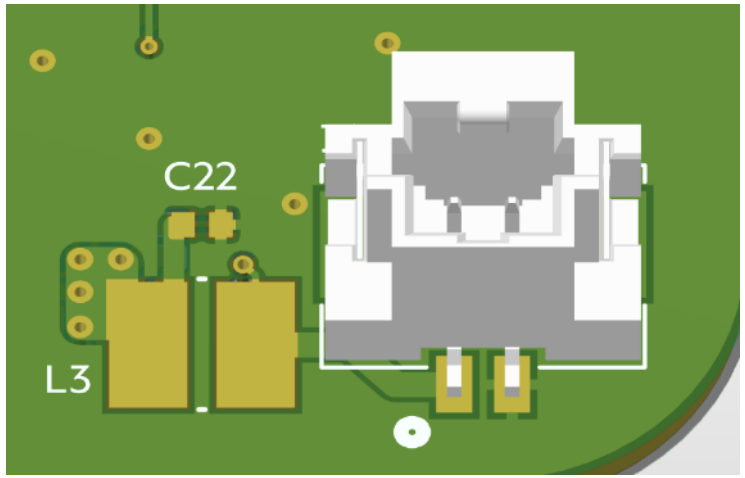
Preliminarne meritve

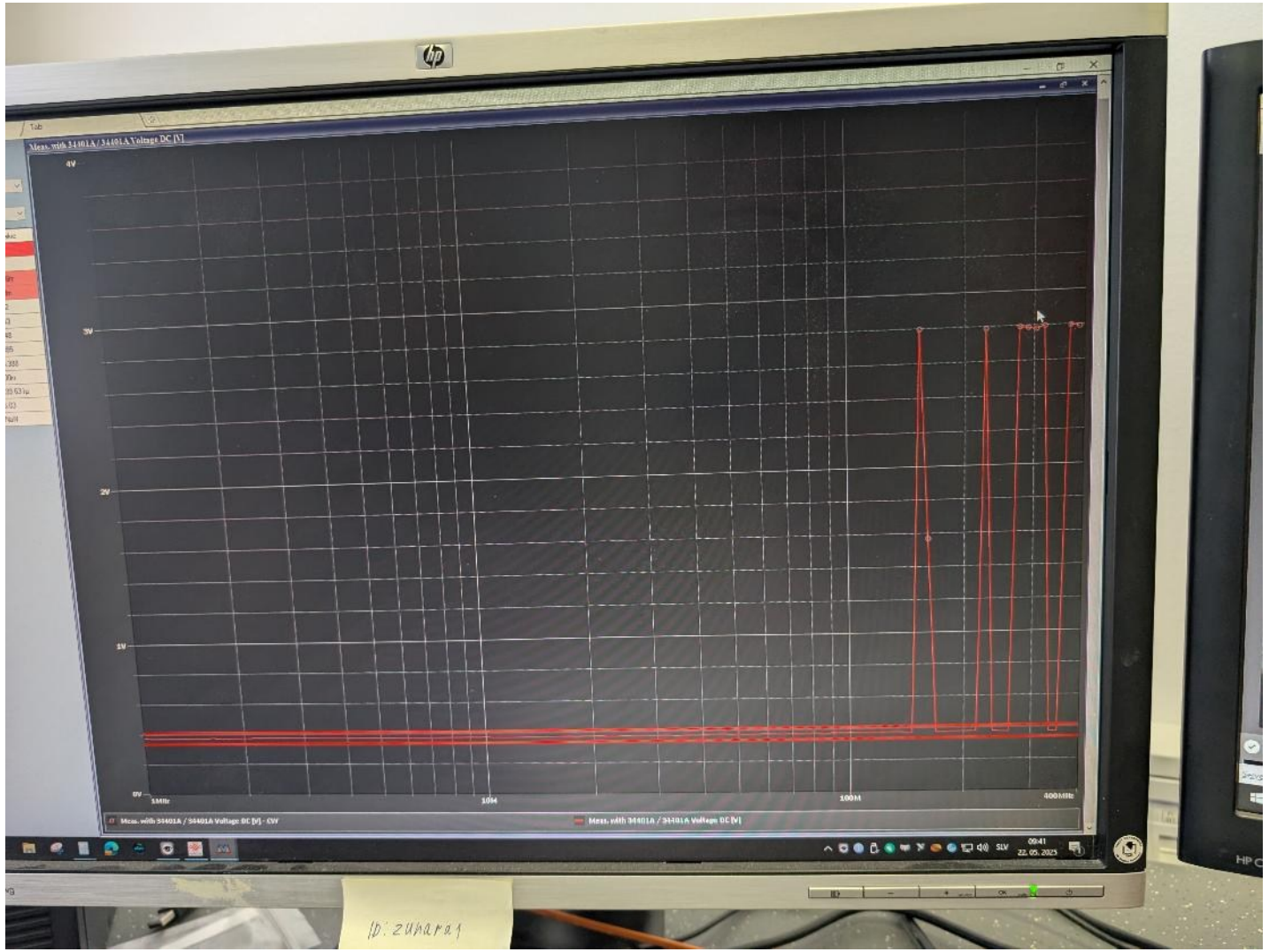
- Fail med 100 in 500 MHz



Preliminarne meritve

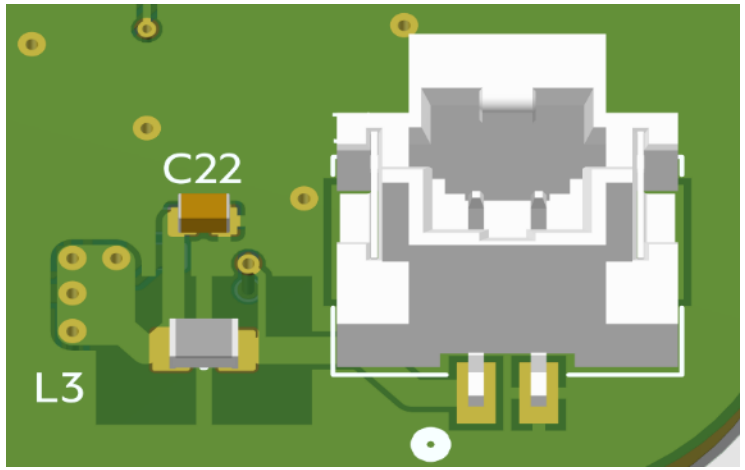
- Fail med 100 in 500 MHz





Preliminarne meritve

- Pass RI



Načrtovanje elektronike za

EMC² 2025

študentska delavnica
in tekmovanje

UNIVERZA V LJUBLJANI
Fakulteta za elektrotehniko

LPVO Laboratorij za fotovoltaiko
in optoelektroniko

Sašo Domadenik

Rezultati

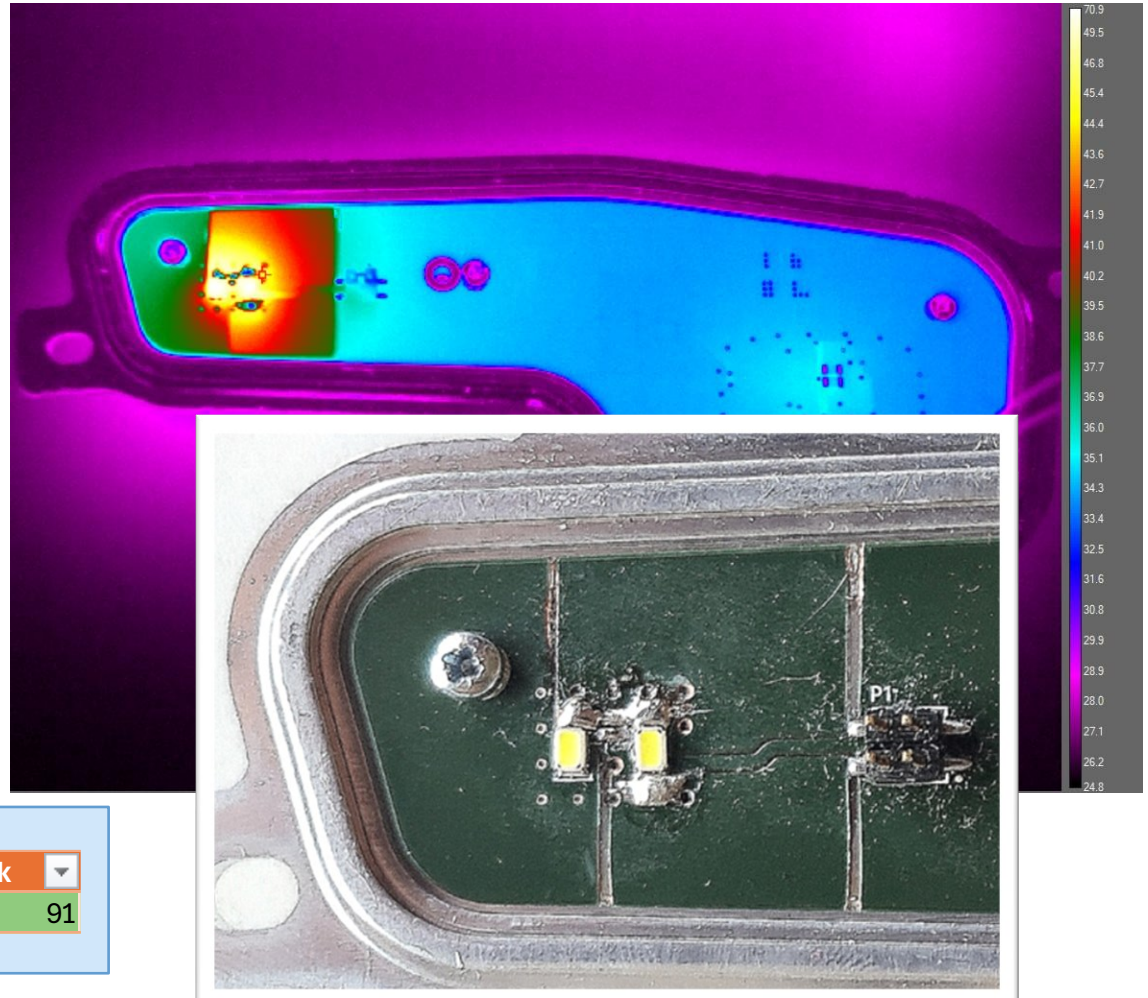
Sašo Domadenik – Funkcionalni in električni testi

Osnovna funkcionalnost		✓
PWM območje	Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	✓
Napetostno območje	Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	✓
Temperaturno območje	Pri prvem PWM pulzu (45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	✓
Obrnjena polariteta		✓

Izkoristek

U1 [V]	I1 [mA]	P1 [W]	U2 [V]	I2 [mA]	P2 [W]	Izkoristek
13.51	141	1.905	6.04	289	1.746	91

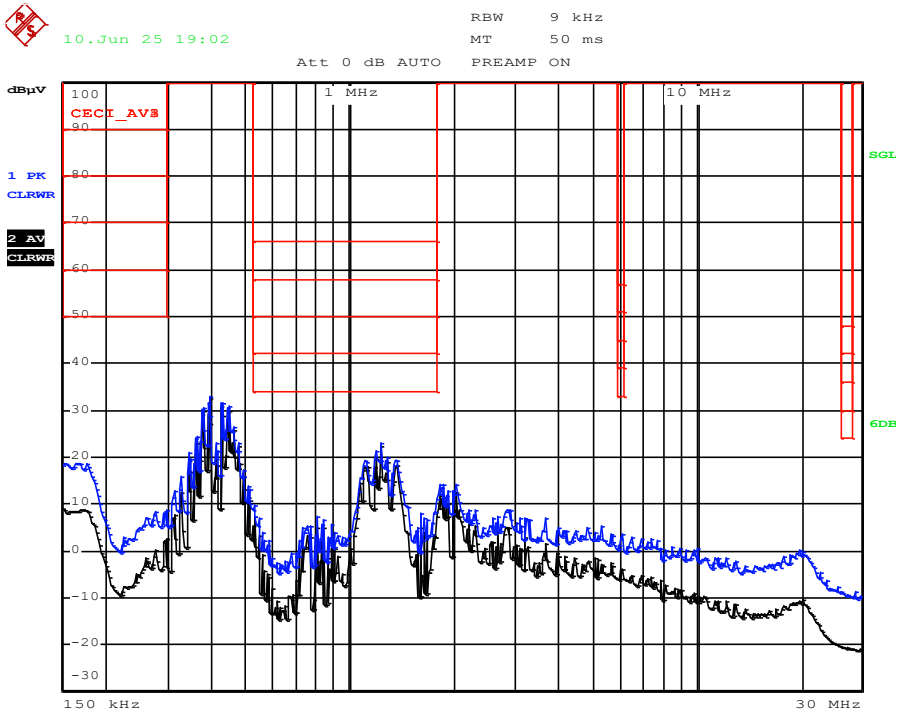
Temperaturna obremenitev: **46.62 °C**



Sašo Domadenik – EMC

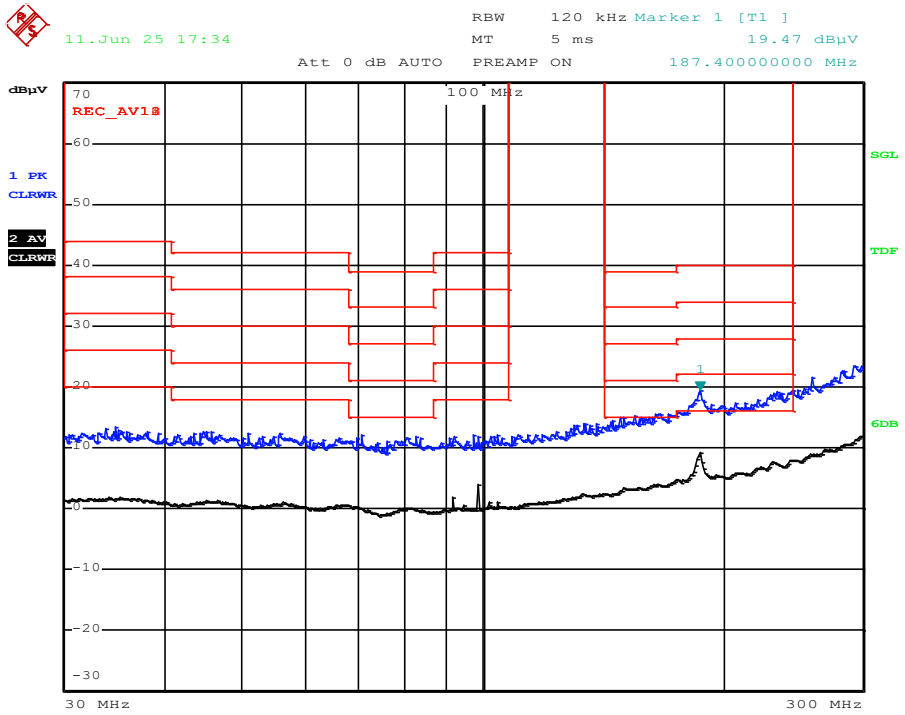
CE

5



RE

5



BCI

100 mA

A

RI

100 V/m H+V

A

Sašo Domadenik – Cena

Designator	Opis elementa	Koda proizvajalca	Proizvajalec	Koda dobavitelja	Dobavitelj	Cena/kos (10000 vezij)	Št. kosov na vezje	Cena za št. kosov
C1, C4, C5, C7, C8, C9, C10, C11, C20, C21, C22	Mali kondiči	N/A	N/A	N/A	N/A	0.0050 €	11	0.0550 €
C2, C3	Capacitor	CC1206KKX7R7BB225	YAGEO	C107183	LCSC	0.0145 €	2	0.0290 €
C6, C12, C13, C14, C15, C16, C17, C18, C19	**Capacitor**	**CL31B106KAHNNNE**	**Samsung Electro-Mechanics**	**C14860**	**LCSC**	**0.0129 €**	**9**	**0.1161 €**
D3, D4, D5, D6	Male diode	1N4148WT	onsemi	C232841	LCSC	0.0086 €	4	0.0344 €
IC1	Dvojni komparator	LM2903A-SR	3PEAK	C7496686	LCSC	0.0346 €	1	0.0346 €
L1	Tuljava za switcher	CY54-33UH	SHOU HAN	C2929433	LCSC	0.0231 €	1	0.0231 €
L2	Tuljava za filter	SL0420-4R7M	TECHFUSE	C22463808	LCSC	0.0523 €	1	0.0523 €
L3	Ferrite bead	FBMJ2125HS420-T	TAIYO YUDEN	963-FBMJ2125HS420-T	Mouser	0.0220 €	1	0.0220 €
Q1	N-MOS	2N7002K-T1-GE3	Vishay Intertech	C81445	LCSC	0.0176 €	1	0.0176 €
Q2	P-MOS	AO3401A	UMW(Youtai Semiconductor Co., Ltd.)	C347476	LCSC	0.0134 €	1	0.0134 €
Q3, Q4	PNP	BC856C	Guangdong Hottech	C181145	LCSC	0.0060 €	2	0.0120 €
R1, R2, R3_1, R3_2, R4, R5, R7, R8, R9, R11, R12, R13, R14, R15, R16, R18	Upori	N/A	N/A	N/A	N/A	0.0050 €	16	0.0800 €

Št. komponent	Cena komponent	Cena polaganja	Skupaj
50	0.49 €	0.50 €	0.99 €

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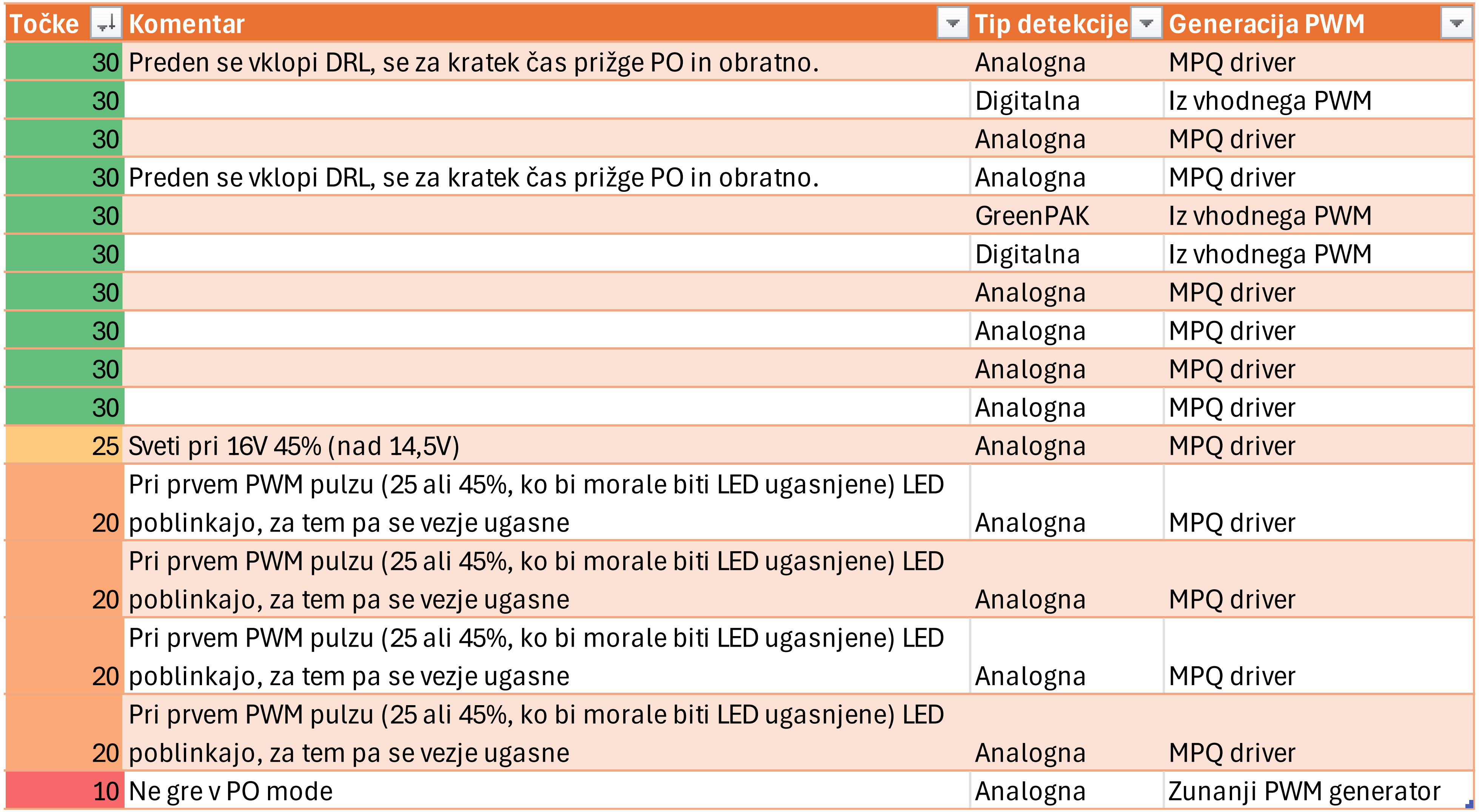
in optoelektroniko

Povzetek rezultatov

PWM test

Točke	Frekvenca	Komentar	Tip detekcije	Generacija PWM
30	514	Preden se vklopi DRL, se za kratek čas prižge PO in obratno.	Analogna	MPQ driver
30	201		Digitalna	Iz vhodnega PWM
30	511		Analogna	MPQ driver
30	498	Preden se vklopi DRL, se za kratek čas prižge PO in obratno.	Analogna	MPQ driver
30	201		GreenPAK	Iz vhodnega PWM
30	201		Digitalna	Iz vhodnega PWM
30	500		Analogna	MPQ driver
30	505		Analogna	MPQ driver
30	497		Analogna	MPQ driver
30	496		Analogna	MPQ driver
30	512		Analogna	MPQ driver
20	507	Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	Analogna	MPQ driver
20	506	Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	Analogna	MPQ driver
20	513	Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	Analogna	MPQ driver
15	488	Pri 80% vezje preklaplja med DRL in PO, (utripa med 77 in 80%). Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne.	Analogna	MPQ driver
10	201	Vezje ne gre v PO mode, tok je, Pri 25% ima 73% izhodnega duty cycla	Analogna	Zunanji PWM generator

Napetostni test



Točke	Komentar	Tip detekcije	Generacija PWM
30	Preden se vklopi DRL, se za kratek čas prižge PO in obratno.	Analogna	MPQ driver
30		Digitalna	Iz vhodnega PWM
30		Analogna	MPQ driver
30	Preden se vklopi DRL, se za kratek čas prižge PO in obratno.	Analogna	MPQ driver
30		GreenPAK	Iz vhodnega PWM
30		Digitalna	Iz vhodnega PWM
30		Analogna	MPQ driver
30		Analogna	MPQ driver
30		Analogna	MPQ driver
30		Analogna	MPQ driver
25	Sveti pri 16V 45% (nad 14,5V)	Analogna	MPQ driver
20	Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	Analogna	MPQ driver
20	Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	Analogna	MPQ driver
20	Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	Analogna	MPQ driver
20	Pri prvem PWM pulzu (25 ali 45%, ko bi morale biti LED ugasnjene) LED poblinkajo, za tem pa se vezje ugasne	Analogna	MPQ driver
10	Ne gre v PO mode	Analogna	Zunanji PWM generator

Temperaturni test

Točke	Komentar	Tip detekcije	Generacija PWM
30		Analogna	MPQ driver
30		Digitalna	Iz vhodnega PWM
30		Analogna	MPQ driver
30		Analogna	MPQ driver
30		GreenPAK	Iz vhodnega PWM
30		Digitalna	Iz vhodnega PWM
30		Analogna	MPQ driver
30		Analogna	MPQ driver
30		Analogna	MPQ driver
30		Analogna	MPQ driver
30		Analogna	MPQ driver
20	Pri prvem pulzu na 45% utripne, za tem ugasne	Analogna	MPQ driver
20	Pri prvem pulzu na 45% utripne, za tem ugasne	Analogna	MPQ driver
20	Pri prvem pulzu na 45% utripne, za tem ugasne, Pri 60°C, 45%, vezje sveti v PO	Analogna	MPQ driver
20	Pri prvem pulzu na 45% utripne, za tem ugasne	Analogna	MPQ driver
10	Ne gre v PO	Analogna	Zunanji PWM generator

BCI

Točke	Komentar	Tip detekcije	Generacija PWM
40		Analogna	MPQ driver
40		Digitalna	Iz vhodnega PWM
40		Analogna	MPQ driver
40		GreenPAK	Iz vhodnega PWM
40		Digitalna	Iz vhodnega PWM
40		Analogna	MPQ driver
40		Analogna	MPQ driver
40		Analogna	MPQ driver
40		Analogna	MPQ driver
40		Analogna	MPQ driver
40		Analogna	MPQ driver
20	318MHz, svetilnost se poveča čez meje 10%	Analogna	MPQ driver
20	100mA, cca 60MHz, vklopi se DRL, 60mA je OK	Analogna	MPQ driver
10	Pri 20MHz se intenziteta poveča za več kot 30%, tudi na 60mA	Analogna	MPQ driver
10	Vezje se "zadima", ne ugasne 100%, vidno na kameri, tudi na 60mA ni znotraj 30%	Analogna	MPQ driver
0	Ne moremo pomeriti, ne deluje PO	Analogna	Zunanji PWM generator

RI

Točke	PWM	Komentar	Tip detekcije	Generacija PWM
40	45		Analogna	MPQ driver
40	43.5		Digitalna	Iz vhodnega PWM
40	44.5		Analogna	MPQ driver
40	46		Analogna	MPQ driver
40	52		GreenPAK	Iz vhodnega PWM
40	52.5		Analogna	MPQ driver
40	67		Analogna	MPQ driver
40	62.5		Analogna	MPQ driver
40	50.5		Analogna	MPQ driver
40	63		Analogna	MPQ driver
40	57		Analogna	MPQ driver
40	39		Analogna	MPQ driver
40	42		Analogna	MPQ driver
20	52.5	Fail na 100V/m 1Ghz	Digitalna	Iz vhodnega PWM
20	58	H OK, Fail na 100V/m vertikalno 1GHz, na 75V/m je	Analogna	MPQ driver
0	0	Ne moremo pomeriti, ne deluje	Analogna	Zunanji PWM generator

Izkoristek

Izkoristek	Točke	RP	Filter	Izklop
92	14	Idealna dioda z analognim krmljenjem.	DM filter	prek NTC vhoda
91	12	Idealna dioda s čipom	DM filter	Prek EN vhoda
91	12	Idealna dioda z analognim krmljenjem 2x	DM filter	prek NTC vhoda
91	12	Idealna dioda z analognim krmljenjem.	DM filter	prek NTC vhoda
90	10	Idealna dioda z analognim krmljenjem.	DM filter	prek NTC vhoda
90	10	Idealna dioda s čipom	DM filter	Prek EN vhoda
89	8	Schottky dioda	DM in CM filter	Prek EN vhoda
89	8	Schottky dioda	2x DM filter	prek MOS tranz.
88	6	Schottky dioda	DM filter	prek NTC vhoda
88	6	Schotky + Idealna dioda z analognim krmljenjem	DM filter	prek MOS tranz.
88	6	Schottky dioda	DM filter	prek NTC vhoda
87	4	Schottky dioda	Ni filtra	prek NTC vhoda
86	2	Idealna dioda z analognim krmljenjem.	DM filter	prek NTC vhoda
86	2	Schottky dioda	DM filter	prek MOS tranz.
85	0	Schottky dioda	DM filter	prek NTC vhoda
73	-24	Idealna dioda s čipom	DM filter	prek MOS tranz.

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Glasujte

https://forms.gle/B2cjJNX9tkwTUFzg7