KOLEKTOR

Kolektor Mobility Electronics & Drives **Development**

Idrija, February 2025

ABOUT US

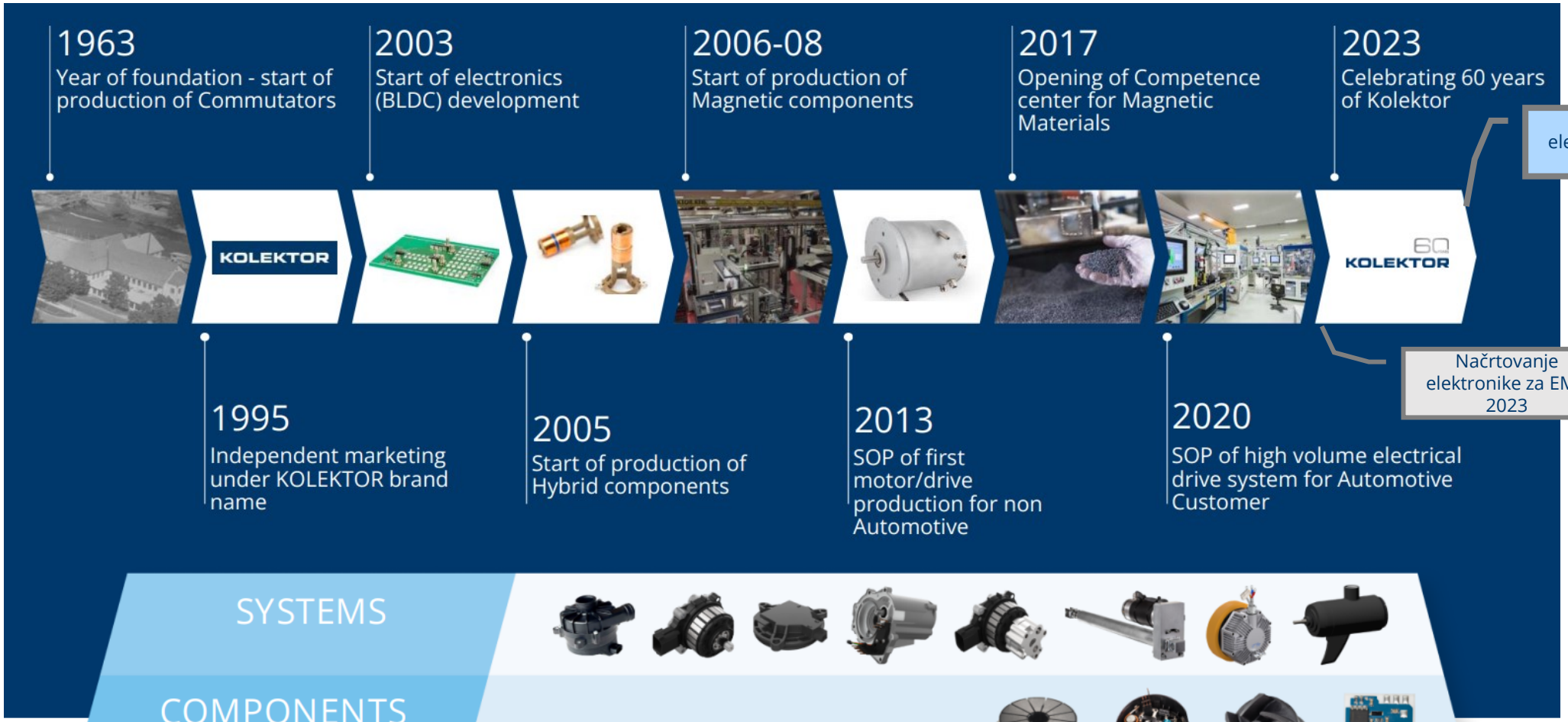
- HEADQUARTERS | Idrija, Slovenia, EU
- 3369 employees
- EUR 396 million in turnover
- 18 legal entities
- FIELDS | passenger cars, commercial vehicles, industry
- Following the megatrend of the green transition to a carbon-free society

*All information is related to the fiscal year 2023

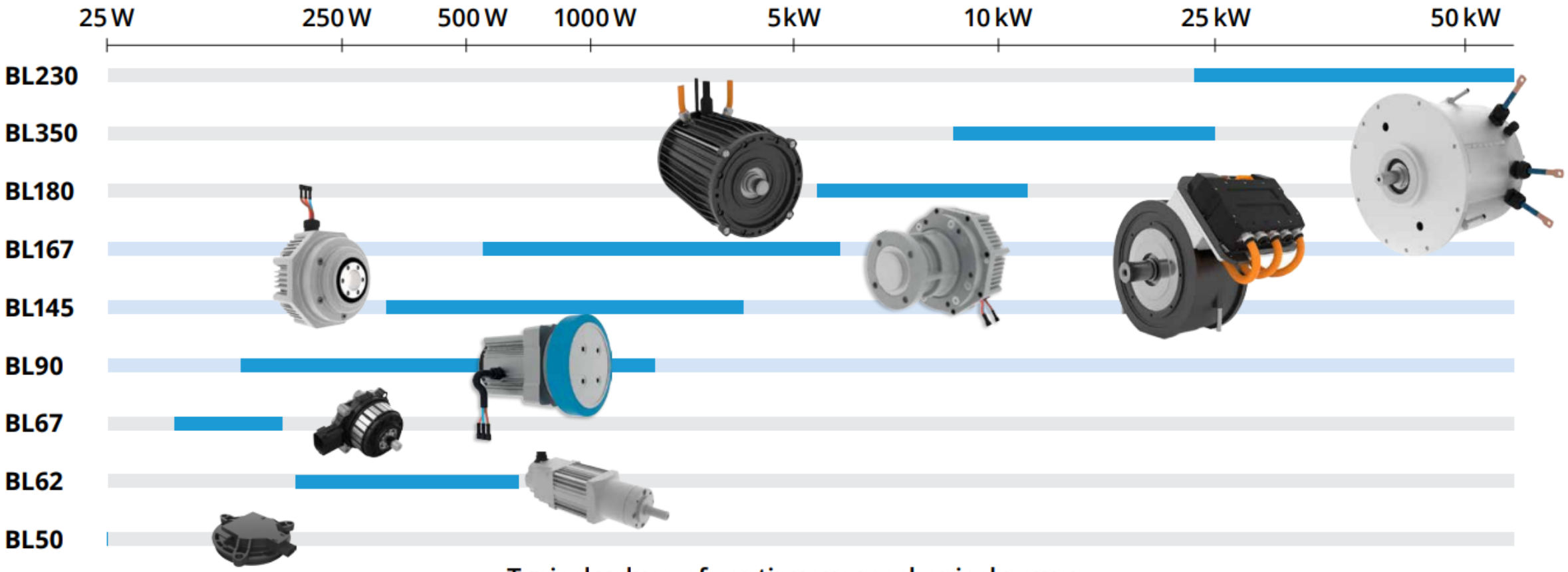
+ dodatna razvojna lokacija LJ Magma, Stegne

KOLEKTOR Mobility

Kolektor Mobility Key Milestones



PERMANENT MAGNET BRUSHLESS MOTORS AND DRIVES



Typical values of continuous mechanical power

AUTOMOTIVE & COMMERCIAL VEHICLE DRIVES

DRIVES AND VACUUM PUMPS

ACTUATOR DRIVES AND ELECTRIC OIL PUMPS

ELECTRICAL MOTORS

Oil mist separation

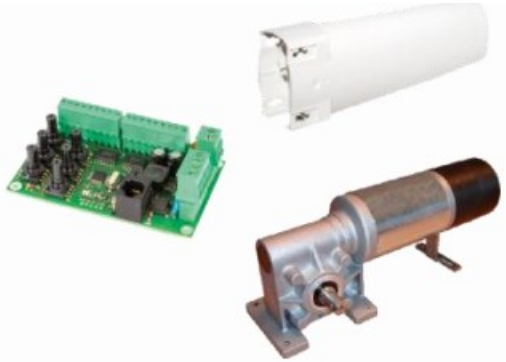
E-transmission

E-clutch

INDUSTRIAL AND OFF-HIGHWAY DRIVES

Industrial automation

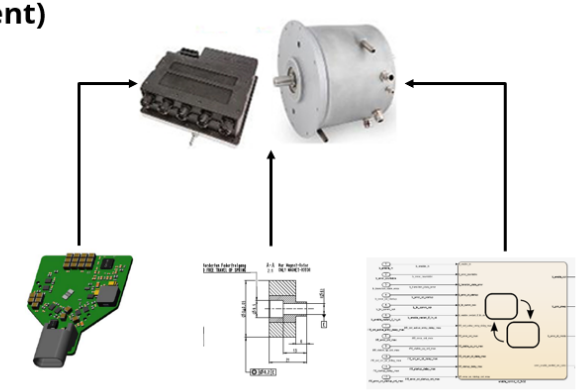
Marine



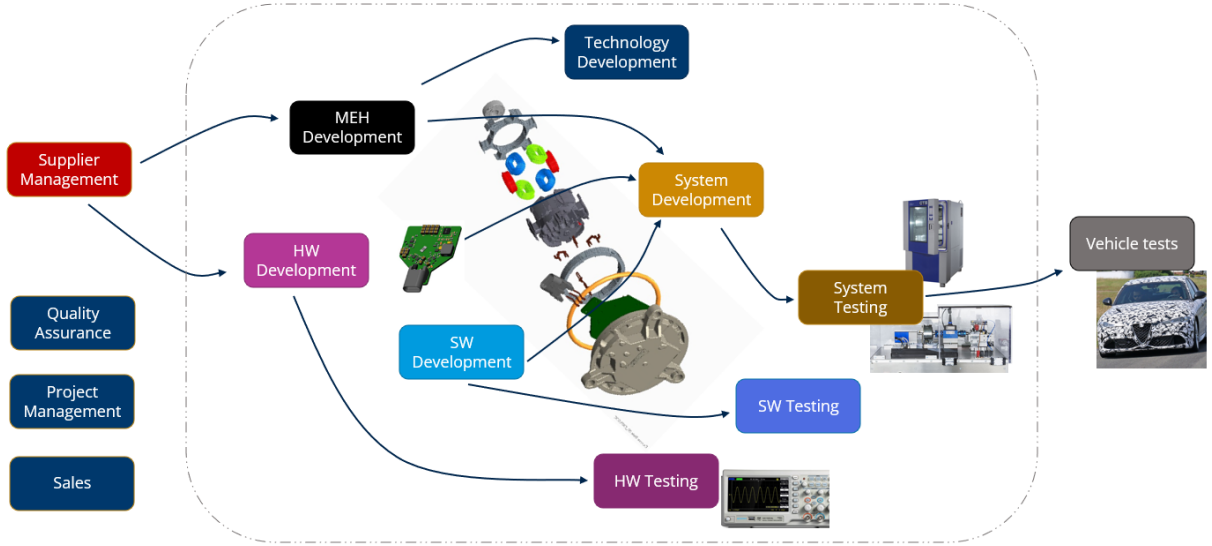
Building automation

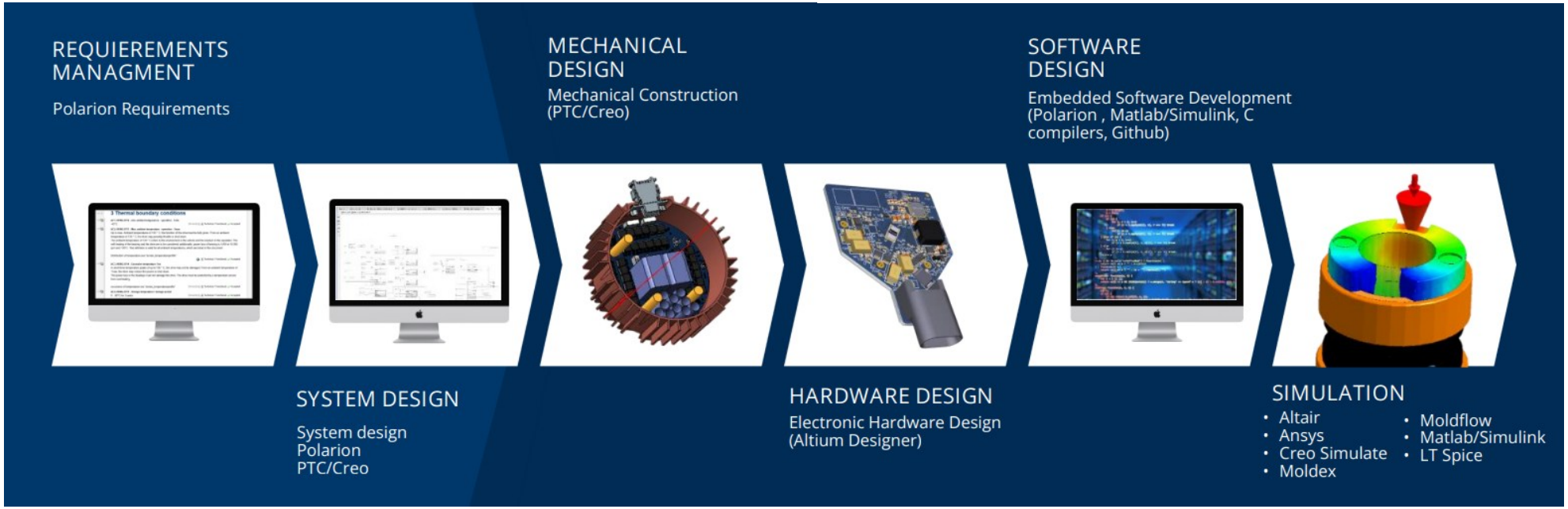
Development Framework

- **APQP frame (design & production development)**
- **4 main domains of development**
  - System
  - Mechanics
  - Software
  - Hardware
- **IATF certified development**
- **Automotive SPICE based processes**
- **Hardware SPICE based processes**
- **ISO 26262, 61508 ready**



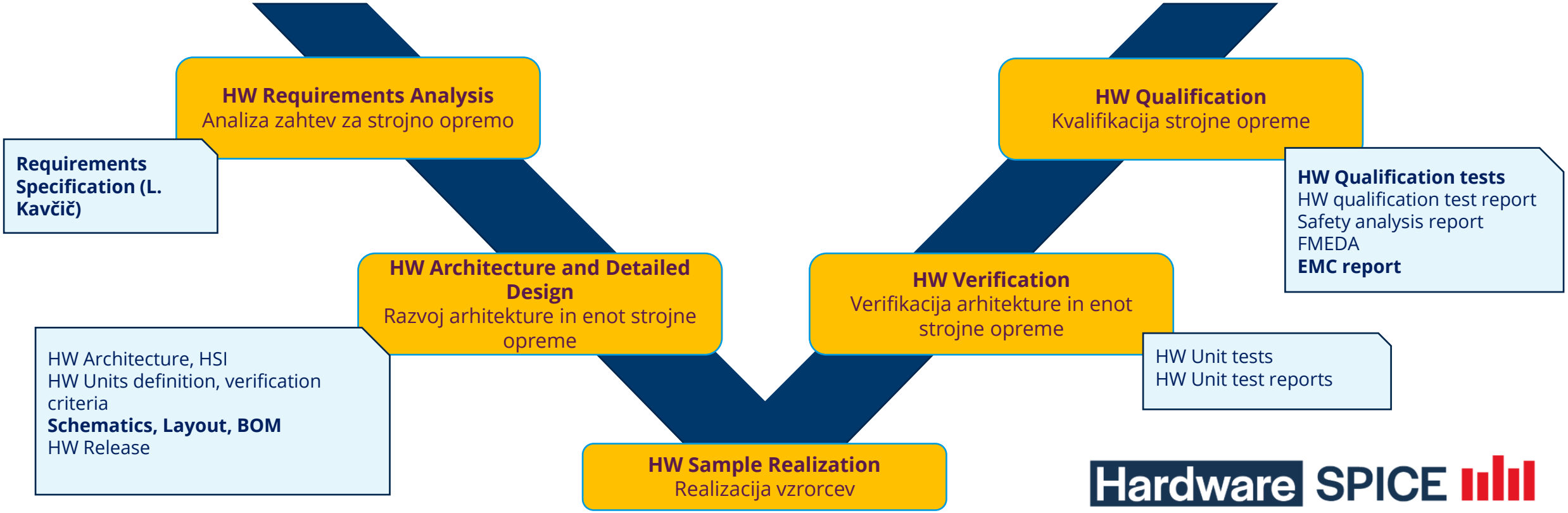
AUTOMOTIVE SPICE®





Kolektor Hardware Development Process Overview

HW processes are developed according to intacs Hardware SPICE process assessment model v2.1. The processes are based on a “plug-in“ principle for existing Automotive SPICE framework for SYS and SW development.



Hardware SPICE

Kolektor Hardware Development Process Example

HW Requirements Analysis

1.8 Power Stage Requirem

2409-30755 - Power stage shall be capable of providing continuous phase current of 2409-30847 - I_AC_PHASE_CONT_MAX = 35 A.
MODUL ELEKTRONSKI 13_2409_03 Rev_A, [Variant(s)], Accepted, Non Functional

2409-30849 - Phase over or under-shoot shall be lower than 2409-30848 - U_PH_OVERSHOOT_MAX = 4 V.
MODUL ELEKTRONSKI 13_2409_03 Rev_A, [Variant(s)], Accepted, Non Functional

2409-30894 - Power stage shall operate at PWM frequency 2409-30892 - F_PWM = 12 kHz.
MODUL ELEKTRONSKI 13_2409_03 Rev_A, [Variant(s)], Accepted, Information

2409-30893 - Power stage shall operate at dead-time set point of 2409-30852 - T_DEAD = 800 ns.
MODUL ELEKTRONSKI 13_2409_03 Rev_A, [Variant(s)], Accepted, Functional

1.9 Voltage & Current Sensing

2409-30718 - Hardware shall enable uC voltage sensing of all external supply voltages.
MODUL ELEKTRONSKI 13_2409_03 Rev_A, [Variant(s)], Accepted, Functional

2409-30699 - Drive shall implement a dual shunt current low-side measurement concept for the phase current.
MODUL ELEKTRONSKI 13_2409_03 Rev_A, [Variant(s)], Accepted, Design Decision

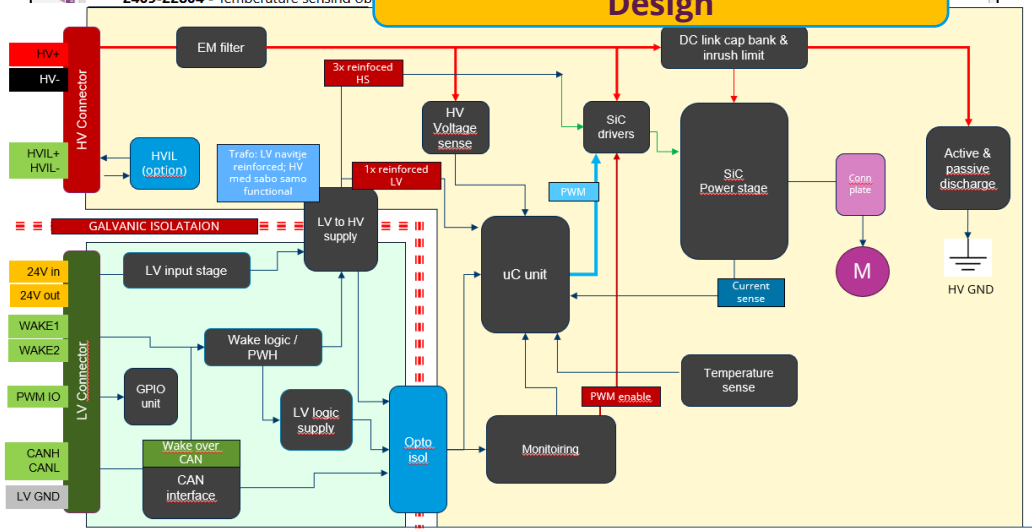
2409-30701 - Voltage measurement is implemented on the DC link (Vbus) power line on the power stage.
MODUL ELEKTRONSKI 13_2409_03 Rev_A, [Variant(s)], Accepted, Design Decision

2409-30900 - All voltage measurements are implemented by a direct ADC acquisition via resitor divider, capacitor and a double diode protector.
MODUL ELEKTRONSKI 13_2409_03 Rev_A, [Variant(s)], Accepted, Design Decision

1.10 Temperature Se

2409-22804 - Temperature sensing ob

HW Architecture and Detailed Design



HW Verification (HW Unit testing)

2409-22841
2409-26533 - Unit Test: Brake Interface REV_A | Induction load switchinc
2409-30961

Type:	Test Case	Requirement origin:	Internal
Project:	13_2409_D_ESP2	Customer DVP Relevant:	No
Author:	Kristjan Saksida	DUT:	
Test Level:	HW Unit	No. of DUTs:	1
Test Methods:	Requirements Based	Resp. for Execution:	Internal
Test Environment:	HW Test Bench	Customer ID:	
Categories:	Strojna oprema		
*Variant(s):			

Description

Targets:
Quantifying V_{DS} overshoot and ringing amplitude/frequency during hard switching of the lo

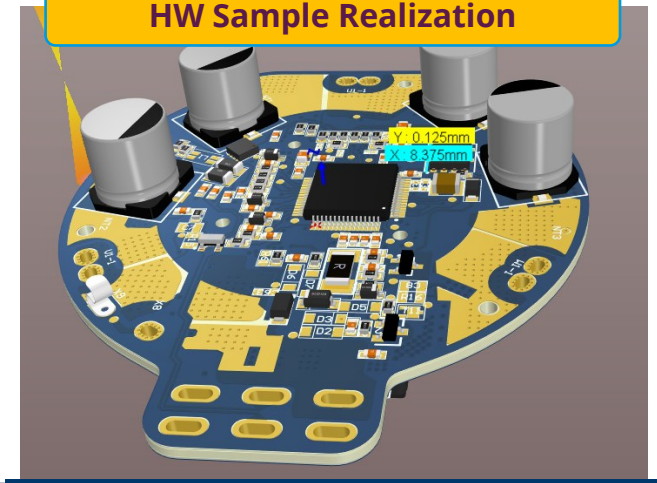
Test type:

- Electrical

Operating point (torque and speed):
No rotation of the motor, brake engaging and disengaging conditions.

Parameter	Value	Increment

HW Sample Realization



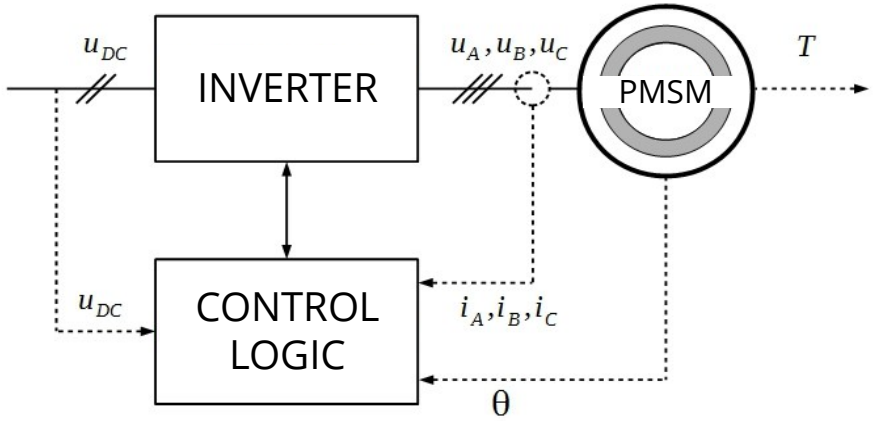
HW Qualification

6. Verdict summary section

Test	Pt. within the report	Conclusion
EQ/IC 01: Resistance to the pulses 1 and 2a	8.1	P
EQ/IC 02: Resistance to pulses 3a and 3b	8.2	P
EQ/IC 03: Resistance to 5b pulses	8.3	P
EQ/IC 04: Resistance to short interruption of the power supply	8.4	P
EQ/IC 07: Immunity to the transients on the signal lines	9.1	P
EQ/IC 08: Immunity to current injection (BCI)	9.2	P
EQ/IR 01: Immunity to radiated electric field (semi-anechoic or anechoic)	9.3	P
EQ/IR 02: Immunity to low frequency magnetic field	9.4	P
EQ/IR 03: Resistance to electrostatic discharges, equipment not connected	9.5	P
EQ/IR 04: Resistance to electrostatic discharges, switched on equipment	9.6	P
EQ/IR 05: Immunity to onboard transmitters	9.7	P
Immunity to transients with wire to wire coupling (EMC12)	9.8	P
EQ/MC 02: Measurement of low frequency conducted noises	10.1	P
EQ/MC 03: Measurement of radio frequency conducted noises on the power supply inputs	10.2	P

Hardware SPICE

General Embedded Software Functionality



Motor control
- FOC, Field weakening
- Control Loops - Position, Speed, Torque

Sensing
- Temperature Management (Sensors, i2t, Derating)
- Current Sensing (Three phase current reconstruction for cost effective solutions)
- Positon Sensing (Sensored – linearization, sensorless opreation in wide temp range -40°C,150°C)

Communication
- Control, Configuration, SW updates - bootloader
- HW layers (LIN, CAN, RS485)
- Application layers (UDS, J1939, CANopen CiA 301 CiA 402, Modbus)

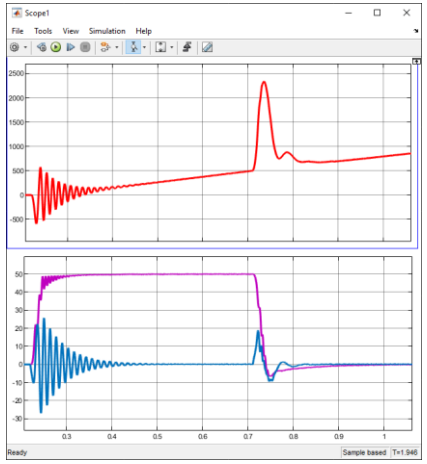
Cybersecurity
- ISO 21434

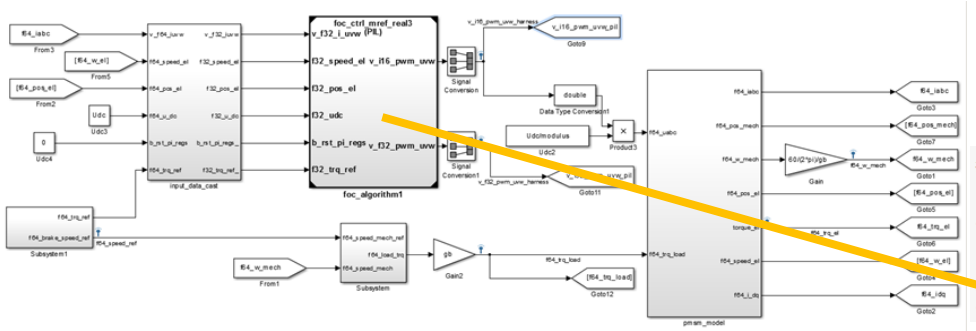
Combination of Model Based Design and C code design

Model Based Design enables SW
- **Design**
- **Simulation**
- **Verification !**

in virtual environment

Simulation of complete system
Autogenerated code from SW model



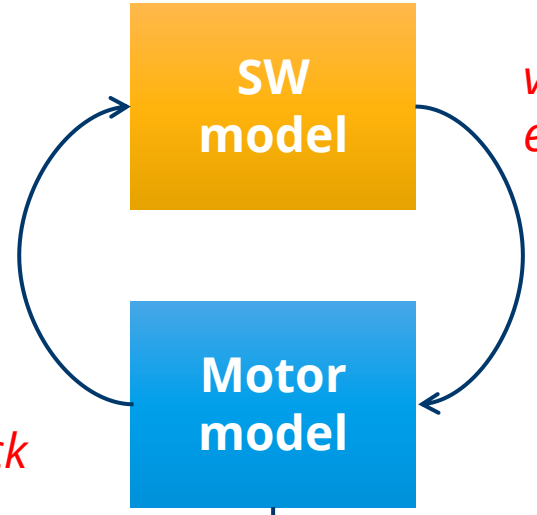


```c
#include <stdio.h>

int main() {
    printf("Hello world");
    return 0;
}
```

0111
1101

current feedback



voltage excitation

torque generation

$$u_d = R_s i_d + L_d \frac{di_d}{dt} - \omega_{el} L_q i_q$$

$$u_q = R_s i_q + L_q \frac{di_q}{dt} + \omega_{el} L_d i_d + \omega_{el} \psi_m$$

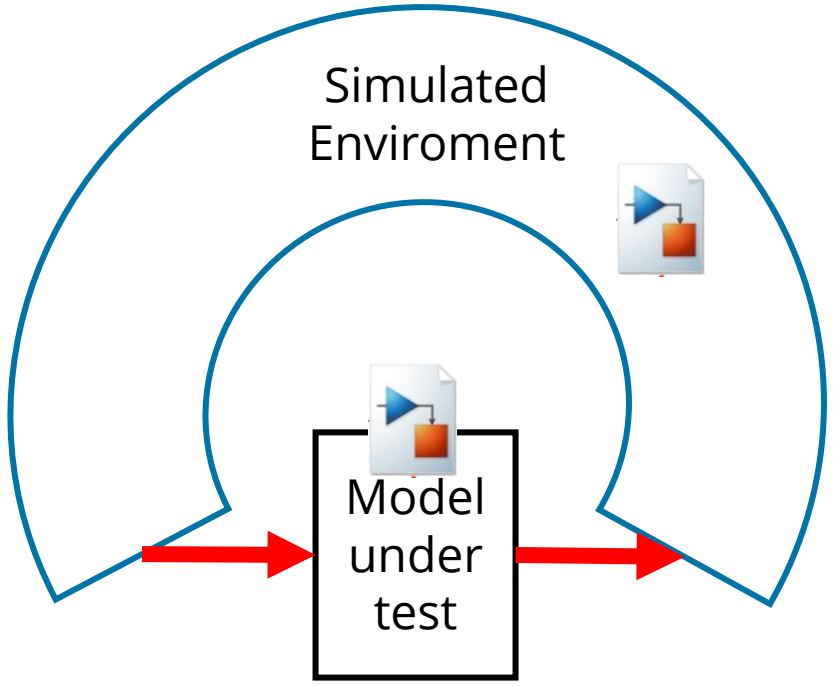
$$T_e = \frac{3}{2} p(\psi_m i_q + (L_d - L_q) i_d i_q)$$

$$J \frac{d\omega_{meh}}{dt} = T_e - T_L - B\omega_{meh}$$

SW verification

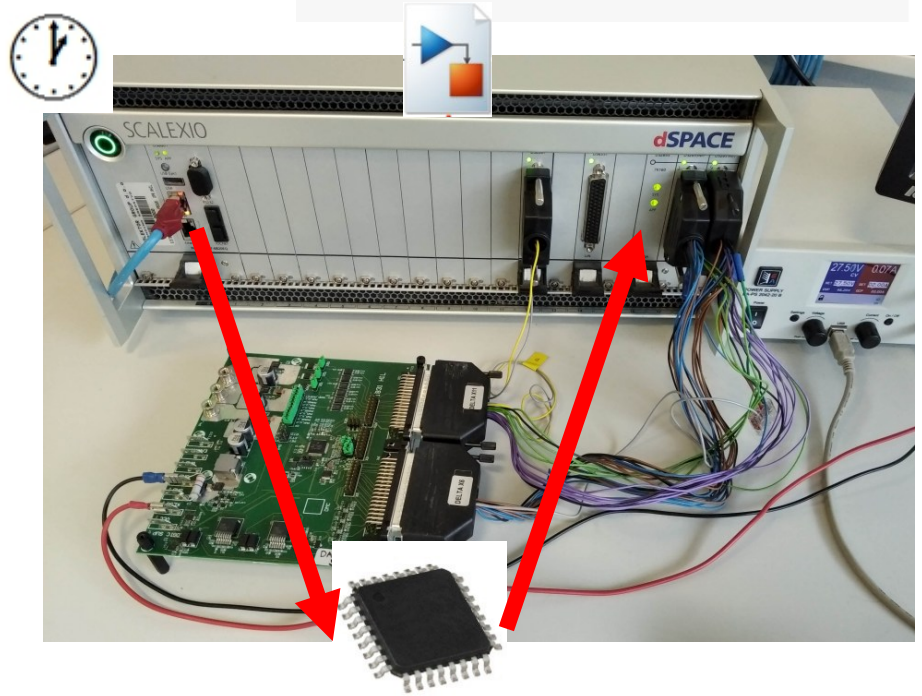
Model In the Loop - Simulation

MATLAB SIMULINK

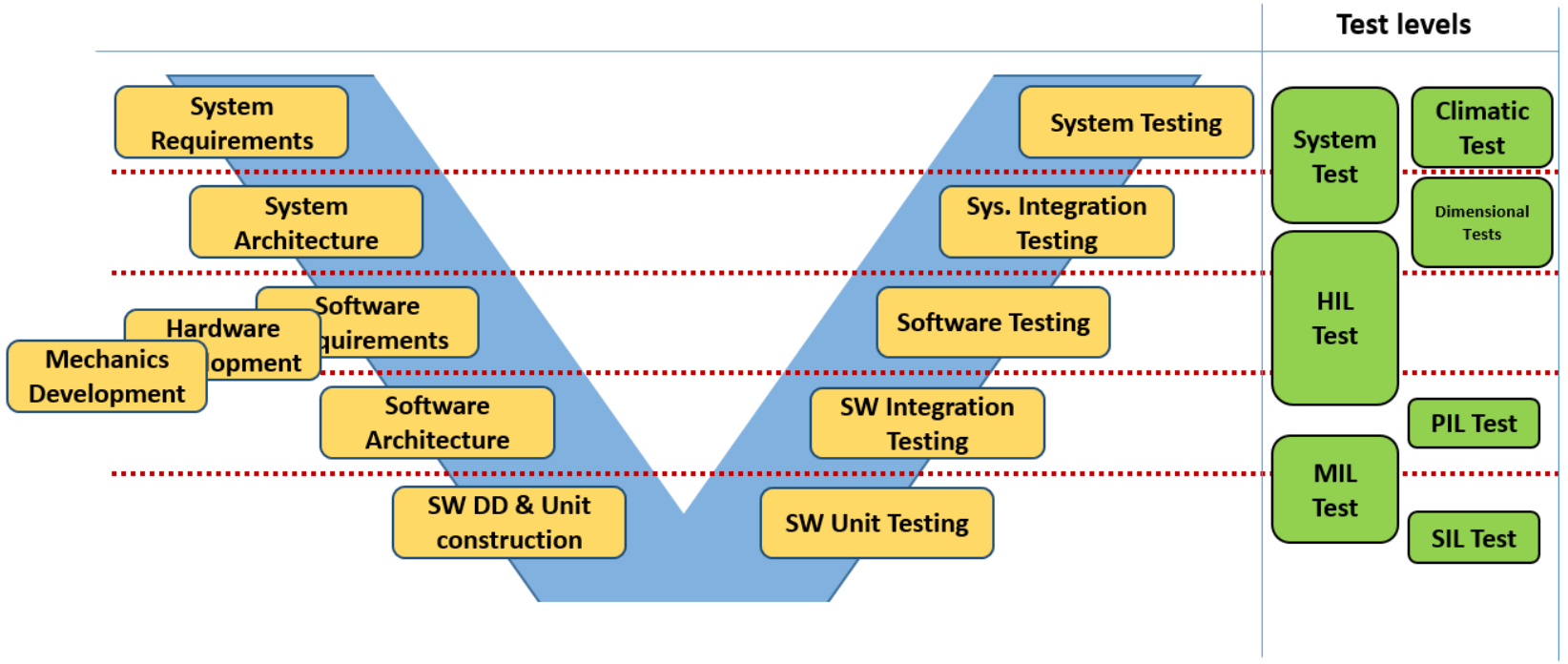


Hardware In the Loop – real time

dSPACE



Software Development Process Capability

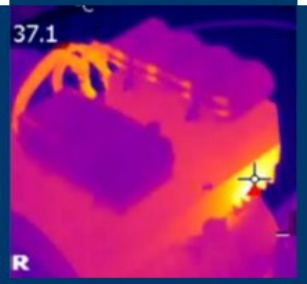


- [illegible]
- [illegible]
- [illegible]
- [illegible]

TESTING & VALIDATION CAPABILITES

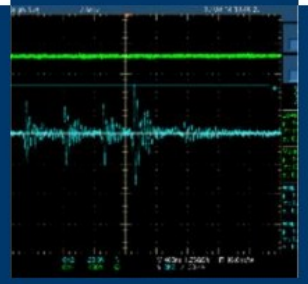
design & process validation tests can be performed internally

THERMAL TESTS



- Temperature Chambers
- Climatic Test Chambers
- Temperature Shock Chambers
- IR Measurement Equipment

ELECTRIC & ELECTRONIC



- Power Supplies
- Oscilloscopes with Probes
- Multi-meters
- Precise RLC Meters
- Low Resistance
- HV Insulation
- CTI Tester
- Nondestructive Insulation

DIMENSIONAL MEASUREMENTS

- High resolution optical 3D scanner
- Coordinate Measuring Machine
- 3D Optical Measuring Machine
- Form tester
- Conturograph

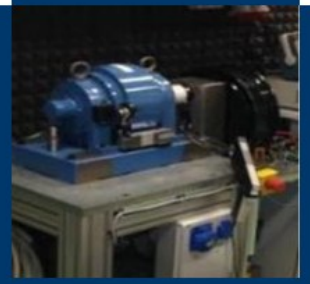
ADVANCED ANALYSIS

- SEM/EDX microscope
- CT Scanner
- Optical 3D microscope
- Confocal 3D microscope

MECHANICAL PROPERTIES

- Tensile strength
- Flexural strength
- Impact strength
- Hardness & Microhardness
- Spin testers

MOTOR & MOTOR CONTROL TESTS



- Computer Guided Test Benches
- Universal Test Benches
- Back-to-Back Test Benches

KOLEKTOR Mobility

VIBRATION TESTING

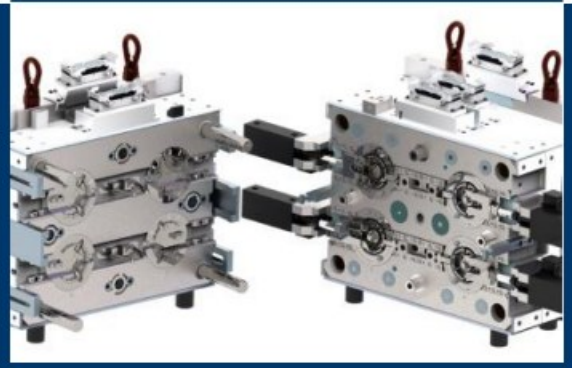
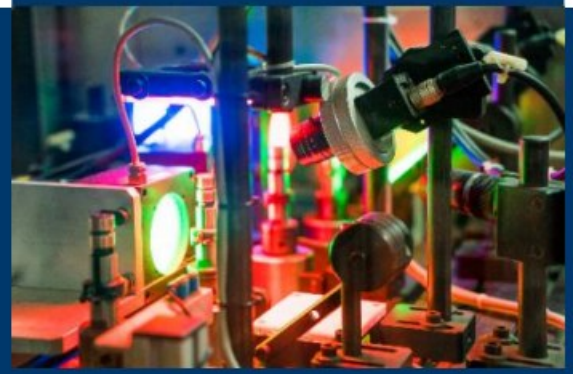
EMC testing at external contractor

SIQ

Plan 2026:

- **EMC pre-compliance chamber**
- **Media resistance chamber**

SUPPORTED BY

PROTOTYPE SHOP	TOOL SHOP	MACHINE BUILDING AND AUTOMATIZATION	END-OF-LINE TESTING
			

Typical industrial motion control drive

BL62 - PMBL Drive

Nominal DC voltage [V]	**48**
Nominal supply DC current [A]	**16,6**
Nominal phase current [A]	**18**
Nominal torque [Nm]	**1,5**
Nominal speed [RPM]	**4300**
Nominal mechanical power [W]	**676**
Nominal efficiency [%]	**85**
IP protection class	**IP65**
Weight [kg]	**3,5**
Gearbox ratio	**n/a**

Peak phase current [A]	**35**
Peak torque [Nm]	**3**
Peak torque speed [RPM]	**4000**
Peak mechanical power [W]	**1256**
Electromagnetic brake [V]	**24**
Encoder sensor type & voltage	**n/a**
Temperature sensor	**n/a**
Motor control unit	**YES**
MCU communication protocol	**CAN**

Features:
- CANopen
- Brake implementation

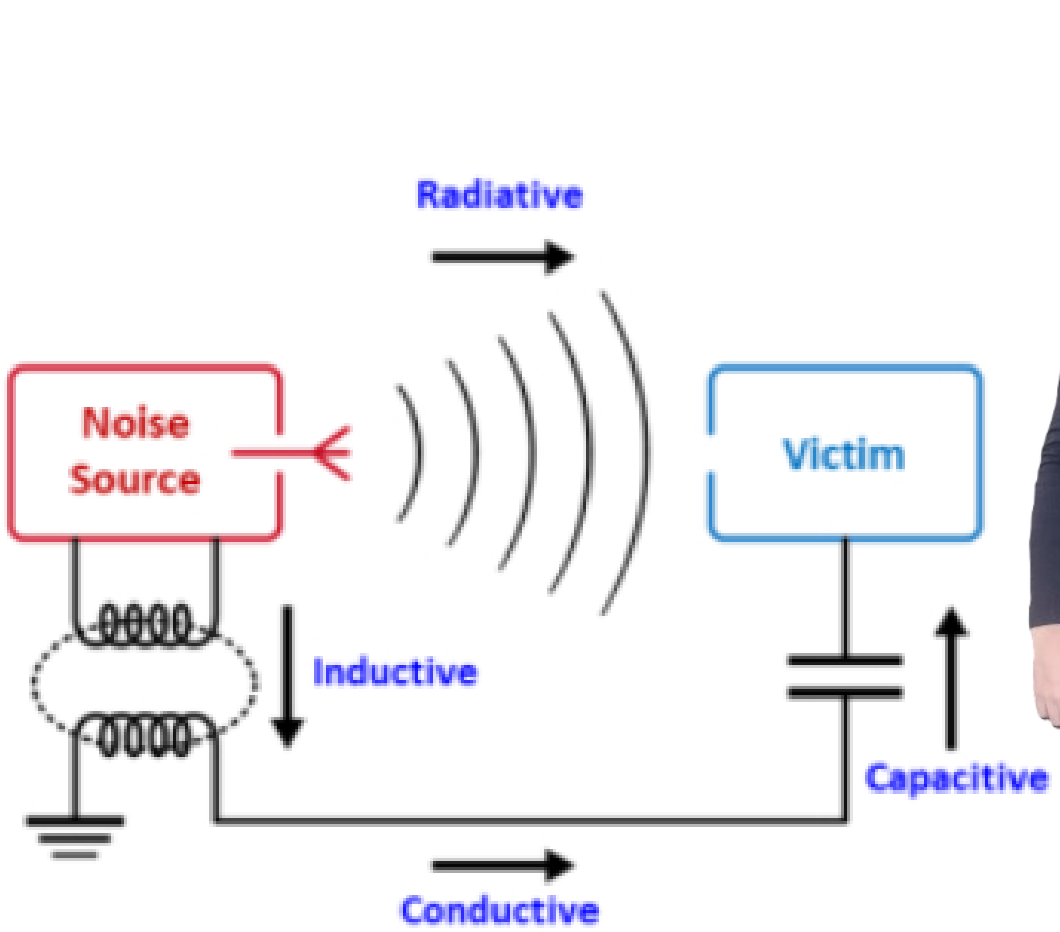
Safety functionality in development:
- STO
- SS1

Priložnost za zaposlitev

- **Razvojnik elektronskih vezij**
  - **Altium SCH/PCB razvoj**
- **Izbira komponent**
- **Simulacije LT Spice**
- **Testiranje HW enot / EMC testiranje**
- **Razvoj HW zahtev in zahtev za testiranje**
- **Zaželen zaključen magisterij smer Elektronika**
- **Delovno mesto LJ Stegne**

- **Kontakt jaka.ivancic@kolektor.com ali prek L. Kavčič**

EMC izziv....



Vir: esongemc.com; L.Kavčič

KOLEKTOR

Načrtovanje elektronike za EMC

Opis izziva: Pogon BLAC motorja

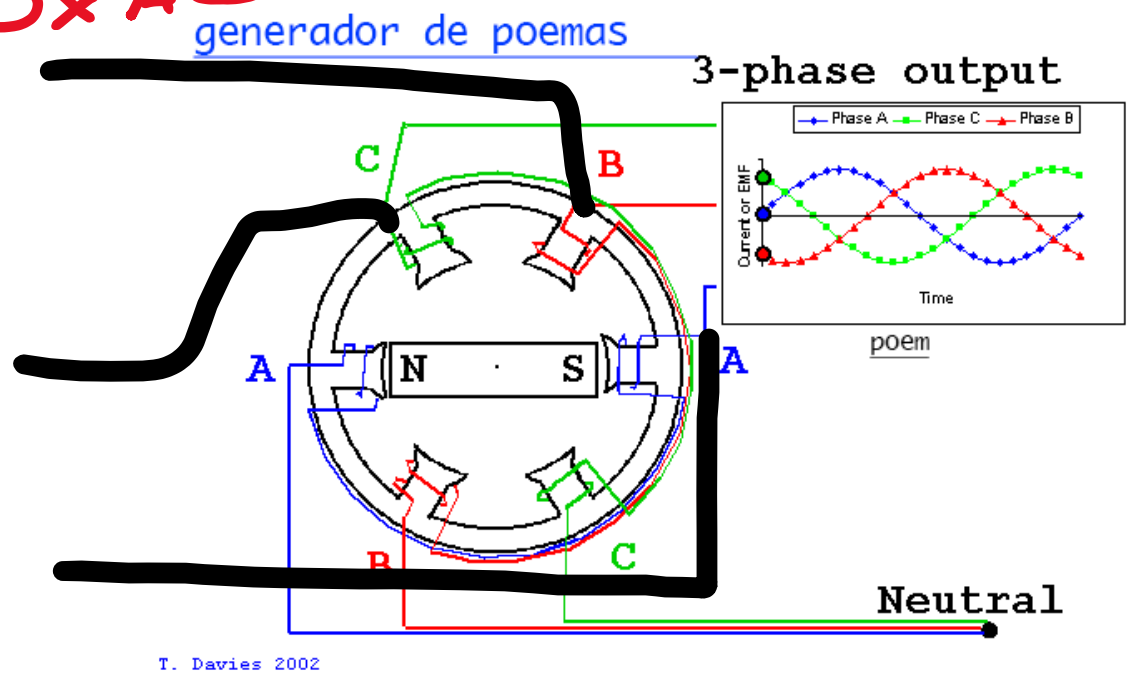
Luka Kavčič

24.2.2026

Kaj je brezkrtačni motor

DC

3x AC

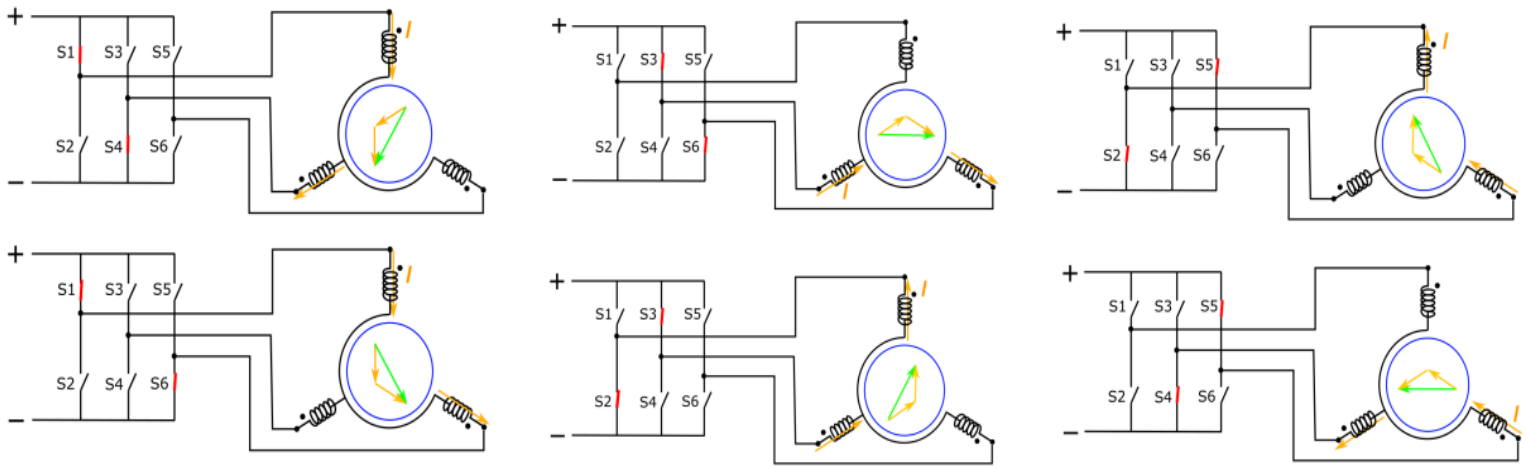


Če sem videl dlje, je to zato, ker sem stal na ramenih Velikanov. - Newton

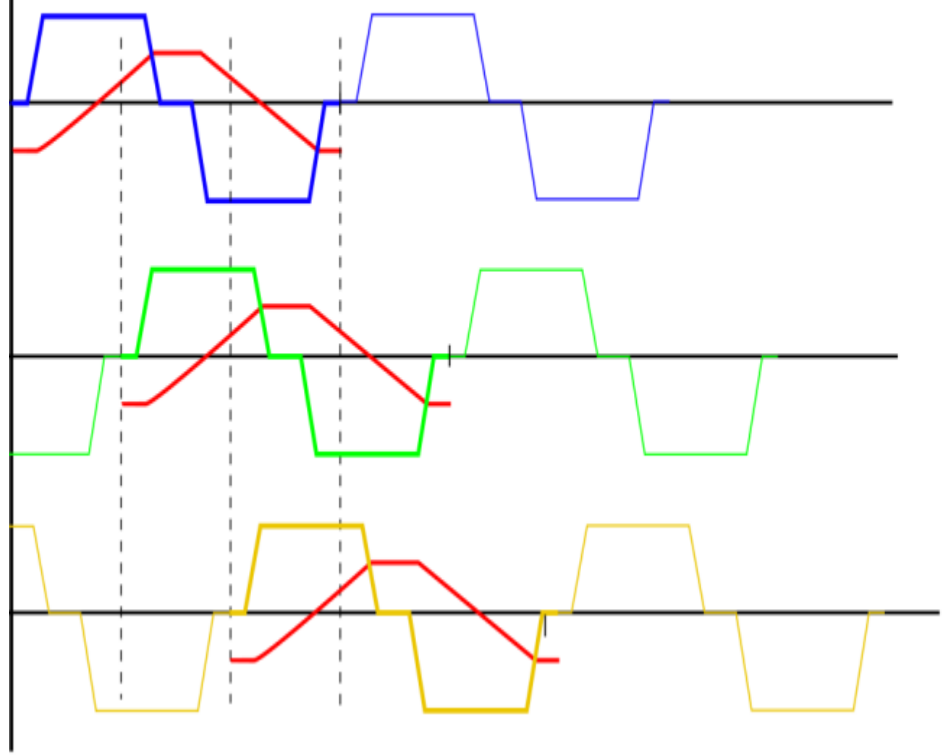
Stikala

University of Ljubljana
Faculty of Electrical Engineering
Laboratory for Electrical Machines

Preklapljanje stikal in vrtilno magnetno polje



Magnetni pretok in inducirane napetosti

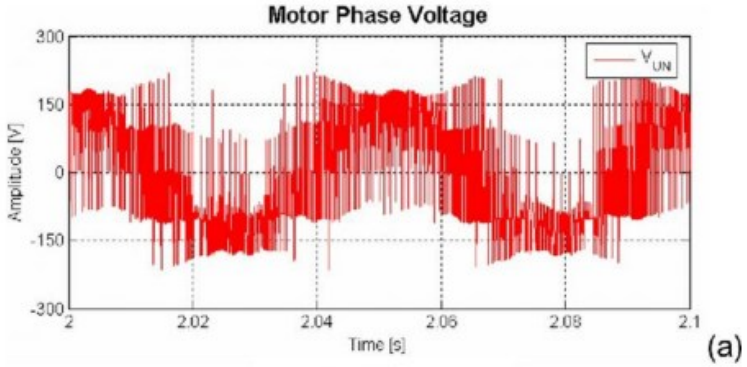


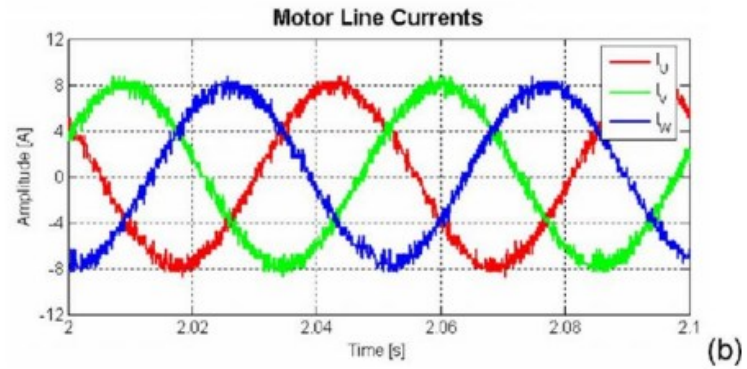
Prof. dr. Damijan Miljavec
28. 2. 2023 EMC 2023 (glavni sponzor Kolektor Mobility d.o.o.)

Hitrejša stikala

University of Ljubljana
Faculty of Electrical Engineering
Laboratory for Electrical Machines

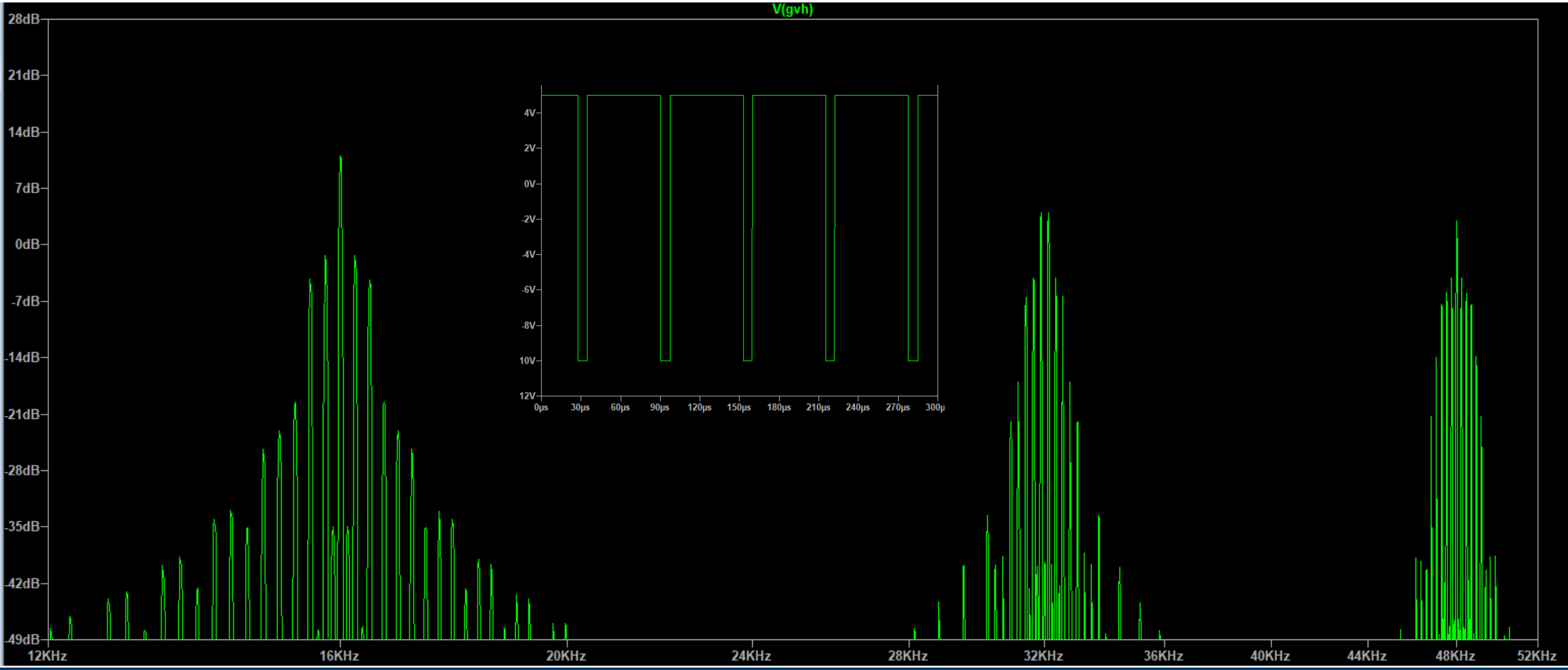
Trifazni sinusni toki



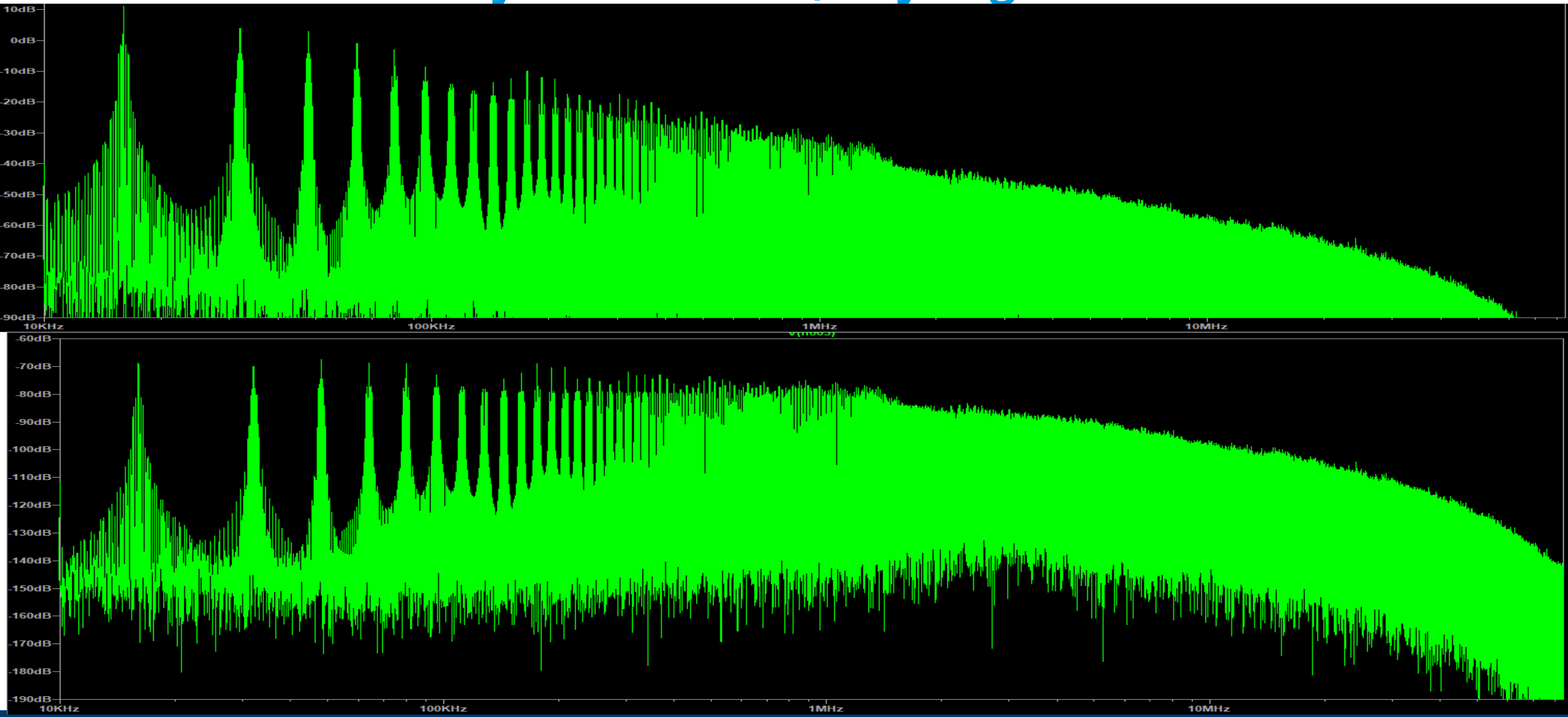


Prof. dr. Damijan Miljavec
28. 2. 2023 EMC 2023

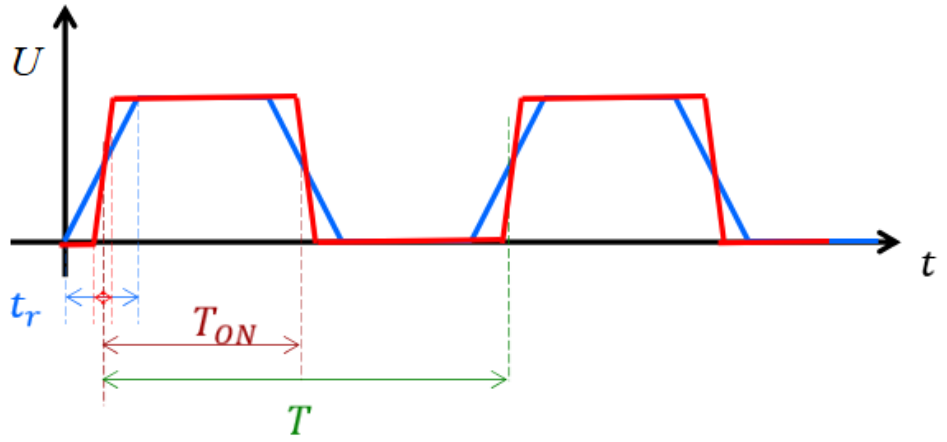
Zakaj merimo MHz, če je signal kHz

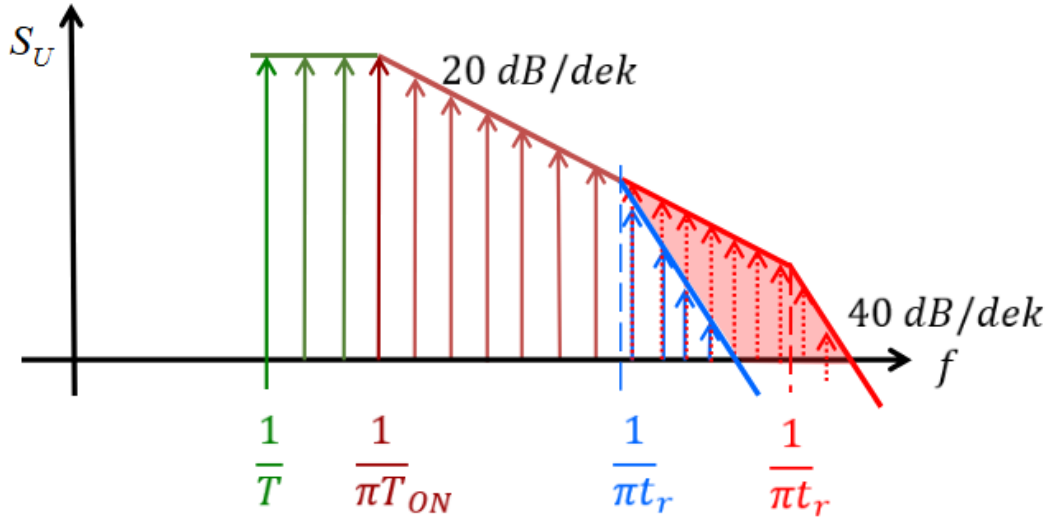


Zakaj merimo MHz, če je signal kHz

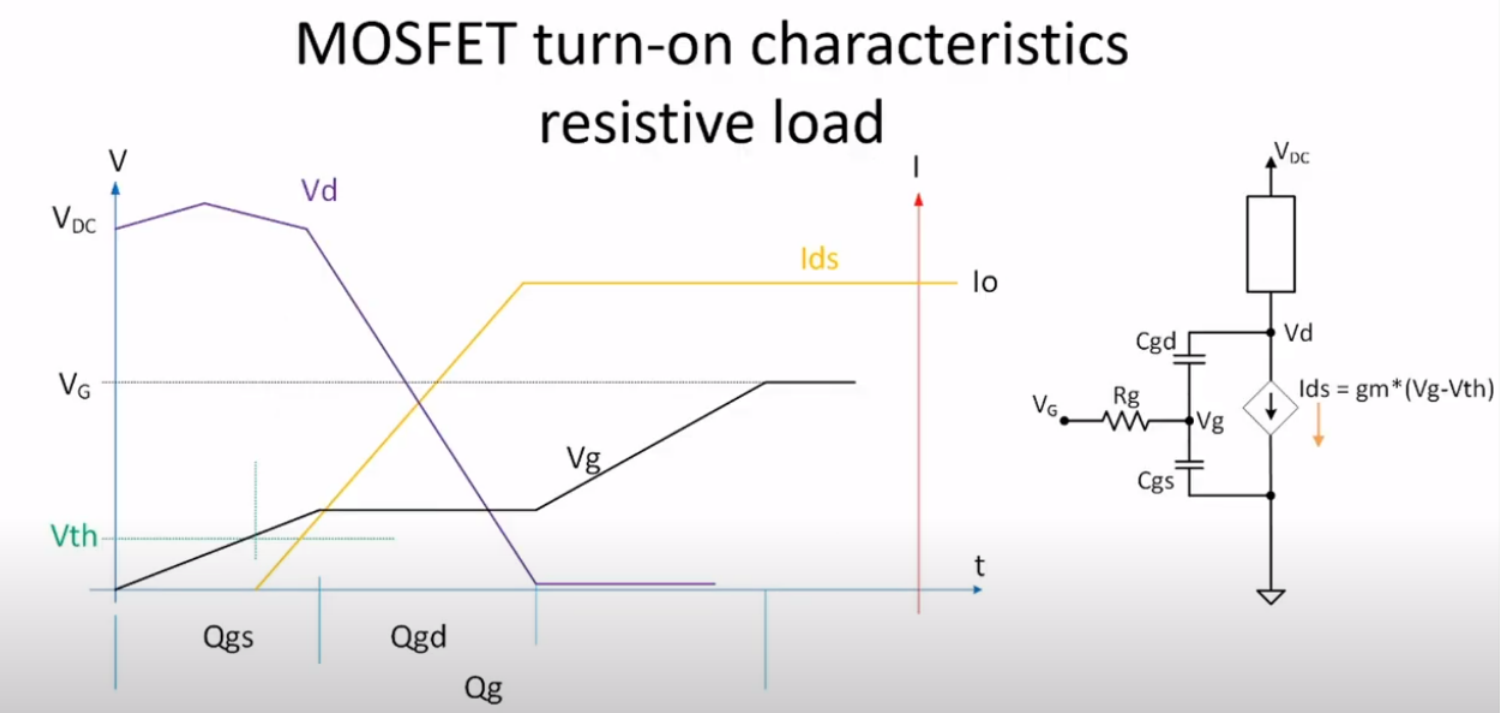


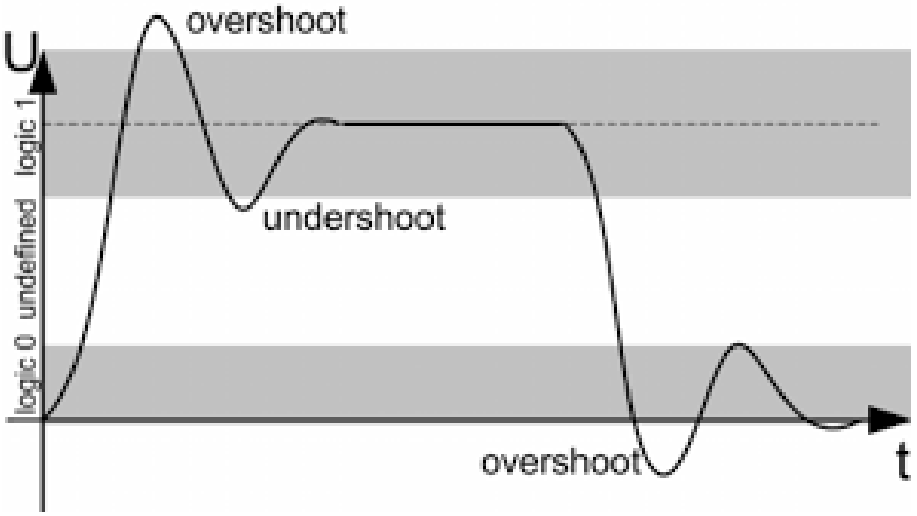
Kaj vpliva na padanje amplitude





Drugi viri motenj



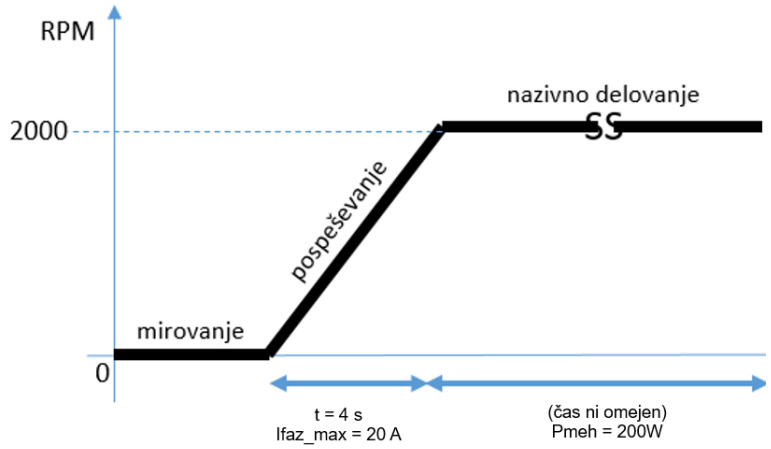


Lastnosti pogona

Splošne lastnosti:

Napetostno območje	45 ÷ 57,5V
Tip motorja	trifazni brezkrtačni, BLAC, delta vezava
Moč motorja	20 A zagonski fazni tok 200 W stalna nazivna moč
Obrati	2000 / min
Tip vodenja	senzorsko
Regulacija toka	dva merilna upor
Komunikacija	/

Profil delovanja:

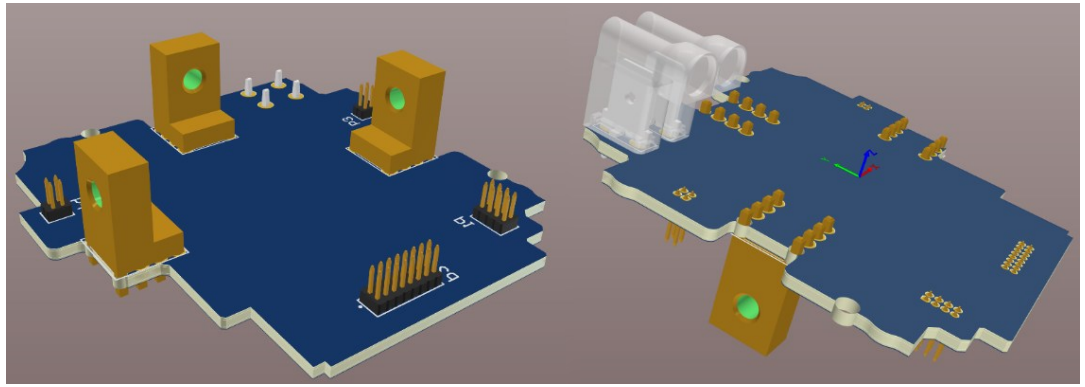


Arhitekturne lastnosti:

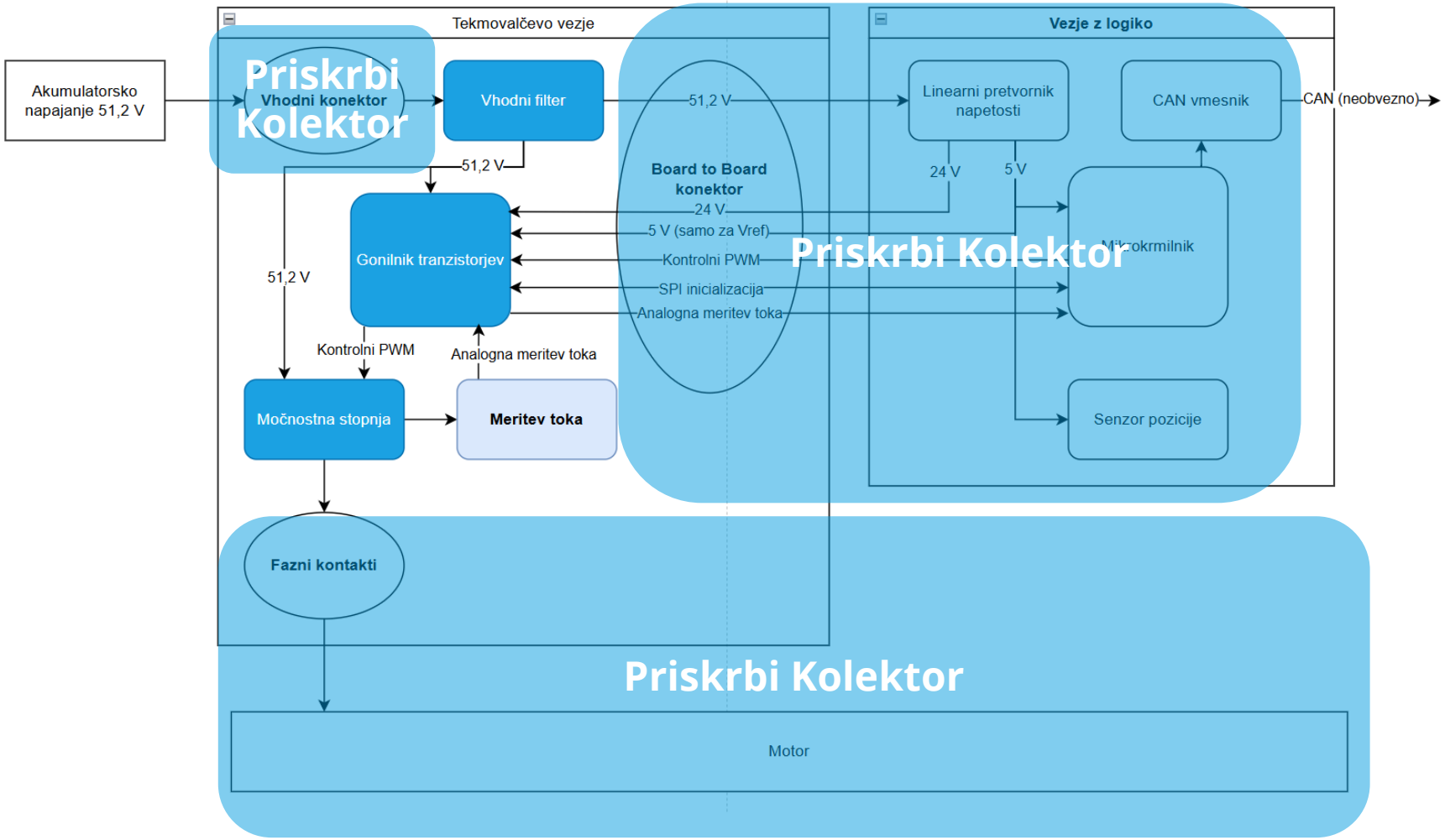
- Gonilnik: DRV8334PHPR
- Tokovni gonilniki končne stopnje
- -20 ÷ 105°C komponente

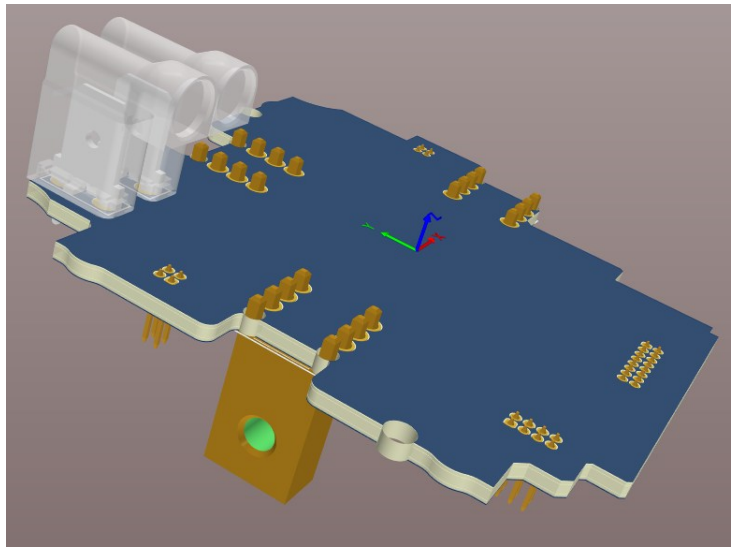
Dimenzijske omejitve:

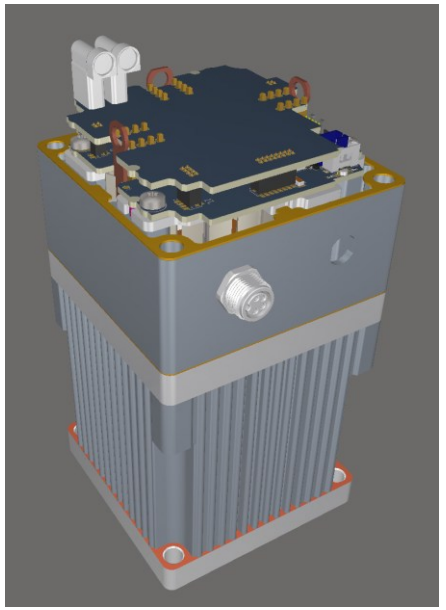
- Predpisana kontura vezja
- Predpisane pozicije vhodnega konektorja, board to board konektorjev in faznih priključkov
- Omejitev 2 mm višine na spodnji strani



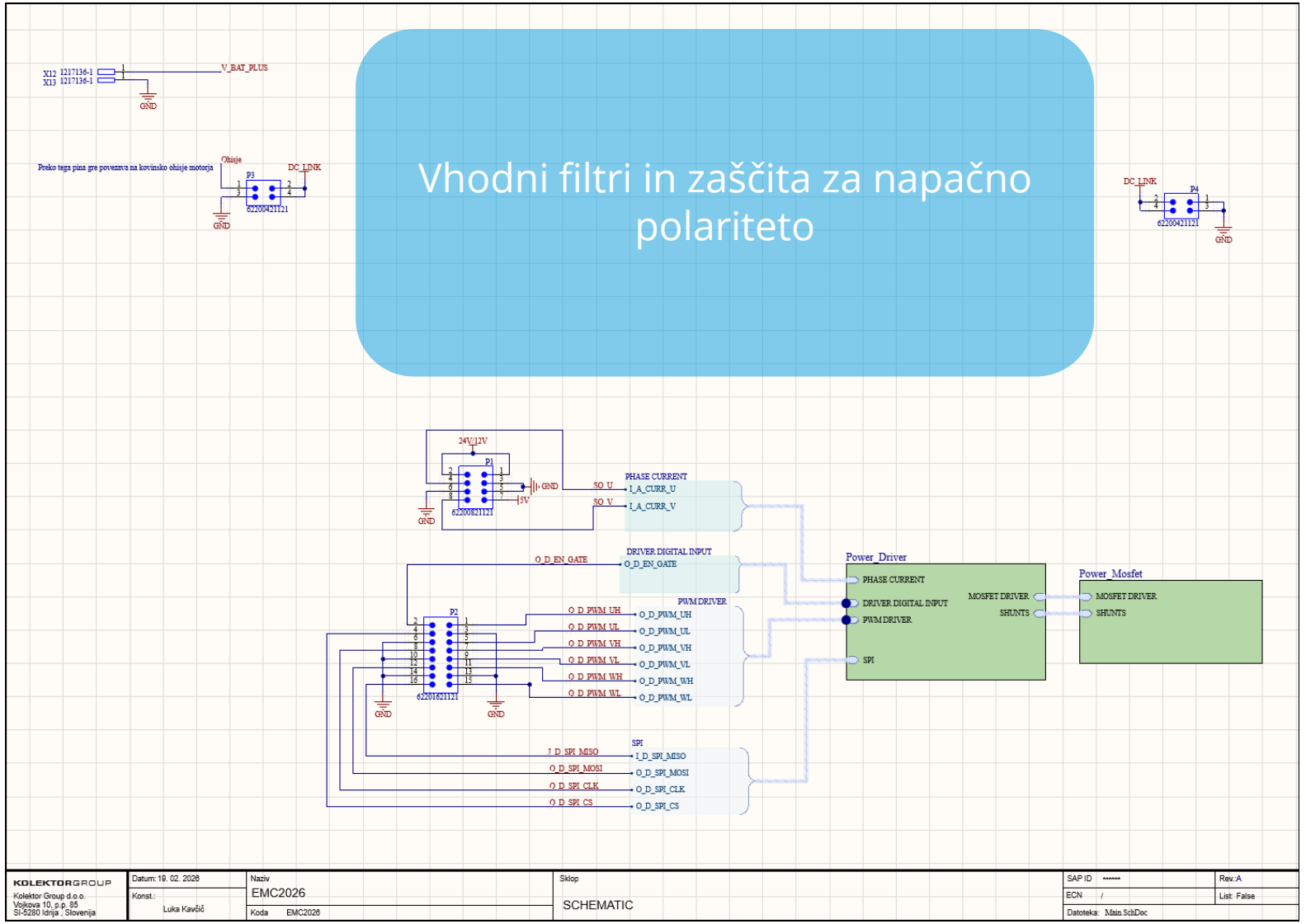
Pogon brezkrtačnega motorja



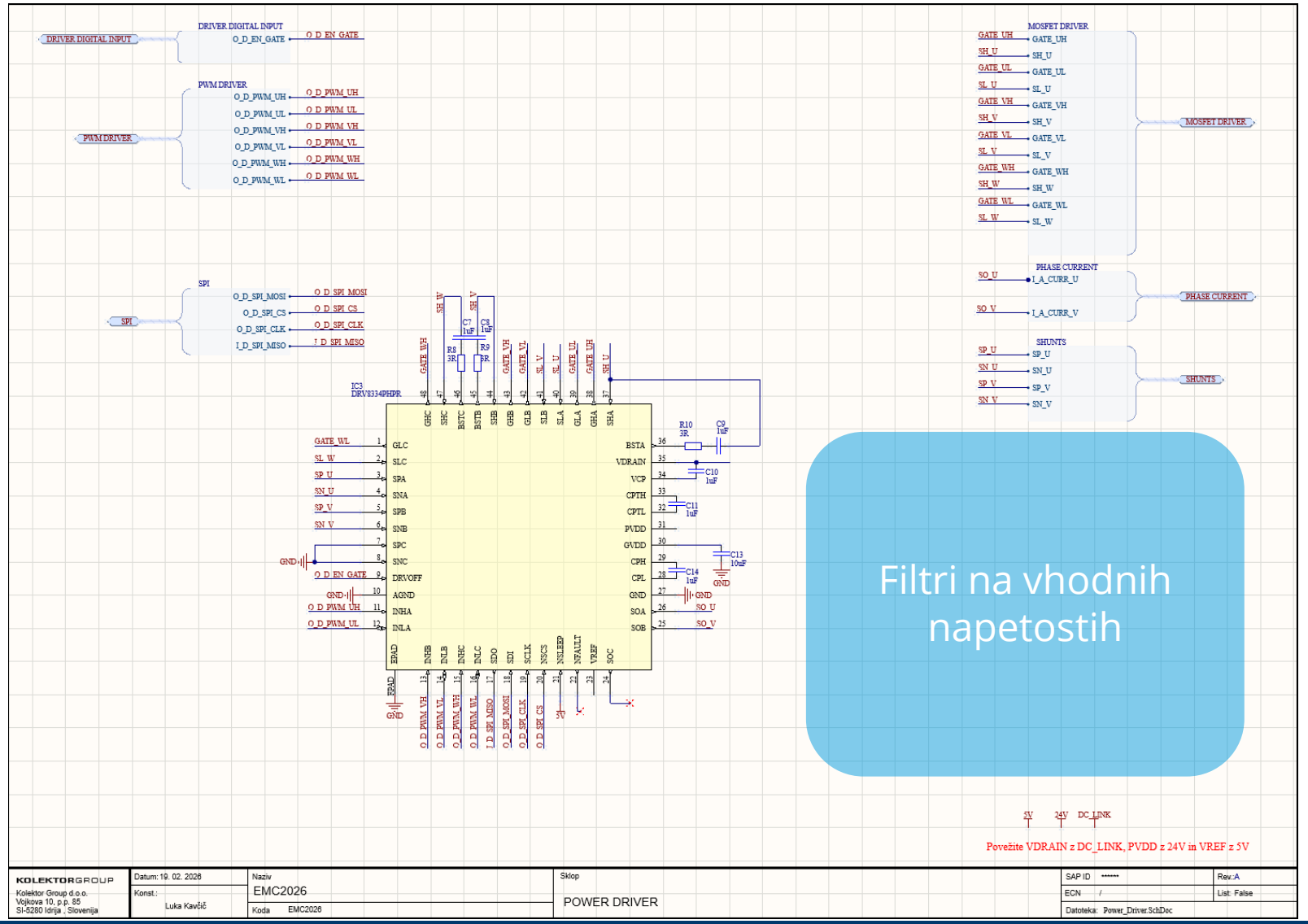




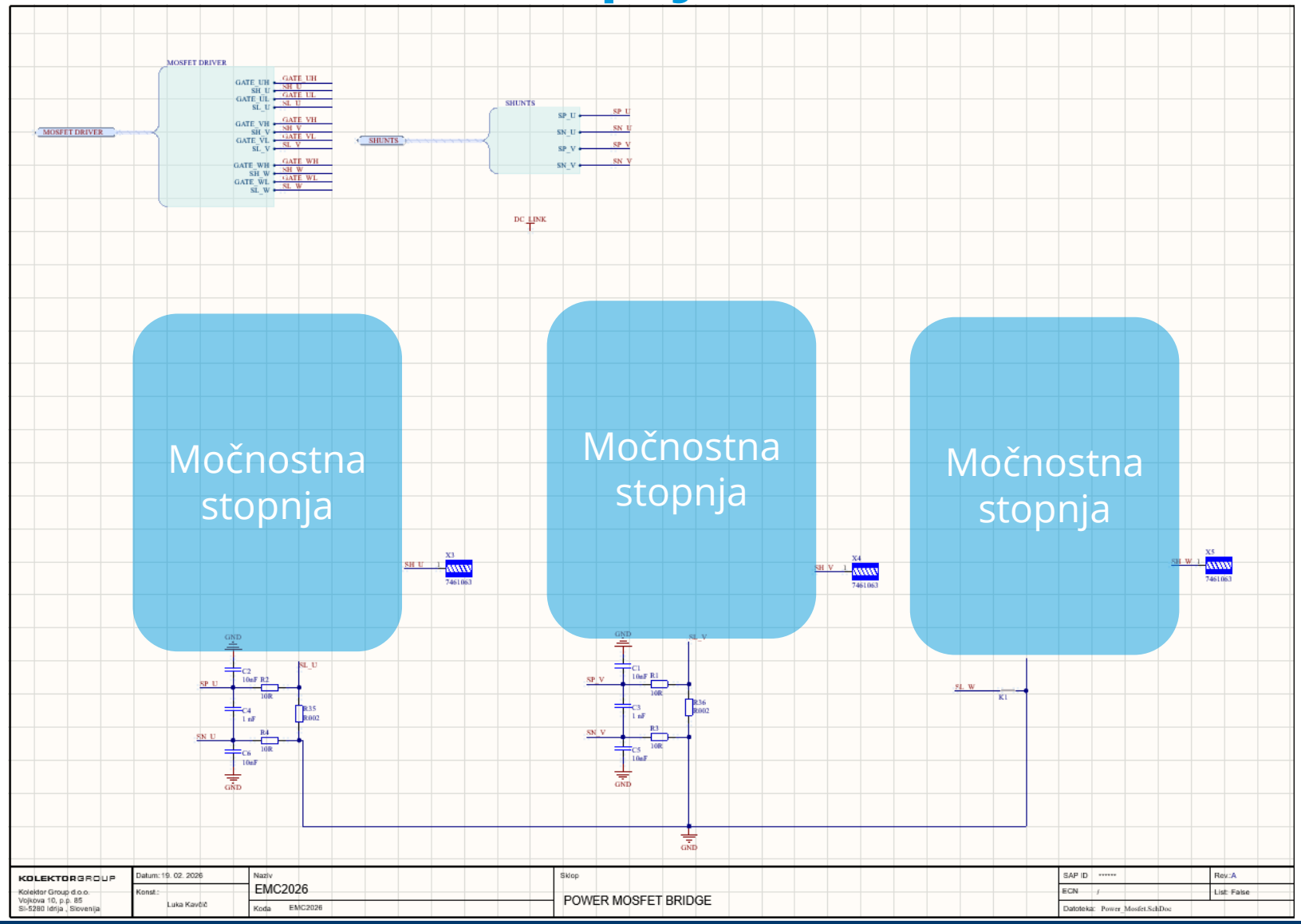
Vhodni filter in konektorji



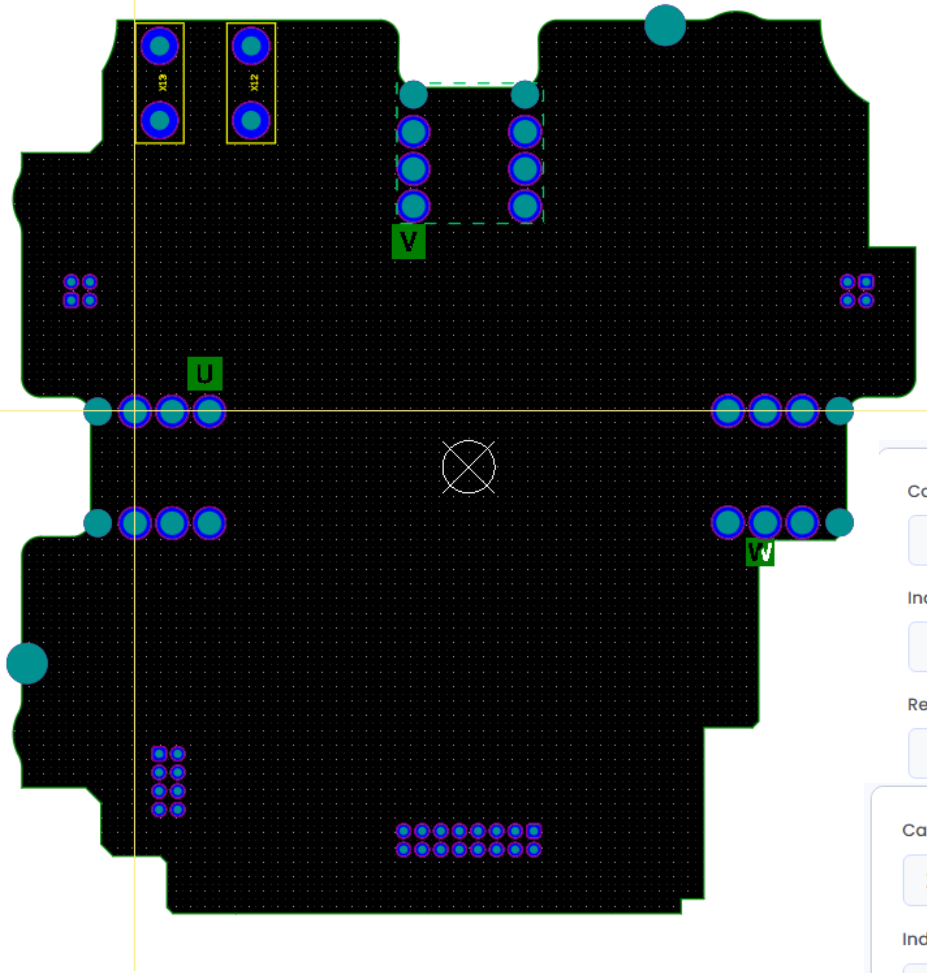
Gonilnik



Močnostna stopnja in meritev toka



Postavitev

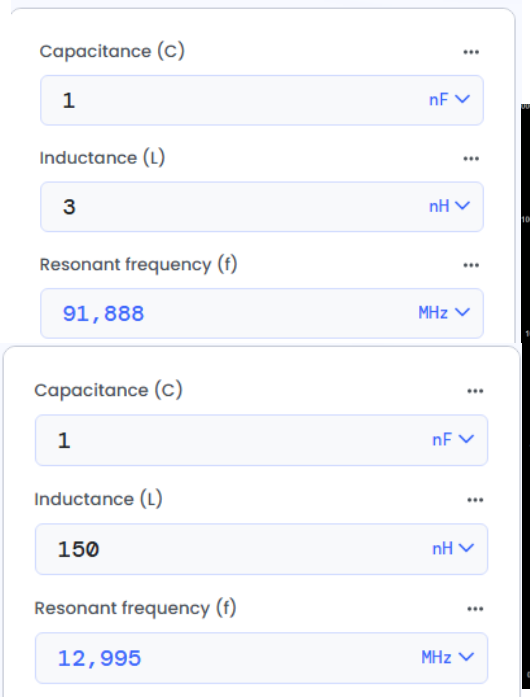


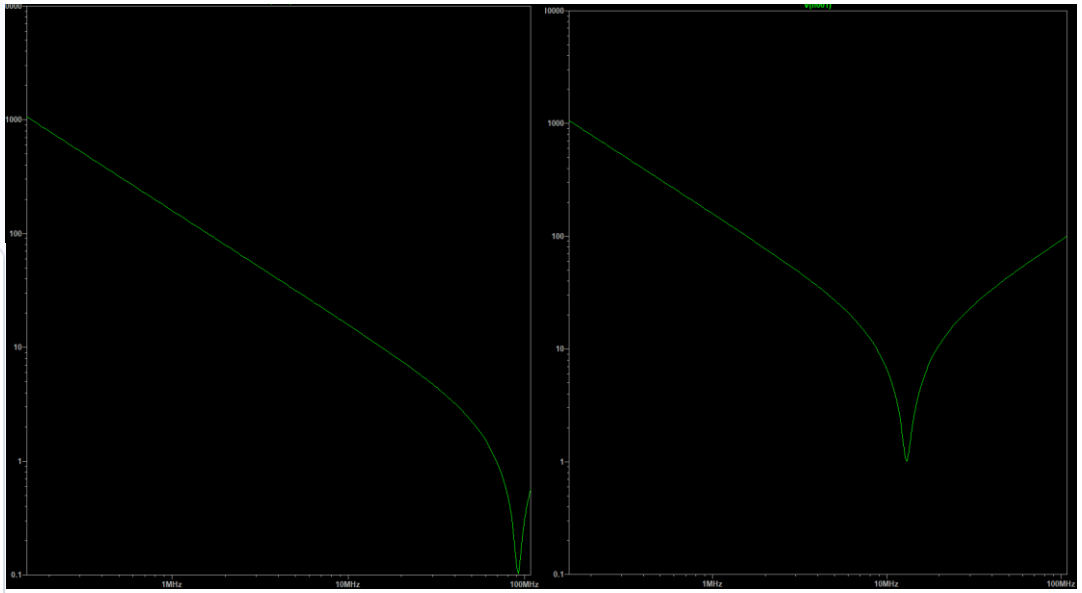
- **Hlajenje tranzistorjev**
- **Pustite prostor za stvari ki jih boste mogoče rabili**

- **EMC!!!**

Pregled, generiran z umetno inteligenco

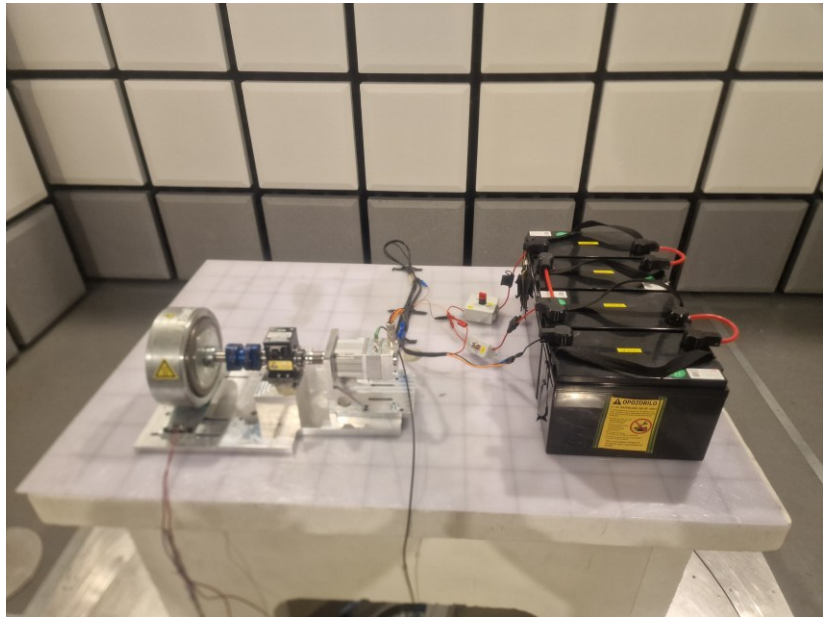
A common, rough rule of thumb for estimating inductance in electronic circuits is **10–25 nH per inch (4–10 nH/cm) of conductor length**. For typical PCB traces, this often translates to roughly 1 nH/mm or 1 nH per 0.04 inches. EDN - Voice of the Engineer +2

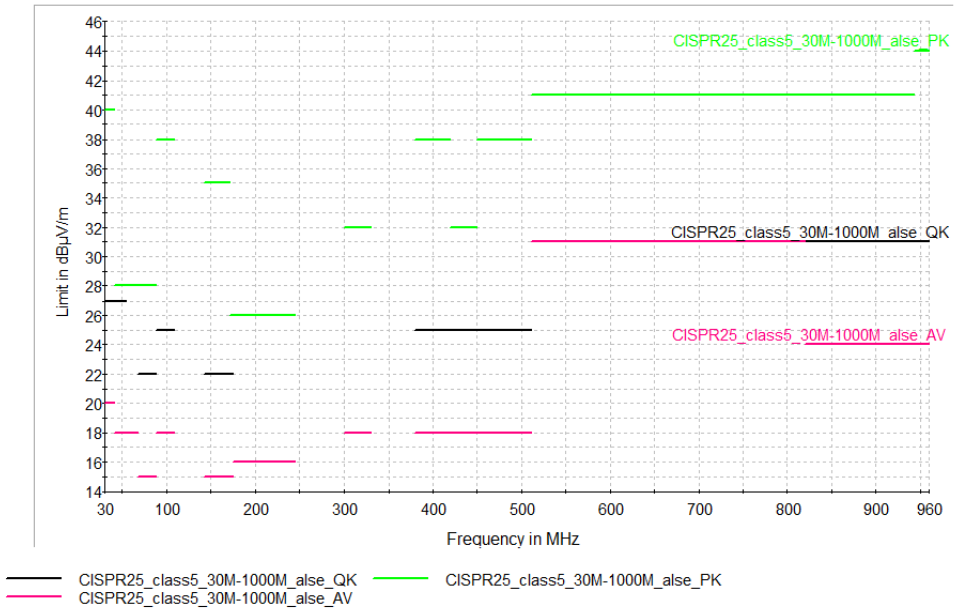




Zahteve in cilji izziva

1. **Osnovna funkcionalnost: 2k rpm 200W**
2. **Skladnost s CISPR 25 in VW81000 zahtevami za sevalne in prevodne emisije** **~ 50 %**
3. **Cena in skladnost komponent (MOSFETi, dušilke, kondenzatorji, …)** **~ 25 %**
4. **Skladnost z dodatnimi funkcionalnimi in nefunkcionalnimi zahtevami** **~ 25 %**
   - Odpornost na napačno polariteto
   - Izgube vezja
   - Gretje MOSFETov
   - Delovanje pri različnih napetostih





Pregled in cena komponent

Pregled 1 - Pregled BOM

Pregled BOM obsega kriterije:

- skladnost z zahtevanim temperaturnim območjem,
- skladnost z ostalimi zahtevami podanimi v tem dokumentu.

Število točk: 5 točk za vsak izpolnjen kriterij. Skupaj: 10.

Pregled 2 - Cena komponent

Med tekmovalci se primerja seštevek cen vseh komponent, ki so jih dodali v shematiko. Cena vnaprej določenih komponent se ne upošteva.

Nižja cena pomeni boljši izid oziroma manjši točkovni odbitek.

Upori velikosti 0603 ali manjše in kondenzatorji do vrednosti 100 nF velikosti 0603 ali manjše imajo ceno 0,01 €.

Cena se izbere na podlagi cene v spletni storitvi Octopart za količino 1000 vezij.

Ceni vsake komponente se doda vrednost 0,02€ zaradi stroška polaganja.

Cene komponent se gledajo iz odobrenega seznama dobaviteljev:

- Farnell
- Mouser
- Arrow
- TME

Osnovna funkcionalnost in dodatne zahteve

Test 1 - Osnovna funkcionalnost

Opis metode: preizkus pogona na namenski testni napravi.

Testni pogoji:
Uin = 45 ÷ 57,5V s korakom 2,5V
T = 23 °C

Pričakovan rezultat:
- pogon uspešno pospeši do 2000 rpm,
- pogon vzdržuje 2000 rpm 2 minuti,

Število točk: 2 točki za delovanje v vsakem od napetostnih korakov. Skupaj: 12.

Test 2 - Izkoristek vezja

Opis metode: Merjenje vhodnega toka v motor pri nazivnem obratovanju.

Testni pogoji:
Uin = 51,2 V
Trajanje t = 600 s
T = 23 °C
n = 2000 rpm

Število točk odbitka: Negativne točke za vhodni tok se izračunajo po spodnji enačbi. Vsem tekmovalcem se odšteje tok, ki ga je imel tekmovalec z najmanjšim tokom. K=2 točki/10mA.

$$Točke = -(I_{meas} - I_{best}) * K$$

Osnovna funkcionalnost in dodatne zahteve

Test 3 - Segrevanje vezja
Opis metode: snemanje zgornje strani vezja z termo kamero. Gleda se najvišja temperatura.

Testni pogoji:
Uin = 51,2 V
Trajanje t = 600 s
T = 23 °C
n = 2000 rpm

Kriterij:
- Gleda se točko z najvišjo temperaturo na zgornji strani z termo kamero. Zahtevana temperatura je pod 60 °C. Temperaturno območje se razdeli na intervale po 5 °C (60-65 °C = -2 točki, 65-70 °C = -4 točke...)

Število točk: Za vsak temperaturni interval nad 60 °C se odbije 2 točki.

Test 4 - Priklop obratne polaritete

Testni pogoji:
Uin = -55 V
Trajanje t = 120 s
T = 23 °C

Kriterij: Na vezje se priklopi -55 V (napačna polariteta). Vezje ne utrpi trajnih poškodb.

Število točk: 10 točk, če vezje po ponovnem priklopu na nazivno napetost spet deluje.

Točkovanje EMC

Prevodne emisije po EN55025
150 kHz – 108 MHz

Število točk glede na doseganje razreda:

- Class 1 : 0
- Class 2 : 5
- Class 3 : 10
- Class 4 : 20
- Class 5 : 40

Sevalne emisije po EN55025
150 kHz – 1 GHz

Število točk glede na doseganje razreda:

- Class 1 : 0
- Class 2 : 5
- Class 3 : 10
- Class 4 : 20
- Class 5 : 40

Sevalne emisije po VW81000
9 kHz – 150 kHz

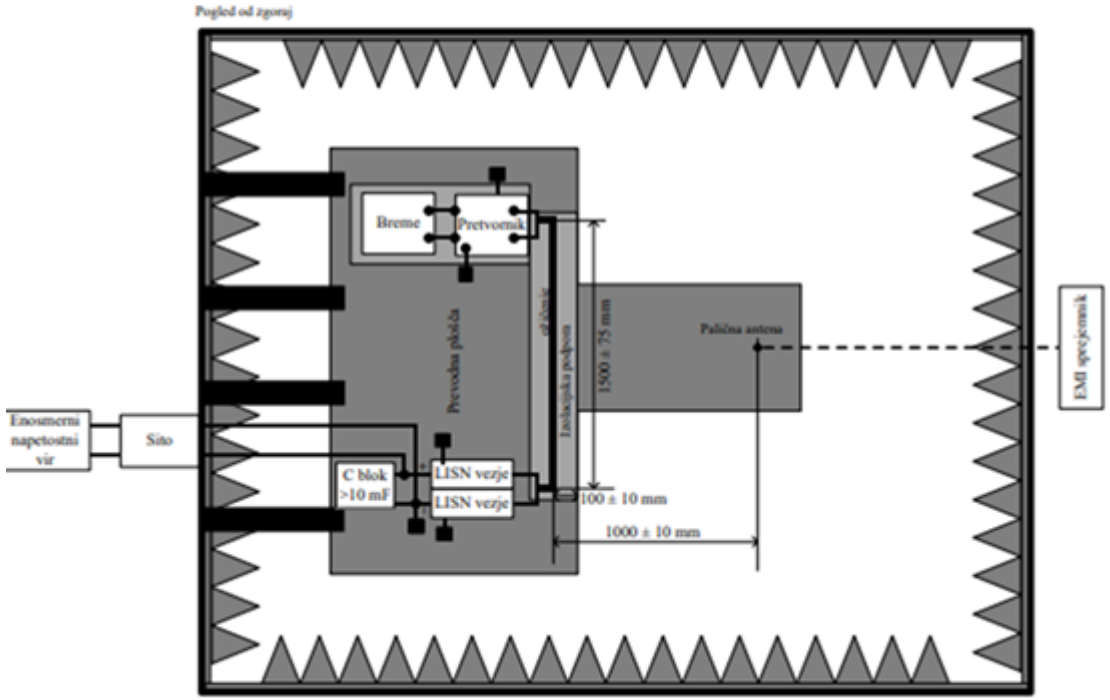
Število točk glede na doseganje razreda:

- Class 3 : 3
- Class 4 : 6
- Class 5 : 10

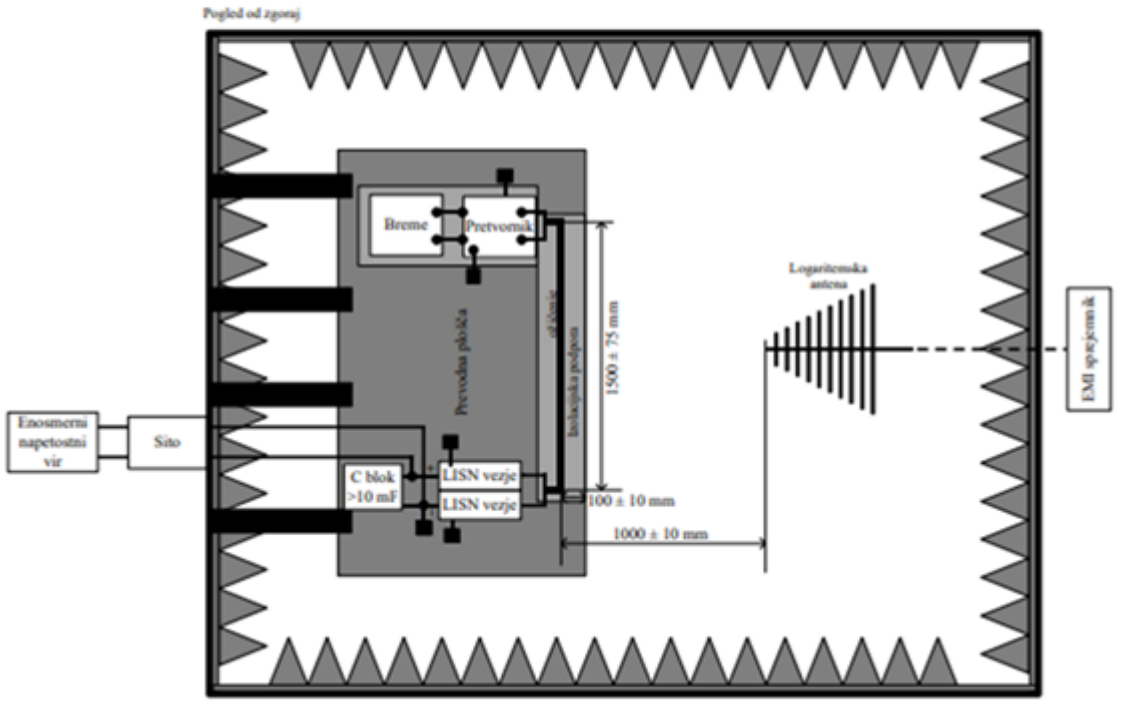
Na voljo dodatne točke za med razredi

Sevalne emisije

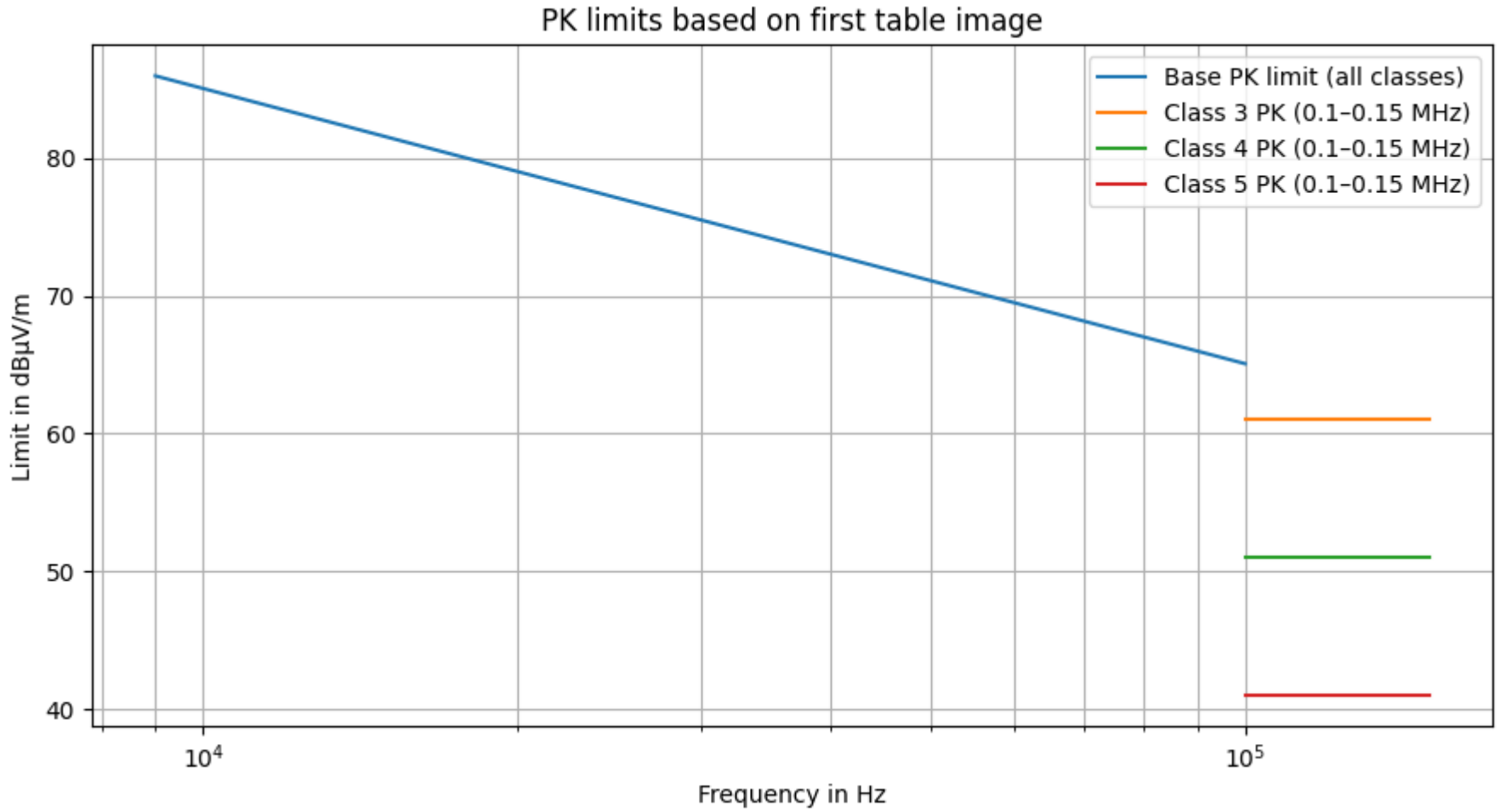
9 kHz - 30 MHz



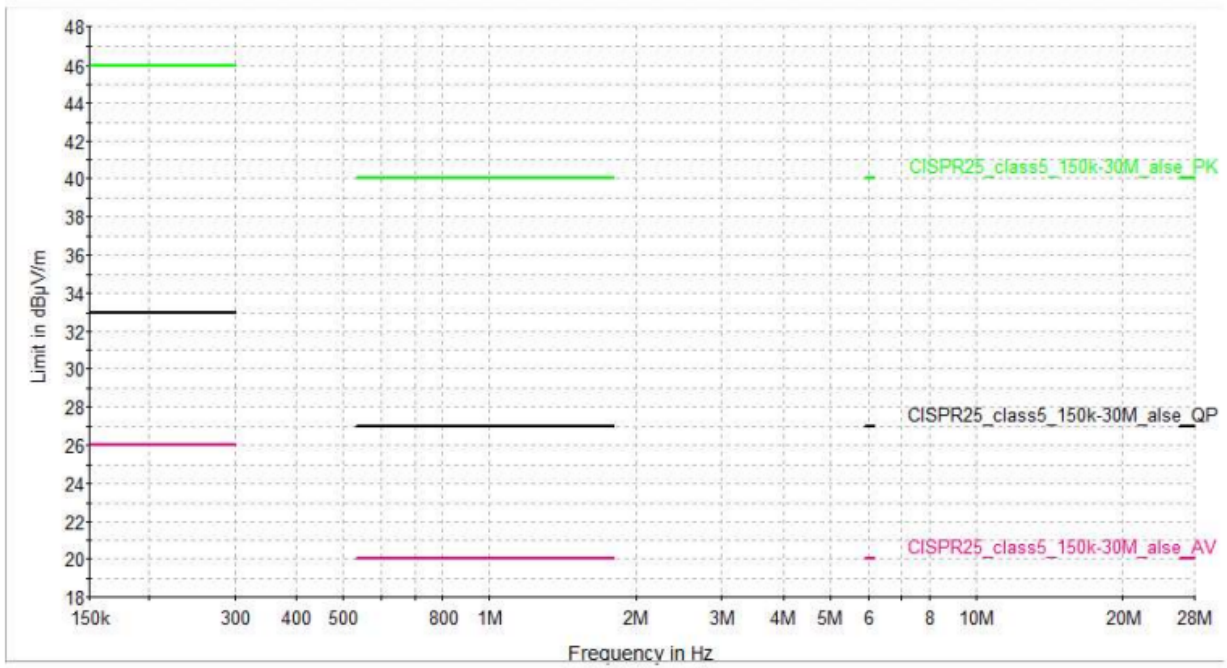
30 MHz – 1000 MHz

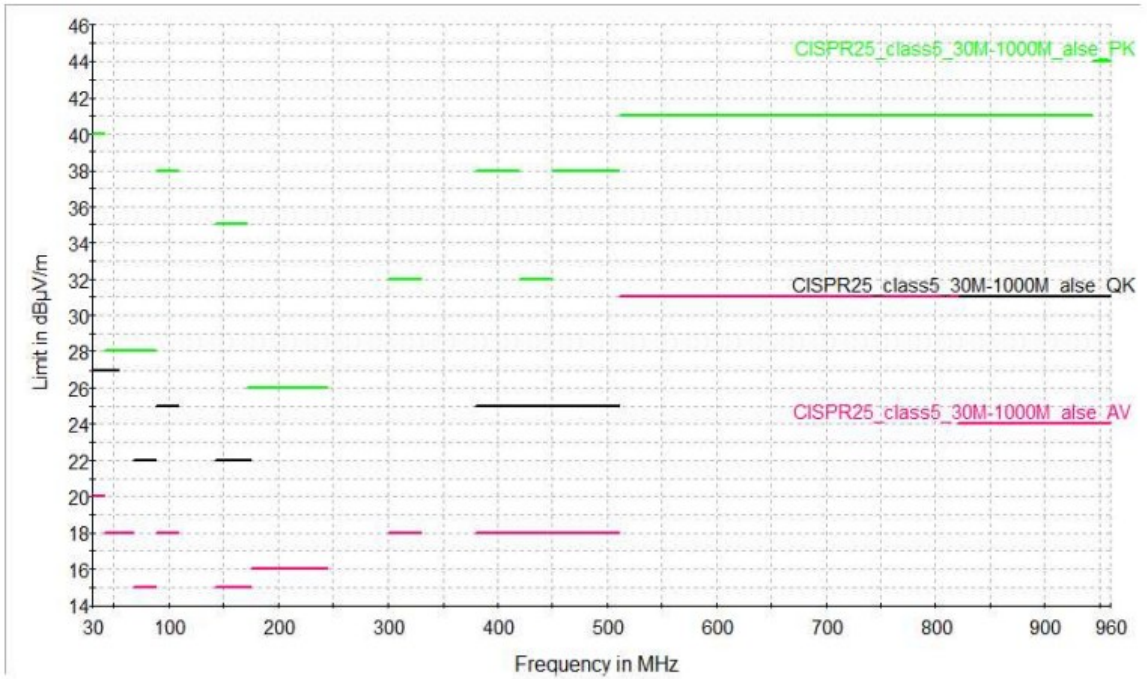


VW81000 Sevalne emisije

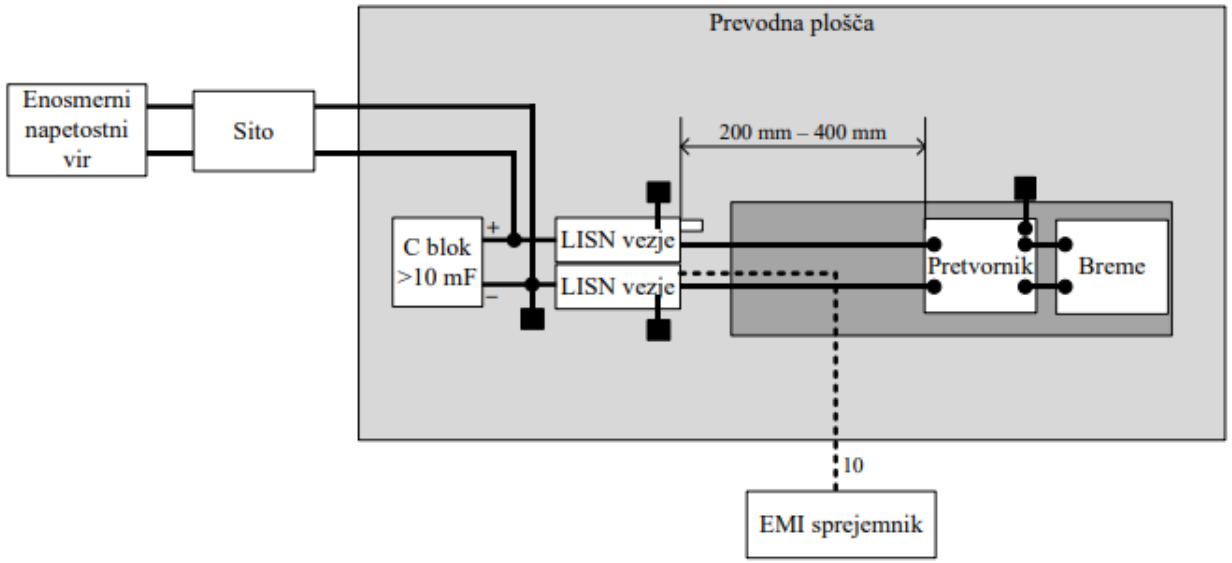


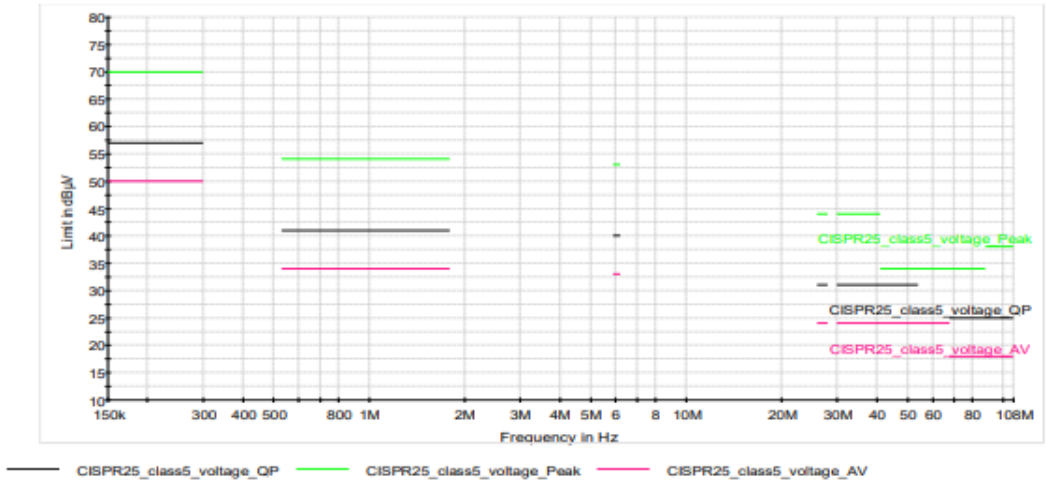
EN55025 sevalne emisije





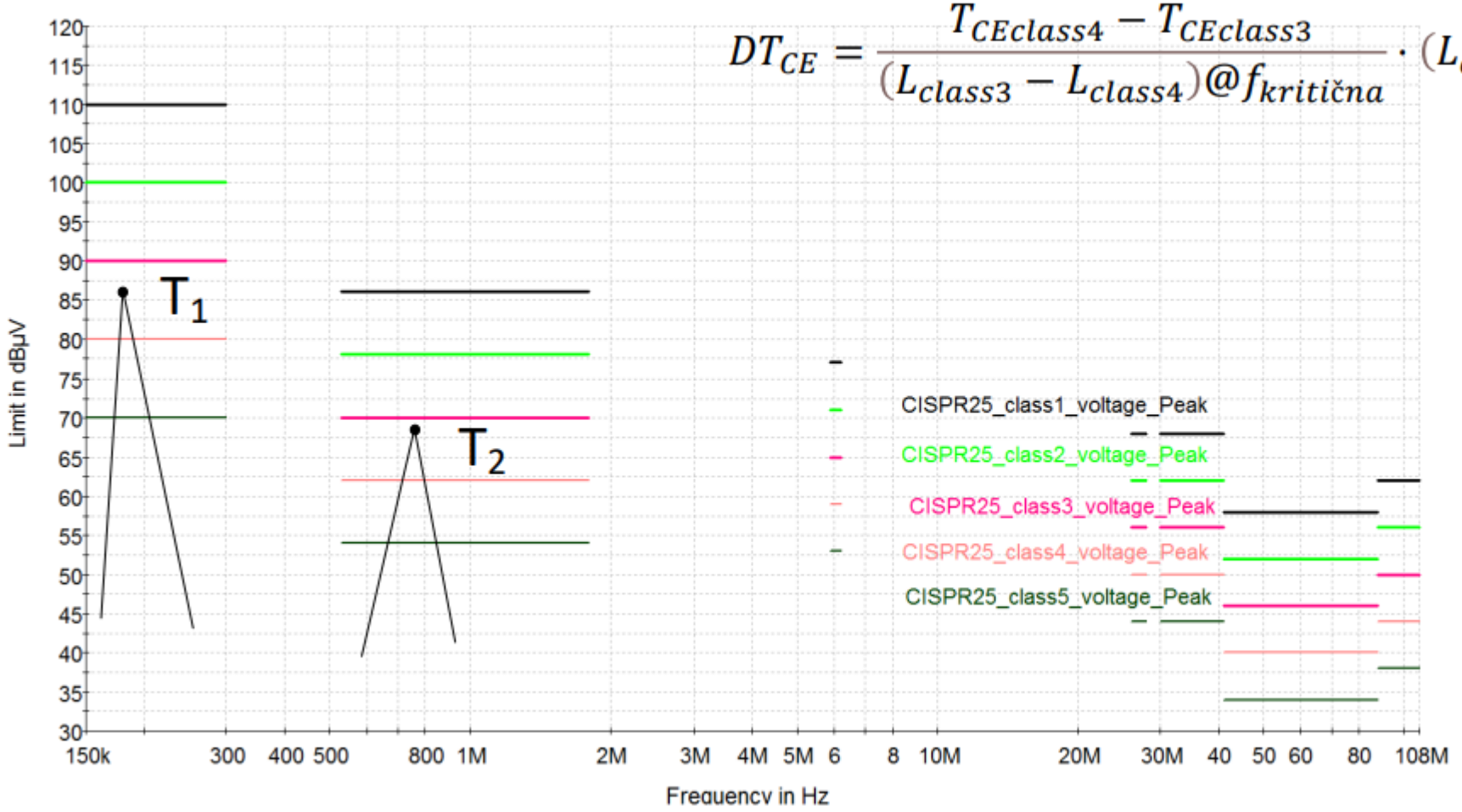
Prevodne emisije





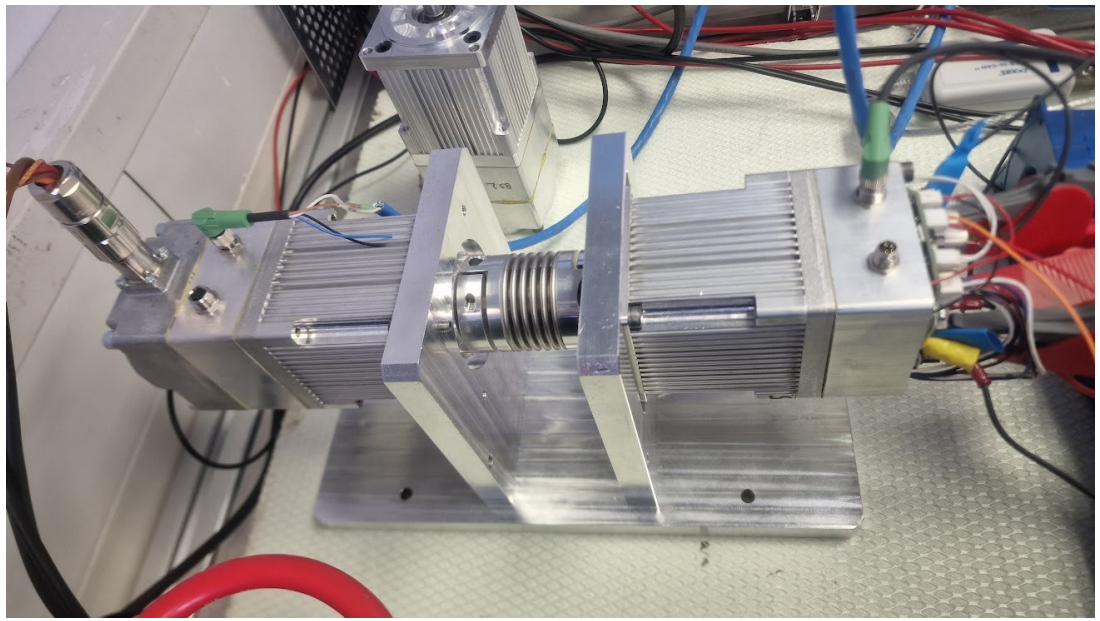
Dodatne točke za EN55025

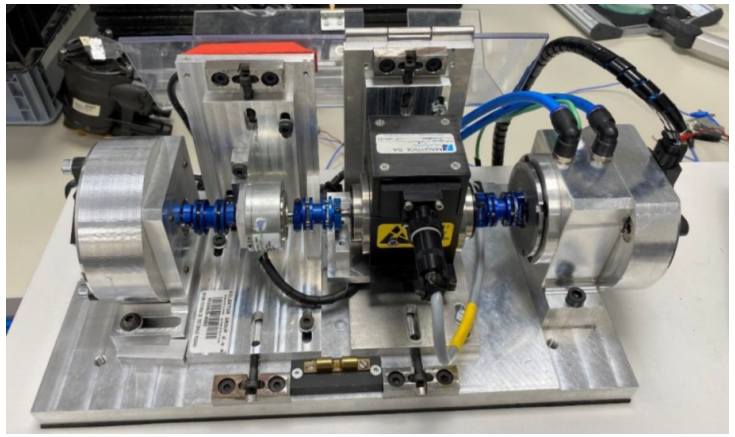
$$DT_{CE} = \frac{T_{CEclass4} - T_{CEclass3}}{(L_{class3} - L_{class4})@f_{kritična}} \cdot (L_{class3} - L_{izm})@f_{kritična}$$



Preizkušanje pogona in pregledi

1. **Razvojno testiranje: Na fakulteti za Elektrotehniko**
2. **Funkcionalno testiranje in izkoristek: Kolektor Mobility**
3. **Pregled BOM: Kolektor Mobility**
4. **Električni testi: Kolektor Mobility**
5. **Testiranje sevalnih in prevodnih emisij: SiQ**

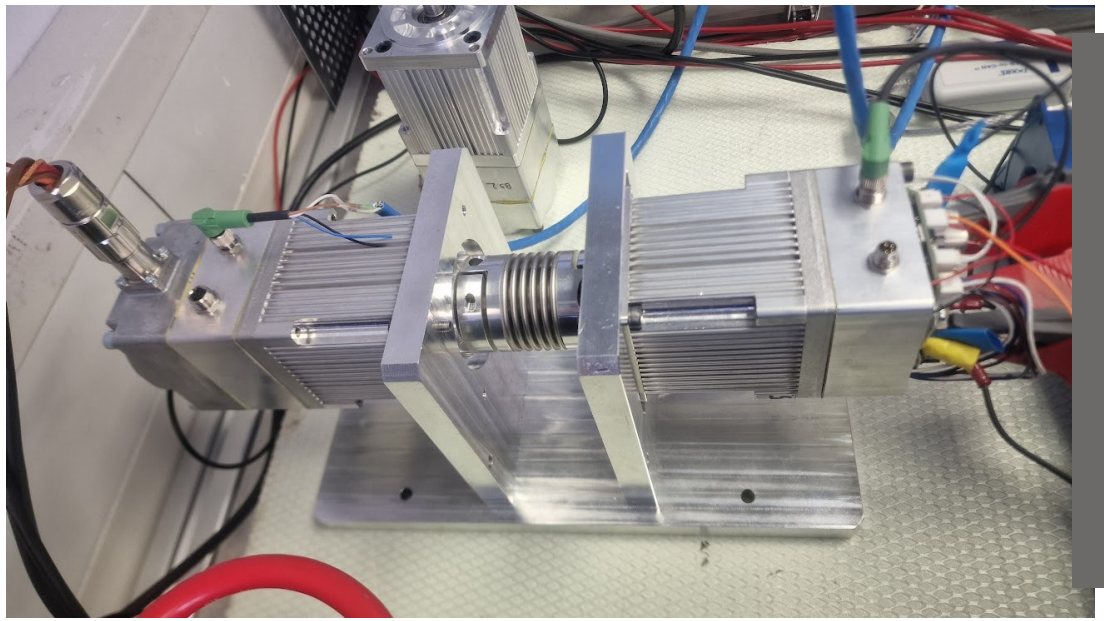


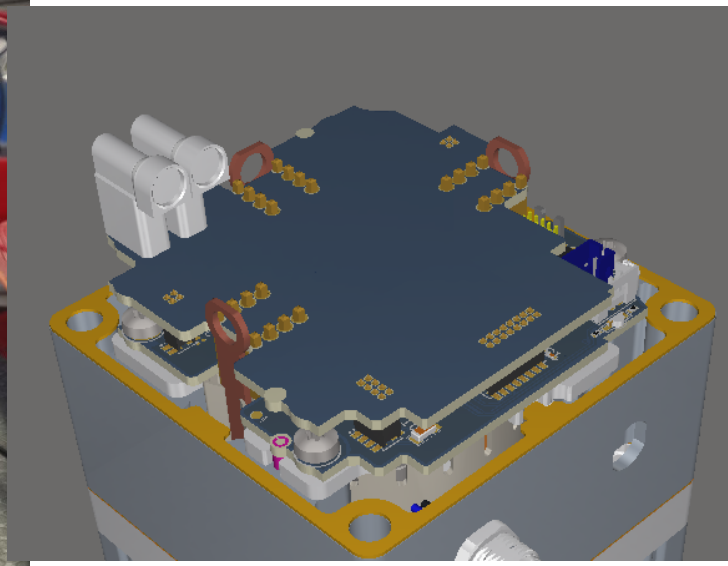


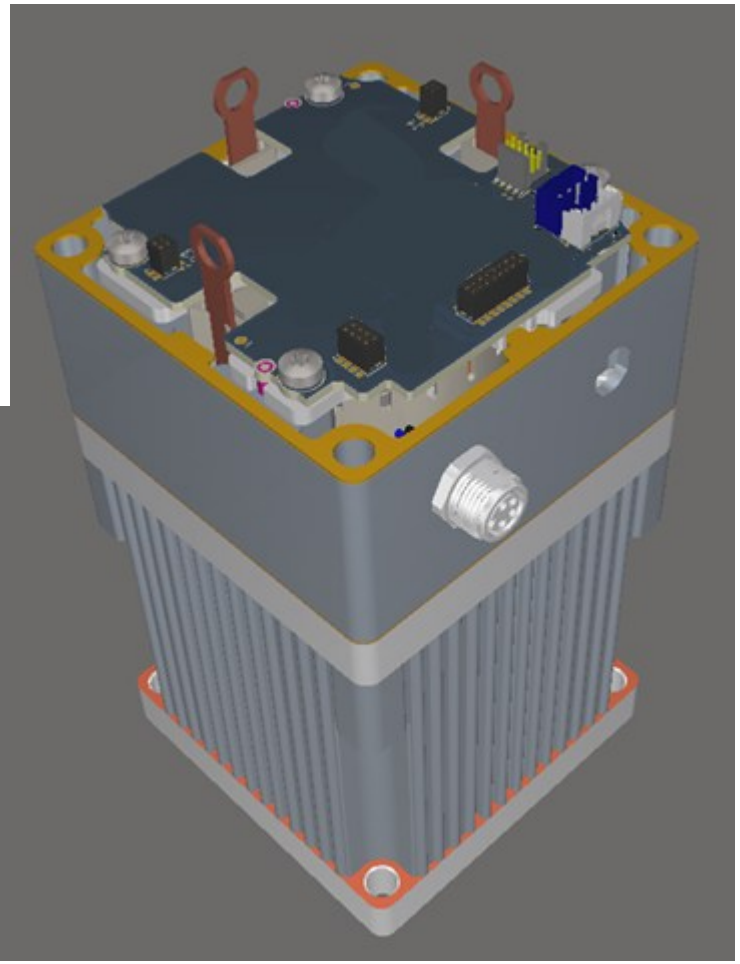
Preizkušanje pogona in pregledi

1. **Razvojno testiranje: Na fakulteti za Elektrotehniko, študentje izvajajo sami**

Ponedeljek	6. April 2026	Naročilo TIV in materiala
Ponedeljek	4. Maj 2026	Začetek preliminarnega testiranja izdelkov
Ponedeljek	1. Junij 2026	Oddaja projektov za testiranje







Povezave

- **Uradna stran tekmovanja: LPVO: Načrtovanje elektronike za EMC 2026 (uni-lj.si)**
- **Texas Instruments DRV8334PHPR domača stran: https://www.ti.com/product/DRV8334/part-details/DRV8334PHPR**
  - **Datasheet: https://www.ti.com/lit/ds/symlink/drv8334.pdf**
  - **Understanding Smart Gate Drive: https://www.ti.com/lit/an/slva714d/slva714d.pdf**
  - **Best Practices for Board Layout of Motor Drivers: https://www.ti.com/lit/an/slva959b/slva959b.pdf**

Kontaktna oseba

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068 128 269

Discord: @Luka Kavčič na EMC delavnica

