

UBICHARGE: RE-THINKING URBAN/CITY EV CHARGING

Technical Development and Results

Hans Anniste

Power Electronics Group

Tallinn University of Technology

Centre of Excellence in Energy Efficiency

Co-funded by the European Union

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TALLINN UNIVERSITY OF TECHNOLOGY

EV Battery Voltage Diversity

- EV battery voltage range: Approximately **290–806 V** across the selected vehicles
- **CCS2 DC charging** voltage range: **150-1000 V**, UbiCharge design target.
- AC charging: Typically **11 kW**, **unidirectional** on-board charger (OBC).

Kia EV 6



- 480 - 806V
- No. 10 EV in Estonia

Tesla Model 3



- 290 – 403 V
- No. 1 EV in Estonia

Tesla Model Y



- 290 – 403 V
- No. 2 EV in Estonia
- No. 1 EV in EU

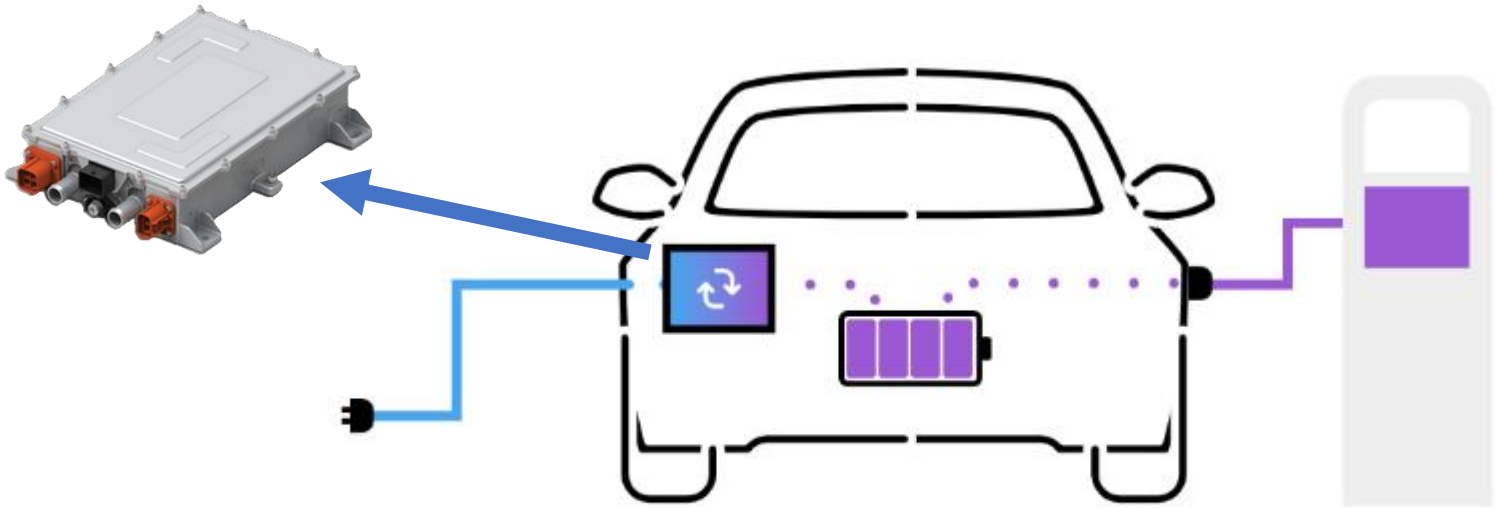
Hyundai IONIQ 5

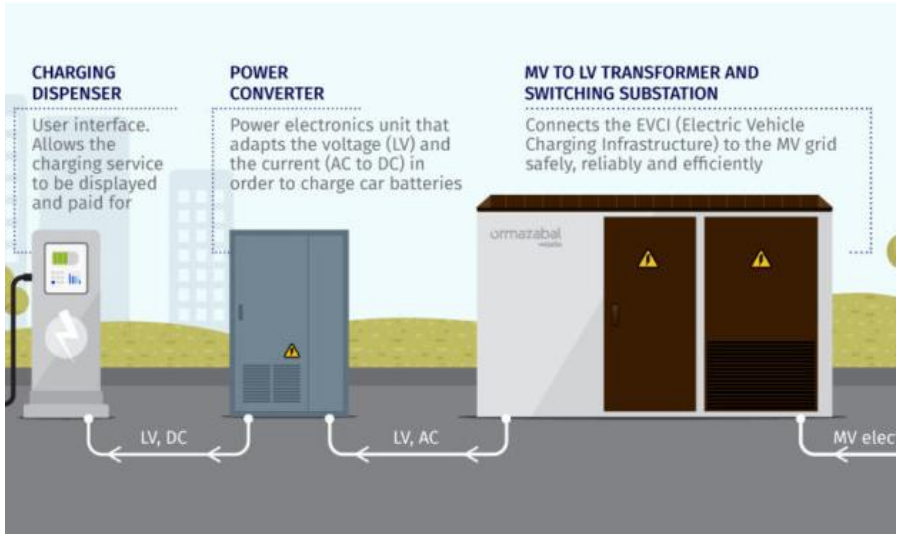


- 522–806 V
- No. 4 EV in Estonia

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Comparison of EV Charging Solutions





On-Board Charger (OBC)

- Integrated into the car
- Typically **11 kW**
- Performance models **22 kW**
- Millions of units dublicated
- **Limited set of features**

Fast DC Charger

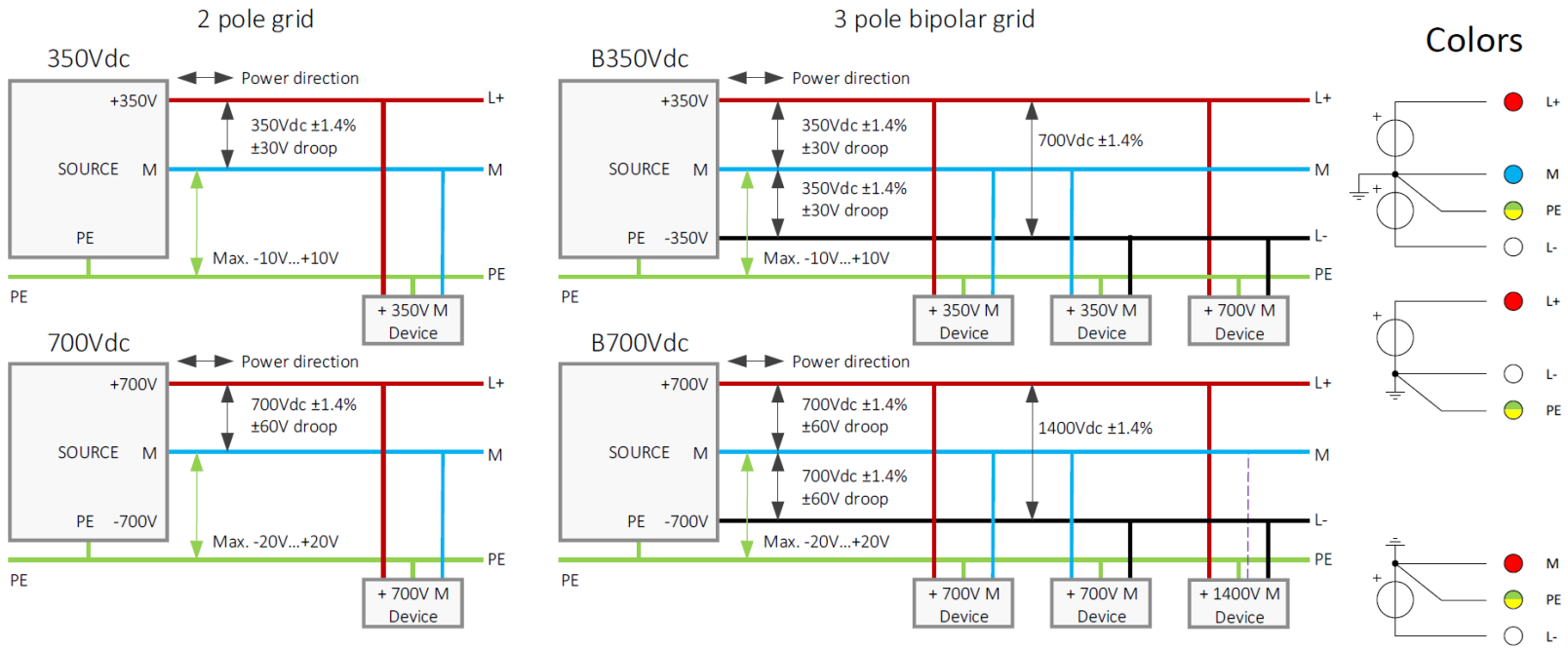
- High installation cost:
  - €200k–€300k
- High power **50 – 350 kW**: reinforced infrastructure required
- Low utilization

DC wall box

- Typically **AC** input
- **Wide range** output voltage
- Power **7 – 50 kW**
- Can be **bidirectional**
- **Shared asset**

Overview of DC Grid

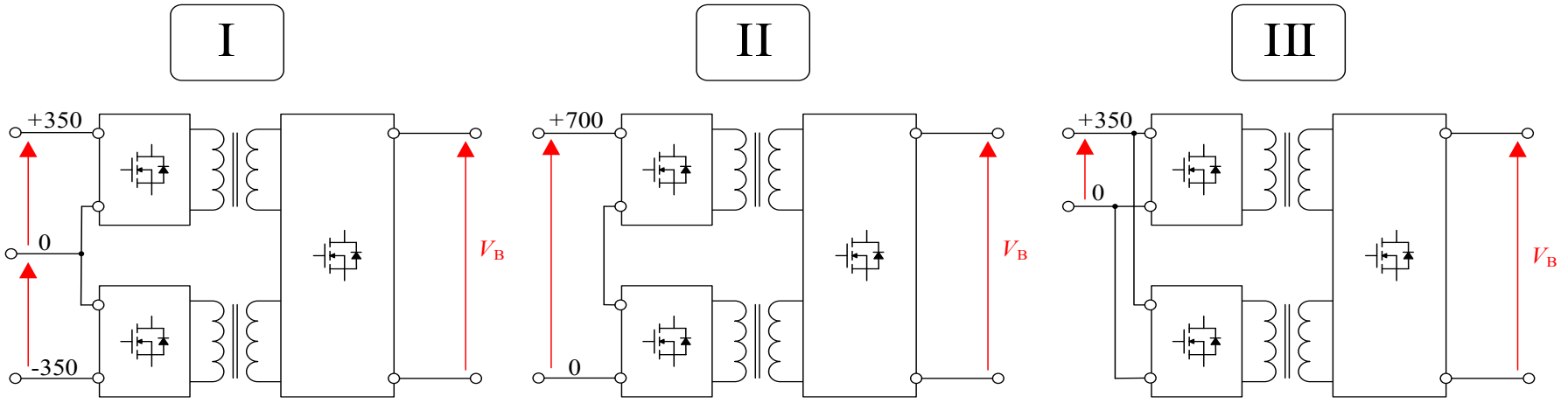
DC Voltages	350V DC / 700V DC / 1400V DC



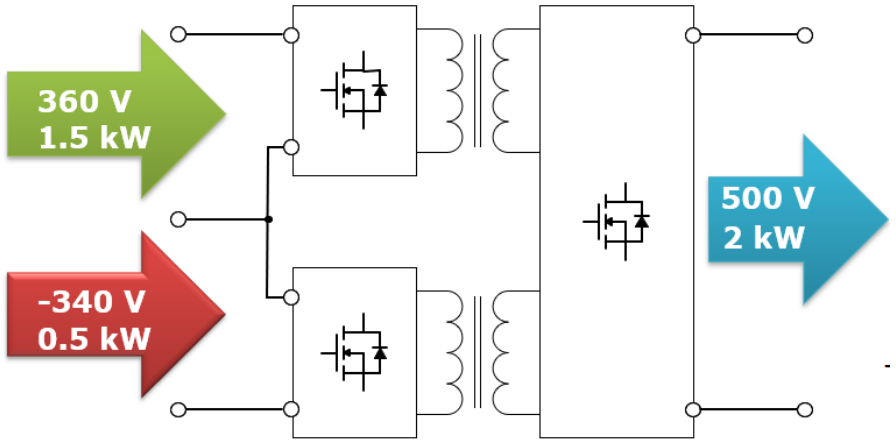
In 2018 the 350 V dc has been implemented formally in the Dutch standardization in the NPR9090 (Dutch Practical Guideline for the installations up to 1500 V dc)

UbiCharge Reconfigurable Input Technology

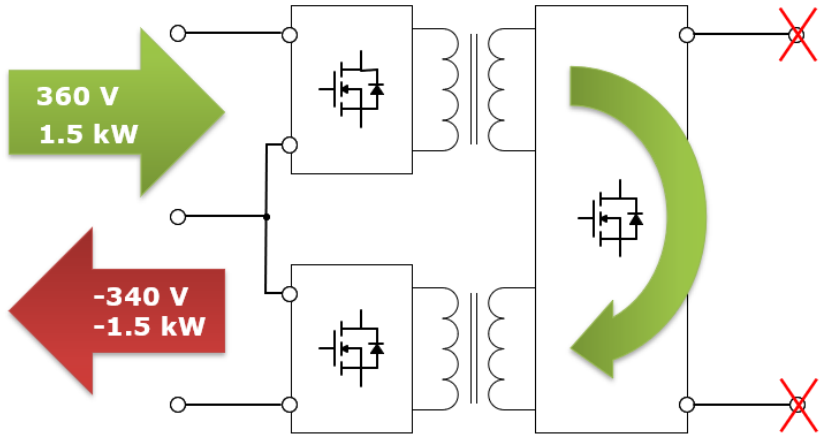
- Supports **3** DC grids
- Can operate as **balancer** in **bipolar grid**
- Balancing mode available:
  - **While charging**
  - **Standby**



±350 V bipolar | **700 V unipolar** | **350 V unipolar**



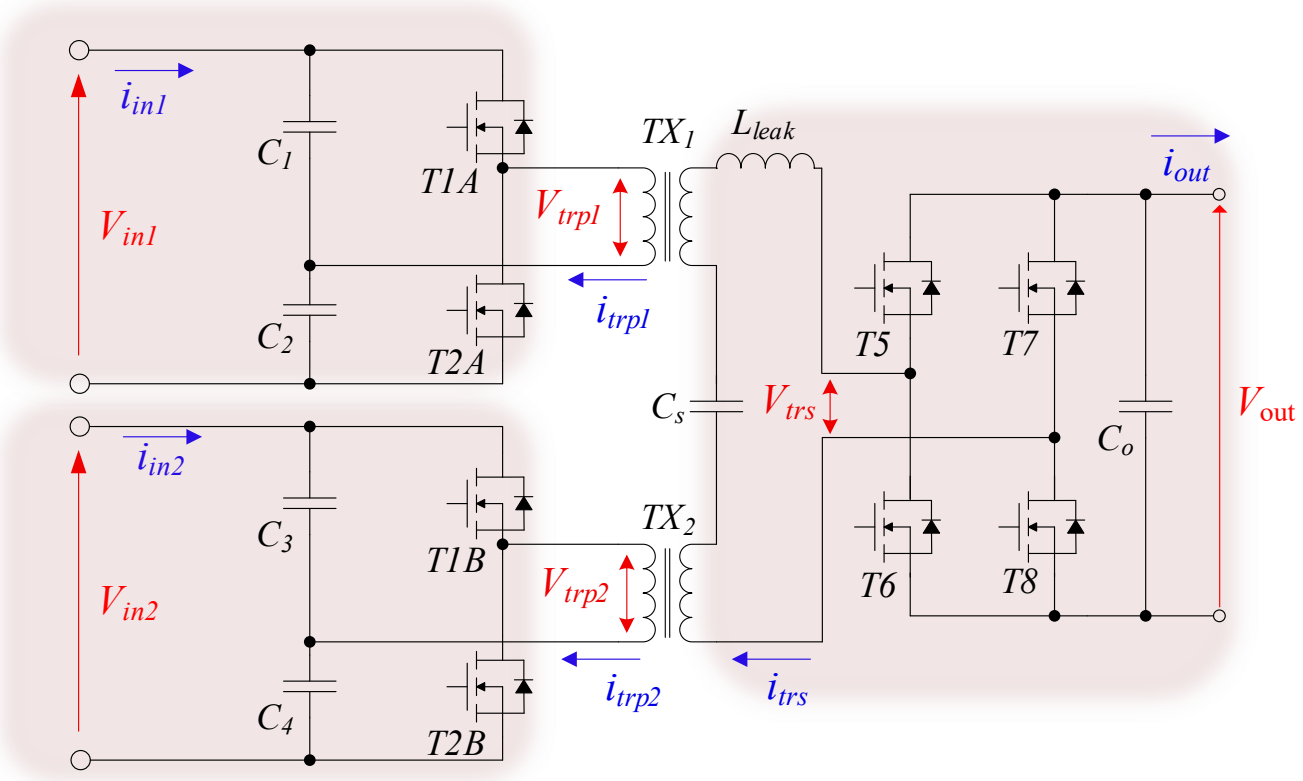
Charging and balancing



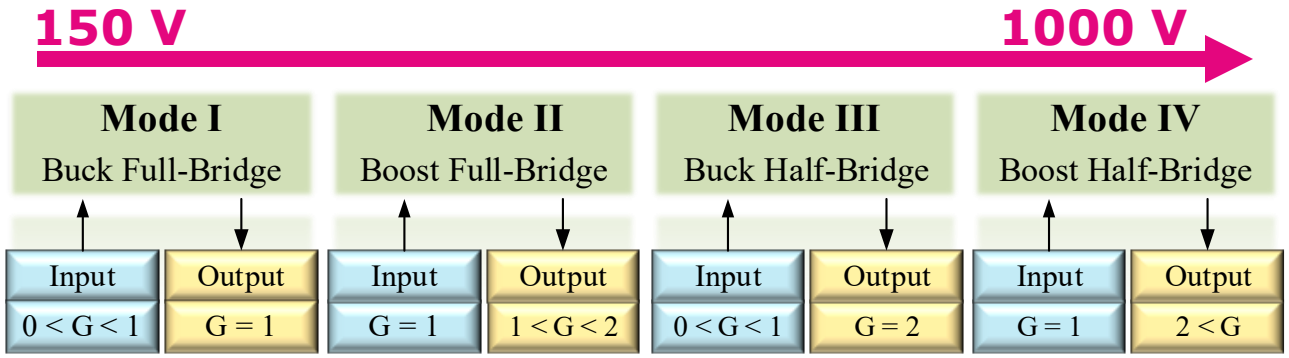
Balancing operation

UbiCharge Topology

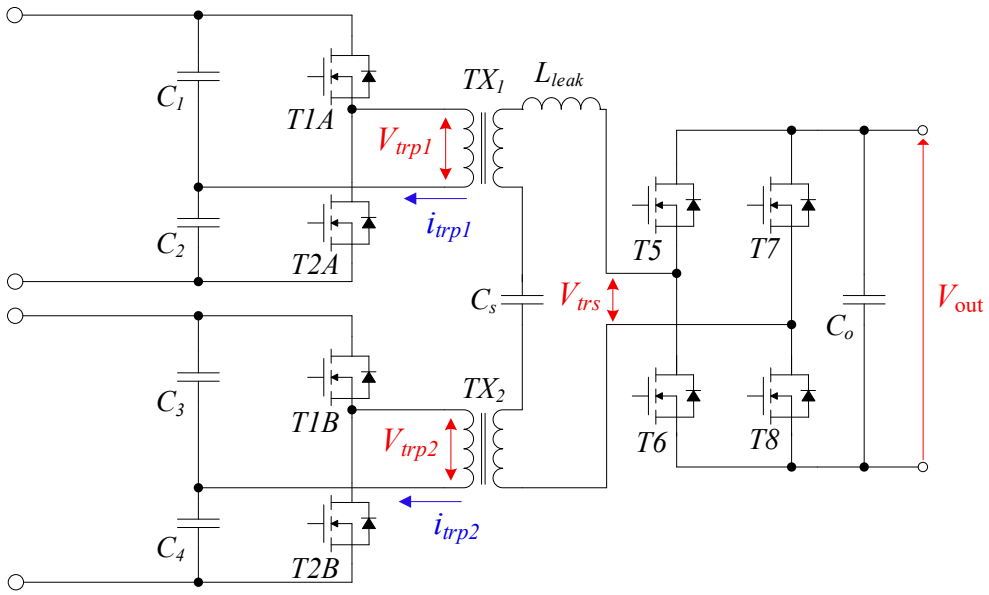
- Based on **Series Resonant Converter (SRC)**
- **Topology Morphing Control (TMC)** for wide voltage range operation
- Possible **bidirectional** operation
- **Buck/Boost** operation
- Can charge **all** commercial **EV models** (**400 V** and **800 V** battery technology)



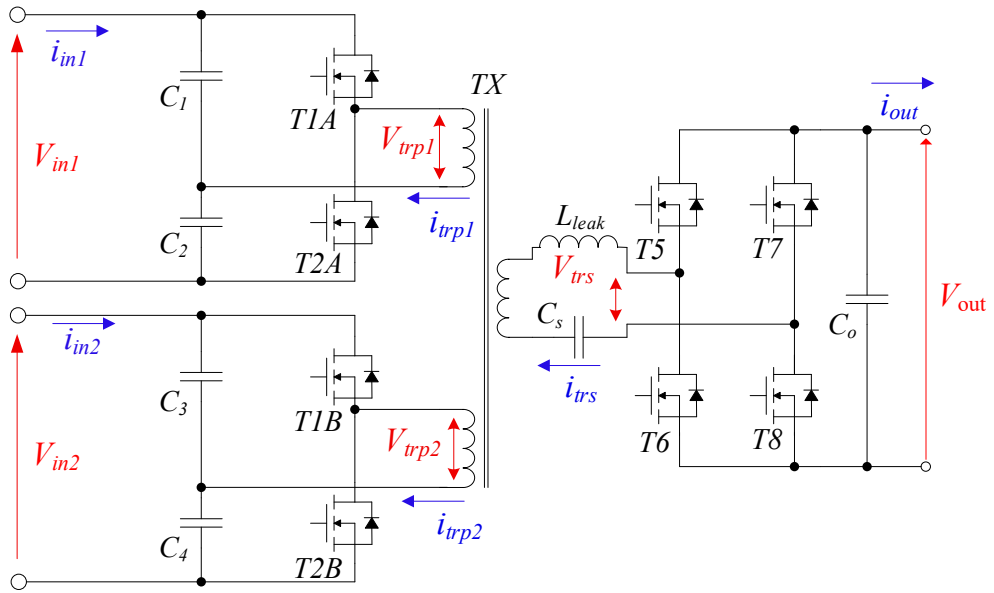
Operating parameters	
Input voltage, V_{in}	320….380 V / 640….760 V
Switching frequency, f_{sw}	100 kHz
Output voltage, V_{out}	150….1000 V
Rated output power	5 kW
Transformer maximum current, $I_{TX(max)}$	16 A rms



Possible Transformer Solutions



Dual transformers



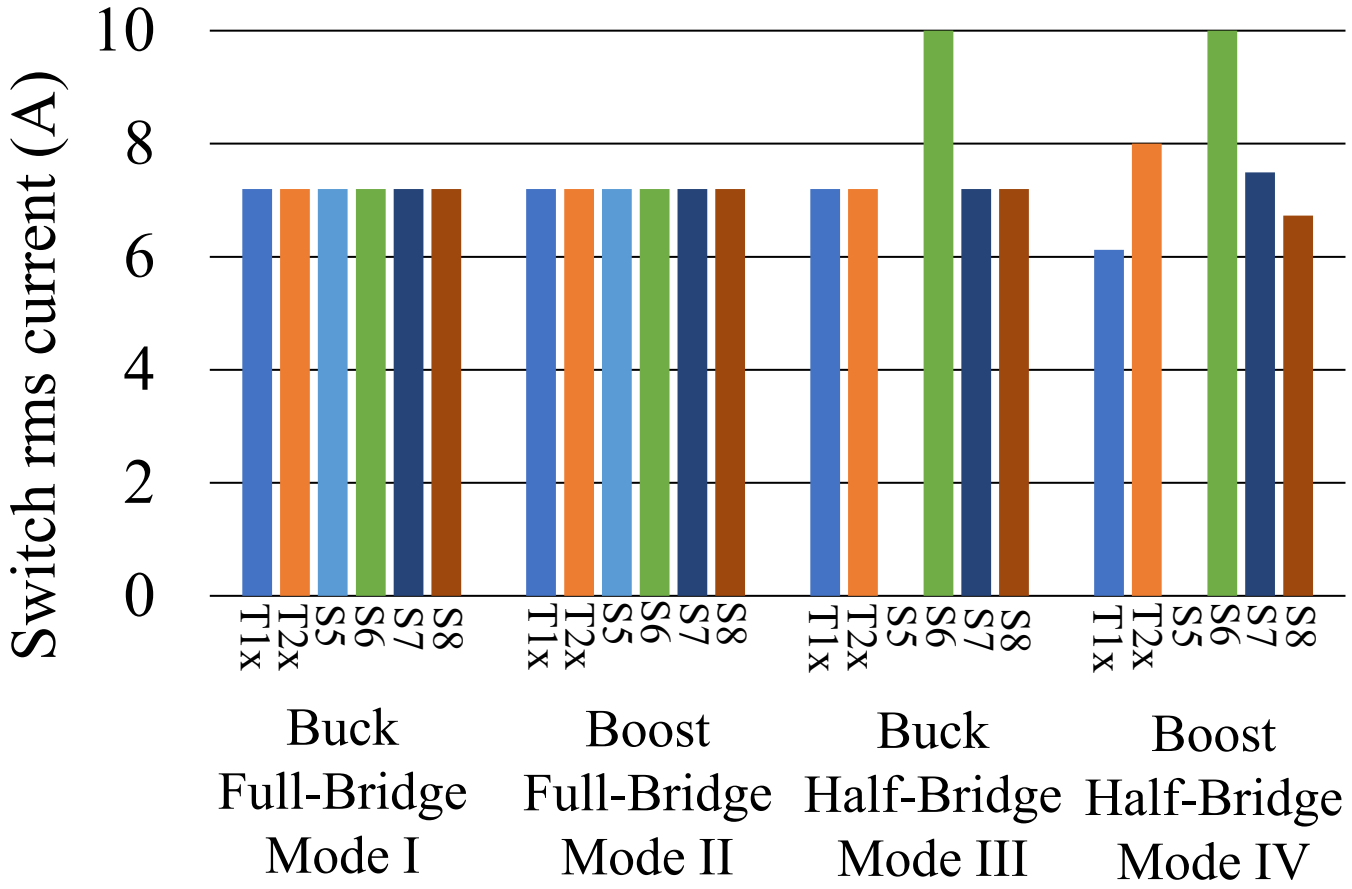
Single transformers

- **Dual-transformer configuration:** Offers **simpler control** but introduces additional secondary-side losses during balancing operation due to duty-cycle-controlled SRC operation
- **Single-transformer configuration:** Operates as a **three-port DAB** during balancing, potentially achieving higher efficiency at the cost of a more **complex modulation** strategy

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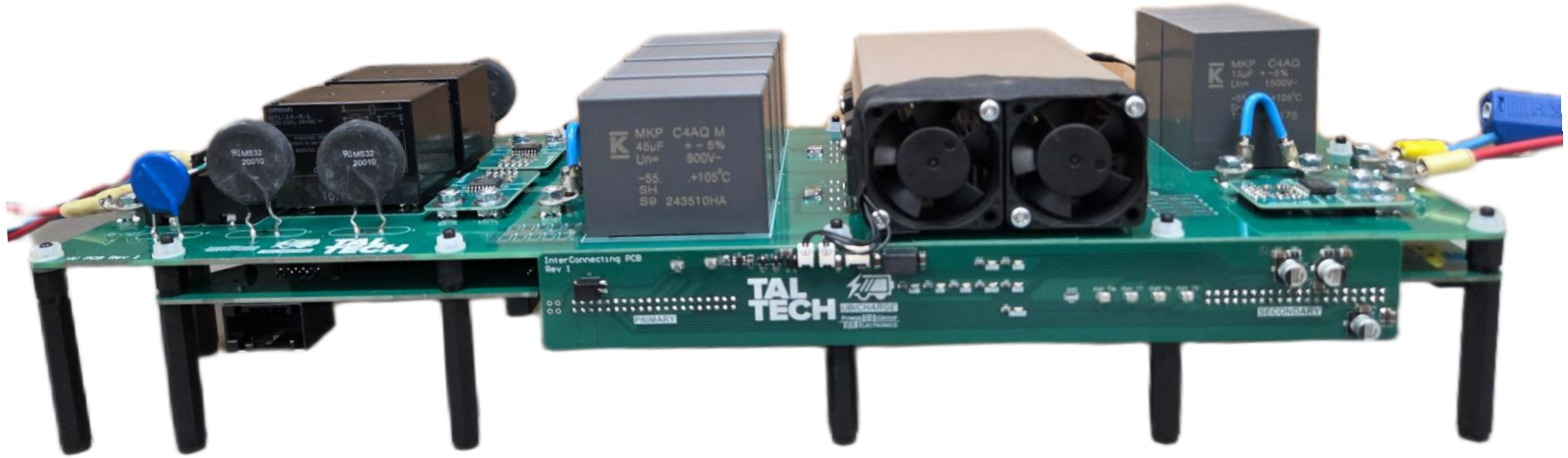
Current Stress of Switches

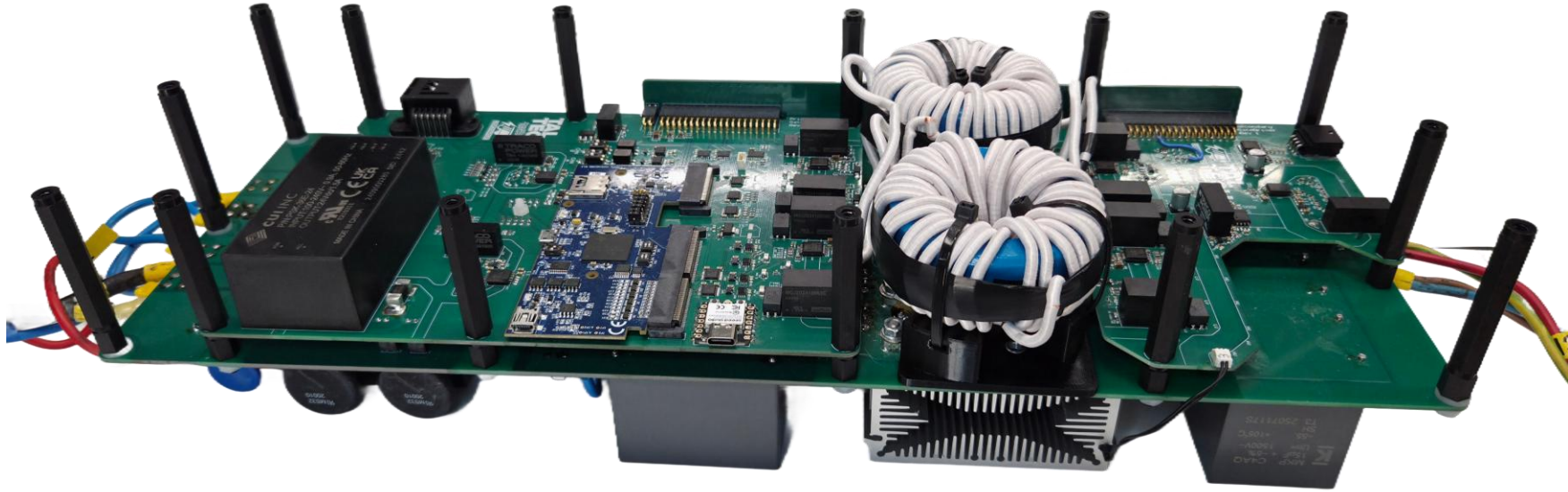
- In full-bridge operation, all switches carry equal current
- Half-bridge operation causes **unequal rms current sharing**
  - Uneven heating of switches
- Additionally switching losses must be considered
- Hard switching occurs:
  - Buck modes: **T1x, T2x**
  - Boost modes: **S5**, **S6** or **S6**



Second Generation Prototype

- Rated power: **5 kW**
- Protection and fault monitoring (**UVLO**, **OVLO**, **OCP**, **OVH**)
- Dual CAN communication channels
- Integrated precharge and relay control
- Improved system integration and functionality
- Closed loop control
- LUT based synchronous rectificaton

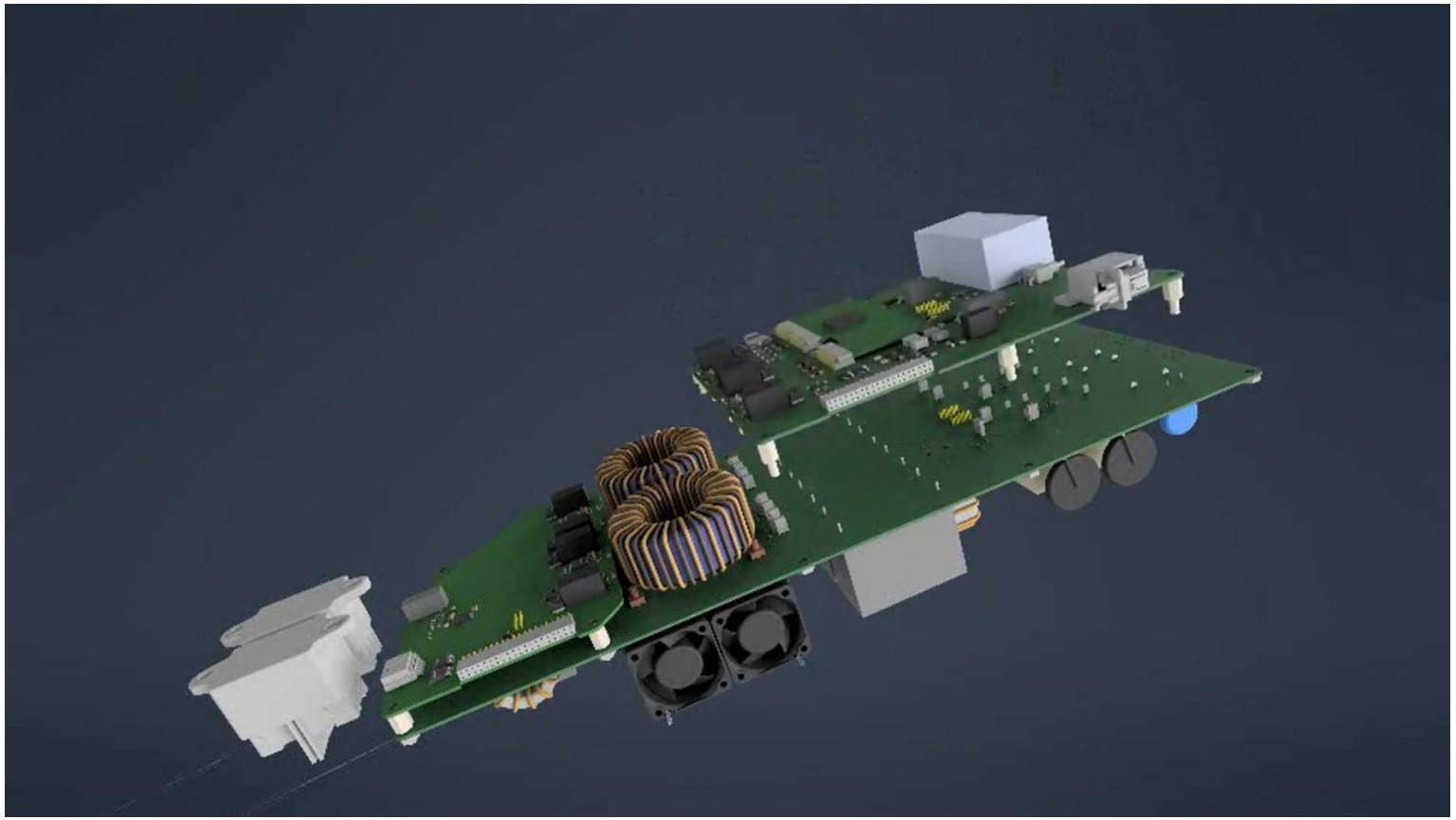




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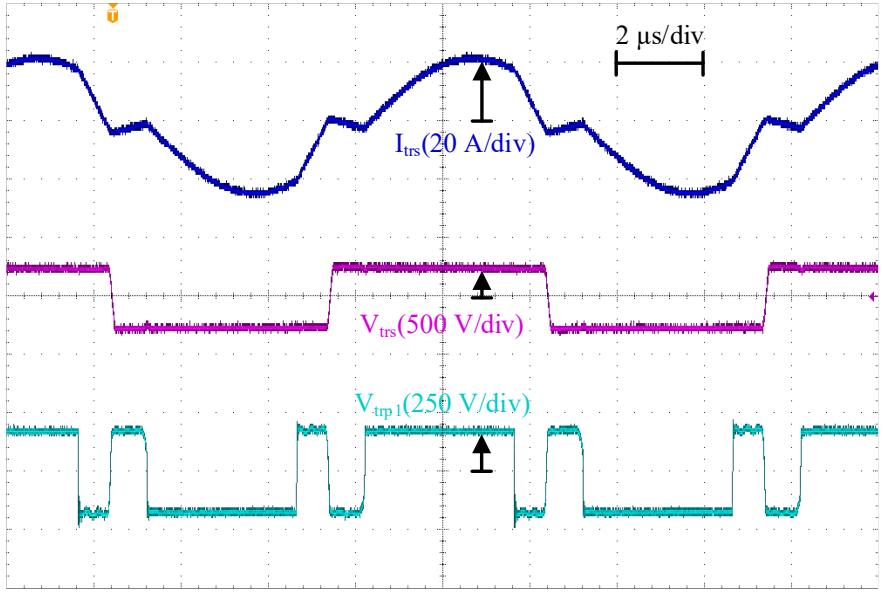
Second Generation Prototype

- Charger assembly consists of 4 PCBs:
  - **HV PCB**
  - **Control and primary gate driver**
  - **Secondary gate driver**
  - **Interconnecting PCB**



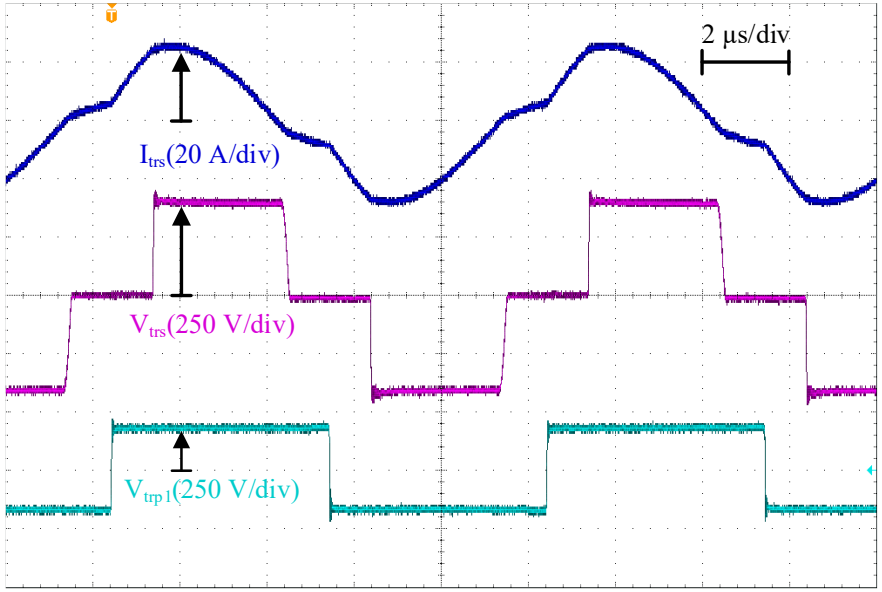
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Experimental Verification



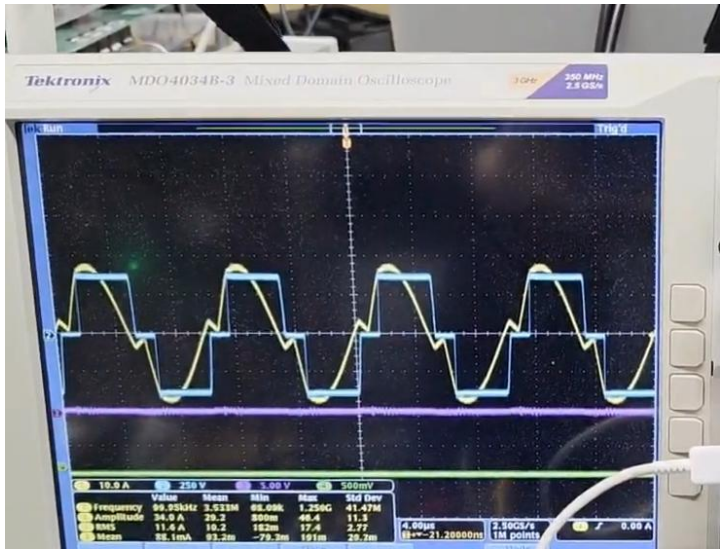
MODE Buck+FB

V_{in} = 350 V,
V_{out} = 264 V,
P_{out} = 3.4 kW,



MODE Boost+FB

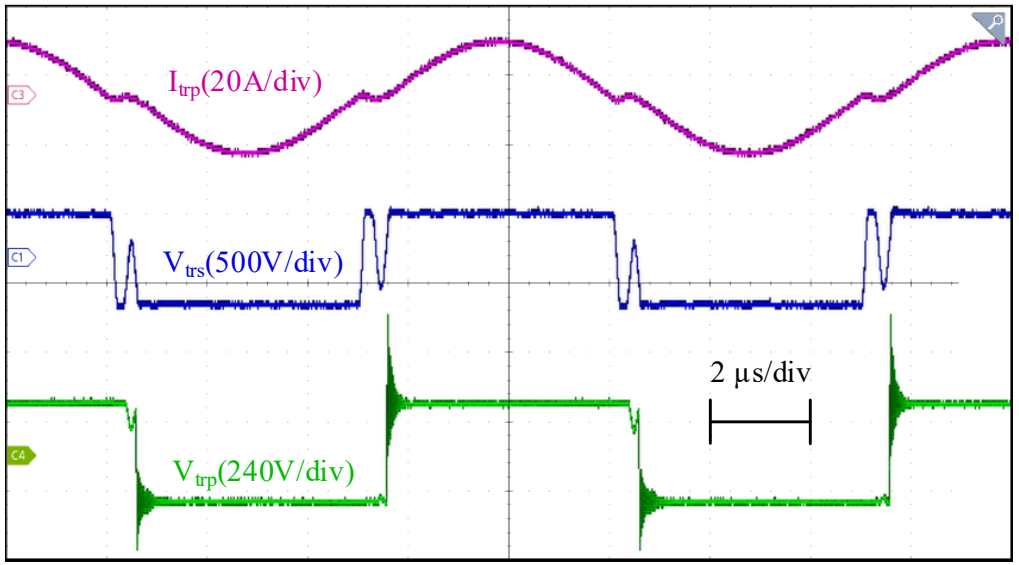
V_{in} = 350 V,
V_{out} = 410 V,
P_{out} = 4.5 kW,



Closed loop regulation, Buck+FB, Boost+FB modes

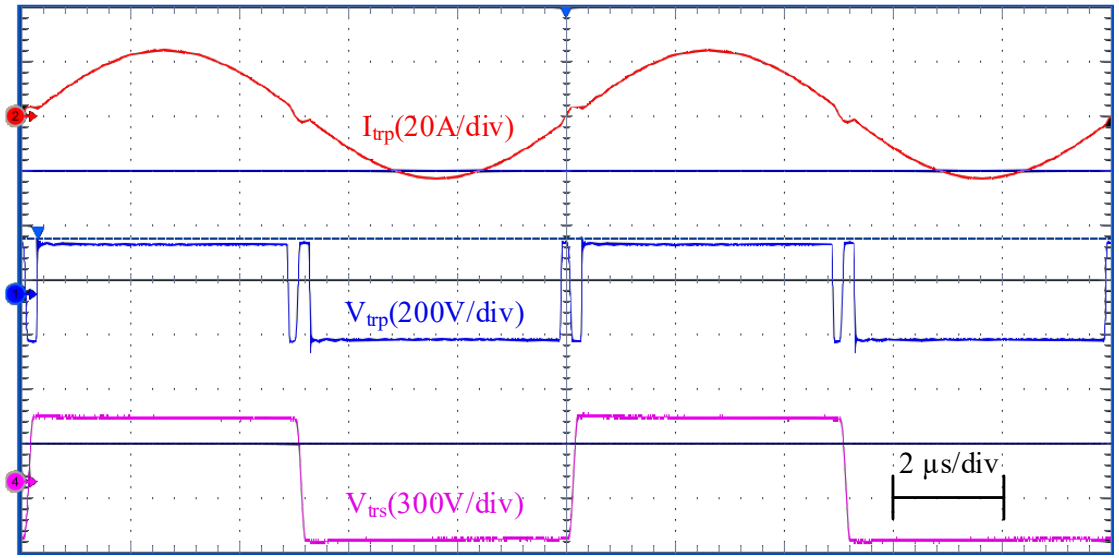
Mode I (Buck+FB) Performance Comparison

1st Prototype



- **Mode I**
- V_{out} = 335.8 V
- P_{out} = **3.1 kW**
- Efficiency = **96.5%**

2nd Prototype



- **Mode I**
- V_{out} = 334.9 V
- P_{out} = **4.9 kW**
- Efficiency = **97.1%**

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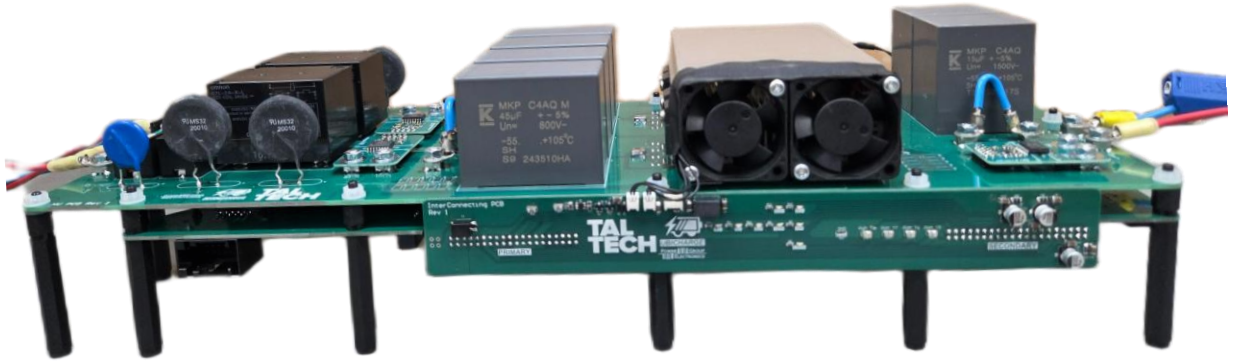
Conclusions and Next Steps

- Wide-range bidirectional DC–DC conversion demonstrated
- Topology-morphing control experimentally validated
- Over 97% efficiency achieved at tested high-power operating points
- Second-generation prototype developed with integrated control and protection

Next Steps:

- Preparing for TRL6
- Additional safety features (IMD)
- Charging controller integration





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Thank You for Attention!

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