

7 kW Bidirectional AC-DC for Energy Storage and Charging

Key Features



Design Considerations



Solution Specifications

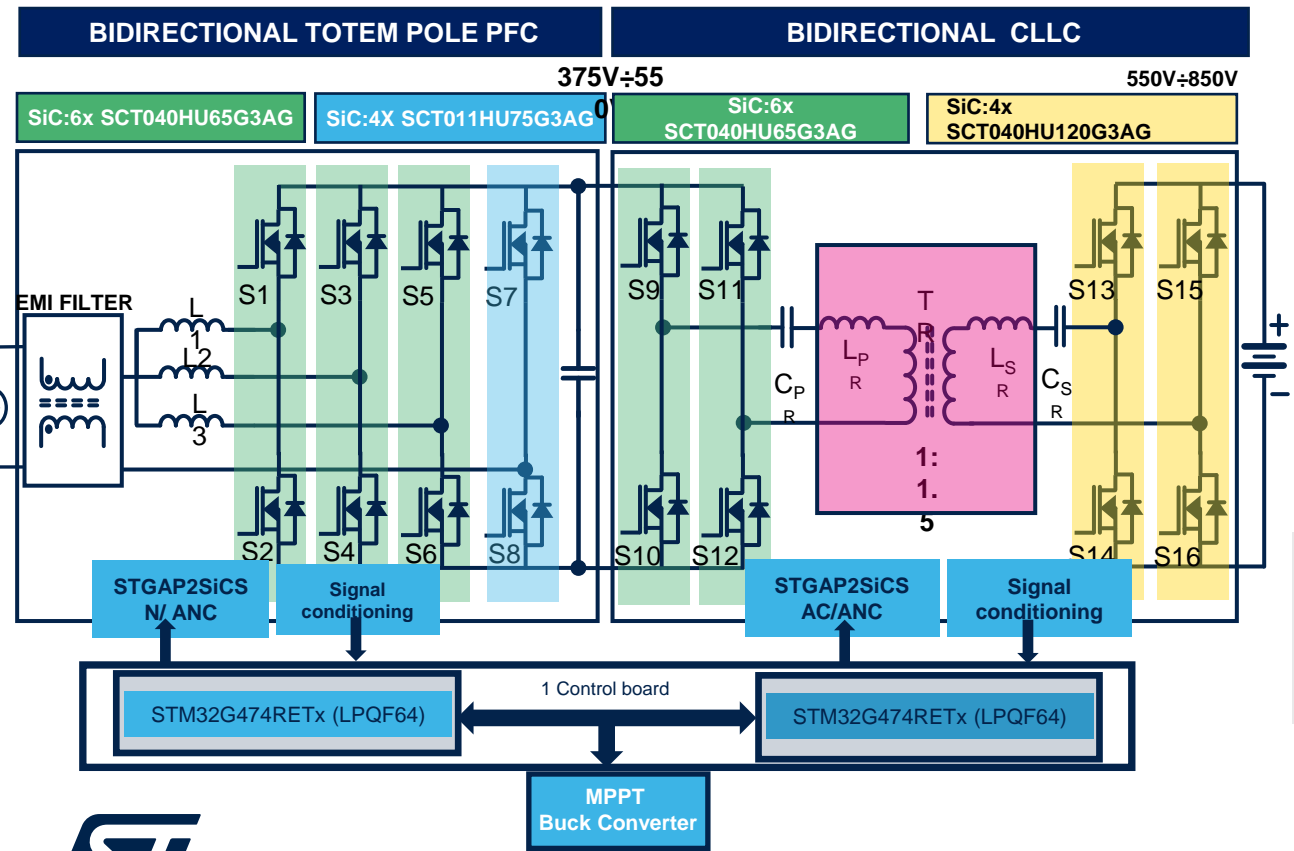


Key Products



7 Kw bidirectional AC-DC Key Features

STEVAL-7BIDIRCB consist in two stages



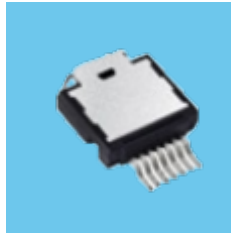
1) Bidirectional Three Channel Interleaved totem pole PFC working at Fixed Frequency in continuous conduction Mode (CCM)

2) Bidirectional resonant full bridge CLLC with synchronous rectification.

The two stages are digitally controlled by two STM32G474RET6 microcontrollers mounted on a single control board

Design Considerations

The Power Stage is fully composed by ST SiC power MOSFET



Driven by STGAP SiC gate drivers with galvanic Isolation. Thanks to a Modular system architecture in combination with HU3PAK a Power Density of 4KW/l is achieved



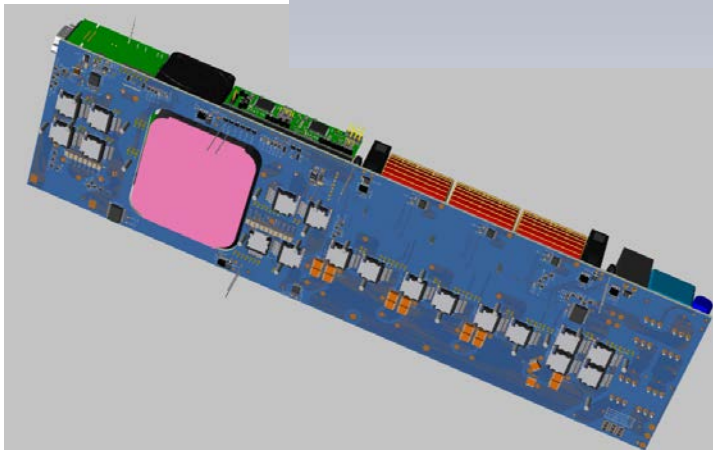
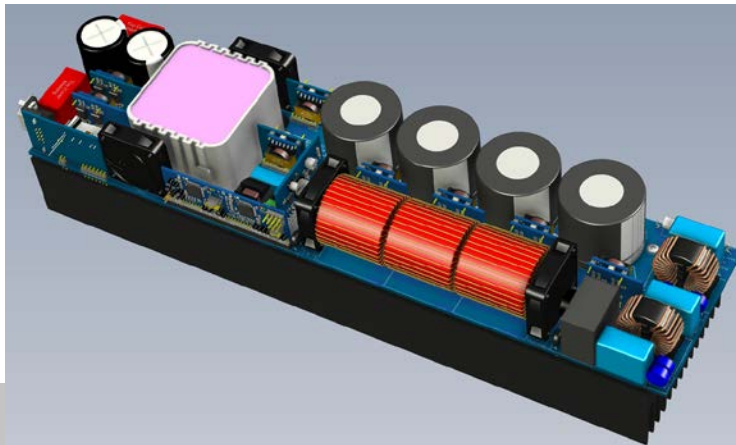
The PFC operates at a switching frequency of 65kHz and the CLLC operates at Variable Frequency from 180 to 600kHz.



Thanks to the Excellent Switching Performance of the Gen3 SiC with very low $R_{DS(on)}$, 96.7% peak efficiency is achieved in charge mode.

Solution Specifications

Open-Frame Power Density 4KW/l (66 W/inch³) Natural Air convection



Charge Mode

Input Voltage range : $V_{in} = 90 - 265 \text{ Vac}$ Switching frequency of PFC : 65kHz
Line Frequency range : $f = 47 - 63 \text{ Hz}$ Resonant frequency of CLLC: 200KHz
Max Input current : 32 Arms at 230Vac Peak efficiency > 96.5%
Input rated power: 7.2kW at 230Vac
Output Voltage range: $V_o = 550 - 850 \text{ Vdc}$
THD < 5% and PF > 0.99 at full load

Inverter Mode

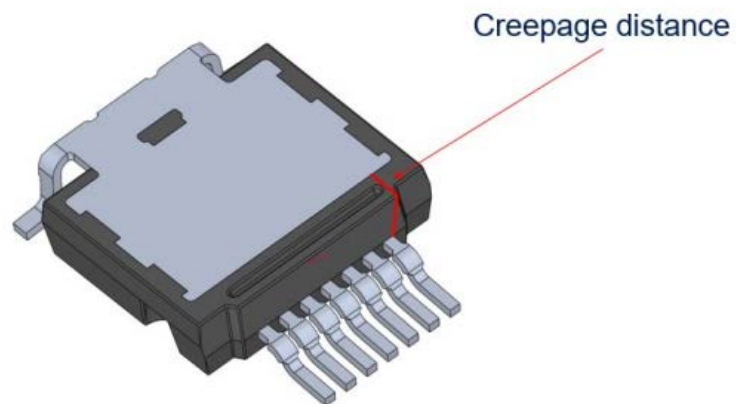
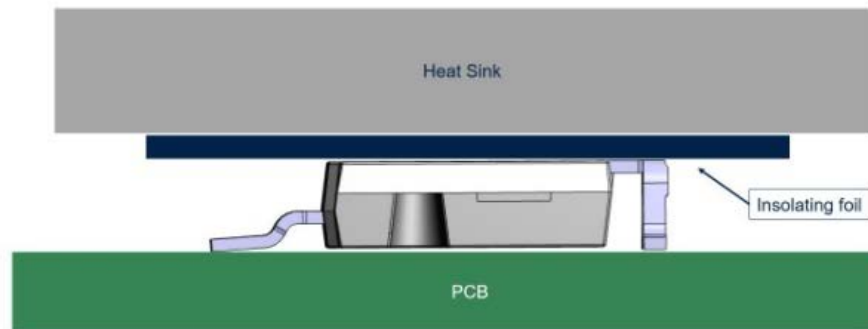
Input voltage range: $V_o = 550 - 850 \text{ Vdc}$
Output voltage range: $V_{in} = 90 - 265 \text{ Vac}$
Input rated power: 3.6 kW
Resonant frequency of DC/DC: 200 kHz
Switching frequency of DC/AC: 65 kHz
Peak efficiency > 95 %

Test Results

The Power density achieved in this design is 4.03 kW/dm³ (66 W/ inc³) The total efficiency is **96.7%**.
The PFC has **peak** efficiency of **98.8%** and the CLLC is **98%**

Key Products

ST HU3PAK SiC Technology with Top Side Cooling Capability



SiC

- SCT040HU65G3AG - SiC Power MOSFET 650 V, 40 mOhm typ.
- SCT011HU75G3AG* - SiC Power MOSFET 750 V, 11 mOhm typ.
- SCT040HU120G3AG* - SiC Power MOSFET 1200V, 40 mOhm typ.,

STGAPSiC

- STGAP2SICSN/STGAP2SICSAC/STGAP2SICSANC
- High Voltage rail up to 1700V
- Driver current Capability 4A sink/source
- dv/dt transient immunity +/-100 V/ns in full temperature range

ISO
BUCK

- A6986I - Automotive 38 V, 5 W synchronous iso-buck converter
- A6986F3V3/A6986F5V - Automotive 38 V, 1.5 A synchronous stepdown switching regulator

7.2 kW Bi-Directional Charger

Documentation



STEVAL-7BIDIRCB

Data brief

7 kW bidirectional AC-DC converter for ESS and industrial charger, full SiC-based



The picture shown is for illustration purpose only.
Actual product may vary depending on buyer's selection and availability.

Features

- Open-frame power density: 4 kW/l (66 W/inch³)
- Cooling: natural air convection

Charger Mode

- Input voltage range: $V_{in} = 90 - 265$ Vac
- Line frequency range: $f = 47 - 63$ Hz
- Max input current: 32 Arms at 230 Vac
- Input rated power: 7.2 kW at 230 Vac
- Output voltage range: $V_o = 550 - 850$ Vdc
- THD < 5 % and PF > 0.99 at full load
- Switching frequency of PFC: 65 kHz
- Resonant frequency of CLLC: 200 kHz
- Peak efficiency > 96.5 %

Inverter Mode

- Input voltage range: $V_o = 550 - 850$ Vdc
- Output voltage range: $V_{in} = 90 - 265$ Vac
- Input rated power: 3.6 kW
- Resonant frequency of DC/DC: 200 kHz
- Switching frequency of DC/AC: 65 kHz
- Peak efficiency > 95 %

Description

The STEVAL-7BIDIRCB is a solution for a 7 kW bidirectional charger, consisting of two stages:

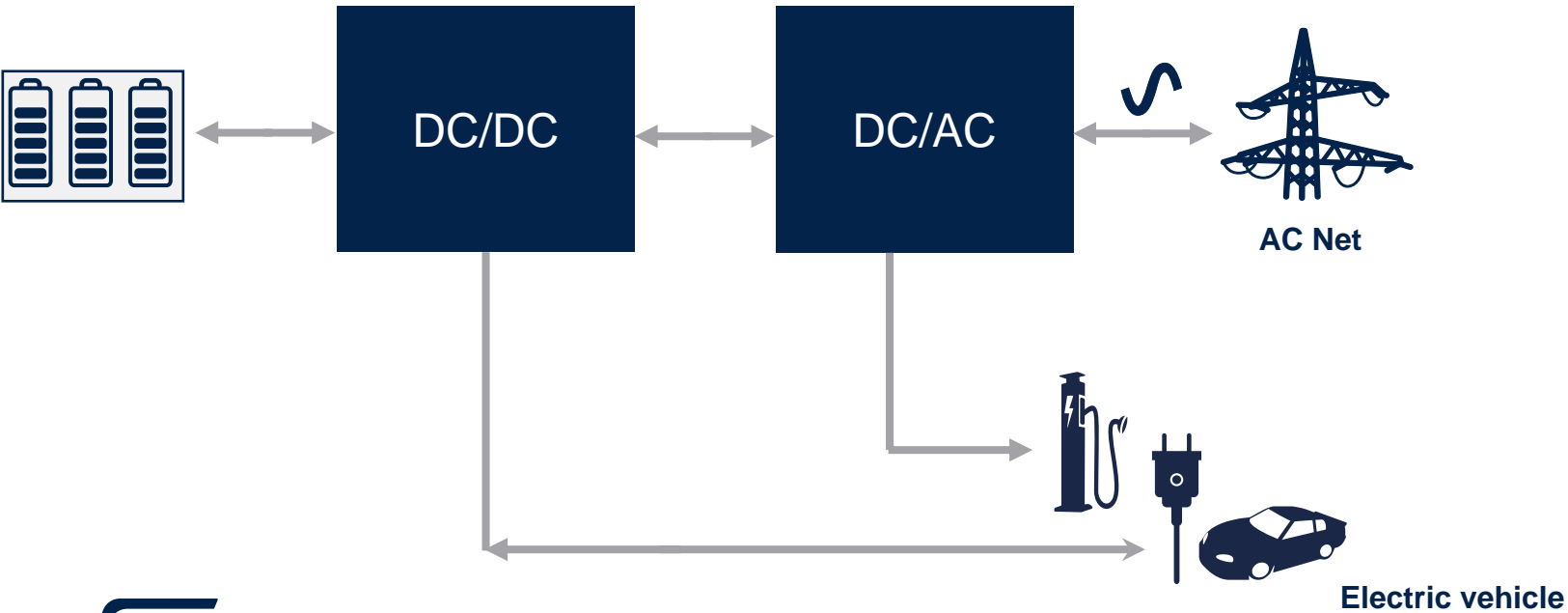
1) Bidirectional three channels interleaved totem pole PFC working at fixed frequency



Product summary	
7 kW bidirectional AC-DC converter for ESS and industrial charger, full SiC-based	STEVAL-7BIDIRCB
Automotive-grade silicon carbide Power MOSFET 650 V, 40 mOhm typ., 30 A in an HU3PAK package	SCT040HU65G3AG
Mainstream Arm Cortex-M4 MCU 170 MHz with 512	STM32G474RET6



New Hybrid Solution use case

Residential hybrid battery – integrated EV charger



-  Versatile chargers
-  Faster charge time

Work, private / public outlet, home
(240V AC home/public)

Power range: 2.5kW-19KW
(most common 7.2 KW)
Current range: 12A - 80A
(most common 32A)

STPOWER SiC MOSFET

Positioning vs. product family & Focus application

Breakdown Voltage

650V

750V / 900V

1200V

1700V

2200V

Series

G2

G3

G3

G1

G2

G3

G1

VHV

On-state resistance

18 mOhm to
55 mOhm

14-55 mOhm

11 mOhm

52 mOhm to
520 mOhm

25 mOhm to
75 mOhm

70 mOhm and
15 mOhm

1 Ohm and
65 mOhm

31mOhm

Focus Applications

OBC & DC-DC
Renewable energy
Power Supply
Industrial drives

Traction
OBC & DC-DC
High density
Power Supply

Traction Inverter
OBC & DC-DC
High density
Power Supply

Photovoltaic
Power supply

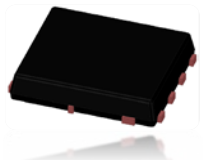





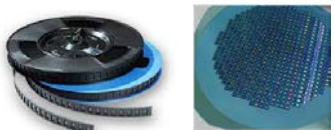
OBC & DC-DC
Inverter
Charging stations
Industrial drives

Traction Inverter
OBC & DC-DC
HF Power Supply

DC-DC
Power
Supply
Renewable
energy

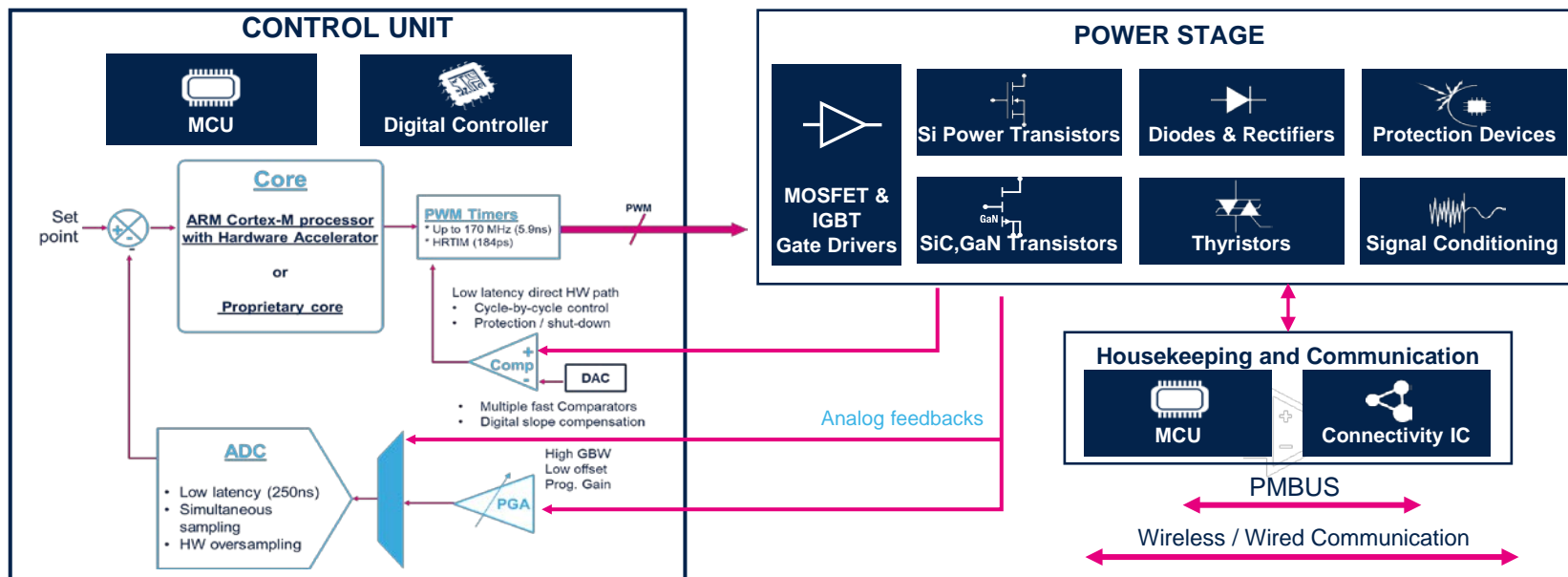
DC-DC
Power
Supply
Renewable
energy

SiC MOSFET Package

Package	Power FLAT 8x8 STD & DSC	H2PAK-7L	HU3PAK	ACEPAK SMIT	HiP-247 3L, 4L & 4L HC	STPAK	Bare Dice
							
	Surface Mounting				Through-Hole	Special Package Solutions	
Characteristics	<ul style="list-style-type: none"> □ Very Thin (< 1mm) □ Well accepted in power conversion □ Dual side cooling option □ Leadless □ Industrial domain 	<ul style="list-style-type: none"> □ AG qualified at 175dC □ Kelvin Source for optimized driving □ High runner for Automotive customers 	<ul style="list-style-type: none"> □ AG qualified at 175dC □ Top side cooling □ Kelvin Source for optimized driving □ Very good thermal dissipation 	<ul style="list-style-type: none"> □ AG qualified at 175dC □ Isolated Top side cooling □ Suitable for different configurations (HB, Dual die, etc.) □ High Power □ Modular Approach 	<ul style="list-style-type: none"> □ AG qualified at 200dC □ Very common Industry standard □ Kelvin Source option for optimized driving □ High creepage version (1200V and 1700V) in development 	<ul style="list-style-type: none"> □ f □ AG qualified at 200dC □ Very High thermal dissipation efficiency □ Sense pin for optimized driving □ Multi-sintered package 	<ul style="list-style-type: none"> □ WLBI & KGD □ T&R or RWF options □ Compliant with the most stringent Automotive Quality Requirements

Exploiting digital power for innovative converters

ST simplifies access to digital power advantages and accelerates roadmap to higher integration, with fewer and smaller devices performing more complex function in power and energy management



Demand for **higher system efficiency**, exceeding the most stringent energy requirements



Greater power density with higher switching frequency and faster control loops

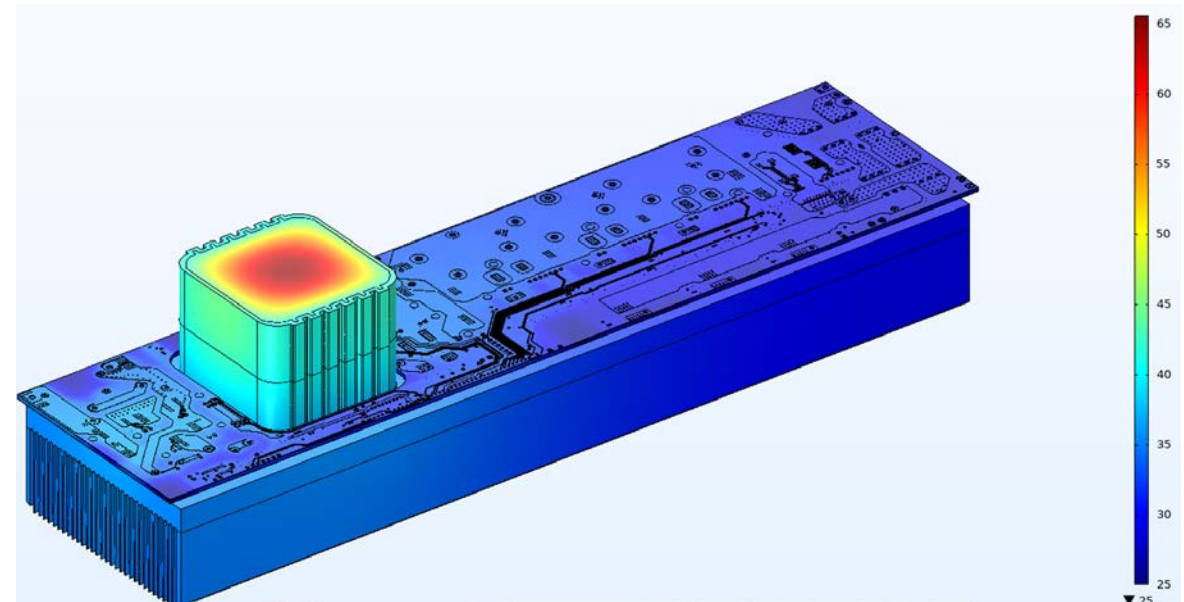
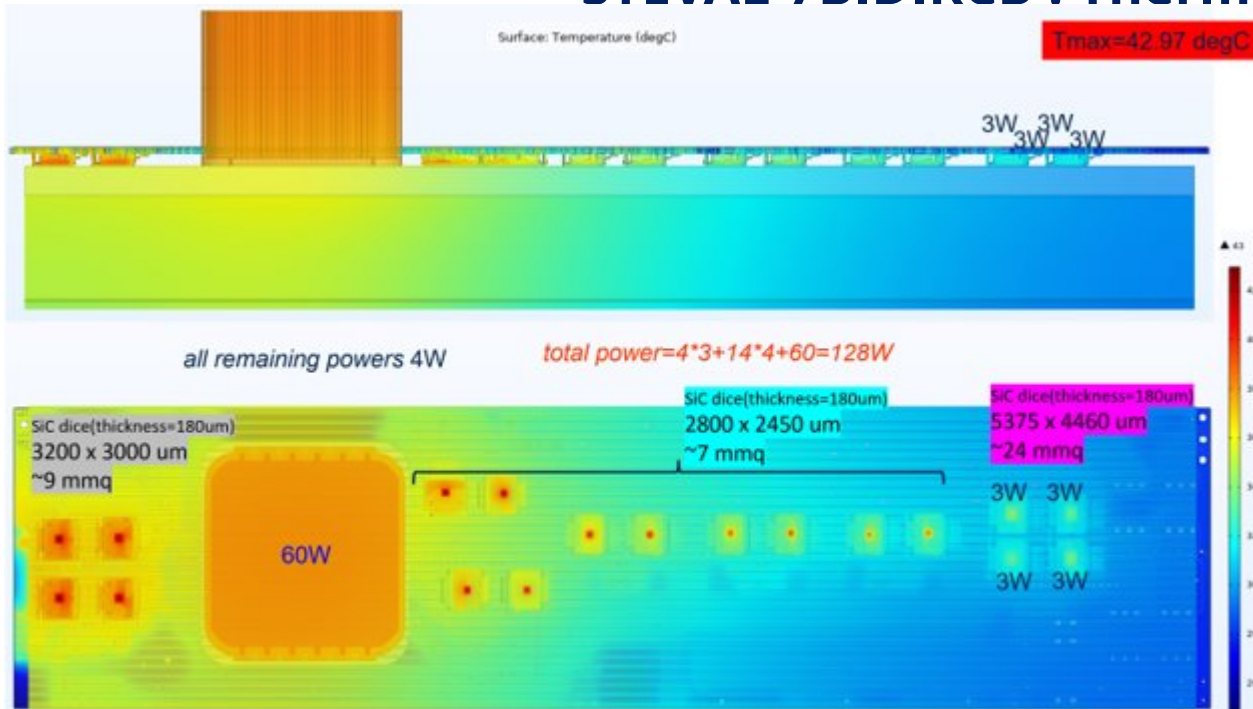
System level reliability, monitoring and safety with failure prediction in power distribution



7.2 kW Bi-Directional Charger

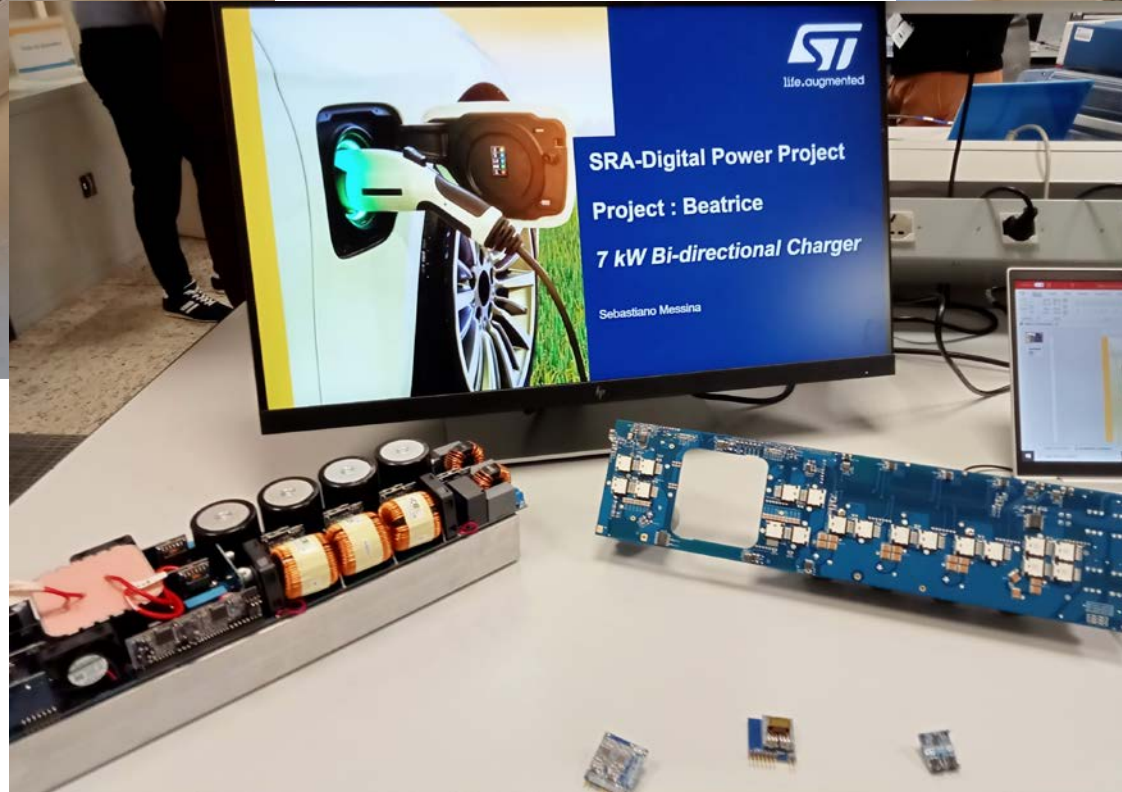
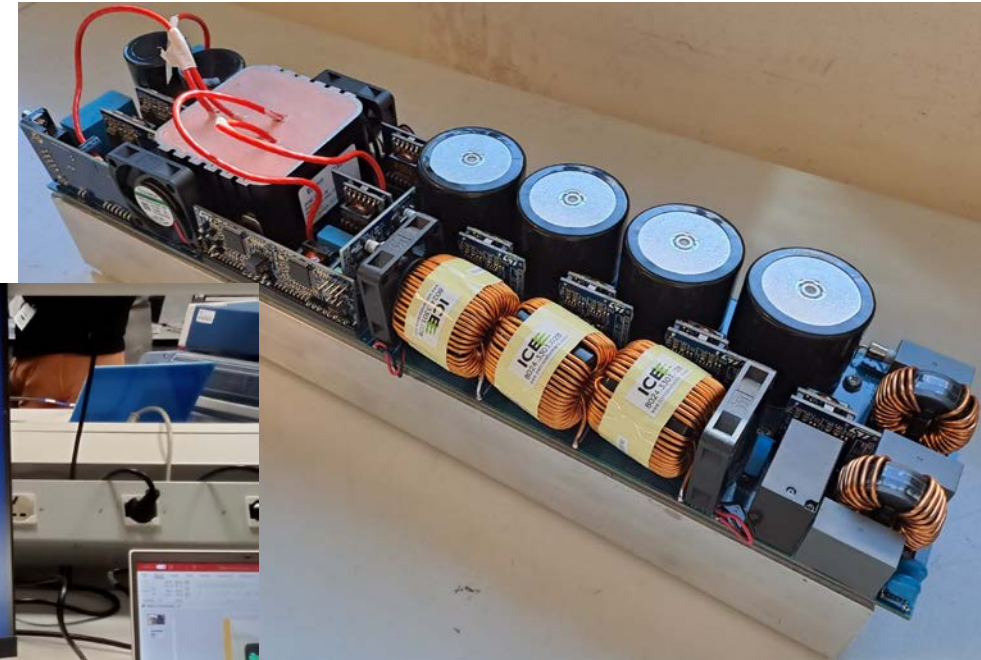
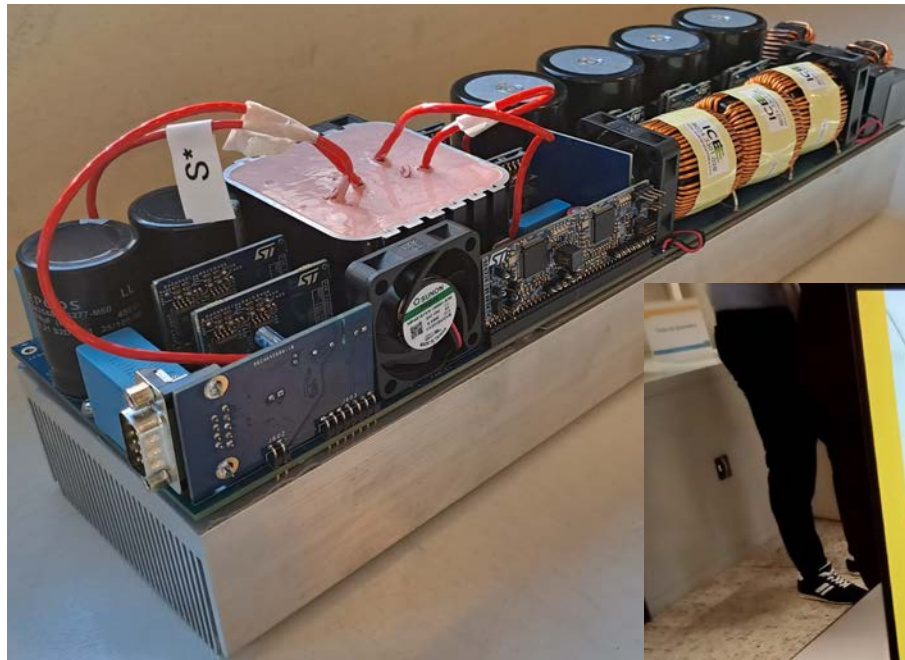
Collaboration with AMS R&D: Roberto Nicolosi

STEVAL-7BIDIRCB : Thermal Simulation done!



7 kW Bi-Directional Charger

Photos



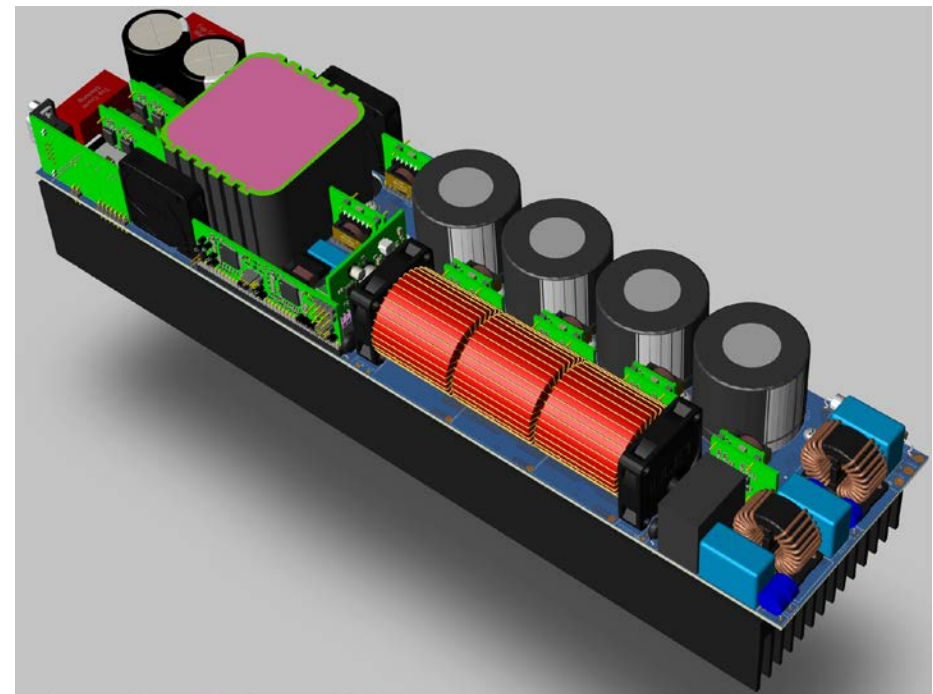
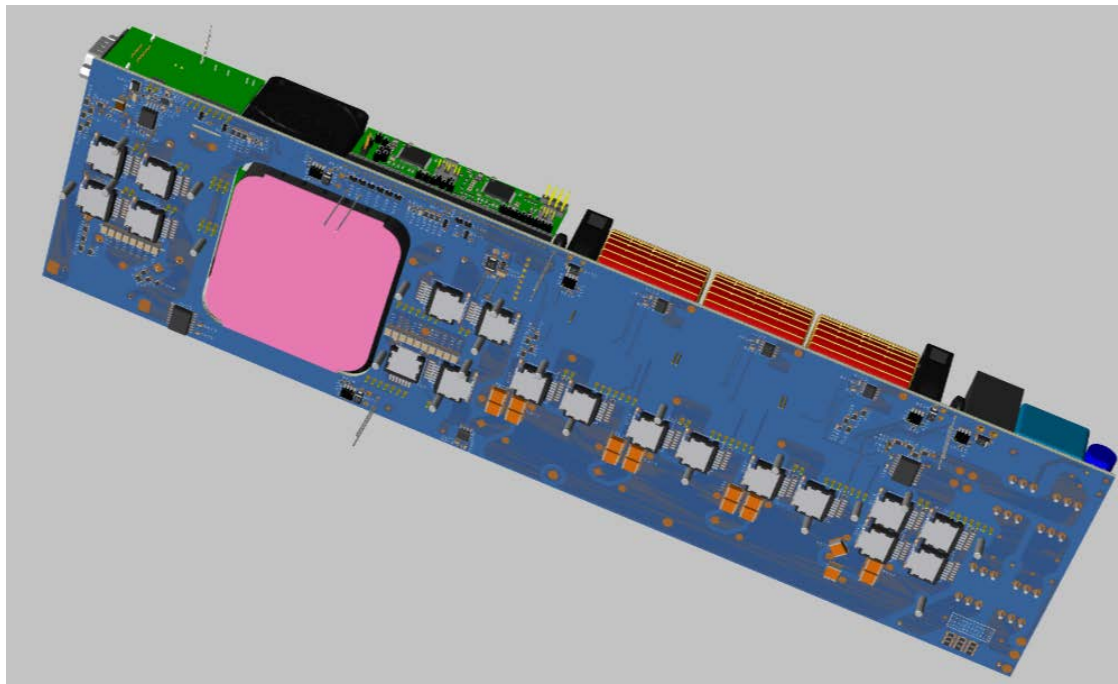
7 kW Bi-Directional Charger

Final dimensions

Dimensions : 397mm x 100mm x 45 mm

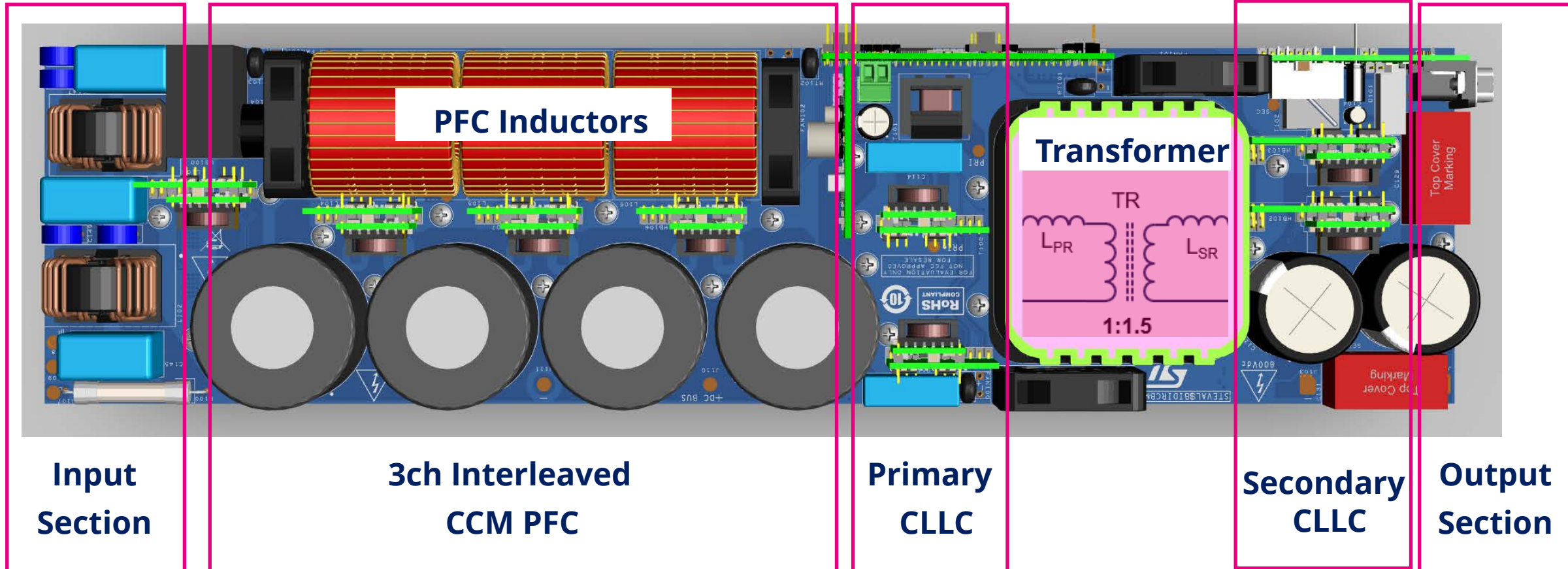
Total volume: 1.78 dm³

Power Density: 4.03 kW/dm³ (66 W/inc³)



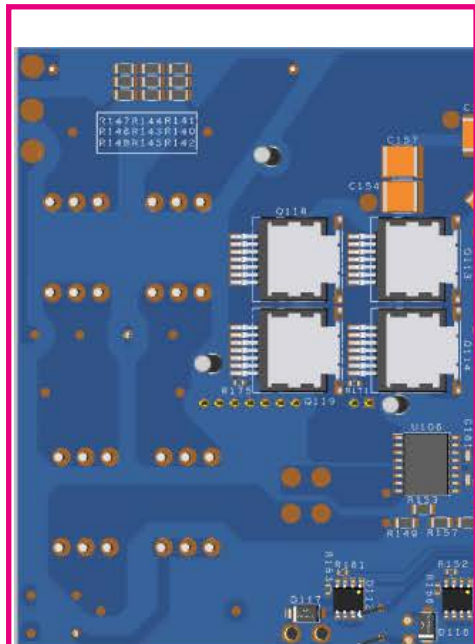
7kW Bi-Directional Charger: High power density Layout

Layout : top view

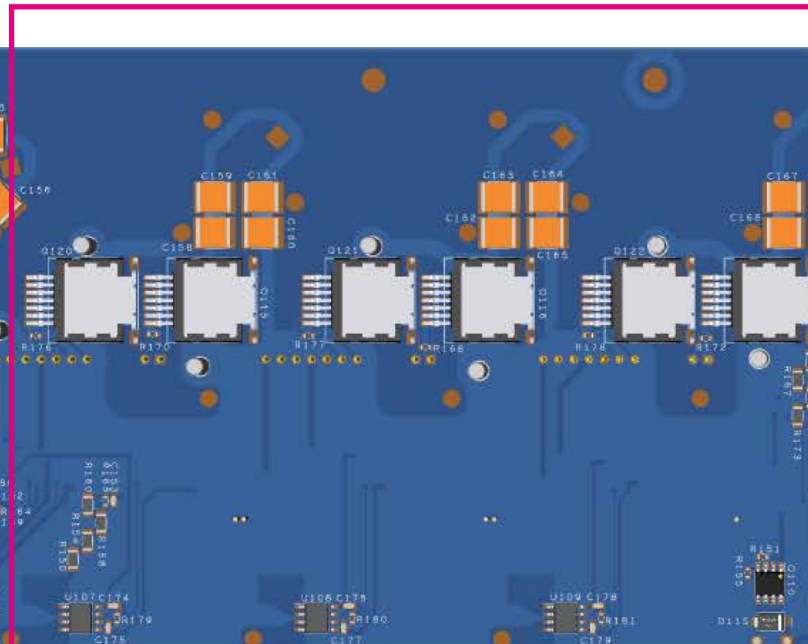


7kW Bi-Directional Charger: High power density Layout

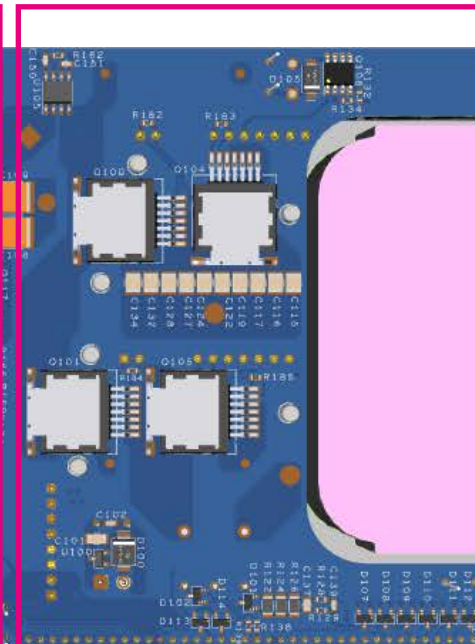
Layout : Bottom view



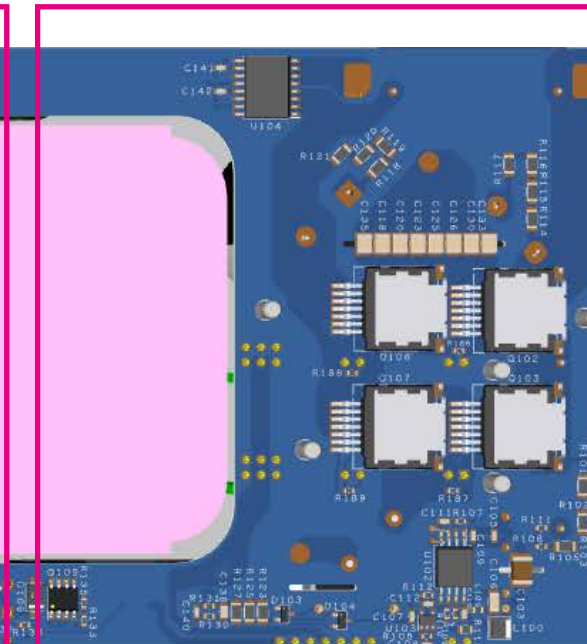
PFC Low freq. leg
4X
SCT011HU75G3AG



PFC High freq. legs
6X
SCT040HU65G3AG



Primary CLLC
4X
SCT040HU65G3AG



Secondary CLLC
4X
SCT040HU120G3AG

7kW Bi-Directional Charger: High power density Layout

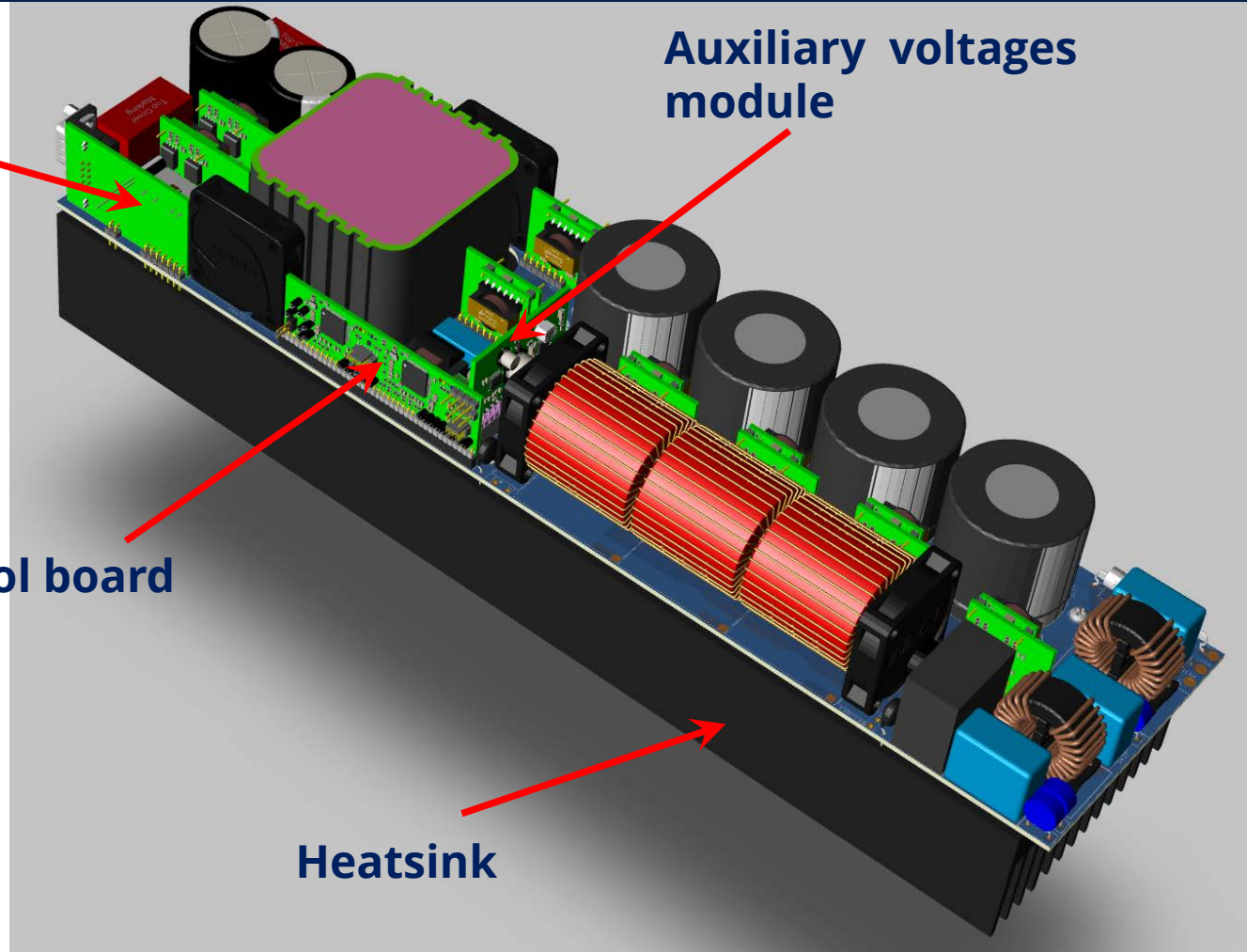
Layout : 3D view

CAN Module

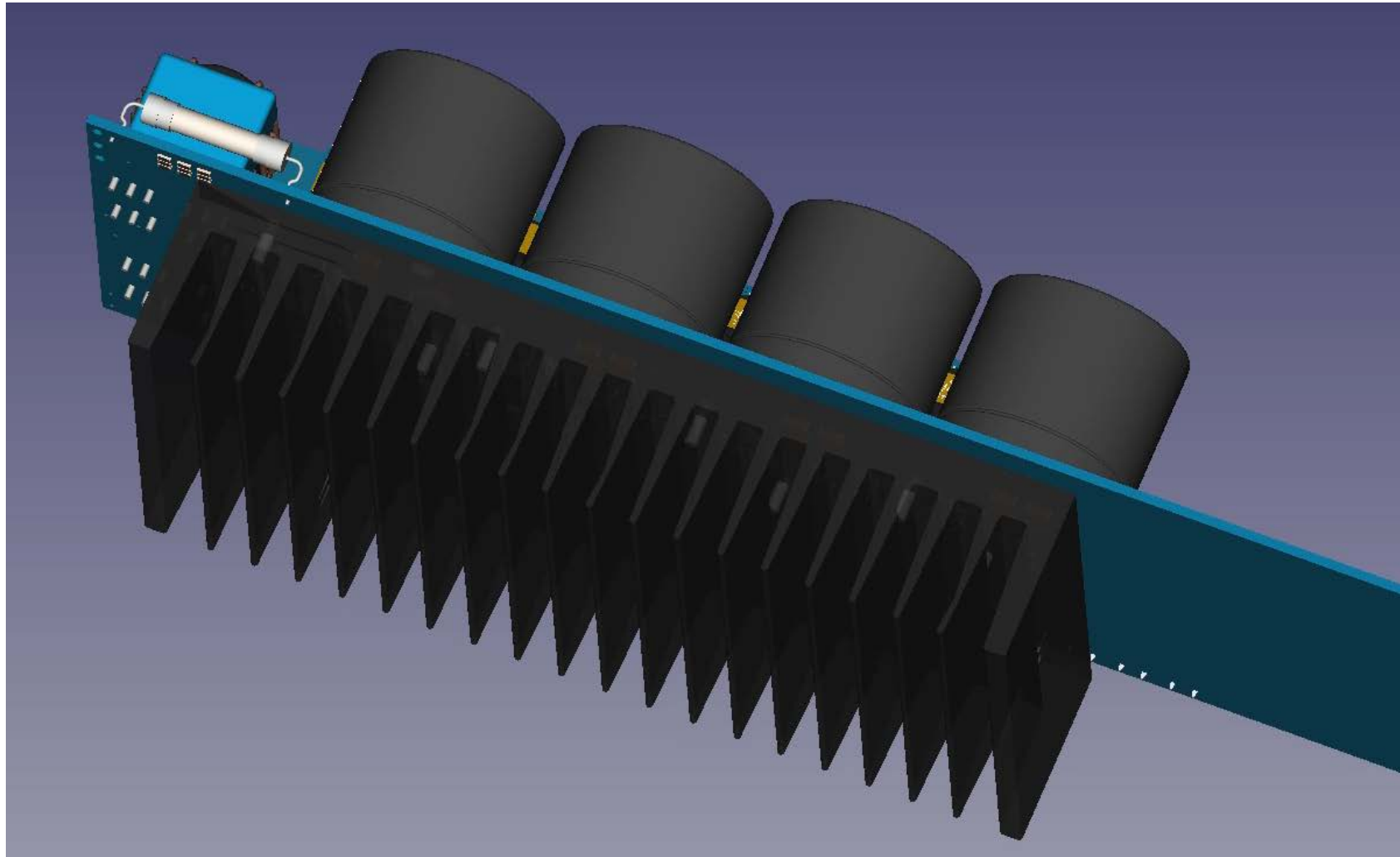
Auxiliary voltages module

Control board

Heatsink



7kW Bi-Directional Charger: Assembly sequence



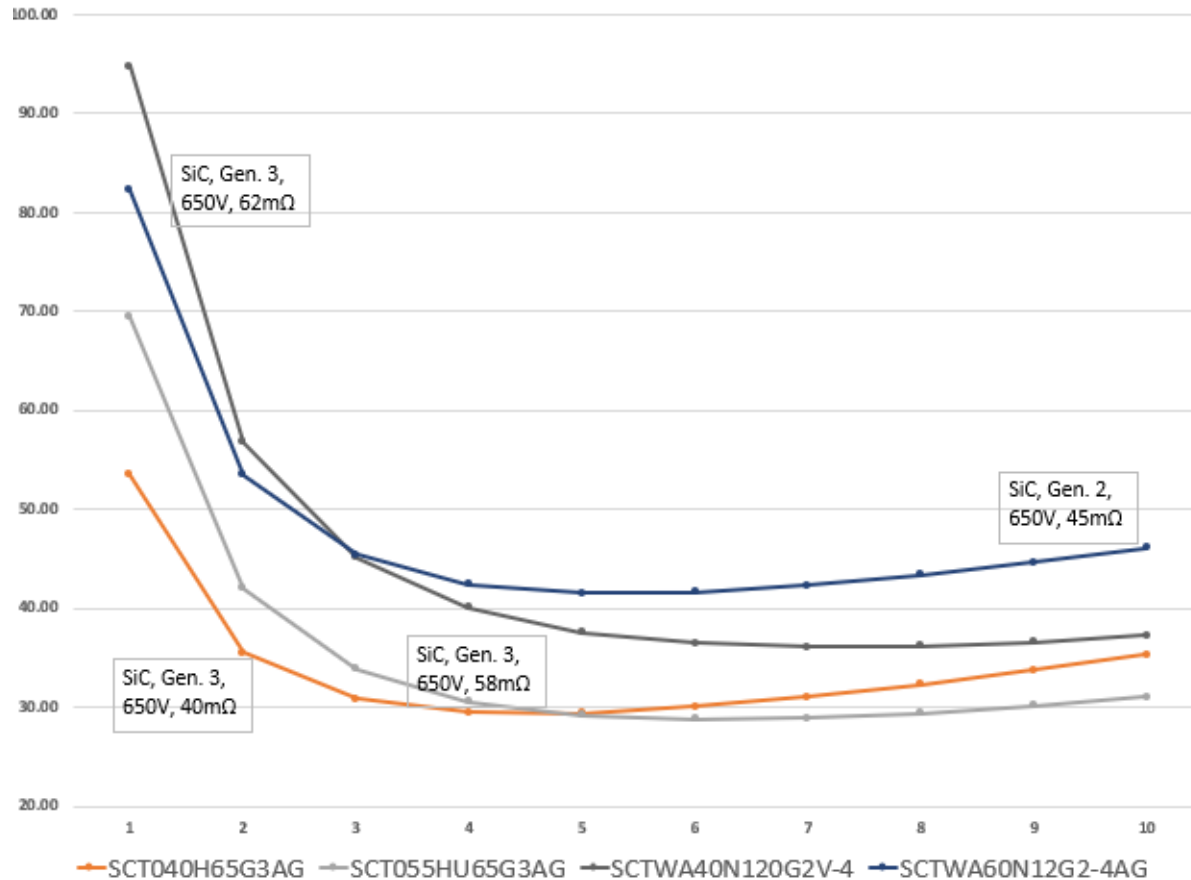
7 kW Bi-Directional Charger

BIDIRECTIONAL TOTEM POLE PFC: Switches Losses estimation using SiC Mosfet

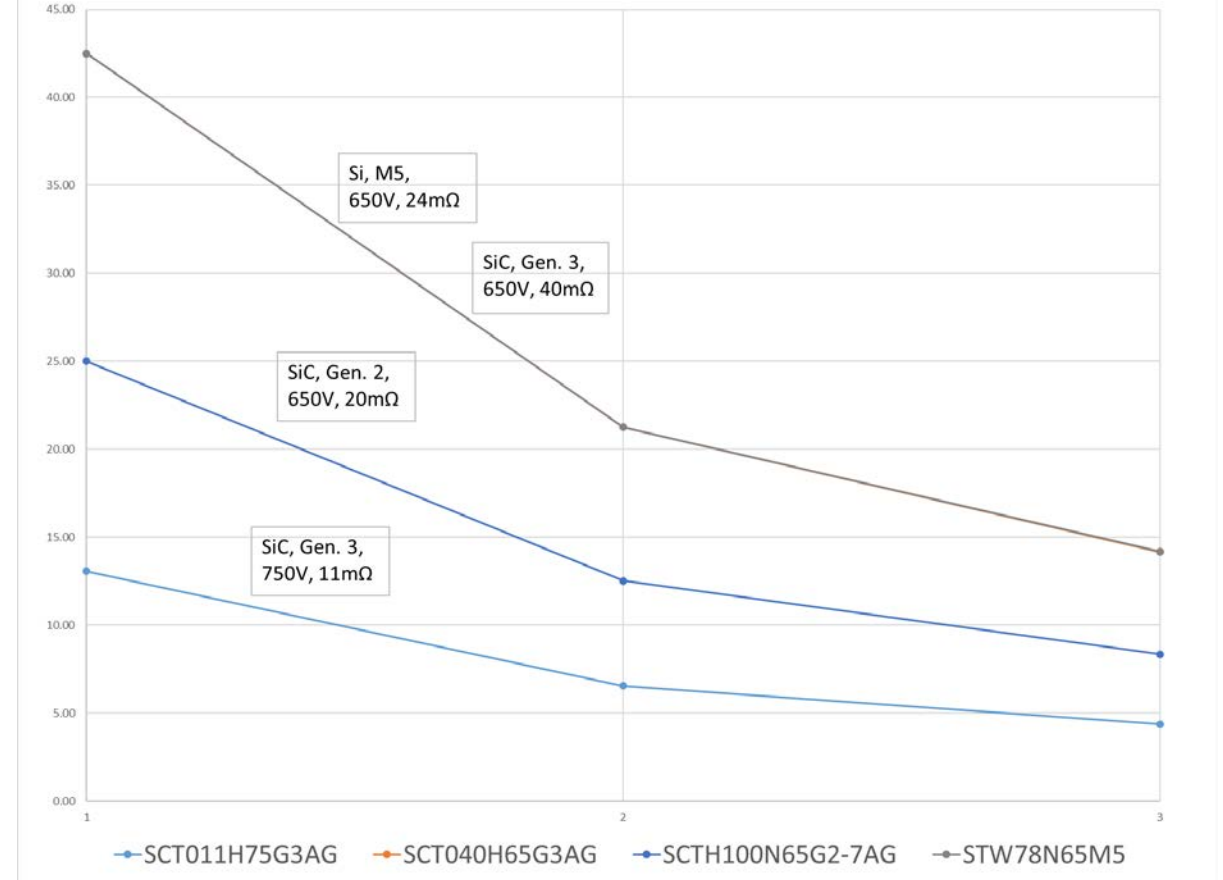
SiC Transistors 8A rms Rdson < 60 mΩ 650V

SJ Mosfets: 32A rms Rdson < 10 mΩ, 650V

HF legs losses vs Nch (@7.2 kW, 120 kHz)



LF leg losses vs N_parallel_devices (@32A)

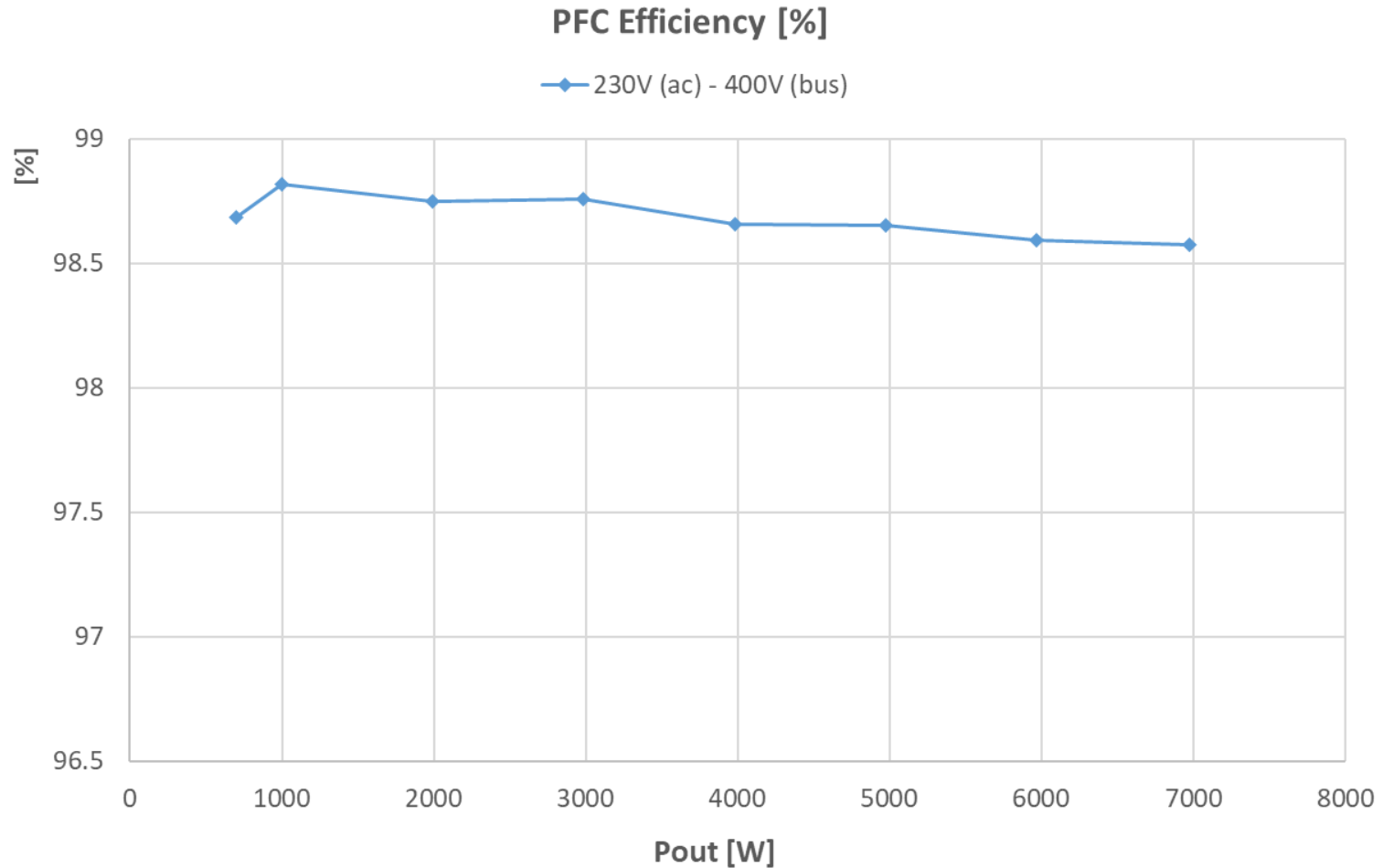


7 kW Bi-Directional Charger

Test Results PFC

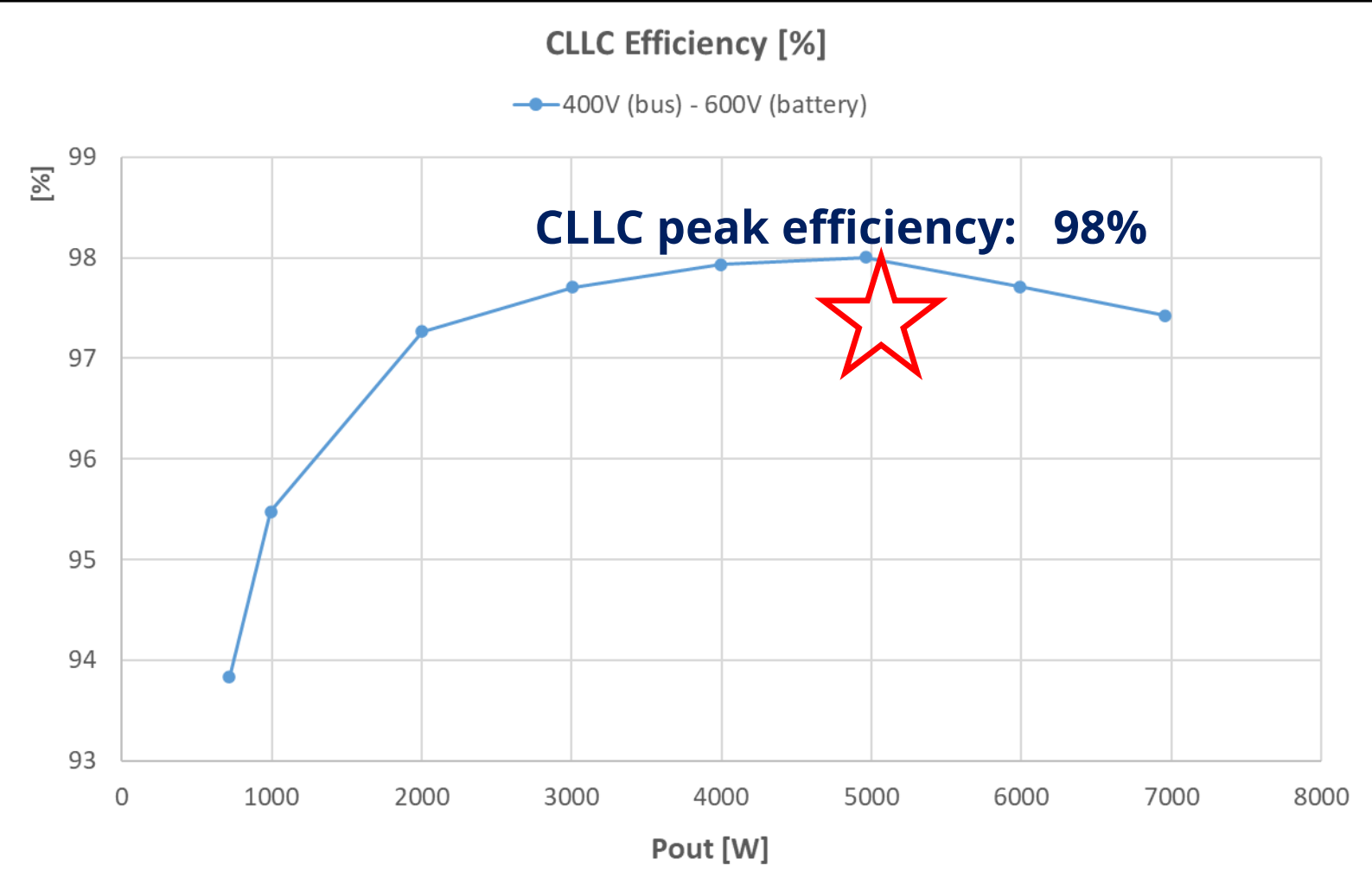
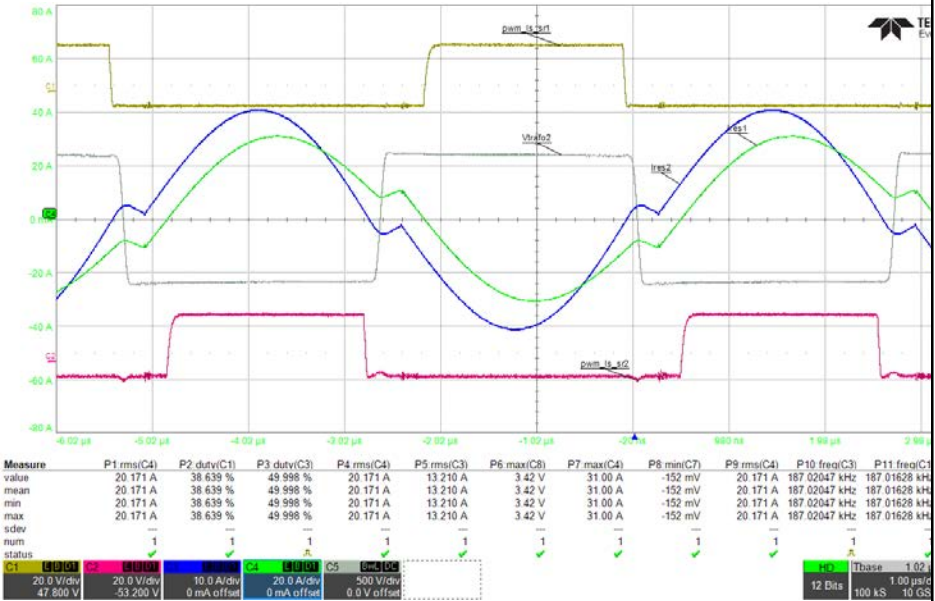
PFC peak efficiency: 98.8%

	INV_OUT Ch1	DC_IN Ch2	M
Vrms	230.33 V	399.67 V	
Arms	30.761 A	17.473 A	
W	7.0731 KW	6.9727 KW	
Freq	50.000 Hz		
VA	7.0851 KVA		
VAR	412.57 VA		
PF	0.9983		
Vthd	0.3964 %		
Athd	2.1956 %		
DP			100.39
EFF			98.581



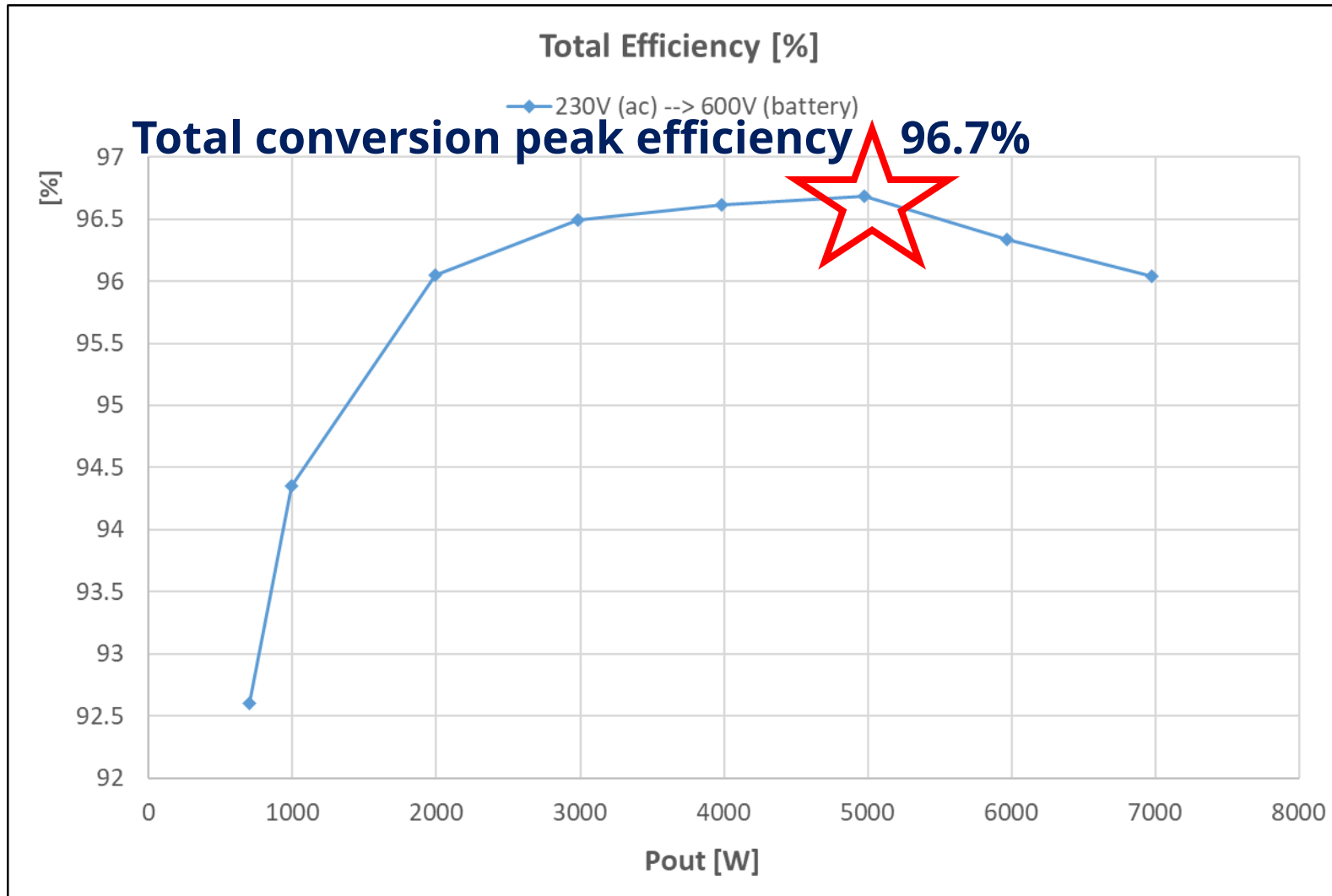
7 kW Bi-Directional Charger

Test Results CLLC



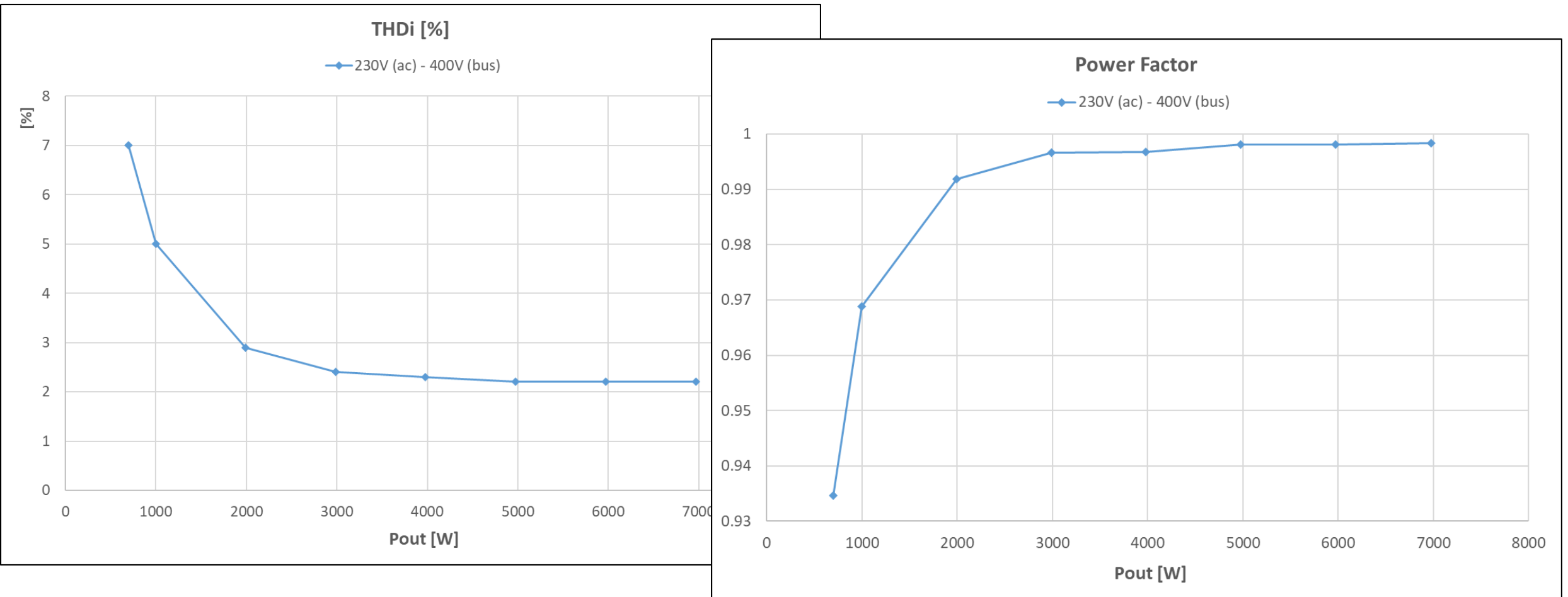
7 kW Bi-Directional Charger

Tests Results PFC + CLLC



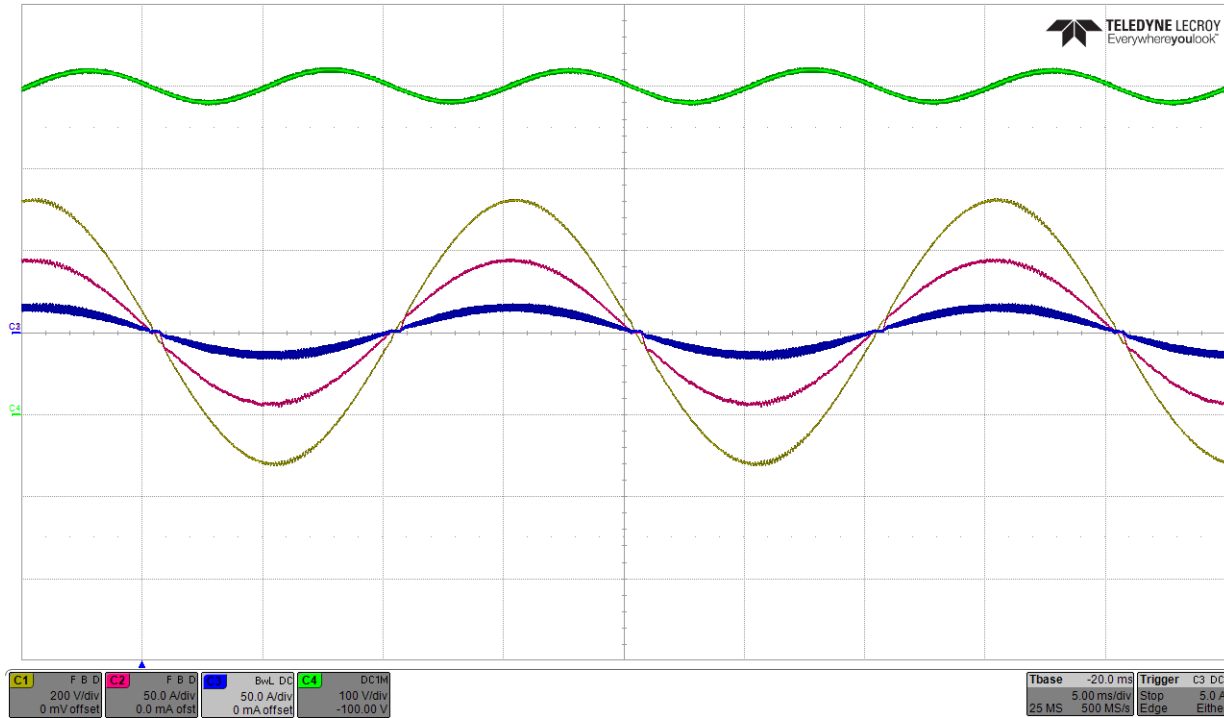
7 kW Bi-Directional Charger

Tests Results PFC + CLLC

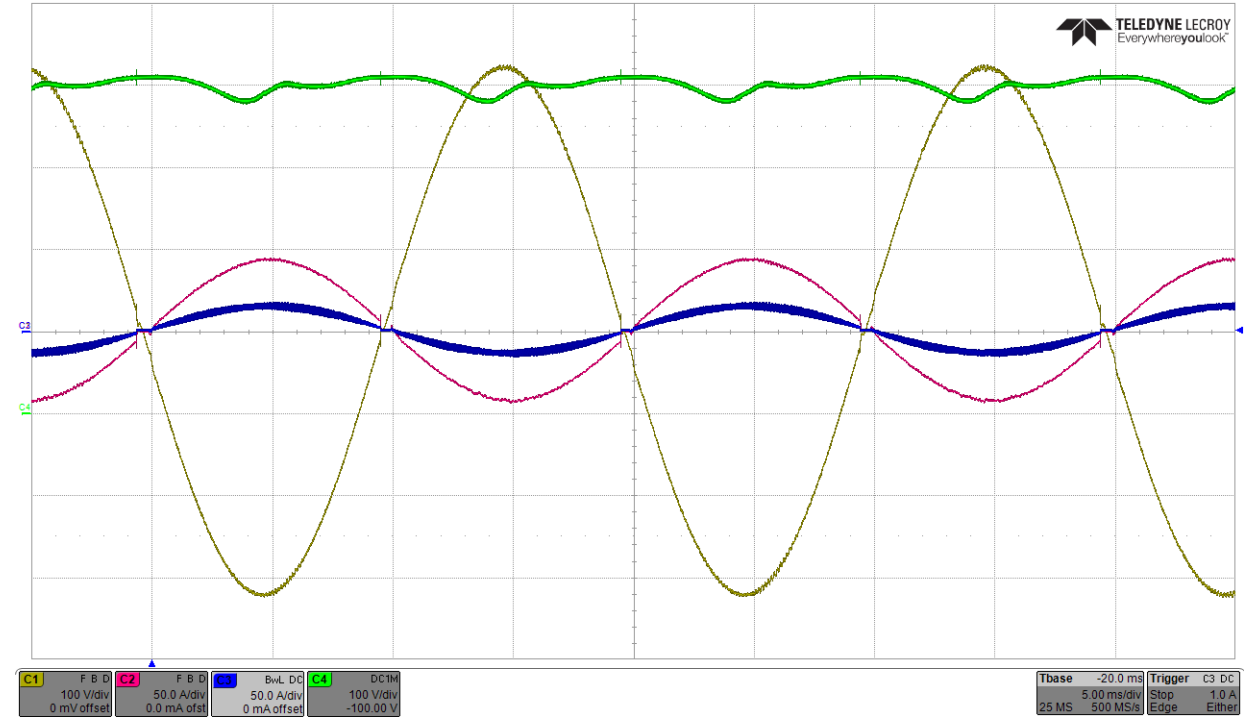


7 kW Bi-Directional Charger

Waveforms



Charger Mode



Inverter Mode