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High Efficiency, Compact DC Chargers for Electric Vehicles

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June 24th, 2020

Content

- **Introduction: DC Chargers**
- **SiC Power Devices Portfolio**
- **Topologies & ST Evaluation Boards**
- **Product Links & Application Tree**

Content

- **Introduction: DC Chargers**
- SiC Power Devices Portfolio
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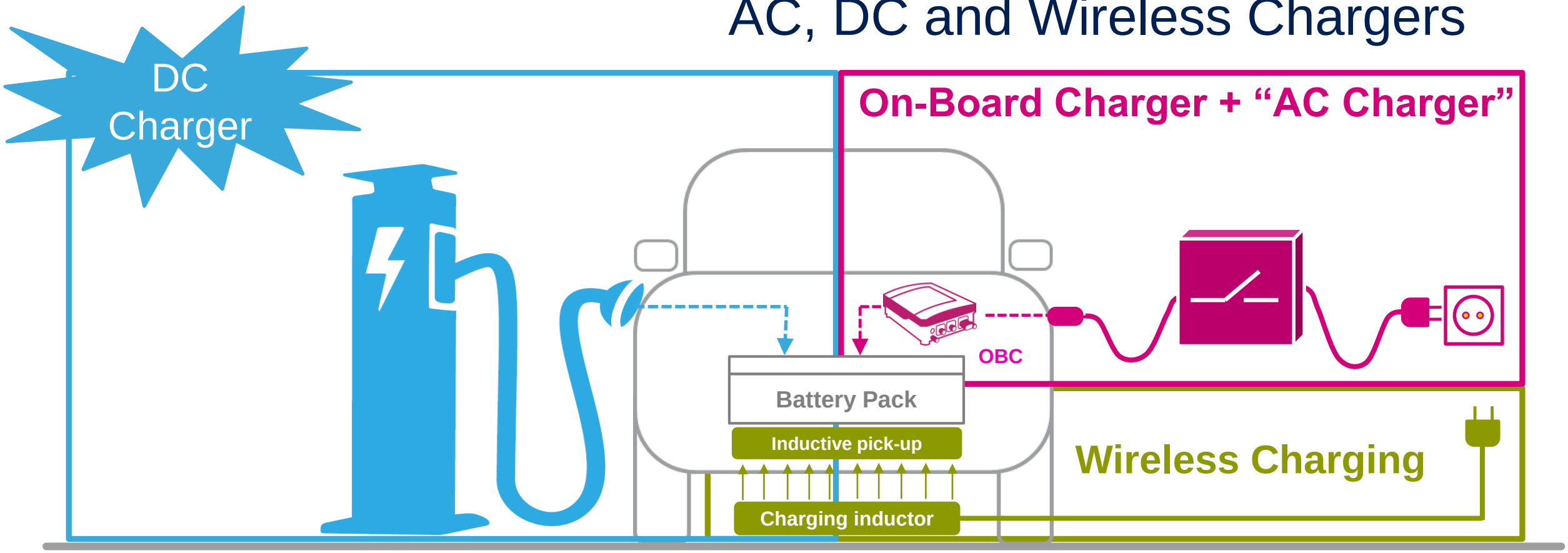
Charging an Electrical Vehicle

AC, DC and Wireless Chargers

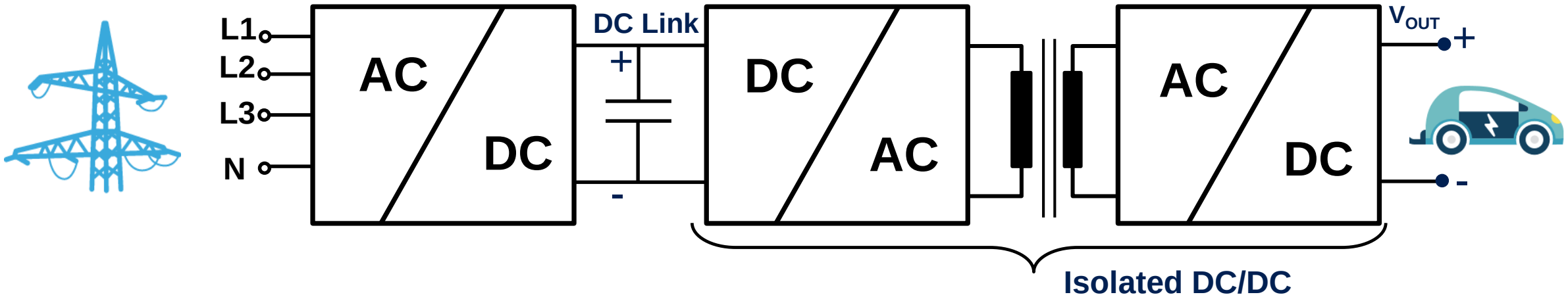


Advantages of DC Chargers:

- ✓ **Charging power not limited to OBC → short charging times.**
- ✓ **No extra volume and weight inside the car.**
- ✓ **Does not require same reliability level of OBC → lower cost per kW**

DC Charger

System Concept

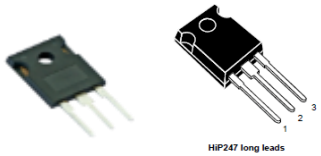


Parameter	Value
Input voltage	L_x-L_y → 400 V_{AC} L_x-N → 230 V_{AC}
DC Link Voltage	400..1000 V
Nominal Power	11..100 kW
Output Voltage	200..500 V_{DC} for 400 V_{DC} Batteries 500..900 V_{DC} for 800 V_{DC} Batteries

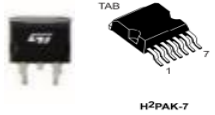
Content

SiC MOSFETs Gen 1

V_{DS} [V]	R_{DS}(on) Typ @ 25 ºC [Ω]	Id A	Package	P/N
1200 Gen1 V_{gs}=20V	0.052	65	HiP247 HiP247/LL H2PAK-7 HiP247-4	SCT50N120 SCTWA50N120 SCTH50N120-7 SCTWA50N120-4 (Q2´20)
	0.08	40	HiP247 HiP247/LL H2PAK–2	SCT30N120 SCTWA30N120 SCT30N120H
	0.169	20	HiP247LL HiP247 H2PAK–2	SCT20N120, SCT20N120AG SCTWA20N120, SCT20N120H
	0.52	12	HiP247 HiP247LL H2PAK–2	SCT10N120 SCTWA10N120 SCT10N120H



HiP-247 (STD & LL) ™



H2PAK
2 and 7 leads

- HiP-247 rated at 200°C Tj max
- H2PAK-7 (with kelvin source) SMD option (175°C Tj max)

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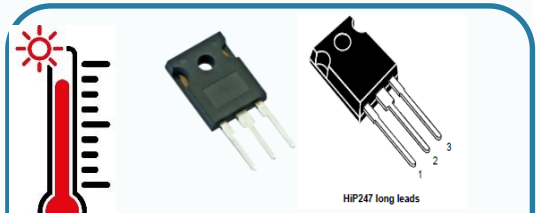
SiC MOSFET Gen 2 – Planned Portfolio

Automotive Grade

V_{DS} [V]	R_{DS}(on) typ @ 18V, 25°C [mΩ]	Id	Package	P/N	
650	**18**	90	HiP247 H2PAK-7 HiP247-4L	SCTW90N65G2V SCTH90N65G2V-7 SCTWA90N65G2V-4	
	23	100	H2PAK-7 HiP247 Bare die	SCTH100N65G2-7AG SCTW100N65G2AG SCT100N65G2D2AG	🚗
	55	45	H2PAK-7	SCTH35N65G2V-7AG	🚗
	55	45	HiP247 H2PAK-7 HiP247-4	SCTW35N65G2V SCTH35N65G2V-7 SCTW35N65G2V-4	
1200	**22**	80	HiP247 HiP247-4 H2PAK-7	SCTW70N120G2V SCTWA70N120G2V-4 SCTH70N120G2V-7	
	30	80	H2PAK-7 HiP247 dice	SCTH100N120G2-AG SCTW100N120G2AG SCT100N120G2D2AG	🚗
	40	60	H2PAK-7 HiP247-4 HiP247	SCTH60N120G2-7 SCTWA60N120G2V-4 SCTW60N120G2V	
	45	60	H2PAK-7 HiP247	SCTH60N120G2-AG SCTW60N120G2AG	🚗
	70	45	HiP247 H2PAK-7	SCTH40N120G2V SCTWA40N120G2V-4 SCTW40N120G2V-7	
	75	40	H2PAK-7 HiP247	SCTH40N120G2V7AG SCTW40N120G2VAG	🚗

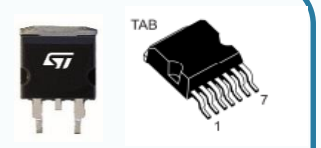
Packages

$T_{j.max}$=200°C



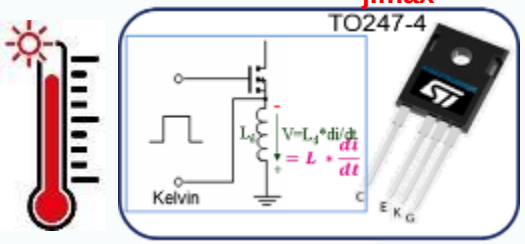
HiP-247 (STD & LL) ™

SMD



H2PAK
2 and 7 leads

Kelvin Source + $T_{j.max}$=200°C



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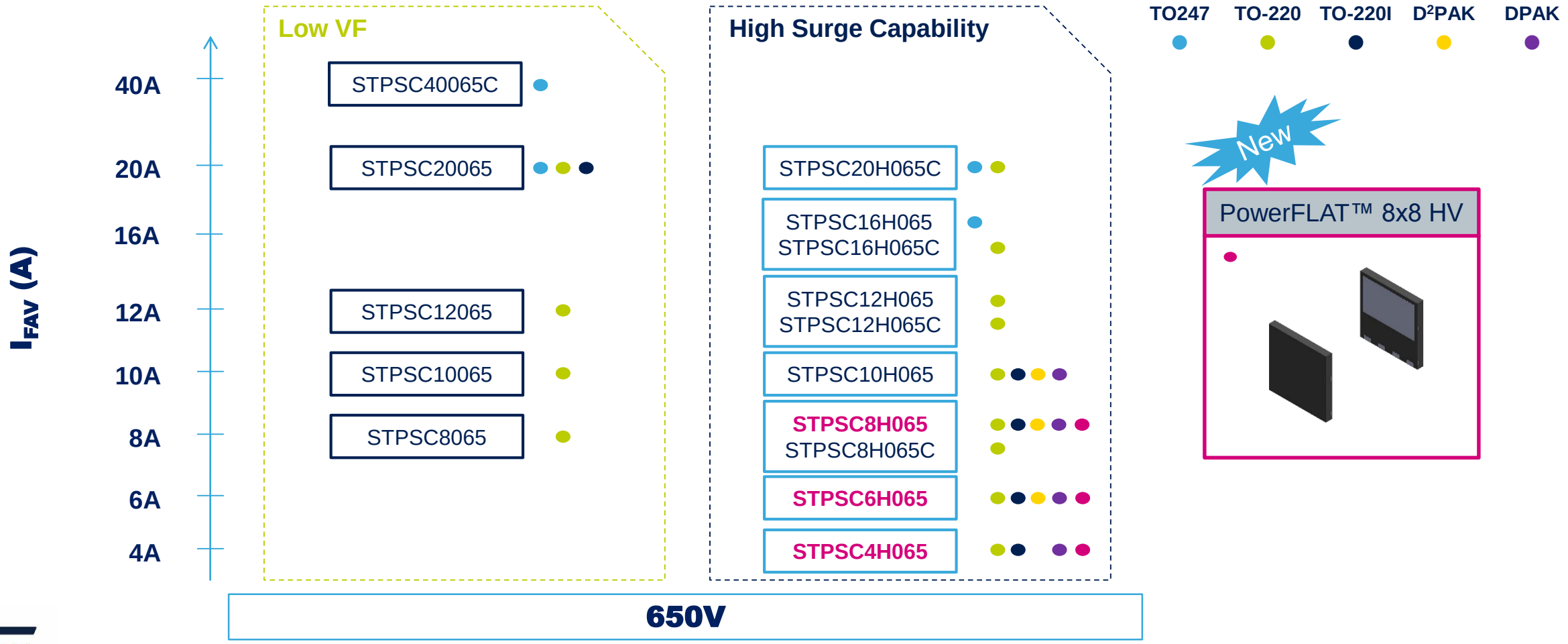
650V SiC Diode Portfolio

Extend package portfolio with Flat Package



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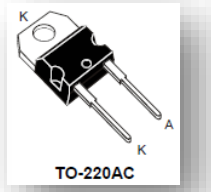
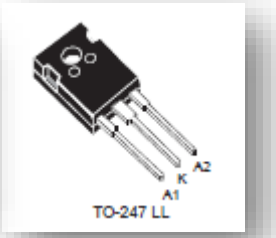
1200V SiC Portfolio

from 2A to 40A





Part number	$I_{F(AV)}$	V_F [V] max Per diode $I_F = I_0$		I_{FSM} [A]		I_R [µA] max	Q_{cj} [nC] typ	Package					Samples Available
		25°C	150° C	10µs 25°C	10ms 25°C	Vr=1200V 150°C	V_R=800 V	DPAK HV	D2PAK	TO-220	TO-247 LL	TO-247	
STPSC2H12	2 A	1.5	2.25	105	15	80	15.6	■		■			√
STPSC5H12	5 A	1.5	2.25	210	35	200	36	■		■			√
STPSC6H12	6 A	1.9	2.6	100	36	1500	29	■					√
STPSC10H12	10 A	1.5	2.25	420	71	400	57	■	■	■	■		√
STPSC15H12	15 A			630	105	600	94			■	■		√
STPSC20H12	20 A			700	140	800	129		■	■	■		√
STPSC10H12C	2x5A	1.5	2.25	210	35	200	36				■		√
STPSC20H12C	2x10A			420	71	400	57				■	■	√
STPSC30H12C	2x15A			630	105	600	94				■		√
STPSC40H12C	2x20A			700	140	800	129				■		√

■ ***In Production***

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STGAP2S /STGAP2D

Galvanic isolated 4 A Single & Dual channel gate drivers

Developed to drive SiC & Si Power MOSFETs,

IGBT High Power applications

Product family:

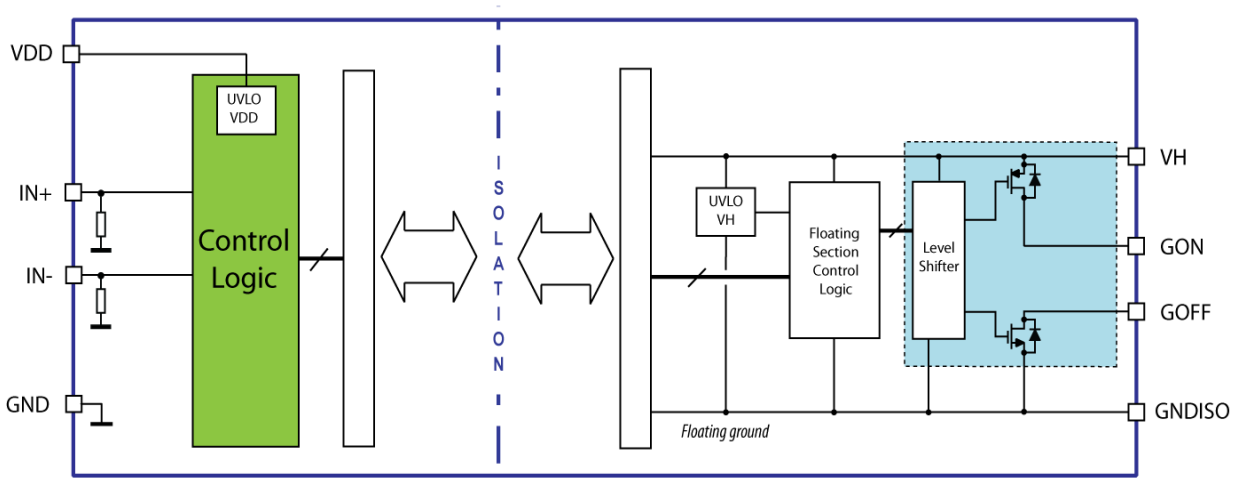
- STGAP2**D** - 2-Channel, 1.7 kV isolation
- STGAP2**S** – 1-Channel, 1.7 kV isolation

To come soon (samples available)

- STGAP2**HS** – 1-Channel, 6 kV isolation
- STGAP2**SiCS** – 1-Channel, 6 kV isolation, increased UVLO*

*under voltage lock-out

- **4A** current capability
- Up to **26 V supply voltage**
- Best in class for **propagation delay 80 ns**
- Common mode transient immunity **CMTI >100 V/ns**



SO-8N

SO-8W

In Production

2020

Main benefits

- Best in Class for **fast speed**
- **Reduced BOM** thanks to embedded Isolation and Miller Clamp feature
- **Minimum footprint** and lightweight

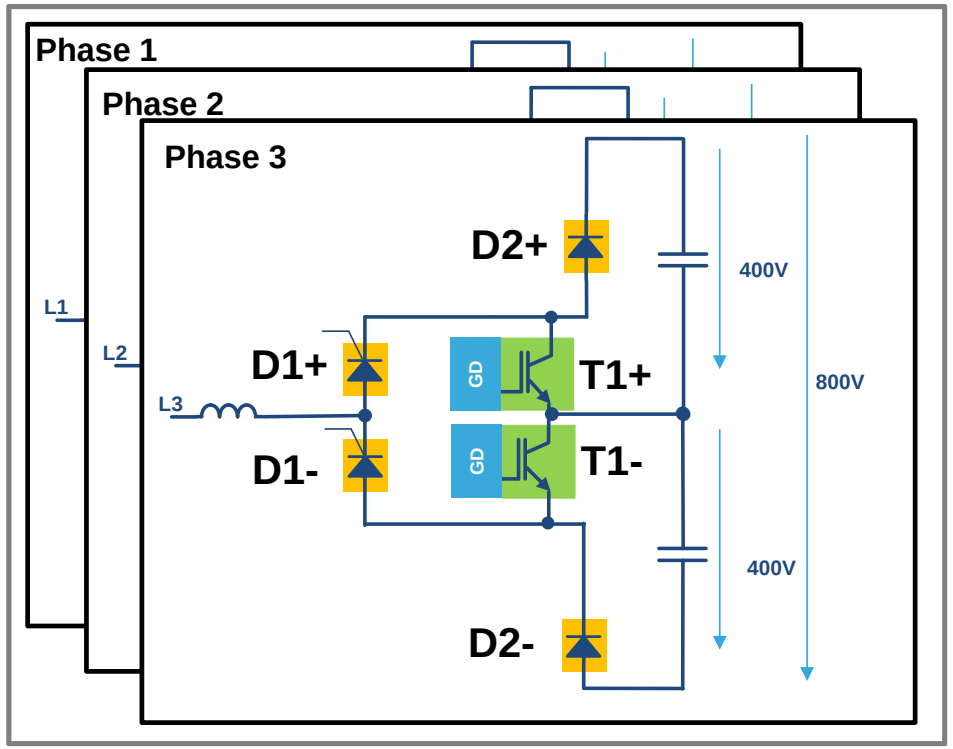
Associated Reference boards:
EVALSTGAP2DM
EVALSTGAP2SM
EVALSTGAP2SCM

Content

AC/DC Concepts

3-Level 3-Phase

Example: Mod. Vienna Type 1



+ 650V Si Switches.

- 6 devices / phase.

3x Independent 1-phase

Example: 3x PFC Booster

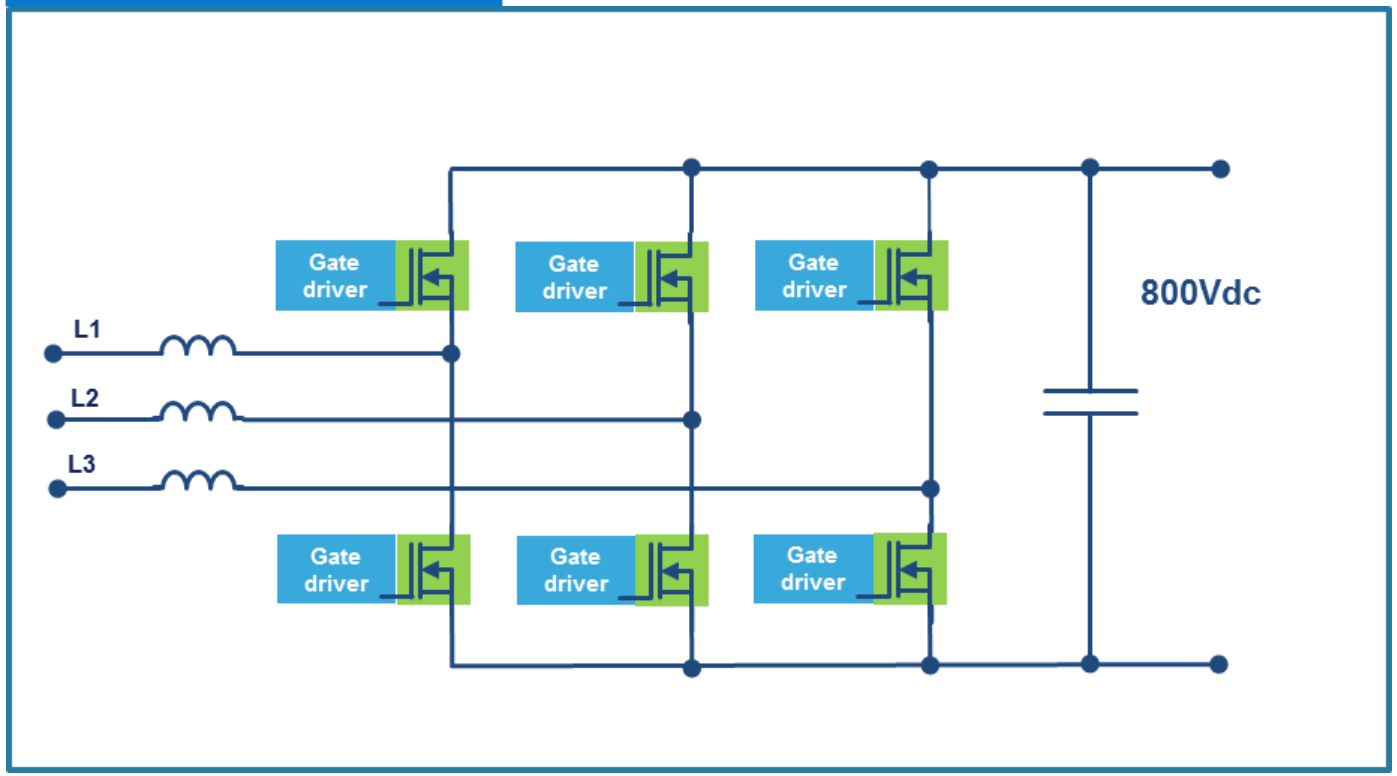
+ 4 devices / phase
+ Flexible grid configuration

- May need of 1200V SiC switches*

* In order to accomplish battery voltage requirements.

2-Level
B-6 Bridge

Bi-directional B6

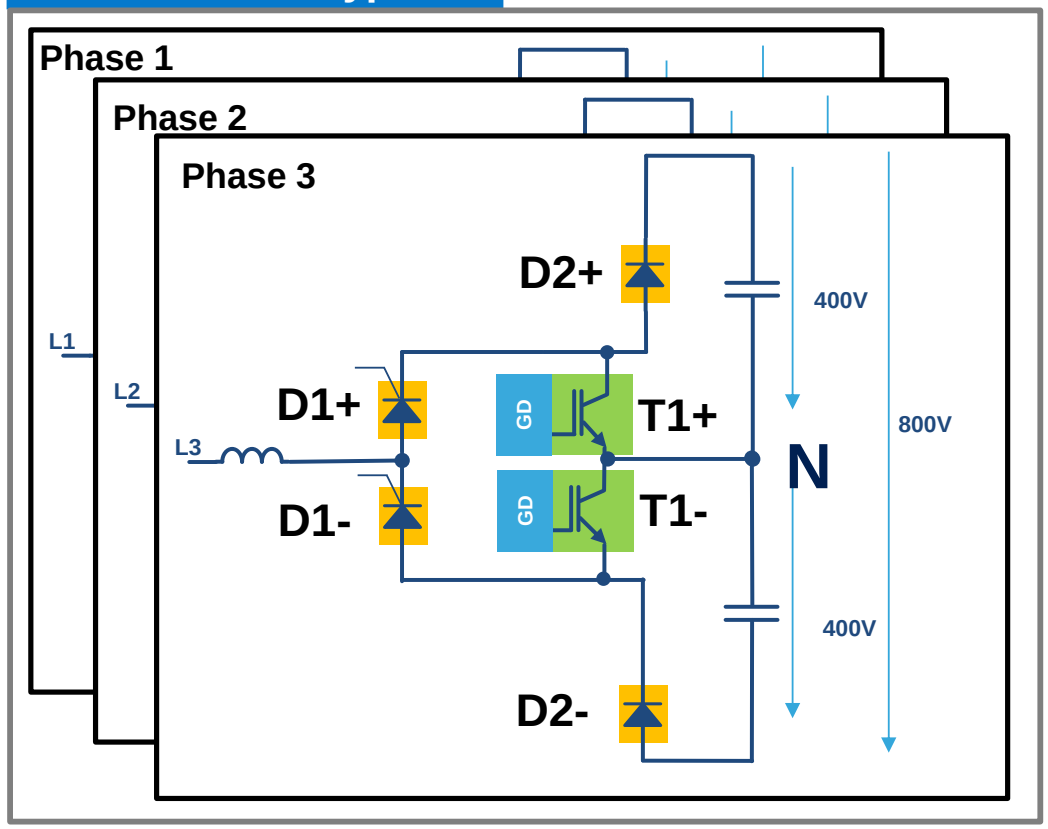


Stage	Required Semiconductor	ST Solution
B6	1200V SiC MOS	SCTxxN120 [Gen 1] SCTxxN120G2V(-4) [Gen2]
Both	Iso Gate Driver	STGAP2S/D
Control	µ-Controller	STM32

Modified Vienna Rectifier

Topology Comparison

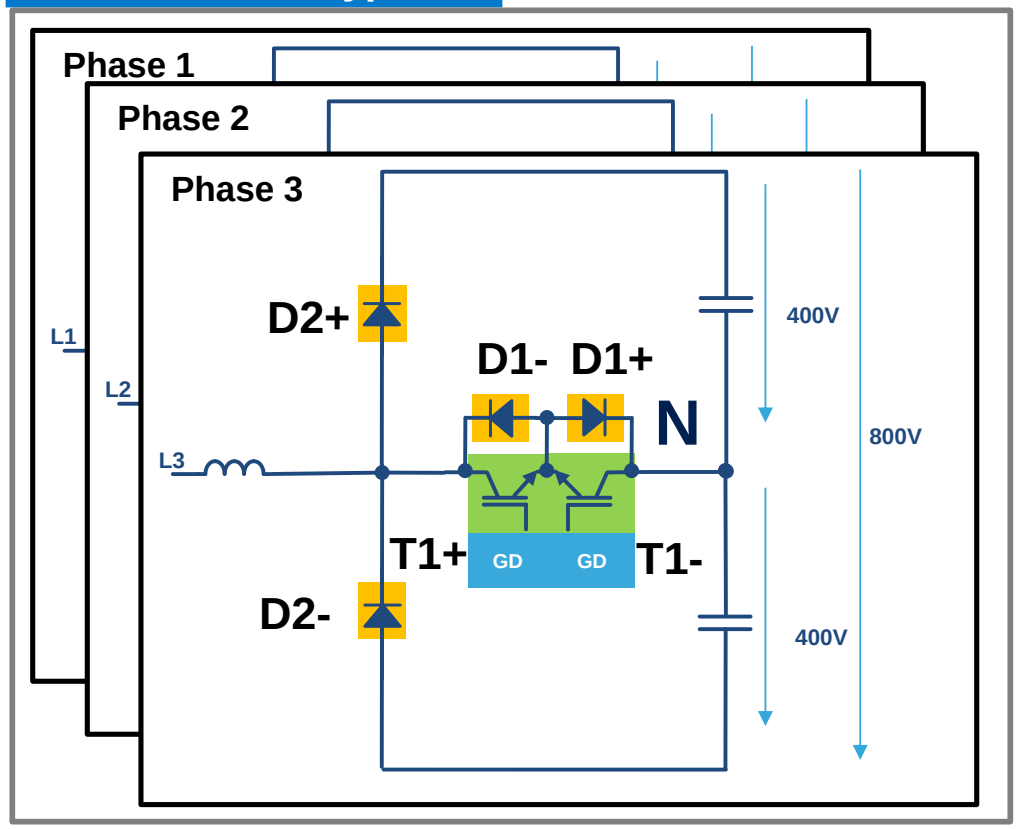
Mod. Vienna Type 1



+ All 650V rated devices
→ lower cost

- 2 devices in the main current path (D1&D2) → lower efficiency

Mod. Vienna Type 2



+ 1 devices in the main current path (D2)
→ Higher efficiency

- Need 1200V diodes (D2), typically SiC.
→ Higher cost

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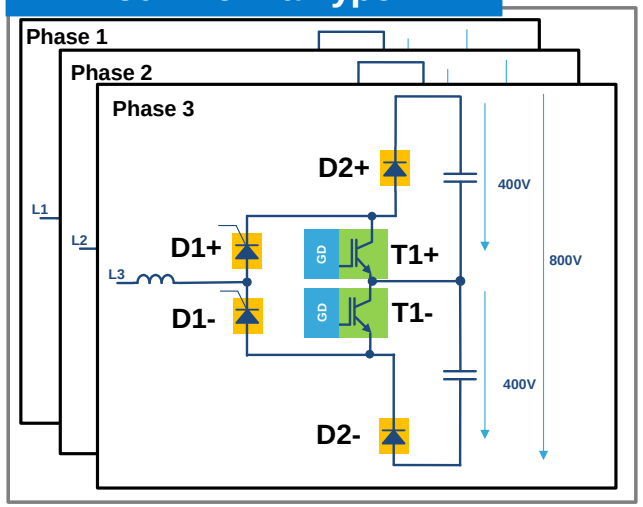
Modified Vienna Rectifier

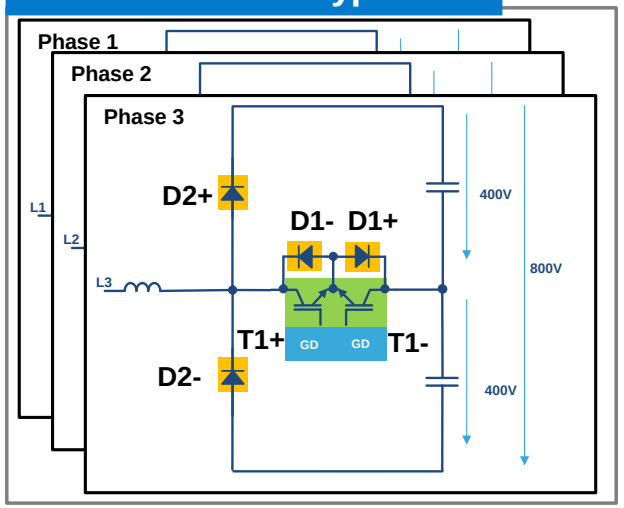
Device Proposal

Mod. Vienna Type 1



	Required Semiconductor	ST Solution
D1	Rectifier SCR	STBRxx12W TNxx50H-12WY
T1	650V IGBT 650V SJ POWER MOSFET 650V SiC POWER MOSFET	STGWAxxH65DFB2 STWxxN65M5 SCTWxxN65G2V
D2	600V FRD 650V SiC Diodes	STTHxxRQ06 STPSCxx065C
GD	Isolated driver	STGAP2S
	Control	STM32 (Digital) STNRGPF0x (Mixed mode)

Mod. Vienna Type 2



	Required Semiconductor	ST Solution
T1/D1	650V IGBT 650V SJ POWER MOSFET 650V SiC POWER MOSFET	STGWAxxH65DFB2 STWxxN65M5 SCTWxxN65G2V
D2	1200V SiC Diode	STPSC40H12C
GD	Isolated driver	STGAP2S
	Control	STM32 (Digital) STNRGPF0x (Mixed mode)

xx→ Current class
x → Family name

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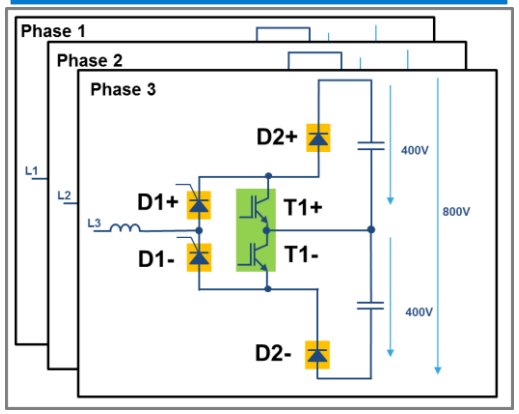
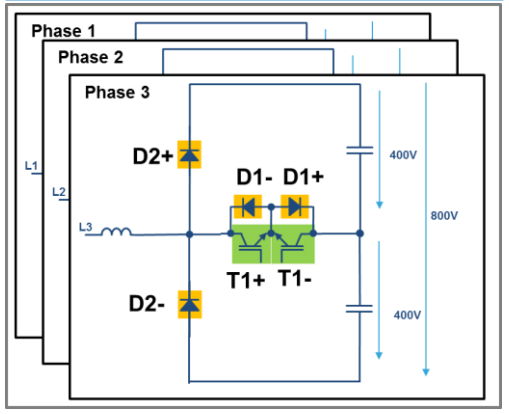
Topology Comparison

Efficiency Comparison @ P_{out}=20 kW

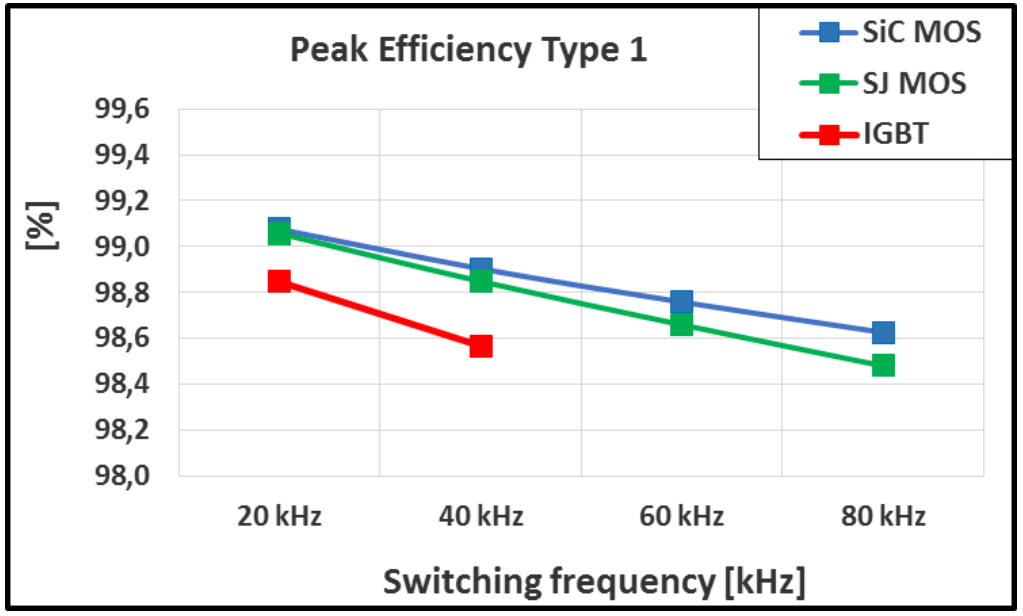
Vienna rectifier Type 1

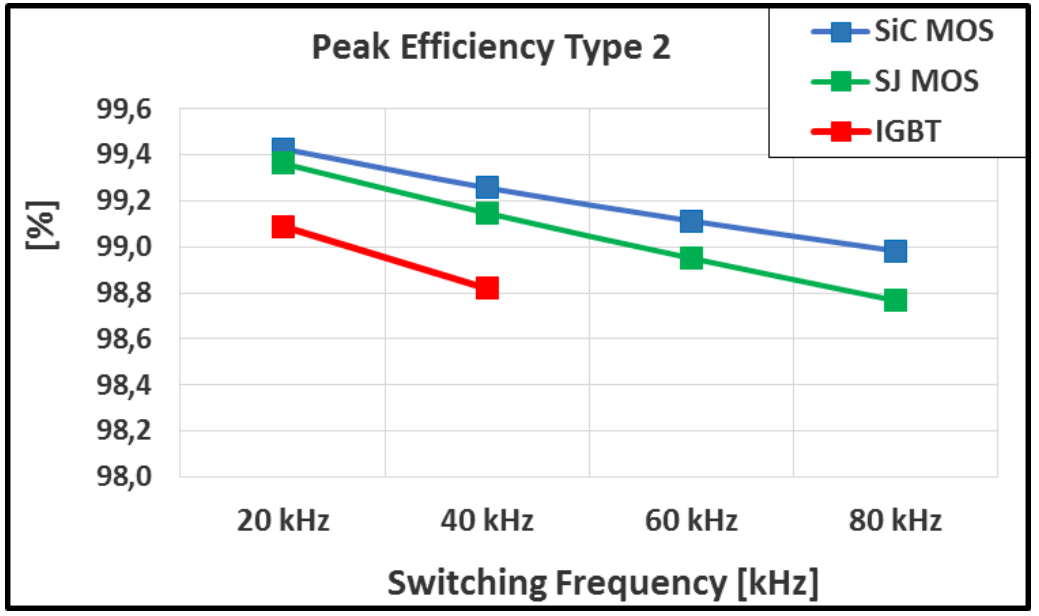


Vienna rectifier Type 2



	Mod. Vienna Type 1	Mod. Vienna Type 2
D1	STBR6012W	---------
T1	STGW40H65DFB-4 STW88N65M5-4 SCTW90N65G2V-4	
D2	STPSC40065C	STPSC40H12C





Simulated efficiency @ T_j = 125°C, considering only semiconductor losses.

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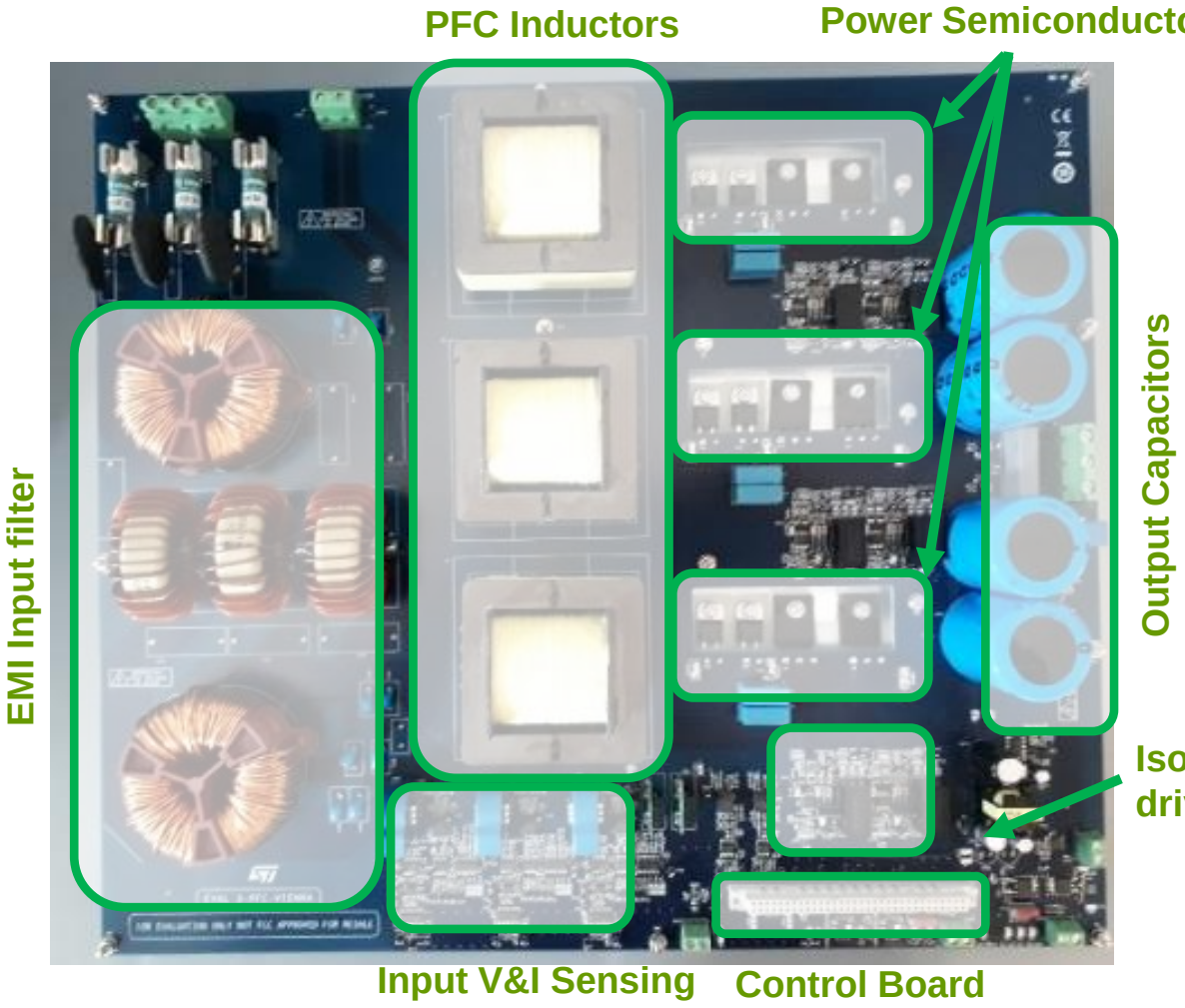
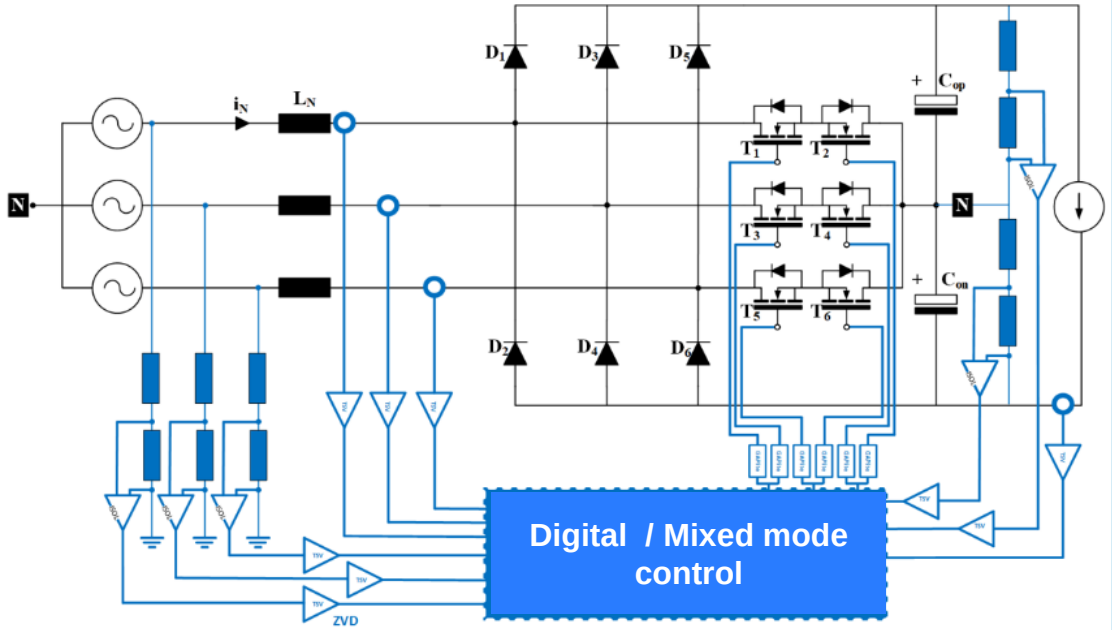
Design Board 1 - STDES-VIENNARECT

T-Type Rectifier

Documentation Available in this link



15 kW 3-ph PFC Converter



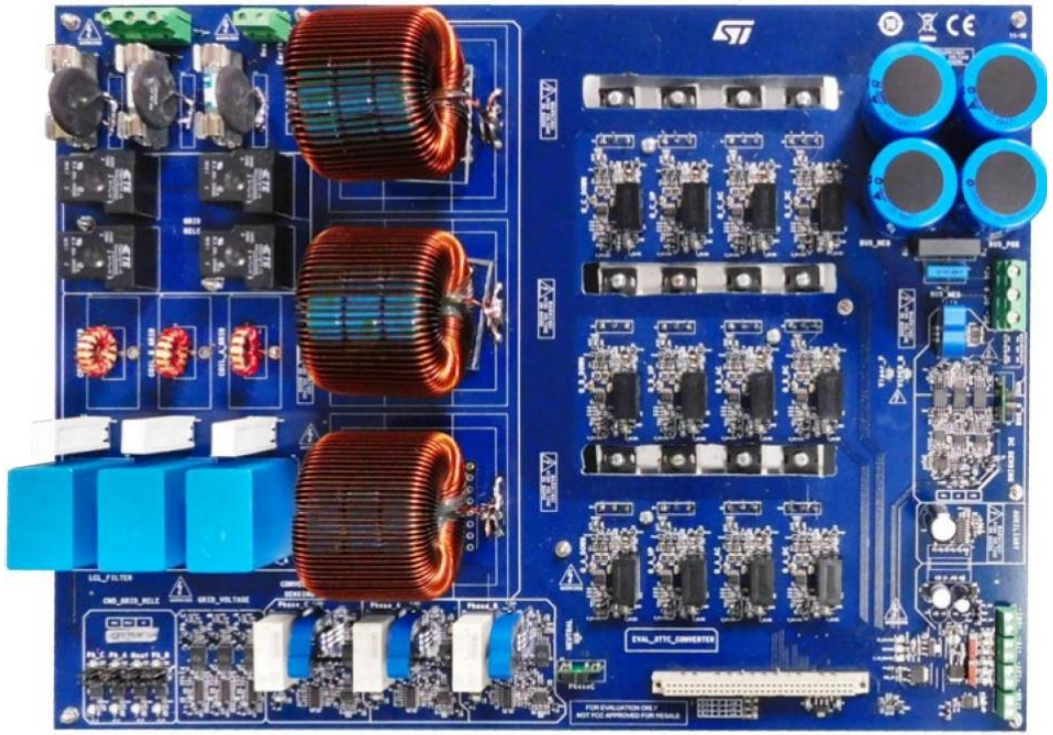
ST Solutions:

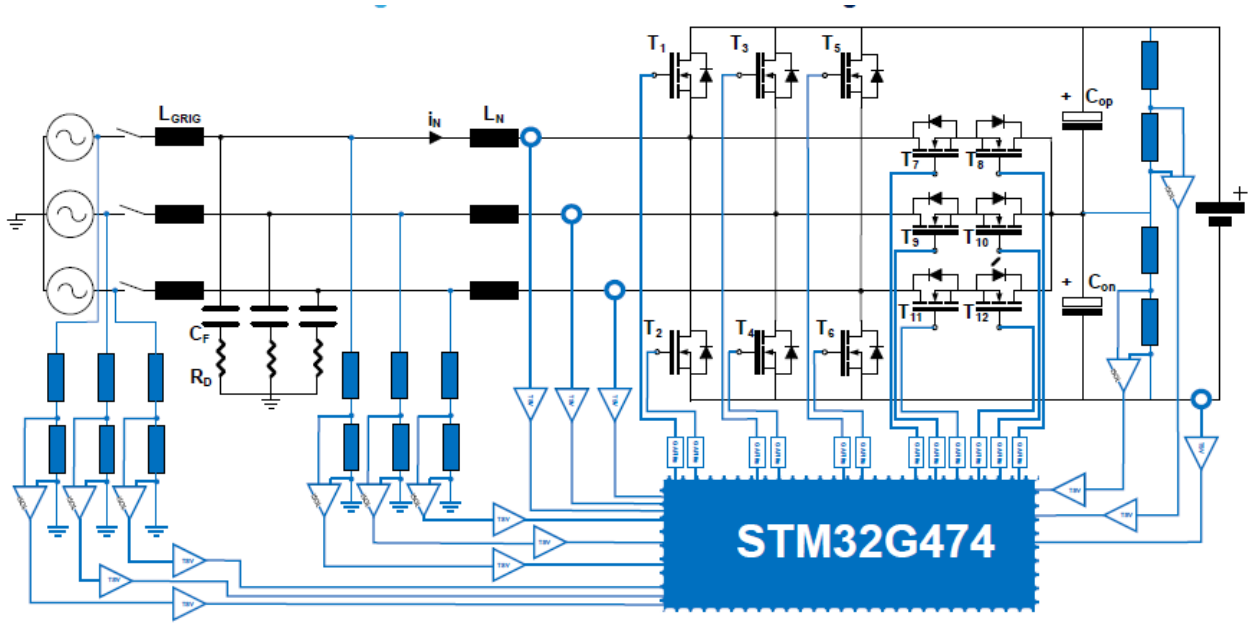
- SCTW35N65G2V (SiC MOSFET);
- STPSC20H12 (SiC Diode);
- STNRGPF0x (mixed mode controller, in development);
- STM32G474 (microcontroller);
- STGAP2S (Gate Driver).

Design Board 2 – STDES-BIDIR

Bi-directional Active Front-End

Documentation Available in this link

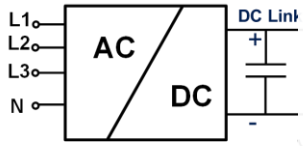




Click on this link for documentation:

- **Full Schematic & BoM**
- **Gerber Files**
- **Firmware (under SLA*)**

*** Software license agreement**



AC/DC Concepts

3-Level 3-Phase

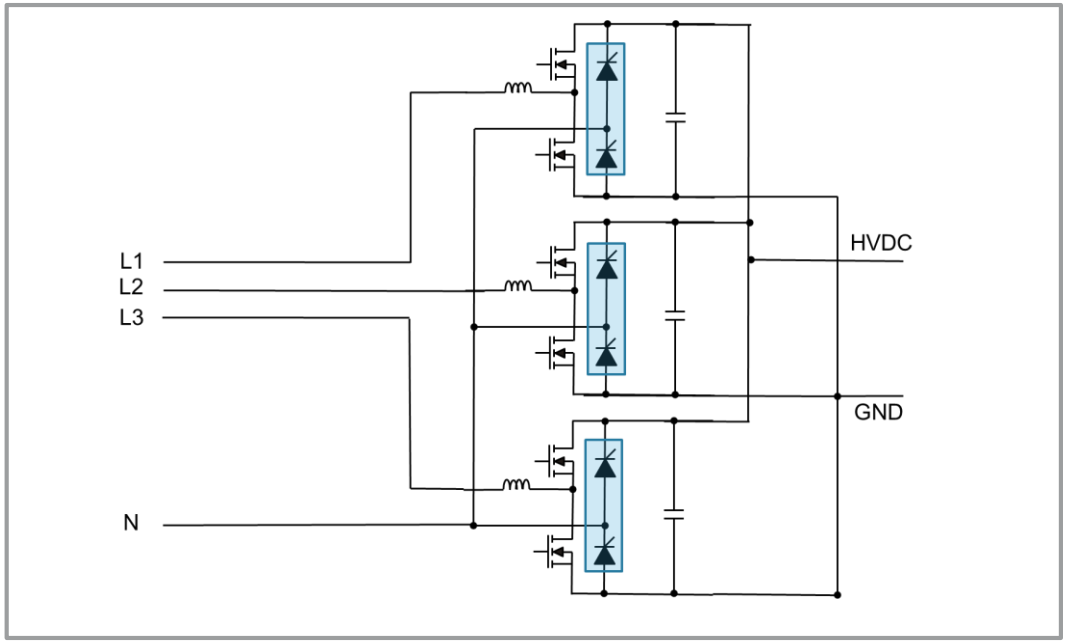
Example: Mod. Vienna Type 1

+ 650V Si Switches.

- 6 devices / phase.

3x Independent 1-phase

Example: 3x PFC Booster



+ 4 devices / phase
+ Flexible grid configuration

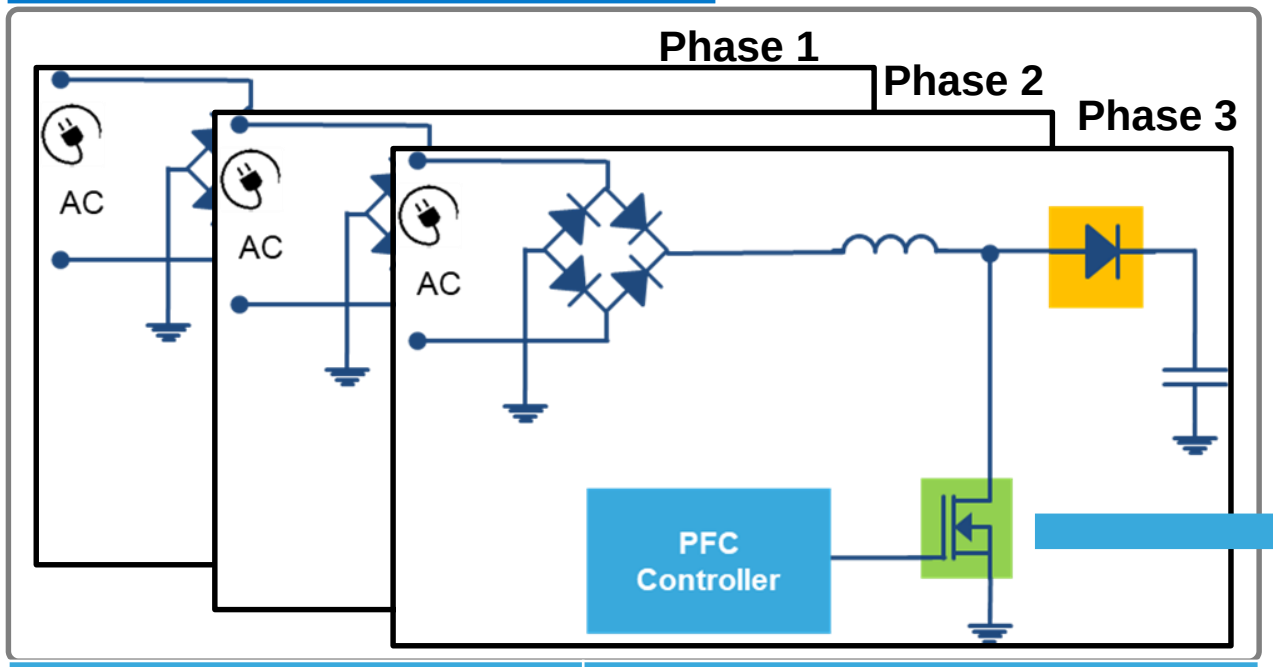
- May need of 1200V SiC switches*

* In order to accomplish battery voltage requirements.

3x 1-phase Topologies

Standard PFC

Booster PFC



1200V SiC MOSFET
Due to high DC link voltage.

Required Semiconductor	ST Solution
Rectifier SCR	STBRxx12W TNxx50H-12WY
1200V SiC POWER MOSFET	SCTxxN120 SCTxxN120G2V(-4) [Gen2]
1200V SiC Diodes	STPSCxxH12C
Isolated driver	STGAP2S
Control	STM32 (Digital) STNRGPF0x (Mixed mode)

xx→ Current class
x → Family name

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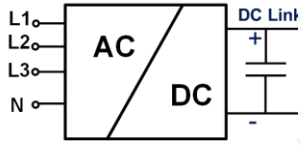
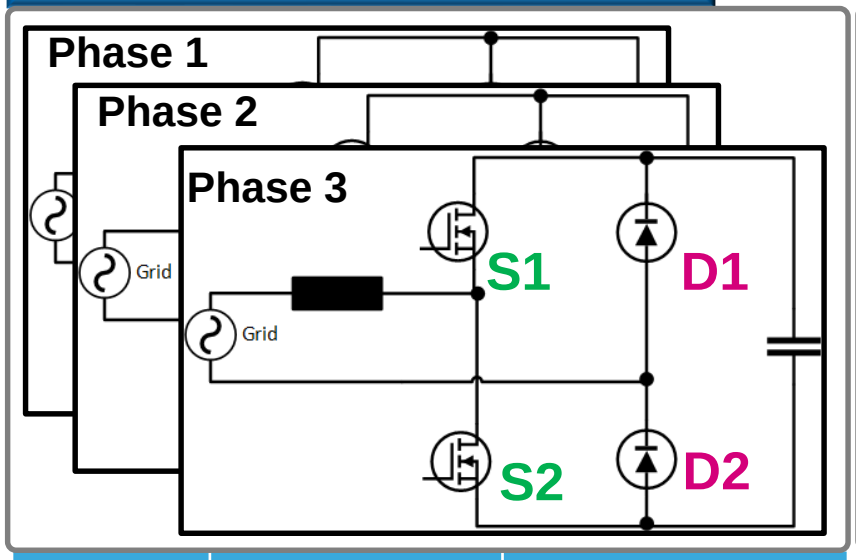


Bridge-less Topologies

Totem Pole PFC

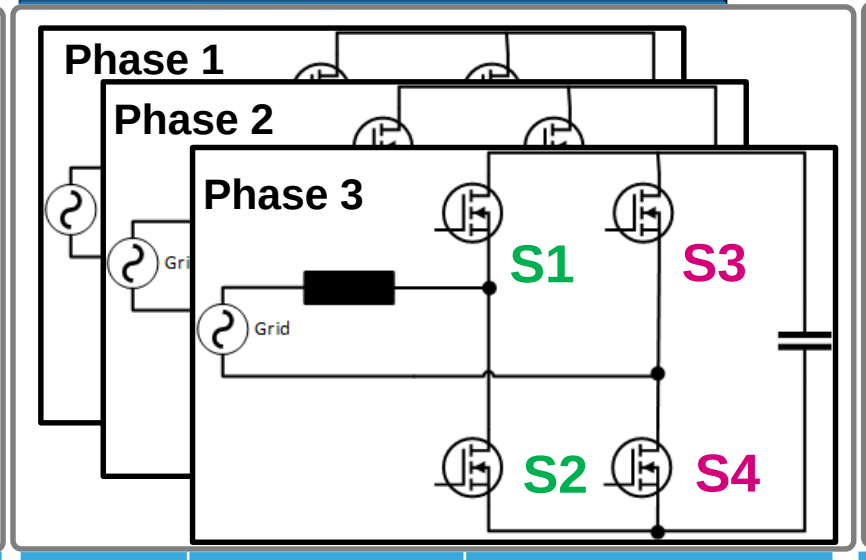
SiC MOSFET mandatory due high DC Votage and body diode robustness.

Var. 1 – Cost – Diode Leg



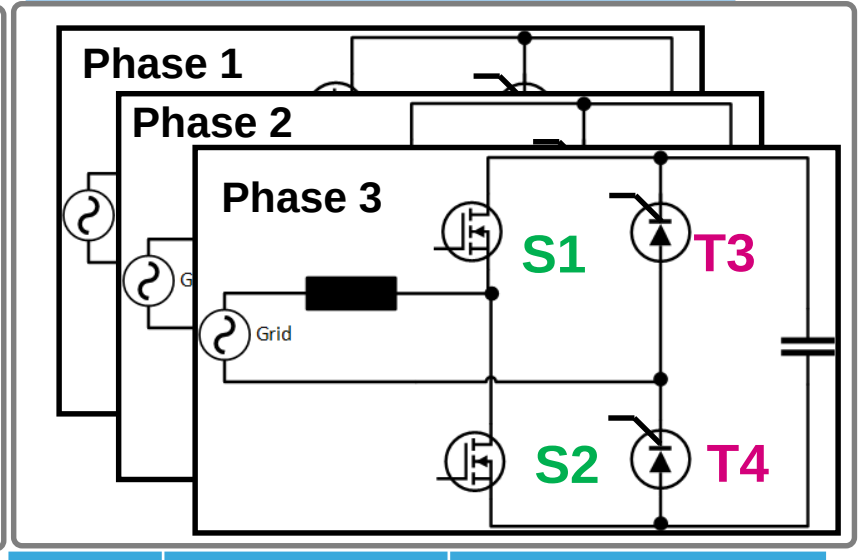
Device	Technology	ST Proposal
S1/S2	1200V SiC MOS	SCTxxN120 SCTxxN120G2V(-4)
D1/D2	1200V Rectifier	STBRxx12W
	Driver	STGAP2S/D
	Control	STM32

Var. 2 – Performance – SiC MOS Leg



Device	Technology	ST Proposal
S1/S2	1200V SiC MOS	SCTWxxN120 SCTxxN120G2V(-4)
S3/S4	1200V SiC MOS	SCTxxN120
	Driver	STGAP2S/D
	Control	STM32

Var. 3 – Relay-less – SCR Leg



Device	Technology	ST Proposal
S1/S2	1200V SiC MOS	SCTxxN120 SCTxxN120G2V(-4)
T3/T4	1200V SCR	TNxx50-12PI
	Driver	STGAP2S/D
	Control	STM32

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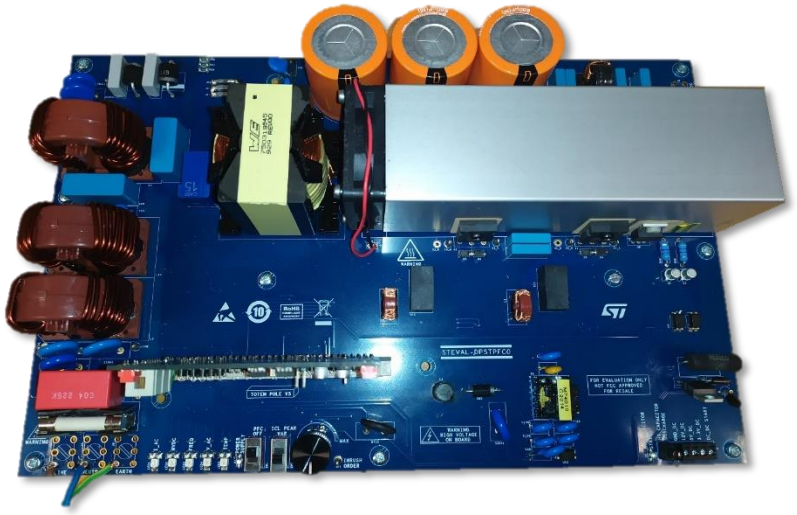
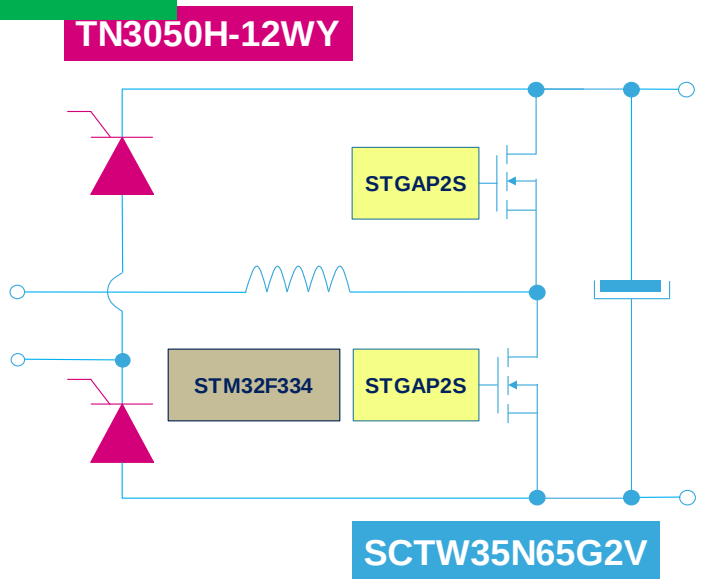
Evaluation Board 1 - STEVAL-DPSTPFC1

3.6 kW Totem Pole PFC

Documentation Available in this link





Key Products

- **TN3050H-12WY → SCR in the Bridge**
- **SCTW35N65G2V → 650V SiC MOSFET**
- **STGAP2S → Isolated Gate Driver**
- **STM32 → 32-bit Microcontroller)**
- **VIPER26LD → HV Converter Controller**

Main Features

- Input AC voltage: 85VAC up to 264VAC
- DC output voltage: 400VDC
- Switching frequency: 72 kHz
- Maximum input curent: 16 A RMS (POUT = 3.6KW)
- Efficiency: > 97,5%
- THD < 10 %
- Remove two bulky relays and an NTC resistor thanks to SCRs progressive start-up

- Compliant to :
  - **EN 55015 and IEC 61000-4-11 and IEC 61000-3-3**
  - **IEC 61000-4-5 surge: 4kV**
  - **IEC 61000-4-4 EFTY burst : criteria A @ 4kV min**
- Design for operation with DC/DC converter
- Peak inrush current tuning

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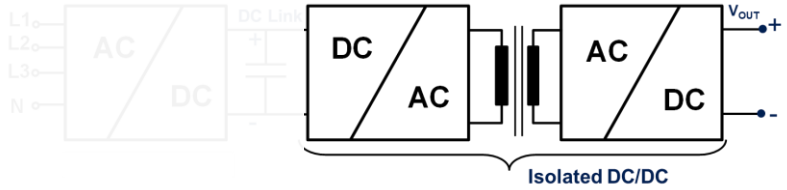
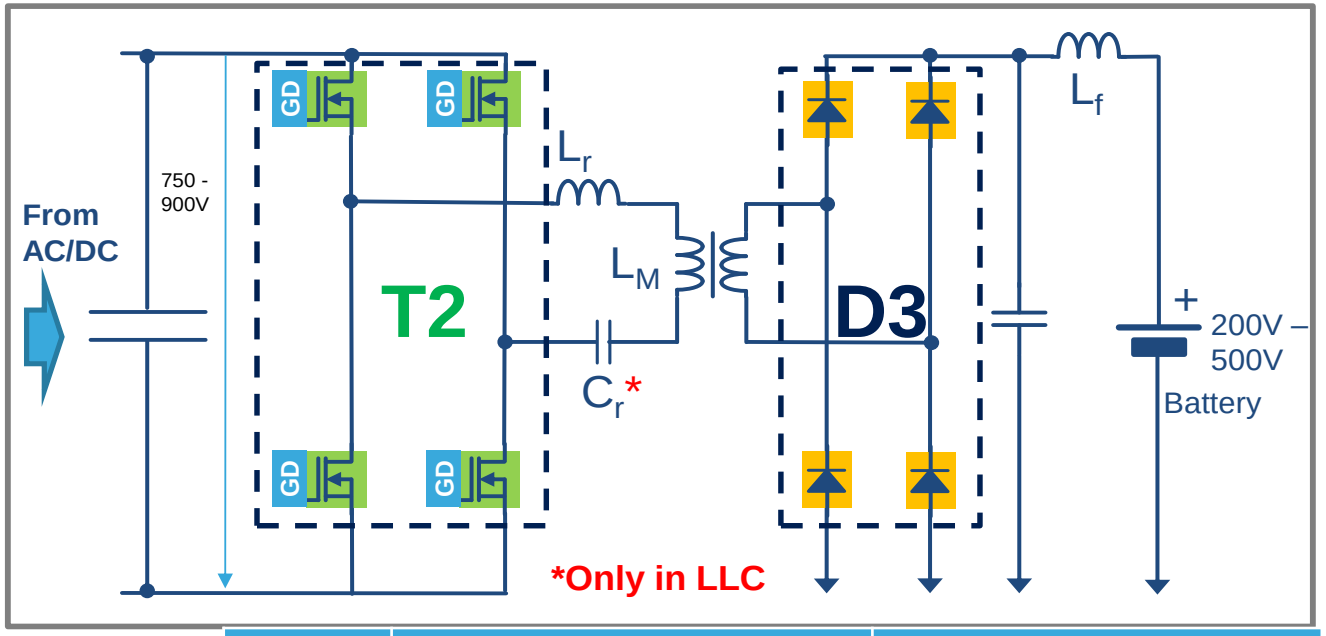


DC/DC Stage Topologies

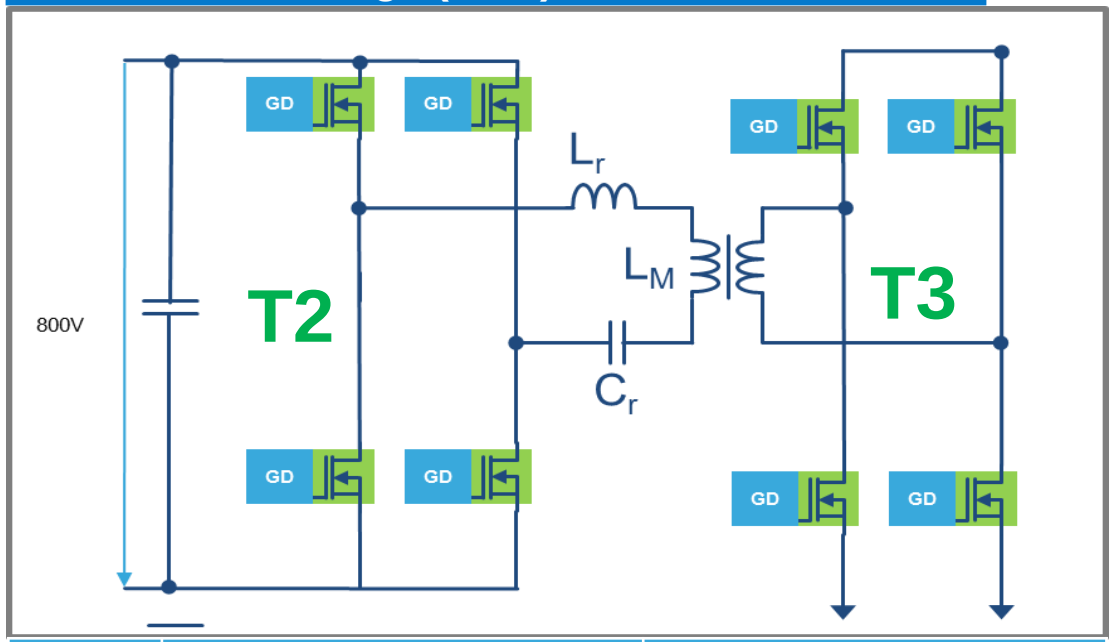
Resonant LLC / ZVS or DAB

Resonant LLC / Zero Voltage Switching



Device	Technology	ST Solution
T2	1200V SiC POWER MOSFET	SCTxxN120 SCTxxN120G2V(-4)
D3	600V FRD 1200V SiC Diodes	STTHxxRQ06 (LLC) STPSCxxH12C (ZVS)
GD	Isolated Driver	STGAP2S/D
Control	Microcontroller	STM32 (Digital)

Dual Active Bridge (DAB) / Bi-directional LLC



Device	Technology	ST Solution
T2	1200V SiC POWER MOSFET	SCTxxN120 SCTxxN120G2V(-4)
T3	650V SiC POWER MOSFET 1200V SiC POWER MOSFET	SCTxxN65G2V [400V Batt.] SCTxxN120 [800V Batt.]
GD	Isolated Driver	STGAP2S/D
Control	Microcontroller	STM32 (Digital)

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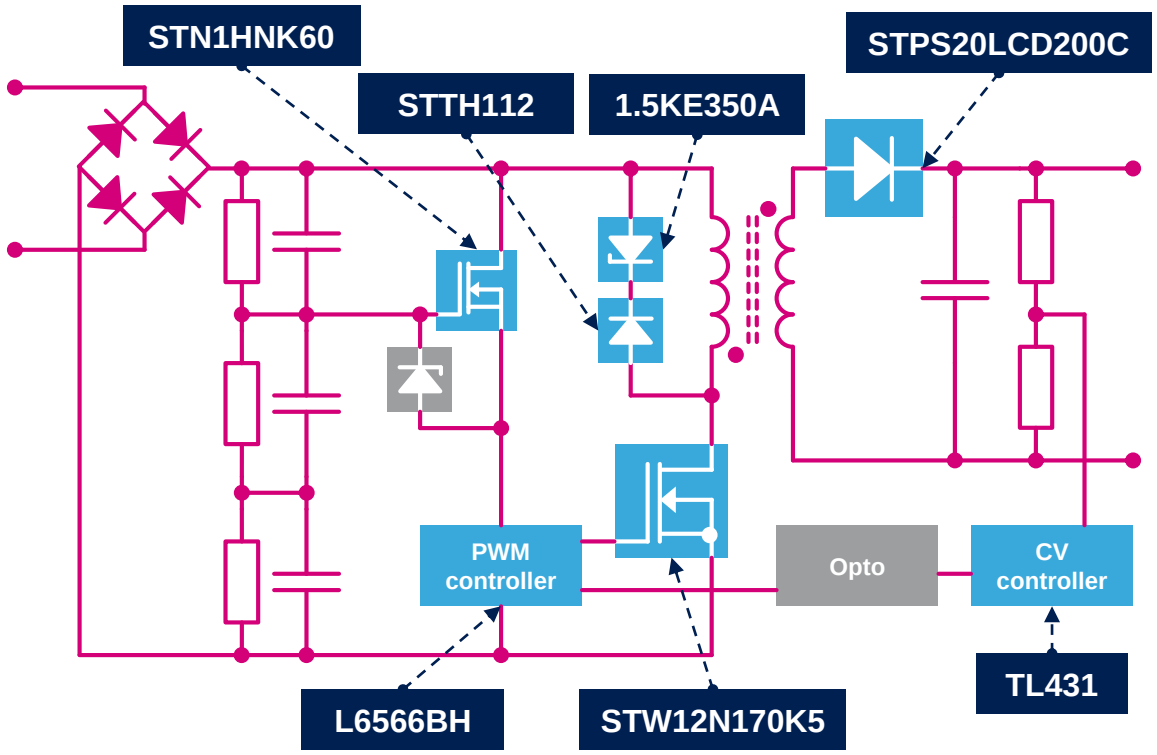
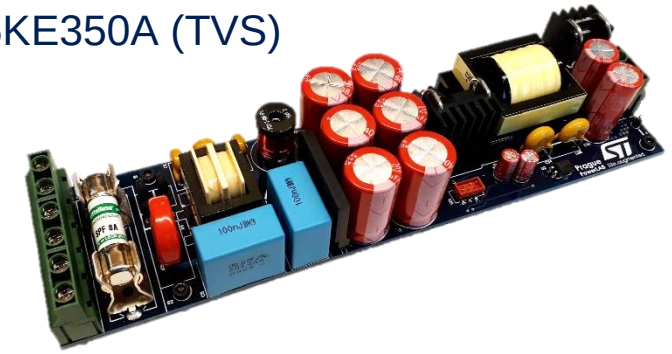
STEVAL-ISA211V1: 100W HV ($1kV_{DC}$) auxiliary power supply



- **ST Products:**
- STW12N170K5 (1700V K5 super-junction MOSFET)
- L6566BH (flyback controller)
- STPS20LCD200C (200V Schottky diode)
- STN1HNK60 (600V planar MOSFET)
- TL431 (voltage reference)
- STTH112 (1200V ultra-fast diode)
- 1.5KE350A (TVS)



Up to 88% efficiency at full load

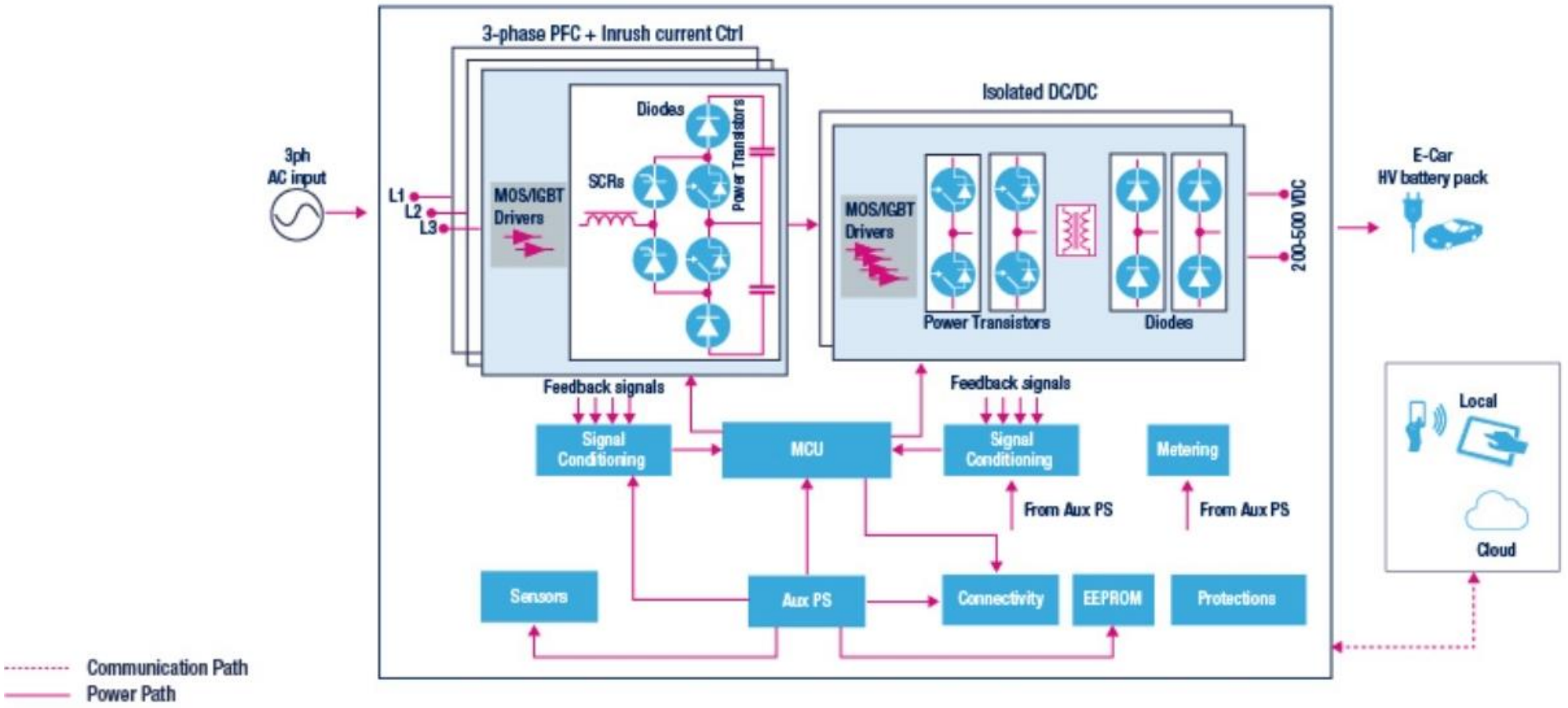
Content

Product Links

- **Auxiliary Power Supply**
- **1200V/1500V Super Junction MOSFETs**
- **Protection Diodes**
- **Off-line controllers**
- **Power Schottky diodes**

- **Power Circuitry**
- **1200V & 650V Gen 2 SiC MOSFETs**
- **1200V & 650V SiC Diodes**
- **650V IGBTs**
- **600V FRDs**
- **650V Super Junction MOSFETs**
- **Isolated gate drivers**
- **STNRGPF01 Controller**
- **STM32 Microcontrollers**

Application Tree – EV Charger



https://www.st.com/en/applications/energy-generation-and-distribution/dc-fast-charging-station.html

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Thank you