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3.6kW Totem-Pole PFC with active in-rush current limiting

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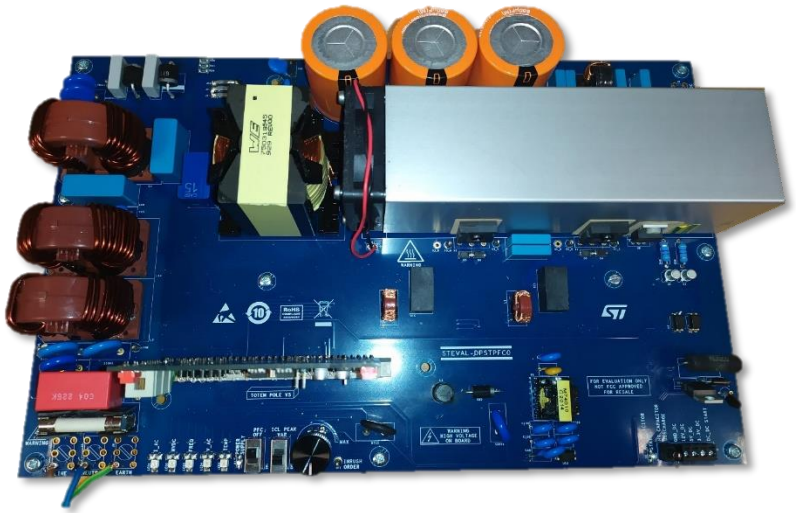
Agenda

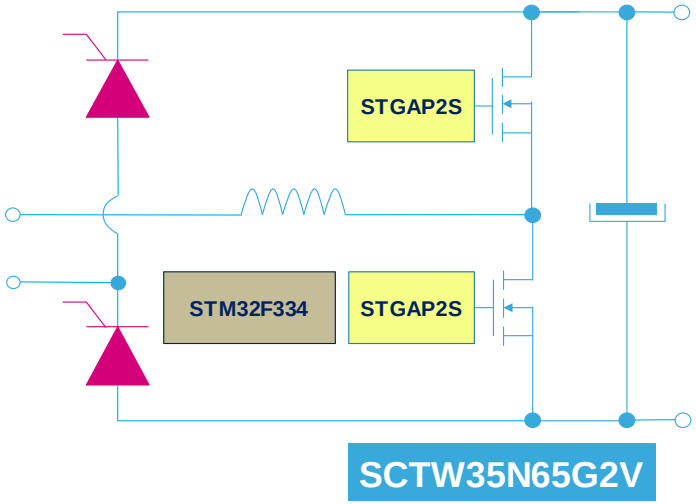
1. 3.6kW Totem Pole PFC Introduction
2. ST AC-DC inrush current limiter solutions
3. PFC totem pole topology using SiC MOSFETs and thyristors
4. Evaluation board performance

Evaluation Board
3.6 kW Totem Pole PFC

Available Q2/20



TN3050H-12WY



Key Products

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

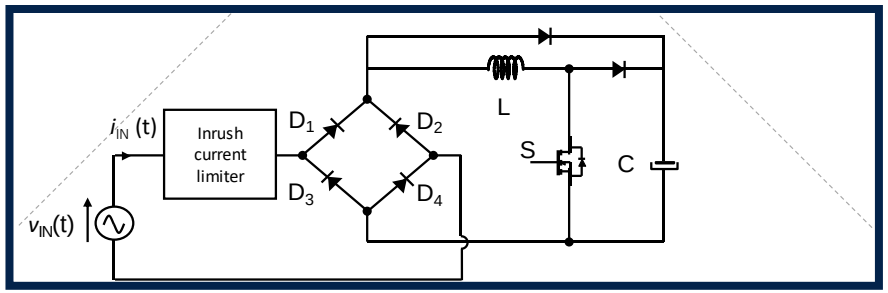
Main Features

- 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**

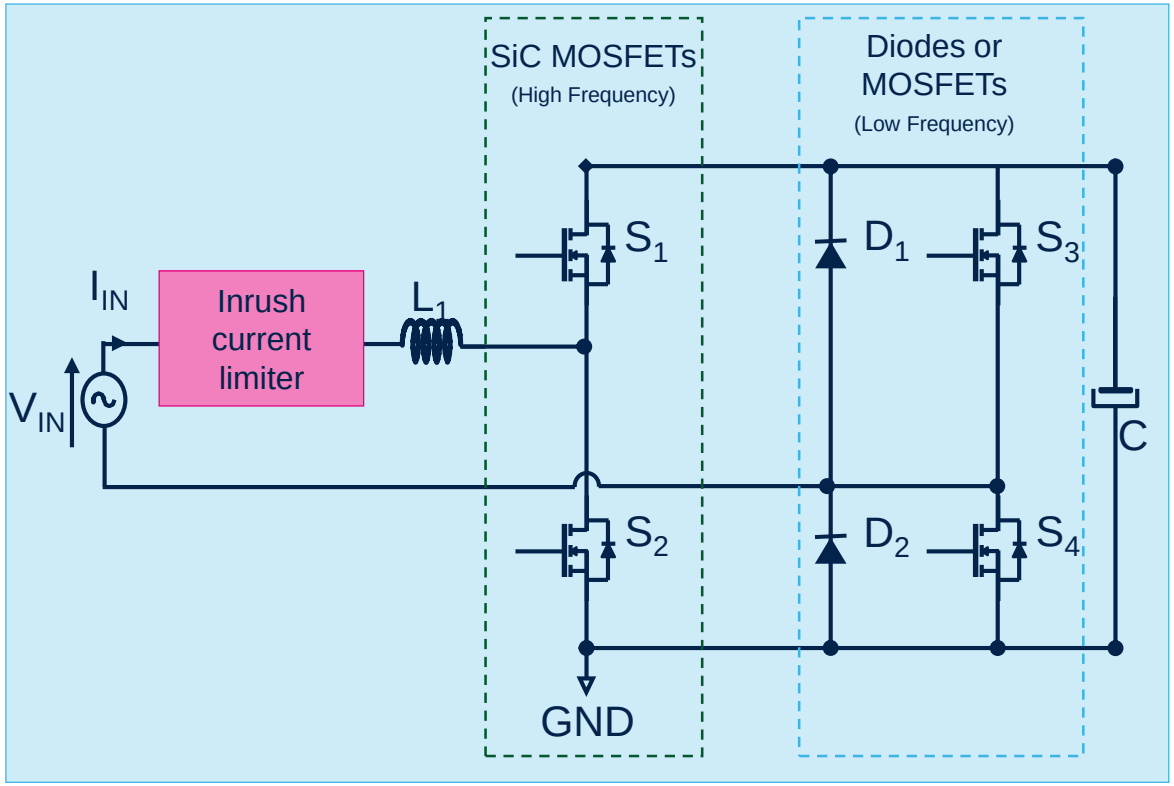
- Compliant to :
  - **EN 55015 and IEC 61000-4-11 and IEC 61000-3-3**
  - **IEC 61000-4-5 surge: 4kV**
  - **IEC 61000-4-4 EFTY burst : criteria A @ 4kV min**
- Design for operation with DC/DC converter
- Peak inrush current tuning

Traditional PFC Totem Pole

- A conventional PFC circuit:
  - Consists of a full bridge rectifier and a boost pre-regulator
  - A large portion of system losses are in the diode bridge



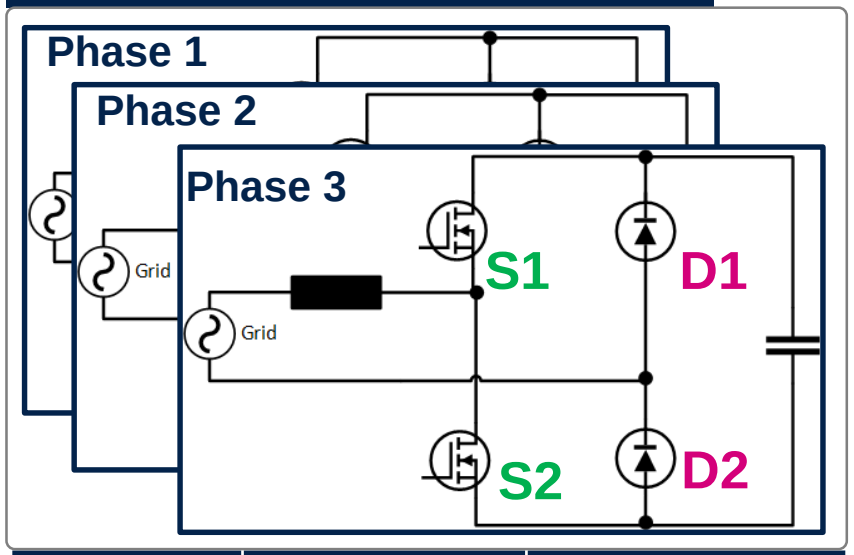
- In a traditional totem pole PFC:
  - The diode losses are eliminated
  - Low frequency switches are diodes or MOSFETs
  - Needs an Inrush current limiter (NTC + relays)



Bridge-less Topologies
Totem Pole PFC

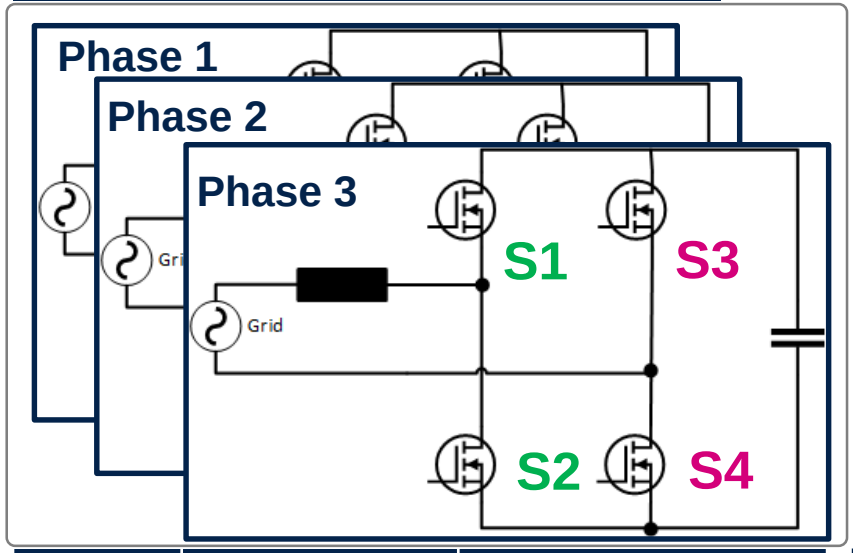
SiC MOSFET mandatory due high DC Voltage and body diode robustness

Var. 1 – Cost – Diode Leg



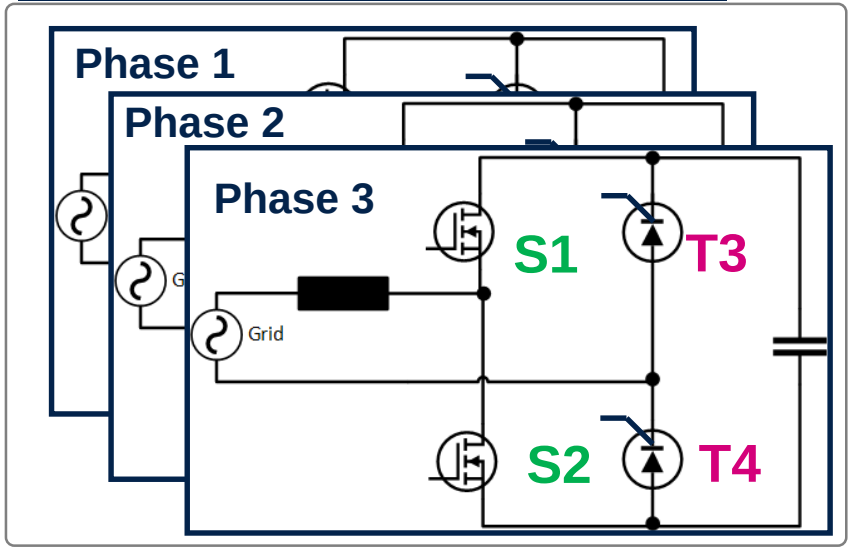
Device	Technology	ST Proposal
S1/S2	1200V SiC MOS	SCTxxN120
D1/D2	1200V Rectifier	STBRxx12W
	Driver	STGAP2S/D
	Control	STM32

Var. 2 – Performance – SiC MOS Leg



Device	Technology	ST Proposal
S1/S2	1200V SiC MOS	SCTWxxN120
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
T3/T4	1200V SCR	TNxx50-12PI
	Driver	STGAP2S/D
	Control	STM32

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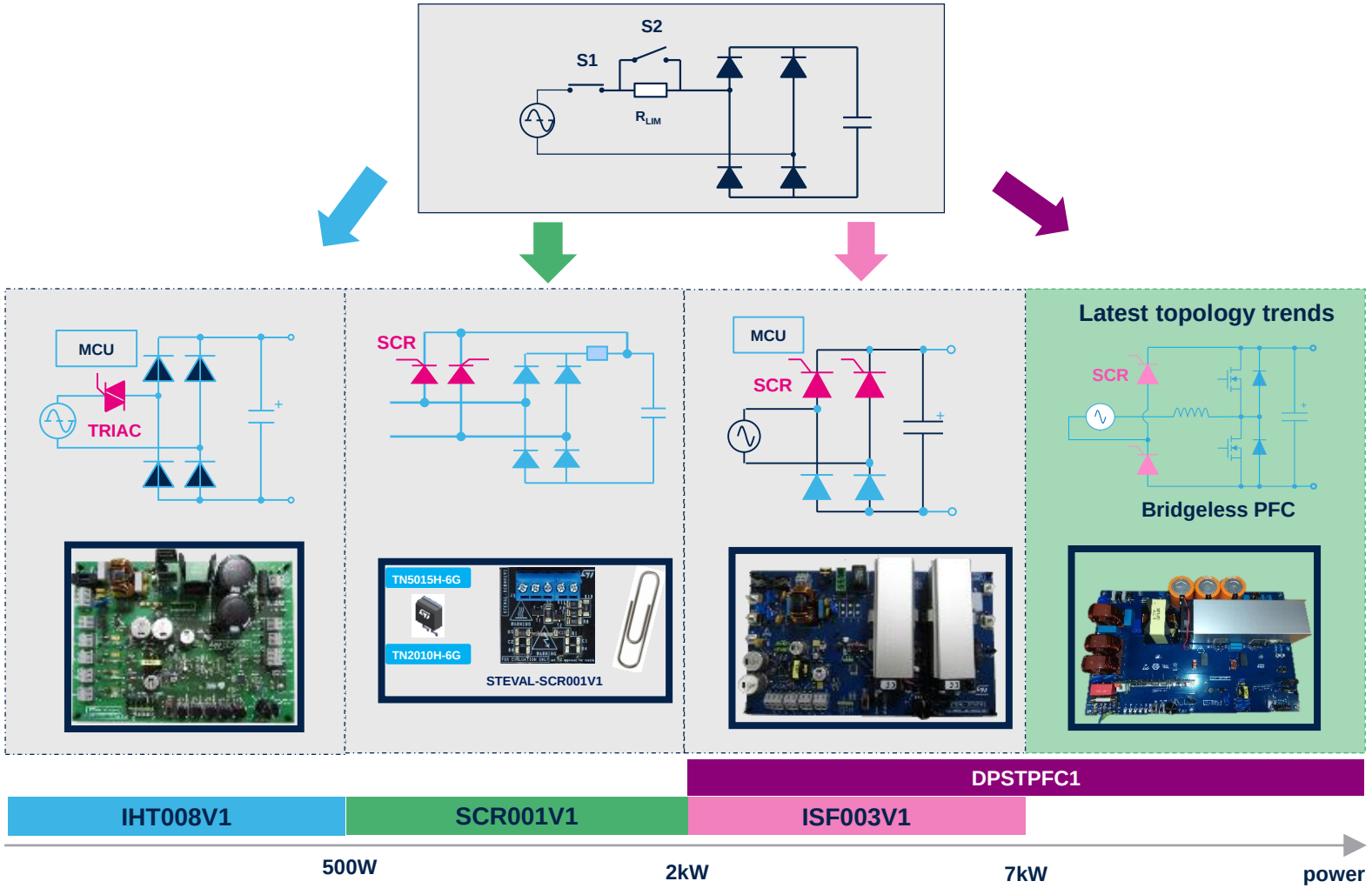
ST AC-DC Inrush Current Limiter solutions



SMART

Programmable soft power up control
Controlled multiple peak current limitation
Zero-current Switch

SAFETY

- No Contact Bounce: no spark, no EMI
- Faster line-drop recovery
- Increase switching life expectancy

COMPACT

Low profile design, smaller height thanks to D²PAK package

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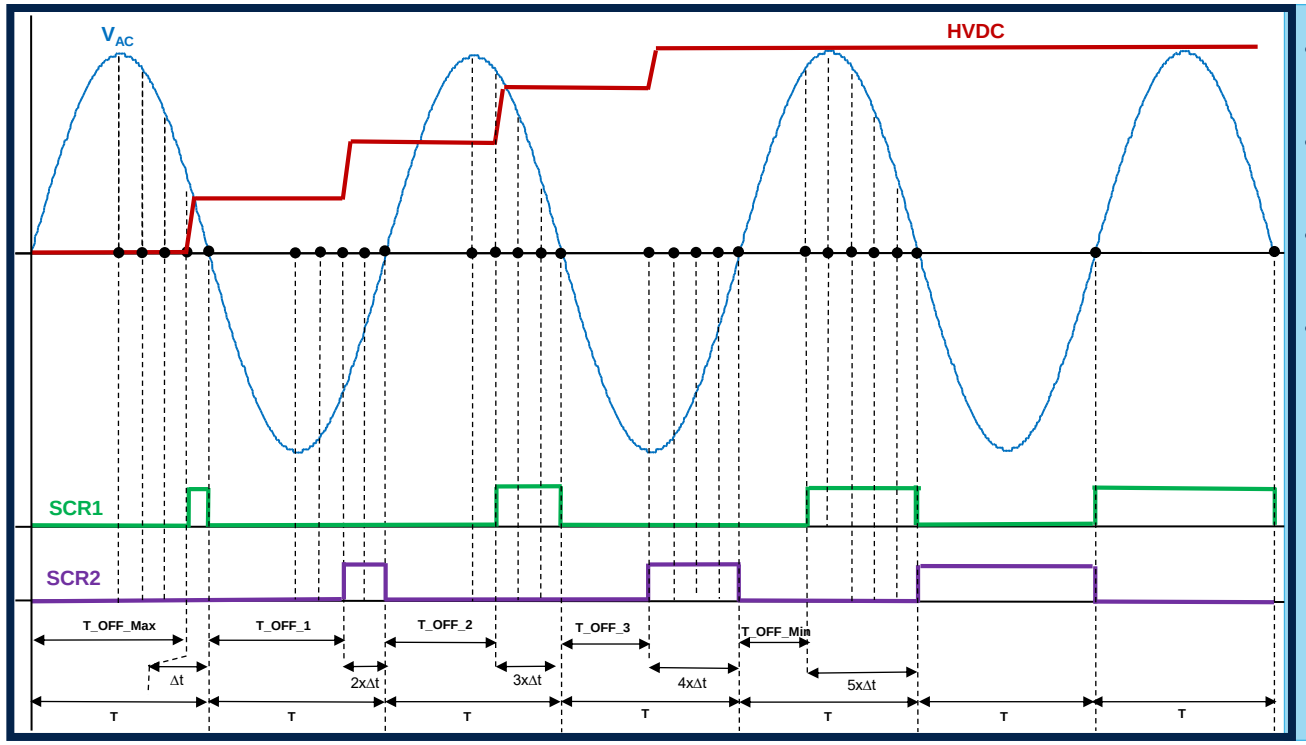
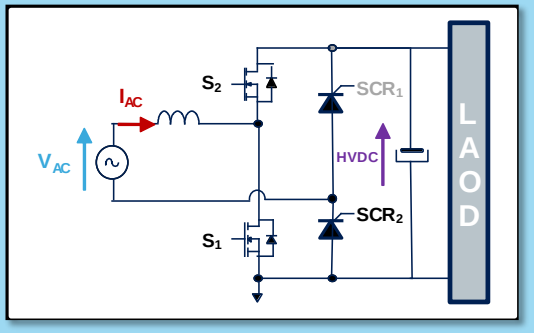
SCRs phase control



- Bulk capacitor is charged according to time-depending pulse train driving SCR1 and SCR2
- SCR1 and SCR2 are synchronized according to the zero crossing (ZVS) of the AC line
- SCR1 and SCR2 are alternatively controlled according to the AC line polarity by reducing the turn-on delay (“T_OFF”) by a constant Δt at each half AC line cycle
- SCR1 and SCR2 are controlled by phase angle up to the turn-on delay (“T_OFF”) is lower than “T_OFF_Min”



- Control the inrush-current to charge a DC bus capacitor
- Disconnect the DC bus capacitor from the AC mains when it does not have to operate

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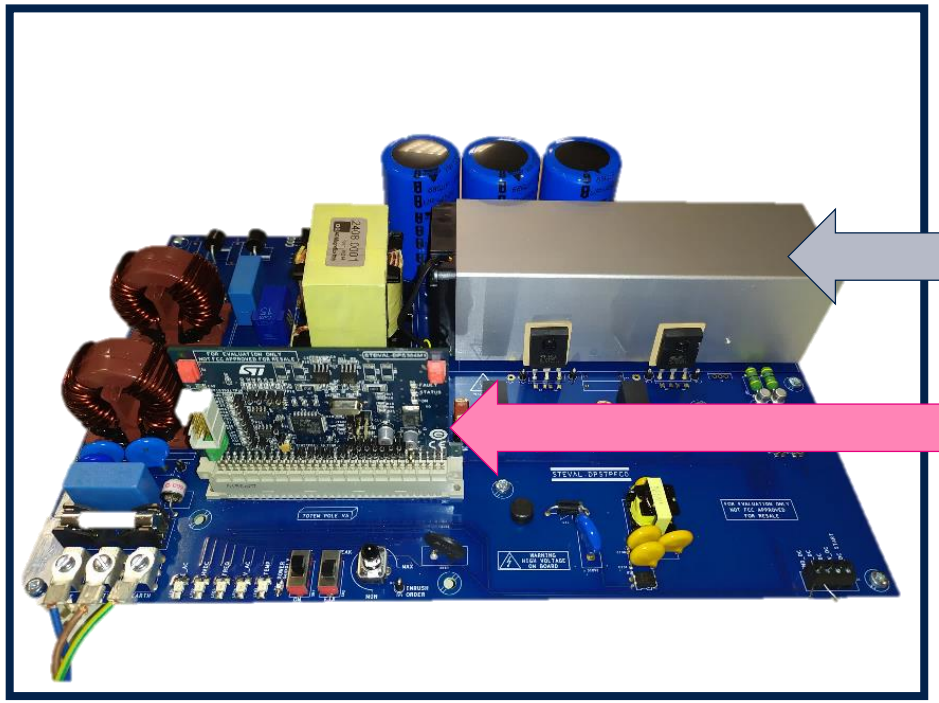
Evaluation board performance
Design content



Reference	Name	Description
STEVAL-DPSTPFC0	AC - DC power board	Bridgeless Totem Pole boost with auxiliary supply
STEVAL-DPS334M1	PFC control board	32-bit MCU control board
STEVAL-DPSADP01	Adapter Board	Interface for MCU debugging and USART communication

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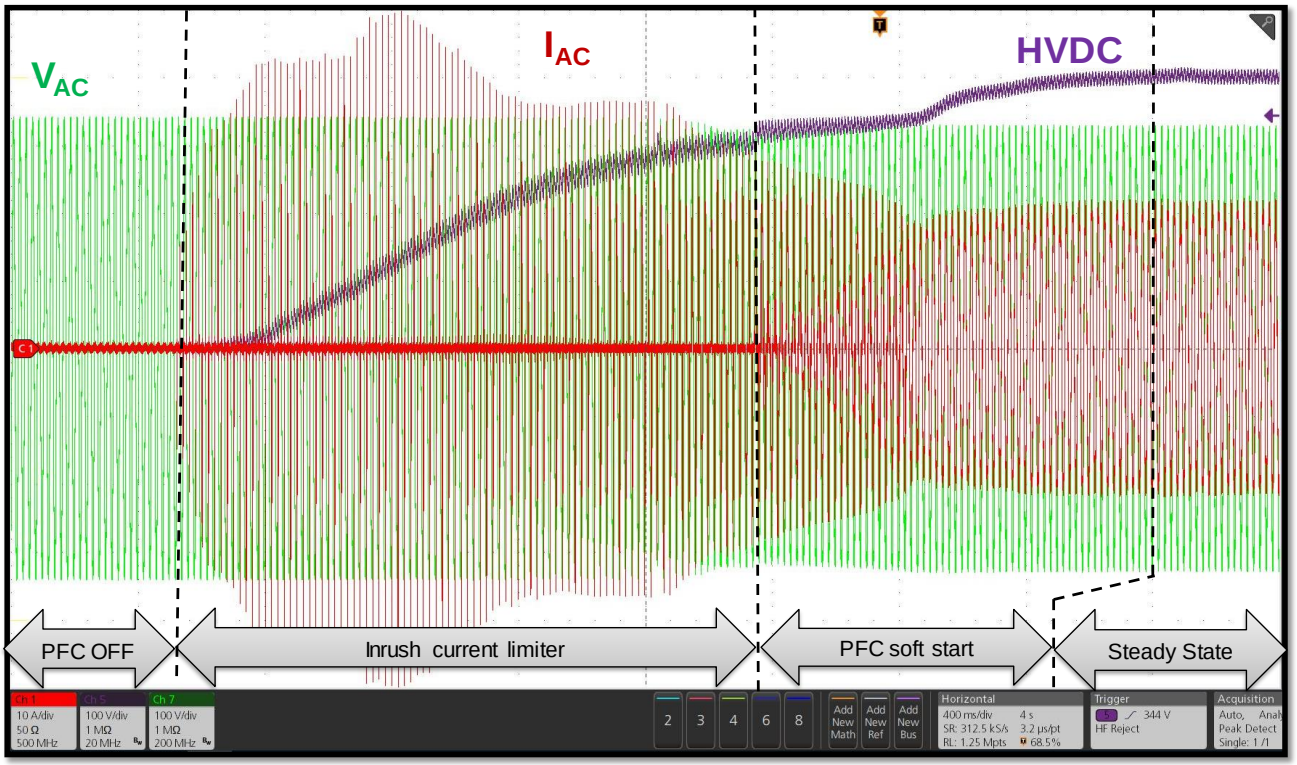
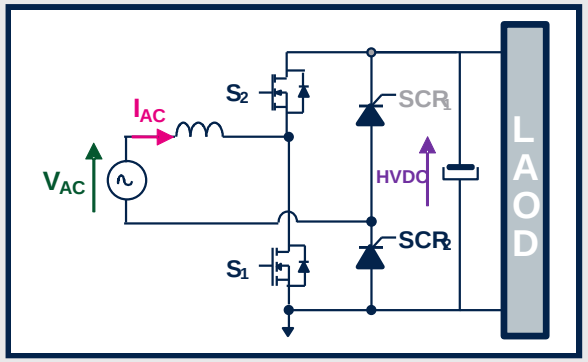
Evaluation board performance
PFC Totem Pole start-up



To ensure a smooth PFC start-up a soft start routines has been implemented on the MCU firmware:

1) **Inrush current limiter**: SCRs are controlled with a progressive phase control and the output capacitor can be smoothly up to the AC line peak voltage.

2) **PFC soft start:** The output voltage reference is controlled from AC line peak voltage to 400 Vdc with a smoothly voltage ramp.



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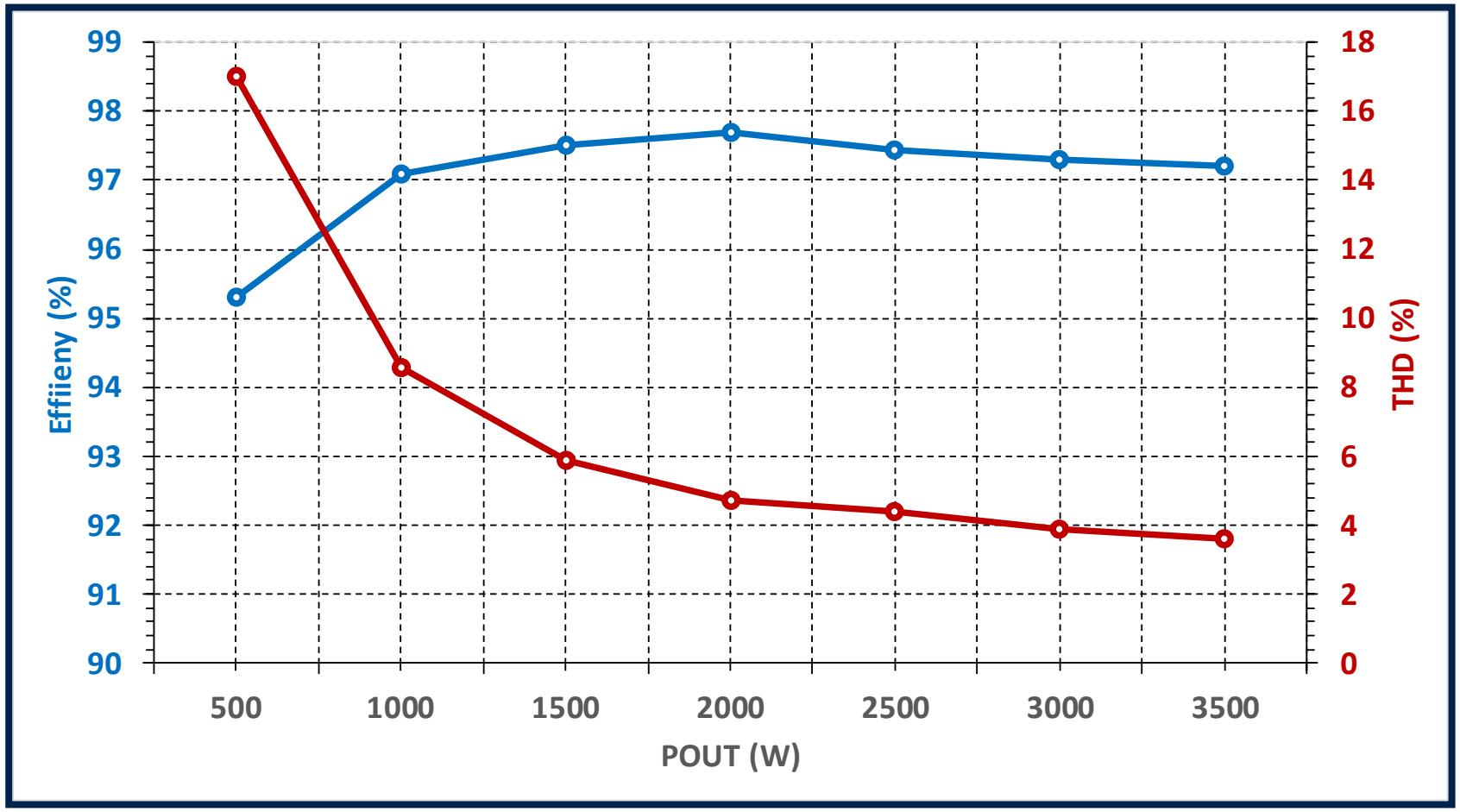
Evaluation board performance
PFC efficiency / THD measurement

VAC = 230 VRMS @ 50 Hz



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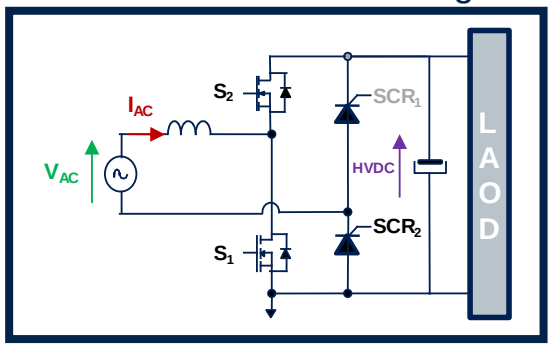
Board features

- Description of a 3.6kW bridgeless totem pole PFC evaluation board for telecom and industrial applications with an digital Inrush current limiter using SiC MOSFETs and Thyristors.
- The Evaluation board design includes
  - A power board bridgeless totem pole boost with an inrush limiter circuit, SiC MOSFET and SCRs switch drivers and an auxiliary power supply
  - A control board with its MCU, a PFC/ICL control firmware
  - An adapter board for software debug



DC/DC or motor inverter can be connected to this evaluation board

- Evaluate a full ST solution
  - SCRs: To control the inrush-current to charge a DC bus capacitor and to fulfill with the IEC 61000-3-3 standard
  - SiC MOSFETs: To reduce passive components size and to provide a PFC with a very high efficiency thanks to low reverse recovery diode body
  - STGAP2S driver: Dedicated and optimized to control SiC MOSFETs
  - STM32 microcontroller: Embedded the PFC control algorithm

Benefits

- Check the stand-by losses
  - Reduce drastically the stand-by losses of the traditional NTC/PTC Inrush-current limitation
  - Disconnect the DC bus capacitor from the AC mains when it does not have to operate
  - Without requiring a relay to be added to open the circuit during stand-by
- Check EMC
  - Immunity to fast transient and surge voltages
  - Common mode noise
- This reference design offering:
  - A high efficiency: > 97,5%
  - A low THD distortion lower than 5 % of maximum load
  - A high switching lifetime with reduced EMI emissions
  - A robust circuit that meets EMC standards up to 4 kV

- SCR allows achieving a smart inrush current limitation at power up or line drop recovery compare to the traditional NTC and relays solution

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Thank you

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