Totem-pole PFC reference design with SiC technology

STMicroelectronics
STMicroelectronics powers totem pole PFC with SiC MOSFETs, thyristor SCRs and digital control

- Bridgeless totem-pole PFC
- Inrush current limiter with SCRs in totem-pole PFC
- 3.6 kW totem pole PFC solution with SCR Inrush current limiter
- Key Power Product Families
Bridgeless totem-pole PFC

Supporting Car Electrification and Power Conversion

- Increased power density with totem pole boost
- Smart Inrush Current Limitation
- SCR high reliability without moving parts
Basic single phase PFC topologies for CCM

With input bridge rectifier

Simple Boost

- Simple
- Simple input voltage sensing
- Two diodes in series all the time

Bridgeless

Totem-pole

- Higher efficiency
- Input voltage sensing requires OpAmp
- More complex
- Needs SiC MOSFETs with no \( Q_{RR} \) of diode
Basic single phase PFC topologies for CCM

With input bridge rectifier

Simple Boost

Bridgeless

Totem-pole

junctons in series: 3

junctons in series: 2
Totem pole bridgeless PFC working in CCM
totem pole PFC operation in steady-state

\[ V_{AC} > 0 \]

- S1 controls PFC choke charging
- S2 body diode is used only for discharging choke to the output
- S2 can be switched on during \( t_{off} \) to reduce voltage drop of the body diode

\[ V_{AC} < 0 \]

- S2 controls PFC choke charging
- S1 body diode is used only for discharging choke to the output
- S1 can be switched on during \( t_{off} \) to reduce voltage drop of the body diode
Inrush current limiter with SCRs in totem-pole PFC

Smart and Reliable control of the AC Power Delivery

- Smooth Progression but Fast Power Up
- Robust against surges, Immune to electrical transients
- No contact bouncing, no EMI noise
Inrush current limiter with SCRs in totem-pole PFC

ICL with NTC and bypassing relay

ICL with SCRs

- Diodes are used for returning current path
- Resistive element is inserted into current path (NTC or PTC)
- NTC is bypassed after startup by relay to decrease power losses on NTC

- SCRs are used for returning current path
- When SCR are not being switched, output capacitor is disconnected
- During startup phase, pulses to SCR are being time controlled to slowly charge output capacitor
- This method requires timing → MCU required
Inrush current limiter with SCRs in totem-pole PFC

**ICL with NTC and bypassing relay**

- Relay can be driven by simple delaying circuit
- Relay causes audible noise when switching
- Relay not usable in systems with vibration
- Relay metal contact aging
- Slower charging time (current drops every cycle):

Charge time = 400 ms

**ICL with SCRs**

- No electromechanical bouncing
- Need exact SCR pulse timing
- Faster startup procedure (constant peak current)

Charge time = 120 ms
Inrush current limiter with SCRs in totem-pole PFC

But a Thyristor has a much higher voltage drop than a diode... Or does it?

Comparison of forward voltage drop

SCR has almost the same voltage drop (at 150°C) compared to bridge rectifier (both 30A/1.2kV)
3.6 kW totem pole PFC solution with SiC MOSFETs, thyristor SCRs and digital control

Innovative topology for D-SMPS, EV charging and motor drives

- 97.5% peak efficiency
- Peak inrush current tuning
- Very low THD and high power factor
**STEVAL-DPSTPFC1**
3.6 kW 1-ph totem-pole PFC

- Input AC voltage: **85 V\textsubscript{AC} up to 264 V\textsubscript{AC}**
- Input AC frequency: 45 Hz up to 65 Hz
- DC output voltage: **400 V\textsubscript{DC}**
- Maximum input current: **16 A\textsubscript{RMS}**
- Ambient temperature: tested from 0 °C up to 45 °C
- Peak Efficiency: **97.7 %** with **4.7%** THD
- Compliant with:
  - EN 55015 and IEC 61000-4-11 and IEC 61000-3-3
  - IEC 61000-4-5 surge: 4 kV
  - IEC 61000-4-4 EFT burst: criteria A @ 4 kV min
- Cooling: forced air cooling with active fan
- Designed for operation with DC / DC converter
- Peak **inrush** current tuning
STEVAL-DPSTPFC1
3.6 kW 1-ph totem-pole PFC

Key Products:
- SCTW35N65G2V (SiC MOSFET)
- TN3050H-12GY (SCR Thyristor)
- STGAP2AS (Galvanic insulated gate driver)
- STM32F334 (32-bit MCU)
- VIPer26LD (converter for aux. PS)

97.5 % efficiency at full load
Digital bridgeless PFC with inrush limiter
STEVAL-DPSTPFC1 – operation during inrush limitation

The SCR gate signals limit the AC inrush current by sweeping triggering angle backward from 180° to 0°
Digital bridgeless PFC with inrush limiter
STEVAL-DPSTPFC1 – MOSFETs control

SiC MOSFETs operate in safe synchronous conduction mode to optimize efficiency
Results: efficiency & THD

\[ V_{AC} = 230 \, V_{RMS} @ 50 \, Hz, \, T_{amb} = 25^\circ C \]

High Efficiency over complete load range – Very low THD in medium / high load
Results: Load variation

\[ V_{AC} = 230 \, V_{RMS} \, @ \, 50 \, Hz, \, P_{OUT} = 3.6 \, kW \, (100\%) \]

Excellent Transient Load Variation thanks to feed forward digital implementation
Results: power device temperatures
$V_{AC} = 230 \, V_{RMS} \, @ \, 50\, hz, \, P_{OUT} = 3.6 \, kW, \, t_{amb} = 28 \, ^\circ C, \, FAN \, ON$

The board is equipped with Over Temperature Protection mounted on the heatsink
A real boost for efficient high power designs

- High reliability and heatsink reduction
- Very high temperature handling capability (max. $T_J = 200\, ^\circ C$ for SiC MOSFETs, max $T_J = 150\, ^\circ C$ for SCRs)
- Higher system efficiency
The most innovative SCR thyristor portfolio

Strong & wide SCR range

High Temperature Applications

High performance characteristics

- $V_{\text{DRM}}$: 600 V to 1200 V
- $I_{\text{GT}}$: 5 µA to 50 mA
- $I_{\text{TRMS}}$: 12 A to 80 A
- $T_J$: 150°C
1200V thyristor SCRs range

Reliable and compact designs in new AC / DC functions

<table>
<thead>
<tr>
<th>Commercial Part</th>
<th>Current (I_{\text{rms}}) (A)</th>
<th>Surge (I_{\text{rms}}) (A)</th>
<th>Trigger (I_{\text{rms}}) (mA)</th>
<th>(\frac{dV}{dt}) (V/µs)</th>
<th>Package</th>
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<tbody>
<tr>
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<td>TYN1212RG</td>
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</tbody>
</table>

NEW = Light Blue

Critical Power UPS
HVAC
Smart Energy
Renewable
Charging Stations
IE3 Motor Drives
# Gen2 650V SiC MOSFET product range

## Key Features
- Enables new technology platform with outstanding Figure Of Merit
- Excellent system efficiency and reduced cooling requirements
- Very low on-state resistance
- 200°C maximum junction temperature
- Very fast and robust intrinsic body diode
- Industrial and Automotive Grade qualified

## Typical Applications
- Charger Stations and On-Board Chargers
- PFC - SMPS for Industrial, Telecom & Class-D Audio Amplifiers
- Traction inverters in HEV and BEV
- Motor drives
- DC-DC converters

### Part Number | $V_{DS}$ [V] | $R_{DS(on)}$ Typ @ 25 °C [Ω] | $I_d$ [A] | Package |
<table>
<thead>
<tr>
<th></th>
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<td>0.020</td>
<td>100</td>
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<tr>
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<tr>
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</tr>
<tr>
<td>SCTH35N65G2V-7</td>
<td>650</td>
<td>0.55</td>
<td>45</td>
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**The best $R_{DS(on)}$ vs $Q_g$ trade-off**
### Isolated Gate Drivers
**STGAP2S & STGAP2D**

#### Different flavors for different needs

<table>
<thead>
<tr>
<th>Feature</th>
<th>STGAP2S</th>
<th>STGAP2D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.7 kV Isolation</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>4 A sink and source current</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Single channel</td>
<td>•</td>
<td>• Dual channel</td>
</tr>
<tr>
<td>Active Miller Clamp or $G_{ON}/G_{OFF}$ pins</td>
<td>•</td>
<td>• Compact layout</td>
</tr>
<tr>
<td></td>
<td><strong>SO8N</strong></td>
<td><strong>SO16N</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Industrial grade</strong></td>
<td><strong>Industrial grade</strong></td>
</tr>
</tbody>
</table>

- **Renewable**
STGAP2S

1700V, 4A isolated gate driver

- 3V3 / 5 V logic inputs (logic thresholds 1/3, 2/3 of VDD)
- Up to 26 V supply voltage
- 4 A Sink/Source current capability
- Short propagation delay: 80 ns
- UVLO Function
- Stand-by function
- 100 V/ns CMTI
- High voltage rail up to 1700 V
- Temperature shut-down protection

- Active High & Active Low input pins, for HW interlocking
- STGAP2SM: Separated outputs option for easy gate driving adjustment
- STGAP2SCM: Miller CLAMP pin option to avoid induced turn-on
- Negative gate drive ability
- SO8 Package
Thank you