15 kW, three-phase, three-level active front end (AFE) bidirectional converter for industrial and electric vehicle DC fast charging applications

**Features**

- 3-phase, 3-level bidirectional AC-DC power converter:
  - Rated nominal DC voltage: 800 V\(_{DC}\)
  - Rated nominal AC voltage: 400 V\(_{AC}\) at 50 Hz
  - Nominal power: 15 kW
- AC to DC rectifier mode:
  - Power factor: PF >0.99
  - Inrush current control and soft startup
- DC to AC inverter mode:
  - Active and reactive power control
  - Integrated grid connection solution
- Power section based on SiC MOSFETs:
  - High frequency operation (70kHz)
  - High efficiency: >98%
  - Passive element weight and size reduction
- Control section based on STM32G474RET3 microcontroller:
  - P2P compatible with different power converters solutions
  - Four integrated high-performance op-amps
  - Control and monitoring interfaces: SWD, UART, P'IC, DACs
  - 64-pin digital power connector
  - Overcurrent and overvoltage protection

**Description**

This reference design represents a complete solution for three-phase AC/DC and DC/AC (800 V\(_{DC}\) to 400 V\(_{AC}\)) applications based on a digital platform optimized for power conversion.

It is well suited for the Active Front End (AFE) stage in high power charging stations, industrial battery chargers and UPS. The high switching frequency of the SiC MOSFETs and the multilevel structure allow nearly 99% efficiency as well as the optimization of passive power components in terms of size and cost.

The **STDES-PFCBIDIR** is a fully assembled kit developed for performance evaluation only, not available for sale.
<table>
<thead>
<tr>
<th>Product summary</th>
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<tbody>
<tr>
<td>45 A, 55 mΩ in HiP247 package</td>
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<tr>
<td>Automotive-grade SiC Power MOSFET 1200 V, 33 A, 75 mΩ in HiP247 package</td>
<td>SCTW40N120G2VAG</td>
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<td>Galvanically isolated 4 A single gate driver</td>
<td>STGAP2SM</td>
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<td>Fixed frequency VIPer plus family</td>
<td>VIPER26HD</td>
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<td>Applications</td>
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<td>PFC Converter - Three Phase Input</td>
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<td>DC Fast Charging Station</td>
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This reference design consists of the following separate components:

- A board with the power converter, LCL filter, sensing circuit, inrush circuit, grid connection management circuit and on-board auxiliary power supply.
- A control module based on the STM32G4 Series microcontroller with connectors for communication and test-points and status indicators for testing and debugging.

The input and output current and voltage measurements necessary for responsive control are acquired through isolated measurement blocks, and the STM32 microcontroller manages connection and disconnection with the AC electrical network, as well as load and source DC management in either inverter or rectifier mode.

The driving signals for the switching devices are managed by corresponding STGAP2S gate drivers to ensure independent management of switching frequencies and dead time.

The hardware math accelerator in the MCU boosts the trigonometric operations of the voltage oriented control (VOC) algorithm, allowing the power converter to achieve very high power quality.

**Figure 1. Bidirectional converter block diagram**

![Bidirectional converter block diagram](image)
2 Schematic diagrams

Figure 2. STDES-PFCBIDIR schematic diagram - control board

- Refer to datasheet for PCB orientation of the LED1
- Solder a 22μF / 16V electrolytic capacitor in parallel to C133
Figure 3. STDES-PFCBIDIR schematic diagram - power board: AC current sensing
Figure 4. STDES-PFCBIDIR schematic diagram - power board: AC voltage sensing
Figure 5. STDES-PFCBIDIR schematic diagram - power board: aux power DC-DC
Figure 6. STDES-PFCBIDIR schematic diagram - power board: aux power VIPER

Figure 7. STDES-PFCBIDIR schematic diagram - power board: connector
Figure 8. STDES-PFCBIDIR schematic diagram - power board: DC current sensing
Figure 9. STDES-PFCBIDIR schematic diagram - power board: DC voltage sensing
Figure 10. STDES-PFCBIDIR schematic diagram - power board: gate drivers (x12)
Figure 11. STDES-PFCBIDIR schematic diagram - power board: grid voltage sensing
Figure 12. STDES-PFCBIDIR schematic diagram - power board: power section

Figure 13. STDES-PFCBIDIR schematic diagram - power board: active inrush current and AC grid connection management
Figure 14. STDES-PFCBIDIR schematic diagram - power board: temp control
### Revision history

**Table 1. Document revision history**

<table>
<thead>
<tr>
<th>Date</th>
<th>Version</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>05-Nov-2019</td>
<td>1</td>
<td>Initial release.</td>
</tr>
<tr>
<td>08-Mar-2022</td>
<td>2</td>
<td>Added logo. Updated cover page features, product summary and Section 2 Schematic diagrams</td>
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