Wolfspeed SiC Power solutions for EV Charging

20kW Off board fast Charger system
### REQUIREMENTS

- The traditional way to meet these requirements is with a two-stage topology: AC/DC and DC/DC
- AC/DC focus on input THDi and provide a somewhat constant voltage to the DC/DC stage
- DC/DC provides galvanic isolation and output voltage/current control suitable for a charger application

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ref.</th>
<th>Value and description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage</td>
<td>Vin</td>
<td>3-ph, 50Hz +/- 6%, 380 Vac l-l rms +/- 10%. 4-wire, 3ph + N + PE</td>
</tr>
<tr>
<td>THDi</td>
<td>%</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>PF</td>
<td>n/a</td>
<td>&gt;0.9</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>Vo</td>
<td>200 – 570 VDC</td>
</tr>
<tr>
<td>Max. continuous Output Power</td>
<td>Po.max</td>
<td>20 kW</td>
</tr>
<tr>
<td>Max. output current</td>
<td>Io.max</td>
<td>50 Adc</td>
</tr>
<tr>
<td>Operating temperature range</td>
<td>T.op</td>
<td>-30C to +50C (typically de-rated at higher temp)</td>
</tr>
<tr>
<td>Galvanic isolation</td>
<td>Viso</td>
<td>Yes, 2.5kV isolation.</td>
</tr>
<tr>
<td>Efficiency</td>
<td></td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Surge withstand requirements</td>
<td></td>
<td>Not known</td>
</tr>
<tr>
<td>Uni-directional or bi-directional</td>
<td></td>
<td>Mostly uni-directional, maybe bi-directional needed in future.</td>
</tr>
</tbody>
</table>
OFF BOARD EV CHARGING IMPLEMENTATION

• **Background**
  - Most existing silicon designs target 12-15KW
    - Modified Vienna PFC + Interleave 3L LLC DC/DC + Full Bridge output rectifier
    - Common 650V silicon MOSFET parts with reasonable efficiency:
      - Silicon dc-dc stage is 97.5% max at 50% load / 550V.
      - Si Vienna is 98% so total efficiency of best silicon solution is 95.5%, typical silicon solution is 94-95%
    - Trend is moving towards 700V DC output.

• **Where Wolfspeed Silicon Carbide makes the difference**
  - Increase power density – 20KW in same form factor + higher efficiency and lower system cost $/kW
    - Existing silicon15KW challenged to achieve 20KW with similar topologies and device cost
    - 20kW gives better system $/W
    - Maximum higher power density per footprint for modularization to 80kW-120kW
    - Drive for higher efficiency (Now 94% is the silicon entry level, we target SiC achieve >96%)

• **Wolfspeed Solution : All SiC 20KW Turnkey design for off board**
  - 3 phase 6-switch PFC to replace the Vienna PFC (in design)
    - Higher frequency with comparable system cost to give better power density
    - Easy design with 2 level topology
    - Highest efficiency
    - Bi-directionality
  - DC/DC Stage
    - 2 level Full Bridge LLC for 200-550V O/P (complete) , 2 level Phase shift Full Bridge for 200-700V O/P (complete)
    - Highest efficiency available
  - Full working hardware solution complete and evaluated by Mid June
    - Design files, performance data suite, Gerber files, BOM & reference hardware will be made available
Wolfspeed SiC enables smaller, cooler and lower $/kW in Off Board EV Chargers

- Use SiC devices to achieve *increased performance, improved efficiency, and reduced size and weight*.
  - Minimize weight and volume with *high-frequency switching*
  - Reduce required thermal management by less device loss
Wolfspeed SiC solutions for EV Charging
20kW Phase shift dc-dc module design
Vo/p 300V to 700V
Input voltage: 700Vdc-750Vdc

Output Voltage: 300Vdc-700Vdc

Frequency: 200KHZ

Output power: 20KW

Output Max Current: 30A

Power Density: >45W/cube inch

E-cap free with long life time and high reliability

Wolfspeed devices: 8pcs C3M0065090D 4L, 4pcs C4D20120D, 2pcs C3D10060A and 1pcs C2M1000170D

Applications: EV charger, EV DC/DC and HVDC
20kW Phase Shift Reference Design Block Diagram

- Active clamp circuit to damp the spike and ringing with C3D10060A SiC SBD
- 7uH resonant inductor for lag leg ZVS operation

Constant Current & Constant Voltage feedback loops

Phase Shift full bridge control TI UCC2895
Note: the efficiency includes aux power losses with air-forced fan cooling
20KW PHASE SHIFT DCDC CONVERTER

- Aux power with C2M1000170D
- Phase shift control
- SiC MOSFET Driver
- C3M0065090D 4L SiC MOSFET
- Isolated Main Transformer
- C3D16065D SiC SBD
- iPhone 6S
SiC MOS C3M0065090D 4L with heat sink

C3M0065090D 4L

12W air-forced fan cooling

Fan cooling MOSFET
WOLFSPEED 20KW OFF BOARD EV CHARGING IMPLEMENTATION

• 20kW LLC Dc-Dc Paper design kit (PDK) –
  – Design & layout files
  – Schematic
  – BOM
  – Component spec sheet
  – User guide

• 20kW Phase shift Dc-Dc Paper design kit (PDK) –
  – Design & layout files
  – Schematic
  – BOM
  – Component spec sheet
  – User guide

• 20kW Phase shift Dc-Dc & 20kW LLC dc-dc demo boards - Available to purchase end of June 2016

• 20kW Active front end Ac-Dc
  – Paper design kit and hardware demo boards available – End August (estimate)
Thank you