Sub-track II –
Power & Energy Presentation
3 kW 5G telecom rectifier with SiC MOSFET and STM32G4 digital controller

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Background
5G telecom power requirements

Higher system integration is the Key for 5G power
Provides higher power density and higher efficiency!

- **Smaller coverage due to higher frequency radio**: to achieve high network speed and low latency
- **Higher power consumption in 5G usage**: to fulfill high traffic density and connection density

Source: Huawei
To achieve high system integration, we need:

- High flexibility and good adaptability for advanced topologies to achieve high efficiency
- Provide benefit on downsizing and BOM reduction
- Support communication for real-time monitoring (safety)
- Less component variation (high reliability)
Introduction for 3 kW digital solution
**Application key features:**
- Fully digital AC-DC power supply
- Input AC voltage: 90–264 VAC
- Input AC frequency: 47–63 Hz
- DC output voltage: 53.5 VDC
- Peak efficiency > 96.5% @ 230 VAC
- Power Factor > 0.99 @ 100% load
- iTHD < 5% @ 100% load
- Hold up time: 10 ms
- Outline dimension: 100 x 310 x 41 mm
- Power density up to 40 W/inch³
- Peak inrush current < 30 A

**Key products**
- **PFC:**
  - SCTW35N65G2V (SiC MOSFET),
  - STY139N65M5 (SJ MOSFET),
  - STGAP2D (galvanic insulated gate driver),
  - STM32G4 (32-bit MCU),
  - VIPER26HD (for aux. power of PFC stage)
- **LLC:**
  - STW70N65DM6 (SJ MOSFET),
  - STGAP2HS (galvanic insulated gate driver),
  - STL130N8F7 (SR MOSFET),
  - STM32G4 (32-bit MCU),
  - VIPER38HD (for aux. power of LLC stage)

**Key benefits**
- Peak efficiency > 96.5%
- Power density up to 40 W/inch³
3 kW CCM totem pole PFC solution

Key specs

- Input AC voltage: 90–264 VAC
- Input inrush current: <30 A
- Switching frequency: 70 kHz
- Operation mode: CCM
- Peak efficiency: 98.5% @ 230 VAC
- Power Factor > 0.99 @ 100% load
- iTHD < 5% @ 100% load
- STM32G4 digital power control

Key products:

- SCTW35N65G2V (SiC MOSFET)
- STY139N65M5 (SJ MOSFET)
- STGAP2D (galvanic insulated gate driver)
- STM32G4 (32-bit MCU)
3 kW full-bridge LLC solution

Key specs

- Input DC voltage: 350–425 V
- Output voltage: 53.5 53.5 V
- Switching frequency: 80 kHz–150 kHz
- Resonant frequency: 115 kHz
- Peak efficiency: 98.2%
- Output voltage dynamic response: < 5%
- Digital (STM32G4) power control

Key products:

- STW70N65DM6 (HV MOSFET)
- STL130N8F7 (SR MOSFET)
- STGAP2HS (galvanic insulated gate driver)
- STM32G4 (32-bit MCU)
- VIPER38LD (converter for aux. PS)
Operation mode of totem pole PFC

$V_{AC} > 0$

S1 controls PFC choke charging
S3 can be switched on to reduce voltage drop of the body diode

$V_{AC} < 0$

S2 controls PFC choke charging
S4 can be switched on to reduce voltage drop of the body diode
SiC MOSFET and driver IC

- Low body diode reverse recovery.
- Low switching loss due to outstanding figure of merit.
- Low power loss at high temperature due to less temperature dependence of on resistance.

650 V Gen2 SiC MOSFET

- SiC has significantly less than 1% of the Qrr than silicon.
- Rds(on) is less sensitive on SiC MOSFET over temperature.
Resonant tank design

**Magnetizing inductance Lm selection**

**Considerations:**

- Select resonant frequency around 110-kHz-based power density target
- Main consideration is to achieve the optimal efficiency
- Primary MOSFET Eoff is related to Lm
- Primary MOSFET conducting loss is related to Lm
- Transformer copper loss is related to Lm
- Resonant inductor copper loss is related to Lm
- Power MOSFET ZVS is related to Lm

When operating at $f_s=f_r=116$ kHz, $L_m=225$ µH:
- RMS magnetizing current is 2.17 A
- MOSFET switching off current is 3.752 A
- Voltage/current phase difference is $\Phi=0.309$
- Total zvs discharging capability is 800 nC

**Calculation**

Check maximum Lm to ensure MOSFET ZVS at light load:

- $f_{rt}=150$ kHz
- $C_{oss} = 286 \cdot (1 + 30\%) \cdot pF = 371.8 \cdot pF$
- $T_d = 400$ ns
- $C_{stray} = 100$ pF

When $L_m = L_m_{vzs}$, the peak value of excitation current is $I_m = \frac{V_p f_{c,v}}{4 L_m_{vzs}}$.

Select $L_m = 230$ µH, then double check $T_d$ margin at full load:

$T_{d_{max}} = \frac{\Phi}{\pi} \cdot \frac{1}{2 f_r} = 423.467 \cdot ns$

$T_d < T_{d_{max}}, ok$
Resonant tank Cr, Lr selection

Considerations:

- Influence for efficiency, mainly Lr
- Output voltage range and its corresponding operating frequency range
- Smaller Lr can reduce total resonant inductor power loss
- Smaller Lr will reduce output capability @ low Vin and full load
- Influence for output maintain time during shutdown
- Smaller Lr means higher frequency is needed for output regulation @ high Vin and light load

When operating with Lm=225 µH, Lr=25 µH, Cr=75 nF:
- K=9, Q=0.42 @ full load
- fs=80 kHz @ Vin=375 V, Vout=53.5 V, full load
- fs=165 kHz @ Vin=425 V, Vout=53.5 V, Iout=1 A

Calculation

Vout vs. fs @ Vin=400 Vdc, each load

Vout vs. fs @ Vin=375 Vdc, each load
EVM board performance
• Efficiency / iTHD / PF
• Soft startup
• Load transient response
• Load on with full power
• Hold-up time

Find more information from https://www.st.com/en/evaluation-tools/stdes-3kwiccp.html
Efficiency curve

- **Totem-Pole PFC Efficiency Curve**
  - Peak efficiency: 98.5%

- **Full-Bridge LLC Efficiency Curve**
  - Peak efficiency: 98.2%

**Test condition:** 230Vac/50Hz

**Total Efficiency Curve**
- **Peak efficiency:** 96.5%

**Test Data**
- China Y/D 731 Telecom Spec
- China Q/ZTT Telecom Spec
iTHD/power factor @ 230 Vac

**Power Factor**

- **PF**

**iTHD**

- **iTHD (%)**

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**Output Load (%)**

10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

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**Test Data**

- **Telecom Power**
- **Data Center Power**
- **Server Power**
Soft start @ 230 Vac/50 Hz

No load

Tss = 7.029 s

Full load

Tss = 6.941 s

CH1: Input current (10 A/div)
CH2: Input voltage (200 V/div)
CH3: Bulk cap voltage (70 V/div)
CH4: Output voltage (10 V/div)
Load transient response @ 230 Vac / 50 Hz

10%~90%~10% 0.1A/µs 100 ms

CH1: Resonant current (10 A/div)
CH2: Input voltage (100 V/div)
CH3: Bulk cap voltage (20 V/div Vos=400 V)
CH4: Output voltage (1 V/div Vos=53.5 V)
CH5: Load current (6 A/div)
Load on with full power @ 230 Vac/50 Hz

CH1: Resonant current (10 A/div)
CH2: Input voltage (100 V/div)
CH3: Bulk cap voltage (20 V/div Vos=400 V)
CH4: Output voltage (2 V/div Vos=53.5 V)
CH5: Load current (8 A/div)
Hold up time @ 230 Vac/50 Hz

Holdup time

$$T_{\text{holdup}} = 10.751 \text{ ms}$$ from 53.5 V drop to 48.5 V
ST products
TOTEM POLE PFC

- High freq switch: SiC MOSFETs
- Low freq switch: SCR thyristors, SJ MOSFETs, BRG DIODEs
- V / I monitoring
- Gate driver IC
- Digital controller

LLC CONVERTER

- Primary side switch: SJ MOSFETs, SiC MOSFETs
- Secondary side switch: SJ MOSFETs, DIODEs
- V / I monitoring
- Gate driver IC
- Digital controller
# STPOWER SiC MOSFET

## Product families and applications

### Breakdown voltage

<table>
<thead>
<tr>
<th>Voltage</th>
<th>G2</th>
<th>G3</th>
<th>G3</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G1</th>
<th>VHV</th>
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</thead>
<tbody>
<tr>
<td>650 V</td>
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<td>750 V/900 V</td>
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<td>1200 V</td>
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<td>1700 V</td>
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<td>2200 V</td>
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### On-state resistance

<table>
<thead>
<tr>
<th>Voltage</th>
<th>G2</th>
<th>G3</th>
<th>G3</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G1</th>
<th>VHV</th>
</tr>
</thead>
<tbody>
<tr>
<td>650 V</td>
<td>18 mΩ to 55 mΩ</td>
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<tr>
<td>750 V/900 V</td>
<td>14-55 mΩ</td>
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</tr>
<tr>
<td>1200 V</td>
<td>11 mΩ</td>
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<tr>
<td>1700 V</td>
<td>52 mΩ to 520 mΩ</td>
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</tr>
<tr>
<td>2200 V</td>
<td>25 mΩ to 75 mΩ</td>
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<tr>
<td>1 Ω</td>
<td>70 mΩ and 15 mΩ</td>
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<tr>
<td>1 Ω</td>
<td>1 Ω and 65 mΩ</td>
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<tr>
<td>1 Ω</td>
<td>31 mΩ</td>
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### Focus applications

- **OBC & DC-DC**
  - Renewable energy
  - Power supply
  - Industrial drives
- **Traction**
  - OBC & DC-DC
  - High density power supply
- **Traction inverter**
  - OBC & DC-DC
  - High density power supply
- **Photovoltaic**
  - Power supply
- **OBC & DC-DC**
  - Inverter
  - Charging stations
  - Industrial drives
- **Traction inverter**
  - OBC & DC-DC
  - HF power supply
- **DC-DC**
  - Power supply
  - Renewable energy
- **DC-DC**
  - Power supply
  - Renewable energy
High-voltage superjunction MDmesh* series

MDmesh series

- **M2**: 400V to 650 V
- **M6**: 600V to 650 V
- **M5**: 550 V to 650 V
- **M9**: 250 V to 650 V
- **DM2**: 400 V to 650 V
- **DM6**: 400 V to 650 V
- **DM9**: 600 V to 650 V
- **K5/DK5 - K6**: 800 V to 1700 V

Focus topology

- **Flyback, PFC, LLC resonant**
- **Hi-end-power PFC hard switching topologies, TTF**
- **Hi-end-power PFC hard switching topologies, LLC soft switching topologies**
- **Half Bridge, full Bridge, ZVS, LLC**
- **Flyback topology**

Focus applications

- **TV SMPS, Fast chargers, adapters LED lighting, microinverters**
- **EV-Car/Charging**
- **Servers, telecom data centers, 5G power stations, solar, medical, motor control**
- **LED driver, LED lighting, auxiliary SMPS, EV-Car, medical**

* is a registered and/or unregistered trademark of STMicroelectronics International NV or its affiliates in the EU and/or elsewhere.
Complete HV MOSFET series for higher efficiency

**Energy generation & storage** need higher & more efficient tailored topologies

**Charging station:** Complete solution up to 22 kW

**Server and datacenter** drive demand for better and higher power density systems

**Telecom power:** rapid increasing of smaller cells requires power system

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**Products for applications**

<table>
<thead>
<tr>
<th>PFC AC-DC converter</th>
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<tr>
<td><strong>MDmesh M5</strong></td>
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<tr>
<td><strong>MDmesh M9</strong></td>
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</table>

**DC-DC converter**

| **MDmesh DM2** | 50 mΩ 650 V |
| **MDmesh DM6** | 34 mΩ 650 V |
| **MDmesh DM9** | 22 mΩ 650 V |

**Flyback section**

| **MDmesh K5** | 80 mΩ 800 V |
| **MDmesh K6** | 220 mΩ 800 V |

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**Charging station:** Complete solution up to 22 kW

**Telecom power:** rapid increasing of smaller cells requires power system

**Server and datacenter** drive demand for better and higher power density systems

**Energy generation & storage** need higher & more efficient tailored topologies

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**Stability & Augmentation**

*Life augmented*
Isolated gate drive for SiC MOSFET

1700 V galvanic isolated single & dual channel
- STGAP2S
- STGAP2SC
- STGAP2SICSN
- STGAP2SICSC

Galvanic isolated, up to 1700 V high voltage rail
Fast switching frequency (Tp 80 ns only)
High current capability 4A Isink / Isource
Extreme transient immunity up to ±100 V / ns

6000 V galvanic isolated single & dual channel
- STGAP2HS
- STGAP2HSC
- STGAP2SICS
- STGAP2SICSC

Galvanic isolated, up to 6000 V high voltage rail
Fast switching frequency (Tp 80 ns only)
High current capability 4A Isink / Isource
Extreme transient immunity up to ±100 V / ns
VIPer family

> 4 Billion units shipped

Power capability

Miniaturization

VIPer0P 800 V
VIPer01 800 V
VIPer02 800 V / 1050 V
VIPerx22 730 V
VIPerx5 800 V
VIPerx7 800 V
VIPerx8 800 V
VIPer II gen 800 V

Buck & Fly-back PSR/SSR

VIPer0P 800 V
VIPer11 800 V
VIPer16 800 V
VIPer22 730 V
VIPerx6 800 V / 1050 V
VIPerx5 800 V
VIPerx7 800 V
VIPerx8 800 V
VIPer II gen 800 V

Fly-back SSR

VIPerP4
VIPerP3

VIPerGaN100
VIPerGaN65
VIPerGaN50

in development MP end 2023
Based on a 32-bit Arm® Cortex®-M4 core with FPU and DSP instructions running at 170 MHz, ideal for digital power conversion

- 170 MHz 32-bit Arm Cortex®-M4 core with FPU
- Routine booster of CCM-SRAM up to 32 KB
- Mathematic hardware accelerators (CORDIC / FMAC)
- High-resolution timer (184 ps) for precise PWM control
- Rich advanced analog
- USB Type-C® Power Delivery (PD)
- ±1% internal clock
Summary
This digital solution with STM32G4 will help you achieve high efficiency / high power density for 5G telecom power supply.

ST provides the latest technologies (SiC/STGAP/M6/STM32) for high power density and high efficiency solutions on 5G telecom power applications.

This reference design offers:
- Digital power solution for totem pole PFC converter and full-bridge LLC with synchronous rectifiers
- Peak efficiency is greater than 96.5%, PFC section is 98.5%, DC-DC section is 98.2%
- Power density up to 40 W/in³
- iTHD distortion lower than 5% and PF greater than 0.99
- Adaptive SR control algorithm for efficiency optimization
Our technology starts with You

Find out more at www.st.com