Isolated DC-DC Converters with eGaN® FETs

Johan Strydom Ph.D.

Efficient Power Conversion Corporation
Agenda

- Overview of Brick Architecture
- Hard-Switching Regulated eGaN FET Brick
- HF Resonant Unregulated eGaN FET Brick
- Summary
Brick Converter Space

48 V +/-10%

36 V - 55 V

36 V - 60 V

36 V - 75 V

Nominal 9.6 V / 12 V

5: 1 / 4:1

Regulated 12 V

5 V

3.3 V

1.2 V
Hard Switching FOM

Graph showing the relationship between device voltage (V) and the product of drain-source on-resistance $R_{DS(ON)}$ and gate charge $Q_{GD}$ for different types of FETs:

- LDMOS FETs (blue squares)
- Vertical MOSFETs (red triangles)
- eGaN FETs (green circles)

The x-axis represents device voltage (V), ranging from 10 to 1000, and the y-axis represents $R_{DS(ON)} \times Q_{GD}$ (pCΩ), also ranging from 10 to 1000.
Regulated Full Bridge Converter

EPC9102 Demo board
Full Bridge, 36 - 60 Vin, 12 V, 200 W, 375 kHz
eGaN FET vs MOSFET

140 W @ 250 kHz

200 W @ 375 kHz
Efficiency Comparison

Regulated 12 V Output

375 kHz eGaN FET

250 kHz MOSFET

Efficiency

Output Current (A)
Power Loss Comparison

- 375 kHz eGaN FET
- 250 kHz MOSFET

**Graph Details:**
- **Y-axis:** Power Loss (W)
- **X-axis:** Output Current (A)
- **Lines:**
  - Blue dashed line: 36 V MOSFET
  - Blue solid line: 36 V eGaN FET
  - Green dashed line: 48 V MOSFET
  - Green solid line: 48 V eGaN FET
  - Red dashed line: 60 V MOSFET
  - Red solid line: 60 V eGaN FET
Thermal Performance

48 $V_{IN}$, 15 $A_{OUT}$, 180 W, 200 LFM airflow
## Improved Brick Converter

### 12V, 240 W Regulated MOSFET Brick

<table>
<thead>
<tr>
<th></th>
<th>MOSFETs</th>
<th>eGaN FETs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary side x 4 (FB)</strong></td>
<td>HAT2174</td>
<td>EPC2007</td>
</tr>
<tr>
<td>Device voltage rating</td>
<td>100 V</td>
<td>100 V</td>
</tr>
<tr>
<td>$R_{DSON}$ (m$\Omega$)</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>$Q_{OSS}$ (nC @ 50 V$_{ds}$)</td>
<td>22#</td>
<td>8.9</td>
</tr>
<tr>
<td>$Q_{GD}$ (nC @ 50 V$_{ds}$)</td>
<td>8.4</td>
<td>0.56</td>
</tr>
<tr>
<td><strong>Switching FoM (pC. $\Omega$)</strong></td>
<td><strong>184</strong></td>
<td><strong>12</strong></td>
</tr>
<tr>
<td>$R_{DSON} \times Q_{GD}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>**Secondary side x 4 (CT, 2</td>
<td></td>
<td>)**</td>
</tr>
<tr>
<td>Device voltage rating</td>
<td>60 V</td>
<td>100 V</td>
</tr>
<tr>
<td>Total $R_{DSON}$ (m$\Omega$)</td>
<td>9.5</td>
<td>5.6</td>
</tr>
<tr>
<td>$Q_{OSS}$ (nC @ 50 V$_{ds}$)</td>
<td>18#</td>
<td>35</td>
</tr>
<tr>
<td>$Q_{G}$ (nC)</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td><strong>SR FoM (pC. $\Omega$)</strong></td>
<td><strong>237</strong></td>
<td><strong>59</strong> No $Q_{RR}$</td>
</tr>
<tr>
<td>$R_{DSON} \times (Q_{G}+Q_{OSS})$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# calculated from datasheet graphs
Brick Converter Summary

• Topologies varied
• Comparison with multiple bricks not practical
• Optimization as important as device selection
• Efficiency is key to power density
  • Maximum power loss is fixed.

• Good comparison requires identical designs
• Given topology, eGaN FETs will outperform MOSFETs based on superior FOM
Unregulated Bus Converter

High Frequency DC/DC Transformer

Experimental Power Stage

MOSFET vs. eGaN FET
<table>
<thead>
<tr>
<th>Parameter</th>
<th>EPC2001</th>
<th>BSC057N08</th>
<th>EPC2015</th>
<th>BSC027N04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Rating ($V_{DSS}$)</td>
<td>100 V</td>
<td>80 V</td>
<td>40 V</td>
<td>40 V</td>
</tr>
<tr>
<td>$R_{DS(ON)}$</td>
<td>5.6 mΩ @ 5 V</td>
<td>5.2 mΩ @ 8 V*</td>
<td>3.2 mΩ @ 5 V</td>
<td>2.9 mΩ @ 5 V*</td>
</tr>
<tr>
<td>$Q_G$ under ZVS</td>
<td>5.8 nC @ 5 V</td>
<td>25.9 nC @ 8 V*</td>
<td>8.3 nC @ 5 V</td>
<td>27.5 nC @5 V*</td>
</tr>
<tr>
<td>$Q_{OSS} @V_{IN}$</td>
<td>35 nC</td>
<td>62 nC*</td>
<td>18.5 nC</td>
<td>40 nC</td>
</tr>
</tbody>
</table>

*: Calculated from manufacturers datasheet curves
ZVS Switching Comparison

$T_{ZVS} = 87 \text{ nS}$

eGaN FET $V_{DS}$

$T_{ZVS} = 42 \text{ nS}$

MOSFET $V_{DS}$

$F_S = 1.2 \text{ MHz}$, $V_{IN} = 48 \text{ V}$, and $V_{OUT} = 12 \text{ V}$
Duty Cycle Comparison

\[ D_{\text{MOSFET}} = 0.34 \]
\[ D_{\text{eGaN FET}} = 0.42 \]

\[ F_s = 1.2 \text{ MHz}, \ V_{\text{IN}} = 48 \text{ V}, \text{ and } V_{\text{OUT}} = 12 \text{ V} \]
F_S = 1.2 MHz, V_IN = 48 V, and V_OUT = 12 V
Loss Breakdown

Power Loss (W)

- Gate Drive
- Transformer Core
- Conduction + Turn Off

For eGaN FETs:
- $I_{OUT} = 2.5 \, \text{A}$
- $V_{IN} = 48 \, \text{V}$
- $V_{OUT} = 12 \, \text{V}$

For MOSFETs:
- $I_{OUT} = 2.5 \, \text{A}$
- $I_{OUT} = 20 \, \text{A}$

Frequency: $F_S = 1.2 \, \text{MHz}$
HF Unregulated Converters

- eGaN FETs improve high frequency resonant converter performance
  - Lower output charge
  - Lower gate charge
  - More power delivery per cycle
Conclusion

• eGaN FETs show performance advantage in both
  – Hard switching and
  – Resonant application

• eGaN FETs offer improved efficiency in Bricks
  – Higher power density
  – Higher output power
The end of the road for silicon.....

is the beginning of the eGaN FET journey!