The eGaN® FET Journey Continues

High Power Fully Regulated Eighth-brick DC-DC Converter with GaN FETs

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Overview

• Existing eighth-brick technology
• Design goals
• Benefits of 4th-generation eGaN FETs
• Converter design
• Experimental results
• Potential Improvements
• Conclusion
Some typical high-power *regulated* eighth-bricks

<table>
<thead>
<tr>
<th>$V_{in}$</th>
<th>38-55</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{out}$</td>
<td>9.6</td>
</tr>
<tr>
<td>$I_{out}$</td>
<td>31</td>
</tr>
<tr>
<td>$P_{out}$</td>
<td>300</td>
</tr>
<tr>
<td>$\eta_{max}$</td>
<td>96.1%</td>
</tr>
</tbody>
</table>

- $V_{in}$: 45-55
- $V_{out}$: 9.6
- $I_{out}$: 33
- $P_{out}$: 320
- $\eta_{max}$: 95.5%

**eGaN FETs can boost power up to 500W and beyond!**
Why GaN FETs?

• Lowest switching loss
  – Fastest switching speed
  – Lowest charge, no reverse recovery ($Q_{rr} = 0$)

• Low $R_{DS(on)}$
  – Reduced conduction loss

• Simple gate drive
  – Normally off
  – 5V gate simplifies design
  – Low gate drive power

Prove the benefit of eGaN FETs with eighth-brick demonstration converter!
500 W Eighth-brick Specifications

• 500 W output at 12 V
• 48 V to 60 V input range (52 V nominal)
• Fully regulated
• Isolated
• > 96% efficient at full load
• DOSA-compliant footprint
• Off-the-shelf parts
Design Approach

Full bridge input
330nF
12*1uF

4:1 Center-tapped transformer SR output

EPC2021, 80 V
EPC2020 60 V

DCR current sense

Energy recovery snubber

Conventional hard-switched PWM
300 kHz primary switching frequency

Digital control

Controller

V_IN+
V_IN-

V_OUT+
V_OUT-

V_BIAS_PRI
V_BIAS_SEC

Vp+
Vp-
vp+
vp-

vsct
vsb
vsct

Q1 Q2
Q3 Q4
Q5 Q6
Q7 Q8

I_OUT_SNS
V_OUT_SNS

V_BIAS_PRI
V_BIAS_SEC

Controller

Vp1
Vp2

s1
s2
snb1
snb2

I_OUT_SNS
V_OUT_SNS

V_IN+
V_IN-

p1
p2

s1
s2

snb1
snb2

Energy recovery snubber

Conventional hard-switched PWM
300 kHz primary switching frequency

Digital control

Controller
Large area eGaN FETs

Fourth Gen eGaN FETs:
- Lowest $R_{DS(on)}$ per area
- Lowest charge per area
- Lowest parasitic inductance

<table>
<thead>
<tr>
<th>Part</th>
<th>Max $V_{DS}$ [V]</th>
<th>$I_D$ [A]</th>
<th>Max $R_{DS(on)}$ [mΩ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPC2020</td>
<td>60 V</td>
<td>60 A</td>
<td>2.0</td>
</tr>
<tr>
<td>EPC2021</td>
<td>80 V</td>
<td>60 A</td>
<td>2.5</td>
</tr>
<tr>
<td>EPC2022</td>
<td>100 V</td>
<td>60 A</td>
<td>3.2</td>
</tr>
<tr>
<td>EPC2023</td>
<td>30 V</td>
<td>60 A</td>
<td>1.3</td>
</tr>
<tr>
<td>EPC2024</td>
<td>40 V</td>
<td>60 A</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Don’t forget about size!

5X6 PQFN
# 80 V FOM Comparison

<table>
<thead>
<tr>
<th>Part</th>
<th>$E_g R_{DS(on)}$ [nJ*mΩ]</th>
<th>$Q_{rr} R_{DS(on)}$ [nC*mΩ]</th>
<th>$Q_{oss} R_{DS(on)}$ [nC*mΩ]</th>
<th>$E_{oss} R_{DS(on)}$ [nJ*mΩ]</th>
<th>$A_{footprint} R_{DS(on)}$ [mm²*mΩ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPC2021</td>
<td>135</td>
<td>0</td>
<td>123</td>
<td>2682</td>
<td>25.0</td>
</tr>
<tr>
<td>AON7280</td>
<td>1836 (13.6x)</td>
<td>1102</td>
<td>229 (1.9x)</td>
<td>3910 (1.5x)</td>
<td>76.3 (3.0x)</td>
</tr>
<tr>
<td>BSZ075N08NS5</td>
<td>1488 (11.0x)</td>
<td>242</td>
<td>200 (1.6x)</td>
<td>3453 (1.3x)</td>
<td>79.8 (3.2x)</td>
</tr>
<tr>
<td>FDMC86430</td>
<td>1900 (14.1x)</td>
<td>125</td>
<td>227 (1.8x)</td>
<td>4480 (1.7x)</td>
<td>57.8 (2.3x)</td>
</tr>
</tbody>
</table>

![Graph showing comparison of different parts across various metrics such as $E_g R_{DS(on)}$, $Q_{rr} R_{DS(on)}$, $Q_{oss} R_{DS(on)}$, $E_{oss} R_{DS(on)}$, and $A_{footprint} R_{DS(on)}$. The graph is labeled with $V_{DS} = 52$ V.](image-url)
## 60 V FOM Comparison

<table>
<thead>
<tr>
<th>Part</th>
<th>$E_g R_{DS(on)}$ [nJ*mΩ]</th>
<th>$Q_{rr} R_{DS(on)}$ [nC*mΩ]</th>
<th>$Q_{oss} R_{DS(on)}$ [nC*mΩ]</th>
<th>$E_{oss} R_{DS(on)}$ [nJ*mΩ]</th>
<th>$A_{footprint} R_{DS(on)}$ [mm²*mΩ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPC2020</td>
<td>120</td>
<td>0</td>
<td>56</td>
<td>633</td>
<td>20.9</td>
</tr>
<tr>
<td>CSD18540Q5B</td>
<td>738 (6.2x)</td>
<td>261</td>
<td>89 (1.6x)</td>
<td>689 (1.1x)</td>
<td>62.2 (3.0x)</td>
</tr>
<tr>
<td>BSC014N06NS</td>
<td>1068 (8.9x)</td>
<td>167</td>
<td>113 (2.0x)</td>
<td>1199 (2.0x)</td>
<td>41.1 (2.0x)</td>
</tr>
<tr>
<td>NTMFS5C604NL</td>
<td>1116 (9.3x)</td>
<td>177</td>
<td>163 (2.7x)</td>
<td>1824 (2.7x)</td>
<td>31.1 (1.5x)</td>
</tr>
</tbody>
</table>

V$_{DS} = 26$ V
EPC9115 Demo Board Layout
## EPC9115 Performance Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IN}$</td>
<td></td>
<td>48</td>
<td>52</td>
<td>60</td>
<td>V</td>
</tr>
<tr>
<td>$V_{OUT}$</td>
<td></td>
<td>11.4</td>
<td>12</td>
<td>12.1</td>
<td>V</td>
</tr>
<tr>
<td>$I_{OUT}$</td>
<td>~400 LFM, 25°C</td>
<td>0</td>
<td></td>
<td>42</td>
<td>A</td>
</tr>
<tr>
<td>$f_{SW}$</td>
<td>Primary side</td>
<td></td>
<td>300</td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td>Eff. (max)</td>
<td>$V_{IN} = 48$ V</td>
<td>96.7</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Eff. (full load)</td>
<td>$V_{IN} = 52$ V</td>
<td>96.4</td>
<td></td>
<td></td>
<td>%</td>
</tr>
</tbody>
</table>
Typical Performance Curves

Operating conditions: 400 LFM (2 m/s) forced convection, ambient temperature 27°C, **thermal steady state**.
Operating conditions: 400 LFM (2 m/s) forced convection, ambient temperature 27°C, thermal steady state.
Power loss breakdown (estimate)

Total: 16.6 W @ 100°C
Excludes: Vias, solder joints, traces
Switching transition waveforms

Vin = 52 V, Vout = 12 V, Iout = 42 A

50 ns/div
Ways to improve E-brick efficiency

- Improve bias supply (draws 1.3W, but bias load 0.6W)
- Add heat sink
- Optimize gate resistors
- Optimize dead time
- Use custom magnetics
- Optimize switching frequency
DCX performance with smaller inductor

Operating conditions: 400 LFM (2 m/s) forced convection, ambient temperature 24°C, *thermal steady state*.

Changes from baseline design

- Inductor: 470 nH, 0.9 mΩ → 210 nH, 0.3 mΩ
- \(D_{\text{max}}\): 0.980 → 0.985 (Fixed)
- Deadtime: 25 ns → 15 ns

48 V in, 58.4A out

667 W Output
Summary
EPC9115 Eighth-Brick Converter

The power of a Quarter Brick…

in the footprint of an Eighth Brick

• Fully regulated, isolated converter hard-switched at 300 kHz
• 12 V, 42 A output with input range of 48-60 V
• Peak Efficiency: 96.7%
• Full Load Efficiency: 96.4% at 52 V
The end of the road for silicon…..

is the beginning of the eGaN FET journey!