Radiation Tolerant Enhancement Mode Gallium Nitride FETs for High Frequency DC-DC Conversion

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Agenda

• Second Generation GaN FETs
  • Electrical Characteristics
  • SEE results
  • TID results
  • DC-DC conversion at high-frequencies

• A Look Into the Future

• Summary
# 1st Gen RH GaN Product Line

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>VOLTAGE</th>
<th>CURRENT</th>
<th>PEAK</th>
<th>$R_{DS(ON)}$ (mΩ)</th>
<th>$Q_G$ (nC)</th>
<th>FOM $Q_G \times R_{DS(ON)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGN2915U4A</td>
<td>40 V</td>
<td>33 A</td>
<td>150 A</td>
<td>4</td>
<td>11.6</td>
<td>46.4</td>
</tr>
<tr>
<td>MGN2914U4A</td>
<td>40 V</td>
<td>10 A</td>
<td>40 A</td>
<td>16</td>
<td>3</td>
<td>48</td>
</tr>
<tr>
<td>MGN2905U4A</td>
<td>60 V</td>
<td>25 A</td>
<td>100 A</td>
<td>7</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>MGN2909U4A</td>
<td>60 V</td>
<td>6 A</td>
<td>25 A</td>
<td>30</td>
<td>2.4</td>
<td>72</td>
</tr>
<tr>
<td>MGN2901U4A</td>
<td>100 V</td>
<td>25 A</td>
<td>100 A</td>
<td>7</td>
<td>10.5</td>
<td>73.5</td>
</tr>
<tr>
<td>MGN2907U4A</td>
<td>100 V</td>
<td>6 A</td>
<td>25 A</td>
<td>30</td>
<td>2.7</td>
<td>81</td>
</tr>
<tr>
<td>MGN2911U4A</td>
<td>150 V</td>
<td>12 A</td>
<td>40 A</td>
<td>25</td>
<td>6.7</td>
<td>167.5</td>
</tr>
<tr>
<td>MGN2913U4A</td>
<td>150 V</td>
<td>3 A</td>
<td>12 A</td>
<td>100</td>
<td>1.7</td>
<td>170</td>
</tr>
<tr>
<td>MGN2910U4A</td>
<td>200 V</td>
<td>12 A</td>
<td>40 A</td>
<td>25</td>
<td>7.5</td>
<td>187.5</td>
</tr>
<tr>
<td>MGN2912U4A</td>
<td>200 V</td>
<td>3 A</td>
<td>12 A</td>
<td>100</td>
<td>1.9</td>
<td>190</td>
</tr>
</tbody>
</table>

(Preliminary)
POL Efficiency Comparison

Efficiency vs. Output Current for different voltages:
- eGaN FETs = 92.5%, 500kHz (12 VIN)
- Rad Hard MOSFETs = 84%, 100kHz

Legend:
- eGaN 1.5 V
- eGaN 2.5 V
- eGaN 3.3 V
- IR 1.8 V
- IR 2.5 V
- IR 3.3 V
# 2nd Gen RH GaN Product Line

<table>
<thead>
<tr>
<th>Part Number</th>
<th>V_DS</th>
<th>Max R_DS(ON) (mΩ) @5VGS</th>
<th>I_D (A)</th>
<th>Pulsed I_D (A)</th>
<th>Q_G</th>
<th>Q_GD</th>
<th>Q_GS</th>
<th>Q_OSS</th>
<th>Q_RR</th>
<th>C_ISS</th>
<th>C_OSS</th>
<th>C_RSS</th>
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<tbody>
<tr>
<td>MGN8904</td>
<td>40</td>
<td>125</td>
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<td>358</td>
<td>31</td>
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<td>45</td>
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<td>160</td>
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<td>6</td>
<td>302</td>
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<td>406</td>
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<td>325</td>
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<td>8</td>
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<td>17</td>
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<td>18</td>
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<td>530</td>
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<td>141</td>
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<td>244</td>
<td>0</td>
<td>21</td>
<td>5.9</td>
<td>0.1</td>
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<td>MGN8910</td>
<td>100</td>
<td>160</td>
<td>3.4</td>
<td>7.5</td>
<td>354</td>
<td>32</td>
<td>109</td>
<td>1509</td>
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<td>MGN8903</td>
<td>100</td>
<td>300</td>
<td>2.5</td>
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<td>110</td>
<td>1100</td>
<td>0</td>
<td>38</td>
<td>18</td>
<td>0.2</td>
</tr>
</tbody>
</table>
This is $Q_{GD}$. It determines the transition speed in a hard-switched converter.
Synchronous Rectifier Figure of Merit

\[ R_{DS(on)} \times Q_G \]

- IR Rad Hard
- 25 x Improvement
- Gen 1

Graph showing the comparison between IR Rad Hard and Gen 1 MiGaN in terms of \[ R_{DS(on)} \times Q_G \] against Rated Voltage.
Hard Switching Figure of Merit

$$R_{DS(on)} \times Q_{GD}$$

- **IR Rad Hard**
- **Gen 1**
- **Gen 2**

Switching Figure of Merit vs. Rated Voltage

- IR RadHard RDS(on)xQGD
- Gen 1 MiGaN RDS(on)xQGD

40 x Improvement
Single Event Performance

MGN8903, $V_{DS} \ 100 \ V$, $V_{GS} \ 0 \ V$
85.4 LET Au

MGN8909 $V_{DS} \ 65 \ V$, $V_{GS} \ 0 \ V$
85.4 LET Au
Total Dose Performance

MGN8909 MiGaN™ FET (65 V, 138 mΩ)

- 

\[ V_{DS} = 52 \text{ V} \]

\[ V_{GS} = 5 \text{ V} \]

\[ \frac{I_{DS}}{I_{GS}} \text{ (µA)} \]

\[ \text{Total Dose} \]

\[ \text{Threshold Voltage (V)} \]

\[ \text{Total Dose} \]
Buck Converter

\[ V_{\text{IN}} = 42 \text{ V} \quad V_{\text{OUT}} = 20 \text{ V} \]

Q1, Q2 = MGN8905 (65 V 230 mΩ)
42V_{\text{IN}} \text{ at } 1A_{\text{OUT}}

MGN8905 (65 V, 230 mΩ)

75V/ns slew rate

Rise time \sim 1.0 \text{ ns}
Total switching time \sim 1.2 \text{ ns}

2 \text{ ns/div and } 10 \text{ V/div, 1 GHz } 100:1 \text{ 1pF TM probe}
Efficiency

$V_{\text{IN}} = 42 \, V \quad V_{\text{OUT}} = 20 \, V$

- **5 MHz**
- **10 MHz**

![Efficiency Graph](image)

Output current (A)

MGN8905
65 V 230 mΩ
Rad Hard Into the Future

First Rad Hard Generation
40 V - 200 V
~500 MHz

Ultra High Frequency Family
1 - 3 GHz

Higher Current
45 A

Higher Voltage
600 V

More functions on a chip
Monolithic half bridge
Driver on power chip

Next Generation Devices
2 x FOM Improvement
Summary

• Moore’s Law is (finally) alive and well in Rad Hard power conversion.
• Second generation GaN FETs are very radiation tolerant.
• Hard-switched DC-DC converters operating at 10 MHz+ are now possible.
• This is just the beginning for GaN technology in space!
The end of the road for silicon.....

is the beginning of the eGaN FET journey!