The eGaN® FET Journey Continues

GaN-on-Si in Power Conversion
Alex Lidow, CEO
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Agenda

- How far have we come?
- What paths are we taking?
- Where is the leverage for integration?
- The road ahead.
Fast Moving Technology

Gen 1,2,3,4 FETs and ICs
2010-2015
30 V - 450 V

Higher Scale
Integrated Circuits

Generation 5
Smaller, Faster, Less Cost
## Gen 5: ½ size and 2X performance

<table>
<thead>
<tr>
<th>Device</th>
<th>Resistance (mOhm)</th>
<th>Area (mm²)</th>
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</thead>
<tbody>
<tr>
<td>EPC2010C</td>
<td>25</td>
<td>6.06</td>
</tr>
<tr>
<td>EPC2046</td>
<td>25</td>
<td>2.82</td>
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<tr>
<td>EPC2001C</td>
<td>7</td>
<td>6.99</td>
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<tr>
<td>EPC2045</td>
<td>7</td>
<td>3.96</td>
</tr>
</tbody>
</table>

Coming October 31, 2016
79% Efficient

150 W

100 W

12 V

1 V

Non Isolated Point of Load Buck Converter
First Generation eGaN® FET

GaN Circa 2010

V_{IN}=12 \text{ V}, \ V_{OUT}=1.2 \text{ V}, \ f_{sw}=1 \text{ MHz}

eGaN® is a registered trademark of Efficient Power Conversion Corporation
Improved Layout

GaN Circa 2012

GaN Circa 2010

$V_{\text{IN}}=12\,\text{V}$, $V_{\text{OUT}}=1.2\,\text{V}$, $f_{\text{sw}}=1\,\text{MHz}$
Fourth Generation eGaN FET

V_{IN}=12 V, V_{OUT}=1.2 V, f_{sw}=1 MHz
Monolithic Half Bridge

![Graph showing efficiency vs. output current for GaN technology circa 2010, 2012, 2014, and 2015. The graph includes the following details:

- **GaN Circa 2010**: Efficiency starts at approximately 79% and rises to about 86% before dropping back down.
- **GaN Circa 2012**: Efficiency is higher than GaN Circa 2010, reaching about 88%.
- **GaN Circa 2014**: Efficiency continues to improve, reaching nearly 92%.
- **GaN Circa 2015**: Efficiency is the highest, peaking at 92%.

- **Conditions**:
  - Input voltage \( V_{\text{IN}} = 12 \text{ V} \)
  - Output voltage \( V_{\text{OUT}} = 1.2 \text{ V} \)
  - Switching frequency \( f_{\text{sw}} = 1 \text{ MHz} \)
Silicon IBC and GaN POL

83%
eGaN FETs and ICs

13.8 kVAC

Distribution Transformers

Uninterruptable Power Supplies (UPS)

AC/DC Conversion

DC/DC Conversion

DC/DC Conversion

DC/DC Conversion

Digital Chip

98%

97%

98%

98%

96%

98%

90%

208 VAC

208 VAC

400 VDC

48 VDC

12 VDC

1 VDC

140 W

85% Efficient

100 W

48 V

12 V

1 V
eGaN FETs and ICs

![Graph showing efficiency vs. output power for different technologies: Traditional Two Stage Isolated IBA, GaN/GaN, Si/GaN.](image-url)
Eliminate 12 V Bus

1.38 kVAC

140 W

One Stage Conversion

48 V

Non Isolated Point of Load Buck Converter

1 V

100 W
Eliminate 12 V Bus

One Stage Conversion

Monolithic Half Bridge
Single Stage Buck Converter with Monolithic Half Bridge

Performance Gap

Traditional Two Stage Isolated IBA

GaN/GaN

Si/GaN

Efficiency (%) vs. Output Power (W)
Single Stage Buck Converter with Monolithic Half Bridge

Improved FETs

Efficiency (%)

Output Power (W)

Traditional Two Stage Isolated IBA

GaN/GaN

Si/GaN
GaN Integrated Circuit Roadmap

- Monolithic Half Bridge
- Half Bridge plus Bootstrap
  - Integrated FET and low side driver
  - Integrated half bridge with level shift and drivers
- Monolithic Buck IC
GaN Integrated Circuit Roadmap

✓ Monolithic Half Bridge
✓ Half Bridge plus Bootstrap
  • Integrated FET and low side driver
  • Integrated half bridge with level shift and drivers
  • Monolithic Buck IC
First Step - Integrated FET and Low Side Driver
Monolithic Gate Driver and FET

Fastest, more efficient GaN Power FETs + First & Fastest Integrated GaN Gate Driver = AllGaN Power IC

Up to 40 MHz switching, 4x higher density & 20% lower system cost

EPC - The leader in GaN Technology
GaN Integrated Circuit Roadmap

- Monolithic Half Bridge
- Half Bridge plus Bootstrap
  - Integrated FET and low side driver
  - Integrated half bridge with level shift and drivers
- Monolithic Buck IC
The graph illustrates the efficiency of different types of power conversion systems as a function of output power. The efficiency is measured in percentage (%). The x-axis represents the output power in watts (W), while the y-axis represents the efficiency (%).

- **Single Stage Buck Converter**: This technology shows a high efficiency across a wide range of output powers, especially at lower power levels, indicating a more efficient design for lower power applications.
- **Traditional Two Stage Isolated IBA**: This system is less efficient compared to the single stage converter, with a peak efficiency around 84% at moderate output powers.
- **Improved FETs**: This category includes GaN and Si technologies, which offer improved performance over traditional silicon (Si) solutions. GaN technology outperforms Si at higher output powers, reaching efficiencies close to 88%.
- **Monolithic IC**: This technology is represented by the highest efficiency curve, consistently maintaining an efficiency close to 88% across the entire output power range, making it the most efficient solution among the options presented.

The graph also highlights the benefits of using GaN and silicon (Si) FETs, with GaN offering a clear advantage at higher power levels.
13.8 kVAC
Distribution Transformers
Uninterruptable Power Supplies (UPS)
AC/DC Conversion
DC/DC Conversion
DC/DC Conversion
DC/DC Conversion
Digital Chip

98% 97% 98% 98% 95% 98% 85%
208 VAC 208 VAC 400 VDC 48 VDC 12 VDC 1 VDC

150 W
79% Efficient
100 W
eGaN Integrated Circuit

134 W

88% Efficient

100 W
eGaN Integration Roadmap

Discrete

Monolithic Half-Bridge IC

Wireless Charging IC

LiDAR IC

Envelope Tracking IC

Power SoC

2010 2014 2015 2016 2017…
Summary

• GaN integration creates a lot of performance leverage.
• The first steps in integration involve reducing parasitic inductance and integration of drive circuitry.
• The second stage involves including level shift and current sense.
• The third stage will include control circuitry in both analog and digital.