GaN Transistors for Efficient Power Conversion

Alex Lidow
CEO

Efficient Power Conversion Corporation
Agenda

• Overview of eGaN FET Technology
• Improving Power Conversion Efficiency
• What is in the future?
Overview of eGaN® FET Technology
eGaN® FET Structure

- AlGaN Electron Generating Layer
- Dielectric
- GaN
- Two Dimensional Electron Gas (2DEG)
- Aluminum Nitride Isolation Layer

- S
- G
- D
- Si
SEM of an eGaN® FET
Flip-Chip LGA Construction

- eGaN FET
- Silicon
- Solder Bar
- Copper Trace

Printed Circuit Board

Absolute Minimum Lead Resistance and Inductance!
Size Comparison

D-PAK

eGaN® FET

5.76 mm²

65.3 mm²

Drawn To Scale
Opportunity to Improve DC-DC Efficiency
Integrated Gate Driver Solution

LM5113 from Texas Instruments
Buck Converter

Advantage:
• High power density and high efficiency

Figure 7 – Buck converter with an input voltage of 48 VDC and output voltage of 1.2 VDC
Efficiency vs Frequency

1.2 Vout / 5A

Efficiency (%)

Switching Frequency (kHz)

- MOSFET @ 12Vin
- MOSFET @ 24Vin
- MOSFET @ 48Vin
- eGaN FET @ 12Vin
- eGaN FET @ 24Vin
- eGaN FET @ 48Vin
Parallel FET Buck Converter

Efficiency at 1 MHz

12 $V_{IN} - 1.2 V_{OUT}$
Isolated Full Bridge Converter

Advantage:

- Isolation and high power density at high power

- 36~75 V
- ~48 V
- ~53V 700 W 2-phase
- 12 V 15 A 180 W
Isolated Full Bridge Converter
Isolated Full Bridge Converter

eGaN FET @ 333 kHz vs MOSFET @ 250 kHz

Efficiency vs Output Current (A)

- 36 V eGaN FET
- 36 V MOSFET
- 48 V eGaN FET
- 48 V MOSFET
- 60 V eGaN FET
- 60 V MOSFET
PoE-PSE Full Bridge Converter
PoE-PSE Full Bridge Converter

Efficiency vs. Output Current (A)

• 38 V eGaN FET
• 38 V MOSFET
• 48 V eGaN FET
• 48 V MOSFET
• 60 V eGaN FET
• 60 V MOSFET

- 140 kHz MOSFET
- 250 kHz eGaN FET
- 550 W
- 700 W
PoE-PSE Full Bridge Converter

Efficiency vs. Output Current (A) for:
- 38 V Two phase
- 38 V Single phase
- 48 V Two phase
- 48 V Single phase
- 60 V Two phase
- 60 V Single phase

Efficiency range from 88% to 98%.
What is in the Future?
Breaking Down the Barriers

• Does it enable significant new capabilities?
• Is it easy to use?
• Is it VERY cost effective to the user?
• Is it reliable?
Breaking Down the Barriers

• Does it enable significant new capabilities?
• Is it easy to use?
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Applications for eGaN® FETs

– Power Over Ethernet
– Wireless power transmission
– RF DC-DC “Envelope Tracking”
– RF Transmission
– Network and Server Power Supplies
– Solar Microinverters
– LED Lighting
– Class D Audio
– Notebook Power Supply
In China Today

Solar

Lighting

Telecom Power
Application Success Story

Faster Transient Response

4x Frequency

75% Reduction
Another Success Story

RF Power – Medical Radiation

Magnetron
500 MHz

eGaN FET PA
1GHz

EPC - The Leader in eGaN® FETs |
Wireless Power
RF Envelope Tracking

Without Envelope Tracking

With Envelope Tracking
Breaking Down the Barriers

• Does it enable significant new capabilities?
• Is it easy to use?
• Is it VERY cost effective to the user?
• Is it reliable?
Is it easy to use?

It’s just like a MOSFET
except

The high frequency capability makes circuits using eGaN FETs sensitive to layout

The lower $V_{G(MAX)}$ of 6 V makes it advisable to have $V_{GS}$ regulation in your gate drive circuitry

The ultra-small LGA increases the concentration of heat on the PCB
Breaking Down the Barriers

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# Silicon vs eGaN® FET Wafer Costs

<table>
<thead>
<tr>
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<th>2010</th>
<th>2015</th>
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<tr>
<td>Starting Material</td>
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<td>Epi Growth</td>
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<tr>
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<tr>
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<tr>
<td>Assembly</td>
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</tr>
<tr>
<td><strong>OVERALL</strong></td>
<td>higher</td>
<td><strong>lower!</strong></td>
</tr>
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</table>
Breaking Down the Barriers

• Does it enable significant new capabilities?
• Is it easy to use?
• Is it VERY cost effective to the user?
• Is it reliable?
eGaN® FETs are Reliable

**EPC2001** $R_{DS(ON)}$ after 100V$_{DS}$ HTRB at 125°C

**EPC2001** $V_{GS(TH)}$ after 100V$_{DS}$ HTRB at 125°C

**EPC9001** Efficiency after Op Life Test at 85°C $T_J$

**EPC2015** $I_{dss}$ after 40V H3TRB at 85°C/85%RH
Beyond 600 Volts

![Graph showing the evolution of GaN FETs from 2009 to 2012 with ratings for different voltage levels and package types.]

- **2009**: 7 mΩ LGA Package
- **2011**: 25 mΩ 5x6mm PQFN
- **2012**:
  - 250 mΩ 5x6mm PQFN
  - 400 mΩ 5x6mm PQFN
  - 90 mΩ 8x8mm PQFN
  - 150 mΩ 8x8mm PQFN

Rated $R_{DS(on)}$ (mΩ) vs. Rated $V_{DSS(MAX)}$
Beyond Discrete Devices

**Driver On Board**

**Discrete FET with Driver**

**Full-Bridge with Driver and Level Shift**
Summary

• eGaN FETs are easy to use but care must be taken due to the higher switching speeds compared with power MOSFETs

• eGaN FETs will replace silicon power MOSFETs in power conversion applications with a low-cost and higher efficiency solution

• Higher voltage devices and the integration of analog plus power will enhance the performance and cost-effectiveness of eGaN FETs
The end of the road for silicon.....
is the beginning of the eGaN FET journey!