Improvements in Hard- and Soft-Switching Applications with GaN Transistors

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Efficient Power Conversion
Key Applications

- Point of Load Modules
- RF DC-DC "Envelope Tracking"
- Wireless Power Transmission
- Network and Server Power Supplies
- Radiation Hard Applications
- RF Transmission
- Solar Micro-inverters
- Energy Efficient Lighting
- Class D Audio

HARD Switching

SOFT Switching
Hard Switching Applications

Hard Switching Figure of Merit

- $Q_{GD} (@ 0.5 BV_{DSS})$ (nC)
- $R_{DS(ON)}$ (mΩ)

- 200 V EPC
- 200 V Si
- 100 V EPC
- 100 V Si
- 40 V EPC
- 40 V Si

Improved Performance

Lower FOM

3x Reduction

2.5x Reduction

Hard Switching Applications
Buck Converter Parasitics

$L_s$: Common Source Inductance

$L_{\text{Loop}}$: High Frequency Power Loop Inductance

$V_{\text{IN}} = 12\, \text{V}$, $V_{\text{OUT}} = 1.2\, \text{V}$, $F_s = 1\, \text{MHz}$, $I_{\text{OUT}} = 20\, \text{A}$
eGaN Packaging Gains

Interleaving reduces inductance further

\[ V_{IN} = 12 \, V \quad V_{OUT} = 1.2 \, V \quad I_{OUT} = 20 \, A \quad F_S = 1 \, MHz \]
EPC9107 Demonstrator

Inductor on back to maximize power density

~3V overshoot @ 15A out

~1.1ns rise time

20ns

28V to 3.3V / 15A @ 1MHz
EPC9107 Efficiency Results

$V_{OUT}=3.3 \text{ V} \quad F_S=1 \text{ MHz}$

GaN T/SR: EPC2015  Driver LM5113
Envelope Tracking Supply

Peak to Average Power Ratio (PAPR)

Reference: Nujira.com website
Effect of PAPR

- Fixed supply
  - Average efficiency only 25%
  - Peak efficiency up to 65%

- Increasing PAPR
  - Output Probability
  - PAPR = 0dB

Diagram showing the relationship between output power (dBm) and PA efficiency (%), highlighting the impact of PAPR on efficiency.
Effect of Envelope Tracking

Average efficiency > 50 % (incl. ET)

Only 1/3 the losses

Envelope Tracking

Output Probability

Average Power

Output Power (dBm)
10x potential bandwidth require 2.5x more phases and 2x losses

- **EPC2007 / EPC9006**
  - 4 MHz / 6 A per phase

- **EPC2001 / EPC9002**
  - 1 MHz / 15 A per phase

**Efficiency Results**

- **Efficiency (%)**
- **Power loss (W)**

**Output Power (W)**
Soft Switching Applications

Soft Switching Figure of Merit

Q_{OSS} (@ \frac{1}{2} BV_{DSS}) + Q_G (nC)

R_{DS(on)} (m\Omega)

- 200 V EPC
- 200 V Si
- 100 V EPC
- 100 V Si
- 40 V EPC
- 40 V Si

Improved Performance

2.5x Reduction

2.5x Reduction

300
30
30
10
100
1000

1
10
10

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Resonant Bus Converter

High Frequency DC/DC Transformer

eGaN FET vs. MOSFET

- Resonant Capacitor
- Secondary Devices
- Transformer
- Primary Devices
- Input Capacitors
Duty Cycle Comparison

$\text{F}_S = 1.2 \text{ MHz}, \text{V}_\text{IN} = 48 \text{ V}, \text{and } \text{V}_\text{OUT} \approx 12 \text{ V}$
Efficiency Comparison

F<sub>S</sub> = 1.2 MHz, V<sub>IN</sub> = 48 V, and V<sub>OUT</sub> ≈ 12 V
6.78 MHz Wireless Power

- Source Board
- eGaN FETs RF connection
- Device Board
- Coils
- Feedback
- RF connection
- Device Coil
Efficiency Comparison

6.639 MHz, 23.6 Ω load

V_{in} = 8 V
V_{out} = 6.8 V

V_{in} = 22 V
V_{out} = 18.2 V

V_{in} = 22 V
V_{out} = 18.3 V

Vin = 8 V
Vout = 6.9 V

Vin = 22 V
Vout = 18.3 V

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Summary

eGaN FETs pushes the frequency envelope in both hard- and soft-switching applications

• Lower switching charge
• Improved device packaging / layout
• Zero diode reverse recovery ($Q_{RR}$)
• Lower output charge
• Lower gate charge

Thank you for your time!