The eGaN® FET Journey Continues

Efficient Power Conversion Corporation
Agenda

• EPC Update
• Overview of eGaN®FET Technology
• eGaN®FET Ecosystem
• Why Gallium Nitride?
• Isolated and non-isolated converter efficiency
• EPC Roadmap
• Enormous capacity already in place
• eGaN FETs shipping to > 350 customers worldwide
• Several major IC companies are developing eGaN optimized drivers – the first of these, the LM5113 by Texas Instruments, was launched in June 2011
• Received ISO9001:2008 Certification in Q3 CY2011
• eGaN FETs have demonstrated that improved efficiency can be obtained now in servers, telecom equipment, solar microinverters, medical equipment, and RF transmission systems
Overview of eGaN® FET Technology
eGaN® FET Structure

AlGaN Electron Generating Layer

Dielectric

Two Dimensional Electron Gas (2DEG)

Aluminum Nitride Isolation Layer

GaN

Si
eGaN® FET Structure
LGA Assembly

HEATSINK

SILICON

Active GaN Device Region

Aluminum Nitride

Solder Bumps

COPPER TRACES

PRINTED CIRCUIT BOARD
EPC MOSFET Killer Products

LGA 4.1x1.6 x0.8

LGA 3.6x1.6 x0.8

LGA 1.7x1.1x0.8

LGA 1.7x0.9x0.8

Development Board available
# EPC Shortform

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<th>T_{J(MAX)} (°C)</th>
<th>V_{DS} (max)</th>
<th>V_{GS} (max)</th>
<th>Max R_{DS(ON)} (mΩ) @5V_{GS}</th>
<th>Q_{G} typ (nC)</th>
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40V - 200V in mass production, 600V sampling in Q4 2011
EPC’s half bridge development boards simplify the evaluation process of our eGaN FETs by including all the critical components and layout for optimal switching performance on a single board that can be easily connected into any existing converter.

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<tr>
<th>Part Number</th>
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<th>$V_{DS}$ (max)</th>
<th>$I_d$ (max RMS)</th>
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eGaN Ecosystem
LM5113 – Half Bridge Gate Driver Optimized for eGaN FETs

Key Features

- 0.5 Ohm Sink and 2 Ohm Source Capability
- Independent Source and Sink Outputs
- Bootstrap Voltage Clamp
- Vcc UVLO optimized for eGaN FETs (3.5V)
- 100V $V_{HS}$ Rating
- $>50V/\text{ns} \ \text{dv/dt}$ Immunity at $V_{HS}$
- Independent TTL Inputs
- Short Propagation Delays (25ns)
- 4ns Delay Matching Between Channels
- Low Power Consumption (2mA @ 0.5MHz)

Availability

- Packages: LLP-10 (4mm x 4mm), uSMD12 (2mm x 2mm)
- Production Release: Oct 2011
Why Gallium Nitride?
eGaN® FETs are Smaller

200V Silicon Device  
(30 milli Ohms)

200V GaN Device  
(25 milli Ohms)
eGaN® FETs are Faster

FOM = $R_{\text{dson}} \times Q_g$ (100V)

Source: Infineon, International Rectifier, Siliconix, and Fairchild data sheets
## eGaN® FETs Can Be Cheaper

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*Source: EPC*
Isolated DC-DC Converter
eGaN FET vs. MOSFET
Performance Comparison

Isolated 1/8th Brick, Regulated 12 Vout
eGaN FET half-brick PSE
Single Phase Vs Two Phase

Efficiency vs Output Current (A) for different voltage levels:
- 38 V: Two phase (solid black), Single phase (dashed green)
- 48 V: Two phase (solid green), Single phase (dashed dot green)
- 60 V: Two phase (solid red), Single phase (dashed red)

The graph shows that two-phase systems generally have higher efficiency than single-phase systems for the same output current level.
Efficiency Comparison

- 38 V eGaN FET
- 38 V MOSFET
- 48 V eGaN FET
- 48 V MOSFET
- 60 V eGaN FET
- 60 V MOSFET

Efficiency vs. Output Current (A) at different voltages and frequencies:
- 38 V eGaN FET: 250 kHz
- 38 V MOSFET: 140 kHz
- 48 V eGaN FET: 250 kHz
- 48 V MOSFET: 140 kHz
- 60 V eGaN FET: 250 kHz
- 60 V MOSFET: 140 kHz

$P_{out}$ = $\frac{1}{2} \times \frac{1}{2} \times V^2 \times f$
Efficiency Comparison

![Graph showing efficiency comparison for various voltage levels (38 V eGaN FET, 38 V MOSFET, 48 V eGaN FET, 48 V MOSFET, 60 V eGaN FET, 75 V MOSFET). The graph plots efficiency (%) on the y-axis against output current (A) on the x-axis.]
Non-Isolated DC-DC Converter
Buck Converter

High step-down ratio buck converter

48Vdc

PWM CONTROL

Vout 1.2Vdc
Efficiency vs Frequency

1.2 Vout / 5A

Efficiency (%) vs Switching Frequency (kHz)

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

Efficiency at 1 MHz

12 $V_{IN} - 1.2 \, V_{OUT}$
EPC Product Plans
5x6 mm PQFN Package (GaNPAK)

EPC3019 Key Specifications*:

- $V_{DS(MAX)}$ 600V
- $R_{DS(ON)(MAX)}$ 100mΩ @25°C
- $I_{D(DCMAX)}$ 5A
- $Q_{GS(typ)}$ 0.3 nC
- $Q_{GD(typ)}$ 4 nC
- $V_{TH(typ)}$ 1.4V

* All key specification limits are preliminary and subject to change without notice
Hard Switched PFC

GaN Transistor Selection

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<th>Part Number</th>
<th>Package</th>
<th>Mode Ch</th>
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<th>Vgs</th>
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<th>Q5 (nC)</th>
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<th>Vgth (V)</th>
<th>Rq (Ω)</th>
<th>Qrr (nC)</th>
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PFC Switch Losses

- **Q_control**: 100kHz
- **Output**: 180V
- **Gate**: 450V

EPC3019 vs SPP20N60S5

Power Dissipation (W)

- **EPC3019**: Output: 1.5, Gate: 2.0, Switching: 5.5, On State: 4.0
- **SPP20N60S5**: Output: 2.0, Gate: 2.5, Switching: 6.0, On State: 5.0
### AC/DC - Half Bridge LLC

![Half Bridge LLC Diagram]

5V Drive!!

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EPC’s eGaN FET products will extend to 600V in 2011 and to 900V and 1200V in 2012 if there is adequate customer interest.
Beyond Discrete Devices

Multiple devices on the same eGaN wafer

- Dual
- Dual Common Source
- Dual Common Drain
- Dual Half Bridge

Driver On Board

Discrete FET with Driver

Full-Bridge with Driver
Conclusion

• After almost two years on the market, eGaN FETs have replaced MOSFETs in many high performance applications.
• Several major IC companies are developing eGaN FET optimized drivers.
• 600 V product will be available soon.
The end of the road for silicon…..
is the beginning of the eGaN FET journey!