Ditching the Package to Drive Down GaN Transistor Costs

Alex Lidow
Power Switch Wish List

• Lower On Resistance
• Faster
• Smaller
• Lower Thermal Impedance
• Lower Cost
• Better Package
Better Starting Material

\[ R_{DS(on)} = \frac{4 \cdot V_{BR}^2}{\varepsilon_0 \cdot \varepsilon_0 \cdot E_{crit}^3} \]
Better End Product

100 V eGaN® FET
6.05 x 2.3 mm

Top View  Bump View

100 V Si MOSFET
6.15 x 5.3 mm

Top View  Bump View

\[ R_{DS(on)} = 2.4 \text{ m}\Omega \ @ \ 5 \text{ V} \]
\[ Q_G = 13 \text{ nC} \]

\[ R_{DS(on)} = 3.4 \text{ m}\Omega \ @ \ 10 \text{ V} \]
\[ Q_G = 58 \text{ nC} \]
Faster Switching

\[ \text{FOM}_{HS} = (Q_{GD} + Q_{GS}) \cdot R_{DS(on)} \cdot (pC \cdot \Omega) \]

Drain-to-Source Voltage (V)

\[ V_{DS} = 0.5 \cdot V_{DSS}, \ I_{DS} = 20 \text{ A} \]
Impact of Package on Power Switch

Source/Gate Clips
Source/Gate Die Attach
MOSFET Die
Drain Die Attach
Drain Pad
PCB Drain Connection
PCB Source Connection
PCB Gate Connection

Source
Gate
MOSFET
A Better Power Package

- eGaN FET Die
- Drain/Source/Gate Connections
- PCB Drain Connection
- PCB Gate Connection
- PCB Source Connection
Impact of Package on Power Switch

Device Loss Breakdown

Thermal Management

Silicon Substrate

Active GaN Device Region

$R_{\Theta_{CA}}$

$R_{\Theta_{JC}}$

$T_J$

$R_{\Theta_{JB}}$

$R_{\Theta_{BA}}$
Thermal Advancements

Single Sided Cooling

\[ R_{\theta JB} \downarrow \ll R_{\theta JC} \uparrow \]

Double Sided Cooling

\[ R_{\theta JB} \downarrow \quad R_{\theta JC} \downarrow \]

Double Sided Cooling

\[ R_{\theta JB} \downarrow \quad R_{\theta JC} \downarrow \]
Thermal Comparisons

![Graph showing Thermal Resistance (°C/W) vs. Device Area (mm²) for different devices. The graph compares thermal resistance for Si (red dots) and GaN (blue dots). The thermal resistance decreases with an increase in device area.]
Thermal Comparisons

Thermal Resistance ($^\circ$C/W)

Device Area (mm$^2$)

$R_{\text{JC}}$, Thermal Resistance

$R_{\theta\text{JC}}_{\text{Si}}$

$R_{\theta\text{JC}}_{\text{GaN}}$
Improved Thermal Performance

Fan Speed=200 LFM $f_{sw}=300$ kHz $V_{IN}=48$ V $V_{OUT}=12$ V $I_{OUT}=30$ A
Better In-Circuit Performance

60% Reduction in Power Losses

Efficiency (%) vs. Output Current (A)

$V_{\text{IN}}=48$ V, $V_{\text{OUT}}=12$ V, 300 kHz
Lifetime Prediction

EPC2016 Time to Failure vs $V_{DS}$

- 0.01%
- 0.0001%
- 150 °C
- 20 yrs
- 10 yrs
Lifetime Prediction

MTTF vs $V_{GS}$

FIT Rate vs $V_{GS}$

Mean Time to Failure (s)

FIT Rate (#/10$^9$ hours)

Gate Bias (V)

1 FIT

10 yrs

EPC - The Leader in GaN

www.epc-co.com
# MOSFET vs. eGaN Costs*

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* Product with the same on resistance and voltage rating
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*Active die <3 mm\(^2\)*

* Product with the same on resistance and voltage rating
A Look Into the Future
GaN Integration

Generation 2/4
Discrete HB

+ 
Top Switch (T)
Synchronous Rectifier (SR)

Generation 4
Monolithic 4:1 HB

33 % die size reduction
Moore’s Law Revival

Gen 2
2010-2013
40 V - 200 V

Generation 3
Higher Frequency
Launched
Sept 2013

Half Bridge ICs
Launched
Sept 2014 – Jan 2015

300 - 450 V Voltage
Launched
Sept-Dec 2014

Generation 4
2 X Performance Improvement
Launched
June 2014
Moore’s Law Revival

Gen 3 & 4 FETs and ICs
2014
30 V - 450 V

Higher Power
RF FETs and ICs
Broadband to 6 GHz
Q3/2015

Higher Scale Integrated Circuits
Q2-Q4/2015

Generation 5
Lower R x A
Q2-Q4 2015
Summary

• Gallium nitride has enabled smaller and faster power transistors.
• The elimination of all packaging has unleashed additional performance advantages due to reduced size, cost, parasitic inductance, thermal efficiency, reliability, and cost.
• For the first time in 60 years there is a technology that is both higher performance and lower cost than silicon!
Where is GaN going...