GaN vs. Silicon – Overcoming Barriers to the Rise of GaN

Alex Lidow
Breaking Down the Barriers

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

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More Wireless Bandwidth

Reference: Nujira.com website

Red represents wasted energy dissipated as heat

W/O Envelope Tracking

With Envelope Tracking

4G (LTE / OFDM)
8.5 dB PAPR (~7:1)

3.5G (HSUPA)
6.5 dB PAPR (~5:1)

3G (W-CDMA)
3.5 dB PAPR (~2:1)

Peak power
Average power

Same average
No More Power Cords
Improved Medical Care

- Heart Pump
- Nerve Stimulator
- Prosthetics
Augmented Reality and Autonomous Cars
What Paces Growth?

Mostly traditional MOSFET applications

- Other: 54%
- Envelope Tracking: 22%
- WiPo: 18%
- LiDAR: 6%
- Other: 54%

New applications
Breaking Down the Barriers

Traditional MOSFET Application

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Breaking Down the Barriers

• Does it enable significant new capabilities?
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• Is it easy to use?
Field Reliability

17B total device hours in the field

- 133 Field Returns (39 Good, 94 Failed)
  - 24 Layout Related
  - 63 Assembly Related
  - 5 Physical Abuse
  - 3 Device degradation

- 3 Device Failures in 17B Hours equals 0.24 FIT (60% confidence)
Breaking Down the Barriers

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GaN Learning Curve

Efficiency (%) vs. Output Current (A)

- GaN Circa 2010
- GaN Circa 2012
- GaN Circa 2014
- GaN Circa 2015

$V_{\text{IN}}=12 \text{ V}$ $V_{\text{OUT}}=1.2 \text{ V}$ $f_{\text{sw}}=1 \text{ MHz}$
## MOSFET vs. eGaN FET Costs*

<table>
<thead>
<tr>
<th>Process Stage</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting Material</td>
<td>lower</td>
</tr>
<tr>
<td>Epi Growth</td>
<td>~higher</td>
</tr>
<tr>
<td>Wafer Fab</td>
<td>lower</td>
</tr>
<tr>
<td>Test</td>
<td>same</td>
</tr>
<tr>
<td>Assembly</td>
<td>lower</td>
</tr>
<tr>
<td><strong>OVERALL</strong></td>
<td>lower!</td>
</tr>
</tbody>
</table>

*Product with the same on resistance and voltage rating*

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Active die < 3 mm²
GaN Integration

Asymmetric HB

Symmetric HB

Wireless Power IC

Symmetric HB

Synchronous Rectifier IC Prototype
Breaking Down the Barriers

- Does it enable significant new capabilities?
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Difficulties

• Layout
• Assembly
• Perception
Measured Efficiency

V_{\text{IN}}=12\ V, \ V_{\text{OUT}}=1.2\ V, \ f_{\text{sw}}=1\ MHz, \ L=300\ nH

EPC Optimal Layout

Reference:
Layout Impact on Peak Voltage

$L_{\text{Loop}} \approx 1.0 \text{ nH}$

$L_{\text{Loop}} \approx 0.4 \text{ nH}$

Switching Node Voltage

$V_{\text{IN}} = 12 \text{ V}$  $V_{\text{OUT}} = 1.2 \text{ V}$  $I_{\text{OUT}} = 20 \text{ A}$  $f_{\text{SW}} = 1 \text{ MHz}$  $L = 150 \text{ nH}$
Assembly

Gen 3 & 4 FETs and ICs
400 um pitch (≤ 100 V)

Gen 5 FETs and ICs (≤ 100 V)

250 um balls, 450 um pitch

350 um balls
600 um pitch

300 um balls 500 um pitch
Changing Perception
Communicating the Learning Curve
GaN Family is Growing

Enhancement-Mode GaN – Normally Off

Depletion-Mode GaN – Normally On
Universities all over the world are graduating well-trained engineers experienced in the use of GaN Transistors.

- Virginia Tech
- MIT
- Auburn University
- National Chiao Tung University
- Zhejiang University
- Kyusyu Institute of Technology
- University of Tennessee
- University of Illinois
- University of Southern Denmark
- University of Texas
- North Carolina State University
- University of Valencia
- University of Kassel
- Case Western University
- Colorado State University
- University of Sheffield
- Delft University of Technology
- National Tsing Hua University
- Yamaguchi University
- FH Joanneum - University of Applied Sciences
- University of Cambridge
- Rensselaer Polytechnic Institute
- ETH Zurich
- University of Michigan
- Nanyang Technological University
- Hong Kong University
- Aalborg University
- University of Toronto
- Universidad Miguel Hernandez
- Mid Sweden University
- RFSS Lab
- New Mexico State University
- Seoul Technical University
- Clausthal University of Technology
- Universita Di Padova
- University of Johannesburg
- University of North Carolina - Charlotte
- Oregon Tech
- DDEEA-ETSE URV
- University of Maryland
- University of Tokyo
- University of Stuttgart
- The Hong Kong University of Science & Technology
- Tallinn University of Technology
- Harvard University
- University of Toledo
- University of Akron
- University of Dayton
- University of Zaragoza
- Stanford University
- University of Applied Sciences
- University of Bologna
- Missouri University
- University of Wisconsin
- Yale University
- Reutlingen University
- Kyushu University
- Ecomas
- Universidad de Oviedo
- University of Arkansas
- Chiba University
- Shimane University
- University of Florida
- University of Bristol
- Universität Erlangen
- Seoul National University
- University of Hamburg - Institute of Experimental Physics
- Otto-Von-Guericke University
- City University of Hong Kong
- National Central University
- Missouri University of Science and Technology
- DTU Elektro
- Florida State University
- University of North Carolina
- University of Auckland
- University Politecnica de Madrid
- Universidad de Roma la Sapienza
- Purdue University
- Uta University
- Arizona State University
- University of South Carolina
- University of Utah
- Catholic University of Leuven
- LAPLACE
- Pontificial Xavierian University
- Macquarie University
- Austrian Institute of Technology GmbH
- Auckland University of Technology
- Friedrich-Alexander University
- University of Warwick
- Centro De Estudios E Investigaciones
- Supelec
- University of Nottingham
- Universitat Rovira i Virgili
- University of Wellington
- University of Bremen
- Ferdinand-Braun-Institut
- The Ohio State University
- Biomedical University
- Queens University
- Pennsylvania State University
- University of Central Florida
- University of Nevada
- University of Manchester
- NTB Hochschule Fur Technik
- University of Hong Kong
- Iowa State University
- Newcastle University
- Imperial College
- Faculte Des Sciences
- Braunschweig University of Technology
- Center for Advanced Power Systems
- University of New South Wales
- Flensburg University of Applied Sciences
- ASIC Lab
- Universite Lille
- Xian JiaoTong Electric
- Queensland University of Technology
- Institute of Technology Sligo
- Dresden University of Technology
- Concordia University ECE
- Korea University
- National University of Colombia
- Universitat Politecnica de Catalunya - EETAC
- Dalhousie University
- Xi'An Jiaotong University
- Federal University of Santa Catarina
- University of Hannover
- Nikhef Institute
- University of Connecticut
- Brunel University
- UC Santa Barbara
- Oregon State University
- University of Applied Sciences
- University of Applied Sciences
- University of Reims
- Instituto de Telecomunicacoes
- Lausitz University
- SUPSI-TTHF Lab
- Naval Postgraduate School
- Texas Tech University
- Curtin University
- Pukyong National University
- Sorbonne Universite
- Space Flight Lab - UTIAS
- National Taiwan University
- University of Pittsburgh
Summary

• GaN adoption in enabled applications is paced by the growth of the end product.

• GaN adoption in traditional MOSFET applications is paced by training and lagging perceptions.

• GaN is developing an excellent field record.

• More GaN suppliers means more end customers and more voices supporting GaN adoption.

• New engineering graduates are leading the field in adoption.

• GaN will crush silicon!
The end of the road for silicon.....
is the beginning of the eGaN FET journey!