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?

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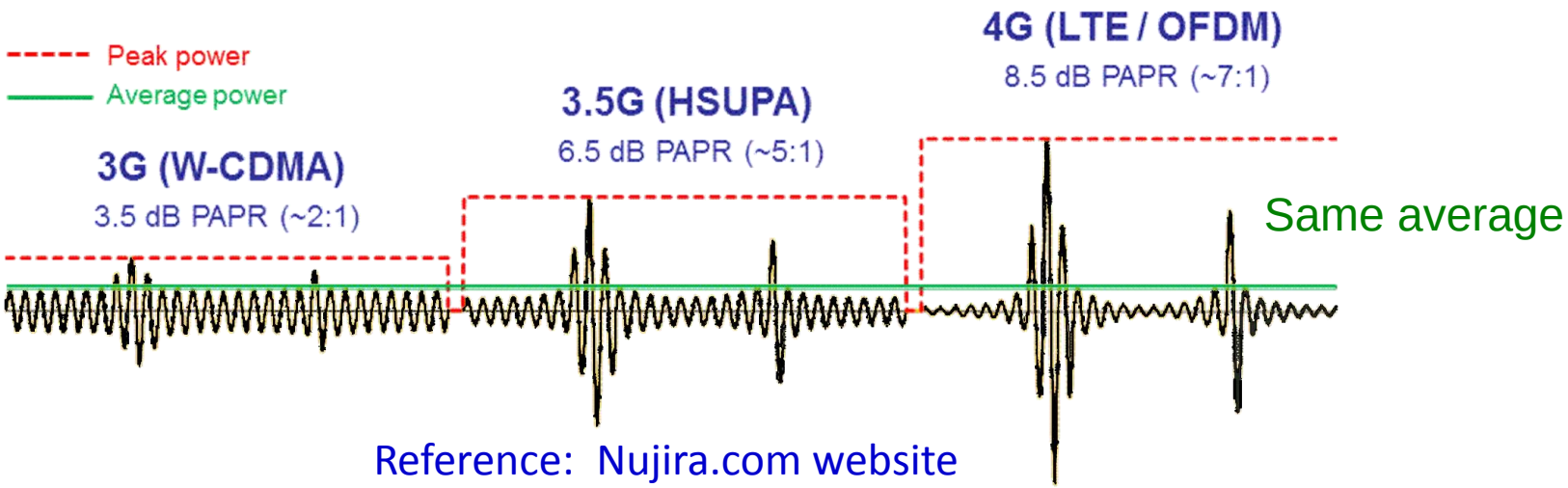
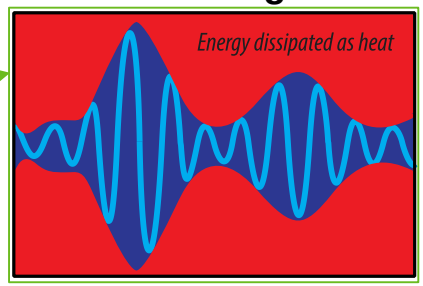
More Wireless Bandwidth



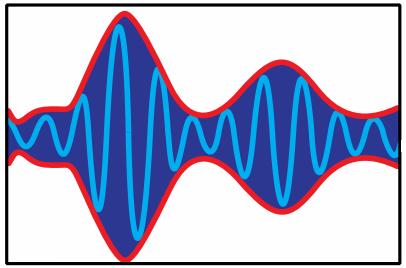
Reference: Nujira.com website

Red represents wasted energy dissipated as heat

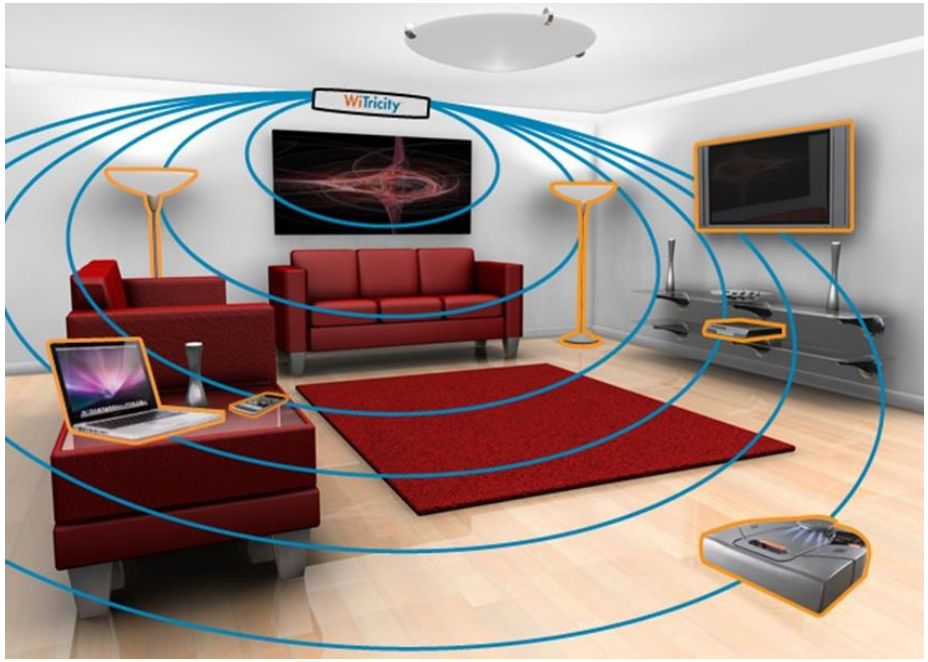
W/O Envelope Tracking



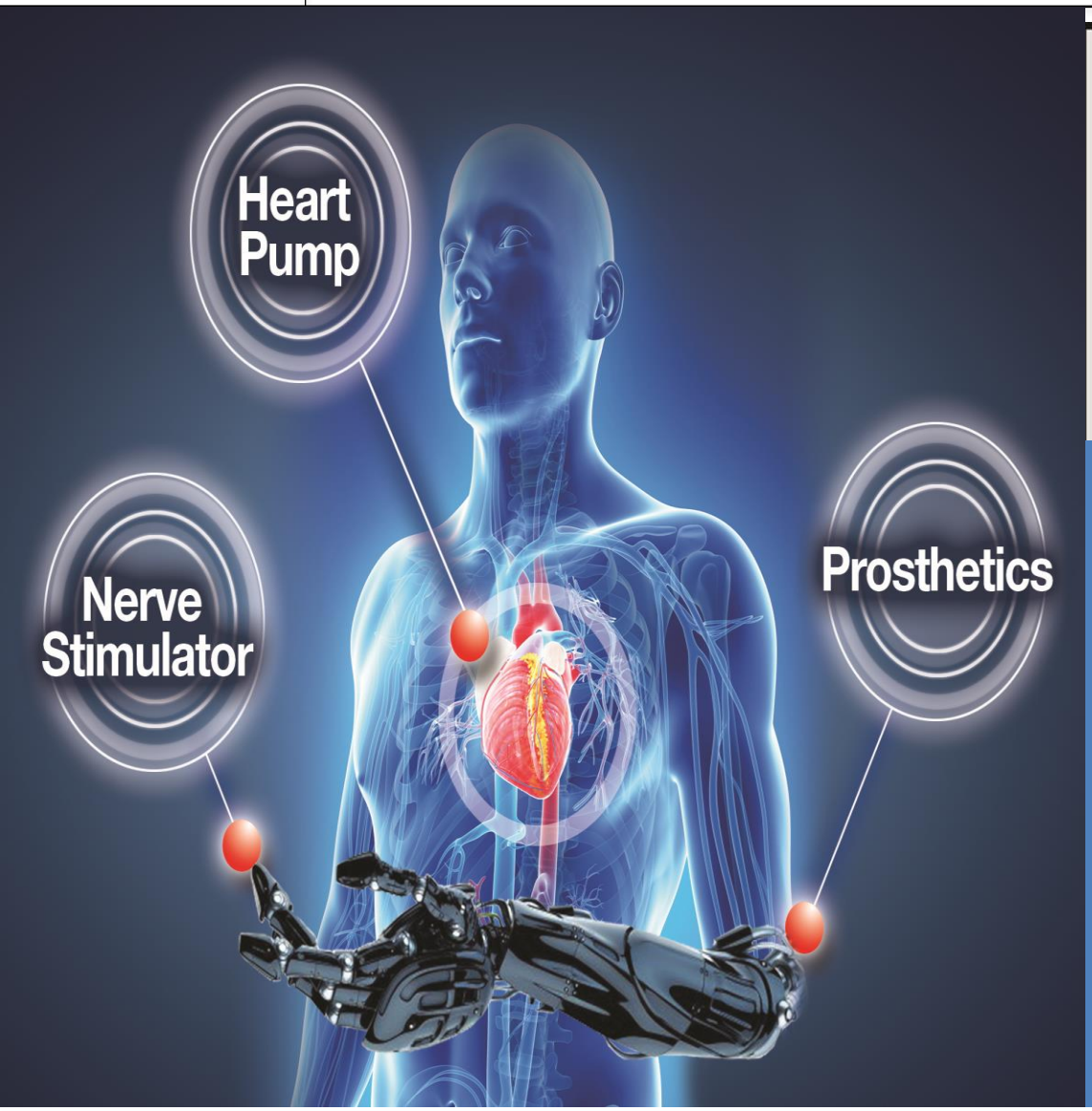
With Envelope Tracking

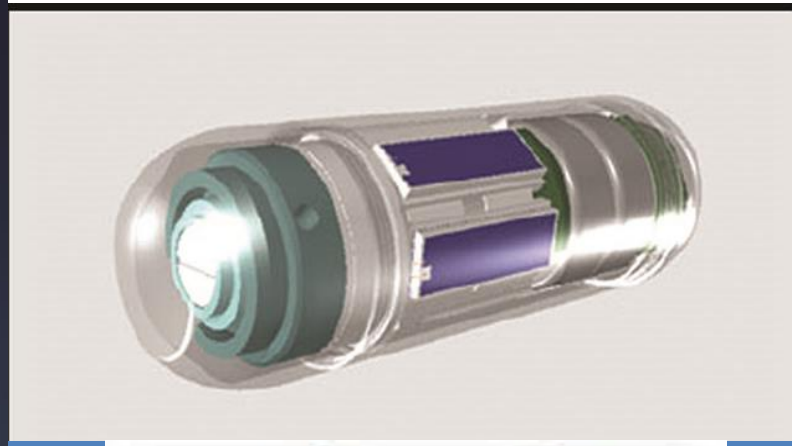


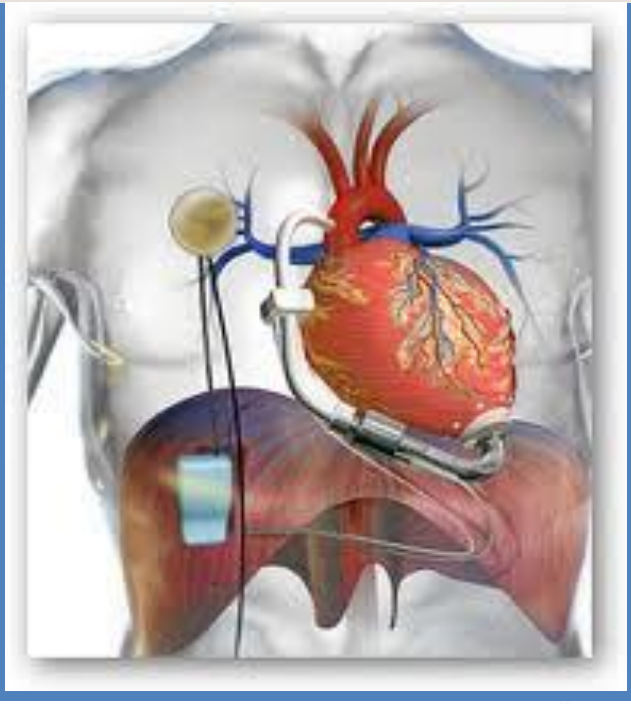
No More Power Cords



Improved Medical Care



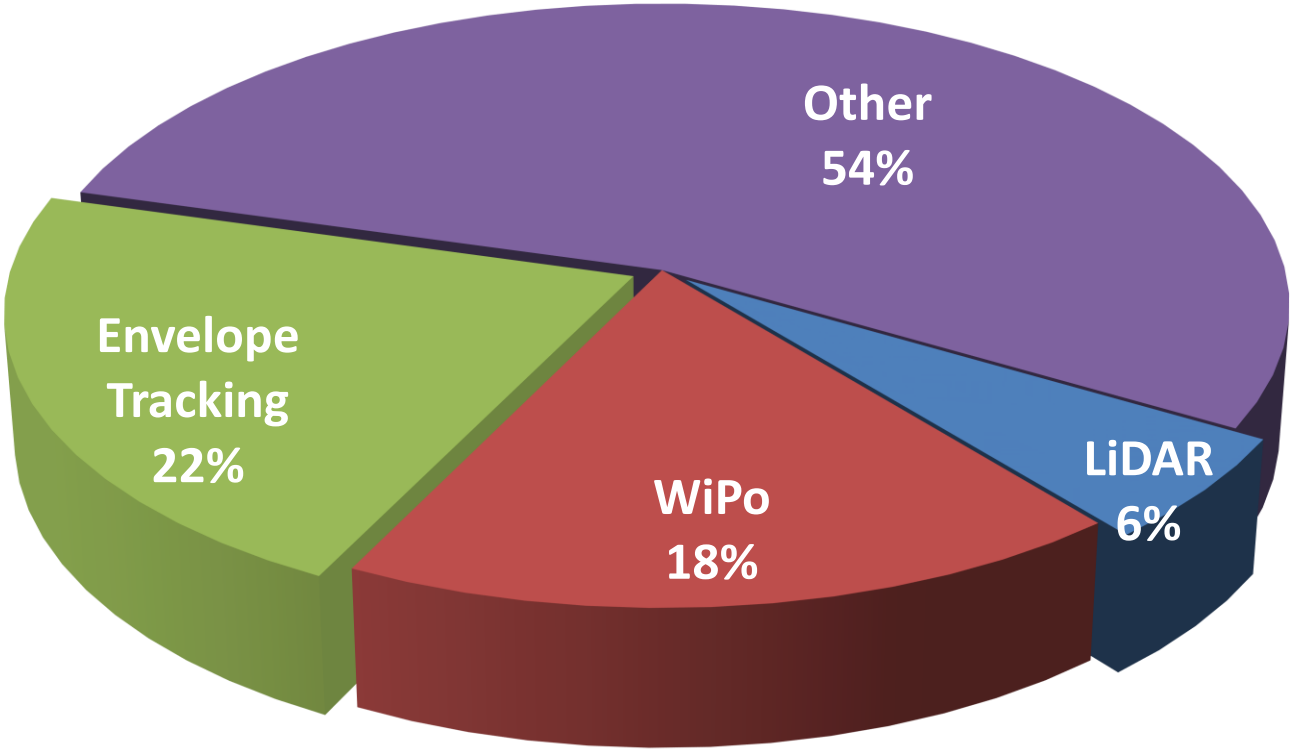




Augmented Reality and Autonomous Cars

What Paces Growth?

Mostly traditional MOSFET applications



New applications

Traditional MOSFET Application

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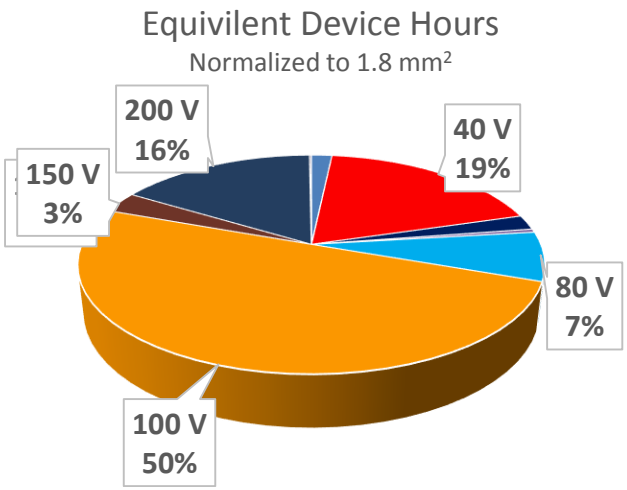
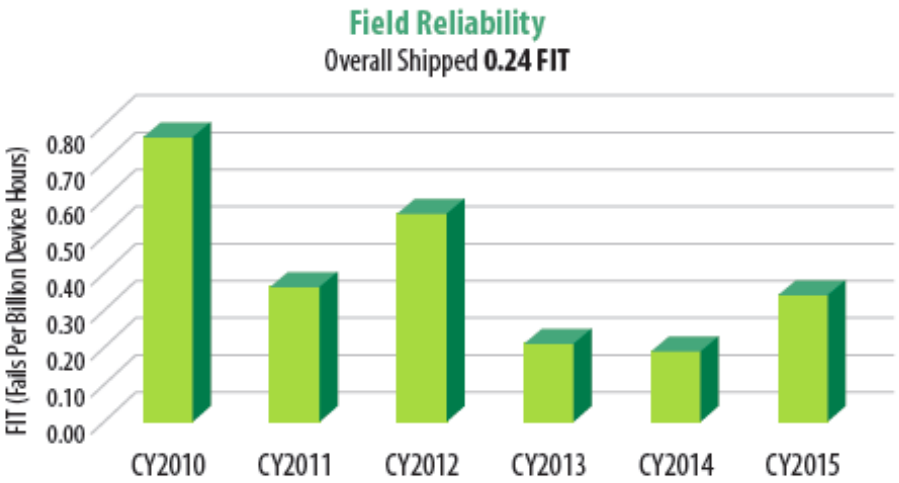
Field Reliability

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)

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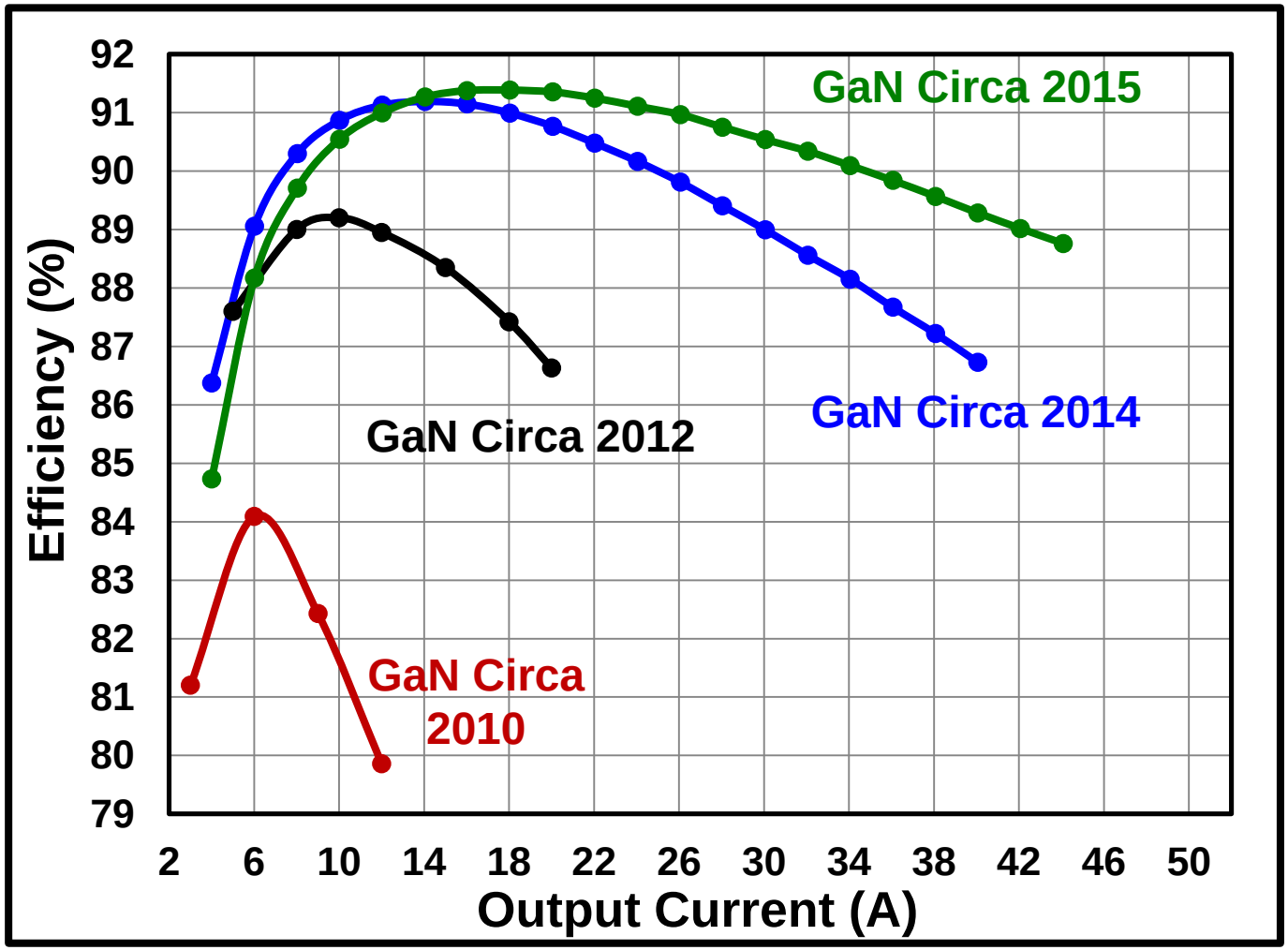
GaN Learning Curve



V_{IN}=12 V V_{OUT}=1.2 V f_{sw}=1 MHz

MOSFET vs. eGaN FET Costs*

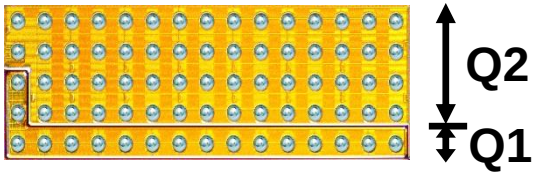
Active die <3 mm^2

	2014
Starting Material	lower
Epi Growth	***~higher***
Wafer Fab	lower
Test	same
Assembly	lower
OVERALL	***lower!***

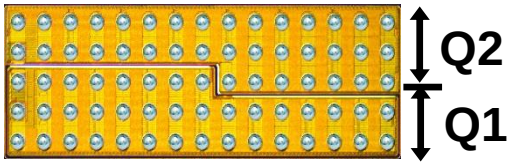
* Product with the same on resistance and voltage rating

GaN Integration

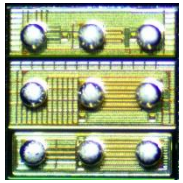
Asymmetric HB



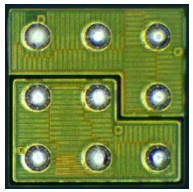
Symmetric HB



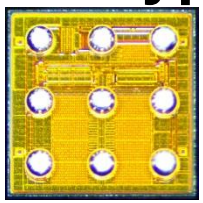
Wireless Power IC



Symmetric HB



Synchronous Rectifier IC Prototype



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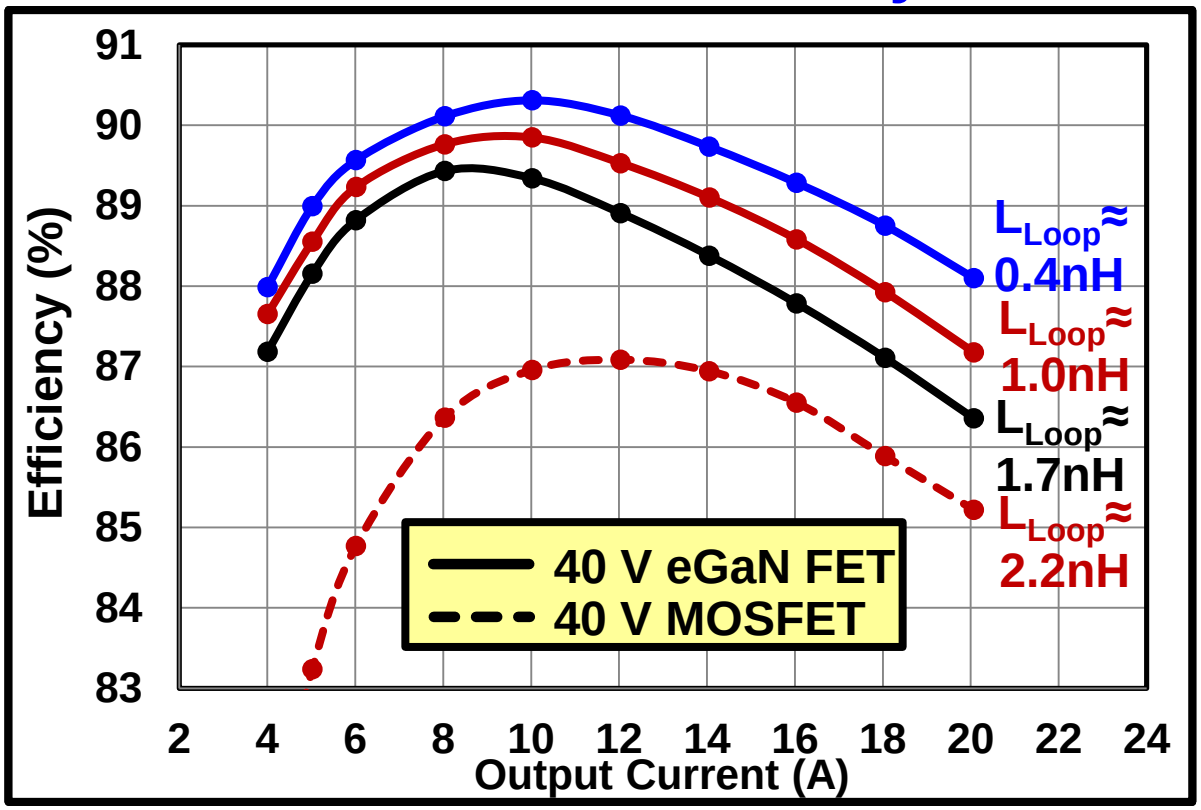
Difficulties

- Layout
- Assembly
- Perception

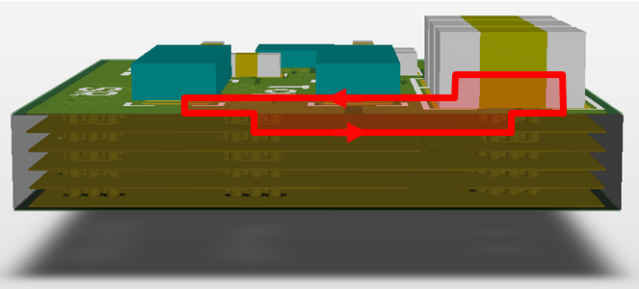
Layout Impact on Efficiency

Measured Efficiency



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

EPC Optimal Layout

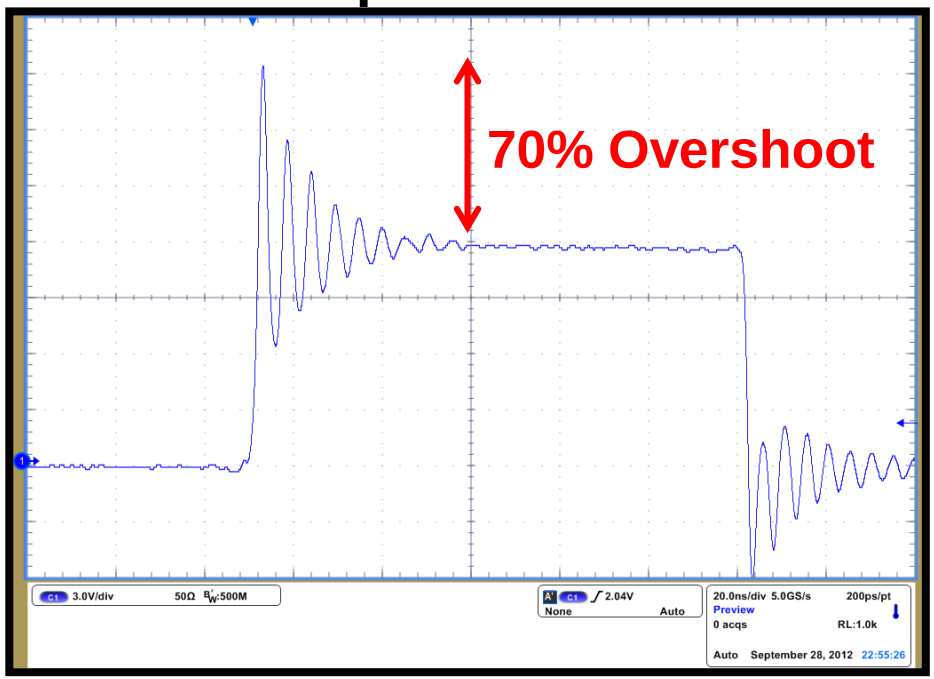


Reerencef:

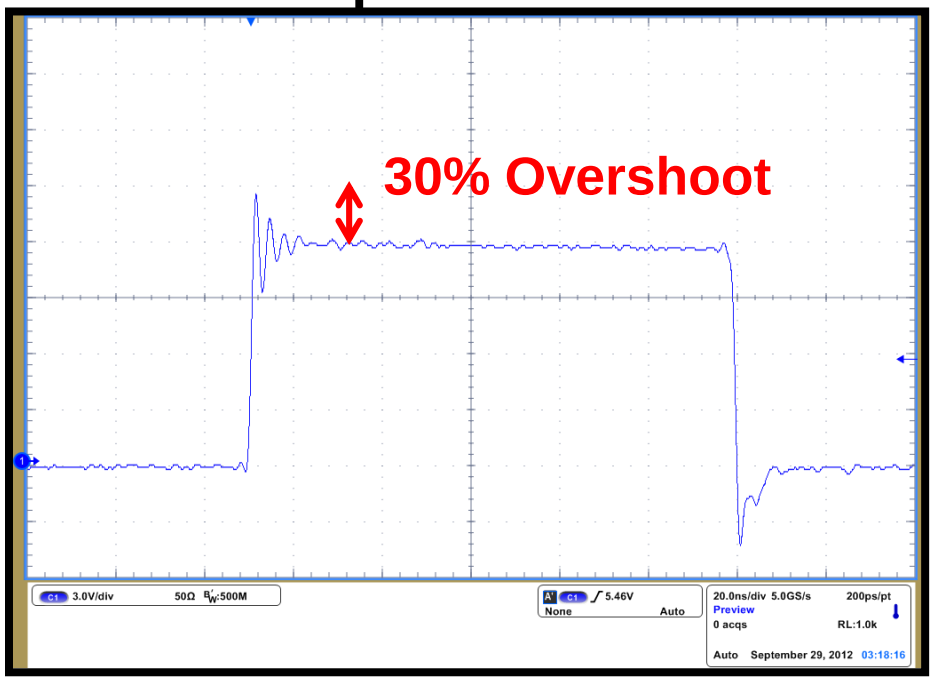
D. Reusch, J. Strydom, "Understanding the Effect of PCB Layout on Circuit Performance in a High Frequency Gallium Nitride Based Point of Load Converter," APEC 2013, IEEE Transactions on Power Electronics 2014

Layout Impact on Peak Voltage

$L_{Loop} \approx 1.0$ nH



$L_{Loop} \approx 0.4$ nH

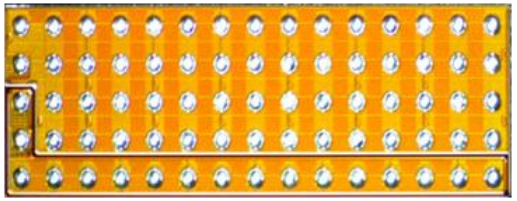


Switching Node Voltage

V_{IN}=12 V V_{OUT}=1.2 V I_{OUT}=20 A f_{sw}=1 MHz L=150 nH

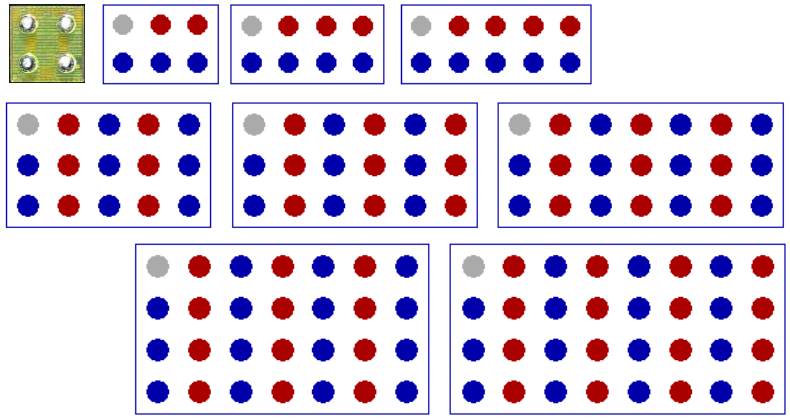
Assembly

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



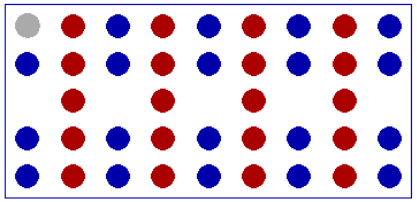
Gen 5 FETs and ICs (≤ 100 V)

250 um balls, 450 um pitch



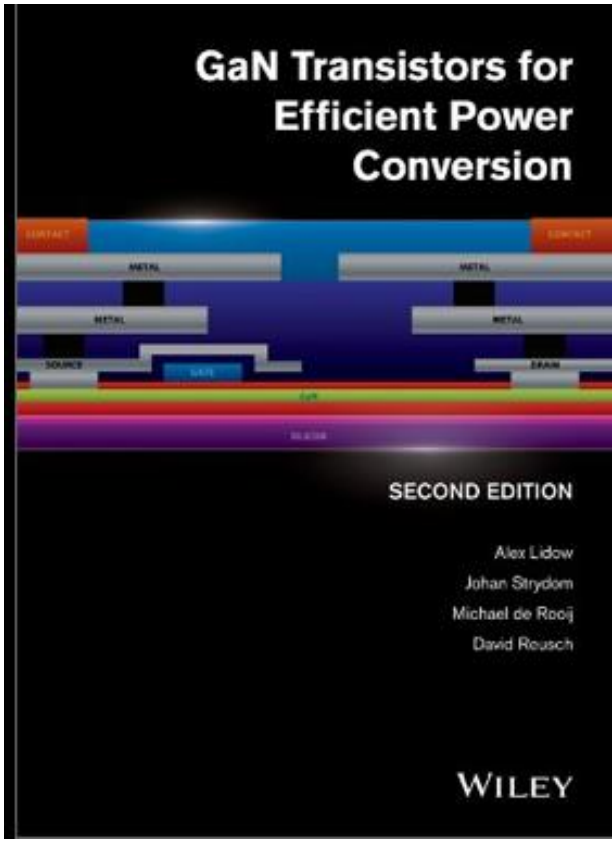
300 um balls 500 um pitch

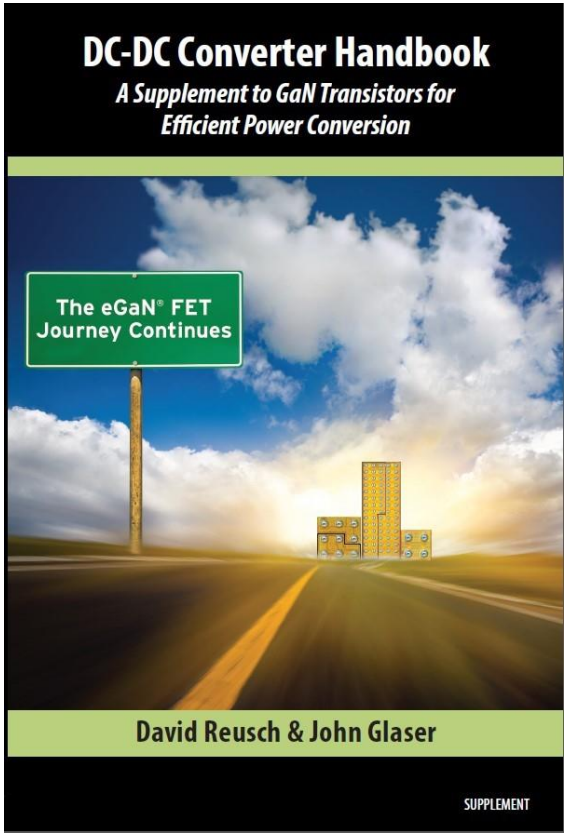
350 um balls
600 um pitch

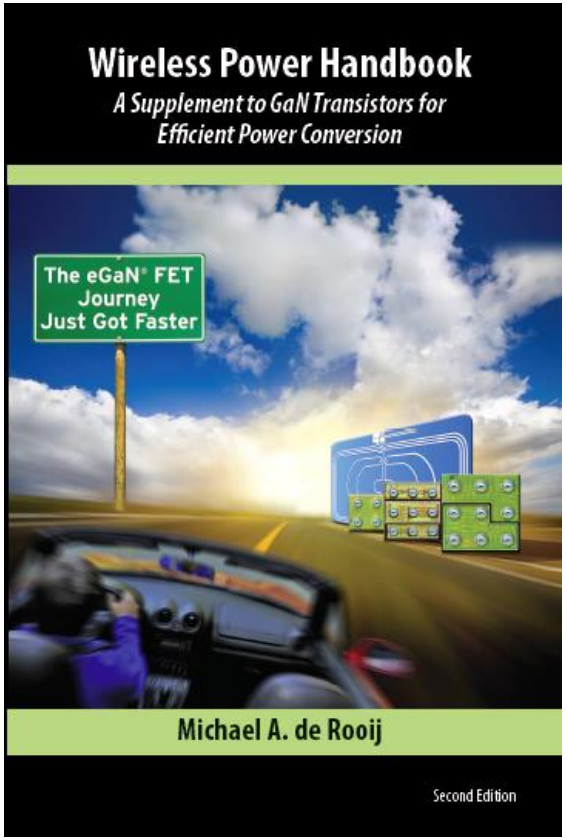


Changing Perception

Communicating the Learning Curve







GaN Family is Growing

Enhancement-Mode GaN – Normally Off

EPC EFFICIENT POWER CONVERSION

GaN Systems

Infineon

Panasonic

Navitas SEMICONDUCTOR

Cambridge Electronics

tsmc

Depletion-Mode GaN – Normally On

transphorm

ON Semiconductor

qorvo™

Training the Next Generation

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
- Kyusu Institute of Technology
- University of Tennessee
- University of Illinois
- University of Southern Denmark
- University of Texas
- North Carolina State University
- University of Valencia
- Universität 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
- DEEEA-ETSE URV
- University of Maryland
- 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
- Universitat Erlangen
- Seoul National University
- University of Hamburg - Institute of Experimental Physics
- Otto-Von-Guerick 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
- Universidad Politenica de Madrid
- UCLA
- Universita di Roma la Sapienza
- Purdue University
- Oita University
- Arizona State University
- University of South Carolina
- University of Utah
- Catholic University of Leuven
- LAPLACE
- Pontifical 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 Waikato
- University of Bremen
- Ferdinand-Braun-Institut
- The Ohio State University
- Bloomsburg 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 Rosenheim
- Instituto de Telecomunicacoes
- Lausitz University
- SUPSI-TTHF Lab
- Naval Postgraduate School
- Texas Tech University
- Curtin University
- Pukyong National University
- Soongsil University
- Space Flight Lab - UTIAS
- National Taiwan University
- University of Pittsburgh
- University of Colorado
- University of Cassino
- Ruhr University Bochum
- University of Zagreb
- Technische Universitaet Berlin
- Integrated System Research Lab
- Denmark Technical University
- University of Washington
- Embry-Riddle Aeronautical University
- Georgia Tech
- Mississippi State University
- Hogeschool van Amsterdam - University of Applied Sciences
- Oregon Institute of Technology
- LS Simulation - Imtek
- University of Applied Sciences Ravensburg-Weingarten
- University of Oulu
- Beijing Jiaotong University
- University of Applied Science Austria
- Sun Yat-Sen University
- Hongik University
- Nagasaki University
- Dartmouth College
- Hochschule Kempten - University of Applied Sciences
- Singapore University of Technology and Design
- Université Laval
- University of Parma
- University of Iowa
- Harbin Industry University
- Rochester Institute of Technology
- Texas A&M University
- Fraunhofer
- University of Applied Sciences Kiel
- Kookmin University
- University of Alberta
- University of Applied Sciences Deggendorf
- University of Windsor
- Carleton University
- College de Maisonneuve
- Chalmers University of Technology
- Wright State University
- Universitat Freiburg
- King's College London
- Rowland Institute at Harvard
- Cardiff University
- Universitat Konstanz
- Cornell University

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!*

EPC
EFFICIENT POWER CONVERSION

The end of the road for silicon…..

is the beginning of the eGaN FET journey!