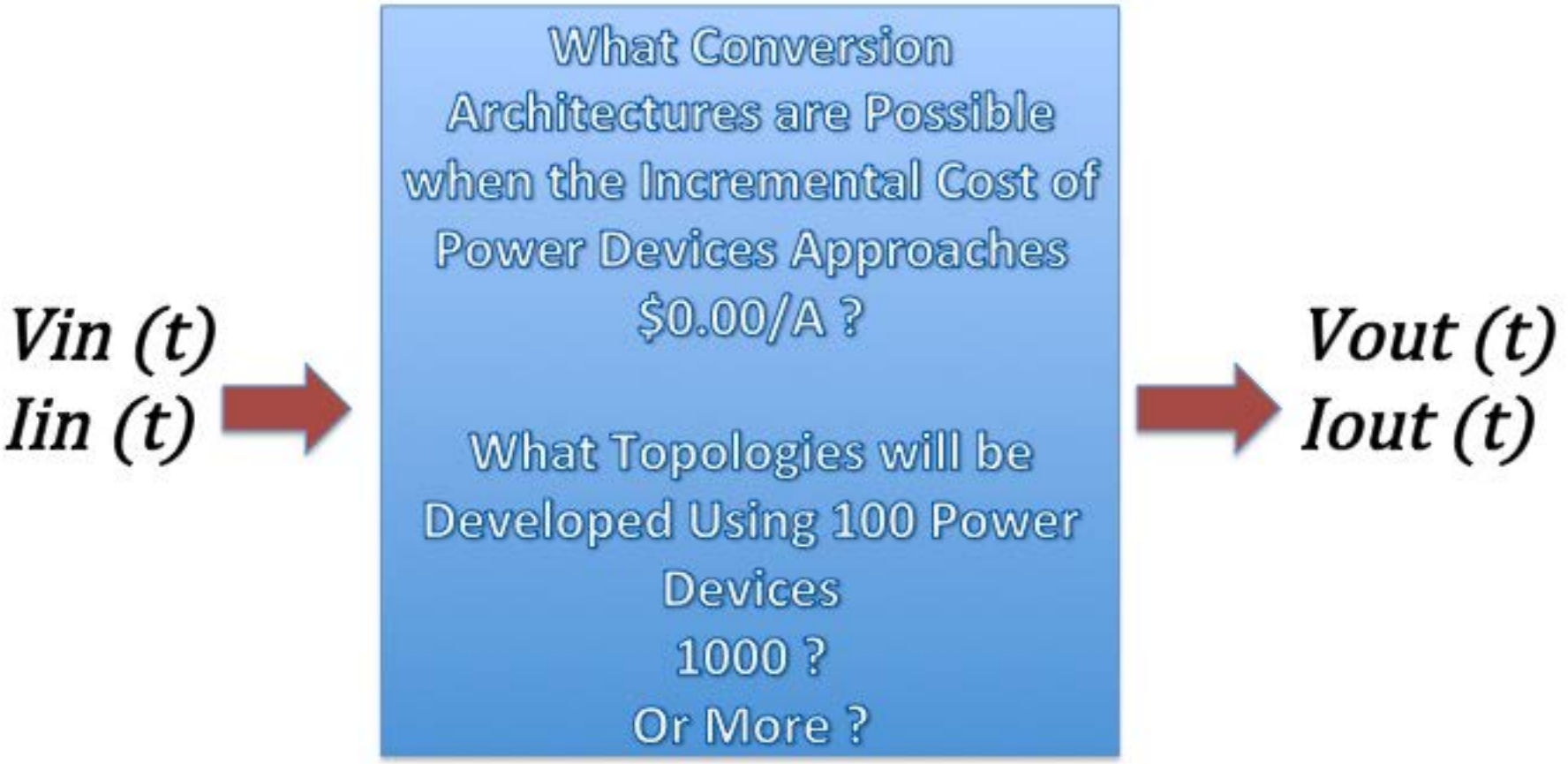
Lateral GaN HEMTs to Significantly Reduce Energy Consumption

Michael A. Briere
ACOO Enterprises LLC

ARPA-E Circuits Workshop
Novel Power Processing Architectures using WBG Semiconductors
September 13, 2016

WBG Led Power Processing Revolution



Highest Fields in GaN HEMTs in overlying Insulators
Dielectric Breakdown Limits Applied Voltage
No p-n junction

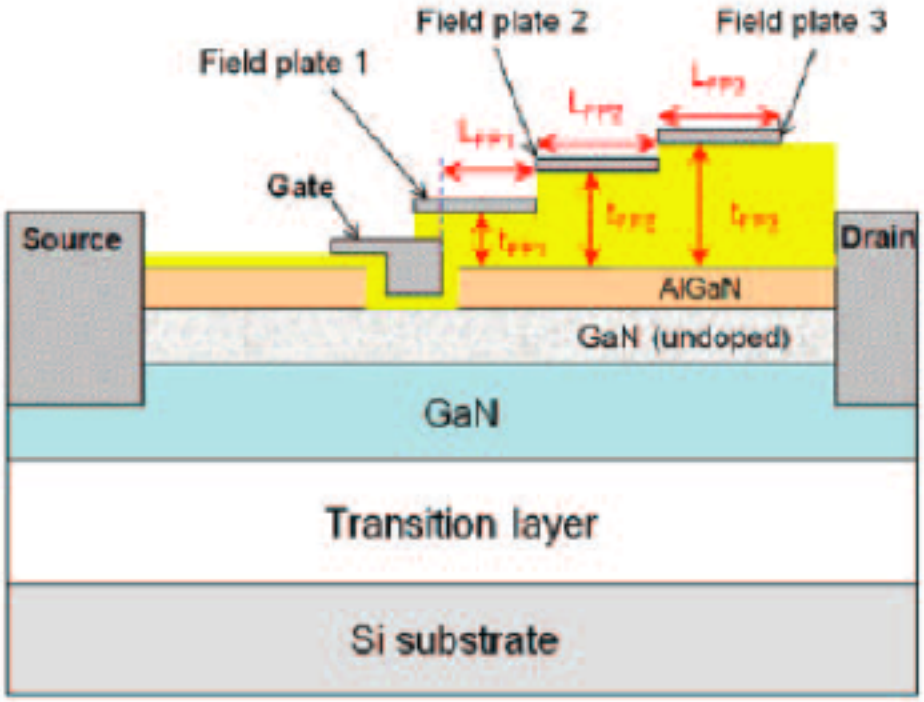


Fig. 1. AlGaN/GaN HEMT structure with multiple f
plates (FPs).

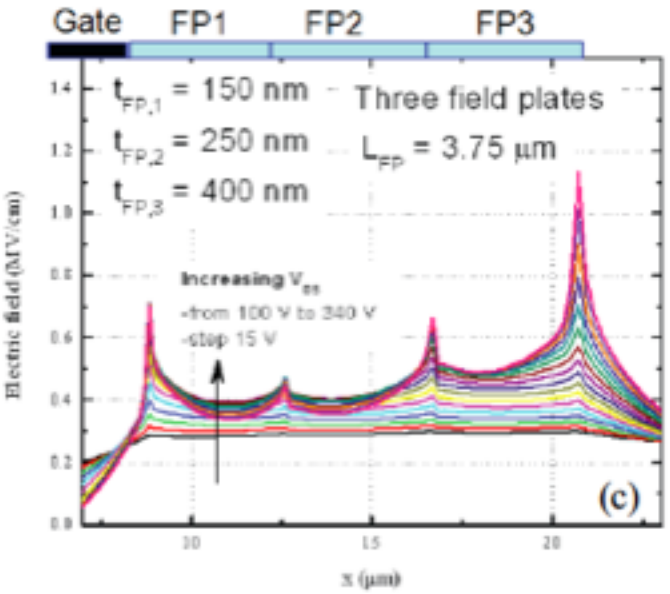
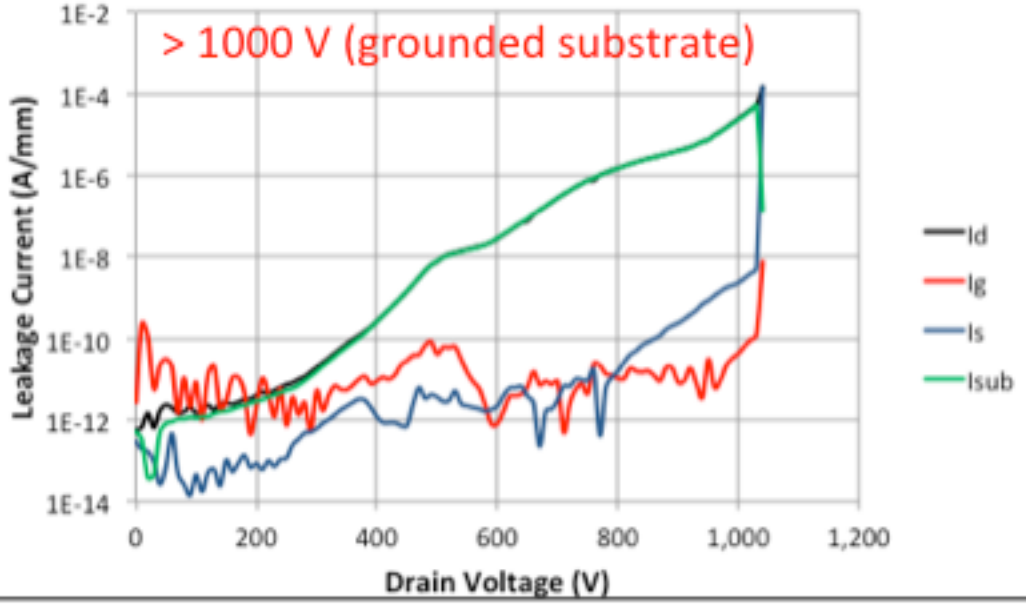


Fig. 4. Electric field distribution between gate and drain showing the picks of the electric field that appear at the ends of the field plate.

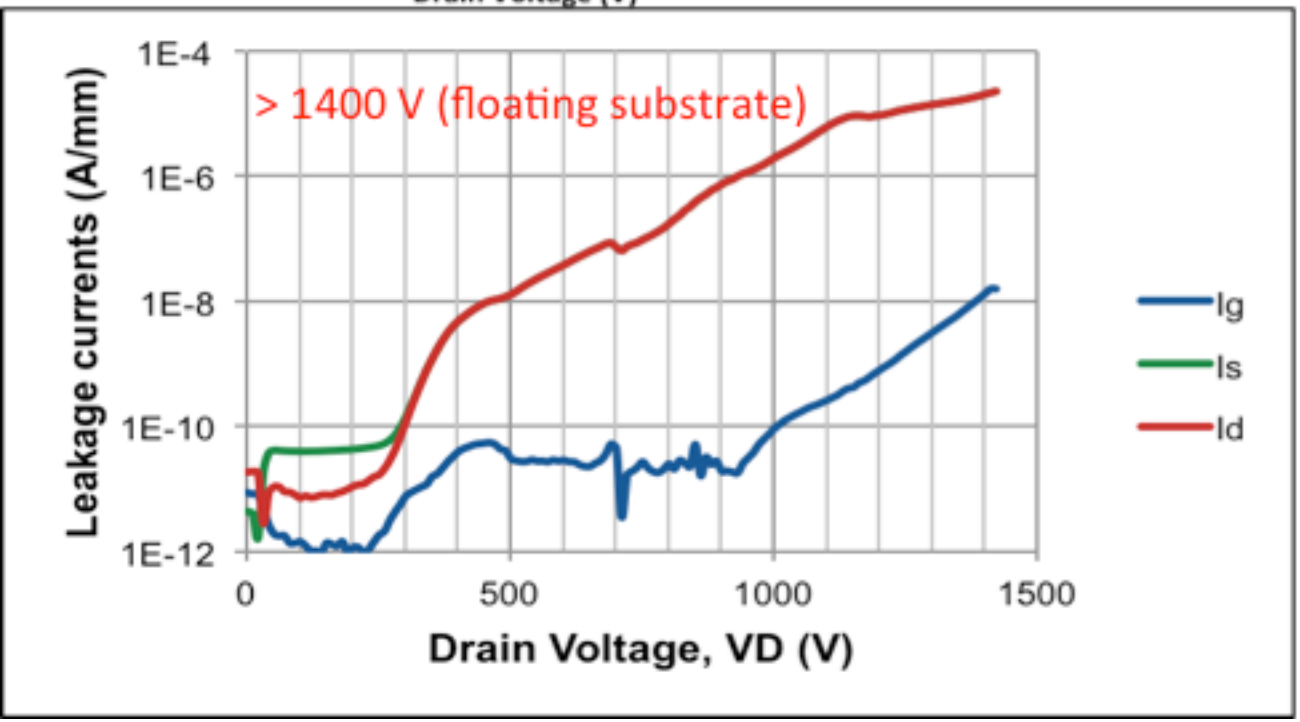
BV = 340 V

P. Andrei (FSU) Proceedings of 10th ICSICT 2010, pp. 1344-1346

Dielectric Breakdown of Gen 1 600 V rated HEMT Wg > 100 mm

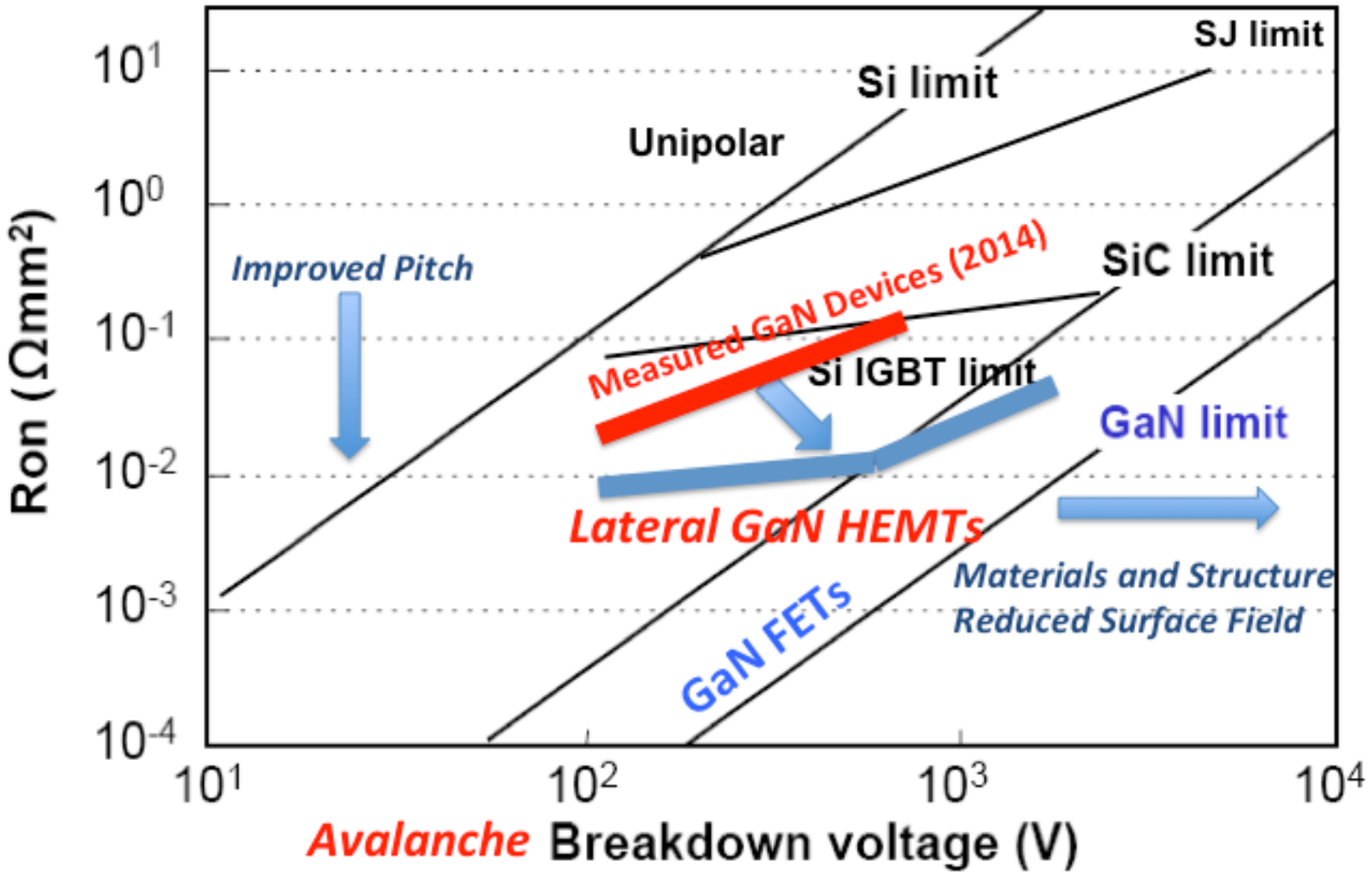


M.A. Briere, "Commercially Viable GaN based power devices
APEC Professional Education Seminars S.7 March 16, 2014



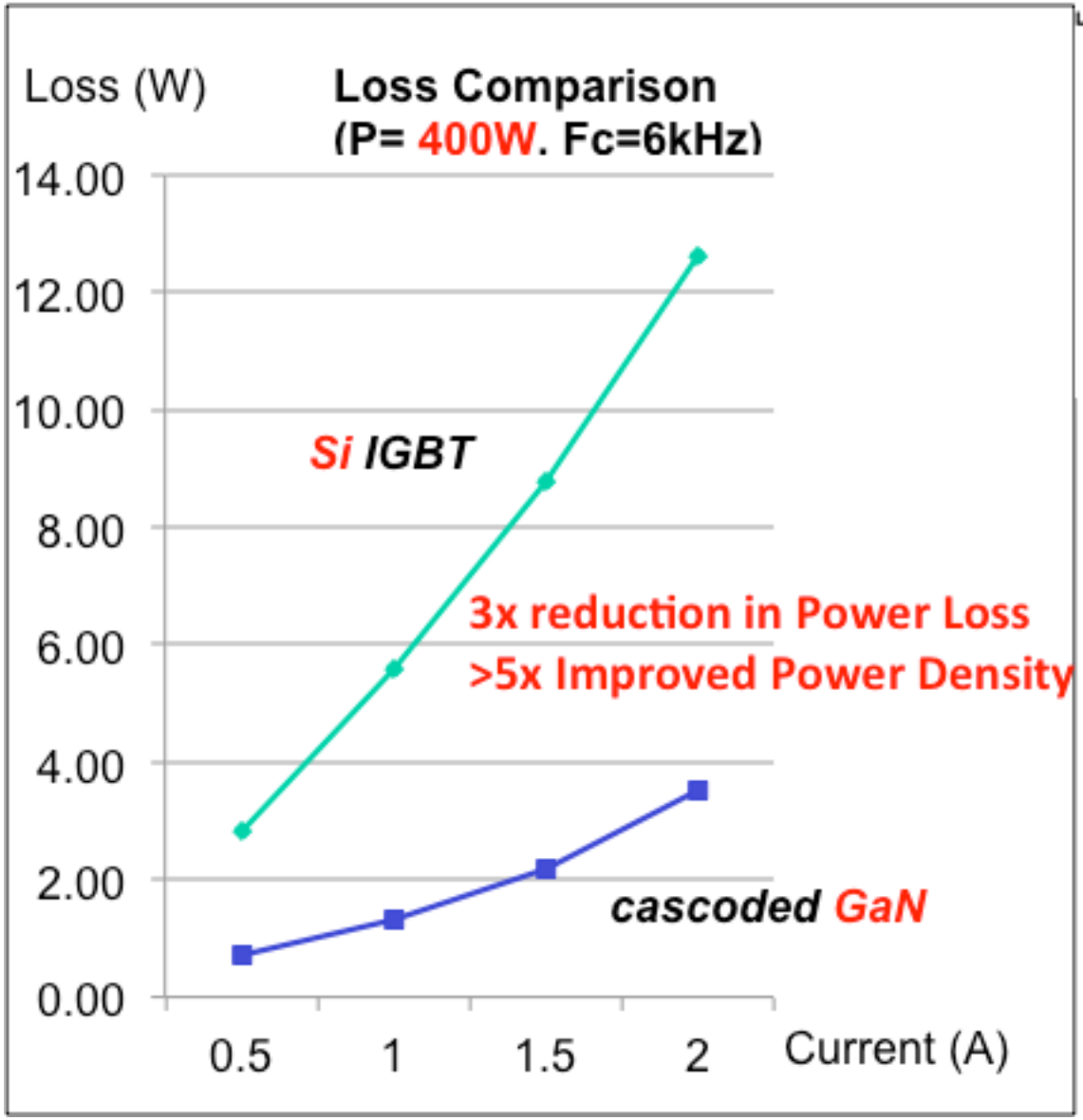
Rdson Limits for Lateral GaN HEMTs

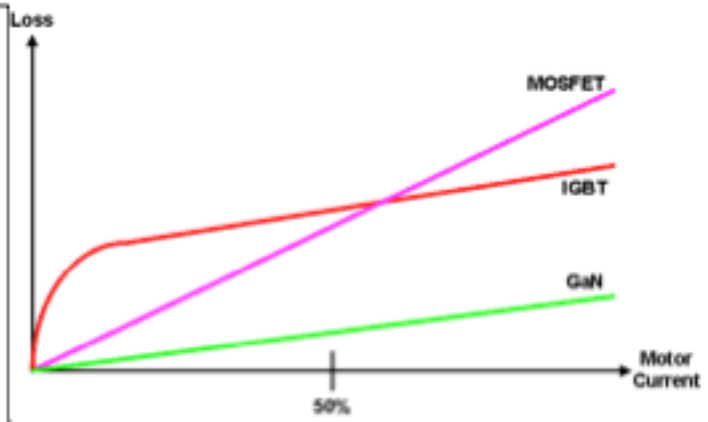
Ron = Ldrift / (q*μdrift*Ndrift)+ (Lch/(q*μch*Nch) +2 * ρcontact)

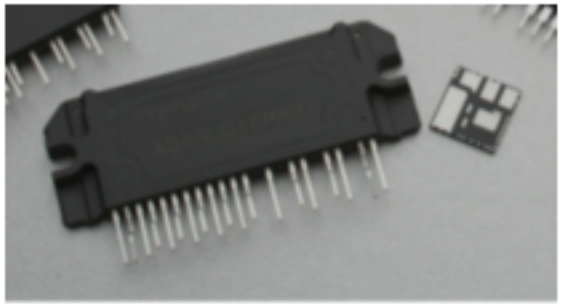


Extended from : M.A. Briere, "Commercially Viable GaN based power devices
APEC Professional Education Seminars S.7 March 16, 2014

Motor Drive Improvement- Drop-in Replacement



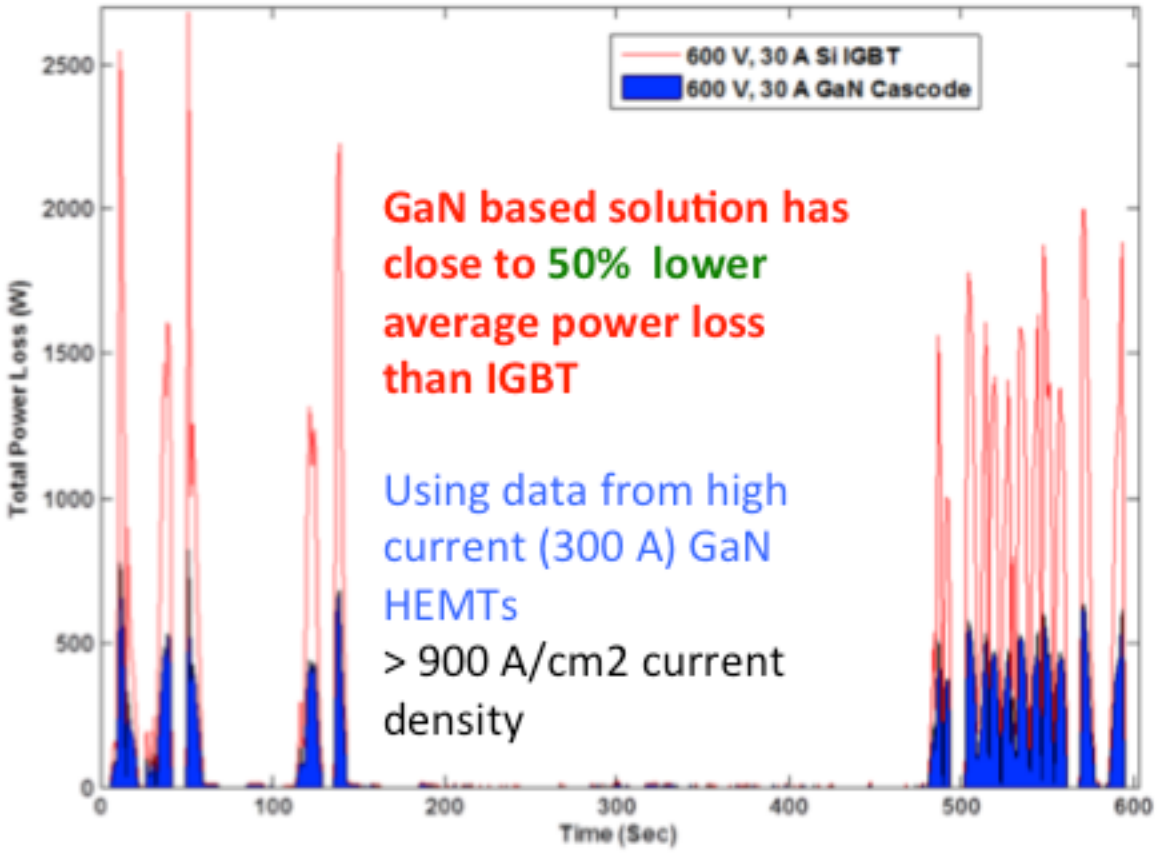




Drop-in replacement
Consumer Appliance Applications

Briere, PEE Issue 2 2014 pp29-31

Predicted Power Dissipation: GaN vs Si IGBT in EV Inverter



GaN based solution has close to 50% lower average power loss than IGBT

Using data from high current (300 A) GaN HEMTs

> 900 A/cm2 current density

- F=20 kHz, T = 105C, buss voltage = 325V

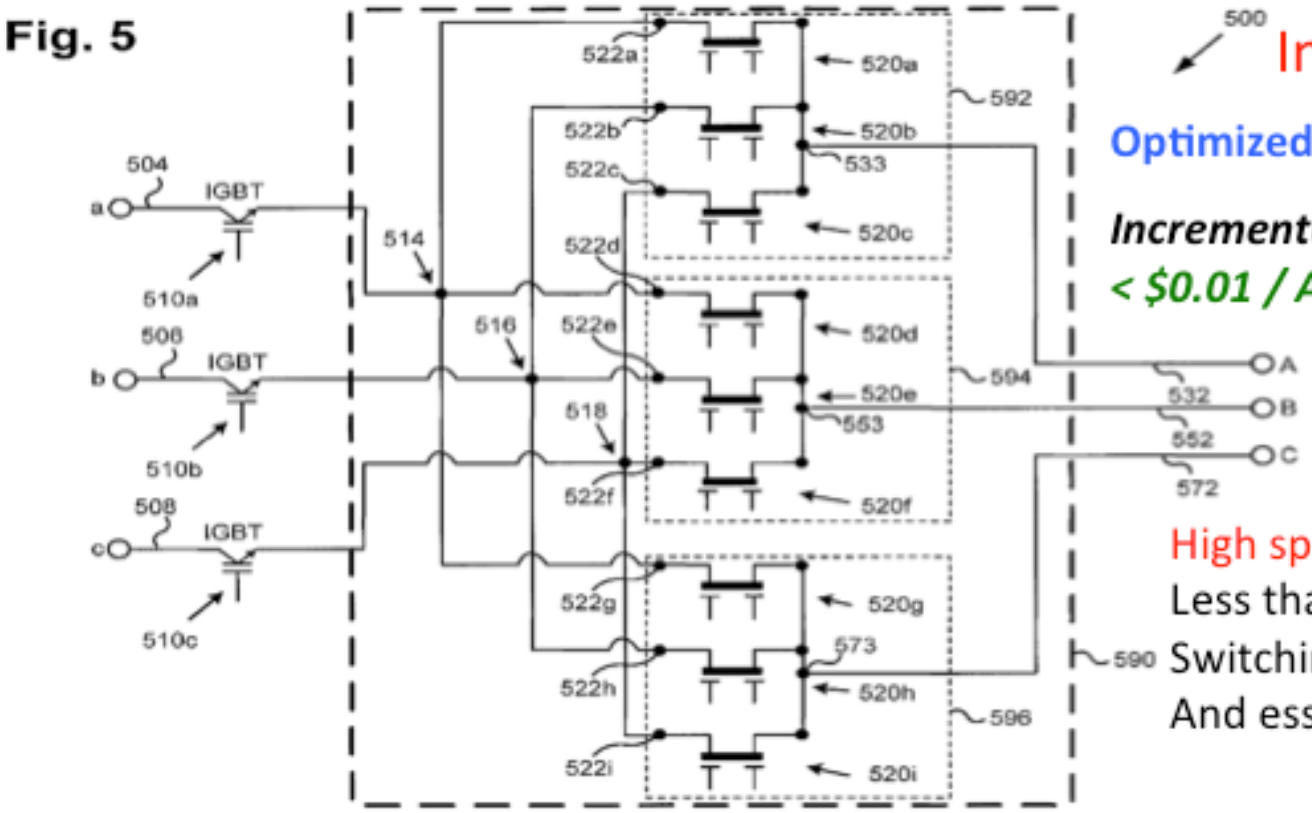
- **55 kW** electric motor in hybrid drive system: average power = 25 kW, Peak Power = 100kW

This material is partially based upon work supported by the Department of Energy, ARPA-E under Award Number DE-AR0000016, resulting from the collaborative development efforts of Delphi Automotive Systems, LLC; International Rectifier; and Oak Ridge National Laboratory.

Modeled Power Dissipation of Silicon IGBT vs GaN devices in US06 Drive Cycle (standardized,20 minute,8 mile long drive)-

Lee et.al.,Power Electronics Technology Jan 2013 pp. 35-38

Bi-directional GaN HEMTs – New Opportunities
ICs - Improved Cost, Performance and Reliability



Integrated Circuit

Optimized 650 V GaN HEMT

Incremental device cost

< $0.01 / A

High speed operation

Less than ***0.5 OhmnC***

Switching charge

And essentially ***0 Qrr***

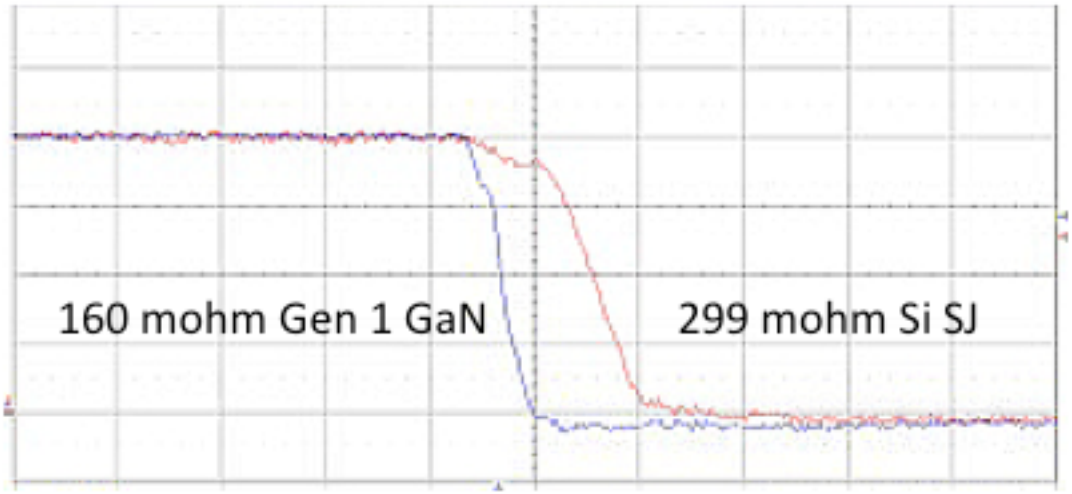
Integrated Circuit for Matrix Converter Motor Drive: ref Briere, US Patent 9349715 Figure 5

Application of matrix converters for motor drive- see

H. Shigekame et.al. (Fuji Electric), Proceedings of IPEMC 2009 pp. 35-39

Gen 1 GaN Switching Speeds

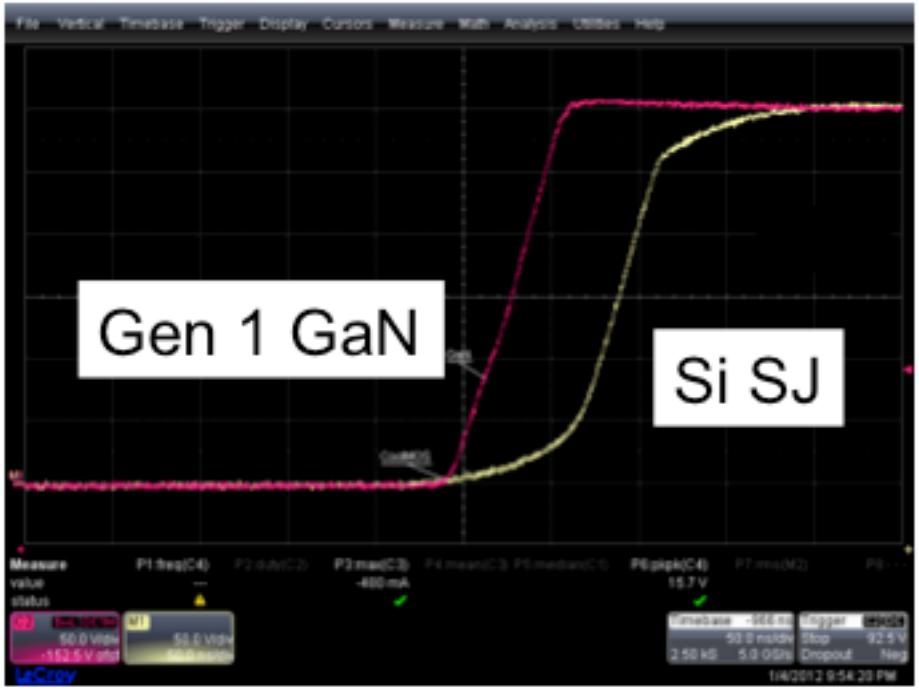
Large Devices, Wg = 120 mm



About 100 V/ns

Turn on

10 ns / div, 100 V/ div



160 mohm Gen 1 Gan vs. 199 mohm Si SJ

Turn off

50 ns / div, 50 V/ div

M.A. Briere, "Commercially Viable GaN based power devices APEC Professional Education Seminars S.7 March 16, 2014

Simplifying the Power Conversion Architecture Saving Energy, Reducing Cost and Improving Density

Other IC Opportunities :

- AC to POL (e.g. Bridgeless PFC 400 V to 1.8V)
  - Single Stage Conversion at e.g. > 100 kHz
  - – With or without (?) transformer
- Arbitrary Input Waveform to Output Waveform Power Processing

Suggested Activities for WBG Power Electronics Adoption

- Power Electronics need to Focus on Reducing Cost and Promoting Adoption of Efficient Loads (Motor Drives are Single Biggest Impact, followed by AC-DC Power Converters)

- Focus on Device Voltage Range that most impacts Global Energy Consumption (650 to 1200V).

- Develop Testing Standards and Provide Independent Certification Facility for Device Quality and Reliability