Unlocking the Power of GaN

PSMA Semiconductor Committee Industry Session

March 24th 2016
Dan Kinzer, COO/CTO
dan.kinzer@navitassemi.com
GaN vs. Si

- WBG GaN material allows high electric fields so high carrier density can be achieved
- Two dimensional electron gas with AlGaN/GaN heteroepitaxy structure gives very high mobility in the channel and drain drift region
- Lateral device structure achieves extremely low $Q_g$ and $Q_{OSS}$ and allows integration
- Large diameter GaN-on-Si, low cost Si-compatible processing
Existing GaN Packages

• Through-hole
  • High inductance, limits switching frequency

• Cascode (co-pack and/or stacking)
  • Multi-die, additional components
  • Higher cost for dice and assembly

• PCB-embedded
  • Non-standard, high cost
Speed Limit: Complex Drive

- dMode GaN needs extra FET, extra passives, isolation, complex packaging
- Early eMode GaN requires many added circuits:

  Slow it down to protect gate from spikes!
  Some even recommend to add a Zener and ferrite bead.

Ref: GaN Systems Application note GN001 Rev 2014-10-21
Package Parasitics Impede GaN Performance

Discrete Si
Limit 200kHz

Discrete GaN
500kHz+

15V

CS

GND

L6562

PFC IC needs sense resistor and source connection for current sensing

Problems with gate drive ringing and clamping

15V

6V

Ferrite bead

FAN3122

Discrete Si
Limit 200kHz

Discrete GaN
500kHz+
GaN with Integrated Driver: Simple, Fast

Discrete Si
Limit 200kHz

Discrete GaN
500kHz+

Integrated GaN
2MHz+

15V

L6562

CS

GND

15V

6V

Ferrite bead

GND

CS

Overvoltage Clamping

Integreated GaN

L6562

GaN + Driver

15V

6V

GND

CS
Multichip Si / GaN Integration

• Multi-chip module integrates Si driver and GaN transistor(s)
  • 80V product example

TI LMG200 integrated driver + half-bridge
Simple Integration of 2 Power FETs & Bootstrap

- Monolithic GaN transistor integration
- Gate drive still external / complex
- 100V example

EPC2107 – Enhancement-Mode GaN Power Transistor Half Bridge With Integrated Synchronous Bootstrap Preliminary Specification Sheet
Monolithic GaN Integration with Buffer

- Monolithic GaN Half-Bridge including input buffer stage
  - Example uses low voltage process, requires eMode and dMode devices
  - Low voltage DC/DC application
Creating the World’s First AllGaN™ Power ICs

Fastest, most efficient GaN Power FETs

First & Fastest Integrated GaN Gate Driver

World’s First AllGaN™ Power IC

Up to 40MHz switching, 4x higher density & 20% lower system cost
• Proprietary core technology platform
• Industry’s first GaN Power IC Process Design Kit (PDK)
• Monolithic integration of GaN IC circuits (drive, logic) up to 650V with GaN FET(s)
• Other functions can also be included, such as
  • Hysteretic digital inputs, voltage regulation, ESD protection
• High-volume production capability
• World-class partners for wafers, assembly & test
Navitas GaN Power IC

- **Monolithic** integration
- 20X lower drive loss than silicon
- Driver impedance matched to power device
- Shorter prop delay than silicon (10ns)
- Zero inductance turn-off loop
- Digital input (hysteretic)
- Rail-rail drive output
- Layout insensitive
Power QFN Packaging

• Attractive attributes
  • Leadframe package outline
  • Industry-standard
  • Low-cost
  • Small (5 x 6 mm)
  • High voltage clearance (>2 mm)
  • Low thermal resistance (<2°C/W)
  • Kelvin gate driver connection
  • Low inductance power connections (~0.2nH)
  • Supports multi-chip co-packaging
  • Low profile (0.85 mm)
Clean Gate Waveforms

- **Discrete driver:**
  - Gate loop inductance creates overshoot (even with good layout)
  - Reliability concern

- **GaN Power IC:**
  - No gate loop parasitic
  - Clean and fast gate signal
Rail-to-Rail Gate Signal

• Other GaN integrations offer simple buffer stages
  • Cannot efficiently deliver $V_{DD}$ voltage to the gate due to lack of PMOS transistor
  • Gate droop creates performance and variability issues

• GaN Power IC delivers rail-to-rail gate signal
High Frequency Drive with Minimal Delay

- 10-20ns propagation delay (can be further reduced)
- Switches at 10MHz effortlessly
- Smooth, clean gate drive waveform
Application example #1:

150W Boost PFC

- **Input**: Universal AC (85-265V<sub>AC</sub>, 47-63Hz)
- **Output**: 400V, 0.27A (150W)
- **Frequency** (*limited by control IC*): PFC >500kHz
- **Size**: 100 x 50 x 20mm “No heatsink” design
- **Construction**: 2-layer PCB, SMT powertrain on bottom side
- **Power Factor**: >0.995 at 150W
- **Efficiency**: 98.1% (220V<sub>AC</sub>) / 97% (120V<sub>AC</sub>)
Simple Circuit Design

- EMI Filter + Rectifier
- Boost Inductor
- VCC Supply
- Boost Diode
- PFC Control IC
- GaN Power IC
- High Voltage Start-Up
Easy, Flexible Layout

- 100 x 50 x 20mm
- All active semis on bottom-side
  - Low profile
  - ‘No-heatsink’ design
  - 2-layer
  - 2 oz Cu
  - Standard vias

- Bulk Cap
- EMI Filter
- PFC Boost Diode
- GaN Power IC
- PFC Control IC
- AC Bridge Rectifier
- PFC Inductor
- Top side
- Bottom side
Fast, Clean, and Cool with Integrated Drive

- Fast, clean PFC operation
  - At $220V_{\text{AC}}$, 50% and 100% of peak line
- Cool GaN Power IC
  - Only 61°C at $220V_{\text{AC}}$ and 150W (full load)
Application Example #2:

150W Half-Bridge

- 500V Switching
- No overshoot / spike
- No oscillations
- ‘S-curve’ transitions
- ZVS Turn-on
- Zero Loss Turn-off
- Sync Rectification
- High frequency
- Small, low cost filter

![Graph showing 1 MHz ZVS, V_DS of Low Side FET, V_GS of Low Side FET, ZVS soft switching, Zero Loss Turn-off, Low Side Sync Rect, 200ns/div.](image)
Conclusion

• GaN offers superior switching performance vs. Silicon
  • Extremely low input, output, and Miller capacitance
• Speed and performance inhibited by discrete drive and packaging
  • Very difficult to have clean gate waveforms that reliably stay within safe operating range
  • eMode GaN is substantially easier to package and enables monolithic drive
• Monolithic GaN Power ICs:
  • Eliminate gate loop parasitics for a fast, clean gate with no overshoot
  • Unlock the power of GaN, enabling significant increase in frequencies and power density
  • Offer best performance and cost potential
• High levels of integration are possible: power, drive, protection, regulation
  • Enables fast adoption of high frequency circuit topologies