Speed Drives Performance
4th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA)
Fayetteville, NC, USA. November 9th 2016.

Gene Sheridan, CEO
gene.sheridan@navitassemi.com
Speed & Efficiency are Key

- **Fast** power devices have *potential* to enable high-frequency and high efficiency
- **Frequency** enables *small size, low-cost* and *faster charging*
- **Efficiency** enables *energy savings*
- With Silicon (or even discrete GaN), you can get one *or* the other
- With GaN power ICs, you get *both at the same time* with unequalled Speed & Efficiency
World’s First AllGaN™ Power ICs

Fastest, most efficient Hi-V GaN Power FETs

- >20x faster than silicon
- >5x faster than cascoded GaN
- Proprietary design
- 15+ pending or issued patents

iDrive First & Fastest Integrated GaN Gate Drivers

- >3x faster than any other gate driver
- Proprietary design
- 8+ pending patents

World’s First AllGaN™ Power IC

Up to 40MHz switching, 5x higher density & 20% lower system cost
Hi-Speed Devices
(V/ns)
GaN Power IC: Hi-Speed FET, Drivers & More

- Proprietary AllGaN™ technology
- **Monolithic** integration of GaN FET, GaN Driver, GaN Logic
- 650 V eMode
- 20x lower drive loss than silicon (<35 mW at 1 MHz)
- Driver impedance matched to power device
- Very fast (prop delay and turn-on/off of 10-20 ns)
- Zero inductance turn-off loop
- High dV/dt immunity (200 V/ns) with control
- Digital input
- Complete layout flexibility

Fast & Clean High Voltage Transitions

- Prop delays 10-20 ns
  - From PWM input to 10% of FET $V_{DS}$ change
- Turn-on & turn-off times 10-15 ns
- Zero gate loop inductance
Speed & Integration ➔ Eliminate Turn-off Losses

External drivers
- Significant turn-off losses
- Just 1-2 nH of gate loop inductance can cause voltage spikes that create unintended turn-on of the GaN FET
- Adding a gate resistor reduces spikes but slows down the circuit creating additional losses

Integrated GaN drivers (iDrive™)
- Eliminate the problem
- Negligible turn-off losses
GaN Power IC – Fast & Efficient

- 500 V Switching
- No overshoot / spike
- No oscillations
- ‘S-curve’ transitions
- Zero Loss Turn-on
- Zero Loss Turn-off
- Sync Rectification
- High frequency
- Small, low cost magnetics
Hi-Speed Magnetics
(mTesla x MHz)
Frequency Drives Size: EMI Filter

Conductive frequency range: 150 kHz - 30 MHz

EMI filter size reduces when $F_{SW} > 150$ kHz

Similar

3x smaller
High Frequency ➔ Small Size ➔ Low Cost

Size Reduction

- 75%

Cost Reduction

PFC

CM EMI

DM EMI

Switching Frequency (kHz)

Normalized Cost ($)

- 40%

Magnetics & EMI Filters
Hi-Speed Systems
(MHz → W/in³)
GaN Power ICs enable Hi-Density Adapters

3x Higher Density with 50% Energy Savings

Existing Si-based 150W

100 kHz
5-10 W/in³
88%

AllGaN™ 2016 150W

2x Higher Density

300-500 kHz
17 W/in³
>93%

AllGaN™ 2017 150W

3x Higher Density

>1 MHz
26.5 W/in³
>95%

Hi-Speed Charging
(Rate, C)
Fast Chargers ... going “GaN Fast”
3x Fast Charging with 50% Energy Savings

Existing Si-based 15W

<table>
<thead>
<tr>
<th>AllGaN™ 2016</th>
<th>AllGaN™ 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>25W</td>
<td>25W</td>
</tr>
<tr>
<td>2x Faster Charging</td>
<td>3x Faster Charging</td>
</tr>
<tr>
<td>300-500 kHz</td>
<td>&gt;1 MHz</td>
</tr>
<tr>
<td>11 W/in³</td>
<td>17.5 W/in³</td>
</tr>
<tr>
<td>&gt;92%</td>
<td>&gt;95%</td>
</tr>
</tbody>
</table>

100 kHz
Up to 6.5 W/in³
88%

Smartphones & Tablets
Fast-charging Drones
AR / VR & Wearables

Accelerating Wireless Power

Existing Silicon-based multi-stage wireless power

AC-DC Adapter
88% Efficiency

DC-DC
94% Efficiency

Power Amplifier
93% Efficiency

Wireless Transfer
90% Efficiency

Single-Stage Amplifier
90% Efficiency

- 650 V GaN Power ICs
- 3-stages integrated in 1-stage
- 6.78 MHz Operation
- High-Efficiency

AirFuel™ Alliance

- Multi-stage Efficiency: 77%
- GaN-enabled single stage: 90%
- 20% lower system cost
- 3x faster charging

GaN-enabled single stage: 90%

Existing Silicon-based multi-stage wireless power

AC-DC Adapter
88% Efficiency

DC-DC
94% Efficiency

Power Amplifier
93% Efficiency

Wireless Transfer
90% Efficiency

Single-Stage Amplifier
90% Efficiency

- 650 V GaN Power ICs
- 3-stages integrated in 1-stage
- 6.78 MHz Operation
- High-Efficiency

Navitas

Multi-stage Efficiency: 77%

GaN-enabled single stage: 90%

20% lower system cost

3x faster charging

Efficiency vs. Output Power
Hi-Speed Adoption ($B/yr)
A Hi-Speed Disruption in Power...

- Linear Regulators
- Switching Regulators
- Switching Regulators
- HF Switching Regulators

Power Density (W/in³)

- 1975: 40% efficiency
- 1985: 80% efficiency
- 2015: 90% efficiency
- 2025: 95-99% efficiency

- 2x Energy Savings
- 3x Lower $/W

- <10%/yr improvement over 30 years
- 5x Increase in 10 years
- 5x Increase in 10 years

AC-DC Converters in the <300W range
Join the High-Speed Revolution
Start Your Engines

MHz+