GaN – Powerful, Efficient, Reliable

David Chen, Co-chair PSMA Energy Management Committee
Director, Applications Engineering, Power Integrations
CPSSC-PSMA Workshop 2019

david.chen@power.com
Applications with Size **AND** Efficiency Needs

- Aftermarket USB PD adapters
- High-end cellphone chargers and other mobile devices
- Notebook adapters

- Products with size **OR** efficiency needs
  - Appliances, TVs, server standby, AIO PCs, video games
Adapter and Wall Socket Designs

Slick

Slim

Multiport

Powerful

Compact
Making GaN Easy to Use

• GaN transistors are better than silicon
  • More efficient, cooler, smaller power supplies
  • Leading the way to “no-heatsink” designs at high power levels

• GaN transistor technology is the future for power conversion

• GaN devices can be used just like other power devices
  • Engineers see significant performance benefits
  • But won’t otherwise notice a change
GaN Switches Significantly Reduce Losses

• MOSFET output capacitance is discharged through itself at turn-on
  • Parasitic capacitances are proportional to the size of the MOSFET
  • Bigger MOSFET = more switching loss
    • Also lower $R_{DS(ON)}$ means less conduction loss

\[
P_{\text{(Loss)}} = \frac{f \cdot C_{\text{OSS}} \cdot V^2}{2}
\]
\[f = \text{Switching frequency}
\]
\[V = \text{Peak of VAC} \sim 400 \text{ V}
\]
Switching Losses Increase with FET Size
Conduction Losses Decrease with FET Size

Conduction losses and switching losses work in opposite directions
GaN Switches Change the Curve

- Power Lost in Switch
  - Total Power Loss (MOSFET)
  - Total Power Loss GaN
  - Switching Loss (MOSFET) $\propto CV^2$
  - Switching Loss GaN
  - Conduction Loss - MOSFET $\propto I^2R$
  - Conduction Loss GaN

- Size of switching device
GaN-Based Design Achieves 95% Efficiency—Eliminates Heatsinks from Adapters

- 65 W, 20 V Adapter: Full-load efficiency is 95% at 230 VAC and 94% at 115 VAC
GaN High Efficiency Also Improves Performance Across Load for 60 W USB PD

• High efficiency across load
  • Ideal for high-power USB PD applications

• Average efficiency is 92.5% at 115 VAC and 93.2% at 230 VAC
Be Confident About Reliability

• Fully qualified to JEDEC standard
  • Same standard as all other products

• Easily passed additional accelerated operating life tests
  • DOPL JESD22-A108 1,000 hr. TJ = 125 °C
  • HALT JESD22-A104 1,000 hr. TJ = 125 °C, at 85 °C / 85% R.H.

• 750 V non-repetitive rating
  • Ideal for wide-range, single-ended, hard-switching flyback converters
# GaN Qualification Mirrors Silicon Product Qualification Protocol

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Symbol</th>
<th>Test Method</th>
<th>Silicon-based product</th>
<th>GaN-based product</th>
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</thead>
<tbody>
<tr>
<td><strong>Fab Process</strong></td>
<td></td>
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<tr>
<td>Preconditioning &amp; Moisture Sensitivity Level</td>
<td>PC</td>
<td>JESD22-A113</td>
<td>MSL3</td>
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<td>JEDEC J-STD-020</td>
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<td>Temperature Humidity Bias</td>
<td>THB</td>
<td>JESD22-A101</td>
<td>Multiple units, multiple lots</td>
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<td>Temperature Cycling</td>
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<td>JESD22-A104</td>
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<td>High Temp. Storage Life</td>
<td>HTSL</td>
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<td>DOPL</td>
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<td><strong>Fab and Package</strong></td>
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<tr>
<td>Highly Accelerated Life Test</td>
<td>HALT</td>
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<td>High Temp. Reverse Bias</td>
<td>HTRB</td>
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<td><strong>Packaging Process</strong></td>
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GaN is Extremely Robust

- **GaN is Extremely Robust**
  - GaN is known for its high efficiency and fast switching speed,
  -Typical margin (150 V)
  -Gives de-rating of > 80%

**Event Voltage**

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<td>0 - 650 V</td>
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<tr>
<td>651 - 750 V</td>
<td>Non-repetitive</td>
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**Safe Surge Voltage Region (SSVR)**

- **Typical margin (150 V)**
- **Gives de-rating of > 80%**

**Primary Switch Voltage Stress (264 VAC)**

- **750 V** = \( V_{\text{MAX}}(\text{non-repetitive}) \)
- **650 V** = \( V_{\text{MAX}}(\text{continuous}) \)
- **~530 VDC**
- **380 VDC**
Flyback Switching Waveforms

- Voltage and Current waveforms on GaN FET for typical operation at 265 VAC input
Efficiency over Line Voltage
Surge Performance Evaluation

• Methodology for surge testing based on IEC 61000-4-5 standard

• Combination Wave Generator (CWG) used in evaluation
  • 1.2/50us voltage surge waveform
  • 50 strikes per VDE 0884-11 standard

• Converter conditions
  • Operating when surge strikes applied
  • Input bus voltage of 375V (265VAC)
  • Steady-state peak drain voltage of 550V on GaN FET
Waveforms During Surge Event

- DC Bus voltage peak = 664V
- Peak Voltage across GaN FET > 650V
- Peak VDS = 830V
- VDS plateau = 774V
- Surge strike instant
- Surge Input
- DC Bus voltage ~ 375V

Measure values:
- P1: max(C3) 830 V
- P2: min(C1) -124 V
- P3: max(C1) 100 V
- P4: max(C4) 664 V
- P5: min(C4) 338 V

Status:
- "Good"
- "Normal"
- "Negative"
- "Positive"
- "Timebase 0.000 ms"
- "Trigger 0.000 ms"
- "Zoom 0.000 ms"
- "500 mV/Div"
- "250 MS/s"
- "12.5 MS/s"
No Degradation of Converter Efficiency

Negligible Change in Efficiency on 10 Production Units after Surge Test (at 265V\textsubscript{AC})

Negligible Change in Efficiency on 10 Production Units after Surge Test (at 90V\textsubscript{AC})
GaN – Powerful, Efficient, Reliable

• GaN devices deliver more power
  • Reduced on-resistance
  • Lower switching loss

• Circuit operation indistinguishable from one using silicon devices

• GaN reliable, qualified, and shipping in mass production
Thank you!