GaN Power ICs: 
Device Integration Delivers Application Performance

5th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA)
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Fast GaN, Slow Adoption?

2012 Forecast = $1.9B by 2020!

2017 Forecast = $180M by 2020

Source: Yole 2012, 2017
Faster with AllGaN™ Integration!

Source: Yole 2012, 2017
World’s First AllGaN™ Power ICs

Fastest, most efficient GaN Power FETs
>20x faster than silicon
>5x faster than cascoded GaN
Proprietary design

iDrive First & Fastest Integrated GaN Gate Drivers
>3x faster than any other gate driver
Proprietary design
30+ patents granted/applied

World’s First AllGaN™ Power IC

Up to 40MHz switching, 5x higher density & 20% lower system cost
The Drive for Better Drivers

- Low $V_{TH}$
- Low $R \times Q$
- Low $V_{GS\_Max}$

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Discrete FET + Discrete Driver
## The Drive for Better Drivers

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**No compromises**

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Galan Power IC
Clean, Controlled FET Gate

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

- **iDrive™ GaN Power IC**
  - No gate loop parasitic
  - Clean and fast gate signal
Integrated Drive ➔ Simple & Robust

- Wide Range $V_{CC}$ (10-30V)
- Regulator ensures $V_{GS}$ within SOA
- PWM Hysteresis for noise immunity
- No inductance or ringing in gate loop
- Total layout flexibility & simplicity
- Gate protected from external noise

![Graph showing PWM and $V_{GS}$ signals with specified divisions.]
Fast & Clean Hard Switching

IC Prevents Noise Coupling Into Gate

Zero Gate Loop Inductance
Eliminate Turn-off Loss

Clean HV Hard Switching
Prop Delay 10-20 ns

PWM

Driver

Load

VDD

V_{IN}

\( L'_{s} \)

\( L_{d} \)

\( L_{\text{load}} \)
Voltage Slew-Rate Control ... Easy EMI Tuning

dV/dt controllable from 180 V/ns to 10 V/ns
Discrete GaN

Low $C_{iss} \rightarrow$ Fast switch, but...

HBM < 250 V (typical)

GaN Power IC

VS.

Integrated ESD Protection

HBM, CDM > 1,000 V
Using Integration to Improve Power Density

- **Hard-switching** vs. **Soft-switching**
  - Hard-switching: Decreases efficiency with increasing frequency.
  - Soft-switching: Maintains higher efficiency across a wider frequency range.

**GaN Power IC** uniquely enables a simultaneous increase in frequency and efficiency, as depicted by the graph.

**Half-Bridge Building Block**

- **ZVS**
- **PQFN 6x8 mm**
- **Simplified Schematic**

**Soft-switching** allows simultaneous increase in frequency and efficiency uniquely enabled by GaN power ICs.
High-Frequency Half-Bridge Integration

Disparate Technologies
Hybrid isolator, discrete driver, discrete power, bootstrap diode

High Power Loss
• Driver loss, $R_G$ loss
• Bootstrap diode $Q_{RR}$, $V_F$
• Pulsed high current level shifter power (?)

Low Power Loss
• No gate driver loop parasitics, matched driver-FET capability, negligible loss vs frequency
• Zero $Q_{RR}$, low $V_{DS}$ in synchronous charging
• Extremely fast, low-power level-shifter, multi-MHz operation, short propagation delay
Simple, Powerful, Efficient, Cost-Effective

- Internal level-shift & bootstrap circuits
- Monolithic integration
- Single component
- Ground-referenced control
- Active Clamp Flyback, Half-Bridge, LLC, etc.
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
Complex Design ➔ Made Simple

Half-Bridge *Discrete* GaN

- 20x smaller PCB area
- 40+ fewer components
- Lower cost
- Robust & protected
- Simple
- Easy layout

PCB Area: 24 x 42 ~ 1,000 mm²

Half-Bridge GaN *Power IC*

PCB Area: 6 x 8 = 48 mm²
The World’s Smallest 65W USB-PD Adapter

MacBook <100 kHz
<6.5 W/in³, 92%

✓ 3-4x power density
✓ 20% lower loss

Navitas 300 kHz
24 W/in³, 94%
= 45 cc cased

Efficiency measured at 90 V_{AC}, 100% load, at PCB
Best-in-Class Efficiency, Cool Operation

![Graph showing efficiency at different loads for Navitas and MacBook 60 W Adapter.](image)

- **Navitas**: 24 W/in³
- **MacBook 60 W Adapter**: 6.5 W/in³

**Load**
- 0%
- 25%
- 50%
- 75%
- 100%

**Efficiency (115 Vₜₐ_c)**
- 87%
- 89%
- 90%
- 91%
- 92%
- 93%
- 94%
- 95%

**Conditions**
- 115Vₜₐ_c, 65W, 20V_OUT
- Temperature:
  - SR: 79 °C
  - Bridge: 82 °C
  - GaN Power IC: 77 °C
65W Charger Roadmap

Power Density (cased, W/in³ ~ Charging Rate)

- **1x Charging**: 88% Efficiency
- **2x Charging**: 93.5% Efficiency
- **2.5x Charging**: 94% Efficiency
- **3x Charging**: 94.5% Efficiency

Switching Frequency (kHz)

- 100
- 300
- 600
- 1,000

Reduced $ BOM Cost

Efficiency at worst case (90V ac, full load)

Navitas
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