New GaNSense Half-Bridge IC Enables Next Gen High-Frequency, High-Efficiency, High-Density Topologies

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Presentation Outline

• GaNFast Power IC Evolution
• GaNSense Half-Bridge IC
• Loss Less Current Sensing
• Soft Switching
• High-Speed Topologies
• 140W-1C TTP+AHB Charger
• Motor Drive Inverter
• Conclusions & Questions
GaNFast Power IC Evolution

- Enable GaN
- Int. gate drive + dV/dt ctrl
- Int. LDO
- Regulated gate drive voltage
- Wide range VCC & PWM
- 2kV ESD
- 650VDScont/800VDSmax
- Large cooling pad

High performance GaN
- Loss-less current sensing (+0.5% efficiency)
- Int. gate drive + LDO + VREF + dV/dt ctrl
- OCP + OTP protection circuits
- Wide range VCC & PWM
- 2kV ESD
- 700VDScont/800VDSmax
- Large cooling pad

High performance GaN half-bridge
- Int. level shift + bootstrap
- Loss-less current sensing (+0.5% efficiency)
- Int. gate drive + LDO + VREF + dV/dt ctrl
- OCP + OTP protection circuits
- Wide range VCC & PWM
- 2kV ESD
- 650VDScont/800VDSmax
- Large cooling pads
GaNSense Half-Bridge IC = Highest Integration, Smallest Size, Highest Efficiency & Largest Cooling Pads
Loss Less Current Sensing = +0.5% EFF Benefit & No PCB Hot-Spot

No $R_{\text{SENSE}}$ = +0.5% Efficiency Benefit

No $R_{\text{SENSE}}$ = No PCB Hot-Spot

**NV6125**
- $R_{\text{DS(ON)}} = 170 \text{ m}\Omega$
- $R_{\text{CS}} = 170 \text{ m}\Omega$
- $R_{\text{ON(TOT)}} = 340 \text{ m}\Omega$

![](image)

**NV6136**
- $R_{\text{DS(ON)}} = 170 \text{ m}\Omega$
- $R_{\text{CS}} = 0 \text{ m}\Omega$
- $R_{\text{ON(TOT)}} = 170 \text{ m}\Omega$

![](image)

**0.5% higher efficiency, same $R_{\text{DS(ON)}}$, lower $R_{\text{ON(TOT)}}$**
Soft Switching + GaNFast Power ICs = High Frequency & High Efficiency

**Primary Silicon FET & external RCS Power Loss:**

\[ P_{FET} = P_{COND} \times k + P_{DIODE} + P_{T-ON} + P_{T-OFF} + P_{DR} + P_{QRR} + P_{QOSS} \]

- \( R_{DS(ON)} \) Loss
- Duty Cycle Loss
- Reverse Conduction Loss
- Switch-ON Transition Loss
- Switch-OFF Transition Loss
- Gate Drive Loss
- Reverse Recovery Loss
- Output Capacitance Loss

\[ P_{RCS} = P_{COND} \]

**Primary GaNFast Power IC & GaNSense Loss-Less Current Sensing Power Loss:**

\[ P_{FET} = P_{COND} \times k + P_{DIODE} + P_{T-ON} + P_{T-OFF} + P_{DR} + P_{QRR} + P_{QOSS} \]

\[ P_{RCS} = P_{COND} \]

Soft-switching and GaNFast Power ICs **ELIMINATE** turn-on & reverse recovery losses & **MINIMIZE** drive, deadtime, and device charging losses.

GaNSense loss-less current sensing **ELIMINATES** RCS conduction losses.
Enabling Next Gen, High Speed Topologies

- High frequency
- High efficiency
- High integration
- High power density

Efficiency

- Low frequency
- Low efficiency
- Low power density

Silicon
- LF: FLYBACK
  <= 65 W
  < 100 kHz
  90%
  0.5 W/cc

HFQR
- <= 65 W
- 200 kHz
- 92%
- 1.0 W/cc

HFQR
- <= 50 kHz
- 1 MHz
- 93%
- 1.2 W/cc

GaN Sense™ Half-Bridge
- ACF
- <= 65 W
- 500 kHz – 1 MHz
- 93%
- 1.2 W/cc

GaN Sense™ Half-Bridge
- PFC + HFQR
- 100-120 W
- 150 kHz
- 92.5%
- 1.4 W/cc

GaN Sense™ Half-Bridge
- TTP + AHB
- 200-300 W
- 500 kHz – 1 MHz
- 94.5%
- 1.6 W/cc

Power
Next Gen Half-Bridge Topologies

**Active Clamp Flyback (ACF)**
- Full ZVS mode enables high frequency operation and smaller magnetics.
- Recycles leakage energy and eliminates snubber and switching losses for higher efficiency.
- Reduced voltage spikes allows for lower voltage, higher performance SR FETs on secondary side.

**Asymmetrical Half-Bridge (AHB)**
- Full ZVS mode enables high frequency operation and smaller magnetics.
- Higher duty-cycle, recycled leakage energy, no snubber, and no switching losses for higher efficiency.
- VDS voltage limited to DC bus level for reduced pri & sec voltage stress.
- Wide Vout range for PD3.1 applications.

**Bridgeless Totem-Pole (TTP)**
- Replaces half of input diode bridge with active switches for higher efficiency.
- Increases switching frequency for smaller boost inductor.
- Zero Qloss of GaN significantly reduces reverse recovery losses.
- 98-99% efficiency, depending whether diodes are replaced with low Rdson FETs.

**LLC Resonant**
- Full ZVS mode enables high frequency operation and smaller magnetics.
- 50% duty cycle for high flux cancellation and highest transformer efficiency.
- VDS voltage limited to DC bus level for reduced pri & sec voltage stress.
- Ideal for fixed Vout applications.
AHB = Asymmetrical Half-Bridge

**AHB Benefits**
- High efficiency → Reduces losses, enables small charger size
- ZVS operation → Enables HF, reduce component size/cost
- No reflected Vout → Reduced VDS stress
- Variable Vout → Enables USB-C PD3.1
TTP = Totem Pole PFC

TTP Benefits
✓ No Input Bridge ➔ High efficiency
✓ GaN Zero Qrr ➔ CRM & CCM modes
✓ GaN High Frequency ➔ Small inductor size

AC

\[ L_{\text{PFC}} \]

\[ D_1 \]

\[ D_2 \]

\[ C_{\text{cap}} \]

\[ \text{LOAD} \]

Positive AC line cycle

Negative AC line cycle
140W-1C TTP+AHB = 130cc = 1.1W/cc

- PCBA size: 60 x 60 x 25mm = 90cc
- Cased size (est.) = 65 x 65 x 30mm = 130cc
- Power Density = 1.1 W/cc
Clean & Sinusoidal TTP Waveforms

Boost Circuit Waveforms (Vin=115VAC, Po=140W)

AC Input Waveforms (Vin=115VAC, Po=140W)

- Clean Boost Circuit Waveforms
- CRM Operating Mode

- Sinusoidal Input Current
- High Power Factor = 0.997
Clean & Smooth AHB ZVS Waveforms

- AHB Tank Current
- Resonant Mode Operation

- GaN Half-Bridge Switched Node
- Resonant ZVS Switching
Highest Efficiency = Lowest Losses = Smallest Size

EFF = 93.5% @ 90VAC/140W/20V/7A
+1% EFF increase vs existing solutions!
GaNSense Half-Bridge ICs Enable Inverter Motor Integration

- **Motor Drive**: compact, high efficiency, reduced thermal management
- **TTP PFC**: highest efficiency, fewest components and smallest footprint
- **Aux Supply**: compact, efficient HFQR topology

- **GaN Power ICs benefits for 2kW motor drive**
  - Inverter efficiency increases 2.5% (96% → 98.5%)
  - Total losses reduced 50% (15W → 6.8W)
  - Significant reduction in cost, weight and size of thermal management (heatsink, fans, etc.)

Ref: “Autonomous GaN Power ICs Deliver High-Performance, Reliable Motor Drives”, white paper, Hesener, May 2022
Fast, Smooth, Cool & Clean Motor Drive
> 99% Efficiency

Navitas 300W 3-phase Motor Inverter Board

- Fast & Smooth Switching
- Clean Sinusoidal Waveforms
- Cool Temperatures w/out Heatsinks
- Peak Efficiency > 99%
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