“GaNFast™ Half-Bridge IC and Applications”

Qin Wei, Zhang Guoxing, Lin Dong
August 15th, 2022: Navitas Semiconductor, industry-leader in gallium nitride power ICs, acquired GeneSiC Semiconductor, silicon carbide pioneer and industry leader.
Accelerating Growth

Headcount, Valuation & Revenues

- 2014: Founded
- 2015: World's 1st GaN Power IC Prototype
- 2016: World's 1st GaN Half-Bridge Prototype
- 2017: World's Smallest 25W USB-A
- 2018: 3.2kW Data Center Prototype, World's Smallest 65W USB-PD
- 2019: World's Thinnest 45W USB-PD
- 2020: World's Smallest 300W
- 2021: 100+ Patents
- 2022: 150+ Patents

Innovation Award Honoree

- Data Center Design Center
- EV Design Center
- Industry-First GaNSense Half-Bridge

50M Shipped Zero Failures

Future

World's 1st GaN Sense Half-Bridge

- 150+ Patents
- 120+ Patents
- 20M Shipped
- Data Center Design Center
- 20M Shipped
- 40M Shipped
- EV Design Center
- Data Center, Solar, EV Validation
- 150+ Patents

IPO: NVTS

- Nasdaq

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The GaN Revolution: Ultimate Integration

**GaNFast™**

- **200-300 kHz**
  - Autonomous Standby
  - Autonomous Protection
  - Loss-less Current Sensing
  - High Precision
  - High Efficiency
  - Internal Gate
  - Integrated Gate Drive
  - dV/dt Immunity
  - Layout Insensitive
  - 2 kV ESD rating
  - Proven Reliability
  - Proven Robustness

- **Exposed gate**
- **External gate drive**
- **dV/dt sensitivity**
- **Layout sensitivity**
- **ESD sensitivity**
- **Unknown reliability**
- **Unknown robustness**

- **Silicon FET**
- **Exposed gate**
- **High Qg**
- **High COSS**
- **FSW < 100 kHz**
- **Old, slow**

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**GaNSense™**

- **500 kHz**
  - Highest integration
  - integrated HS and LS FETs
  - Integrated level-shift isolation
  - integrated boot-strap
  - Shoot-through protection
  - Enlarged cooling pads
  - Fastest switching
  - Highest efficiency

- **Fastest switching**
- **Highest efficiency**

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**GaNSense Half-Bridge**

- **1 MHz**
  - **800 Vmax**
  - **24V ESD**
  - **Over-Temperature Protection**
  - **Shoot-through Protection**
  - **Level-Shift**
  - **Drive Control Sensing Protection**
  - **Integrated Boot-strap**
  - **Enlarged Cooling Pads**

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GaNFast Half-Bridge IC with GaNSense

- **GaNSense™ Technology**
  - Integrated loss-less current sensing
  - Over-current protection
  - Over-temperature protection
  - Autonomous low-current standby mode
  - Auto-standby enable input

- **Small, low profile SMT QFN**
  - 6x8 mm footprint, 0.85 mm profile
  - Minimized package inductance
  - Enlarged cooling pads

- **Sustainability**
  - RoHS, Pb-free, REACH-compliant
  - Up to 40% energy savings vs Si solutions
  - System level 4 kg CO₂ Carbon Footprint reduction

- **Product Reliability**
  - 20-year limited product warranty

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**GaNFast Half-Bridge IC with GaNSense**

**Features**
- Two independent logic inputs with hysteresis
- 3.3, 5, 12 V PWM input compatible
- Floating high-side with internal level-shift
- 200 V/ns common mode transient immunity
- Integrated high-side bootstrap
- Shoot-through protection
- Wide $V_{CC}$ range (10 to 20 V)

- Low-side turn-on dV/dt slew-rate control
- 800 V transient voltage rating
- 650 V continuous voltage rating
- 160 mΩ high-side FET, 160 mΩ low-side FET
- Zero reverse-recovery charge
- 2 kV ESD Rating (HBM)
- 2 MHz operation

**Simplified schematic**

**Typical Application (LLC)**
GaN Integration Drives Speed, Efficiency, Stability

Discrete GaN Half-Bridge

- 33 components
- 250 mm² footprint
- External HB driver HVIC
- External HV bootstrap
- 2x HV bypass diodes
- 2x external gate drives
- Exposed gates

GaNSense Half-Bridge IC

- 61% fewer components
- 64% smaller footprint
- Complete integration

- 13 components
- 90 mm² footprint
- Level shifters
- Bootstrap
- Gate drivers
- No exposed gates

Severe Ringing & Glitching!

No Ringing, No Glitching!
Navitas: Smallest Package, Biggest Thermal Pads

NV6247 QFN6*8 Total 18.5 mm²
PGND 9.5 mm²
VSW 9 mm²

C* GaN QFN8*8 Total 12.9 mm²
PGND 6.1 mm²
VSW 6.8 mm²

S_GND Nearly no impact to thermal dissipation

M* GaN1 QFN9*9 Total 11.5 mm²
PGND 5.76 mm²
VSW 5.76 mm²
Digital In, Power Out!

Integrated Gate Drivers

GaN Half-Bridge IC Timing Diagram (ZVS Mode)

Turn-on dV/dt slew rate control

- PWM Inputs
- Integrated Level-shifter & Bootstrap
- Integrated Gate Drivers
Loss-less Current Sensing

\[ R_{DS(ON)} = 160 \, \text{mΩ} \]

\[ R_{CS} = 160 \, \text{mΩ} \]

\[ R_{ON(TOT)} = 320 \, \text{mΩ} \]

\[ R_{DS(ON)} = 160 \, \text{mΩ} \]

\[ R_{CS} = 0 \, \text{mΩ} \]

\[ R_{ON(TOT)} = 160 \, \text{mΩ} \]
Autonomous Over-Current Protection (OCP)

Discrete GaN Solution

- Existing solutions use ext. $R_{CS}$
- Filter + controller delay slow

Uses QR controller OCP function

$T_{OCP} = 180$ ns

Integrated SCP function

$T_{OCP} = 30$ ns

- Autonomous OCP
- Fast-acting self-protection
- Cycle-by-cycle protection
- Excellent robustness

6x faster protection

- QR controller OCP = slow turn-off (180 ns)
- NV6136 OCP = fast turn-off (30 ns)
# Mid-Power Circuit Topologies

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High Efficiency = Small Size

- PFC + QR
- PFC + LLC
- PFC + ACF
- PFC + AHB
- TTP + AHB

Lower EFF, Larger Size
Higher EFF, Smaller Size

140W Adapter Size [cc]
Max Load Efficiency @90 V_{ac} [%]
NV62xx in Totem-pole PFC

**TTP Benefits**

- Eliminates Input Bridge ➞ High efficiency
- GaN Zero Qrr ➞ CRM & CCM modes
- GaN High Frequency ➞ Small inductor size
Totem-pole PFC CRM Operation

Boost Circuit Waveforms ($V_{IN} = 115\, V_{AC}$, $P_{OUT} = 140\, W$)

- Clean Boost Circuit Waveforms
- CRM Operating Mode

AC Input Waveforms ($V_{IN} = 115\, V_{AC}$, $P_{OUT} = 140\, W$)

- Sinusoidal Input Current
- High Power Factor = 0.997
NV62xx in AHB converter

AHB Benefits

- **High efficiency**  →  Reduces losses, enables small charger size
- **ZVS operation**  →  Enables HF, reduce component size/cost
- **Variable V_{OUT}**  →  Enables USB-C PD3.1
AHB Resonant ZVS Switching

- AHB Tank Current
- Resonant Mode Operation

- GaN Half-Bridge Switched Node
- Resonant ZVS Switching
NV62xx in LLC converter

- Integrated gate driver
- Few peripheral devices
- Simplified system
- Small critical loop area

- LLC Controller or MCU
PD 140 W PFC+AHB

- Output: 28 V / 5 A, 20 V / 5 A, 15 V / 3 A, 9 V / 3 A, 5 V / 3 A
- PCBA: 53.6 x 53.6 x 23 mm (66 cc) = 2.1 W/cc
- Cased: 58 x 58 x 29 mm (98 cc) (estimate) = 1.4 W/cc
200 W 2C1A

- TPFC+AHB+DCDC

PCBA = 104 cc = 1.92 W/cc

- Full load AC-DC Effi. (28V) *excluding NTC

Effi. (%) vs. $V_{AC_{RMS}} (V)$

PCBA = 104 cc = 1.92 W/cc
240 W AC-DC PD3.1

- TPFC+LLC, Single 48 V Output

PCBA = 104 cc = 2.3 W/cc

- Full load AC-DC Effi. *excluding NTC

![PCBA diagram with measurements]

Efficiency (%)

90 115 230 264

V_{AC,RMS} (V)
High Speed Shrinks Passive Components

Typically, slow-speed designs have ~70% of volume used by transformer, capacitors, EMI filter, etc.

High-speed GaN IC designs shrink ‘passive’ components by ~50%\(^{(1)}\)

Half-Bridge IC delivers ~2x the power, or ~2x faster charging in the same size\(^{(1)}\)

~65 kHz Silicon
65 W 43 cc

~75 kHz GaN Discrete / MCM
65 W, 46 cc

~400 kHz GaN IC
65 W, 31 cc

~750 kHz peak Half-Bridge GaN IC
120 W, 44 cc

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(1) Sep’22 Navitas survey of 20 publicly-available Navitas and MCM example chargers and reference designs 65W - 200W. Nominal 100 cc charger size selected, power capability determines charging speed

~2x faster charging!
GaNSense half-bridges in:

- **Motor Drive:** Compact, highly efficient inverter stages with significantly reduced thermal management, elimination of per-phase current sense resistor
- **TTP PFC:** Highest efficiency, fewest components and smallest footprint
- **Aux Supply:** Compact, efficient HFQR topology
GaNSense ICs Deliver 50% Energy Savings

- 2 kW 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, other thermal components

- Benefits increase with higher switching frequency

Power Loss Comparison between IGBT, SJ-MOSFET, and GaNFast IC in Motor Drives

- 78% reduction in switching losses compared to IGBTs
- 70% reduction in switching losses compared to MOSFETs
50-300W Motors – going GaNFast!

Legacy Si-Based GE Brush-less DC (BLDC) Motor & Inverter for Washing Machine (~80% efficiency)

Navitas 300W 3-phase Platform for Inverter-Motor Integration

- 2x higher frequency
- >60% fewer components, PCB area
- 95-97% efficiency
- 80% energy savings vs Silicon BLDC
- 90% energy savings vs AC motors
- High reliability
- Fast time to market
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Datasheets, electrical (SPICE) and mechanical (.stp) models available at: https://navitassemi.com/download/
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