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

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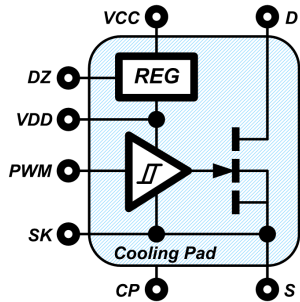
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Navitas

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
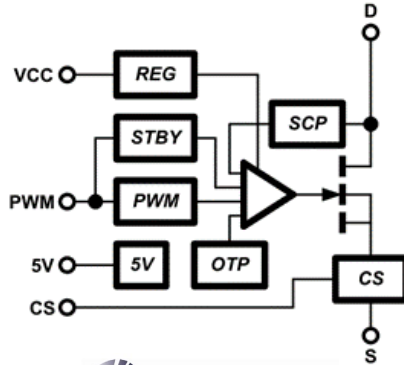
GaNFast Power IC Evolution

GaNFast™

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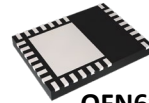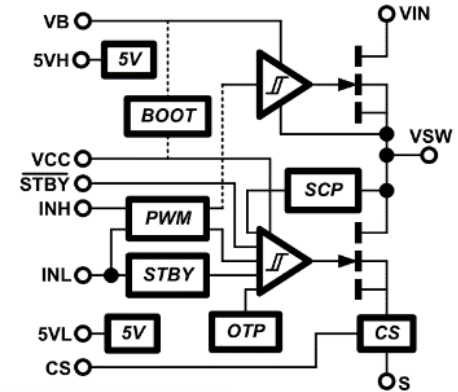- 650VDScont/800VDSmax
- Large cooling pad

QFN6x8

GaNSense™

- 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

QFN6x8

GaNSense™ Half-Bridge

- 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
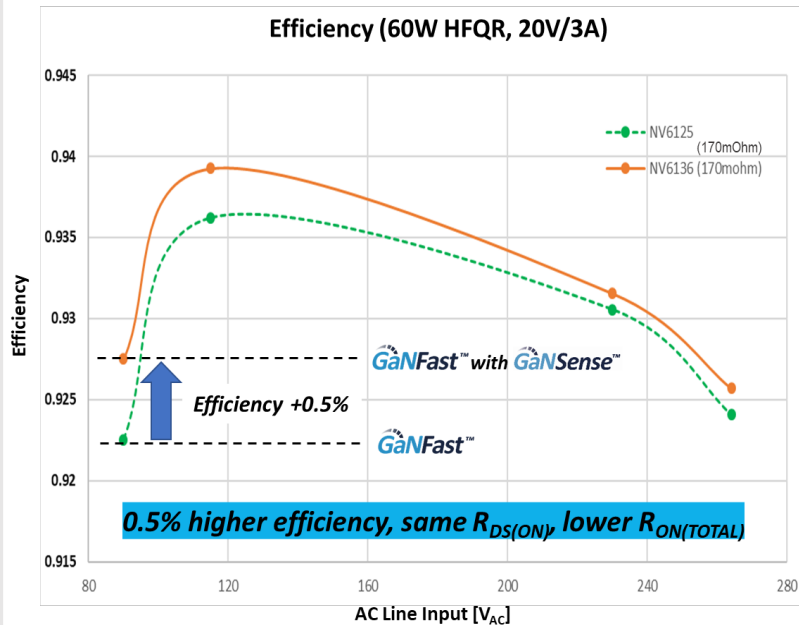- 2kV ESD
- 650VDScont/800VDSmax
- Large cooling pads

QFN6x8

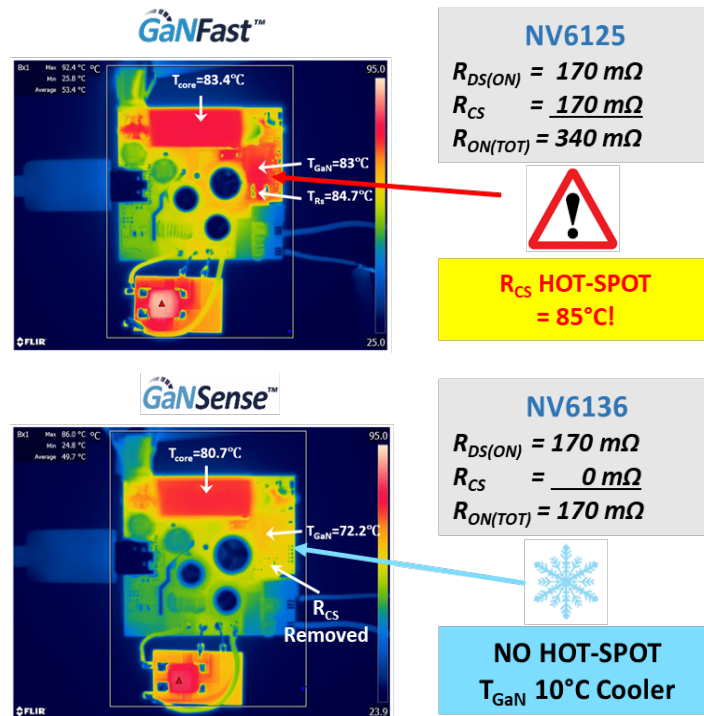# GaNSense Half-Bridge IC = Highest Integration, Smallest Size, Highest Efficiency & Largest Cooling Pads

QFN6x8
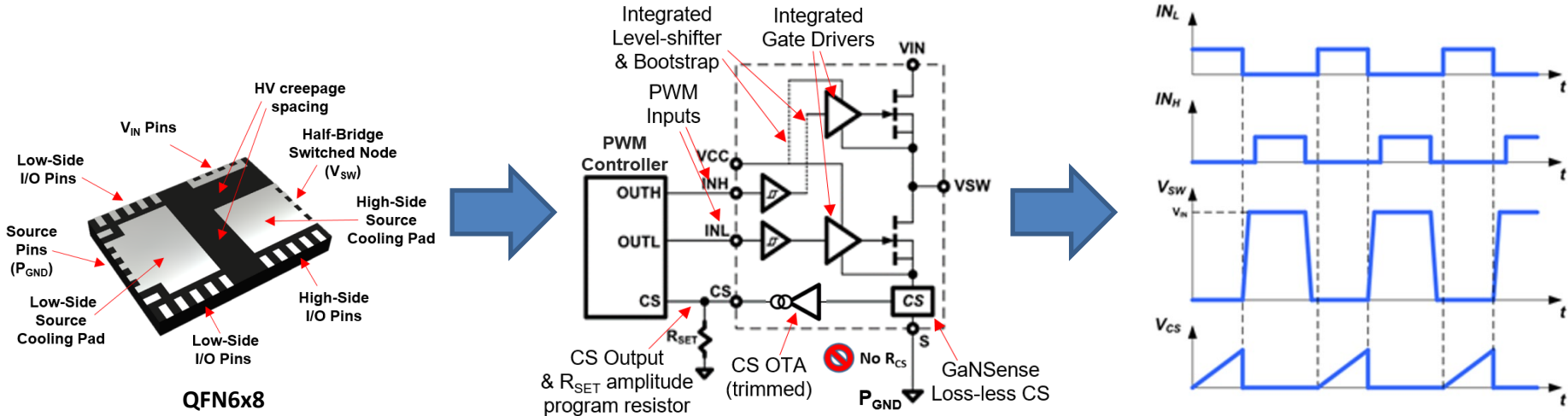
Loss Less Current Sensing = +0.5% EFF Benefit & No PCB Hot-Spot

No R$_{SENSE}$ = +0.5% Efficiency Benefit

Efficiency (60W HFQR, 20V/3A)

NV6125 (170mOhm)
NV6136 (170mohm)

GaNFast™ with GaNSense™

Efficiency +0.5%

GaNFast™

Efficiency

0.5% higher efficiency, same R$_{DS(ON)}$, lower R$_{ON(TOTAL)}$

AC Line Input [V$_{AC}$]

No R$_{SENSE}$ = No PCB Hot-Spot

GaNFast™

T$_{core}$=83.4℃

T$_{GaN}$=83℃
T$_{Rs}$=84.7℃

NV6125
$R_{DS(ON)}$ = 170 mΩ
R_{CS} = 170 mΩ
$R_{ON(TOT)}$ = 340 mΩ

R$_{CS}$ HOT-SPOT = 85℃!

GaNSense™

T$_{core}$=80.7℃

T$_{GaN}$=72.2℃

R$_{CS}$ Removed

NV6136
$R_{DS(ON)}$ = 170 mΩ
R_{CS} = 0 mΩ
$R_{ON(TOT)}$ = 170 mΩ

NO HOT-SPOT T$_{GaN}$ 10℃ Cooler

Soft Switching + GaNFast Power ICs = High Frequency & High Efficiency

Primary Silicon FET & external RCS Power Loss:

$$P_{FET} = P_{COND} * k + P_{DIODE} + P_{T-ON} + P_{T-OFF} + P_{DR} + P_{QRR} + P_{QOSS}$$

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

$$P_{RCS} = P_{COND} \longrightarrow R_{CS} \text{ Loss}$$
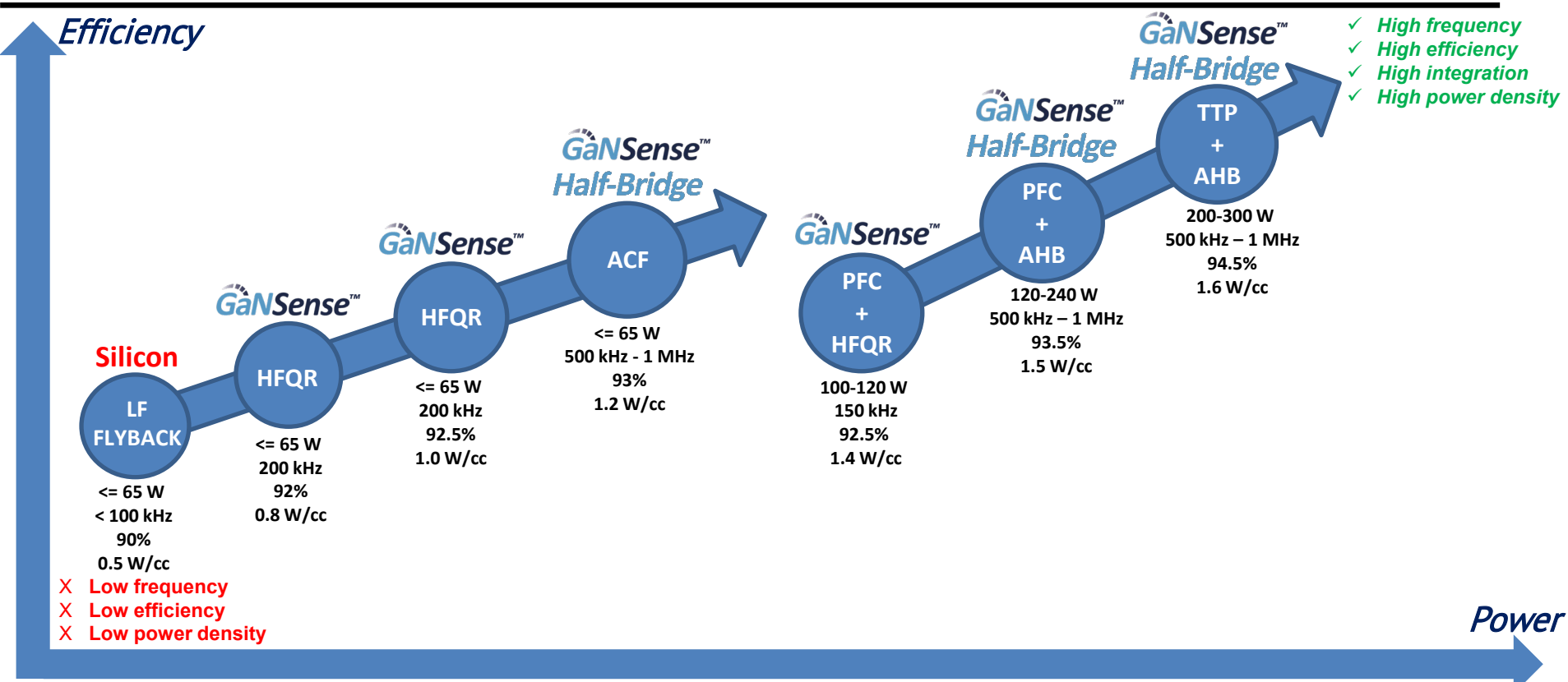
Primary GaNFast Power IC & GaNSense Loss-Less Current Sensing Power Loss:

$$P_{FET} = P_{COND} * k\text{(MINIMIZED)} + P_{DIODE}\text{(MINIMIZED)} + P_{T-ON}\text{✗} + P_{T-OFF} + P_{DR}\text{✗} + P_{QRR}\text{✗} + P_{QOSS}\text{✗}$$

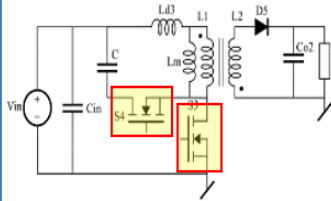$$P_{RCS} = P_{COND}\text{✗}$$

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

Efficiency

✓ **High frequency**
✓ **High efficiency**
✓ **High integration**
✓ **High power density**

GaNSense™
Half-Bridge

**TTP
+
AHB**

200-300 W
500 kHz – 1 MHz
94.5%
1.6 W/cc

GaNSense™
Half-Bridge

**PFC
+
AHB**

120-240 W
500 kHz – 1 MHz
93.5%
1.5 W/cc

GaNSense™

**PFC
+
HFQR**

100-120 W
150 kHz
92.5%
1.4 W/cc

GaNSense™
Half-Bridge

ACF

<= 65 W
500 kHz - 1 MHz
93%
1.2 W/cc

GaNSense™

HFQR

<= 65 W
200 kHz
92.5%
1.0 W/cc

GaNSense™

HFQR

<= 65 W
200 kHz
92%
0.8 W/cc

Silicon

**LF
FLYBACK**

<= 65 W
< 100 kHz
90%
0.5 W/cc

X **Low frequency**
X **Low efficiency**
X **Low power density**

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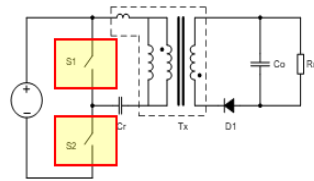
- Full ZVS mode enables high frequency operation and smaller magnetics.
- Higher duty-cycle, recycled leakage energy, no snubber, and no switching losses for higher efficiency.
- VDS voltage limited to DC bus level for reduced pri & sec voltage stress.
- Wide Vout range for PD3.1 applications.

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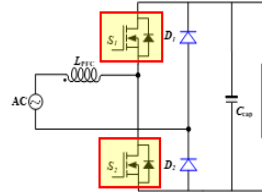
- Replaces half of input diode bridge with active switches for higher efficiency.
- Increases switching frequency for smaller boost inductor.
- Zero Q_{RR} of GaN significantly reduces reverse recovery losses.
- 98-99% efficiency, depending whether diodes are replaced with low Rdson FETs.

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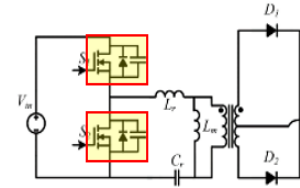
- Full ZVS mode enables high frequency operation and smaller magnetics.
- 50% duty cycle for high flux cancellation and highest transformer efficiency.
- VDS voltage limited to DC bus level for reduced pri & sec voltage stress.
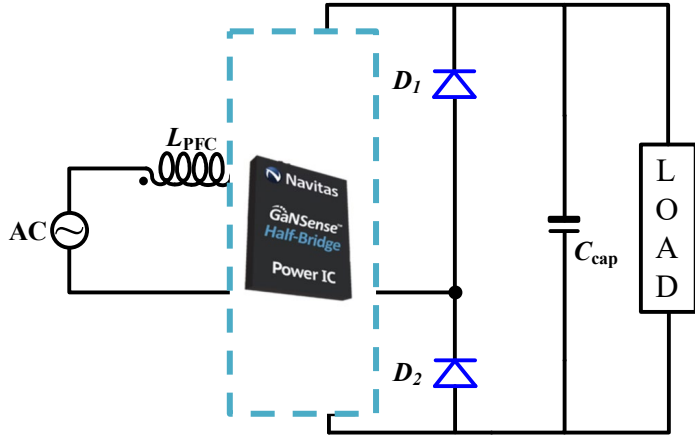- Ideal for fixed Vout applications.

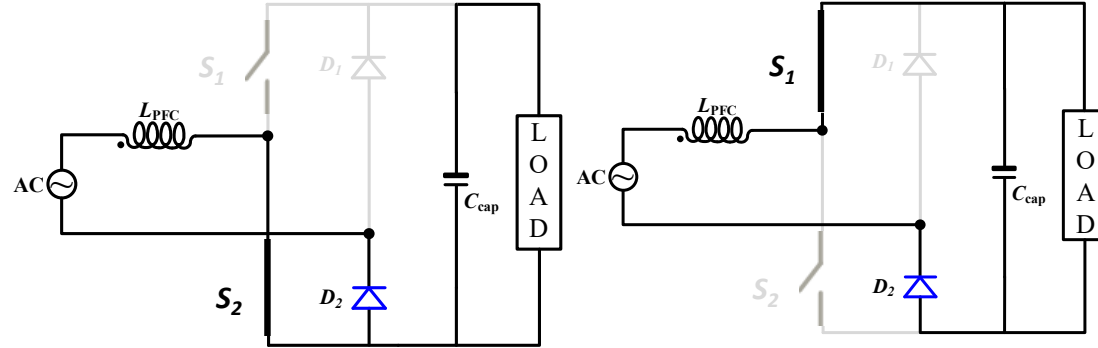# AHB = Asymmetrical Half-Bridge
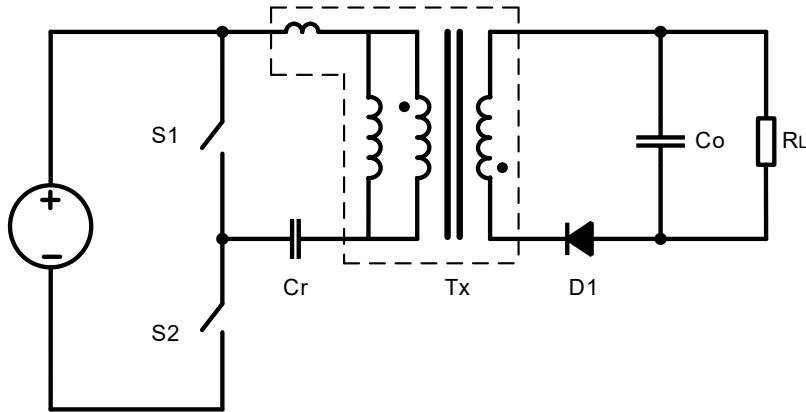
AHB Benefits

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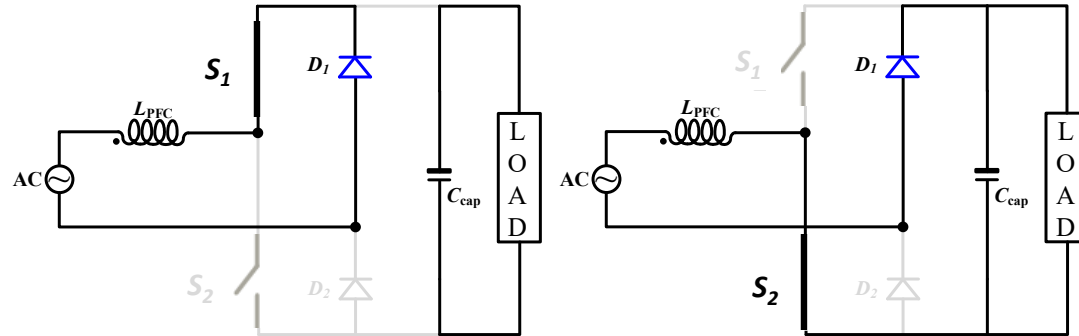✓ **Variable Vout** → **Enables USB-C PD3.1**
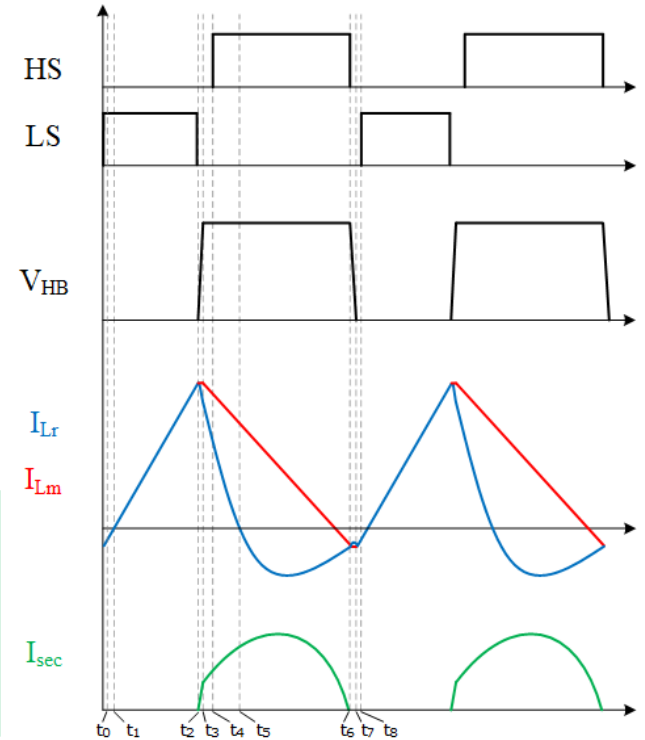
TTP = Totem Pole PFC
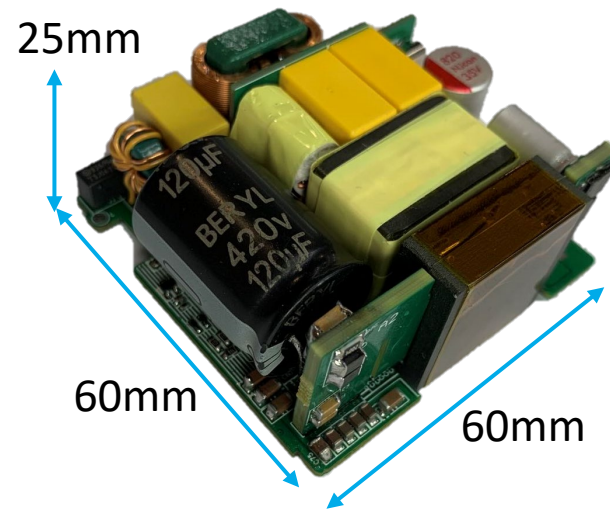
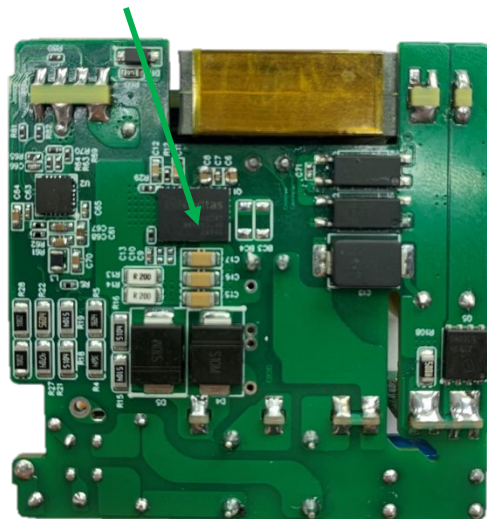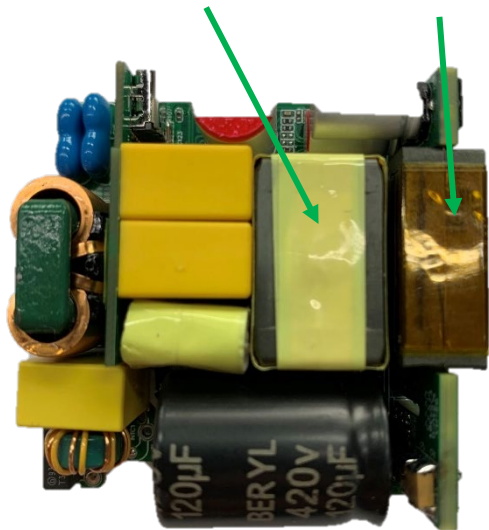**Positive AC line cycle**

Negative AC line cycle

TTP Benefits

- ✓ *No Input Bridge* → *High efficiency*
- ✓ *GaN Zero Qrr* → *CRM & CCM modes*
- ✓ *GaN High Frequency* → *Small inductor size*

140W-1C TTP+AHB = 130cc = 1.1W/cc

PFC Inductor   Planar XFMR   NV6247C

25mm
60mm
60mm

✓ **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

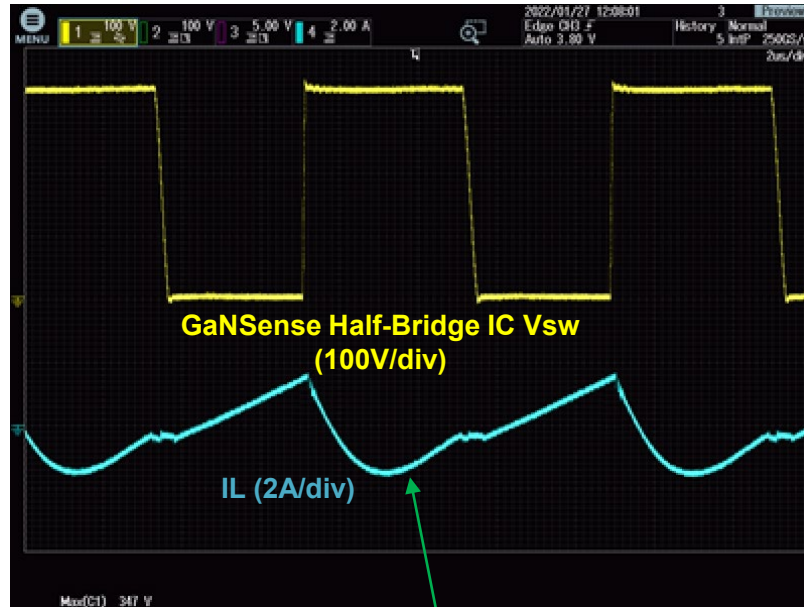**Boost Circuit Waveforms (Vin=115VAC, Po=140W)**

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

GaN Half-Bridge IC
VSW (100V/div)

IL (2.5A/div)

- **Clean Boost Circuit Waveforms**
- **CRM Operating Mode**

Vin (100V/div)

Iin (2.5A/div)
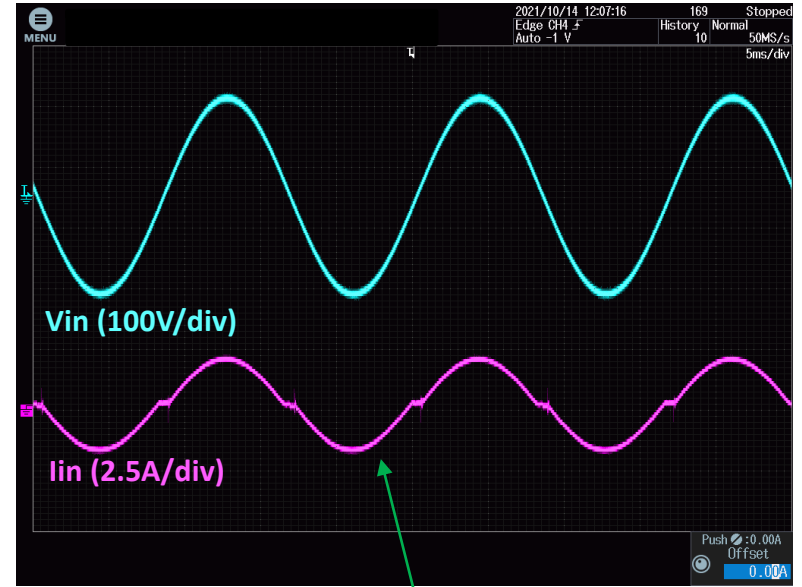
- **Sinusoidal Input Current**
- **High Power Factor = 0.997**

Clean & Smooth AHB ZVS Waveforms

GaNSense Half-Bridge IC Vsw (100V/div)

IL (2A/div)

- AHB Tank Current
- Resonant Mode Operation

GaNSense Half-Bridge IC Vsw (100V/div)

IL (1A/div)
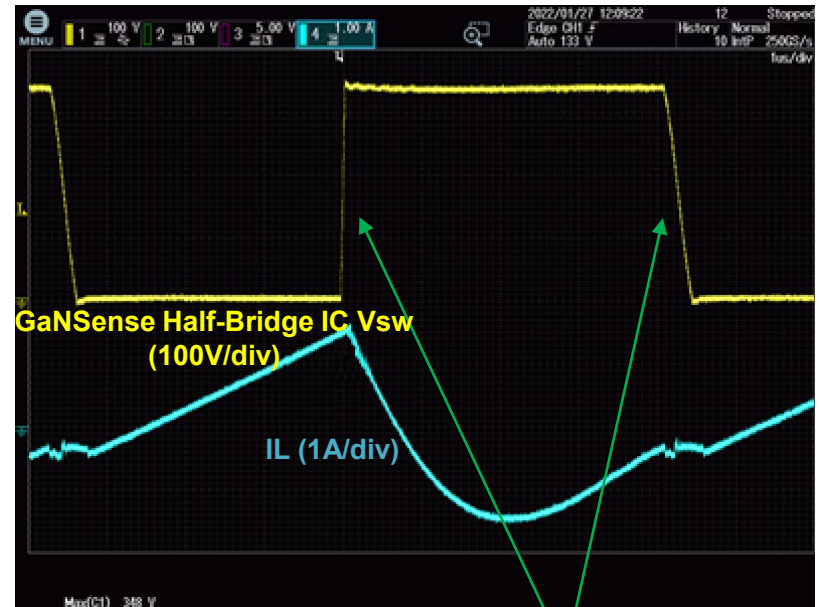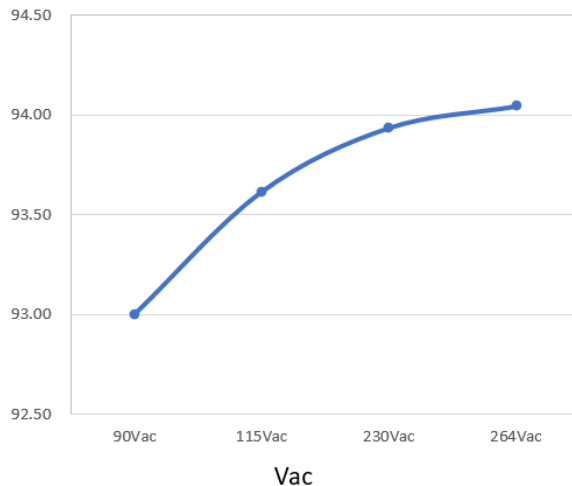
- GaN Half-Bridge Switched Node
- Resonant ZVS Switching

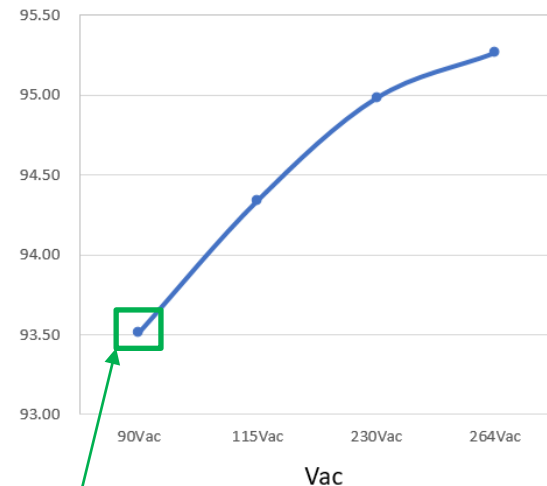# Highest Efficiency = Lowest Losses = Smallest Size

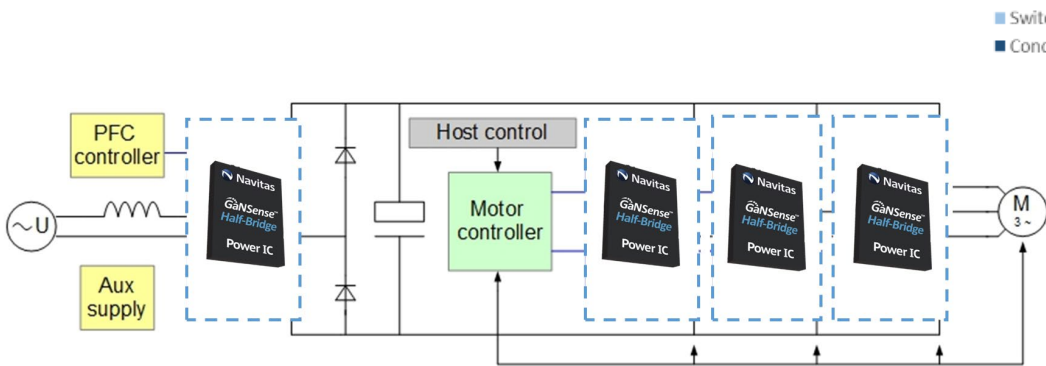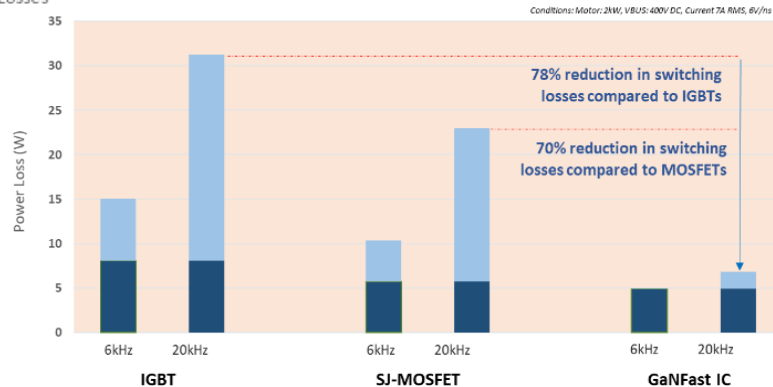## 4 Point Efficiency
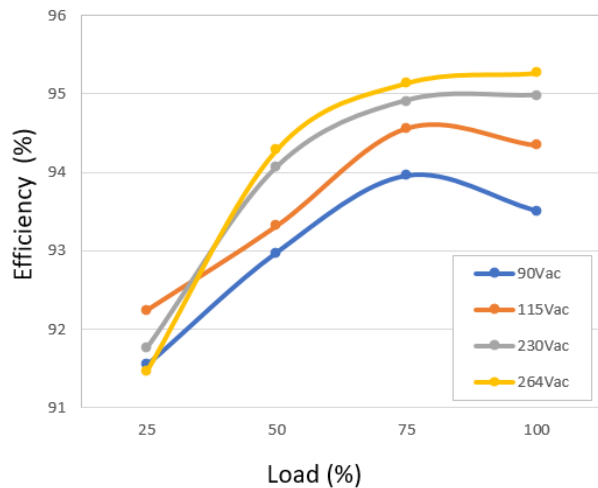
Average Efficiency

Max Load Efficiency

> ➤ **EFF = 93.5% @ 90VAC/140W/20V/7A**
> ➤ **+1% EFF increase vs existing solutions!**

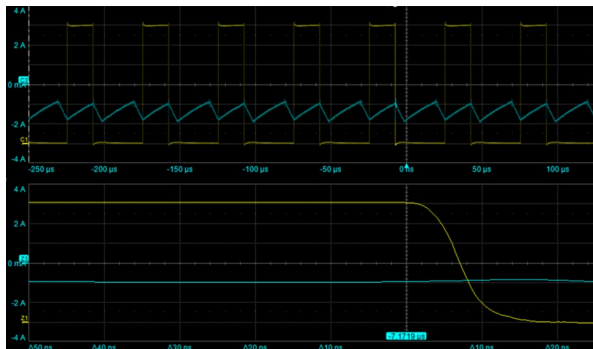# GaNSense Half-Bridge ICs Enable Inverter Motor Integration

- **Motor Drive**: compact, high efficiency, reduced thermal management

- **TTP PFC**: highest efficiency, fewest components and smallest footprint

- **Aux Supply**: compact, efficient HFQR topology

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

Conditions: Motor: 2kW, VBUS: 400V DC, Current 7A RMS, 6V/ns

78% reduction in switching losses compared to IGBTs

70% reduction in switching losses compared to MOSFETs

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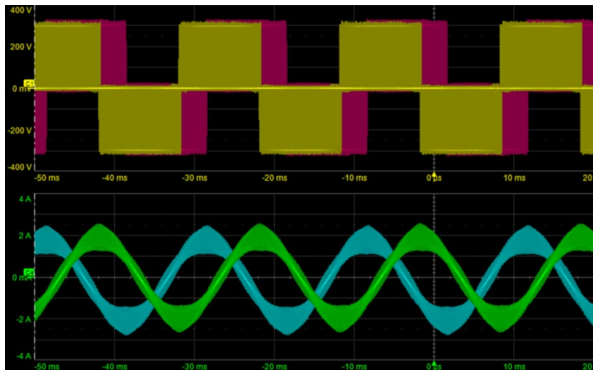
Ref: "Autonomous GaN Power ICs Deliver High-Performance, Reliable Motor Drives", white paper, Hesener, May 2022
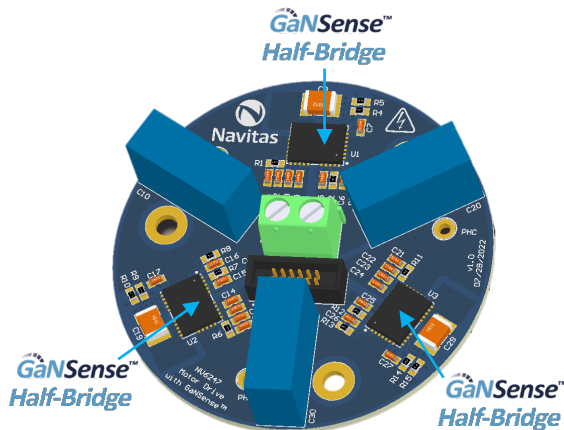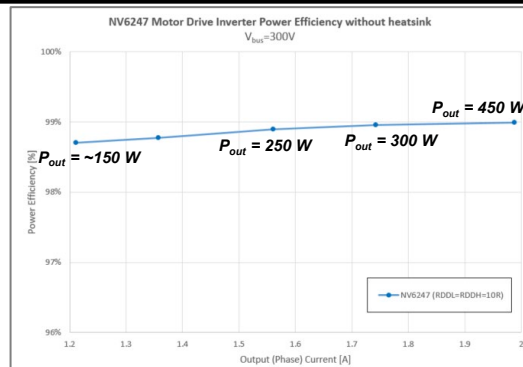
Fast, Smooth, Cool & Clean Motor Drive > 99% Efficiency
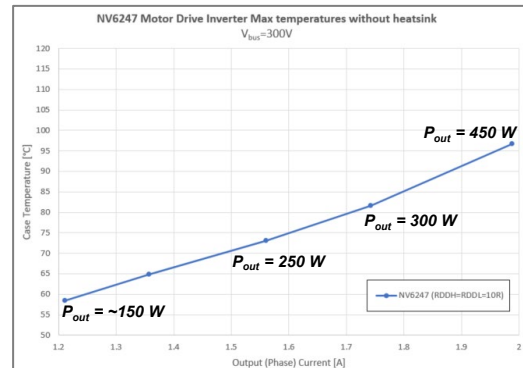

✓ **Fast & Smooth Switching**

✓ **Clean Sinusoidal Waveforms**

GaNSense™ *Half-Bridge*

GaNSense™ *Half-Bridge*

GaNSense™ *Half-Bridge*

**Navitas 300W
3-phase Motor
Inverter Board**

NV6247 Motor Drive Inverter Power Efficiency without heatsink
V_{bus}=300V

P_{out} = ~150 W
P_{out} = 250 W
P_{out} = 300 W
P_{out} = 450 W

NV6247 (RDDL=RDDH=10R)

✓ **Peak Efficiency > 99%**

NV6247 Motor Drive Inverter Max temperatures without heatsink
V_{bus}=300V

P_{out} = 450 W
P_{out} = 300 W
P_{out} = 250 W
P_{out} = ~150 W

NV6247 (RDDH=RDDL=10R)

✓ **Cool Temperatures w/out Heatsinks**

Acknowledgements & Questions

Special Thanks To:
- **_Xiucheng Huang (Navitas)_**
- **_Akos Hodany (Navitas)_**