GaN Integrated Circuits for Highest Performance Power Supplies

Thierry Bouchet, Dominique Bergogne
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www.ganwise.com  thierry.bouchet@ganwise.com
How to integrate power blocks delivering 15W (smartphone) up to 60W-100W (computer/display/TV)?

Business model

Innovative patented circuit architecture for AC/DC Power supply

Design expertise and improved GaN/Si Design Kit for GaN IC

National R&D center

GaNWise Fabless company

Offer to market

Gan-ICs
Power + driver
Mass production (TMSC)
Reference design
Application support
How to integrate power block delivering 15W (smart phone) up to 60W - 100W (computer / display / TV)?

**Business environment**

- **Innovation from national R&D center**
- **Industrial partner for applications**
- **Industrial partner for manufacturing**

**GANWISE Fabless company**

- **15W**
- **100W**
- **500W**
- **3kW**

- **Wall outlet**
- **Charger**
- **TV displays**
- **Data centers**

**Applications:**
- Battery Operated Consumer Electronics
- House Hold Power Supplies, Charger
- TV displays, datacenters
Breakthrough: size & efficiency

Integration of GaN IC with Innovative Architectures

Power density (W/inch³)

- 45
- 30
- 15

Efficiency

- 90%
- 94%
- 98%
- 100%

Volume reduction x 6

Conventional Silicon Based designs
GaN integration: Why?

GaN for power conversion has now proved its ability to enable higher operating frequencies and higher efficiency, however...

- High frequency means high speed commutations,
- High speed commutation (high \( \frac{dv}{dt} \) and \( \frac{di}{dt} \)) produces unwanted perturbations due to *stray inductances* in the circuit, \( V = L \frac{di}{dt} \). Stray inductances come from packaging and coppers tracks in PCB connecting various elements in the power signal path.

→ Integrating along the power path reduces stray inductance and allows fast and clean commutations.

→ GaN integration means getting the power transistors together with the gate drivers on the same die to start with.
Our innovative e-DAB architecture

- Innovative embedded Dual Active Bridge (e-DAB)

  - 1 gate Bidirectional GaN transistors
  - ZVS detection & control

AC input bridge using AC switches
Integrated in one die!

Smaller: High power density & rectifier bridge removed with bidirectional devices

Reliability: Reduced high voltage component count

More efficient: Low losses with ZVS in the DAB architecture

Cost effective: TSMC GAN/Si CMOS compatible technology high volume capability
Our Product: GAN IC

→ Monolithic Power GaN integrated circuit (Driver + Power in one die)

→ Done with a patented innovative e-DAB architecture

→ On a new GaN/Si qualified technology from TSMC
First Targeted GaN IC: half bridge

Half bridge + driver + level shifter

Half bidirectional bridge + driver + level shifter
How to integrate power block delivering 15W (smart phone) up to 60W - 100W (computer / display / TV)?

**e-DAB architecture benefits**

- Improve efficiency: 96% to 98%
- Reduce size: power density > 3kW/l
- Compatible for all power range: PFC integrated in the primary side

<table>
<thead>
<tr>
<th>Power (W)</th>
<th>Efficiency (%)</th>
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<tbody>
<tr>
<td>27</td>
<td>90</td>
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<tr>
<td>45</td>
<td>92</td>
</tr>
<tr>
<td>65</td>
<td>94</td>
</tr>
<tr>
<td>100</td>
<td>96</td>
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- **e-DAB**
  - Improve efficiency: 96% to 98%
  - Reduce size: power density > 3kW/l
  - Compatible for all power range: PFC integrated in the primary side
Integrating Magnetics

• Super Flat 1mm thick Magnetic Core integrated in PCB

10W, 1MHz prototype integrated transformer using proprietary magnetic core (CEA-tech Liten)

4W sharing losses for AC/DC 100W power supply

- Smaller
- More efficient

100W, 1MHz AC-DC power supply tests
240V AC → 20 VDC
Target: high frequency planar compact transformer working at 1MHz with optimized yield upper 97%.

Optimize Copper and Fe losses. We use Ferroxcube material with 30mT and we have
• Fe losses: 1W
• Copper losses: 2W
Transformer is included in the PCB board. Primary side is inside the PCB board.
Integrated circuit chips

Half bridge 100mR  Half bridge 20mR

Scalable current capability

Half bi-directional bridge 100mR

Half bridge 100mR + Gate Drivers

Active Clamp Flyback < 65W

e-DAB > 65W

Integrated circuit chips
Device Static characterisation

- Validation of static behavior of all devices in the first lot
- Discrete power transistor 650V/100mΩ /50mΩ and 20mΩ (Ron.S=4 mΩ.cm²)
- With kelvin source and current sense pad
- Bidirectional power transistor 650V/40mΩ & 80mΩ
- Driver for half bridge 1MHz operation
- Level shifter for half bridge
- Pad ESD protection
Device Static characterisation

Ron=50mΩ

Vth=1,5V

BV>650V @ 1uA

before stress
after stress
RON comparison - T1A

slow
fast
standard
**Temperature characterisation**

- **Vth decreases with the temperature**
  - $V_{th@25^\circ C} = 1.5V$
  - $V_{th@150^\circ C} = 1.3V$

- **$R_{DS(ON)}$ increases with the temperature**
  - $R_{on@25^\circ C} = 26 \Omega.mm$
  - $R_{on@150^\circ C} = 53 \Omega.mm$

- **$I_{dss}$ increase with the temperature**
  - $I_{dss@25^\circ C} = 1.9 \times 10^{-9} \text{ A/mm}$
  - $I_{dss@150^\circ C} = 1.3 \times 10^{-7} \text{ A/mm}$
Dynamic device characterisation

Input capacitance ($C_{iss}$) = $C_{gd} + C_{gs}$
Output capacitance ($C_{oss}$) = $C_{ds} + C_{gd}$
Reverse transfer capacitance ($C_{rss}$) = $C_{gd}$

Spec  | $T = 25^\circ C$
--- | ---
$C_{iss}$ (pF/mm) | 0.64
$C_{oss}$ (pF/mm) | 0.1
$C_{rss}$ (pF/mm) | $4 \times 10^{-3}$

AC magnitude = 30mV
$f = 100$ kHz
Device dynamic evaluation

- Integrated half bridge tested in buck mode 1MHz / 400V / 2A
First GaN IC in QFN package

- GaN IC assy in 8x8mm QFN package: half bridge with source sense and source kelvin
- Use for prototyping the 100W USB type C PD power supply

GW0506502A
Half bridge Power GaN IC 650 V E-mode GaN transistor
Preliminary Datasheet

Features
- 650 V enhancement mode half bridge power switch
- Bottom-side cooled configuration
- $R_{DS(on)} = 50 \, \text{m} \Omega$ per switch
- $I_{D(max)} = 5 \, \text{A}$
- Low inductance QFN PACKAGE
- Easy gate drive requirements (0 V to 6 V)
- Transient tolerant gate drive (-20 V / +10V)
- Very high switching frequency (> 10 MHz)
- Fast and controllable fall and rise times
- Integrated Source sense
- Reverse current capability
- Zero reverse recovery loss
- Small 8 x 8 mm² PCB footprint
- RoHS 6 compliant
How to integrate power block delivering 15W (smart phone) up to 60W - 100W (computer / display / TV)?

- **First innovative 100W USB PD demonstrator**
  - Target is to validate the new innovative system topology with our first GaN IC
    - 100W
    - 96% of efficiency (+2% vs actual state of the art)
    - Using new innovative ST controller STUSB4761 to manage USB C protocol
    - Design with EMI filters
    - Available for demonstration in April 2019

- **GaN IC GaNWISE (design, device)**

- **Innovative e-DAB architecture (design, prototype realization, test, BOM, support)**

- **STUSB4761 controller**
  - USB PD supplier and support
100W USB PD demonstrator

- STUSB4761 controller
- GANWISE planar Transformer
- GANWISE GAN IC

Dimensions:
- 5 cm
- 14 cm

APEC
GaN Power Integration

BEST BUY
Wall plug application

- What are the challenges to integrate?

  - Integration
    - Limited volume of wall plug
  - Thermal dissipation
  - Robustness & device interoperability
How to integrate power block delivering 15W (smart phone) up to 60W -100W (computer / display / TV)?

- **Integration**
  - Limited volume of wall plug

- **Thermal dissipation**

- **Robustness & device interoperability**

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**GaN technology with innovative power**

GaN integrated circuit and system architecture  
(GANWISE GAN IC + e-DAB)

**Smart USB Power Delivery controllers**
with power sharing  
New discrete component technologies

**Certified USB Power Delivery controllers**
Smart USB Power Delivery controllers with embedded protections  
(overvoltage / current / temp)
Others applications

• GaN is robust to radiation!

DC-DC converters for spatial market

• GaN is working at high temperature > 200°C

Motor drive for industrial applications in harsh environment
Standalone USB PD controller STUSB4761 with integrated CC/CV for AC/DC applications

**Benefits**

- No software skills required
- Robustness to high voltage
- Configurable and flexible
- Easy industrialisation
- Reduced PCB area and cost versus discrete (small QFN 3x3 package)
How to integrate power block delivering 15W (smart phone) up to 60W - 100W (computer / display / TV)?

GaNWise Road map

- road map, next improvement steps and cost evaluation

System cost (BOM $/W)

2019 2020 2021 2022 2023 2024 2025

G1
650V / 5A Power Half Bridge + Drivers

G2
650V / 5A Full bridge + drivers

G3
G2 + passives

Through SOC + intelligent + smaller

POWER ANALOG
DIGITAL
Thank You