GaN Power ICs:
Device Integration Delivers Application Performance

5th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA)
Albuquerque, NM, USA. November 1st 2017

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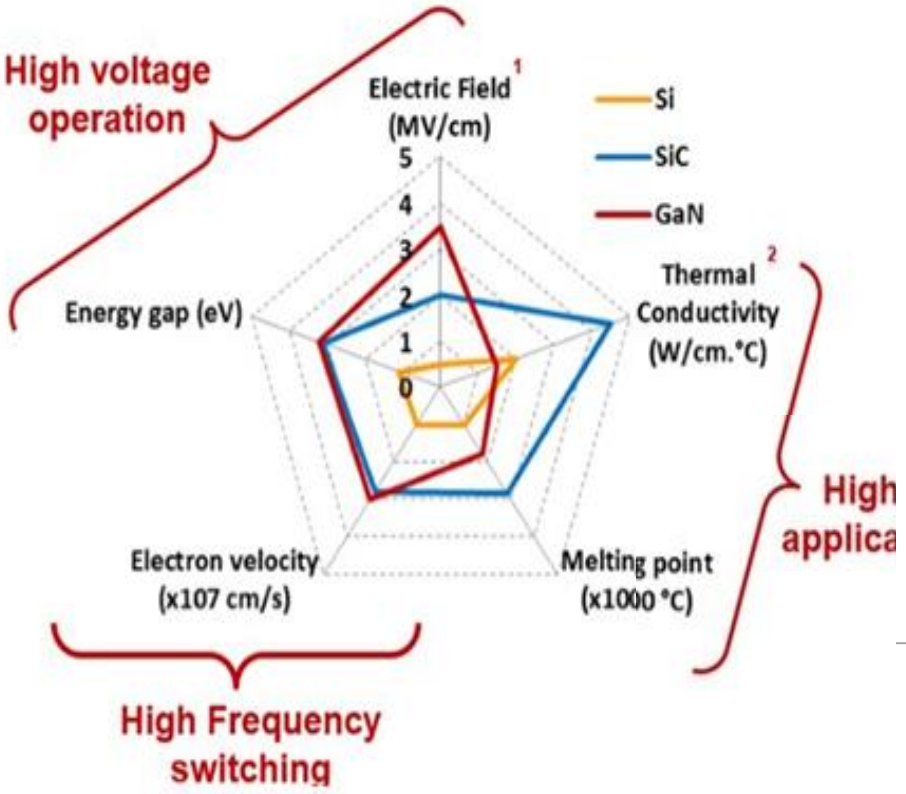
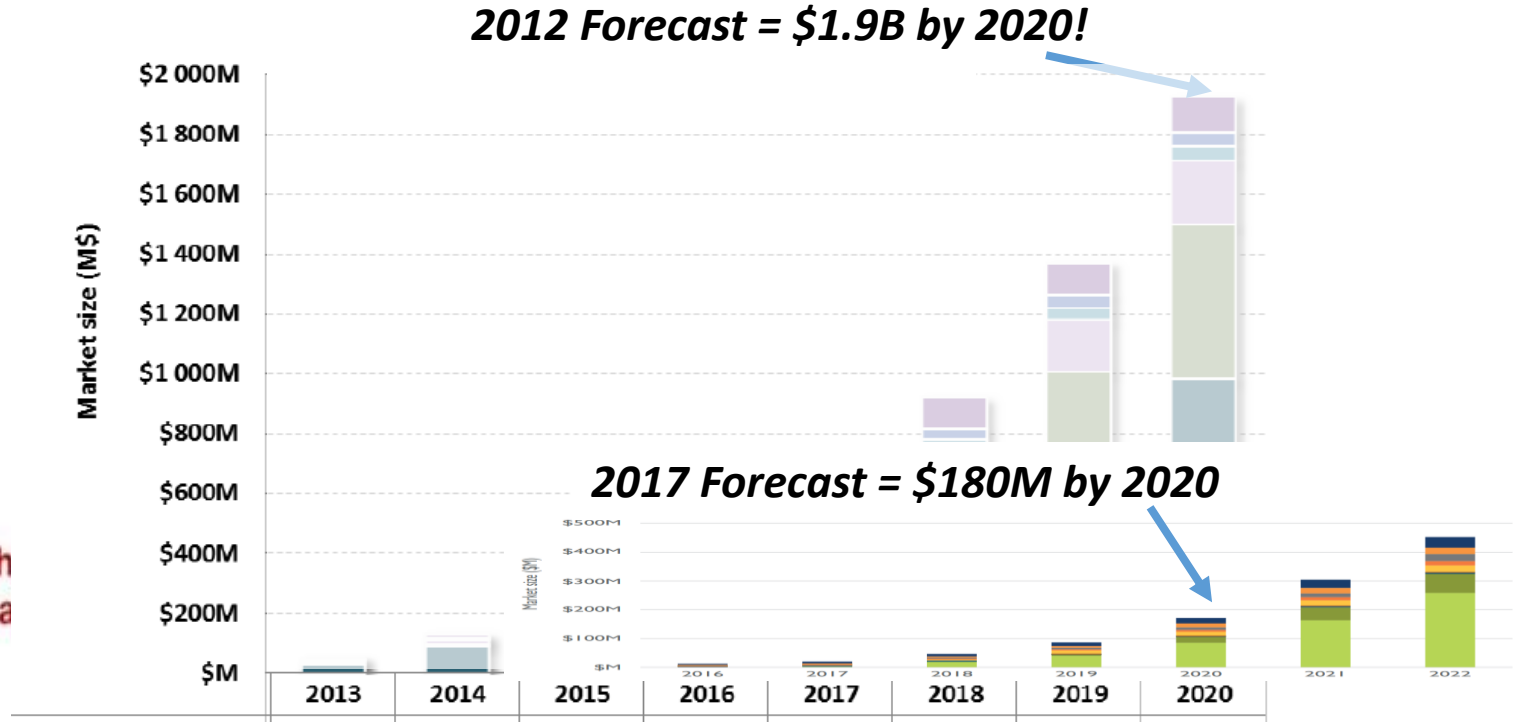
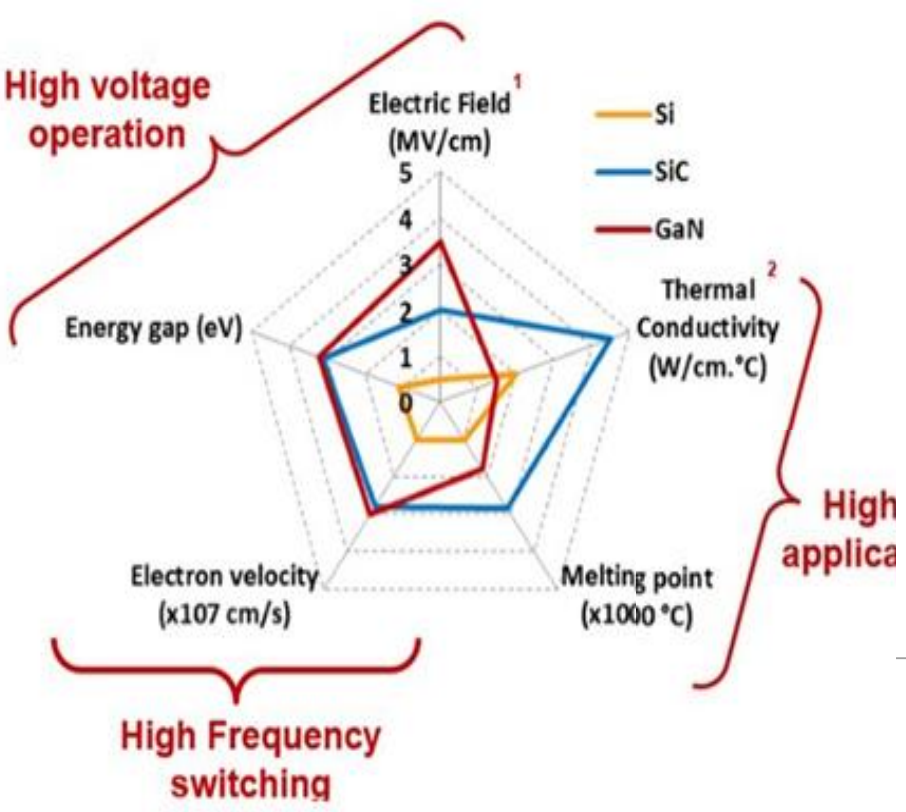
Fast GaN, Slow Adoption?

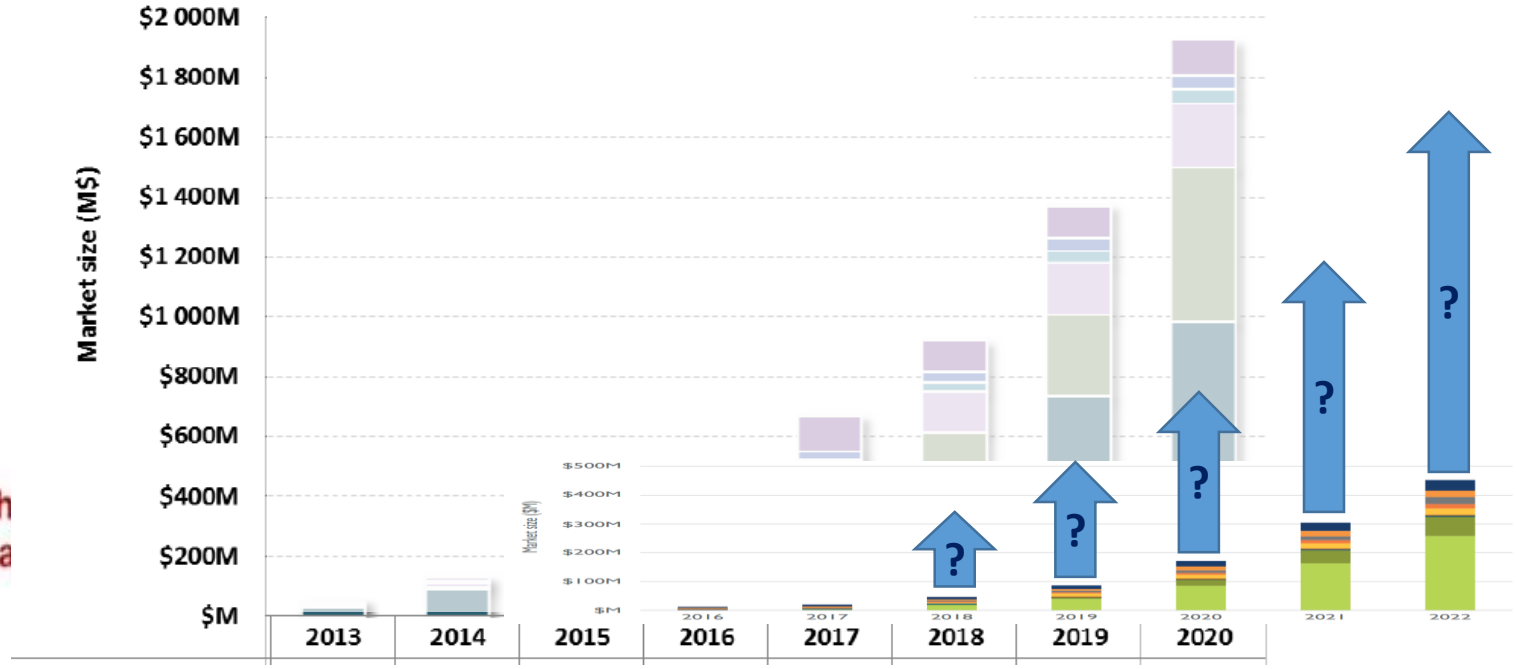




Source: Yole 2012, 2017

Faster with AllGaN™ Integration!





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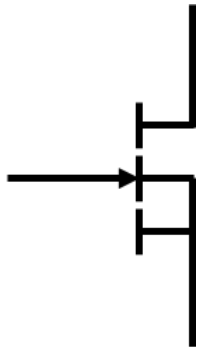
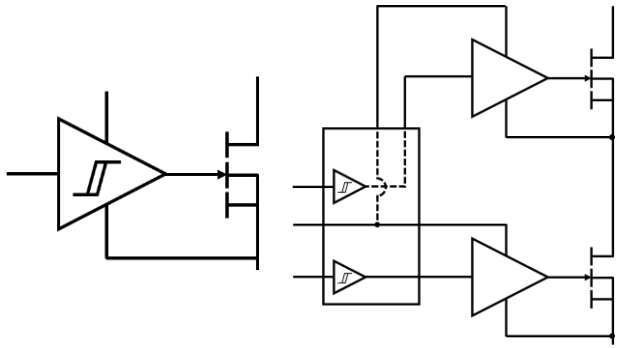
World's First AllGaN™ Power ICs

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

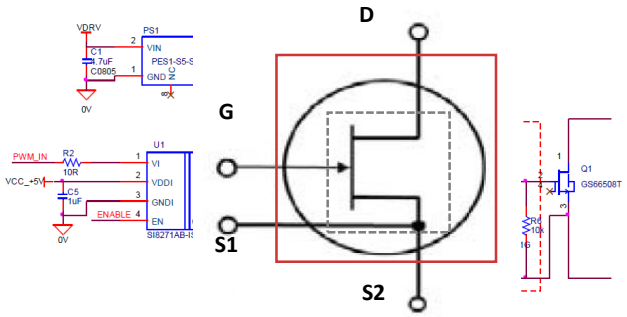
World's First AllGaN™ Power IC

Up to 40MHz switching, 5x higher density & 20% lower system cost

The Drive for Better Drivers

- Low V_{TH}
- Low R x Q
- Low V_{GS_Max}

Discrete FET + Discrete Driver



Gate Drive Challenges	Discrete FET + Discrete Driver	Discrete FET + Custom driver	GaN Power IC
Eliminate Gate Oscillations	✓		
Eliminate dV/dt Induced Turn-on	✓		
Regulate Gate Drive Voltage	✓		
Gate Overvoltage Protection	✓		
Reduce Design Complexity	✗		
Manage Noise Sensitivity	✗		
Fast Turn-on/off Speed	✗		
Gate ESD Protection	✗		
Layout Insensitive	✗		
Lowest PCB Area	✗		
Lowest Cost	✗		
Remove Negative Drive	✗		
Fast Start-up	✓		
Eliminate Standby Loss	✓		

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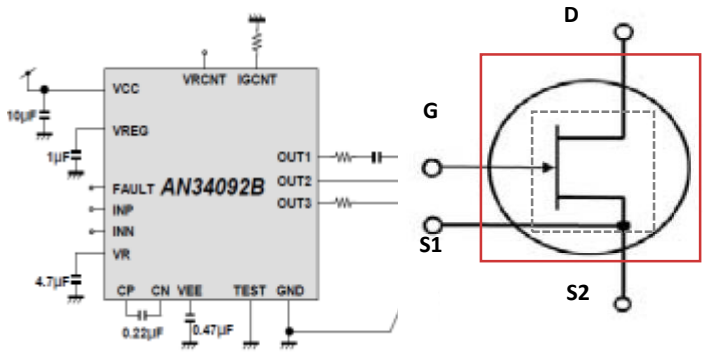
- Low R x Q
- Low V_{GS_Max}

Discrete FET + Custom Driver



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Gate ESD Protection	✗	✗	
Layout Insensitive	✗	✗	
Lowest PCB Area	✗	✗	
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Fast Start-up	✓	✗	
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The Drive for Better Drivers

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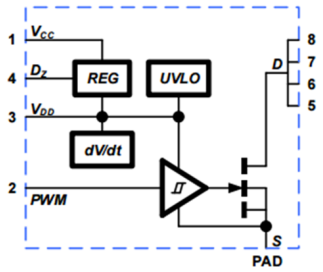
GaN Power IC



No compromises

Gate Drive Challenges	Discrete FET + Discrete Driver	Discrete FET + Custom driver	GaN Power IC
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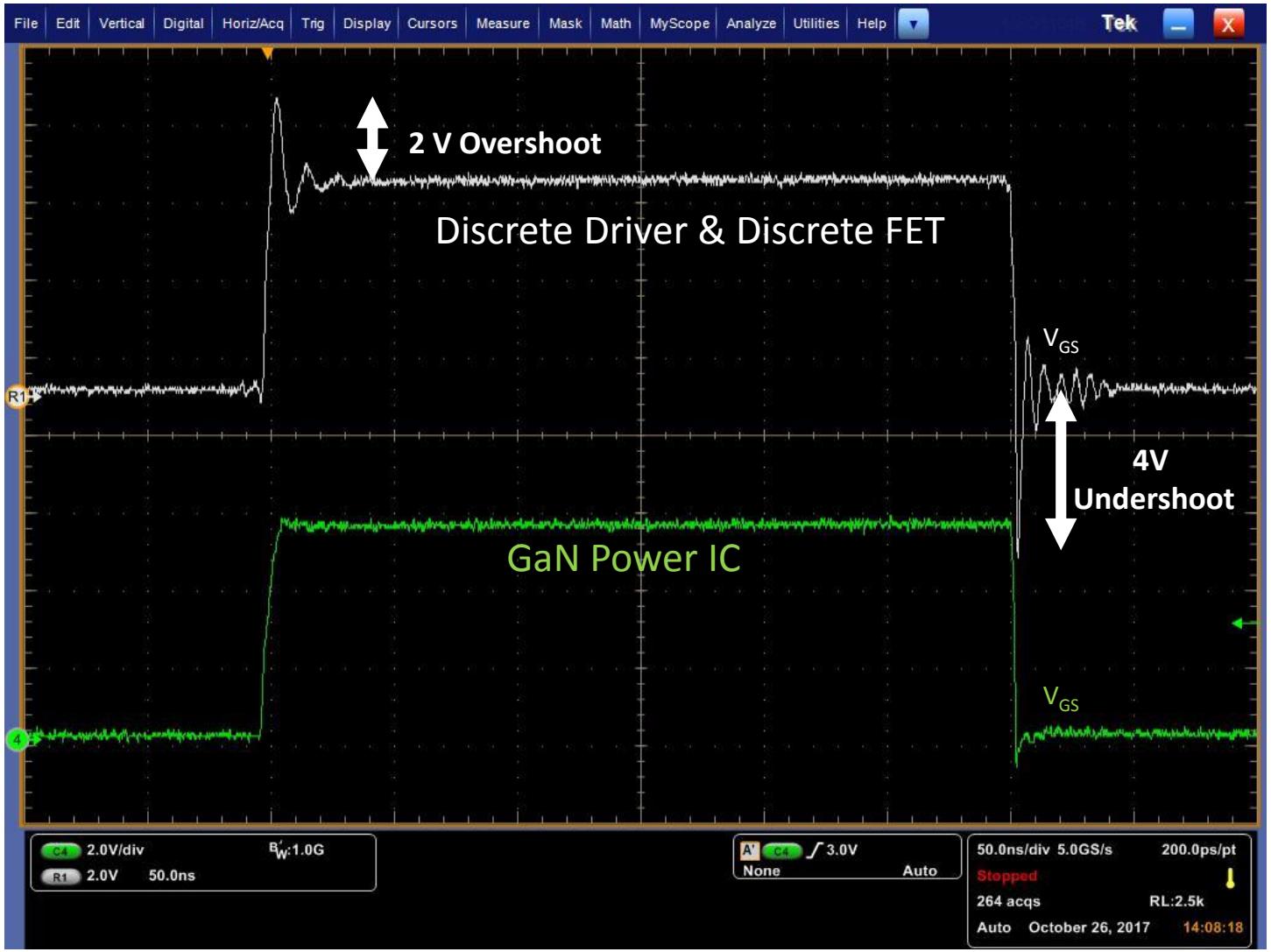
Lowest Cost	✗	✗	✓
Remove Negative Drive	✗	✗	✓
Fast Start-up	✓	✗	✓
Eliminate Standby Loss	✓	✗	✓

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)

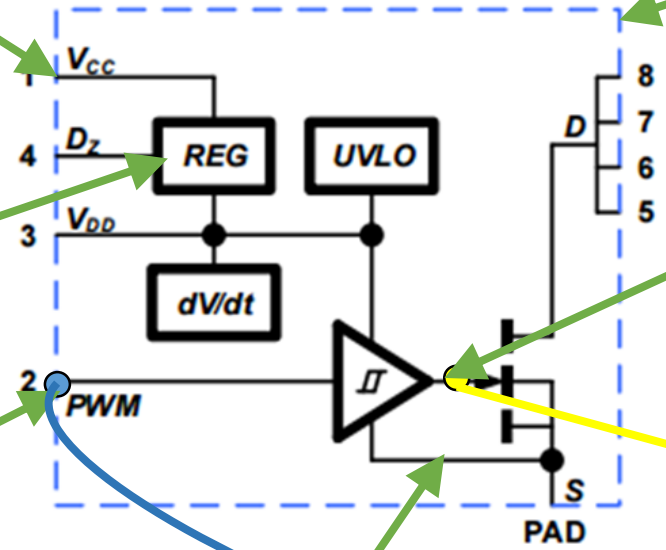
Total layout flexibility & simplicity

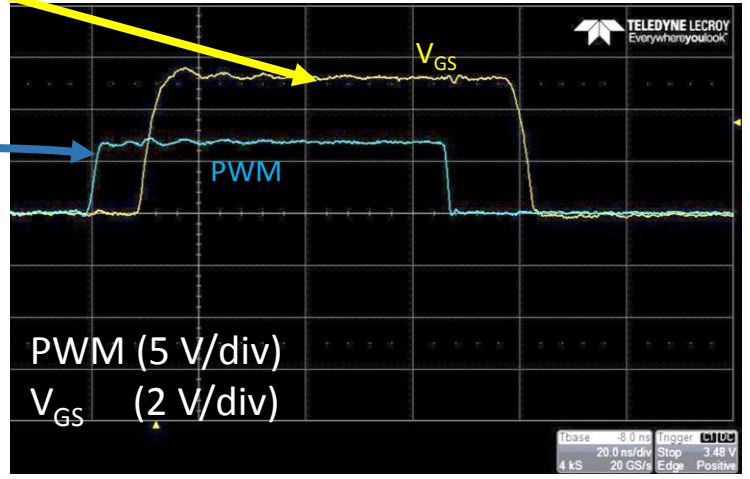
Regulator ensures V_{GS} within SOA

Gate protected from external noise

PWM Hysteresis for noise immunity

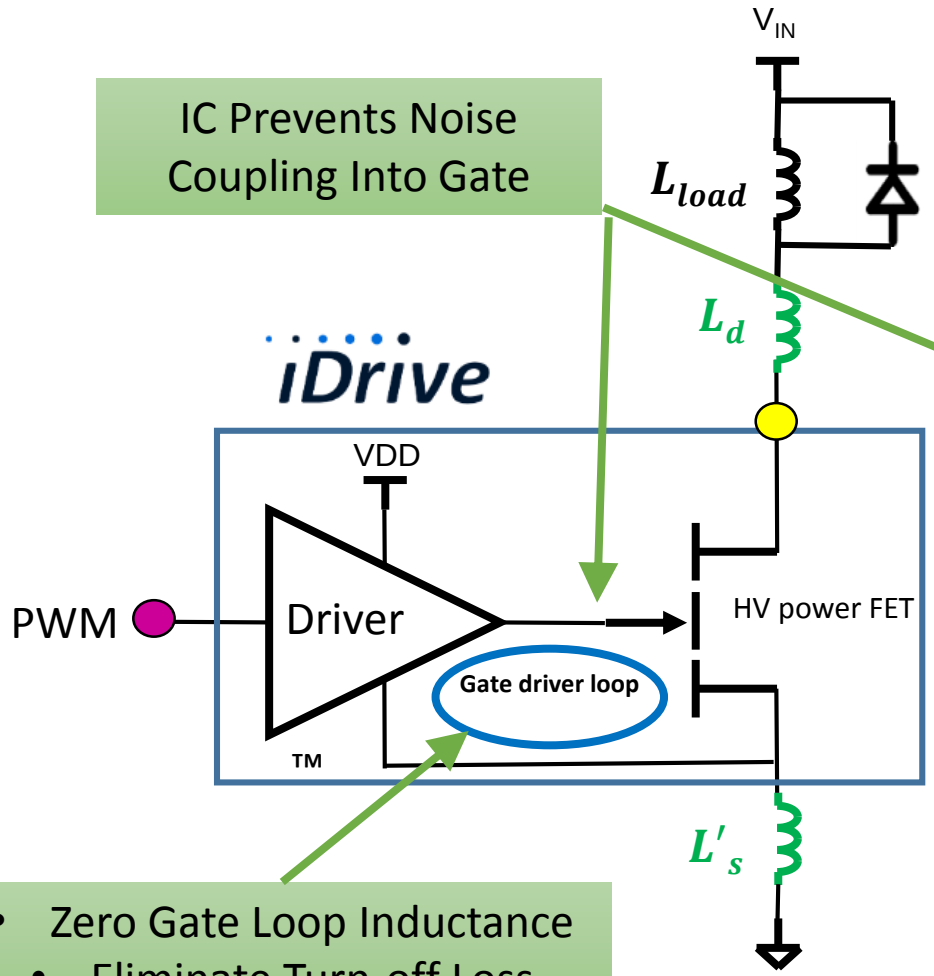
No inductance or ringing in gate loop





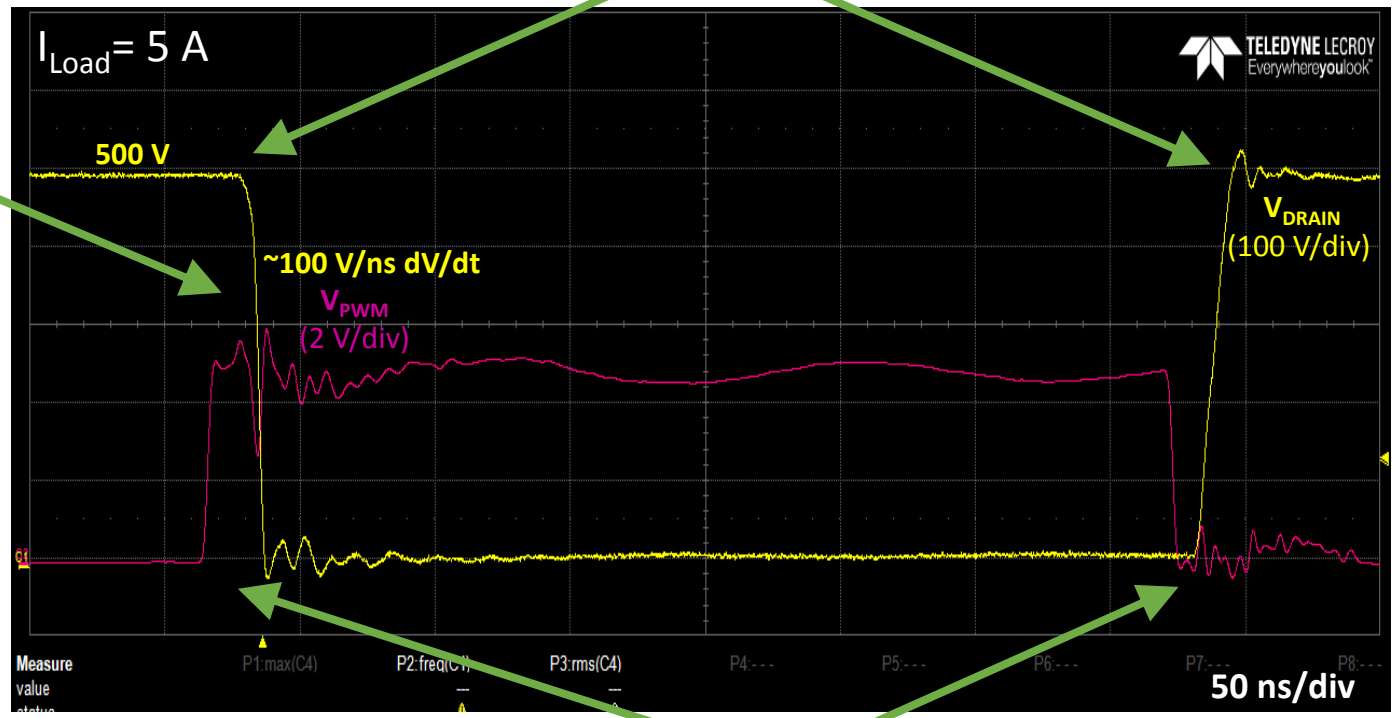
Fast & Clean Hard Switching

IC Prevents Noise Coupling Into Gate



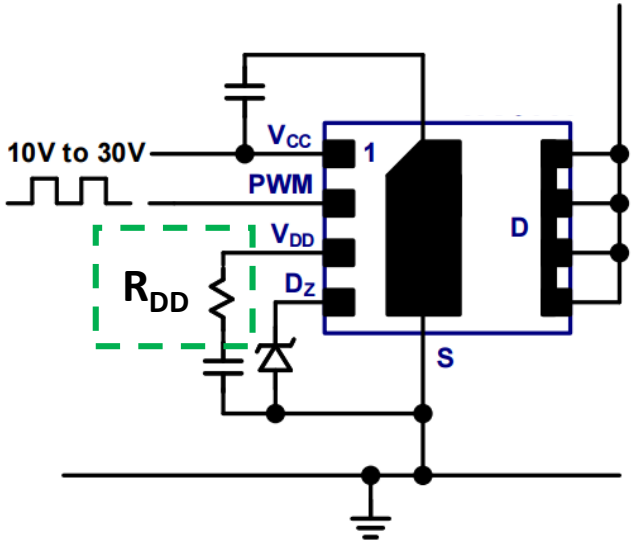
- Zero Gate Loop Inductance
- Eliminate Turn-off Loss

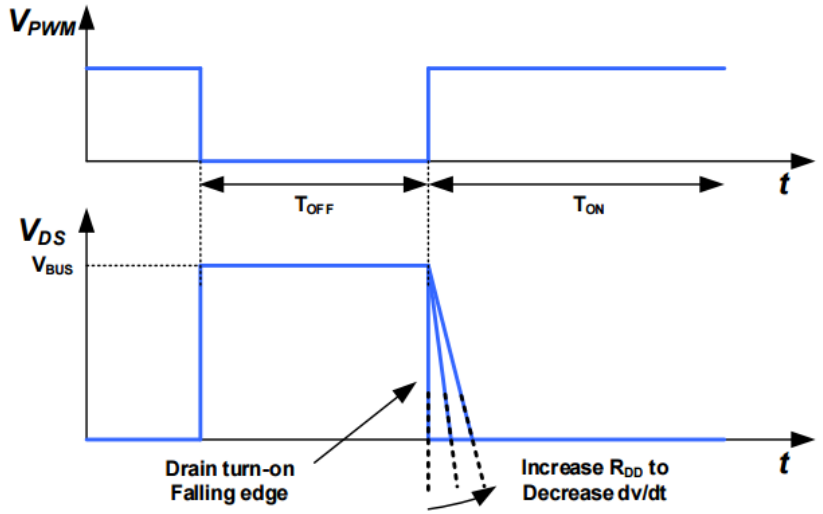
Clean HV Hard Switching

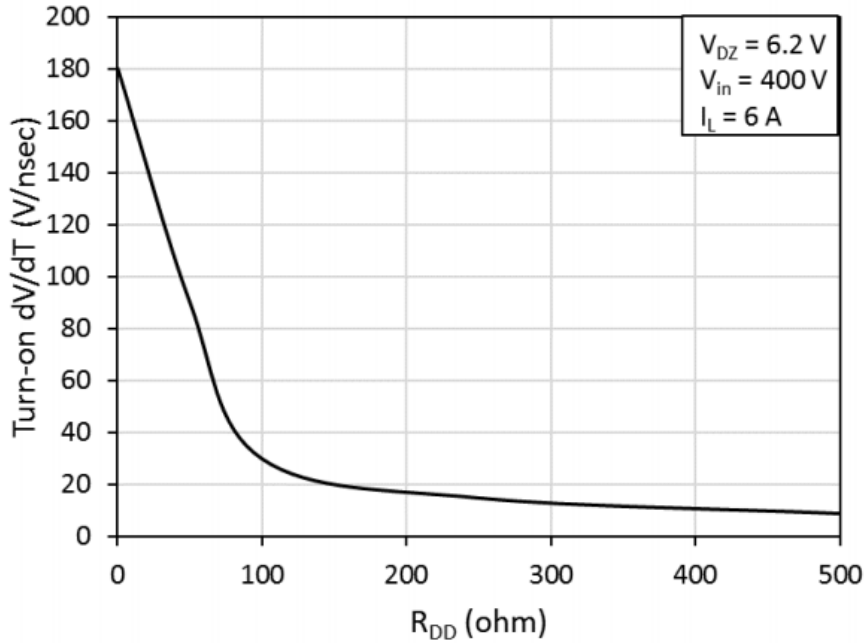


Prop Delay 10-20 ns

Voltage Slew-Rate Control … Easy EMI Tuning



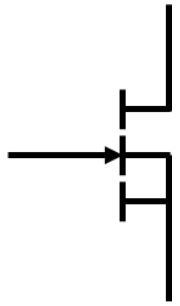




dV/dt controllable from 180 V/ns to 10 V/ns

ESD Protection?

Discrete GaN

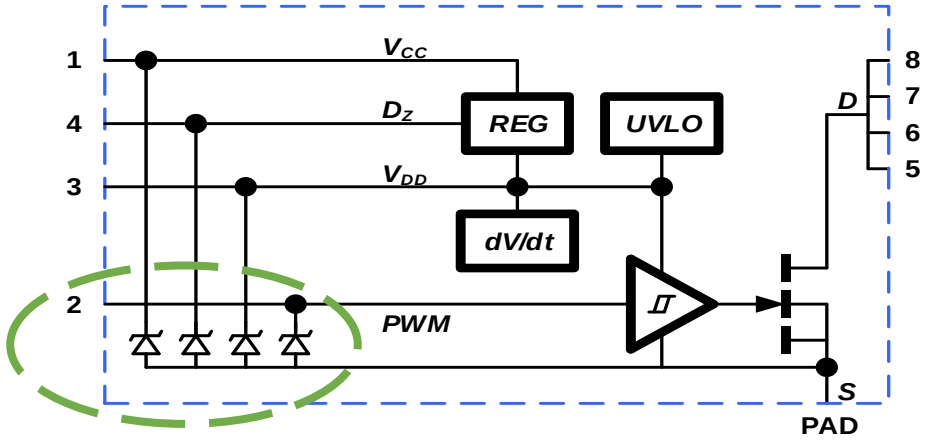


Low C_{ISS} → Fast switch, but…

HBM < 250 V (typical)

VS.

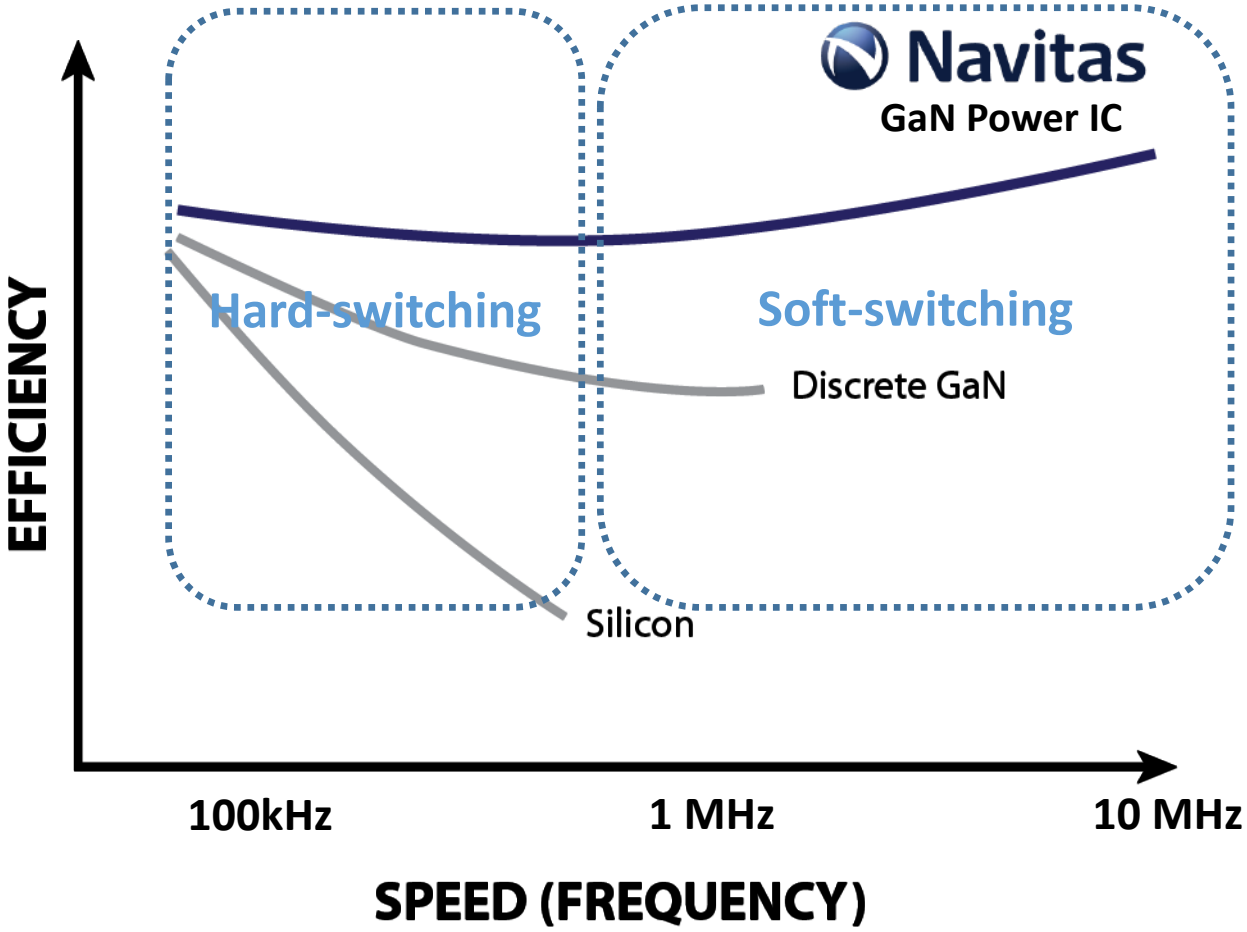
GaN Power IC



Integrated ESD Protection

HBM, CDM > 1,000 V

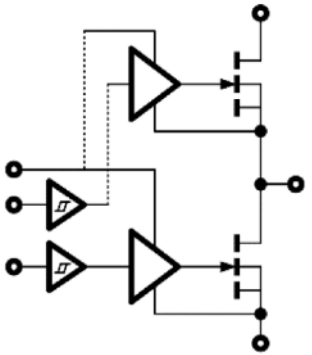
Using Integration to Improve Power Density



ZVS

Half-Bridge Building Block

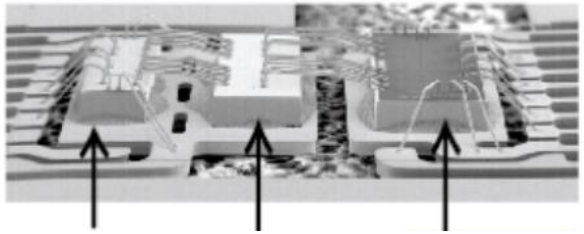
PQFN 6x8 mm



Simplified Schematic

Soft-switching → allows simultaneous increase in frequency and efficiency uniquely enabled by GaN power ICs.

High-Frequency Half-Bridge Integration

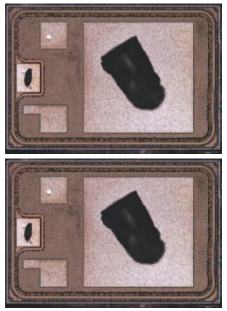


I/F Chip Si CMOS

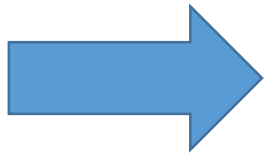
On-chip Transformer SiO_2 / Polyimide

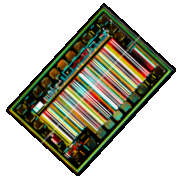
Gate Driver Chip Si CMOS

Bootstrap Diode Si / SiC



Half-Bridge FETs Si





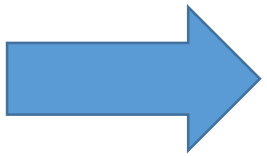
AllGaN™ Technology
Lateral 650V GaN-on-Si

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

Monolithic Platform
Lateral GaN-on-Si, Half-Bridge GaN Power IC

High Power Loss

- Driver loss, R_G loss
- Bootstrap diode Q_{RR}, V_F
- Pulsed high current level shifter power (?)

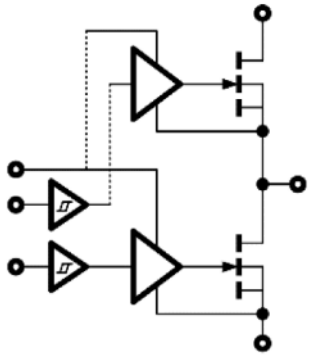


Low Power Loss

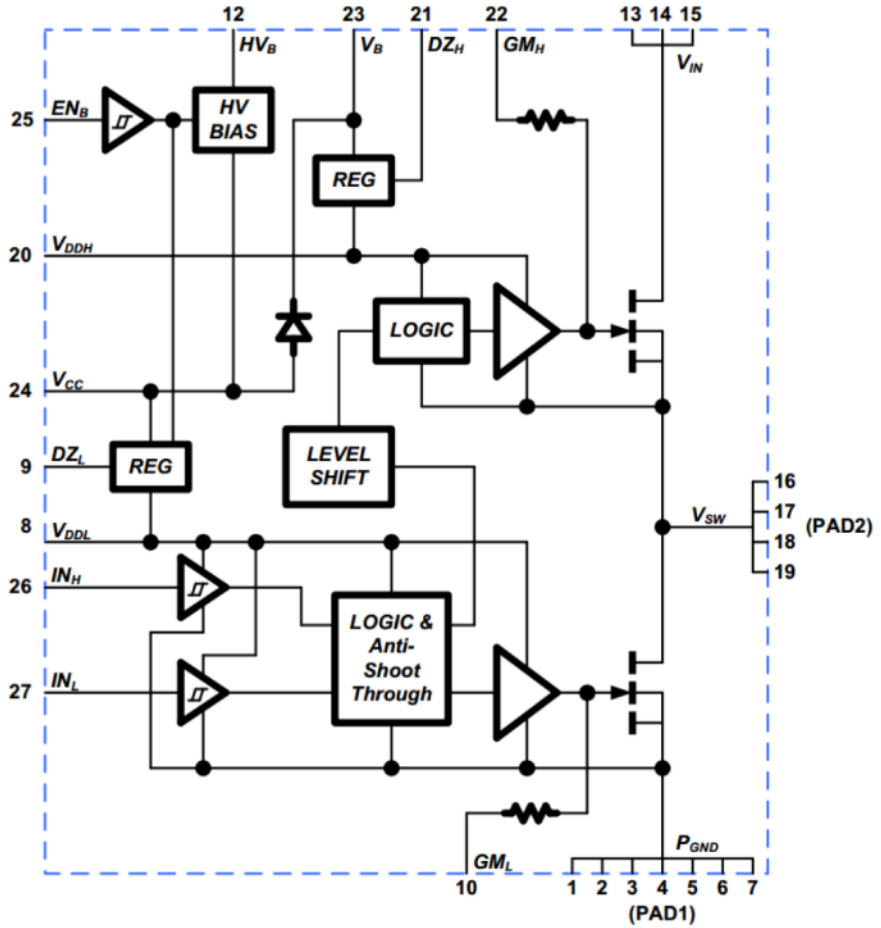
- No gate driver loop parasitics, matched driver-FET capability, negligible loss vs frequency
- Zero Q_{RR} ,low V_{DS} in synchronous charging
- Extremely fast, low-power level-shifter, multi-MHz operation, short propagation delay

Simple, Powerful, Efficient, Cost-Effective

PQFN 6x8 mm



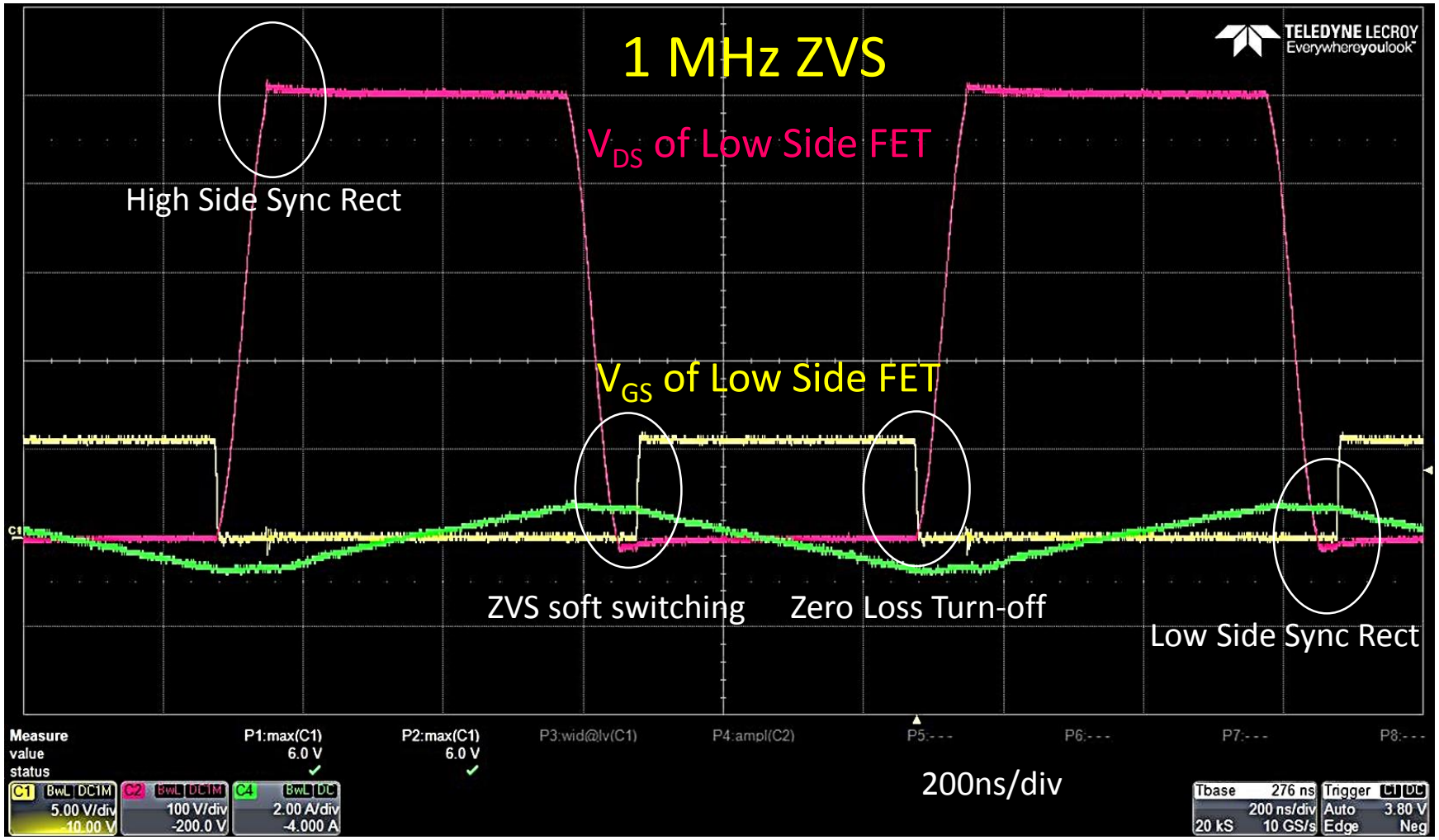
Simplified Schematic



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

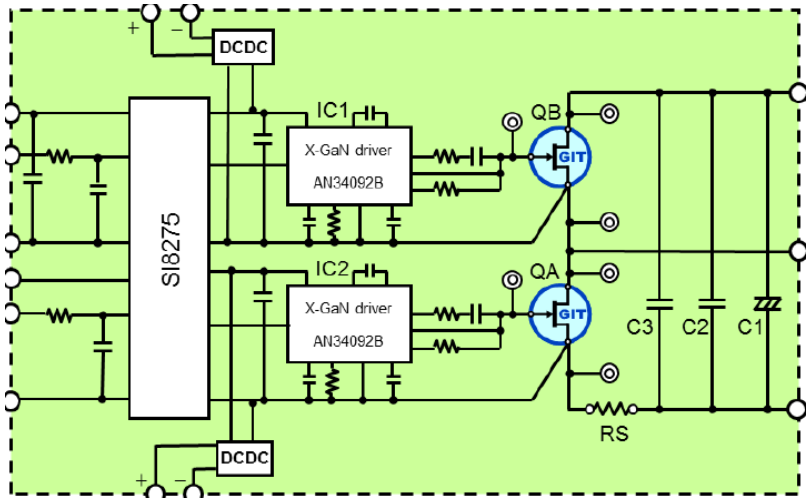
GaN Power IC – *Fast & Efficient*

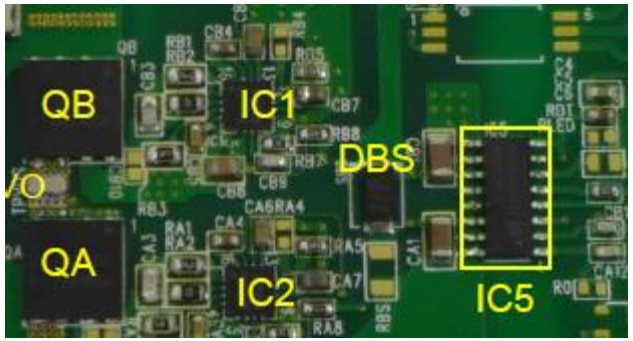
- 500 V Switching
- No overshoot / spike
- No oscillations
- ‘S-curve’ transitions
- Zero Loss Turn-on
- Zero Loss Turn-off
- Sync Rectification
- High frequency
- Small, low cost magnetics



Complex Design → *Made Simple*

Half-Bridge *Discrete* GaN

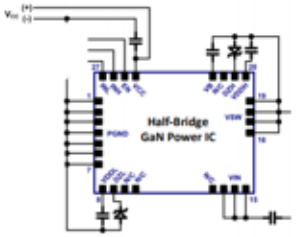




PCB Area: 24 x 42 ~ 1,000 mm²

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

Half-Bridge GaN *Power IC*



PCB Area: 6 x 8 = 48 mm²

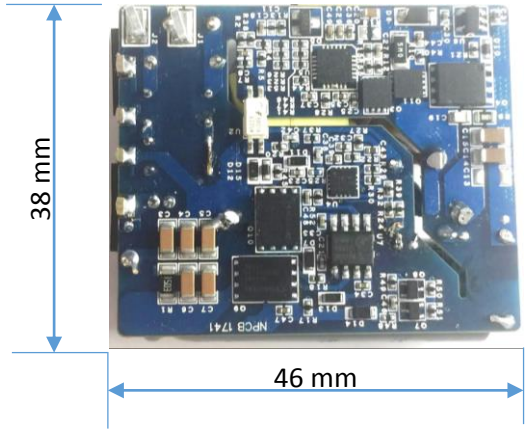
The World's Smallest 65W USB-PD Adapter

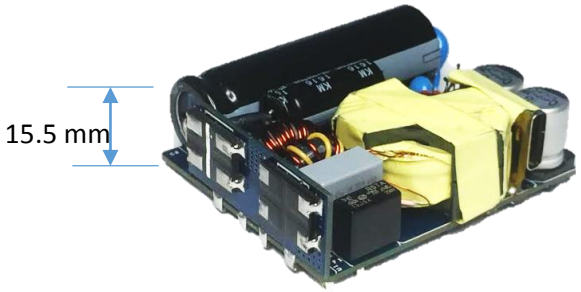
MacBook <100 kHz
<6.5 W/in³, 92%

✓ **3-4x power density**

✓ **20% lower loss**

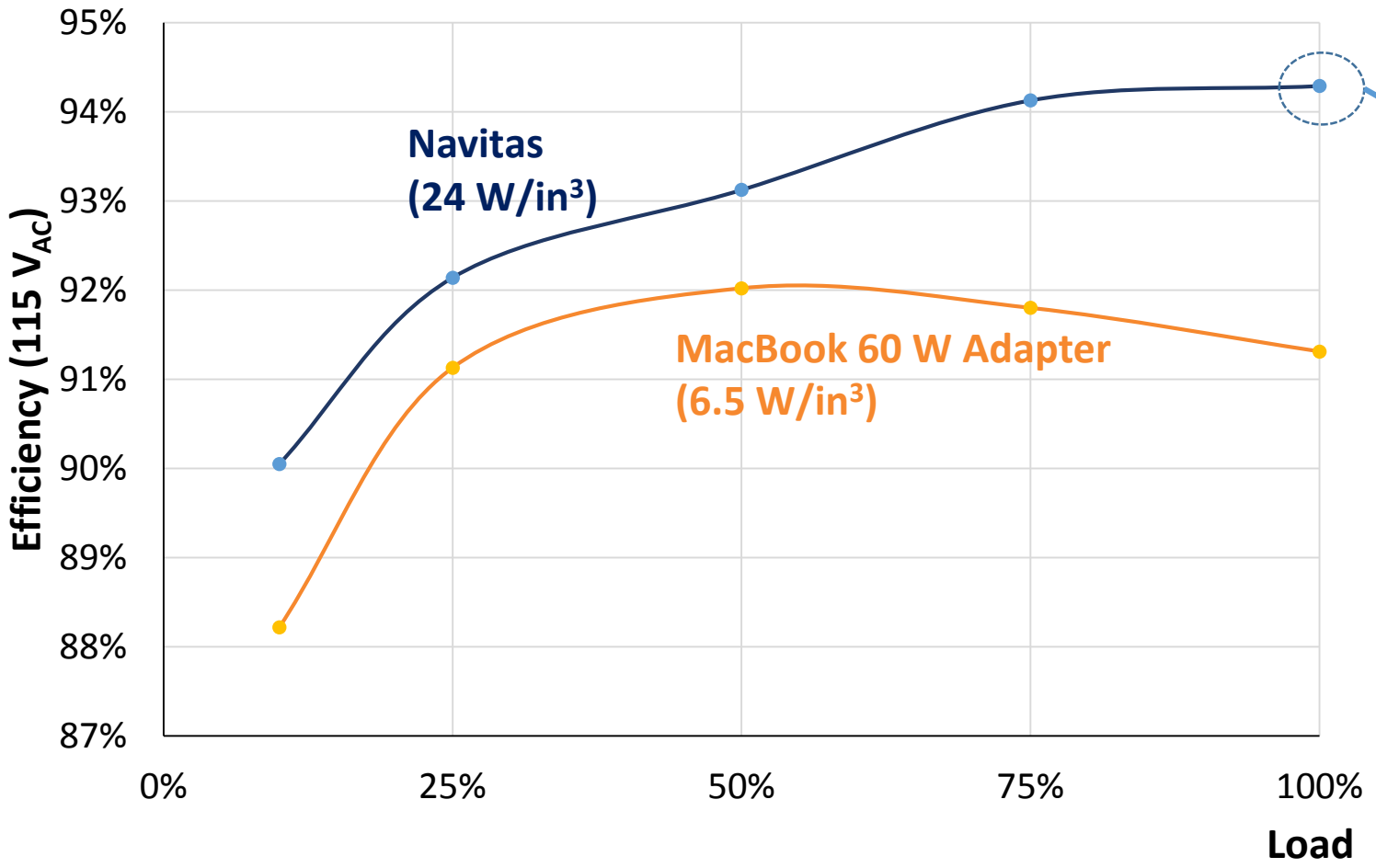
Navitas 300 kHz
24 W/in³ , 94%
= 45 cc cased

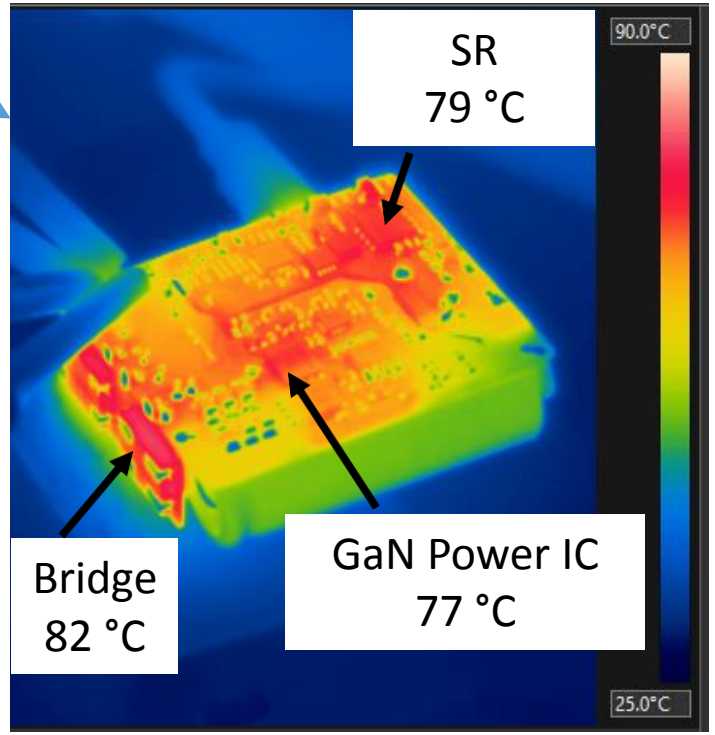




Efficiency measured at 90 V_{AC}, 100% load, at PCB

Best-in-Class Efficiency, Cool Operation



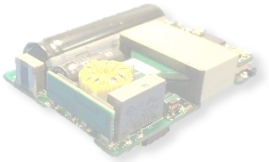


$115V_{AC}$, 65W, $20V_{OUT}$, 25°C

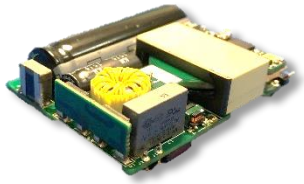
65W Charger Roadmap

Navitas

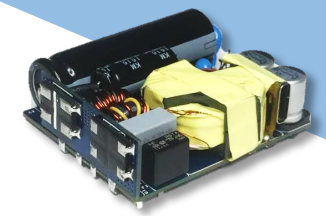
3x Charging
94.5% Efficiency



2.5x Charging
94% Efficiency



2x Charging
93.5% Efficiency



1x Charging
88% Efficiency

Reduced $ BOM Cost

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

35
30
25
20
15
10

1,000
600
300
100

Switching Frequency (kHz)

2H 2017
1H 2018
2H 2018

Efficiency at worst case ($90V_{AC}$, full load)

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Device Integration Delivers Application Performance

5th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA)
Albuquerque, NM, USA. November 1st 2017

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GaN
纳微 Navitas
65W USB-PD