



Power Accelerated

GaN Power ICs: Integration Drives Performance

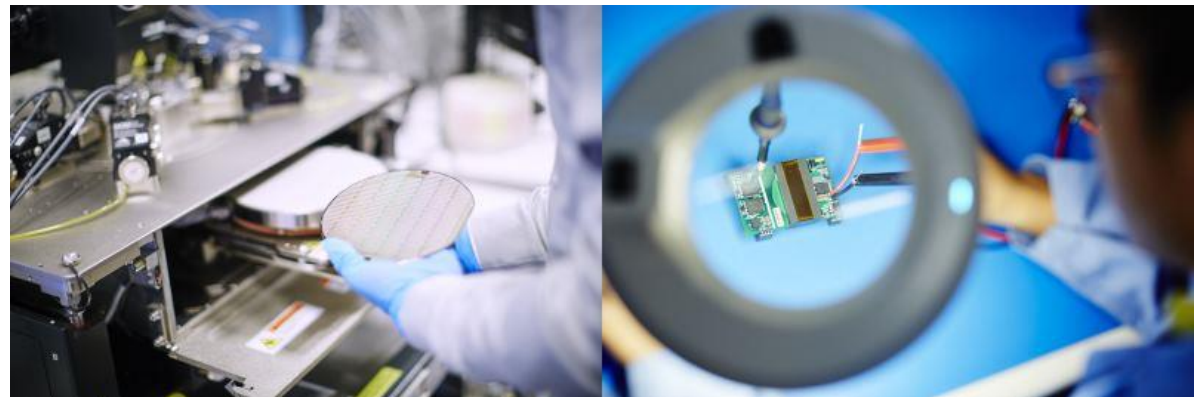
Stephen Oliver, VP Sales & Marketing
stephen.oliver@navitassemi.com

Bodo's Power Conference, Munich December 5th, 2017

Navitas Semiconductor Inc.

- World's first & only GaN power IC company
- Founded January 2014
- HQ in El Segundo, CA, USA
- World-class team
- World-class manufacturing partners
- www.navitassemi.com

navitas
noun | en·er·gy



A Question on History...

- *What happened in 1977?*



TWENTIETH CENTURY-FOX Presents A LUCASFILM LTD. PRODUCTION **STAR WARS**

Starring **MARK HAMILL HARRISON FORD CARRIE FISHER**
PETER CUSHING

and
ALEC GUINNESS

Written and Directed by
GEORGE LUCAS

Produced by **GARY KURTZ** Music by **JOHN WILLIAMS**

**STAR
WARS**

Making Films Sound Better
DOLBY SYSTEM
Noise Reduction - High Fidelity

PANAVISION® PRINTS BY DE LUXE® TECHNICOLOR®

Original Motion Picture Soundtrack on 20th Century Records and Tapes

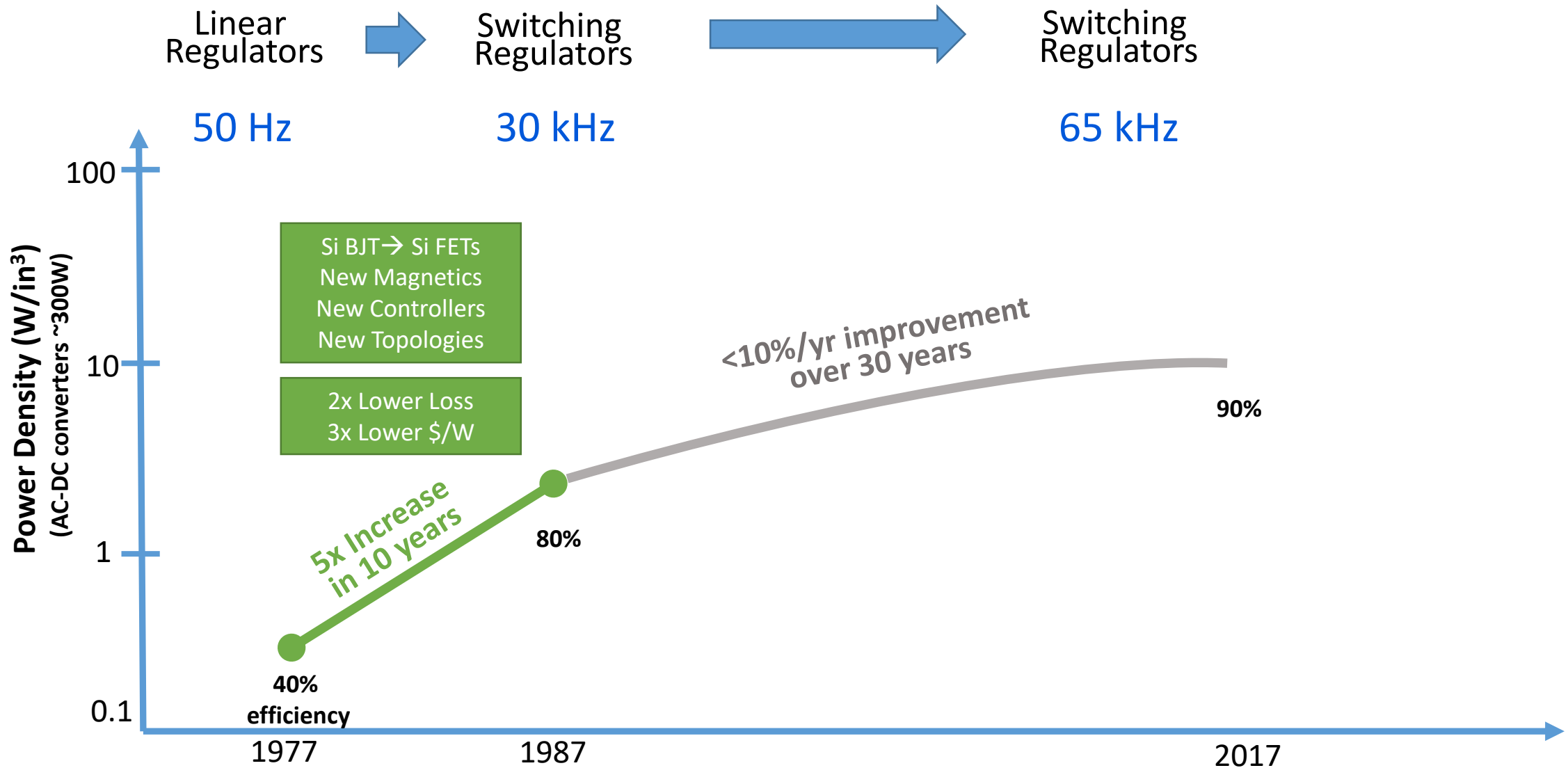


ONE SHEET STYLE "C"

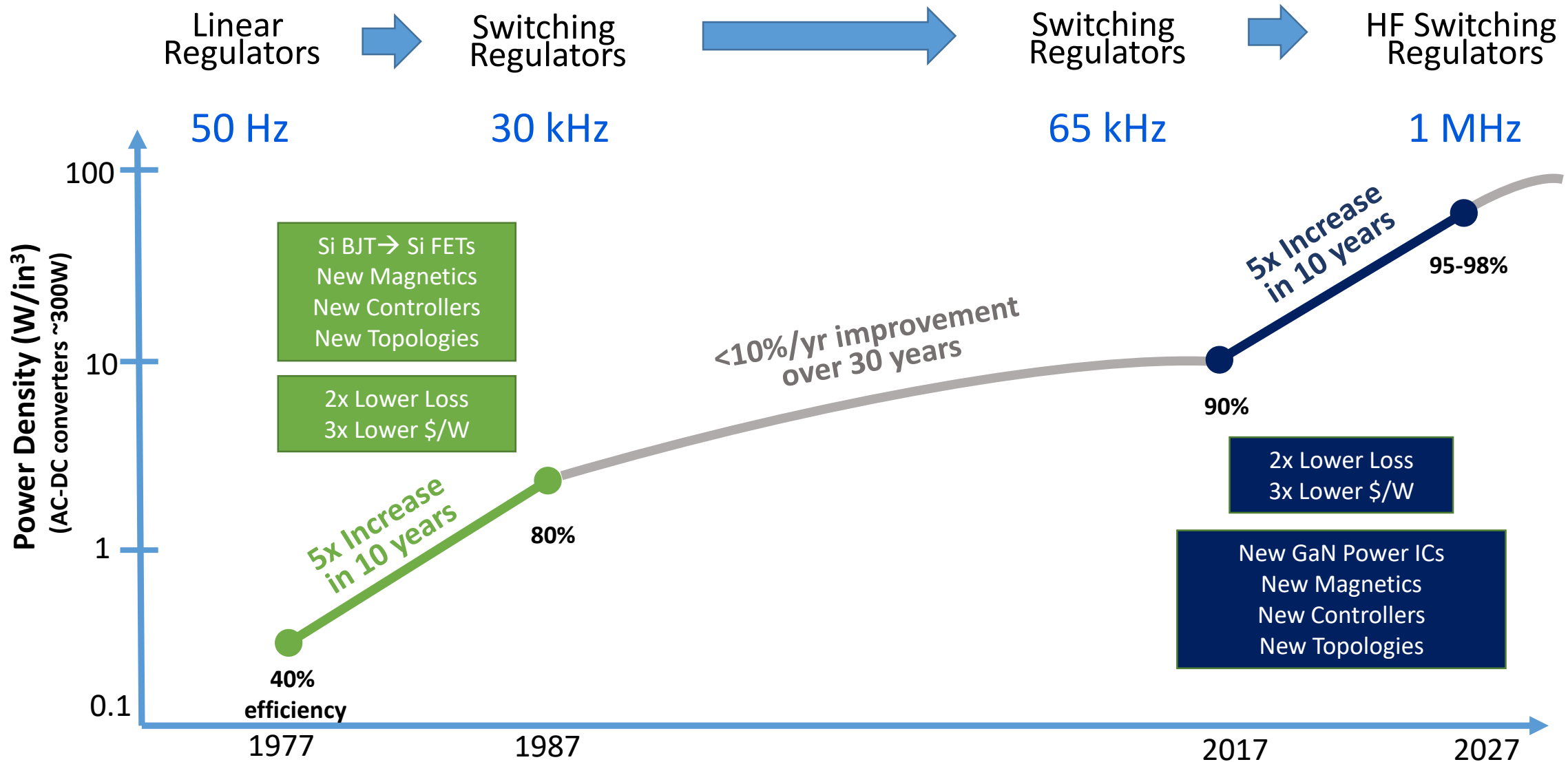
A Question on History...

- *What else happened in 1977?*

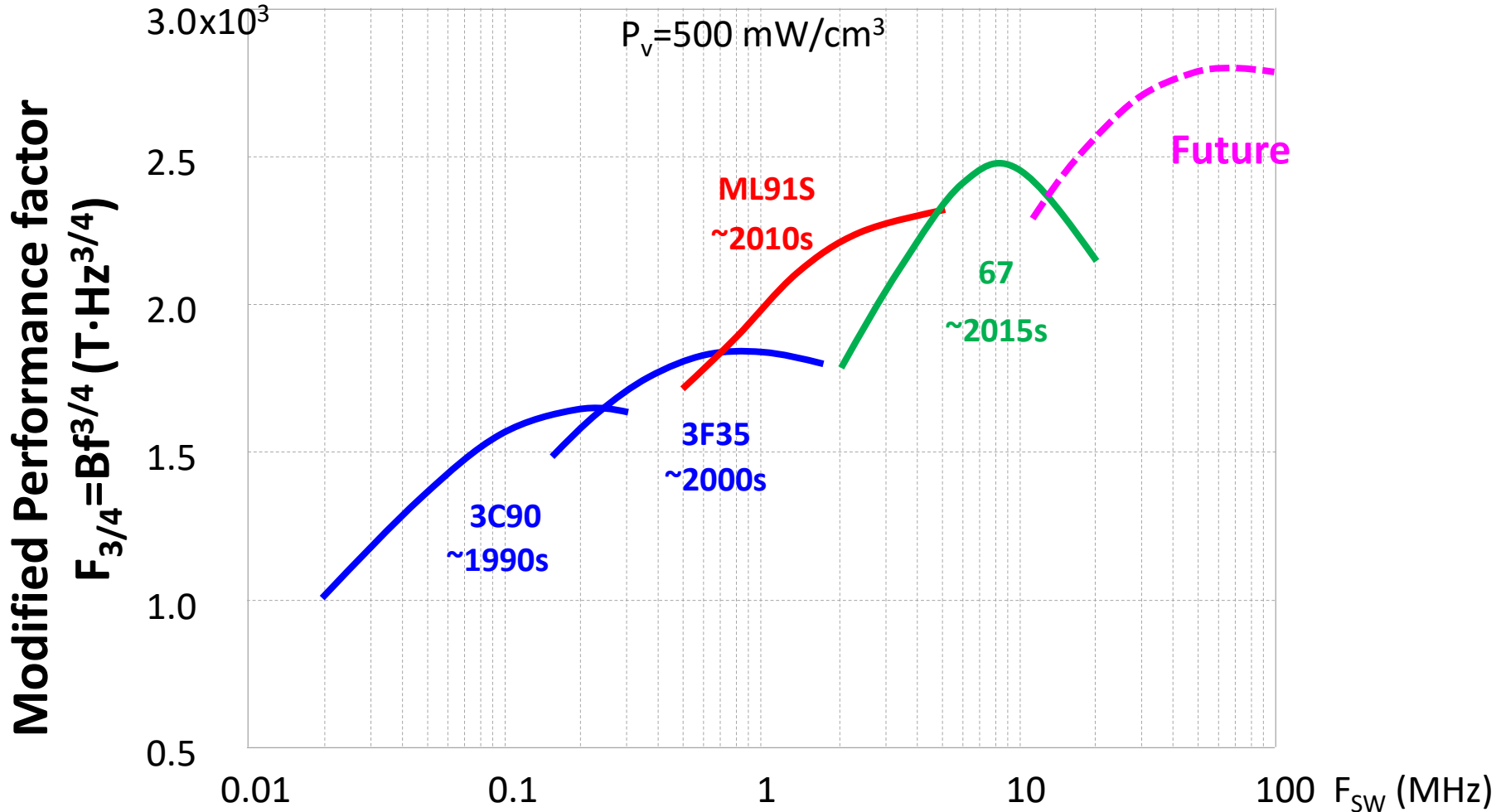
The First Revolution in Power



Today's Power Revolution



HF Magnetics

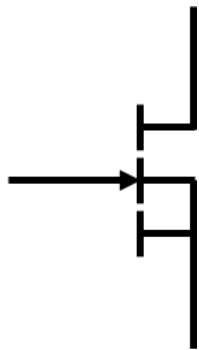


Y. Han, G. Cheung, A. Li, C. R. Sullivan and D. J. Perreault, "Evaluation of Magnetic Materials for Very High Frequency Power Applications," in *IEEE Transactions on Power Electronics*, vol. 27, no. 1, pp. 425-435, Jan. 2012.

A. J. Hanson, J. A. Belk, S. Lim, C. R. Sullivan and D. J. Perreault, "Measurements and Performance Factor Comparisons of Magnetic Materials at High Frequency," in *IEEE Transactions on Power Electronics*, vol. 31, no. 11, pp. 7909-7925, Nov. 2016.

World's First AllGaN™ Power ICs

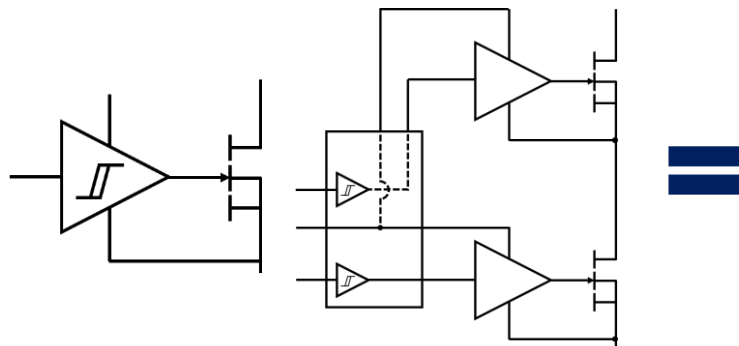
**Fastest, most efficient
GaN Power FETs**



**>20x faster than silicon
>5x faster than cascoded GaN
Proprietary design**



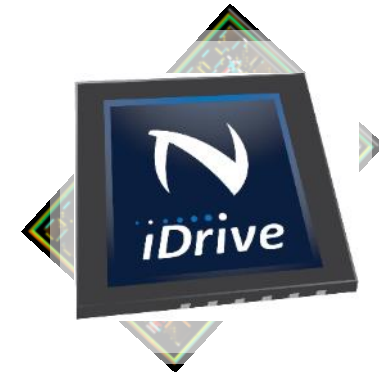
***iDrive* First & Fastest
Integrated GaN Gate Drivers**



**>3x faster than any other gate driver
Proprietary design
30+ patents granted/applied**



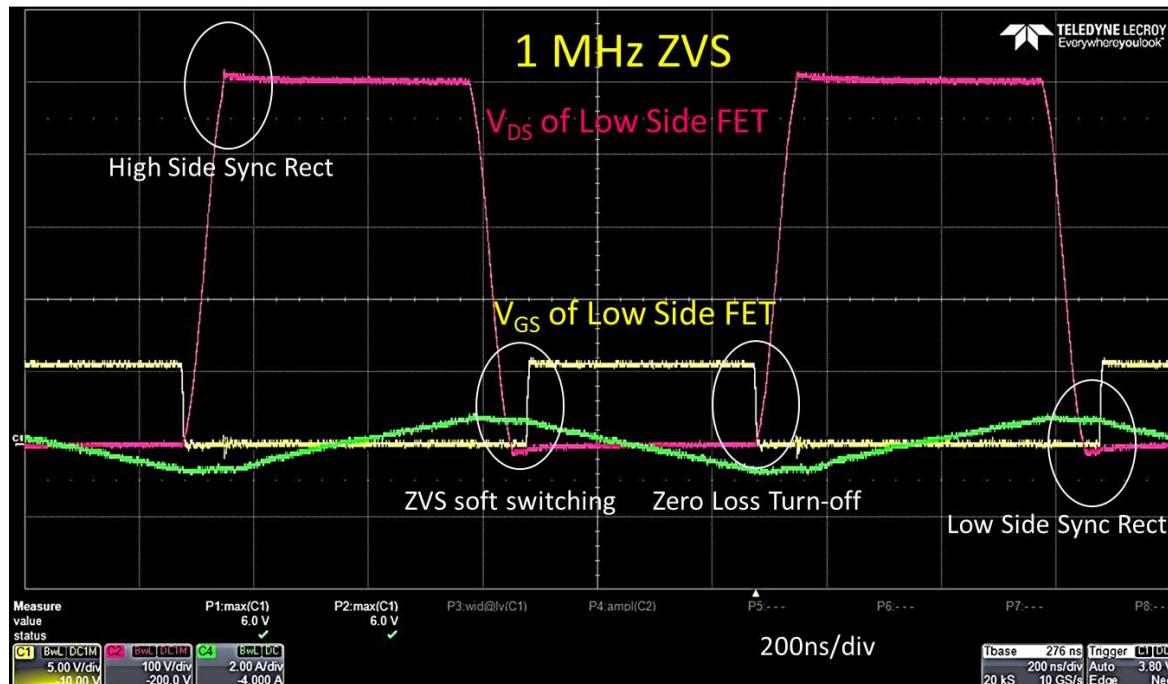
**World's First
AllGaN™ Power IC**



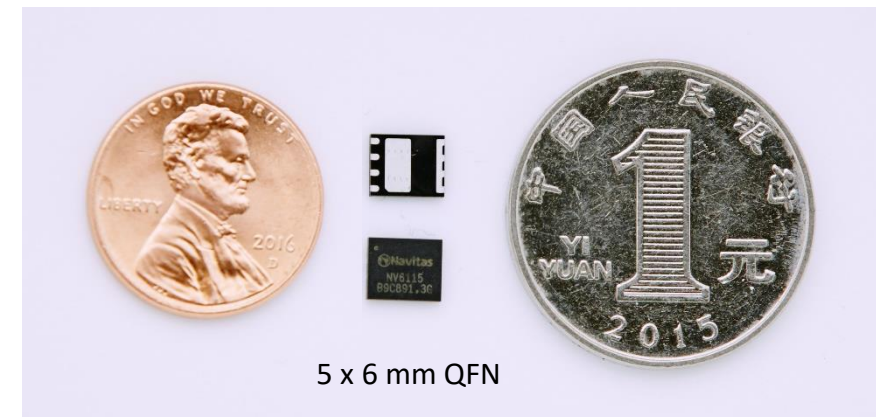
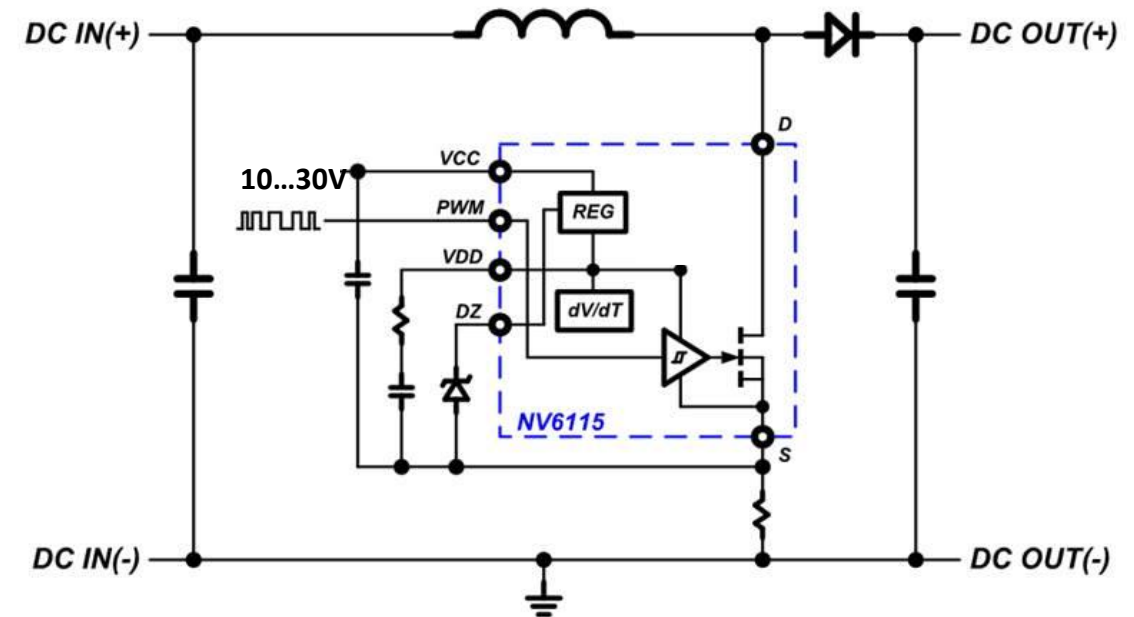
Up to 40MHz switching, 5x higher density & 20% lower system cost

AllGaN™: Monolithic GaN Power IC

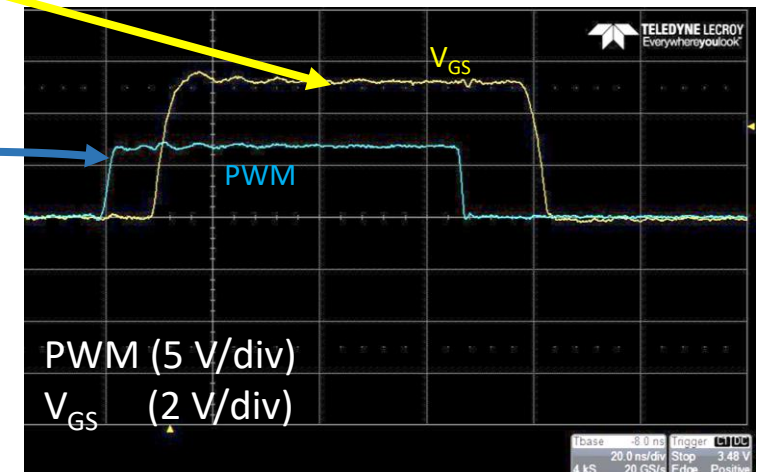
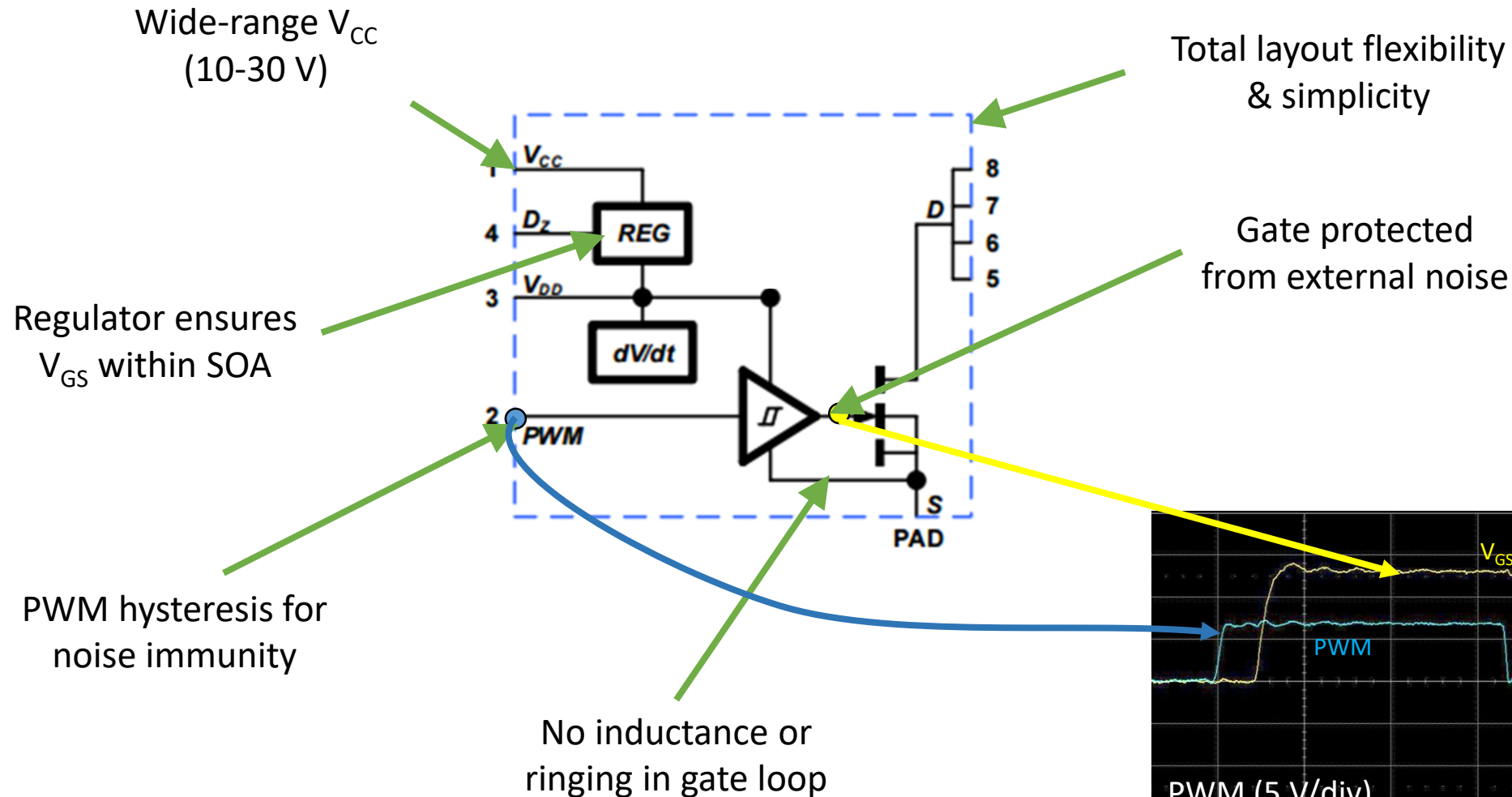
- Monolithic integration at 650 V
 - GaN FET (range 110-560 mΩ)
 - GaN Driver (iDrive™)
 - GaN Logic
- “Digital In, Power Out”



Half-bridge waveform



Integrated Drive → Simple & Robust



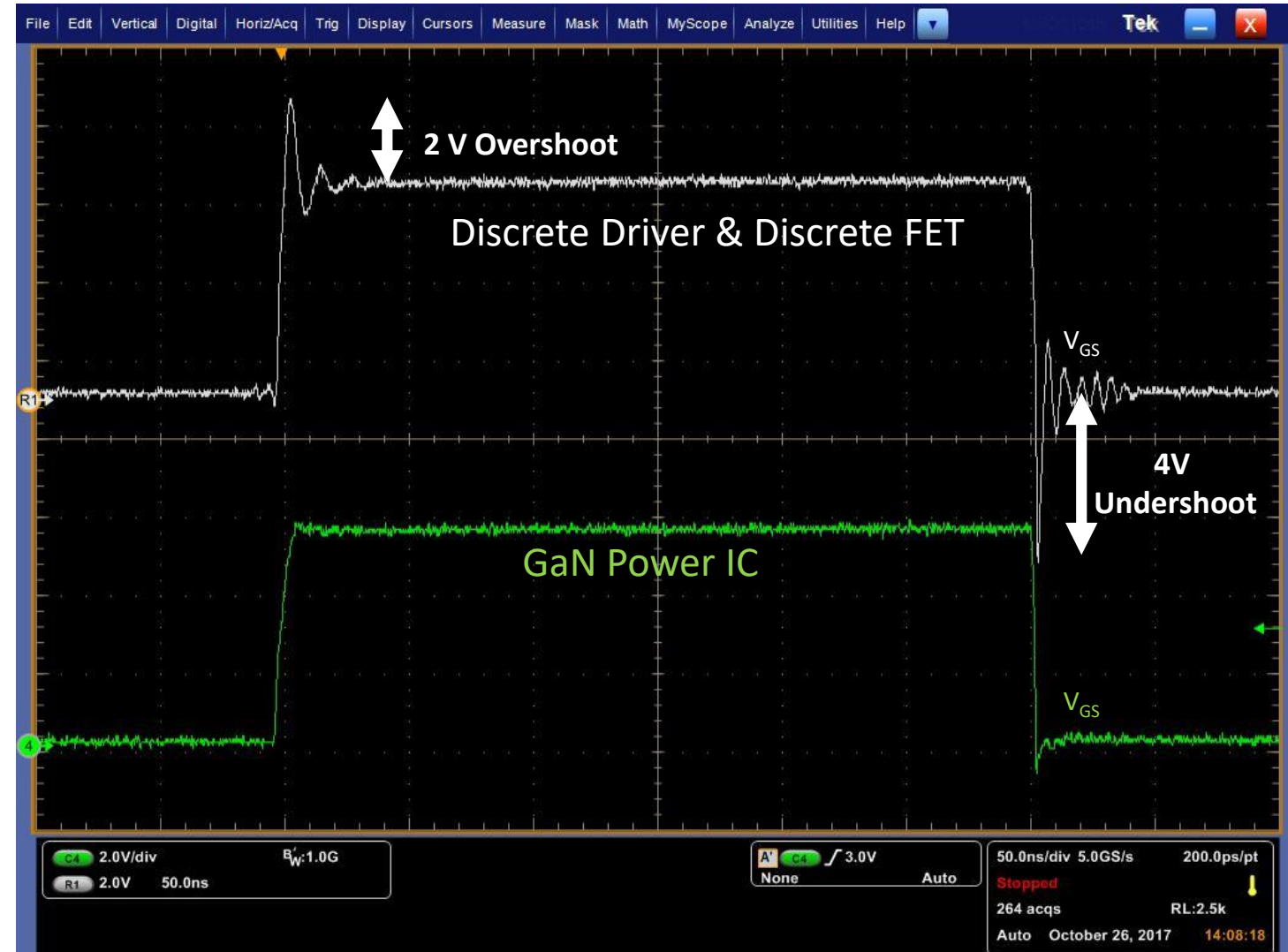
Clean, Controlled FET Gate

- **Discrete driver**

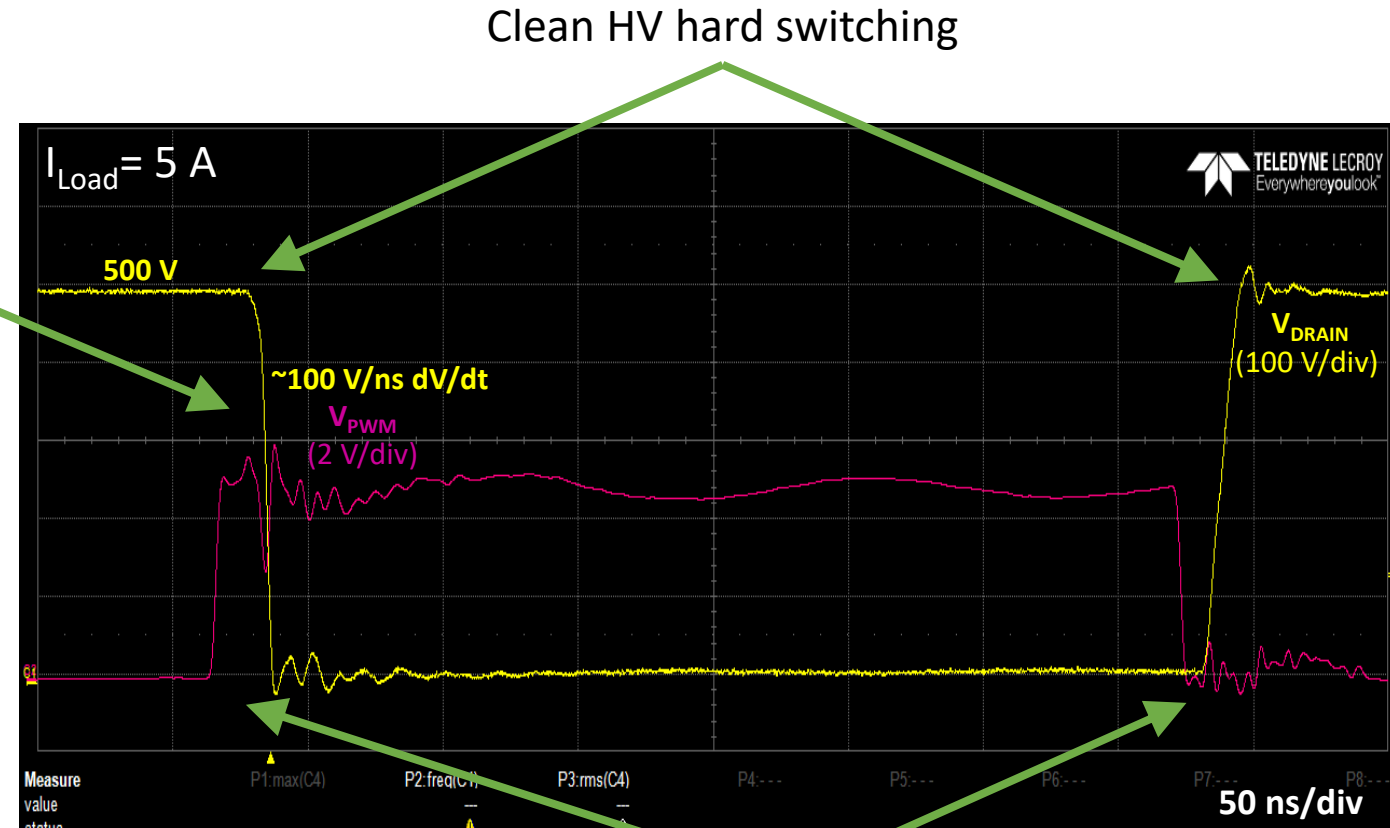
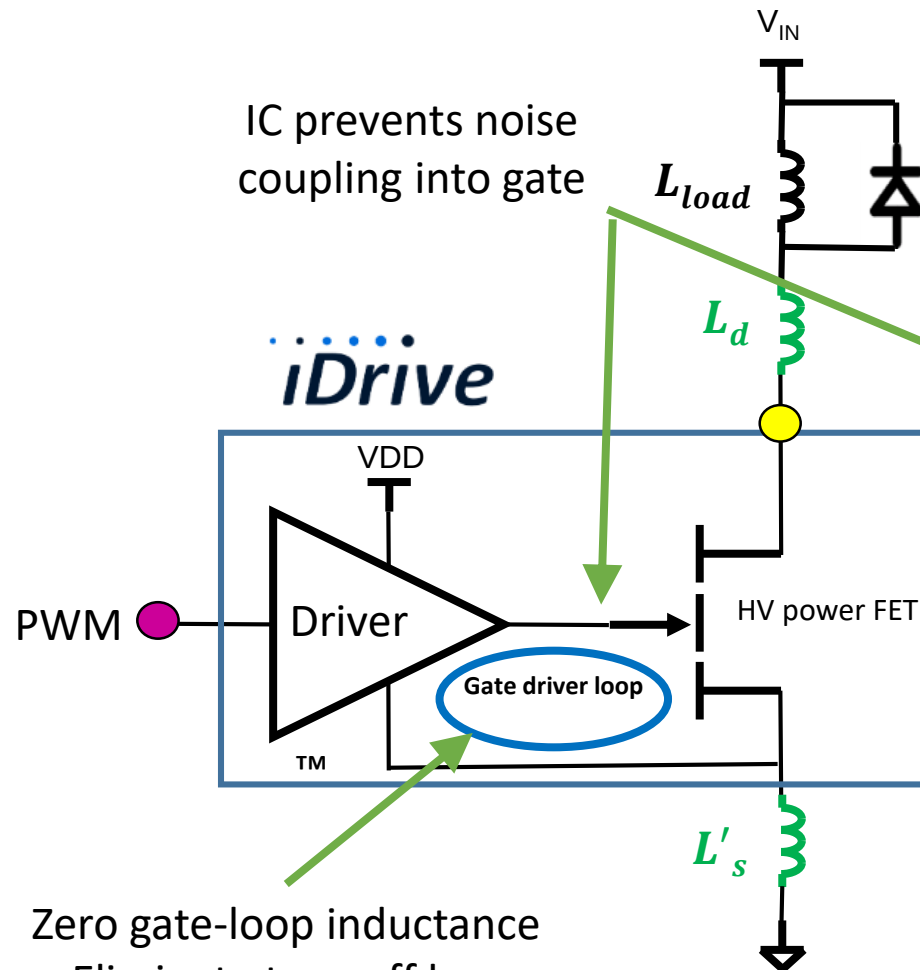
- Gate loop inductance creates overshoot (even with good layout)
- Reliability concern

- **iDrive™ GaN Power IC**

- No gate loop parasitic
- Clean and fast gate signal



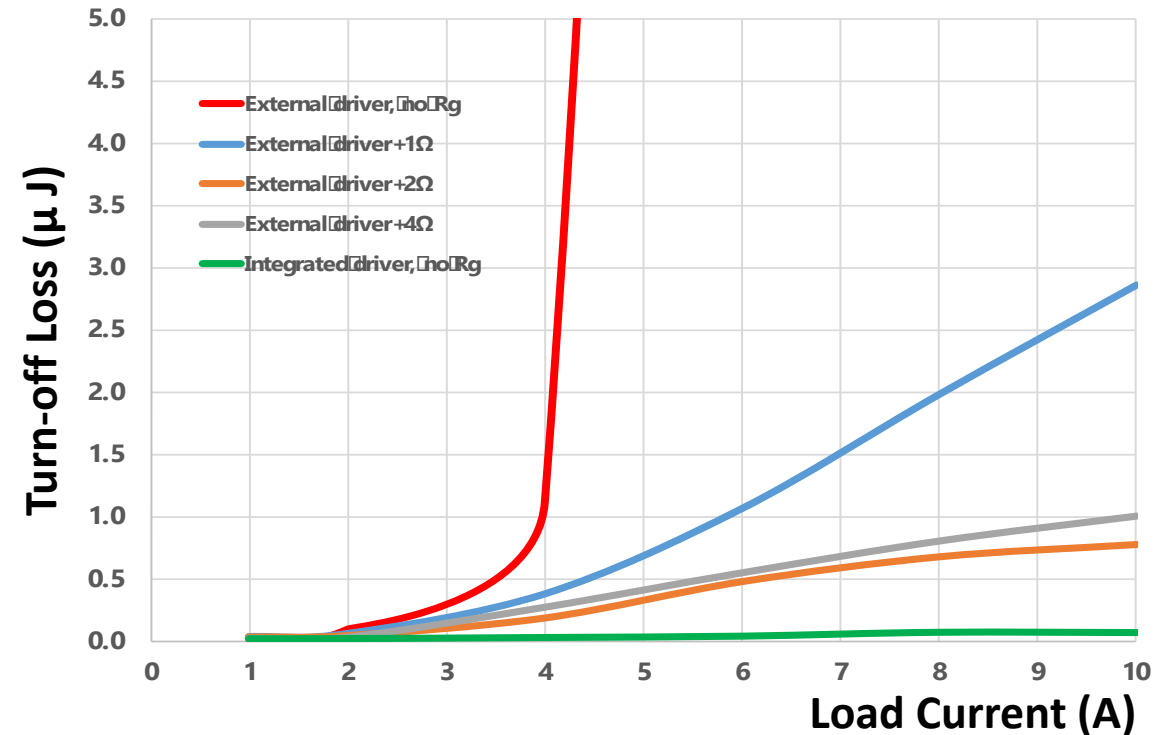
Fast & Clean Hard Switching



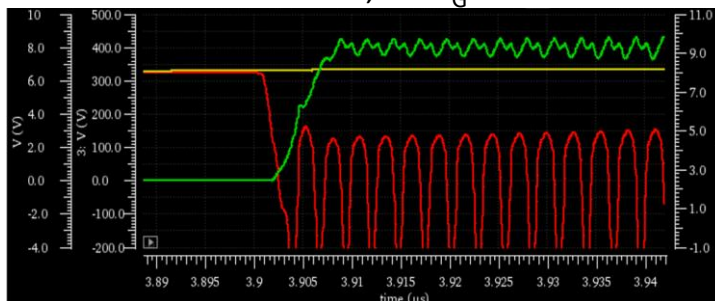
Prop delay 10-20 ns

Speed & Integration → Eliminate Turn-off Losses

- **External drivers**
 - Just 1-2 nH of gate loop inductance can cause unintended turn-on
 - Gate resistors reduce spikes but create additional losses
- **Integrated GaN drivers (iDrive™)**
 - Eliminate the problem
 - Negligible turn-off losses
 - Removes unintended dV/dt turn-on



Discrete FET and drive, no R_G = out of control



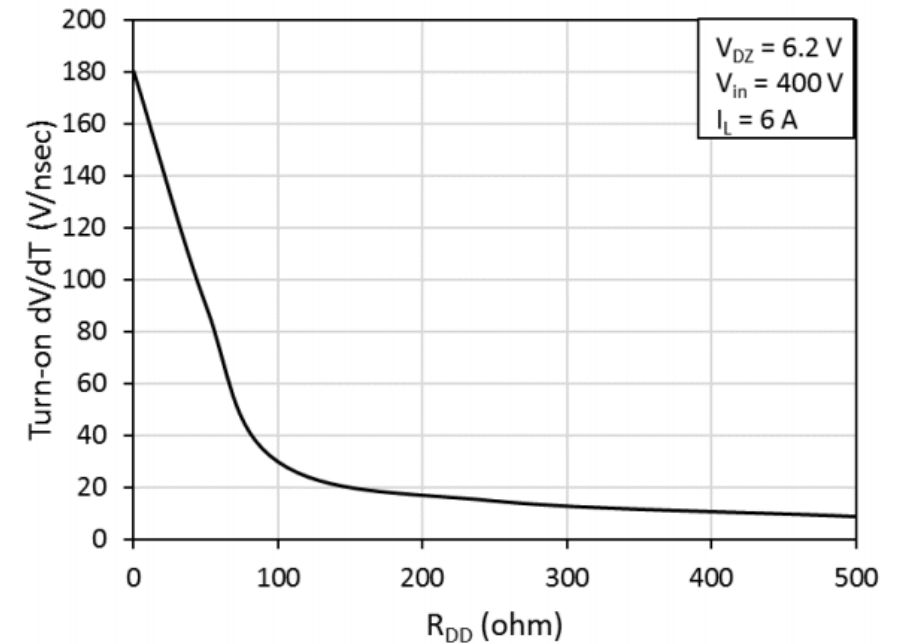
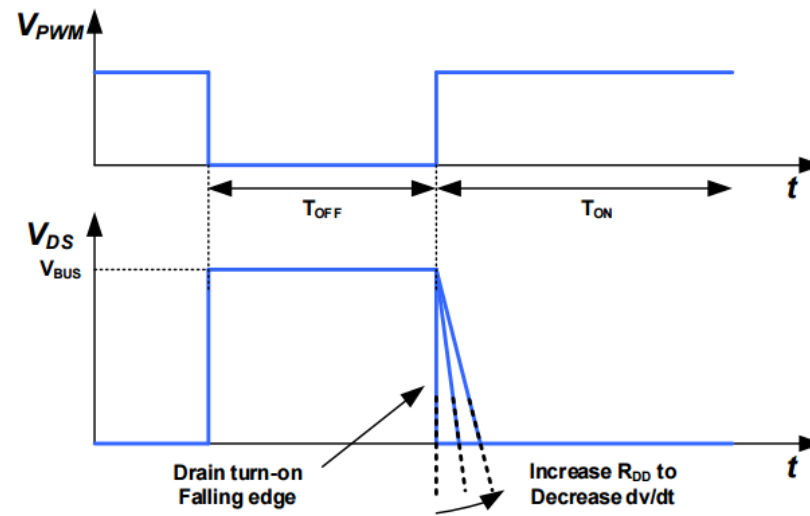
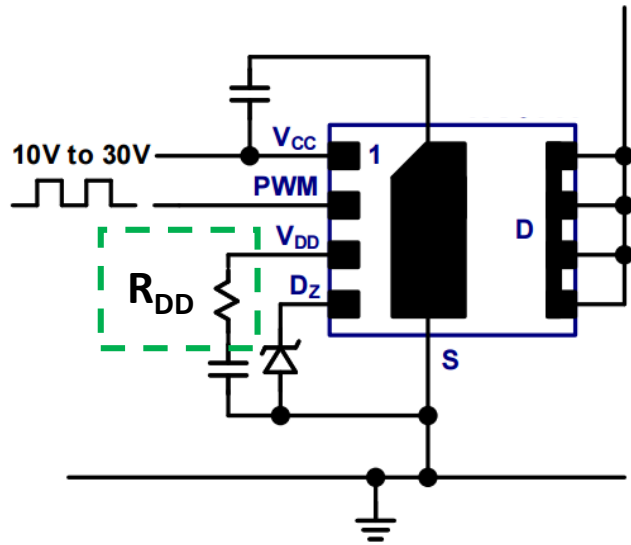
Discrete FET and drive, with R_G = slow, lossy



Integrated FET and drive, no R_G = fast, efficient



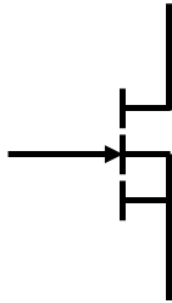
Easy EMI with dV/dt control



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

ESD Protection?

Discrete GaN

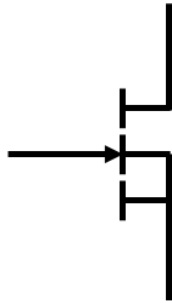


Low C_{ISS} → Fast switch, but...

HBM < 250 V (typical)

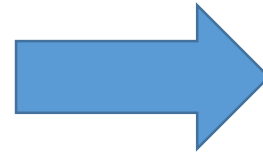
ESD Protected

Discrete GaN

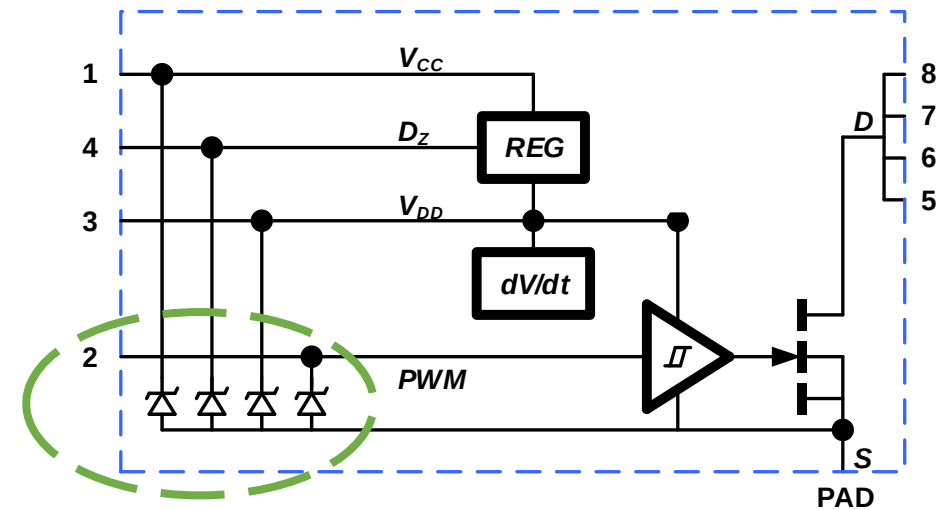


Low C_{ISS} → Fast switch, but...

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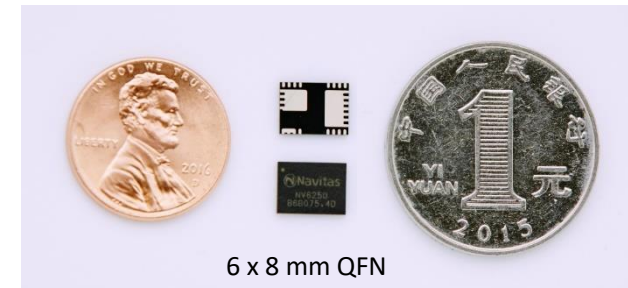
GaN Power IC



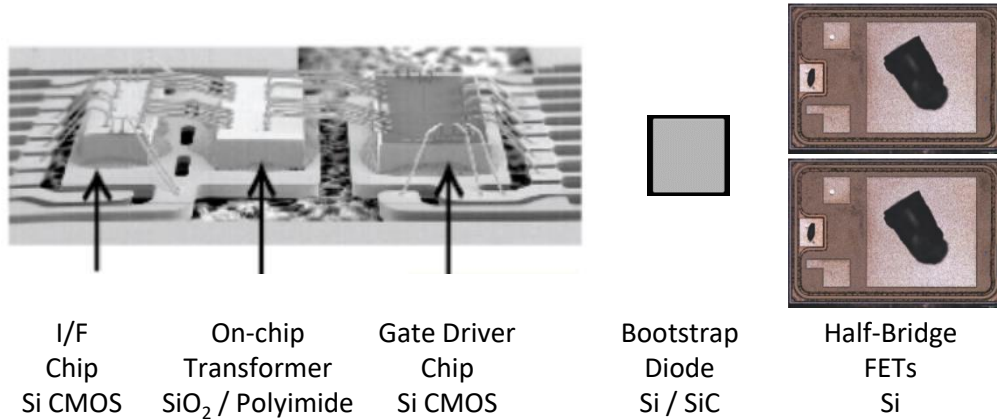
Integrated ESD Protection

HBM, CDM > 1,000 V

-



Old Level-Shift: High Loss, High Cost



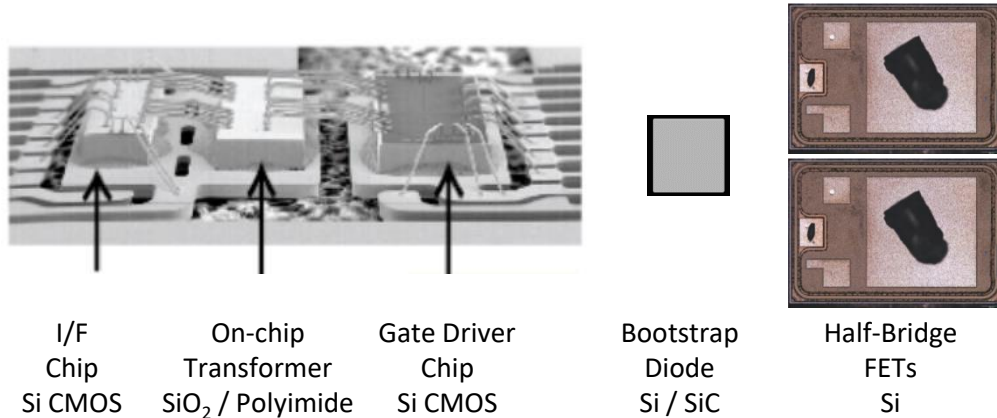
Disparate Technologies

Hybrid isolator, discrete driver, discrete power, bootstrap diode

High Power Loss

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

GaN Level-Shift: Low Loss, High-Frequency

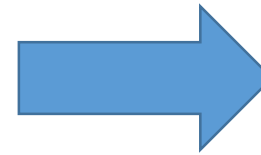
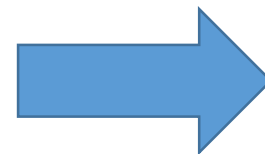


Disparate Technologies

Hybrid isolator, discrete driver, discrete power, bootstrap diode

High Power Loss

- Driver loss, R_G loss
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Monolithic Platform

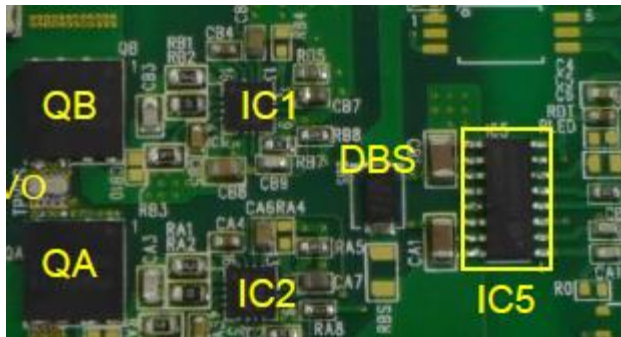
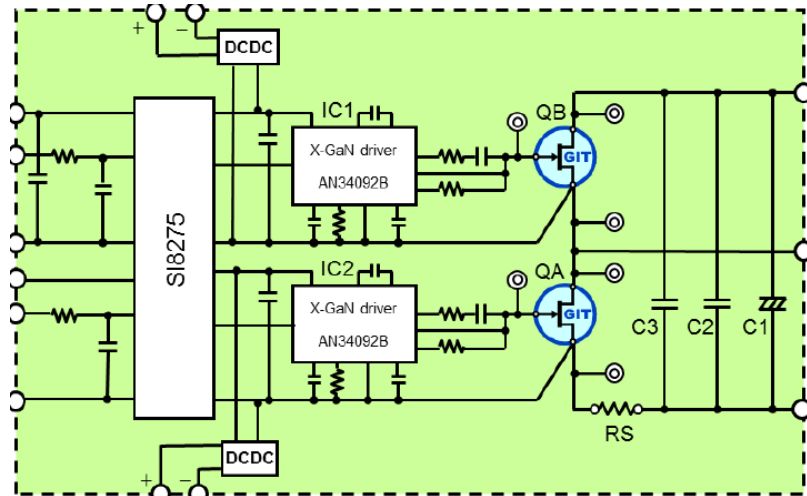
Lateral GaN-on-Si, Half-Bridge GaN Power IC

Low Power Loss

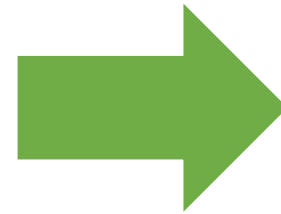
- No gate driver loop parasitics, matched driver-FET capability, negligible loss vs. frequency
- Zero Q_{RR} , low V_{DS} in synchronous charging
- Very fast, low-power loss, MHz+

Complex Design → Easy-to-Use

Half-Bridge Discrete GaN

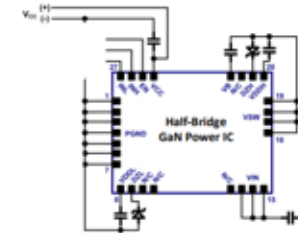


PCB Area: 24 x 42 ~ 1,000 mm²



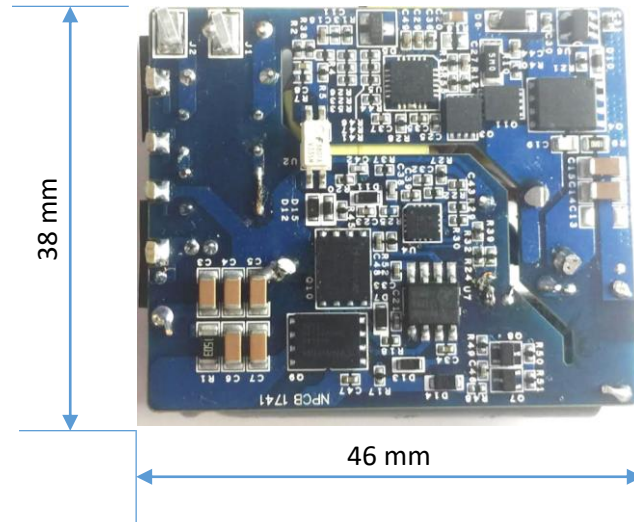
- ✓ 20x smaller PCB area
- ✓ 40+ fewer components
- ✓ Lower cost
- ✓ Robust & protected
- ✓ Simple
- ✓ Easy layout

Half-Bridge GaN Power IC

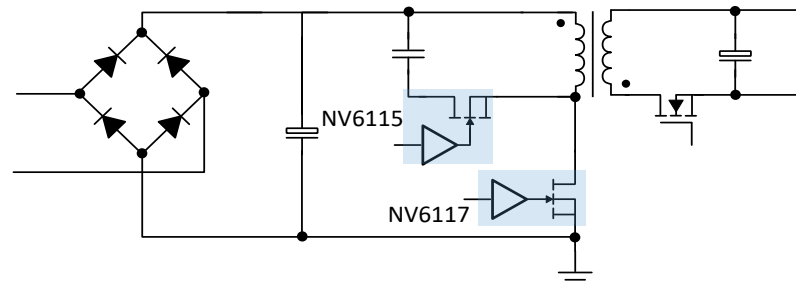


PCB Area: 6 x 8 = 48 mm²

65W USB-PD ACF: *World's Smallest Adapter*

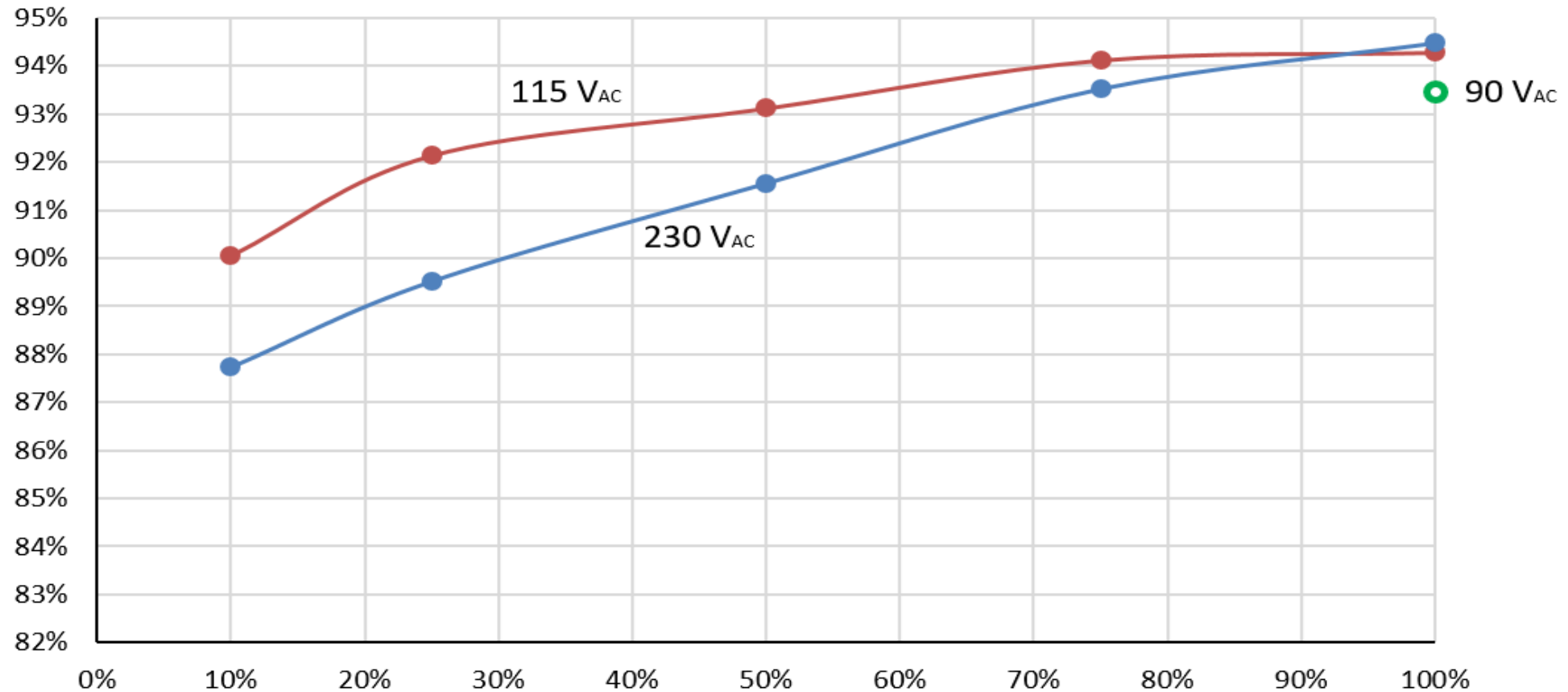


- Input : Universal AC (85-265V_{AC}, 47-63Hz)
- Output : USB-PD (5-20V) (65W)
- Primary : NV6115 (160mΩ) + NV6117 (110mΩ) GaN Power ICs
- Frequency : ~300 kHz
- Size : 38 x 46 x 15.5 mm = 27 cc uncased
43 x 51 x 20.5 mm = 45 cc with 2.5 mm case
- Power Density : 2.4 W/cc (39 W/in³) uncased
1.5 W/cc (24 W/in³) cased
- Construction : 4-layer, 2-oz Cu PCB, SMT powertrain
“No heatsink” design



65W USB-PD ACF

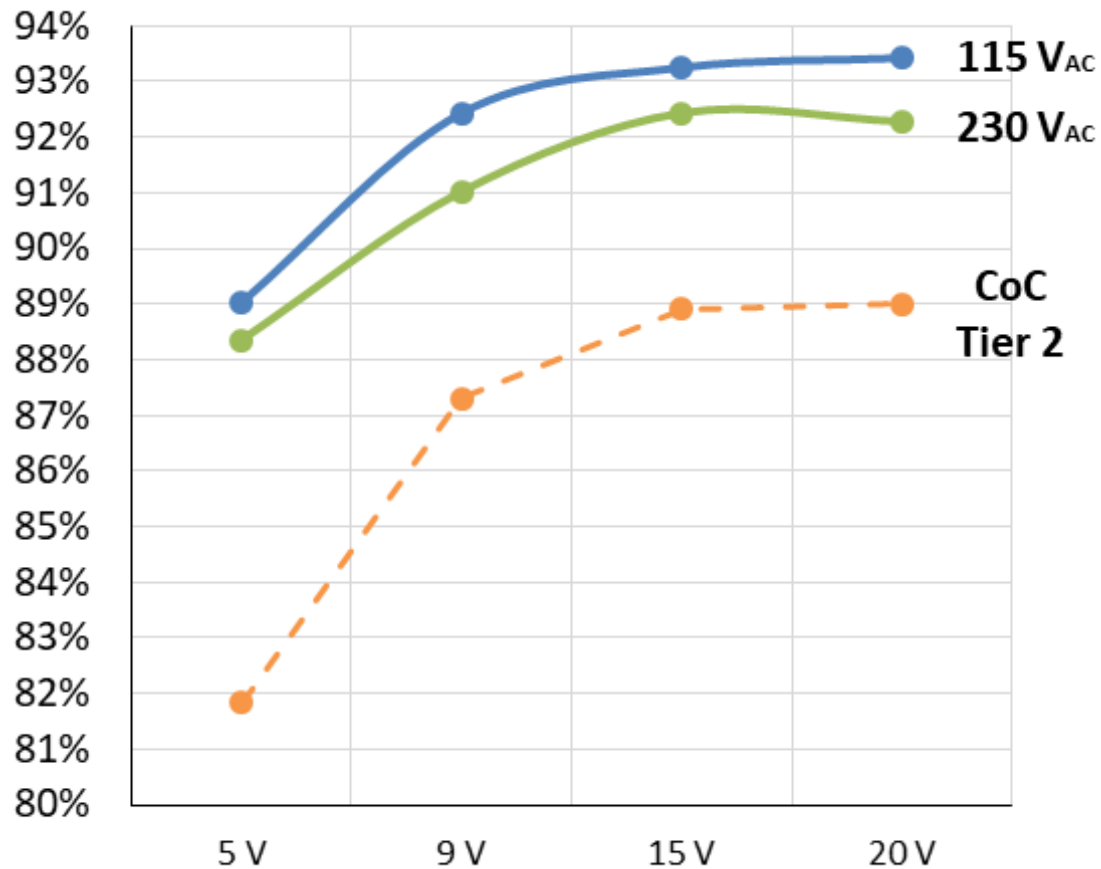
Efficiency at 20 V_{OUT} (25°C, no airflow)



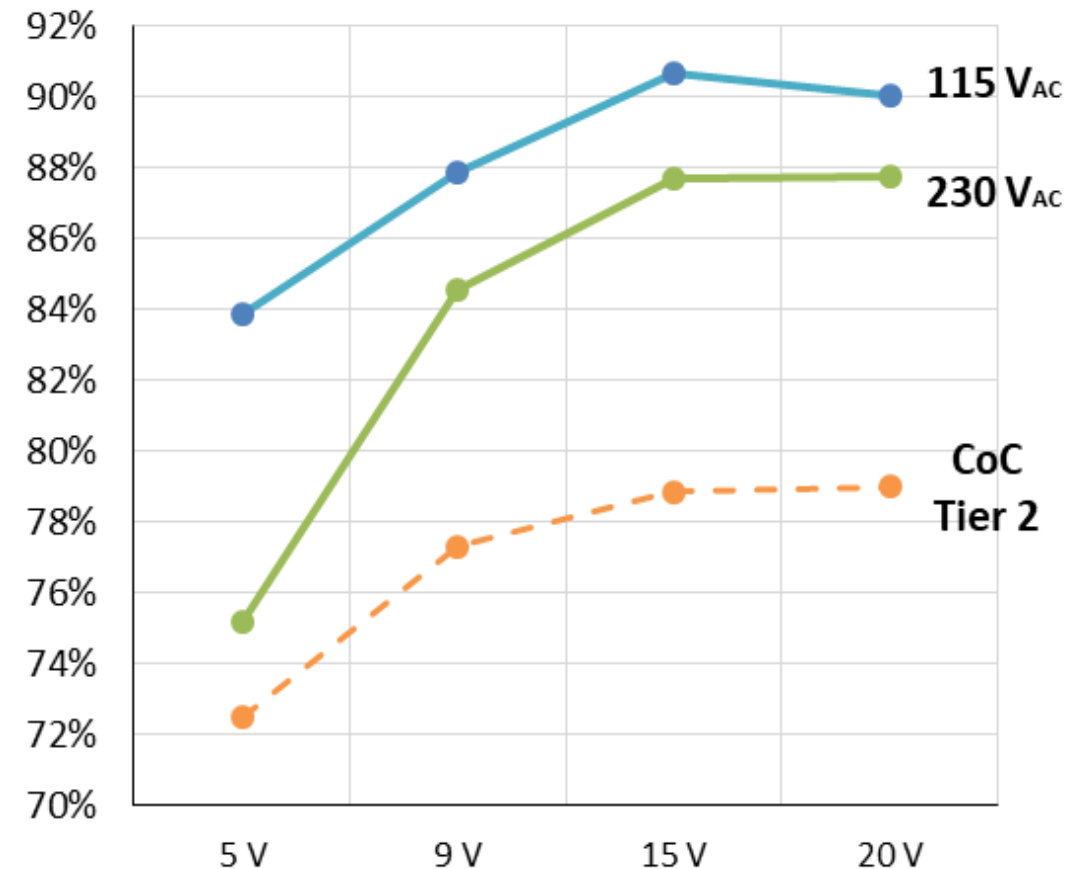
65W USB-PD ACF

Efficiency (25°C, no airflow)

4-point Average Efficiency

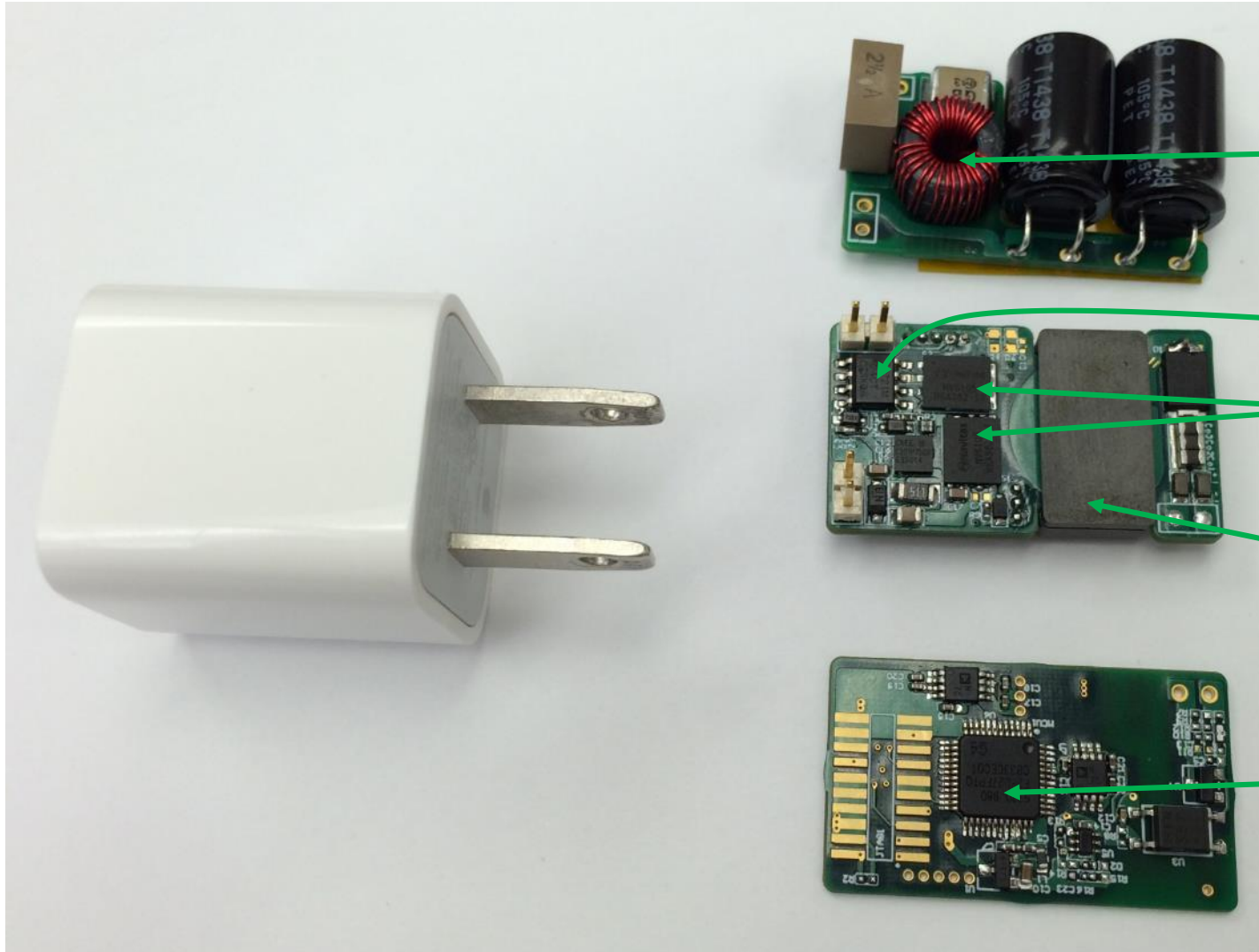


10% Load Efficiency



- Standby: 25 mW at 115 V_{AC}, 40 mW at 230 V_{AC} (CoC Tier 2 spec is < 75mW, DoE Level VI spec <= 210 mW)

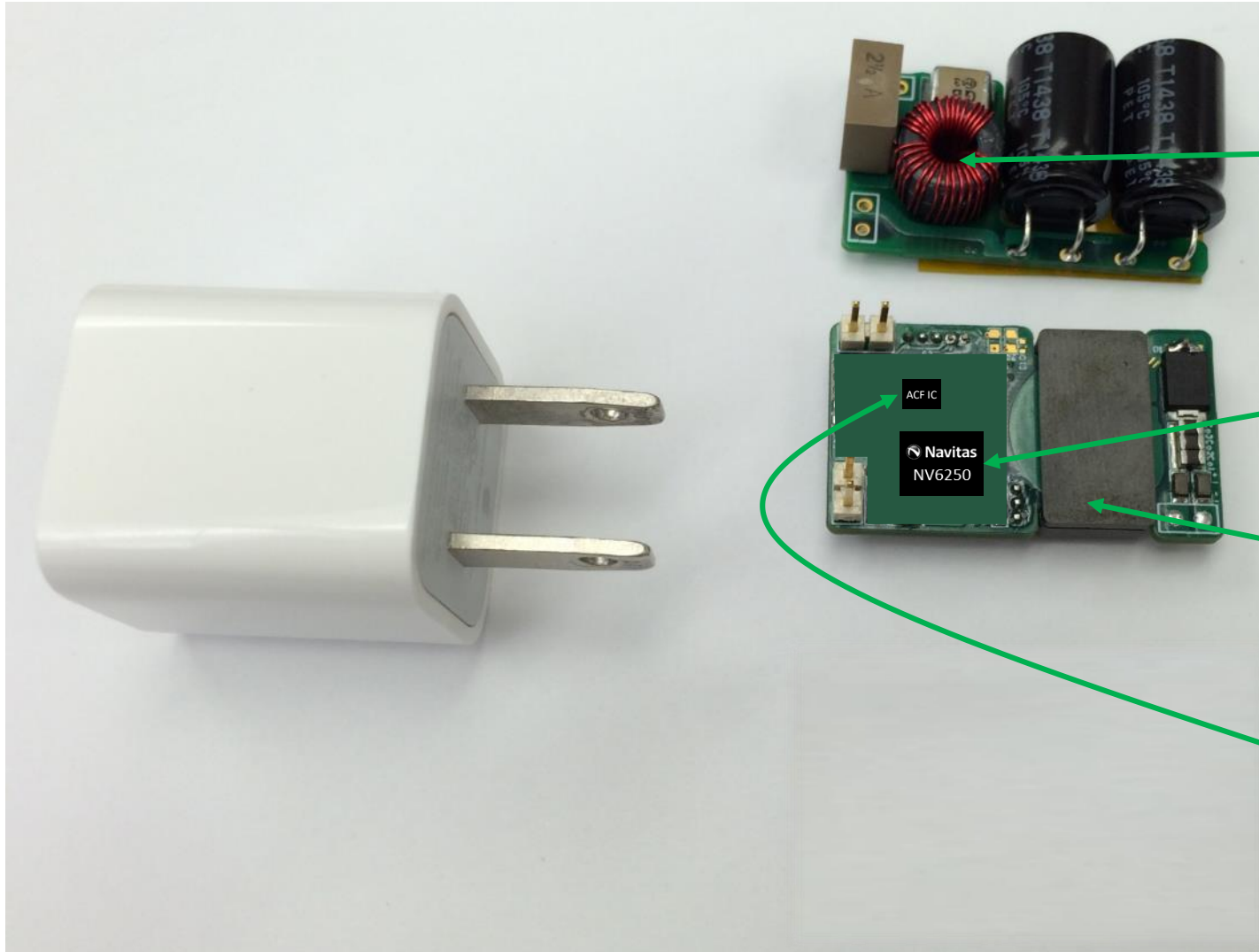
1 MHz, 25 W ACF in 5W Size



- Single-stage EMI
- Level-shifter
- 2x Navitas single GaN Power ICs
- Planar transformer
- DSP (for prototype)



1 MHz, 25 W ACF – Next Step



- Single-stage EMI

- 1x Navitas Half-Bridge GaN Power IC

- Planar transformer

- ACF IC





GaN



GaN Power ICs: Integration Drives Performance



纳微 Navitas

65W USB-PD