GaN Power ICs: Integration Drives Performance

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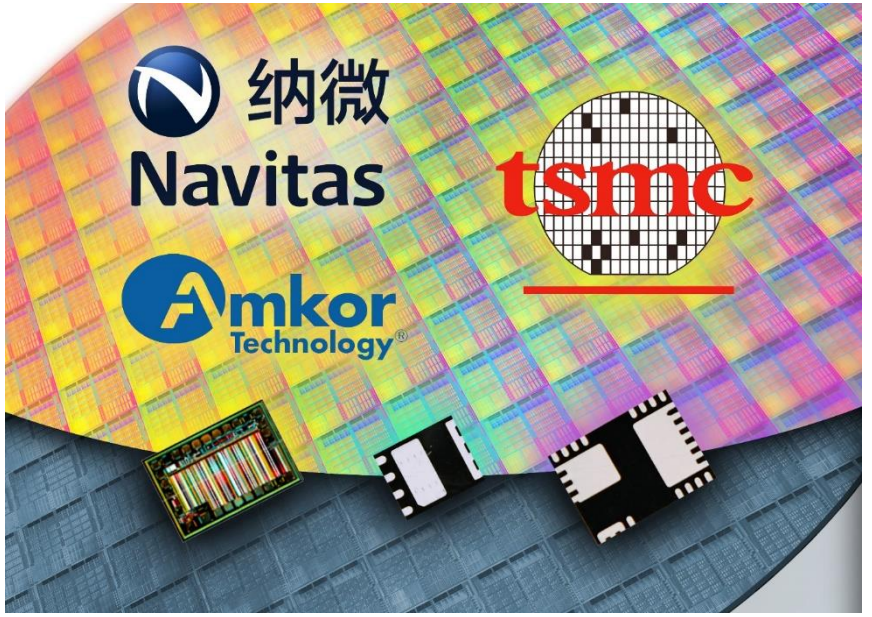
Bodo's Power Conference, Munich December 5th, 2017

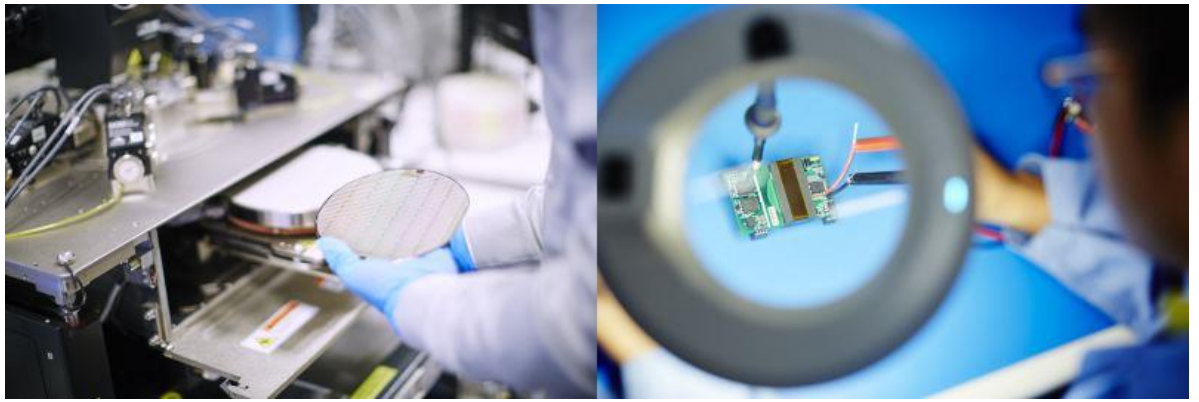
Navitas Semiconductor Inc.

- 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

STAR WARS

Written and Directed by
GEORGE LUCAS

Produced by
GARY KURTZ

Music by
JOHN WILLIAMS

PANAVISION® PRINTS BY DE LUXE® TECHNICOLOR®

Making Films Sound Better
DOLBY SYSTEM®
Noise Reduction - High Fidelity

Original Motion Picture Soundtrack on 20th Century Records and Tapes

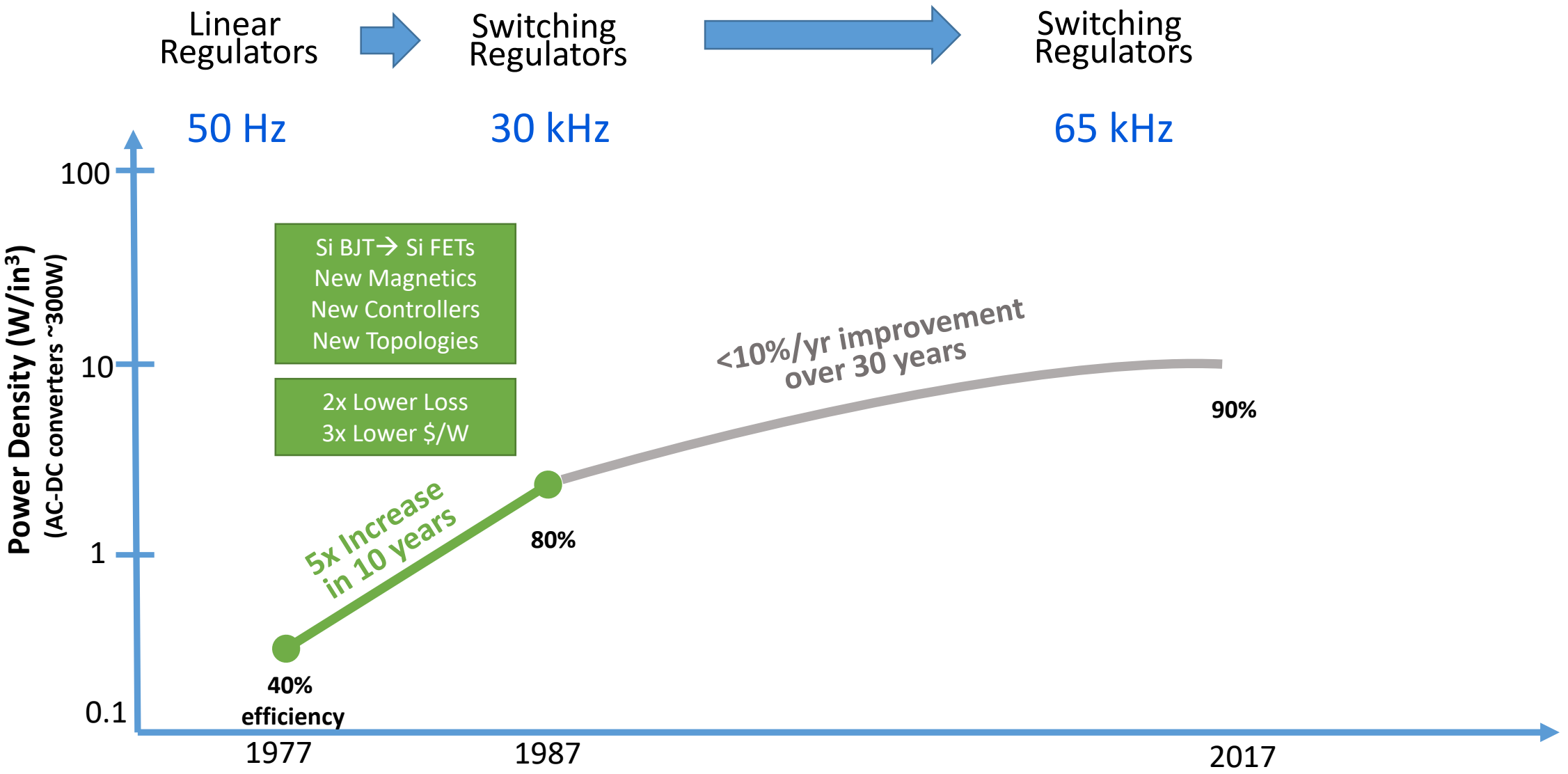
PRINTED IN U.S.A.

ONE SHEET STYLE "C"

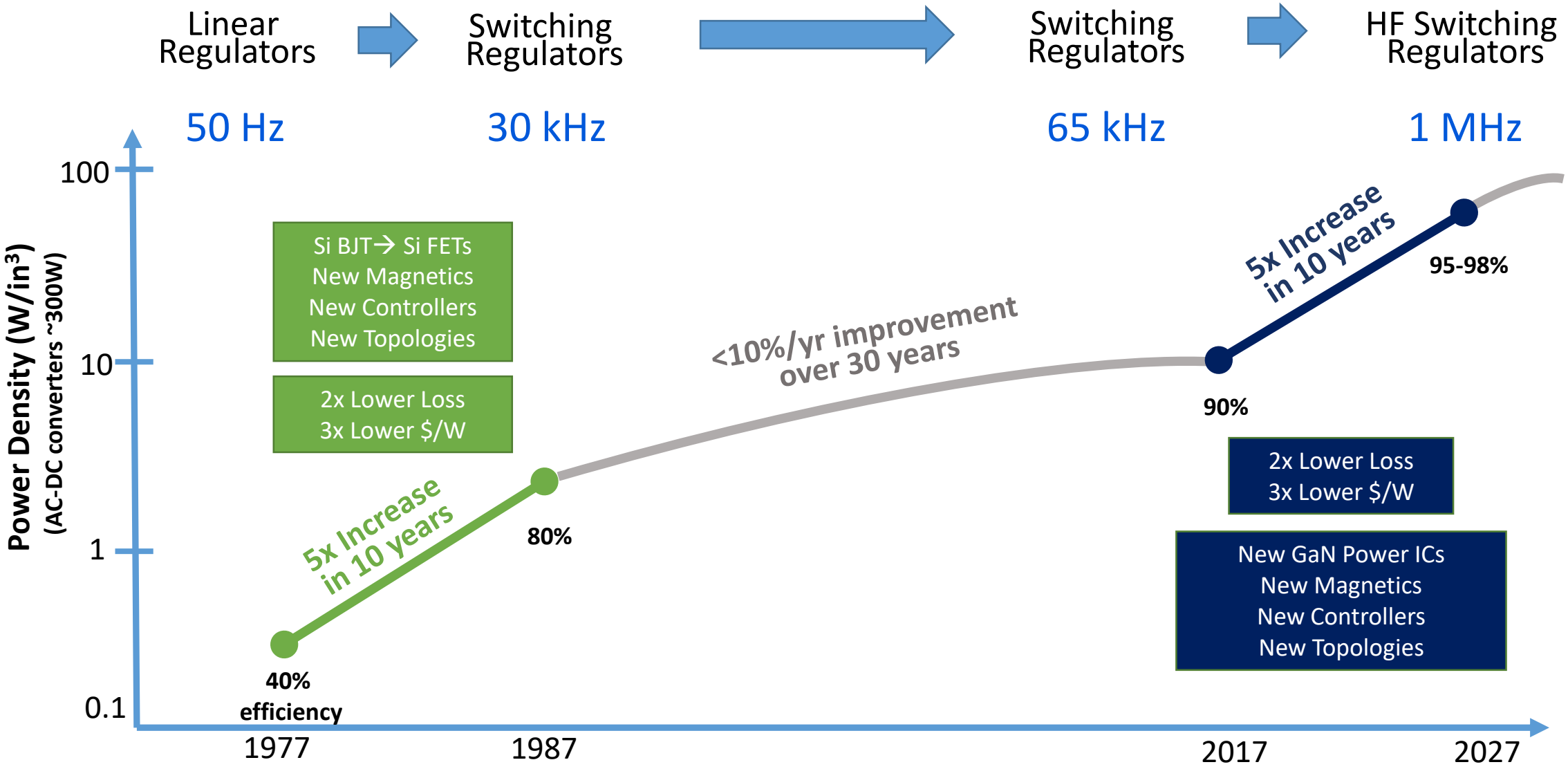
A Question on History…

- *What **<u>else</u>** happened in 1977?*

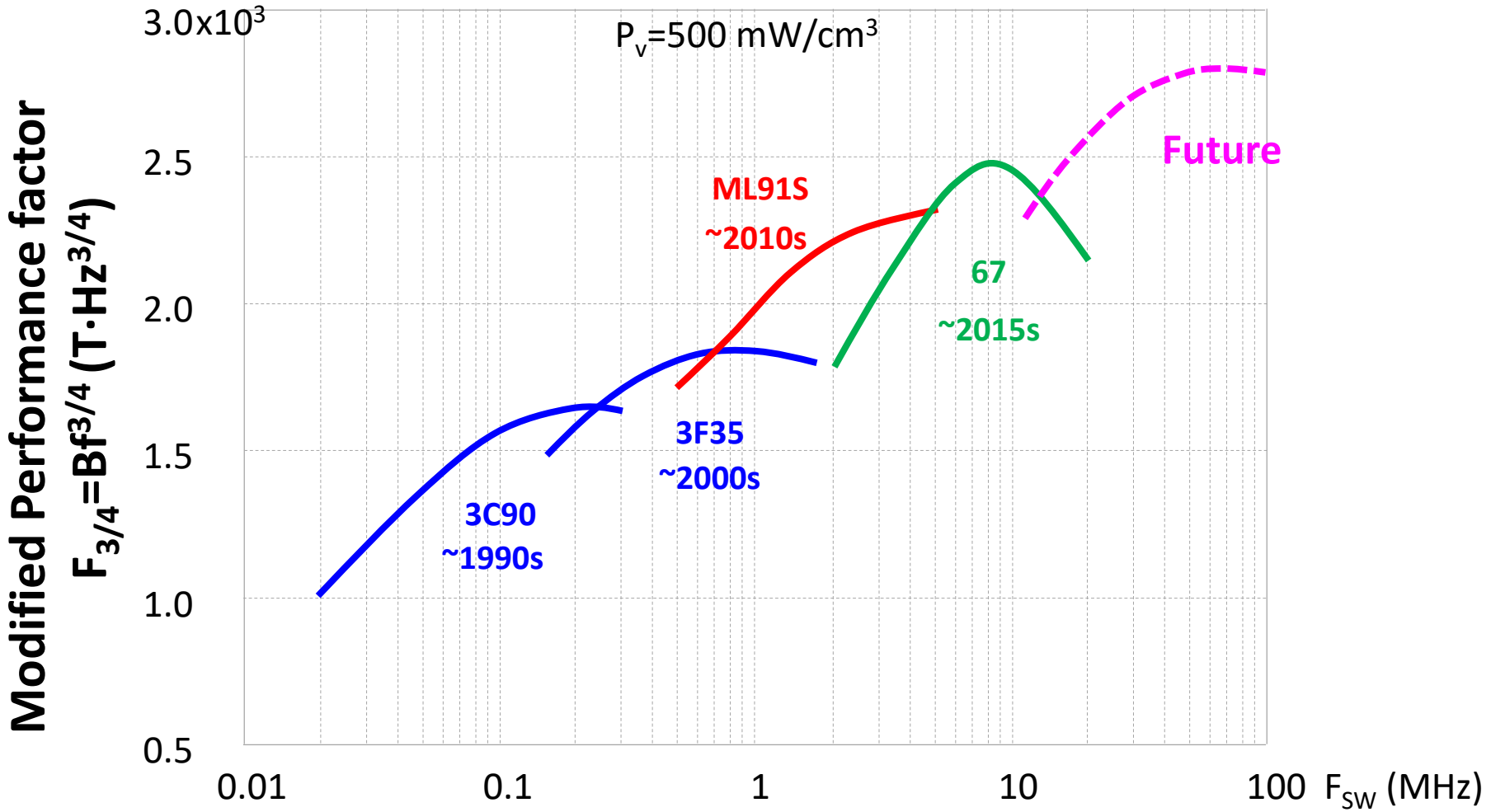
The First Revolution in Power



Today's Power Revolution



HF Magnetics

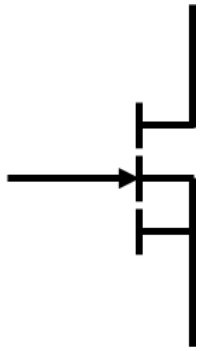


Y. Han, G. Cheung, A. Li, C. R. Sullivan and D. J. Perreault, "Evaluation of Magnetic Materials for Very High Frequency Power Applications," in *IEEE Transactions on Power Electronics*, vol. 27, no. 1, pp. 425-435, Jan. 2012.

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

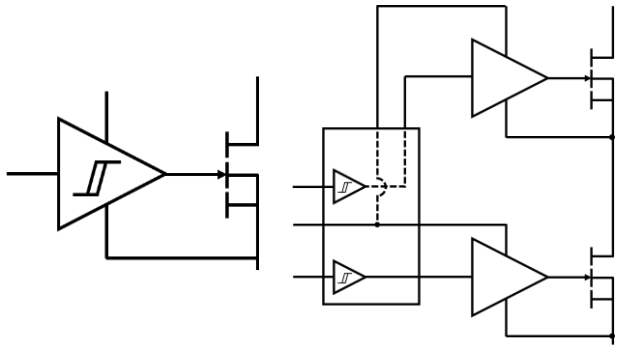
Fastest, most efficient GaN Power FETs



>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

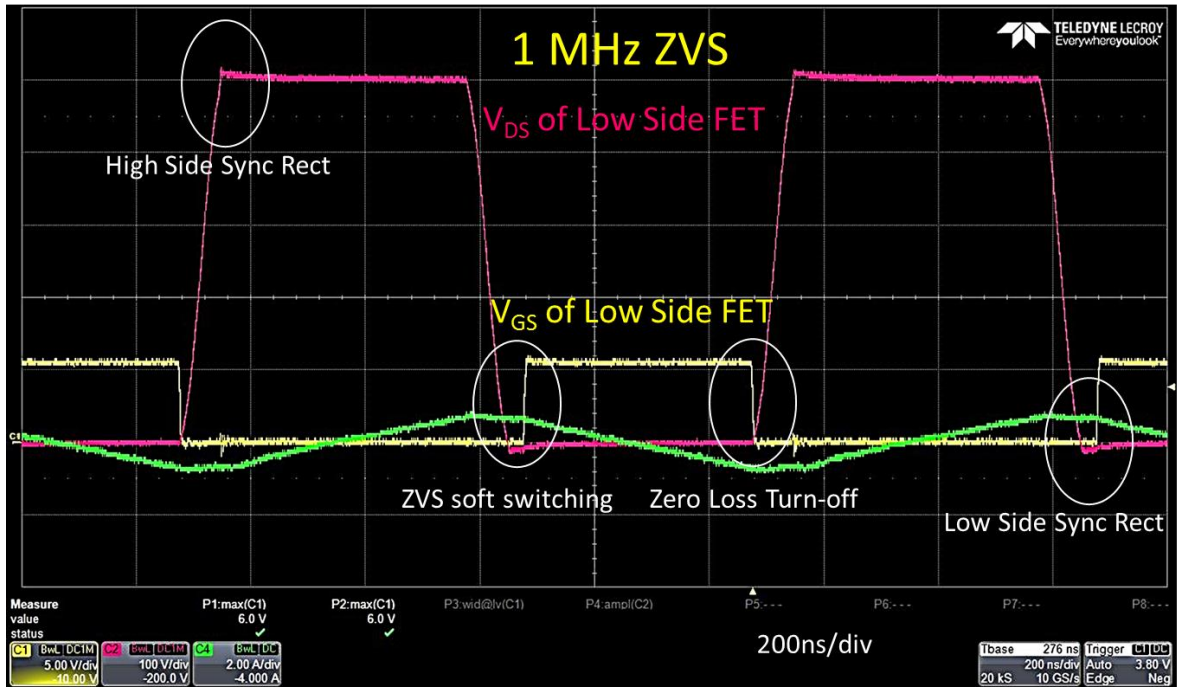
=

World's First AllGaN™ Power IC

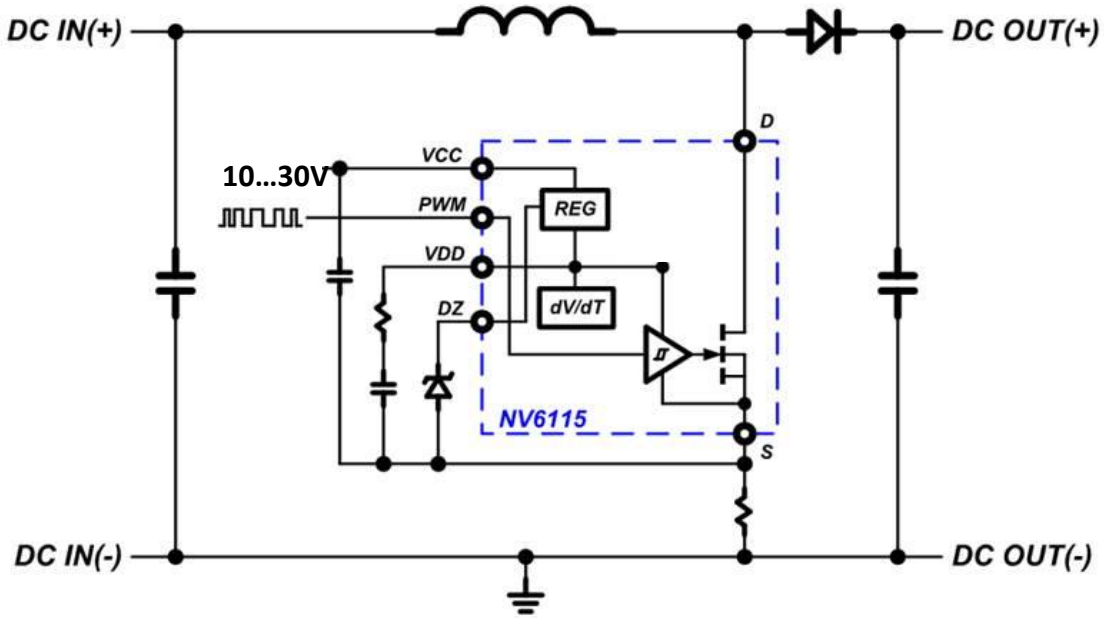
Up to 40MHz switching, 5x higher density & 20% lower system cost

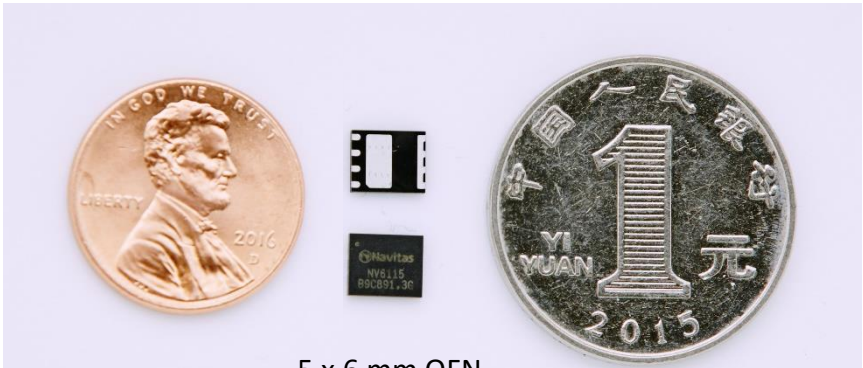
AllGaN™: Monolithic GaN Power IC

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



Half-bridge waveform





5 x 6 mm QFN

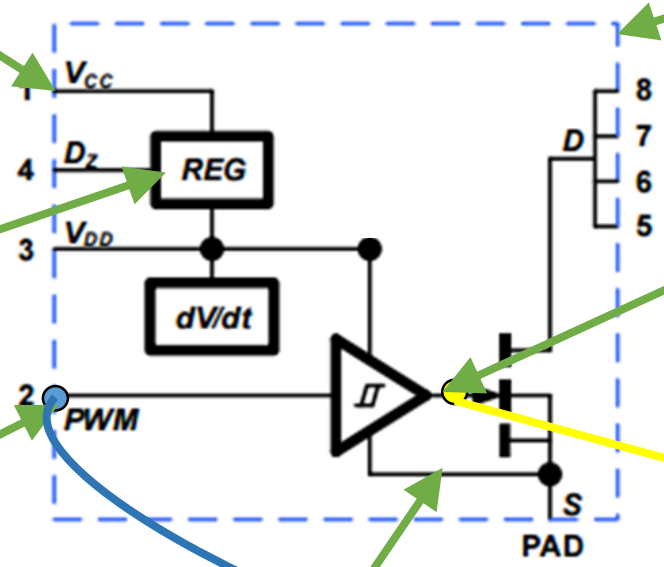
Integrated Drive→ Simple & Robust

Wide-range V_{CC} (10-30 V)

Total layout flexibility & simplicity

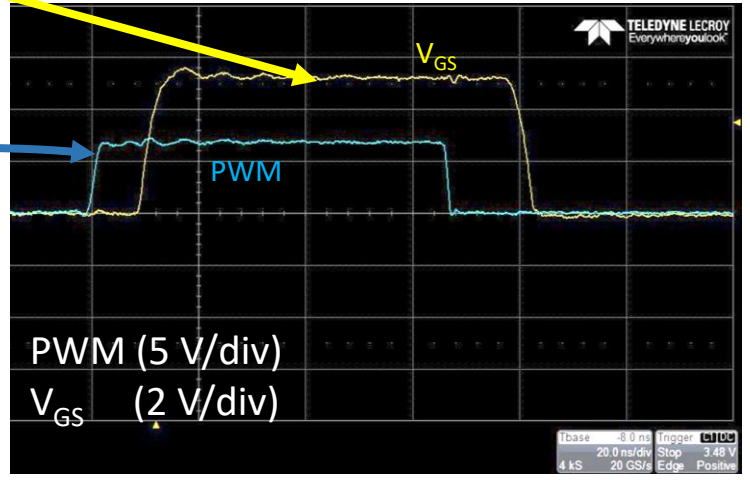
Regulator ensures V_{GS} within SOA

Gate protected from external noise



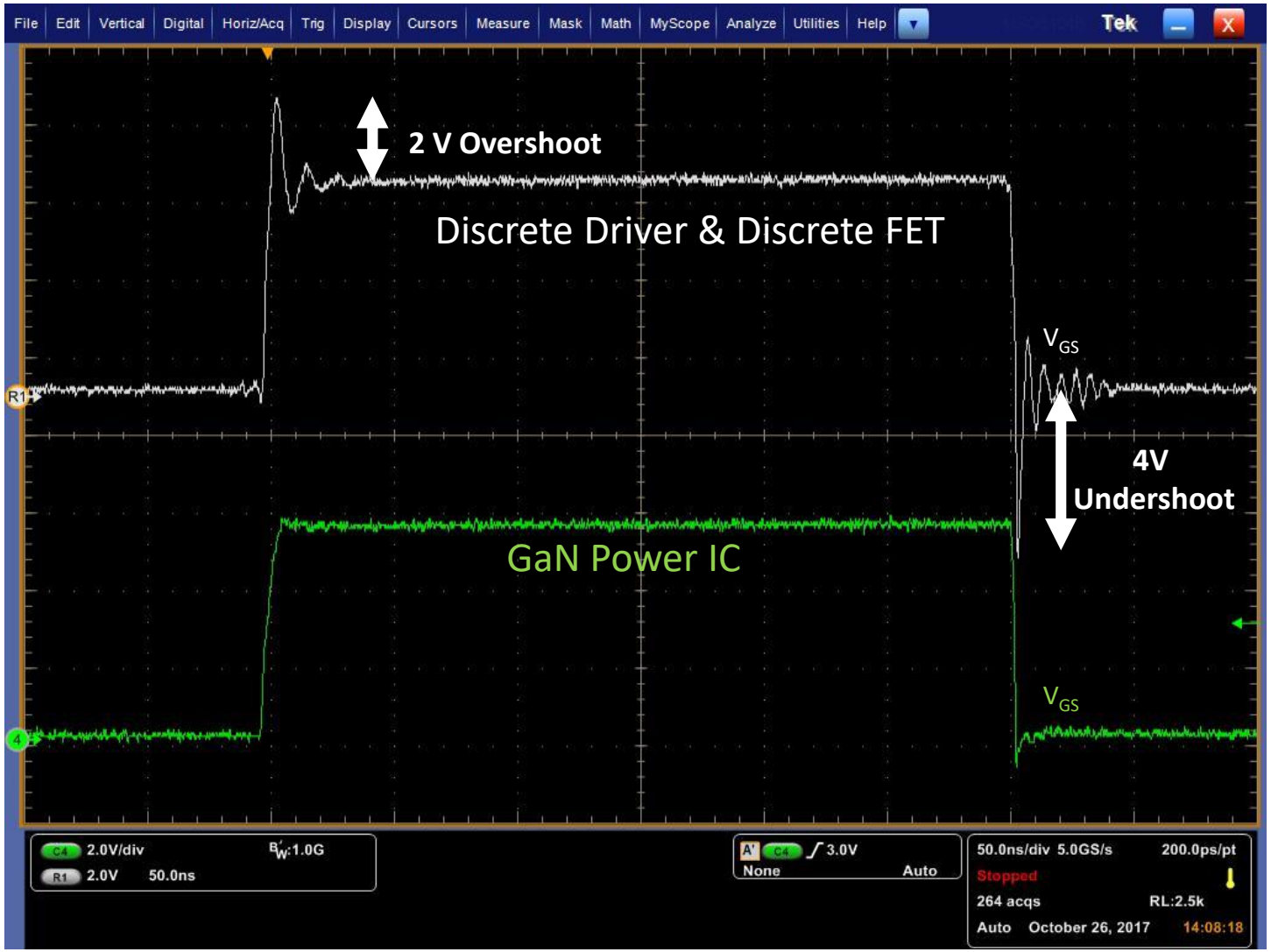
PWM hysteresis for noise immunity

No inductance or ringing in gate loop

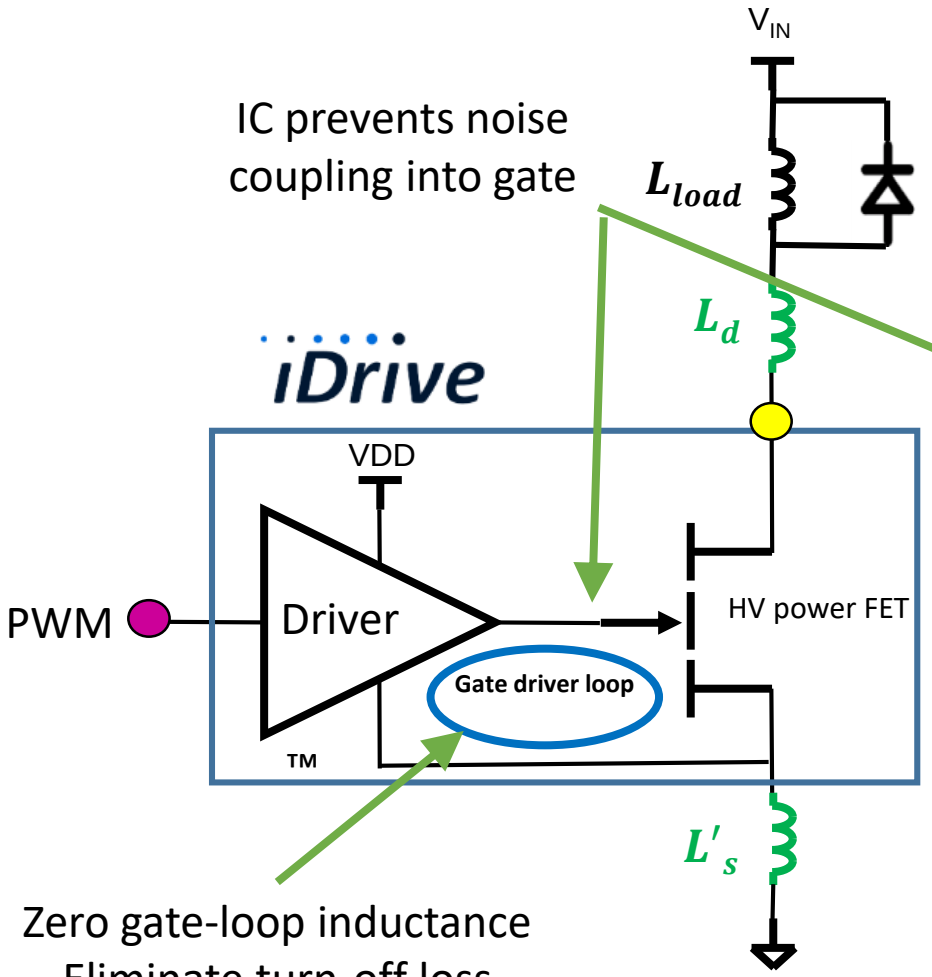


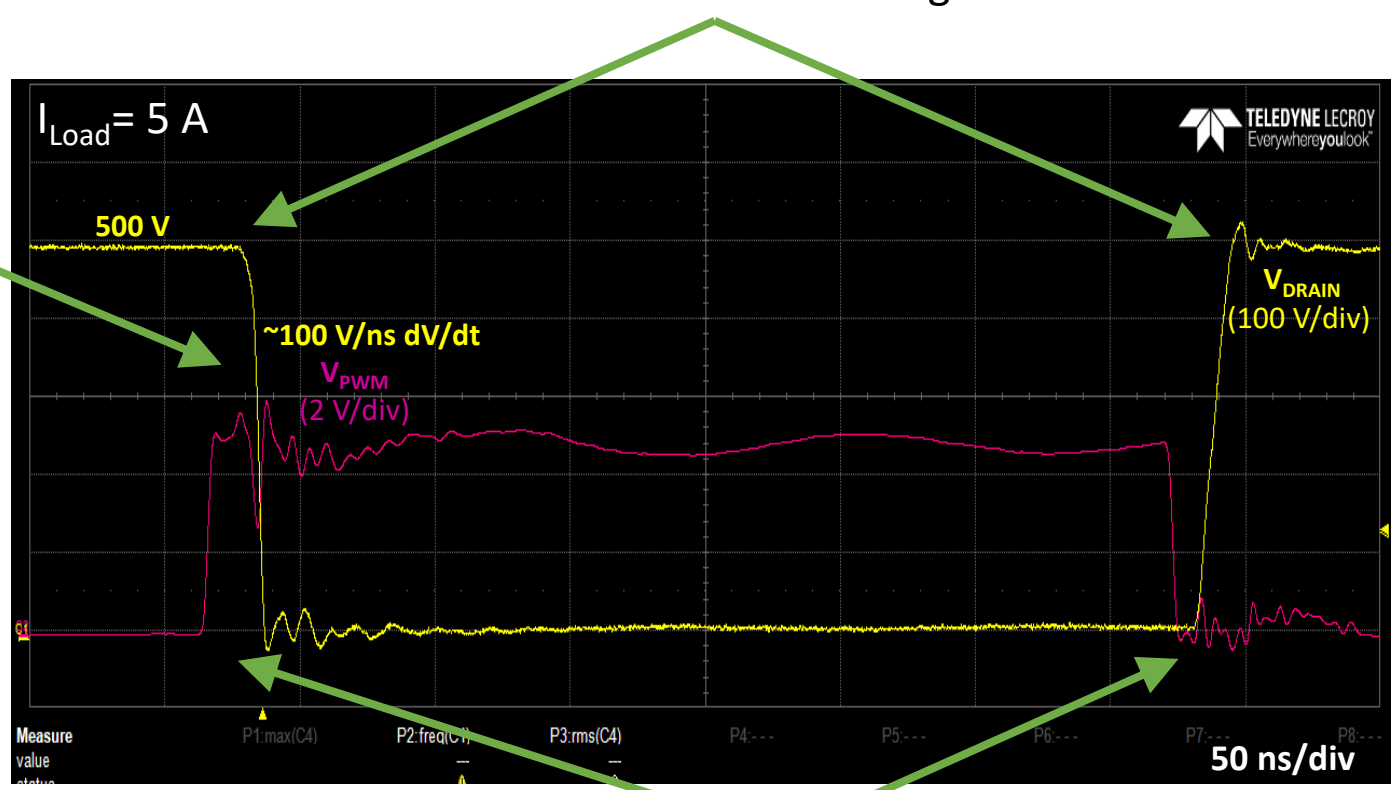
Clean, Controlled FET Gate

- **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



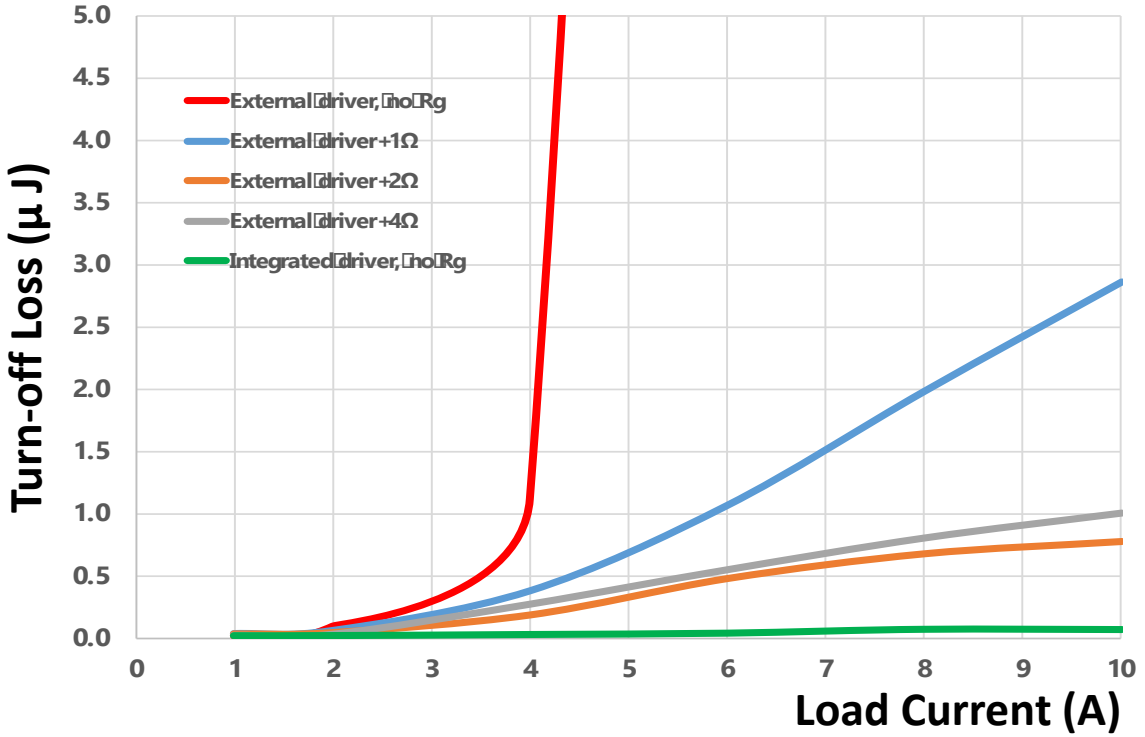
Fast & Clean Hard Switching



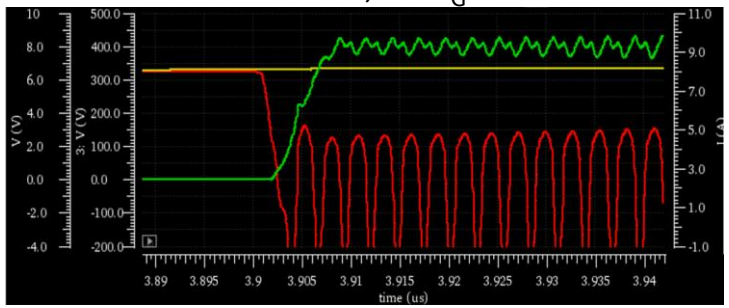


Speed & Integration → Eliminate Turn-off Losses

- **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



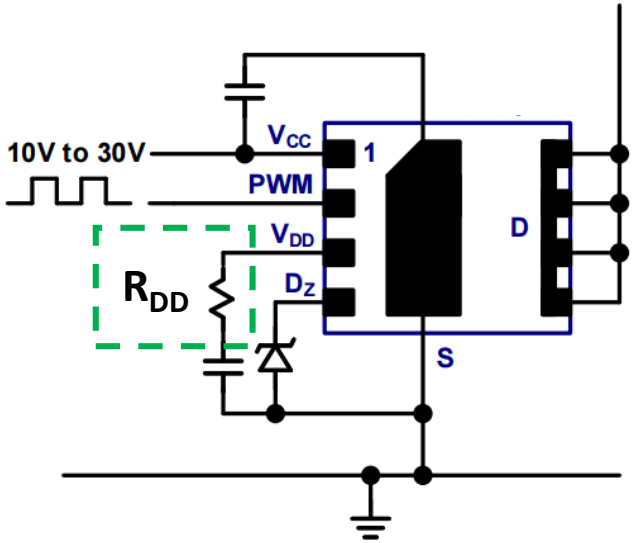
Discrete FET and drive, no R_G = out of control

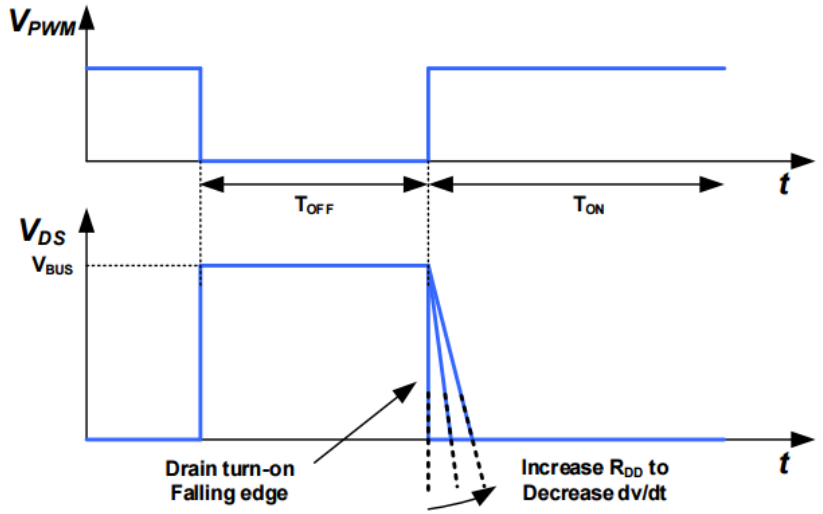


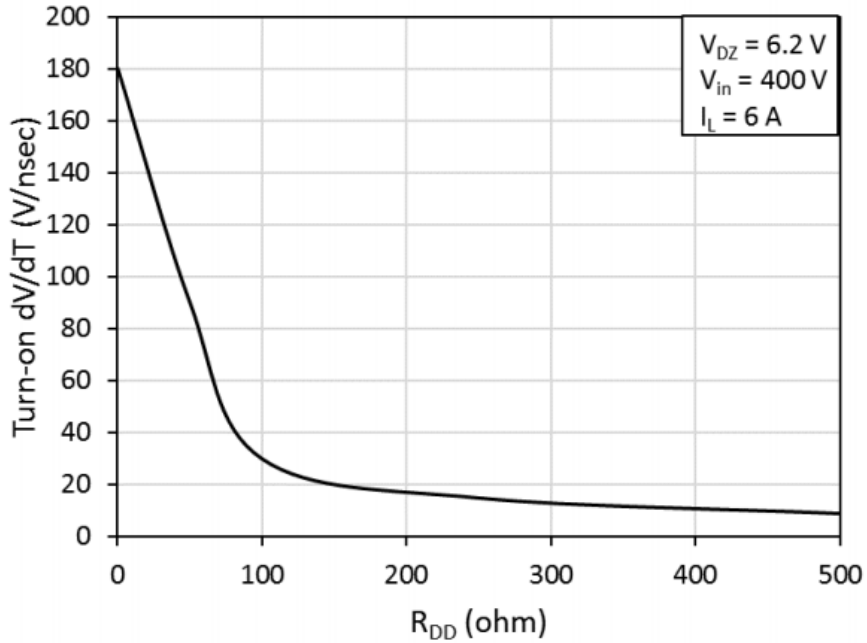
Discrete FET and drive, with R_G = slow, lossy

Integrated FET and drive, no R_G = fast, efficient

Easy EMI with dV/dt control



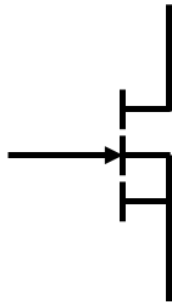




dV/dt controllable from 180 V/ns to 10 V/ns

ESD Protection?

Discrete GaN

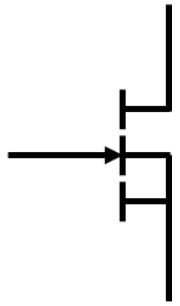


Low C_{ISS} → Fast switch, but…

HBM < 250 V (typical)

ESD Protected

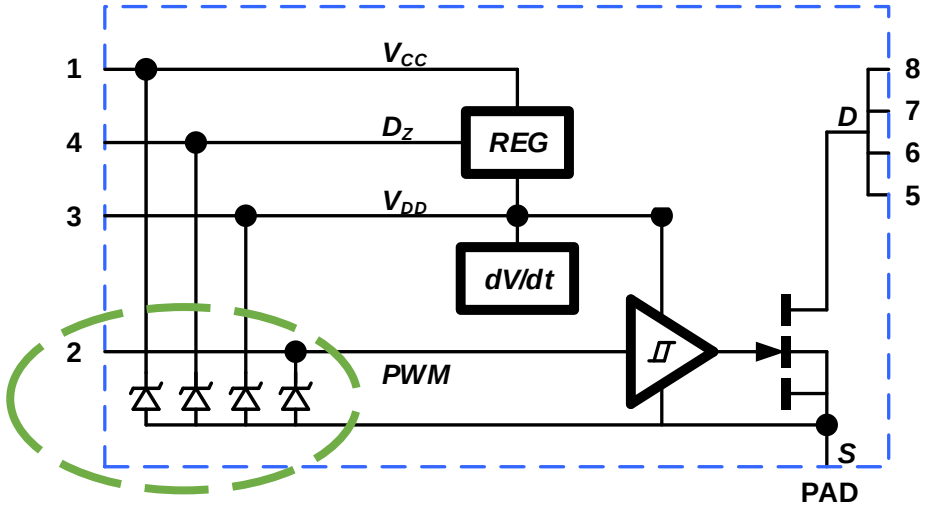
Discrete GaN



Low C_{ISS} → Fast switch, but…

HBM < 250 V (typical)

GaN Power IC

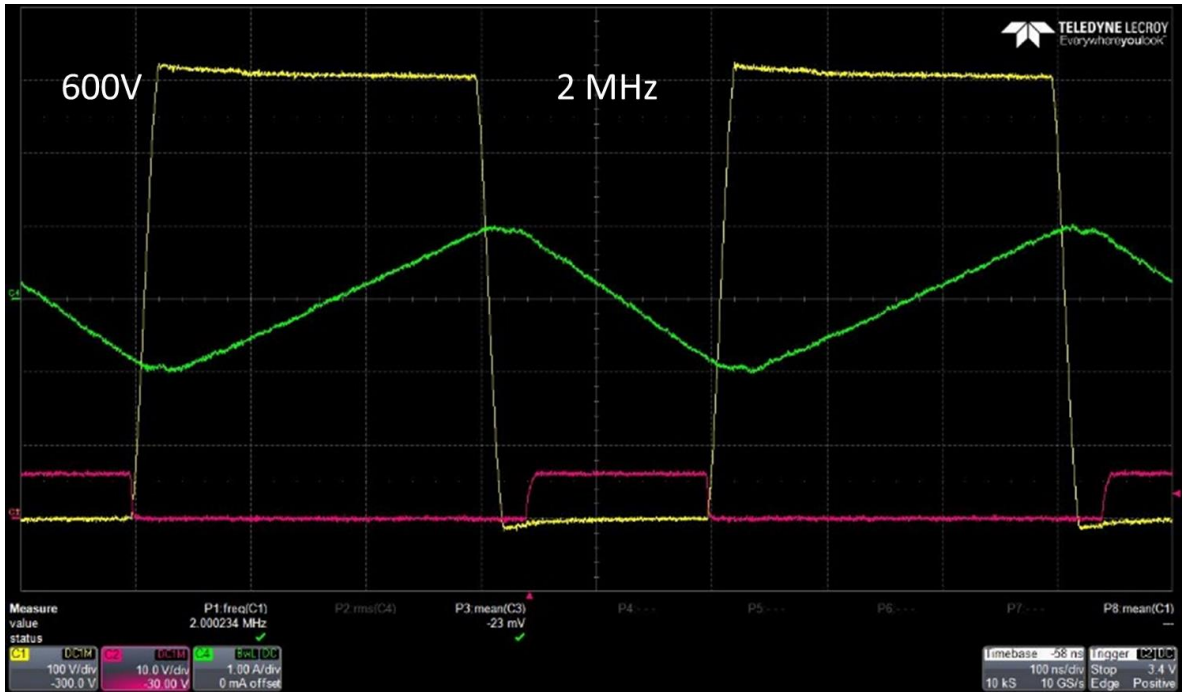


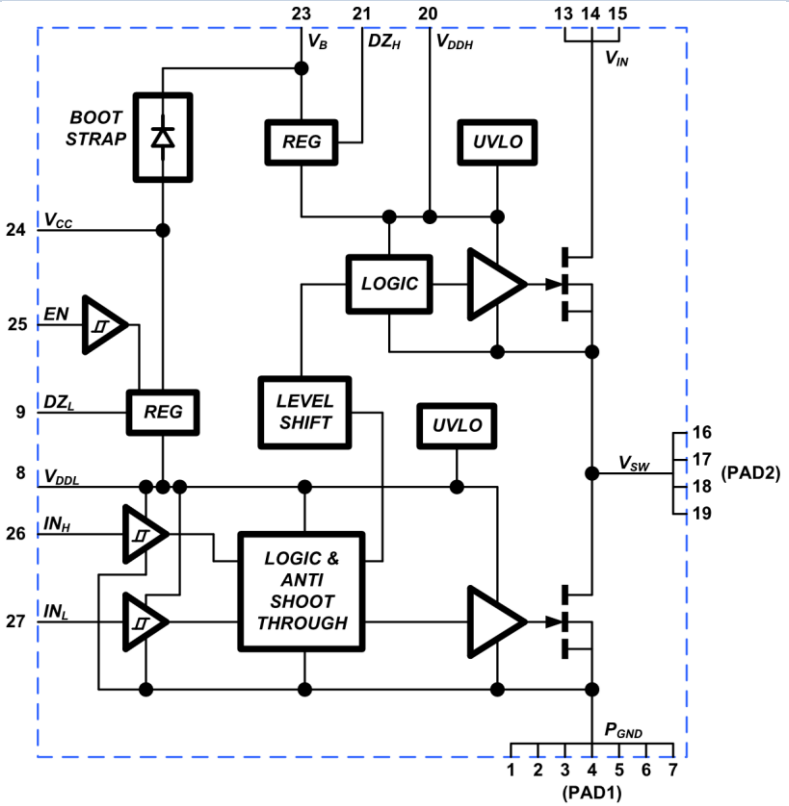
Integrated ESD Protection

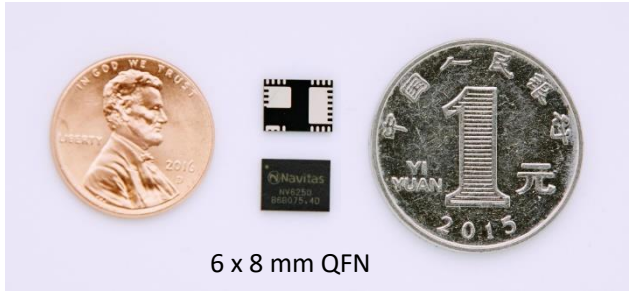
HBM, CDM > 1,000 V

AllGaN™ Half-Bridge GaN Power IC

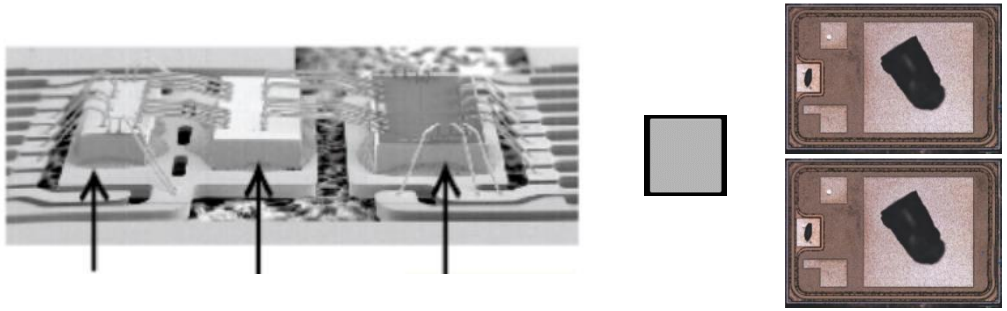
- Monolithic integration at 650V
  - 2x GaN FETs *(110-560 mΩ)*
  - 2x GaN drivers (iDrive™)
  - GaN Logic (level-shift, bootstrap, UVLO, shoot-through, ESD)
- "Digital In, Power Out"







Old Level-Shift: High Loss, High Cost



I/F Chip Si CMOS | On-chip Transformer SiO_2 / Polyimide | Gate Driver Chip Si CMOS | Bootstrap Diode Si / SiC | Half-Bridge FETs Si

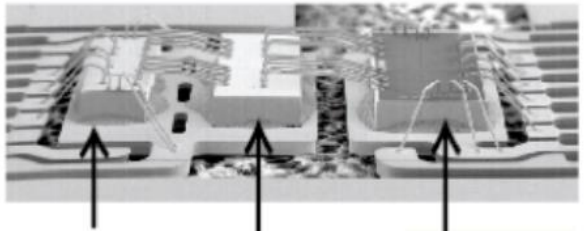
Disparate Technologies

Hybrid isolator, discrete driver, discrete power, bootstrap diode

High Power Loss

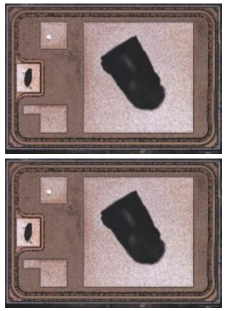
- Driver loss, R_G loss
- Bootstrap diode Q_{RR}, V_F
- Pulsed high current level shifter power (?)

GaN Level-Shift: Low Loss, High-Frequency

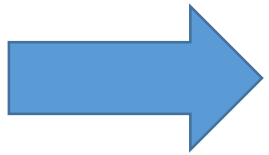


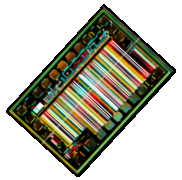
I/F Chip Si CMOS | On-chip Transformer SiO_2 / Polyimide | Gate Driver Chip Si CMOS

Bootstrap Diode Si / SiC



Half-Bridge FETs Si





AllGaN™ Technology
Lateral 650V GaN-on-Si

Disparate Technologies

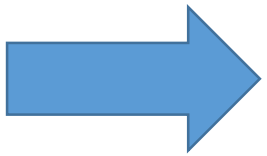
Hybrid isolator, discrete driver, discrete power, bootstrap diode

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 (?)

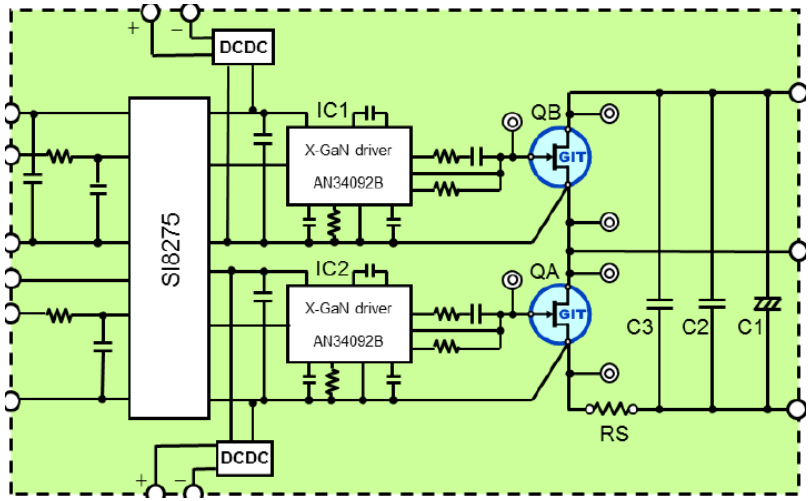


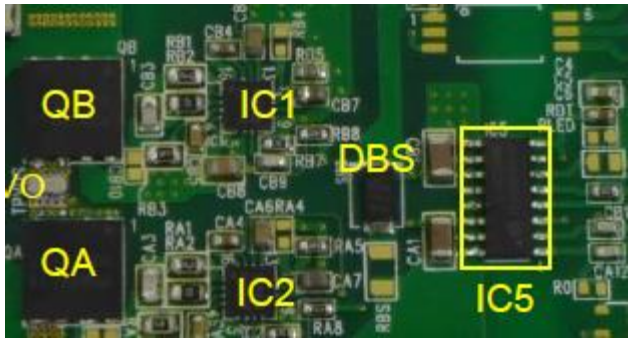
Low Power Loss

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

Complex Design → Easy-to-Use

Half-Bridge *Discrete* GaN

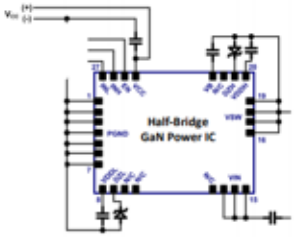




PCB Area: 24 x 42 ~ 1,000 mm^2

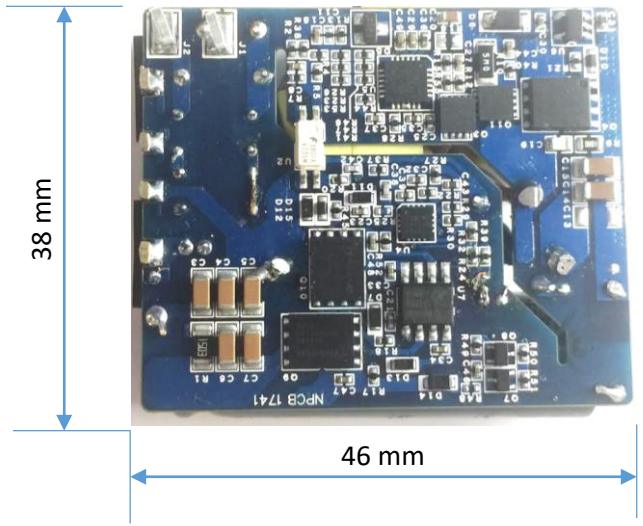
- ✓ 20x smaller PCB area
- ✓ 40+ fewer components
- ✓ Lower cost
- ✓ Robust & protected
- ✓ Simple
- ✓ Easy layout

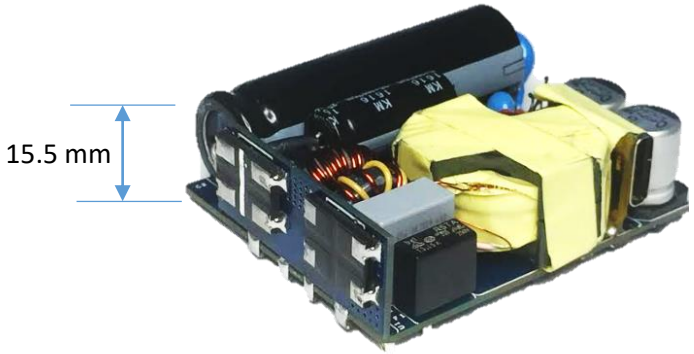
Half-Bridge GaN *Power IC*



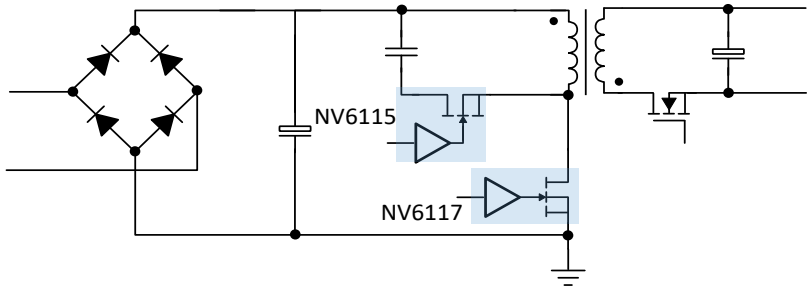
PCB Area: 6 x 8 = 48 mm^2

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

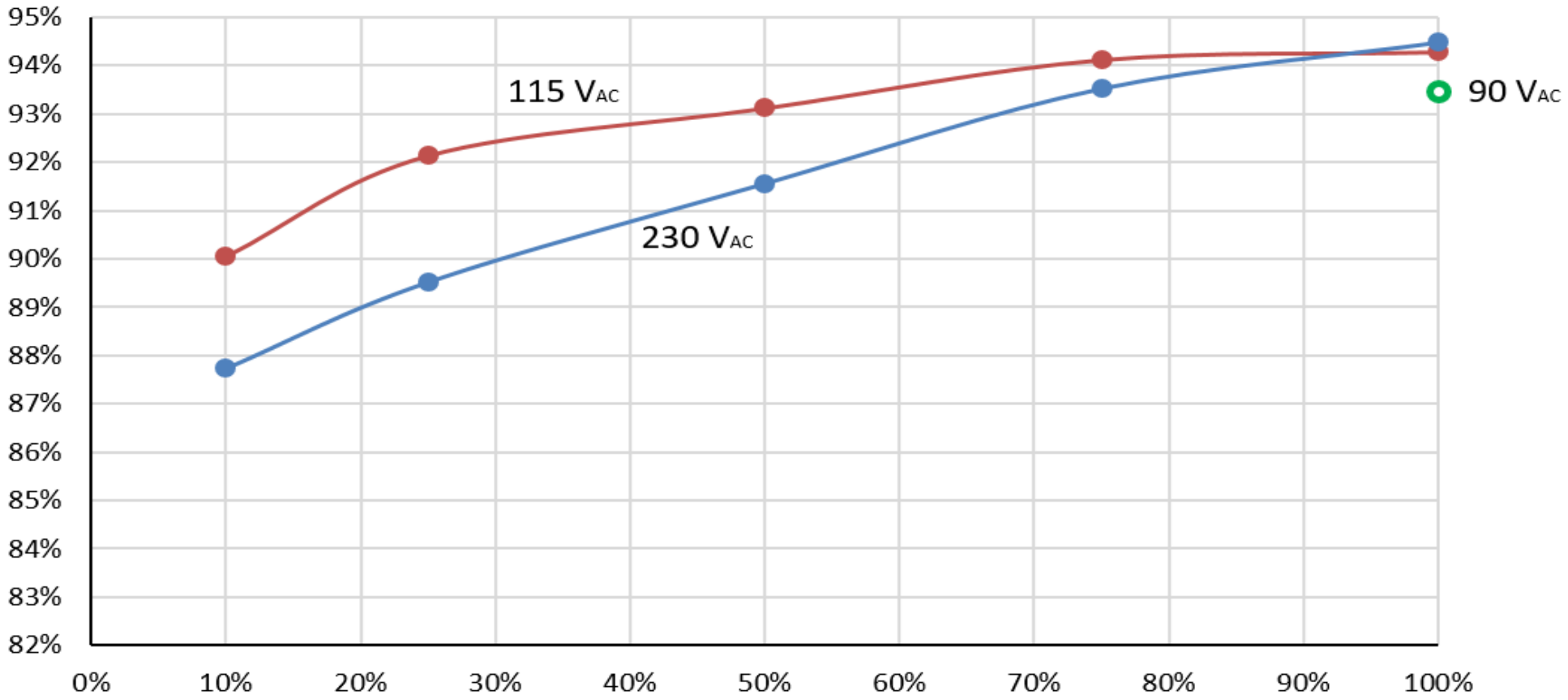




- Input : Universal AC (85-265V_{AC}, 47-63Hz)
- Output : USB-PD (5-20V) (65W)
- Primary : NV6115 (160mΩ) + NV6117 (110mΩ) GaN Power ICs
- Frequency : ~300 kHz
- Size : 38 x 46 x 15.5 mm = 27 cc uncased
  43 x 51 x 20.5 mm = 45 cc with 2.5 mm case
- Power Density : 2.4 W/cc (39 W/in^3) uncased
  1.5 W/cc (24 W/in^3) cased
- Construction : 4-layer, 2-oz Cu PCB, SMT powertrain
  "No heatsink" design



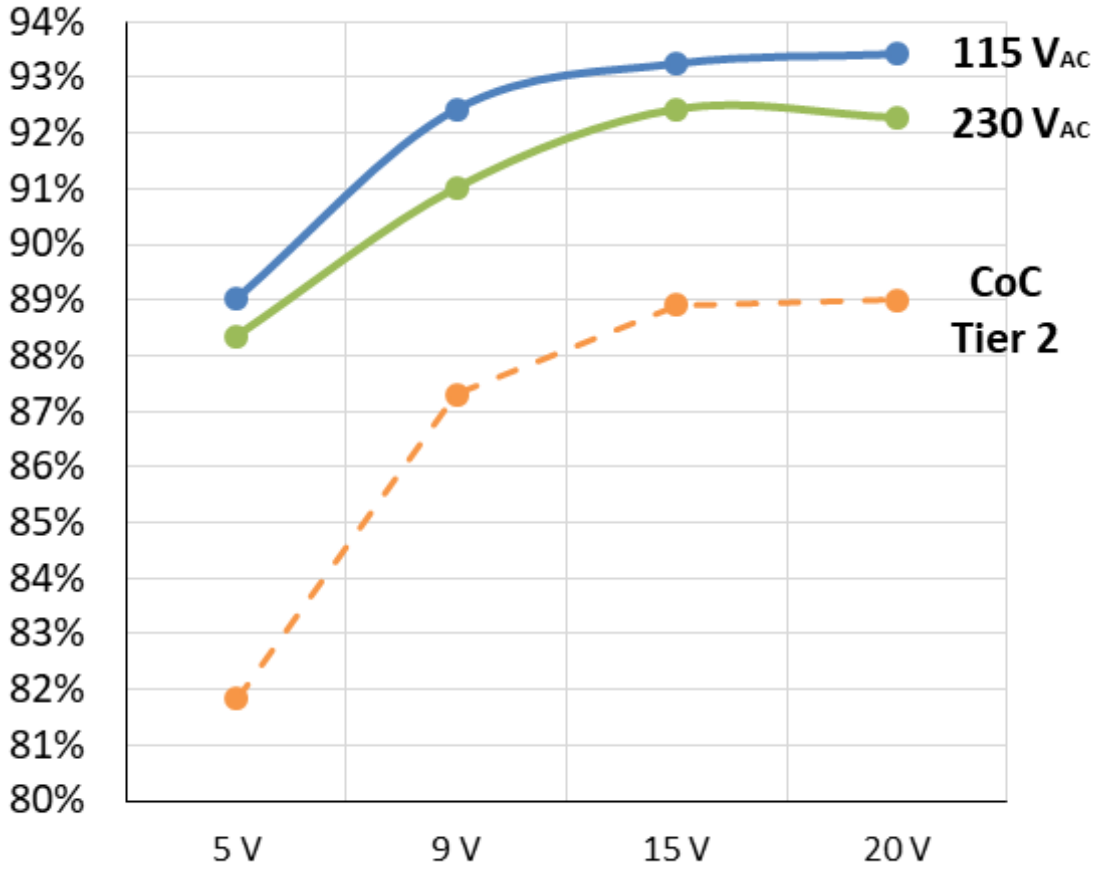
Efficiency at 20 V_{OUT} (25°C, no airflow)



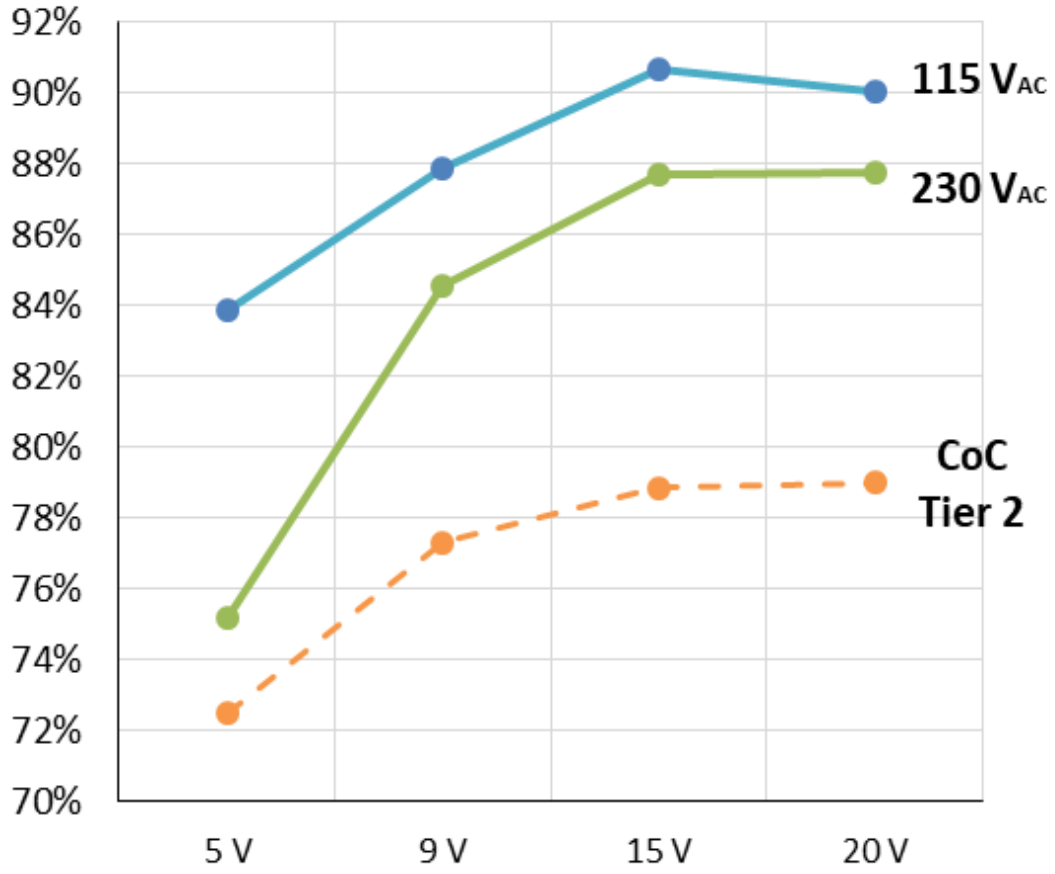
Efficiency measured at PCB

Efficiency (25°C, no airflow)

4-point Average Efficiency



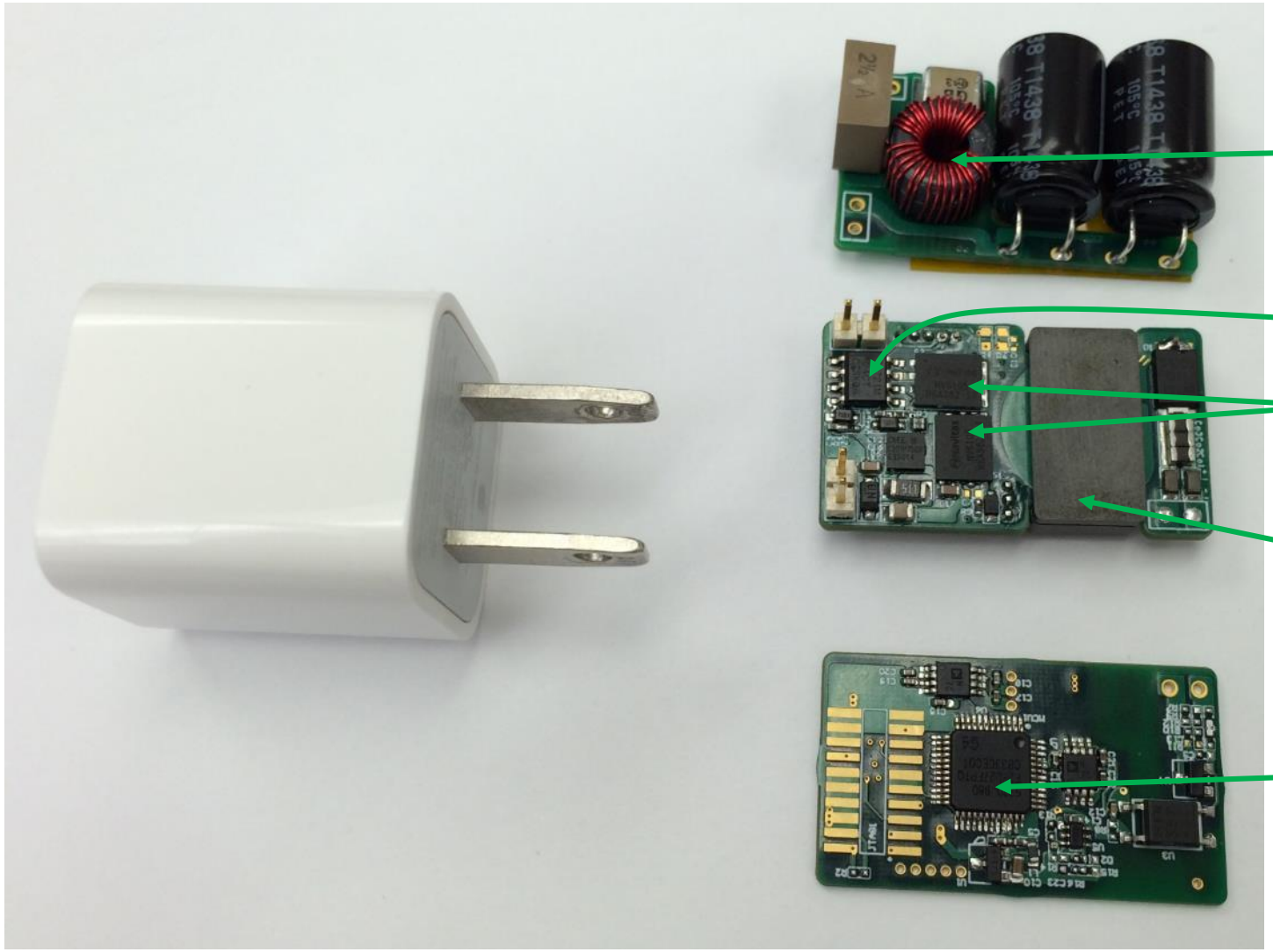
10% Load Efficiency



- 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)

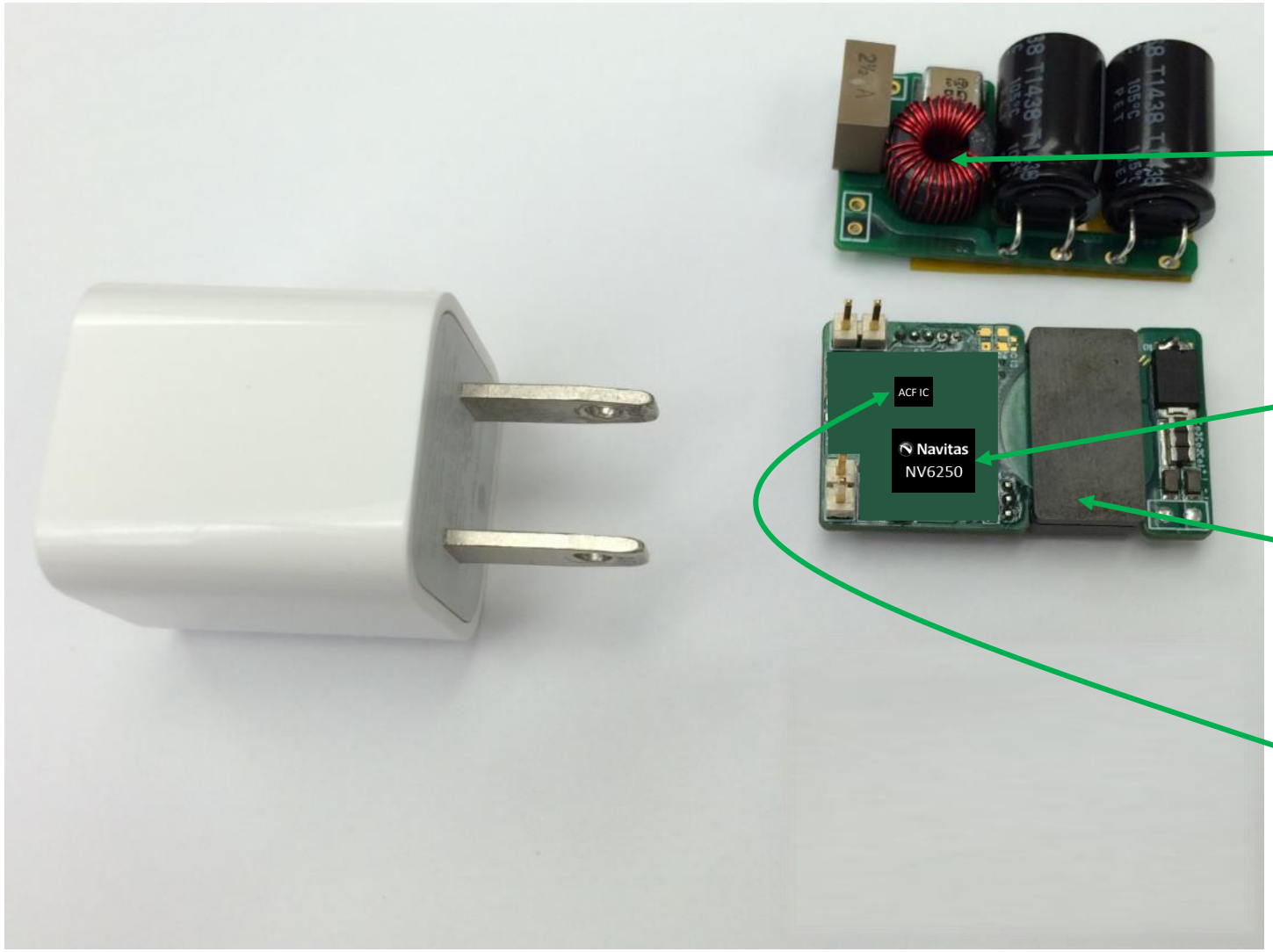
Efficiency measured at PCB

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