

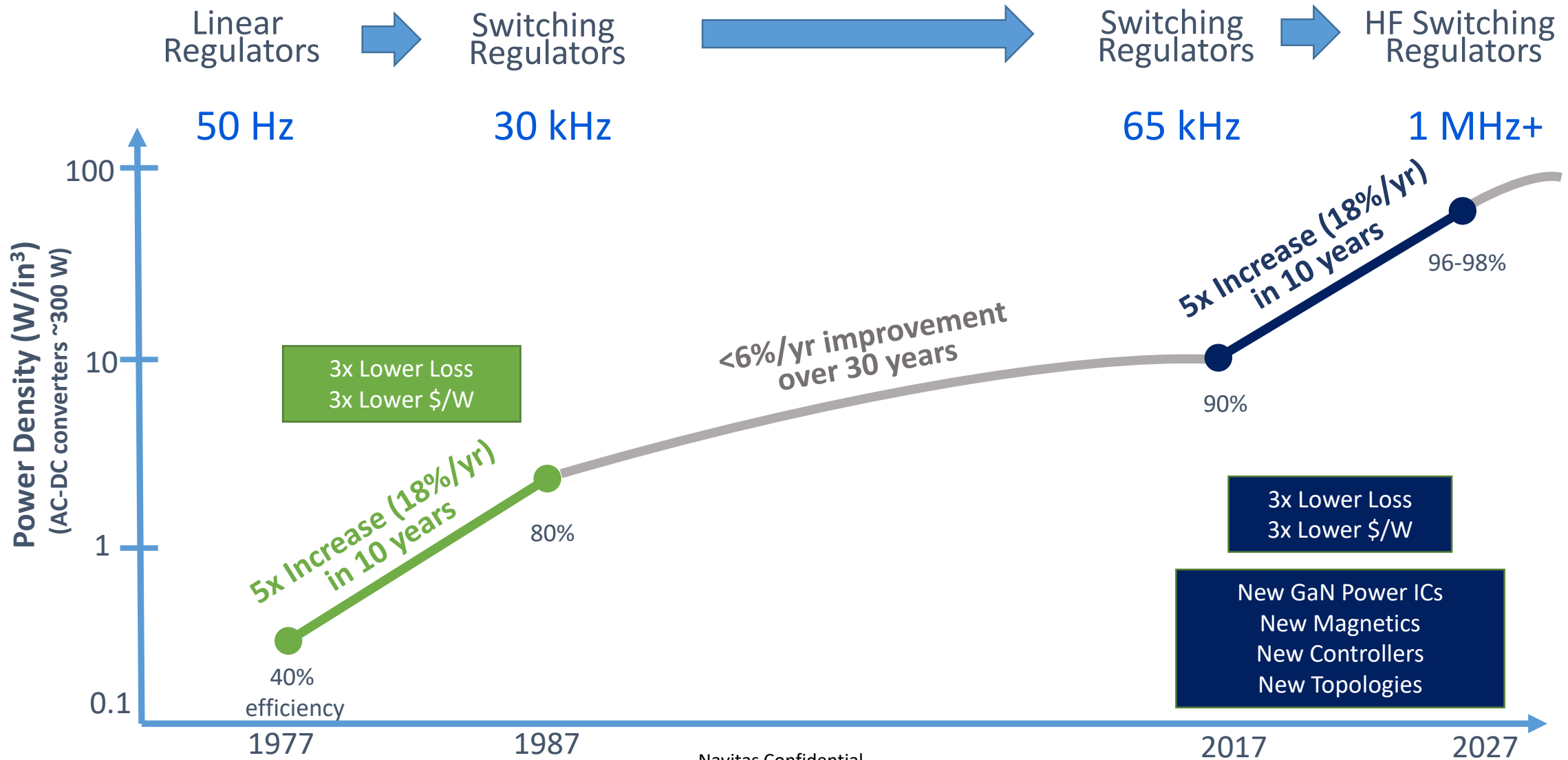


Let's Go GaNFast™

Company, Technology & Demo Update

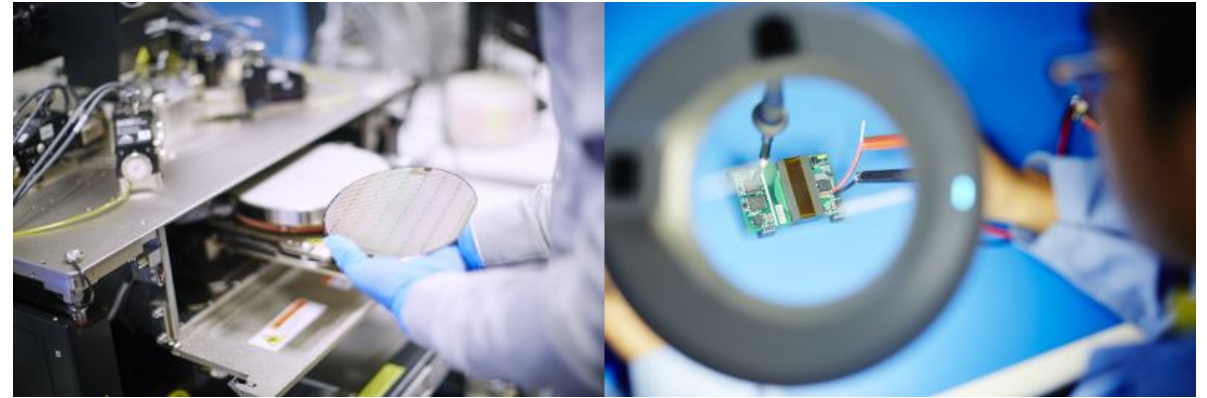
May 2018

A Disruptive Change to Power Systems



Navitas Semiconductor Inc.

- World's first & only GaN power IC company
- Navitas: Latin for *Energy*
- Founded January 2014
- HQ in El Segundo, CA
- World-class management team
 - 30+ employees
- World class manufacturing partners
 - Wafer foundry, packaging
- World-class investors
 - Over \$1B capital under management
 - Focus on semis & sustainability

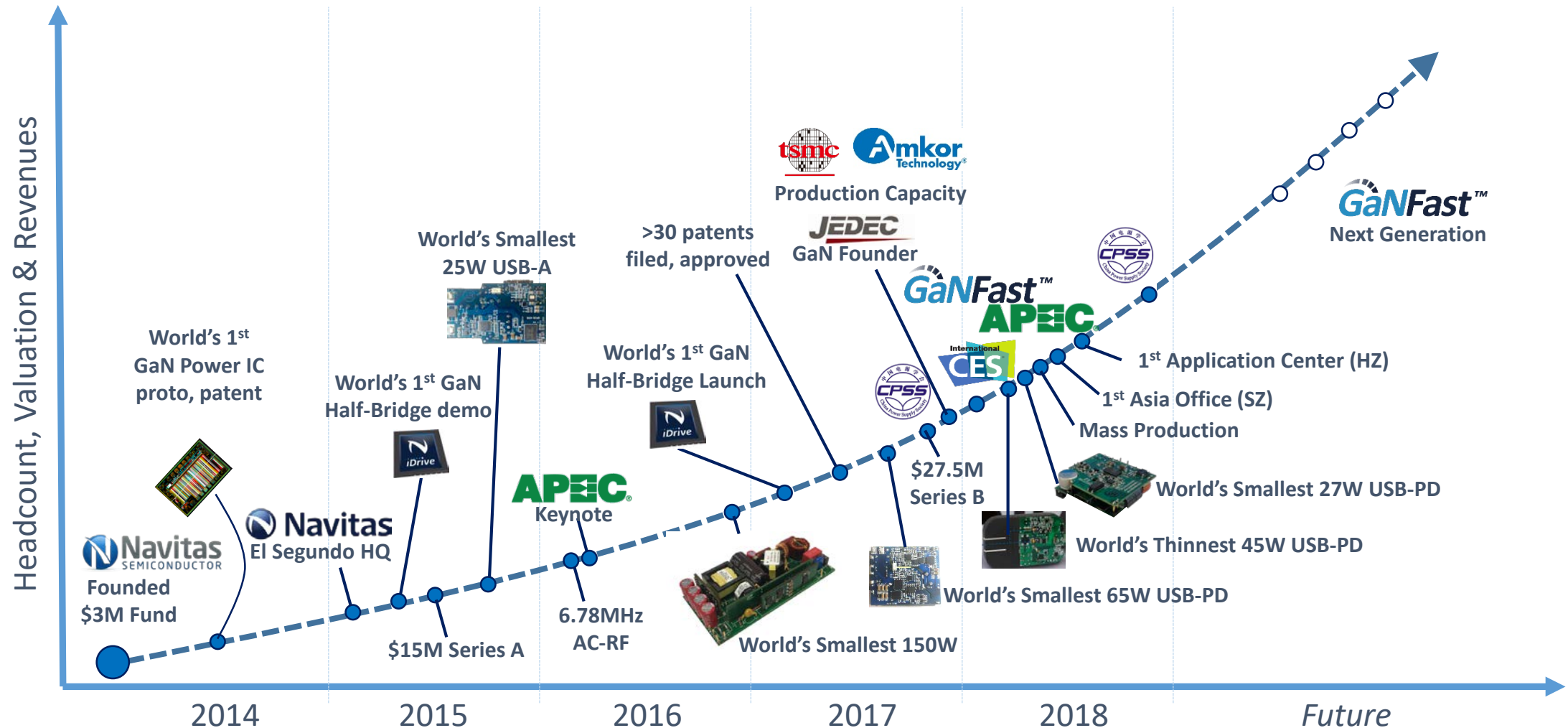


navitas
noun | en·er·gy

C>PRICORN
INVESTMENTGROUP



Pioneering Achievement



Powerful Manufacturing Partners

- Wafers
 - Standard CMOS using GaN-on-Si wafers
 - Add GaN epi reactors in <6 months
- Packaging
 - Standard QFN
 - Standard processes & equipment
 - Add high-speed final testers in <3 months
- Big capacity in 2018
- Big increase in 2019



World-Class Management Team

Highly successful & proven power semi industry executives



Gene Sheridan
CEO & Co-Founder

25+ years across power semi & CEO startups
with multiple high growth successes



Jason Zhang
VP Applications Engr & Co-Founder

20+ years in power electronics circuit design,
including 7 years as GaN Apps Engr leader



Stephen Oliver
VP Sales & Marketing

20+ years in power semi sales & marketing at
Motorola, Philips (NXP), IRF and Vicor



Dan Kinzer
CTO / COO & Co-Founder

30+ years at IRF as VP, Design Engineering
and Fairchild CTO; with over 100 patents



Nick Fichtenbaum, Ph.D.
VP Engineering & Co-Founder

10+ years GaN materials & device experience
at Transform, UCSB



Marco Giandalia
VP, IC Design Engineering

20 years in power IC design at
IRF & ST Microelectronics

Proven Industry Experience

Over 200 issued patents

Over 20 keynotes

Co-developer of 1st cascode
GaN power FET

Over \$4B/yr of power
semiconductor revenues created

Over 200 technical papers

Inventor of 1st integrated
driver + power FET

Co-inventor of 1st p-channel power MOSFET

Inventor of 1st GaN power IC

Co-Inventor of 1st
commercial planar MOSFETs

Over 20 generations of
power semiconductors

Inventor of 1st High-Voltage Power ICs for voltage
regulators, half-bridge drivers and LED drivers

Market launch of over
5,000 power products

Market Demands

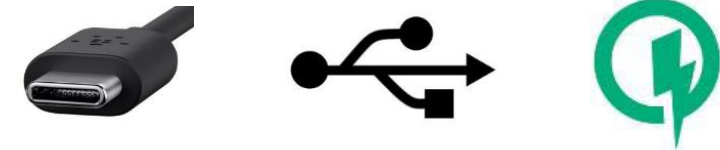
- **Legislative**

- US DoE VI, Euro CoC Tier 2



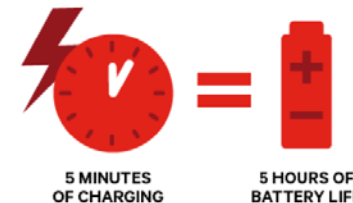
- **Features**

- Type C, USB PD 3.0 / PPS / QC 4.0



- **Performance**

- Fast charging, size, weight, low profile



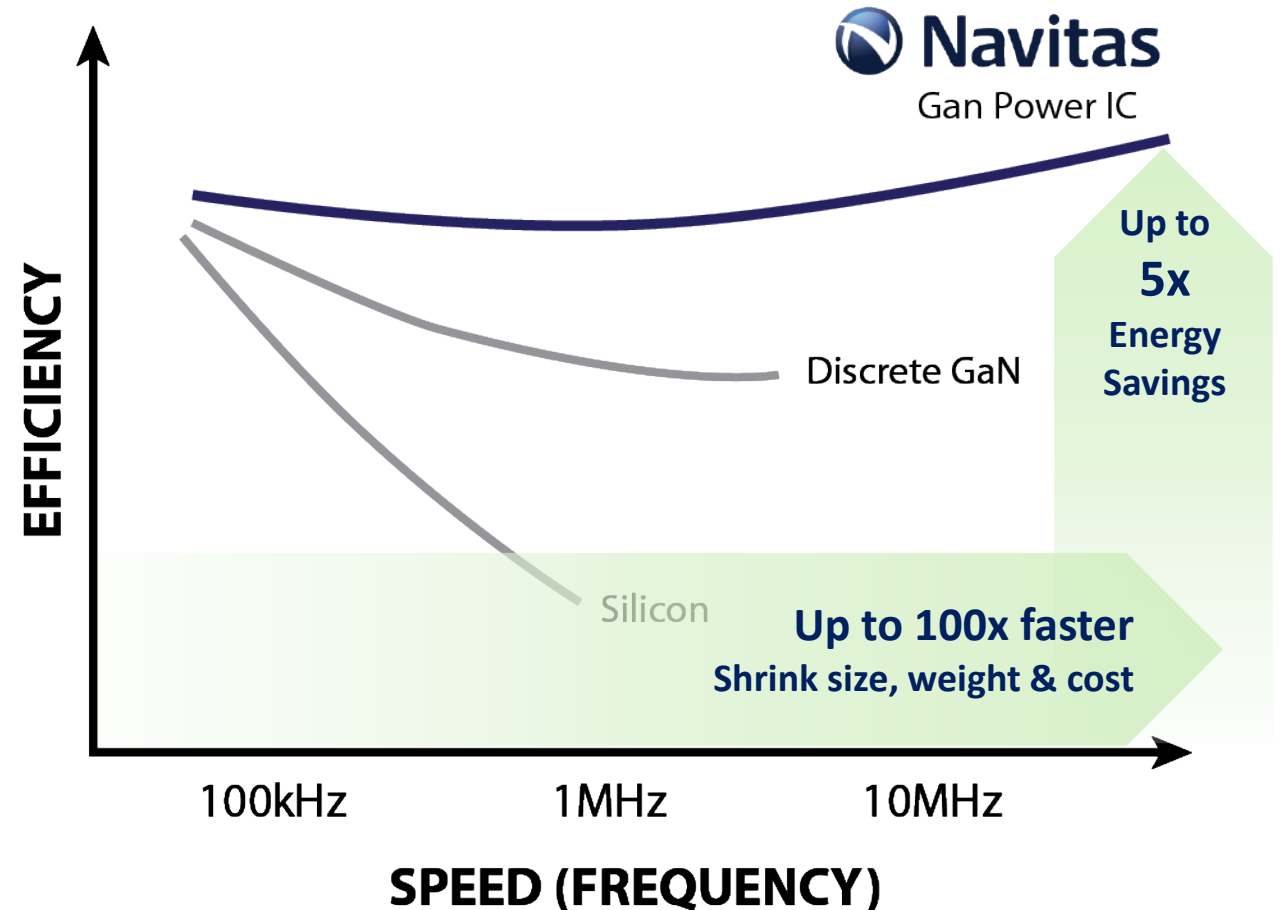
- **Cost**

- Premium vs old, slow designs?



Power Electronics: *Speed & Efficiency are Key*

- **Speed** enables *small size*, *low-cost* and *faster charging*
- **Efficiency** enables *energy savings*
- With Silicon or Discrete GaN power devices, you can get one **or** the other
- With GaN power ICs, you get **both at the same time**, unequalled **Speed & Efficiency**



The *GaNFast*[™] MHz Eco-System

Navitas GaN Power ICs plus...

- High-frequency controllers (PFC, PWM, DSP, LLC, SR)



- High-frequency magnetics



- High-frequency SR FETs

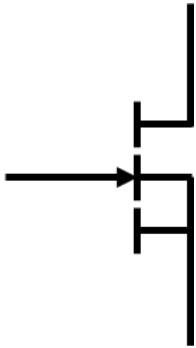


- Advanced Architectures (customers & universities)



World's First GaNFast™ Power ICs

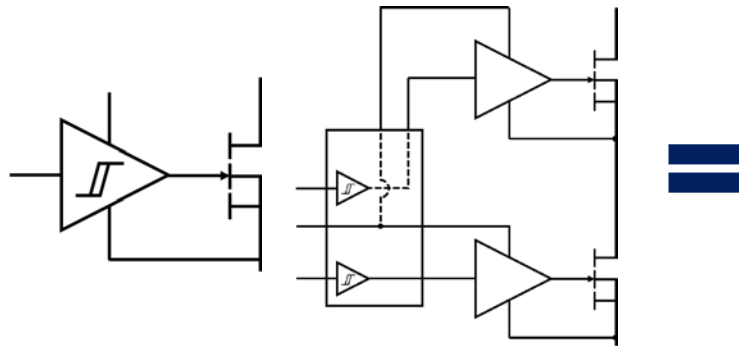
**Fastest, most efficient
GaN Power FETs**



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



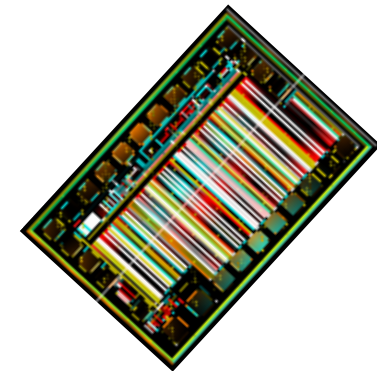
**First & Fastest Integrated
GaN Gate Drivers**



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

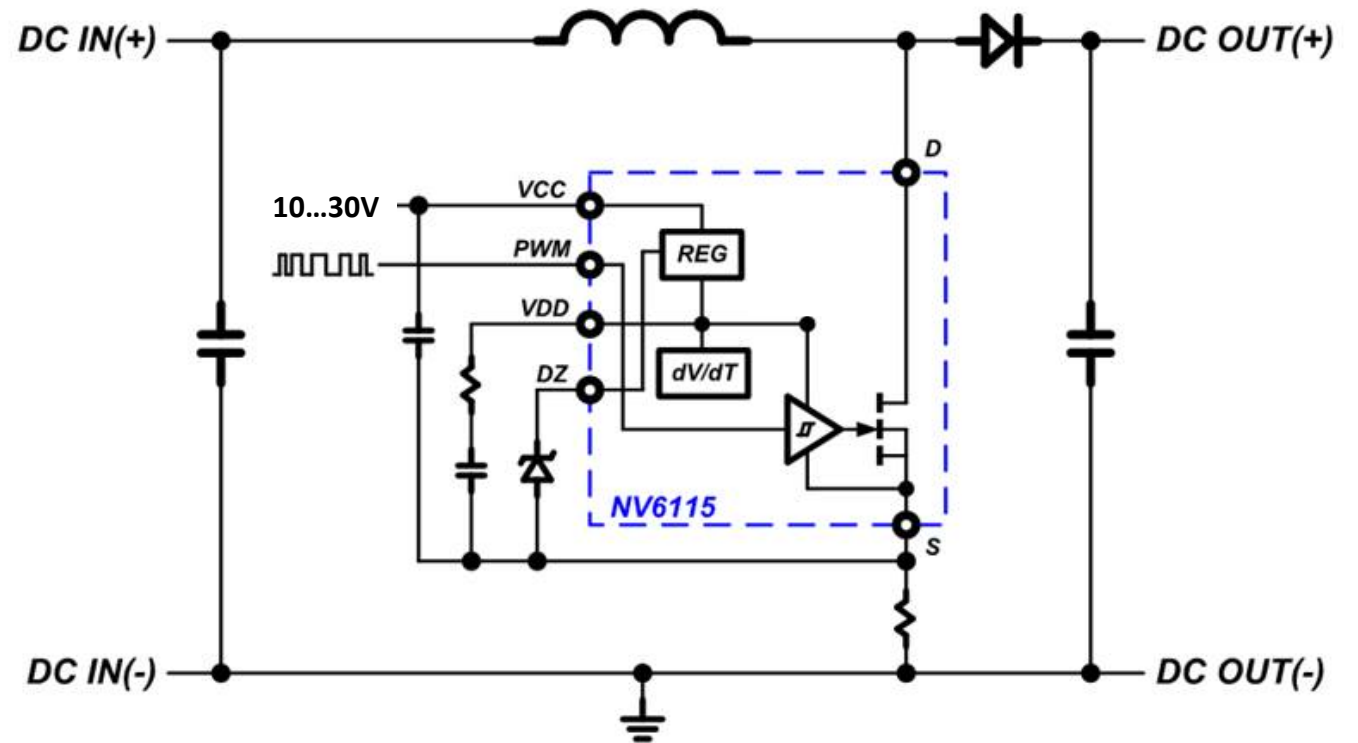
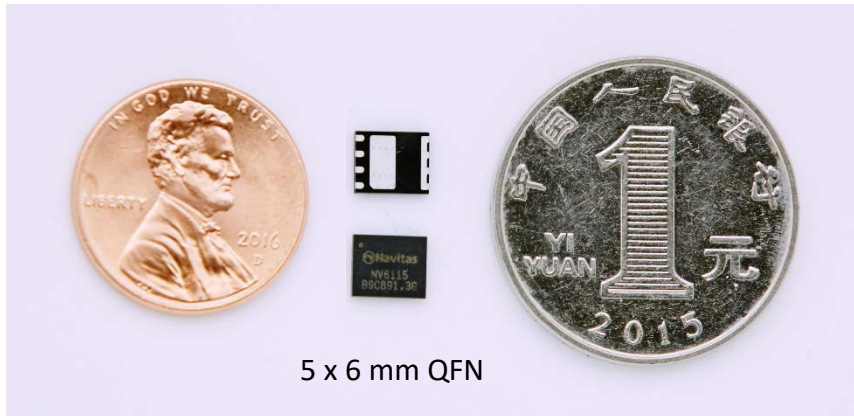


**World's First
GaNFast™
Power ICs**



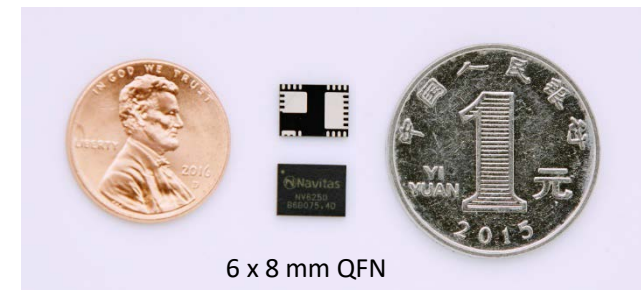
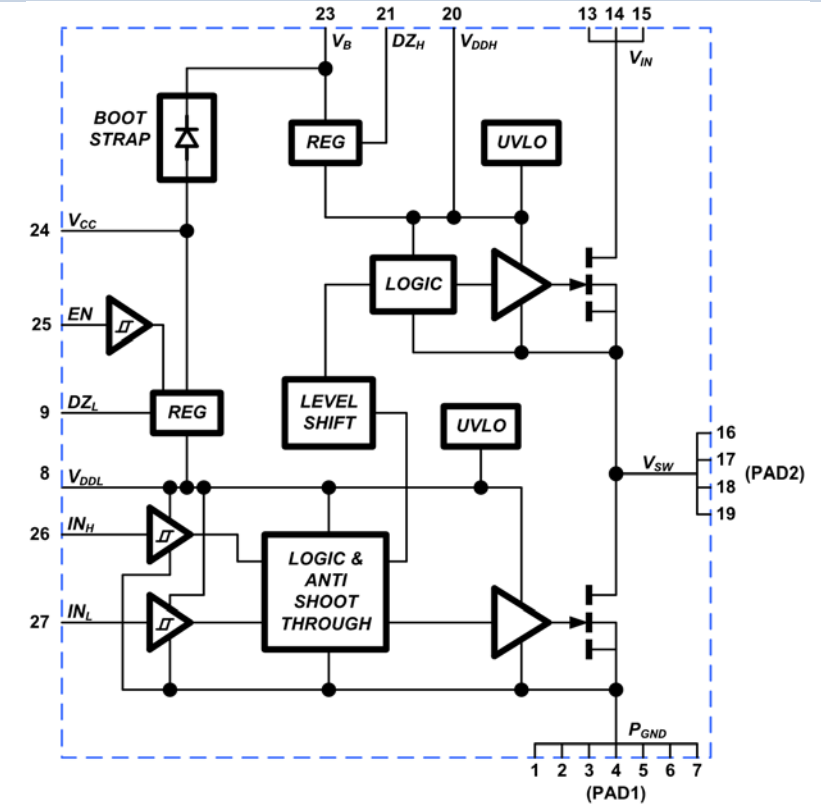
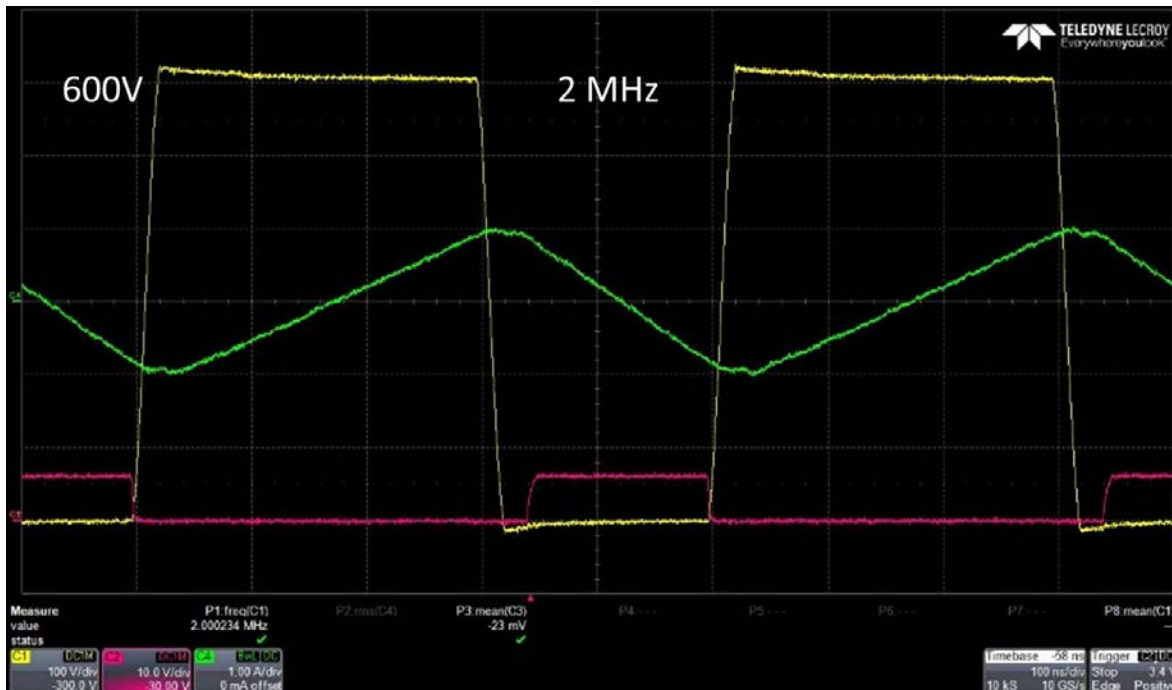
Up to 40MHz switching, 5x higher density & 20% lower system cost

- Monolithic integration at 650V
 - GaN FET (range 110-560 mΩ)
 - GaN Driver
 - GaN Logic



Half-Bridge **GaNFast™** Power IC

- Monolithic integration at 650V
 - 2x GaN FETs (a/symmetrical range 110-560 mΩ)
 - 2x GaN drivers
 - GaN Logic (level-shift, bootstrap, UVLO, shoot-through, ESD)



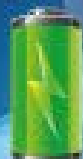


World's Smallest, Fastest Charger

GaN



GaN

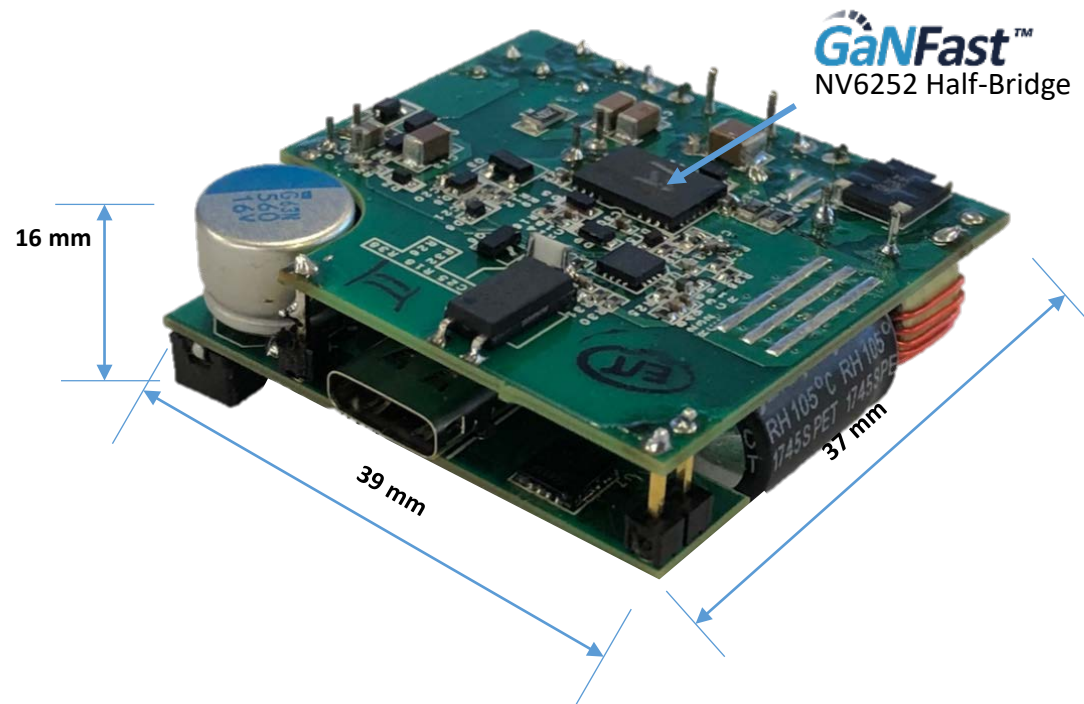


27W USB-PD 3.0

QC 4.0



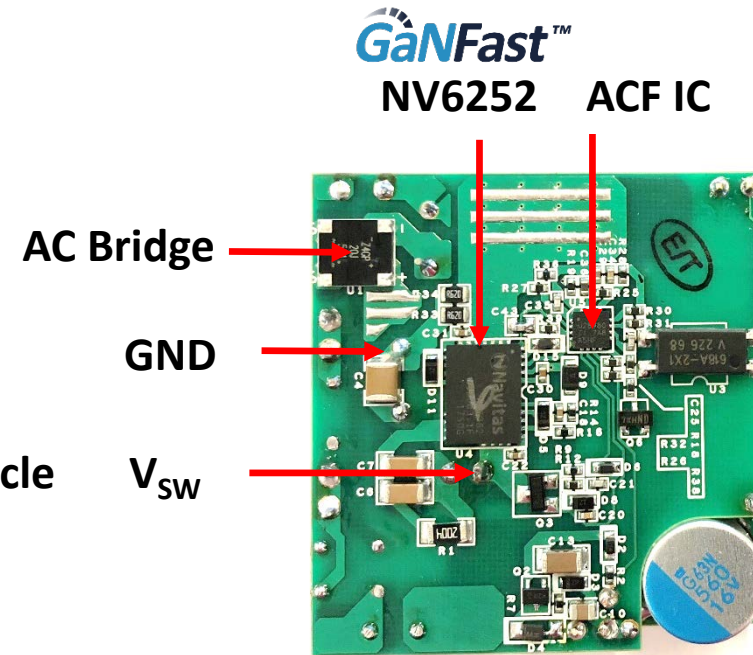
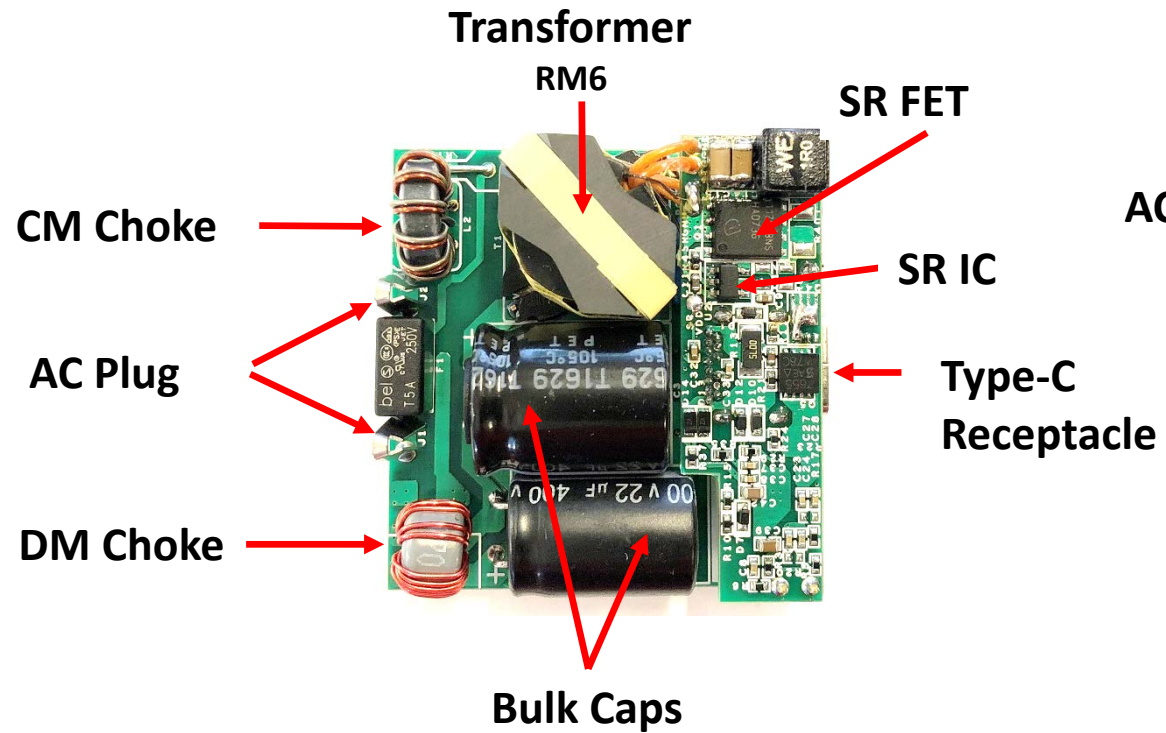
World's Smallest 27 W USB-PD



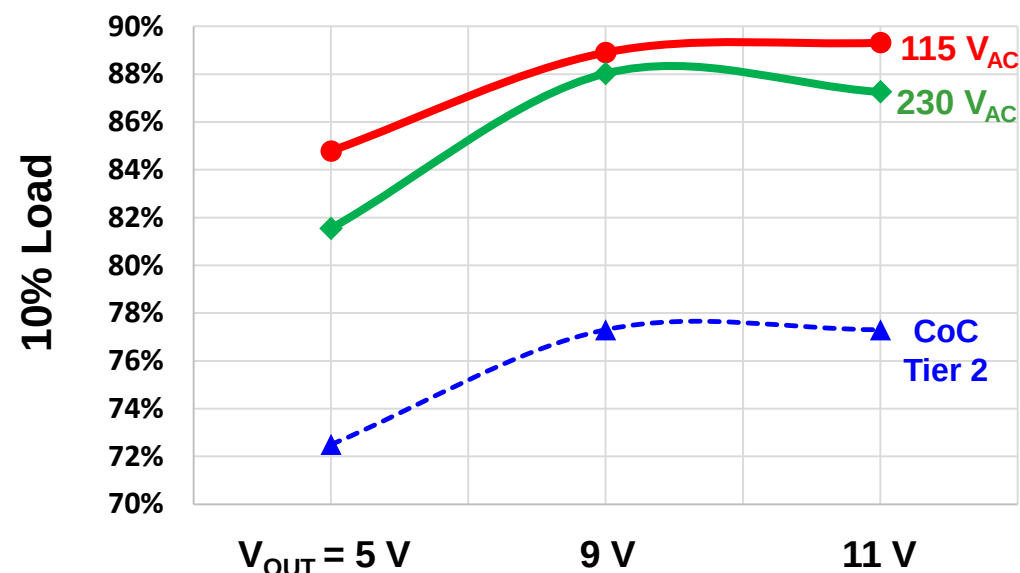
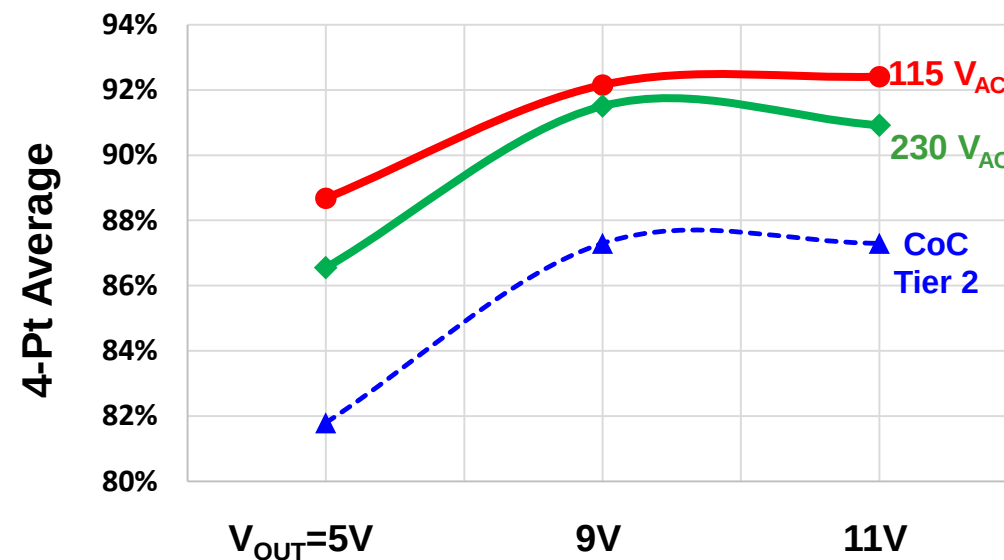
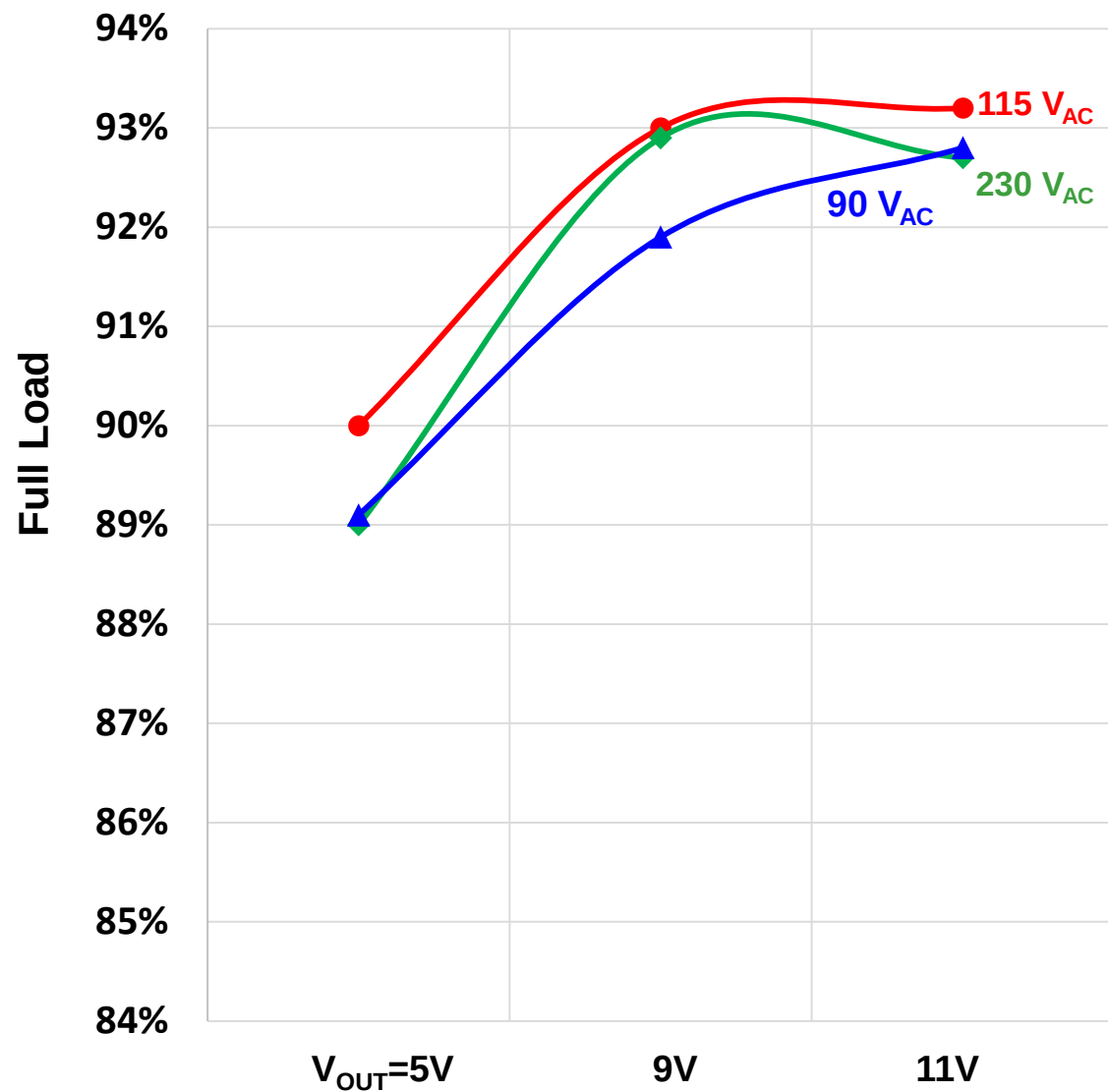
Power, Output	27 W USB-PD
Topology	ACF with UCC28780 and NV6252 GaNFast Power IC
Frequency	300 kHz
Size	23 cc (39 cc with case)
Density	1.2 W/cc (19 W/in ³) (0.7 W/cc (11 W/in ³) cased)
Efficiency	>93% peak, 92.8% at 90 V _{AC} , full load DoE Level VI, Euro CoC (EuP) Tier 2

Available Q2'18

Major Components

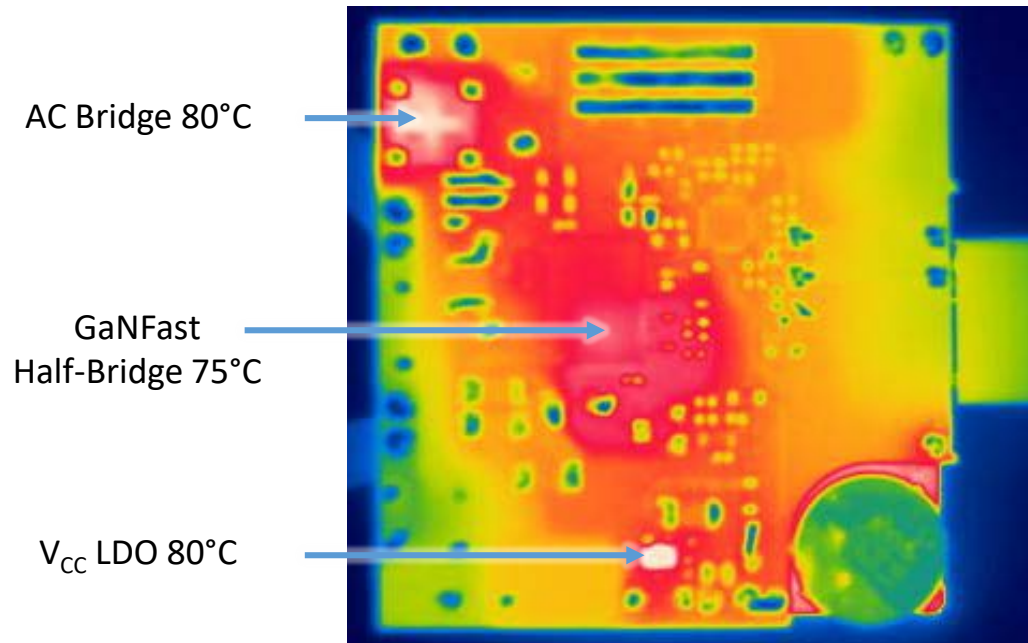


27W High Efficiency

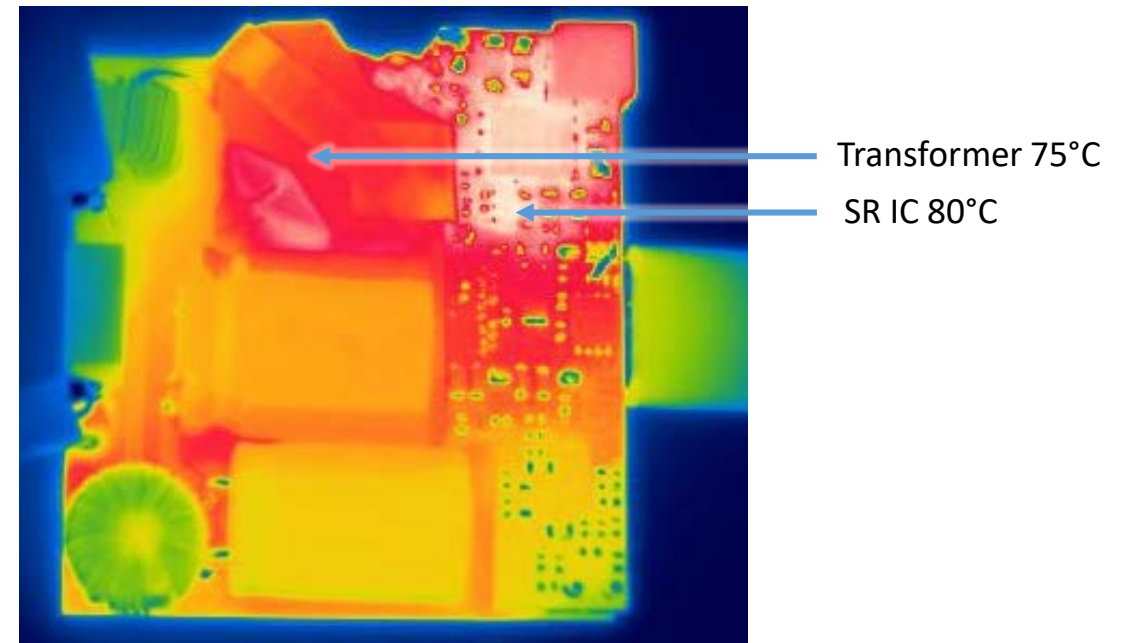


Cool Operation

Top

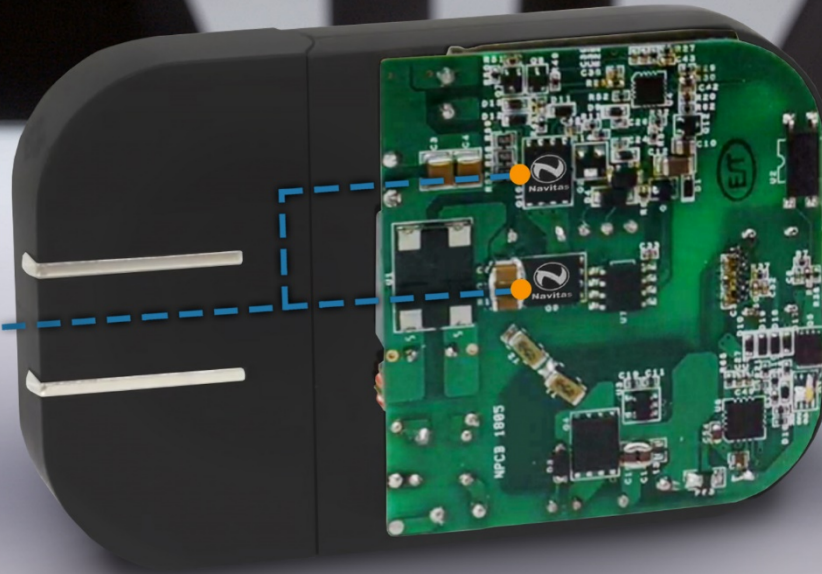


Bottom



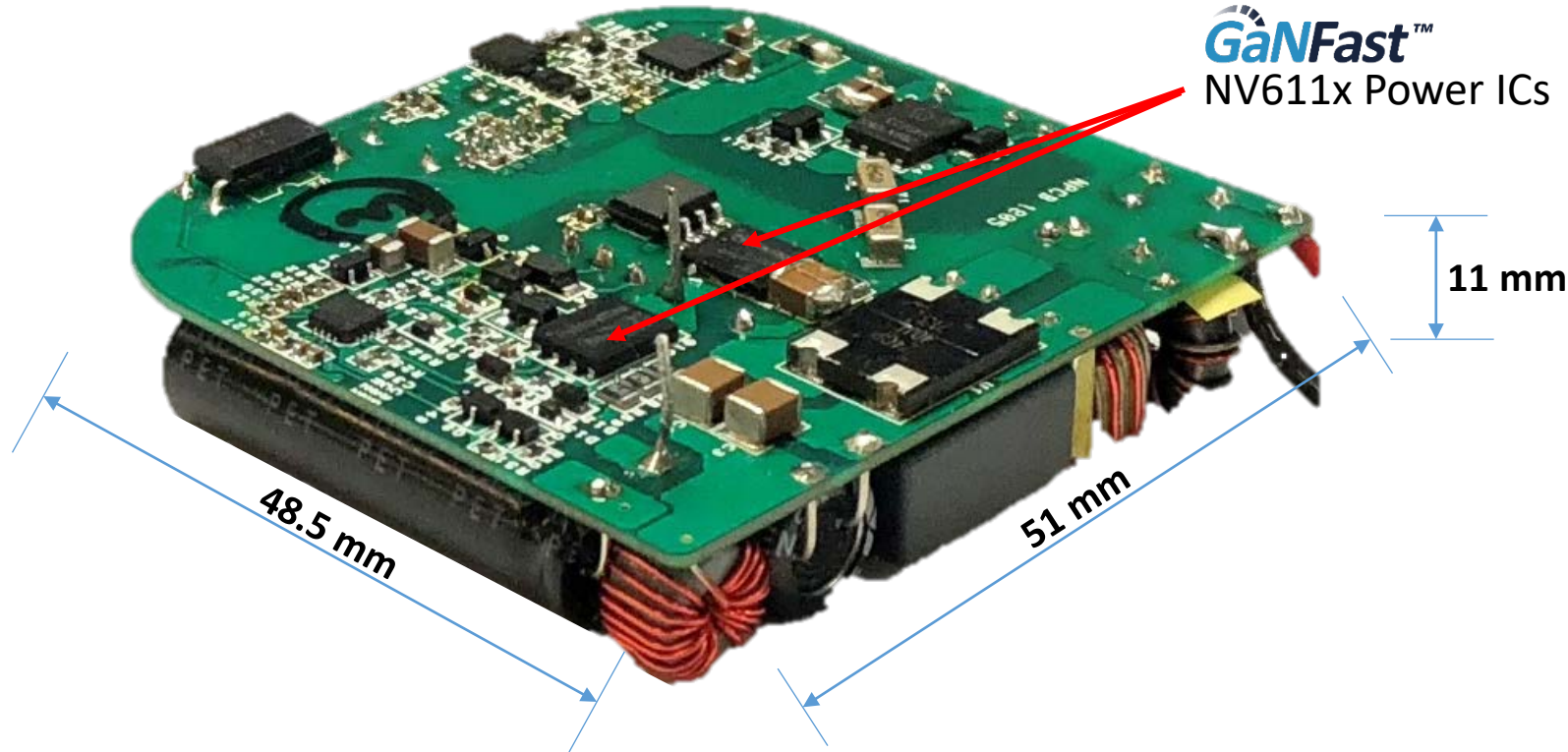
90 V_{AC}, 27 W, 25 °C, uncased, no airflow

GaNFast™
GaN Power IC



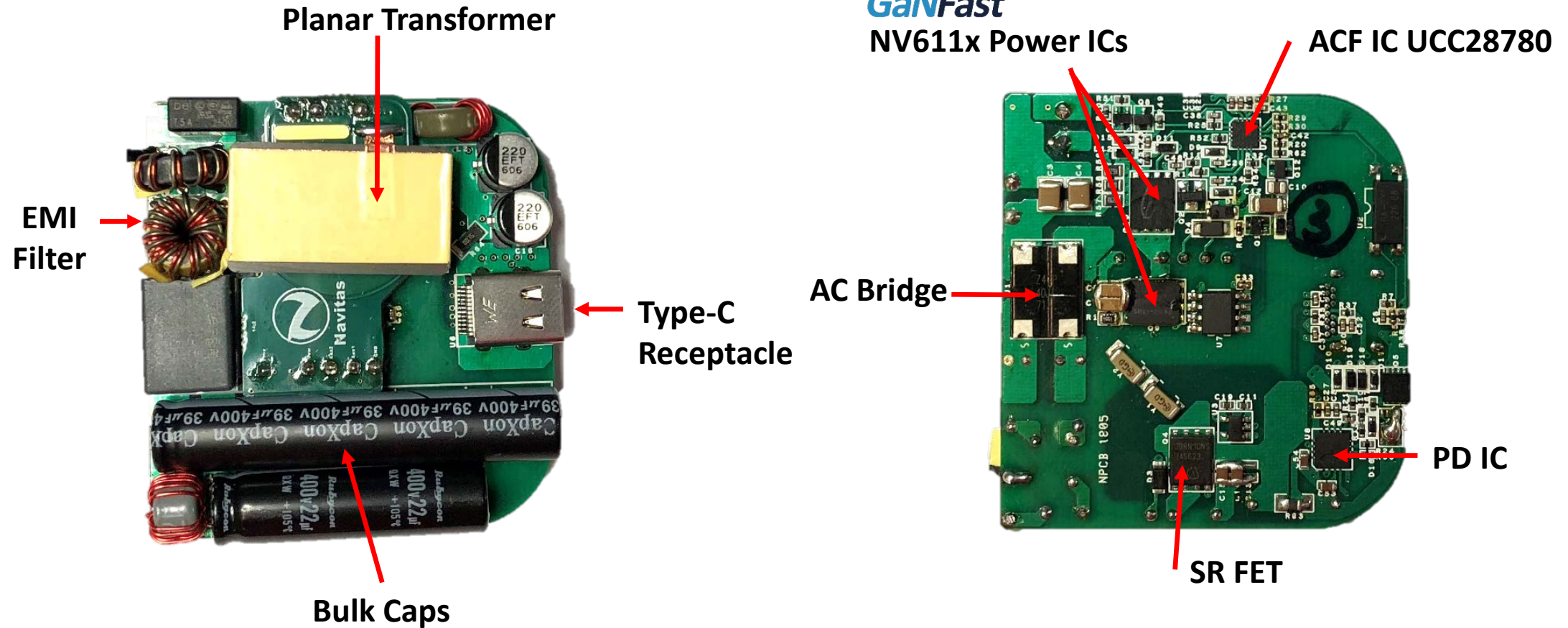
μ^{||}one

World's Thinnest Universal 45W (600 kHz ACF)



- Size : 29 cc (41 cc with case)
- Density : 1.7 W/cc (27 W/in³), 1.1 W/cc (18 W/in³) cased

Major Components



Cool Operation

Top

Bottom

GaNFast
Power IC 75°C, 80°C

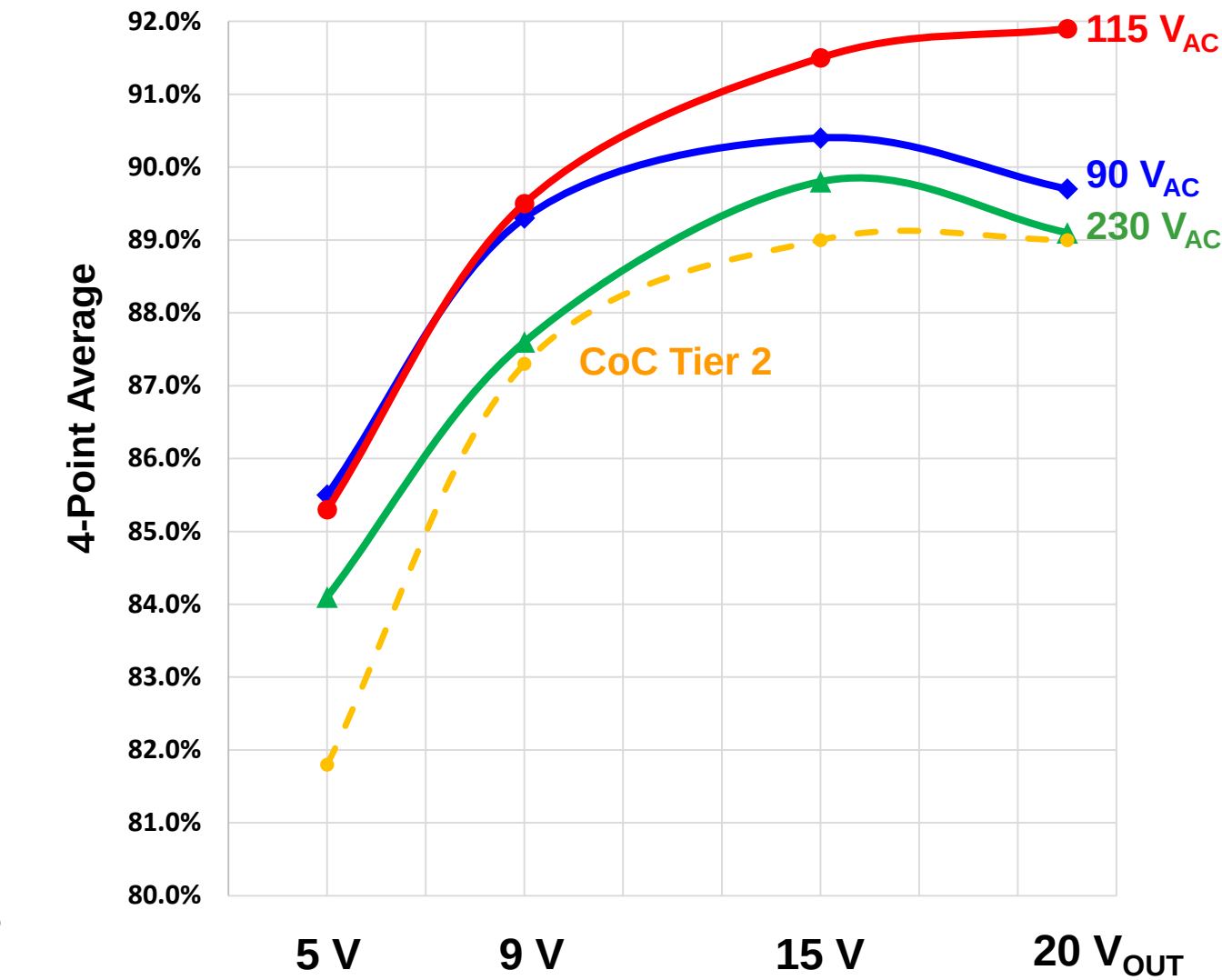
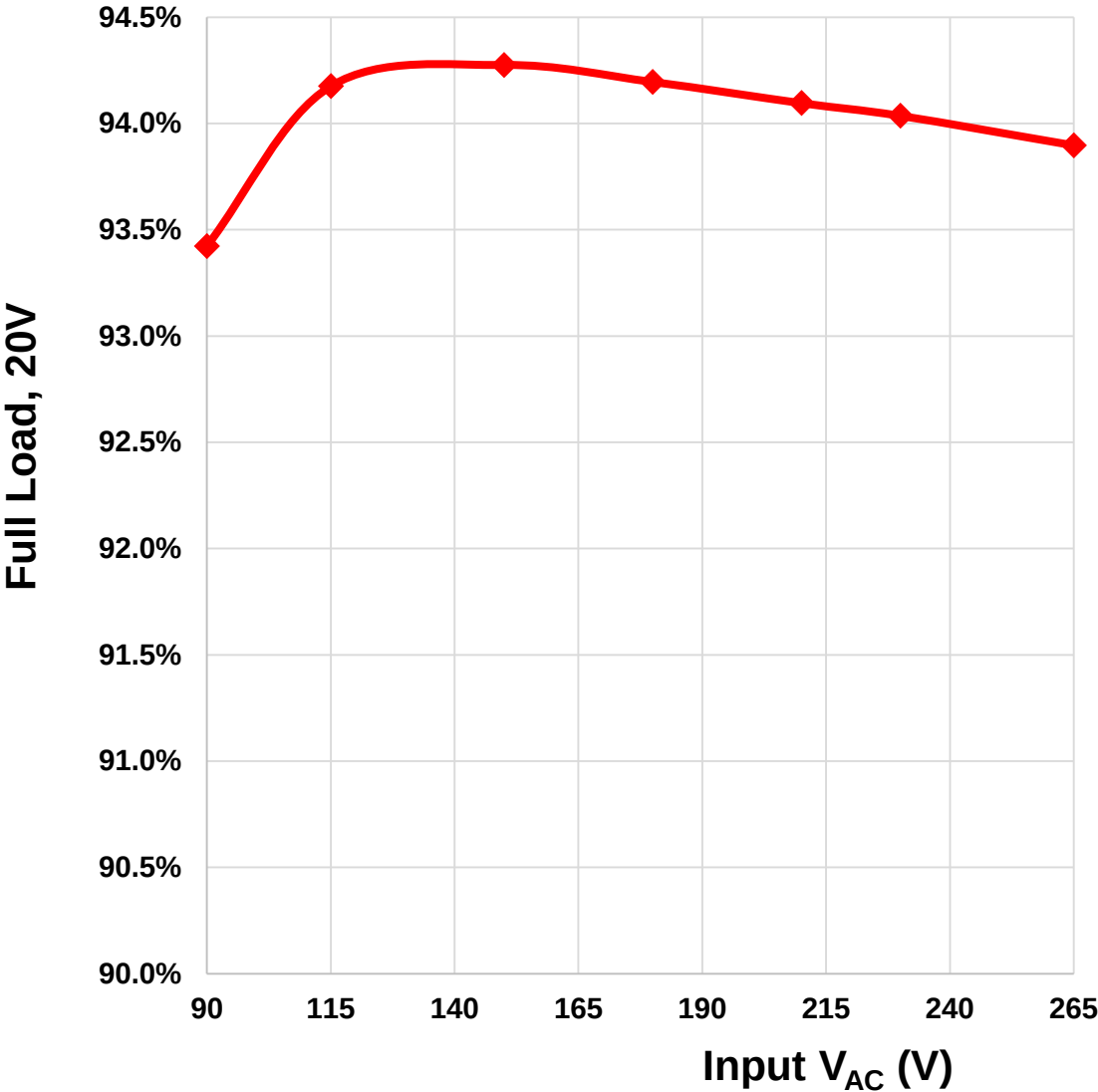
AC Bridge 80°C

SR IC 85°C
SR FET 85°C

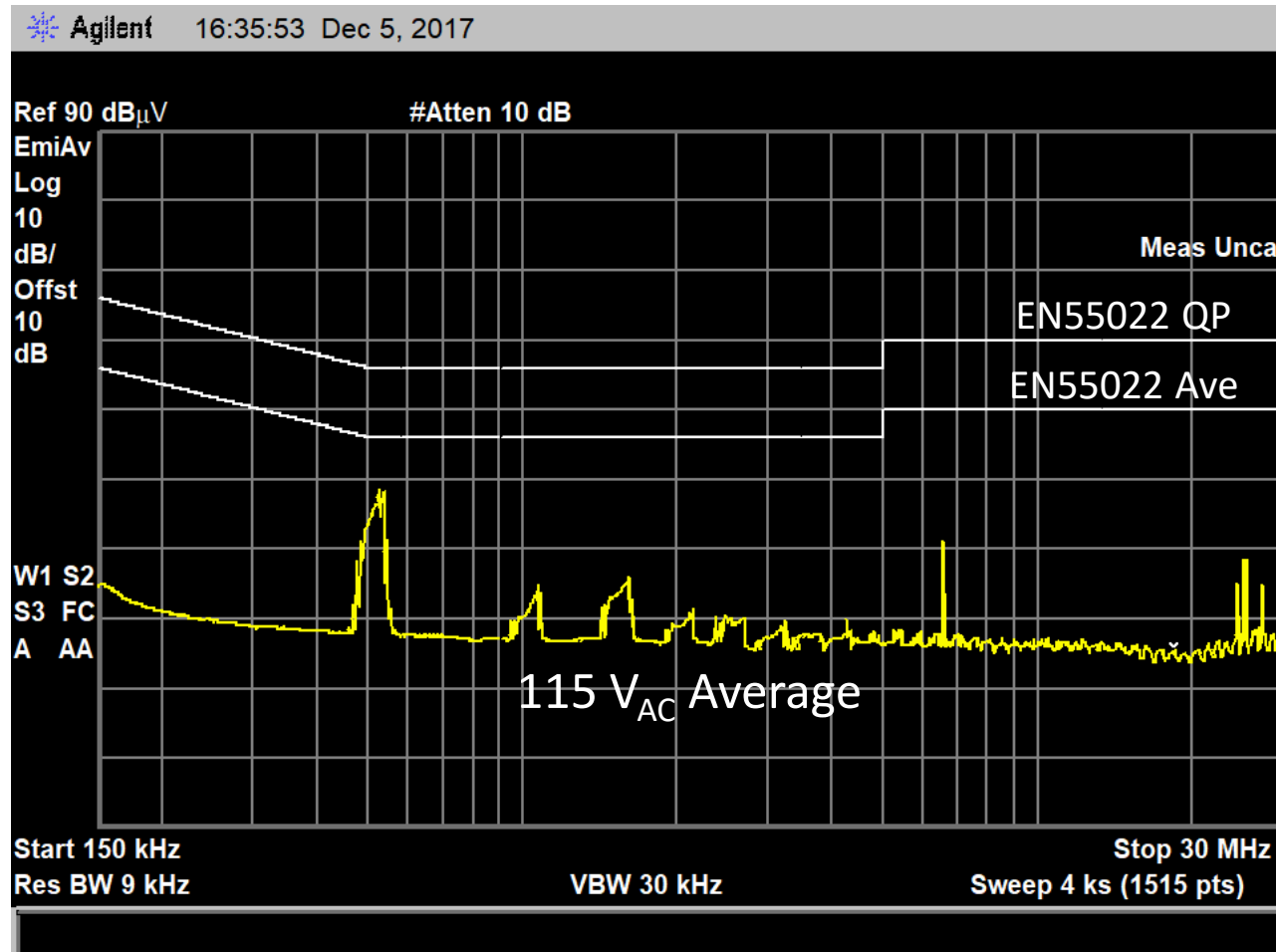
Transformer 80°C

90 V_{AC}, 45 W, 25 °C, uncased, no airflow

45W Efficiency



Quiet Operation

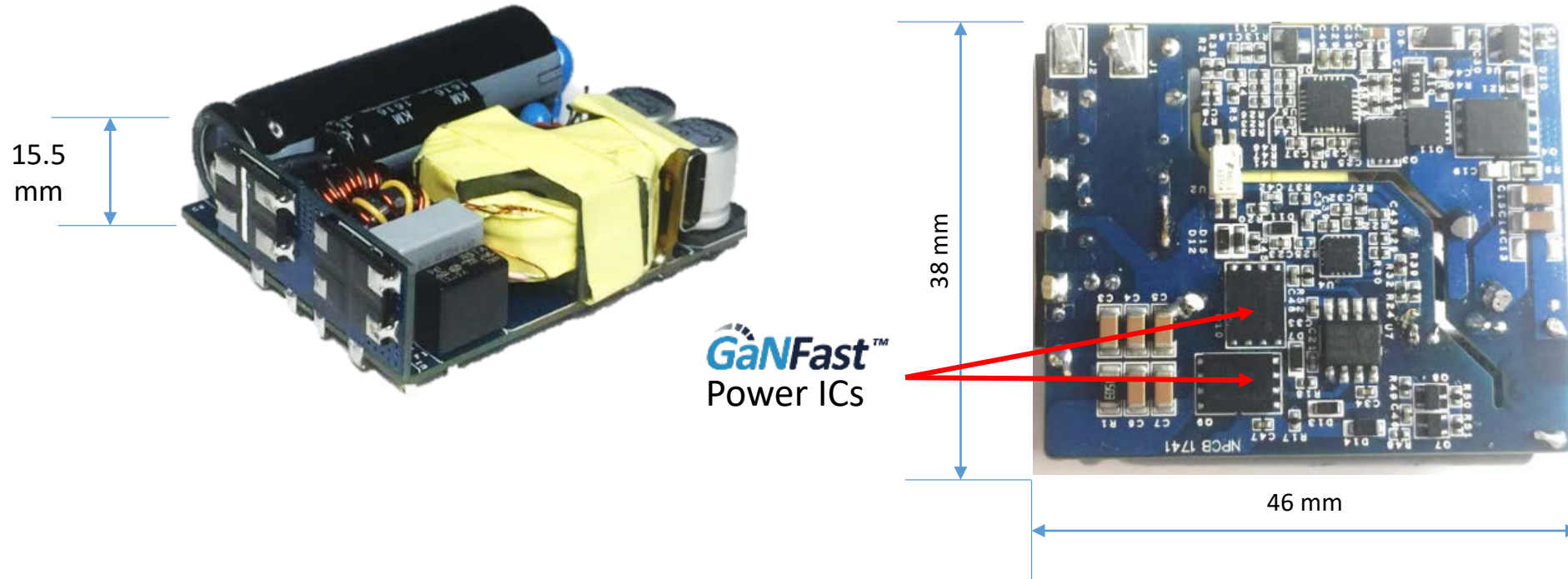




纳微 Navitas

65W USB-PD

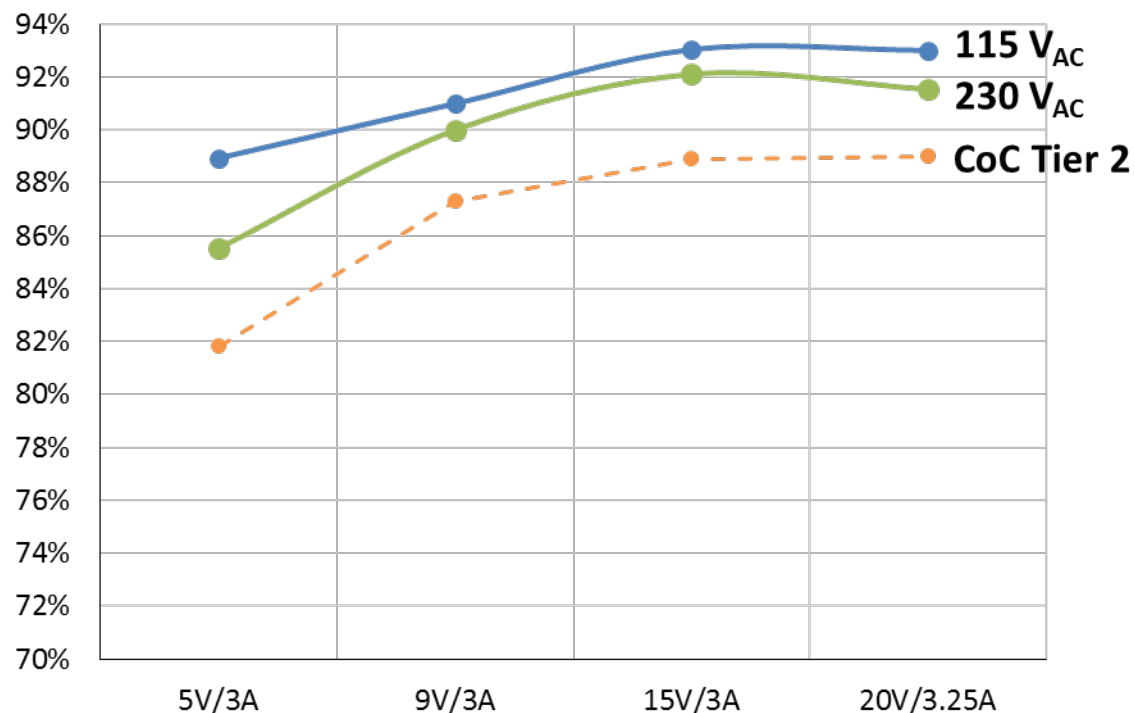
World's Smallest 65 W USB-PD Adapter



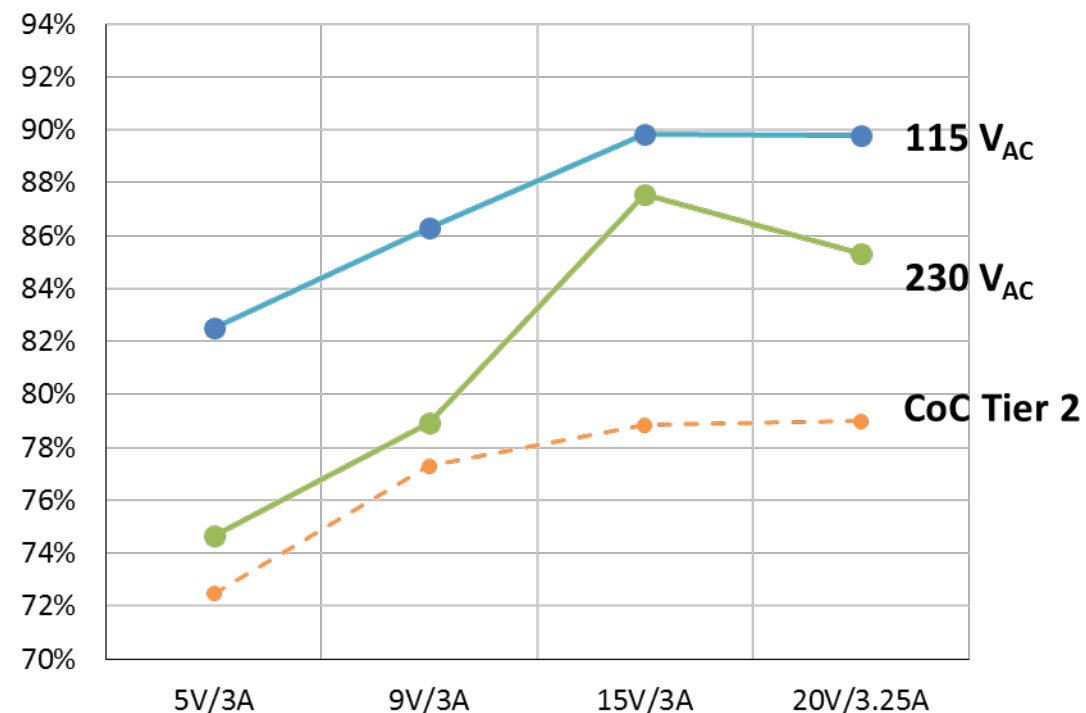
Power, Output	65 W USB-PD
Topology	ACF with UCC28780 and NV6115, NV6117 GaNFast Power ICs
Frequency	300 kHz
Size	27 cc (45 cc with case)
Density	2.4 W/cc (39 W/in ³) (1.5 W/cc (24 W/in ³) cased
Efficiency	>93% peak, 92.8% at 90 V _{AC} , full load DoE Level VI, Euro CoC (EuP) Tier 2

Highest Efficiency

4-Point Average Efficiency

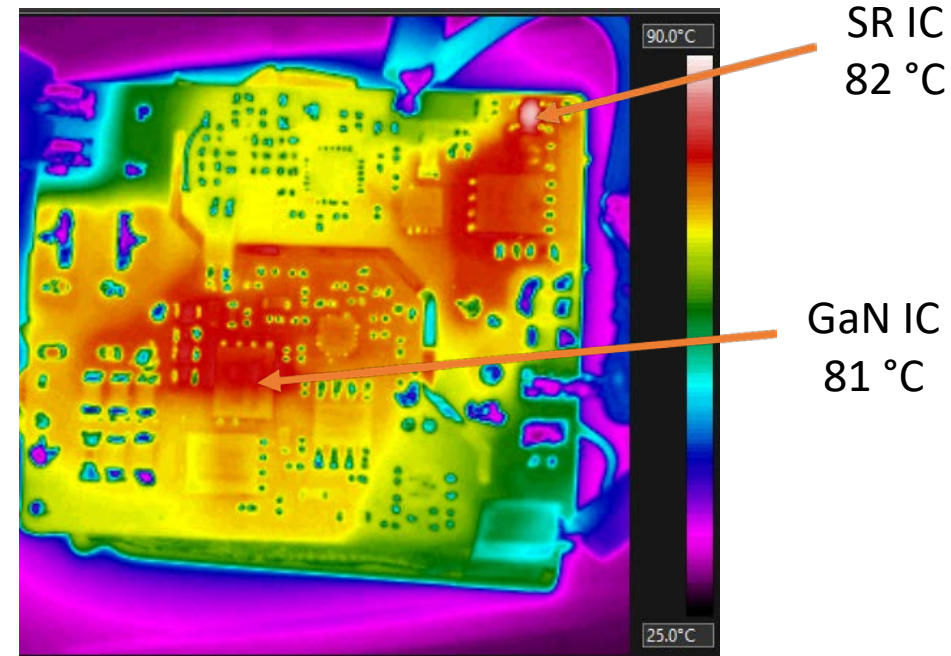
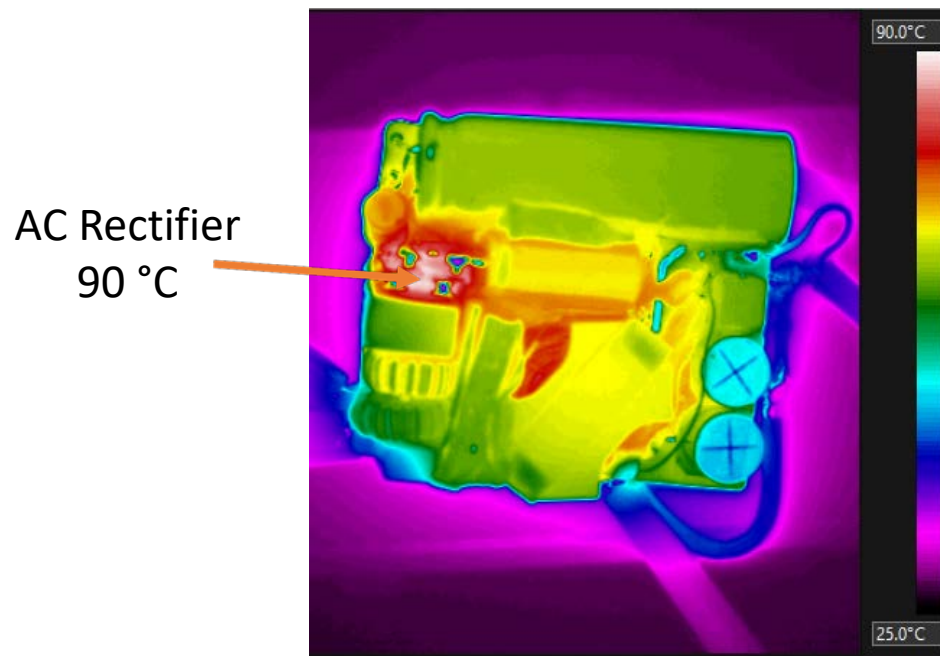


10% Load Efficiency



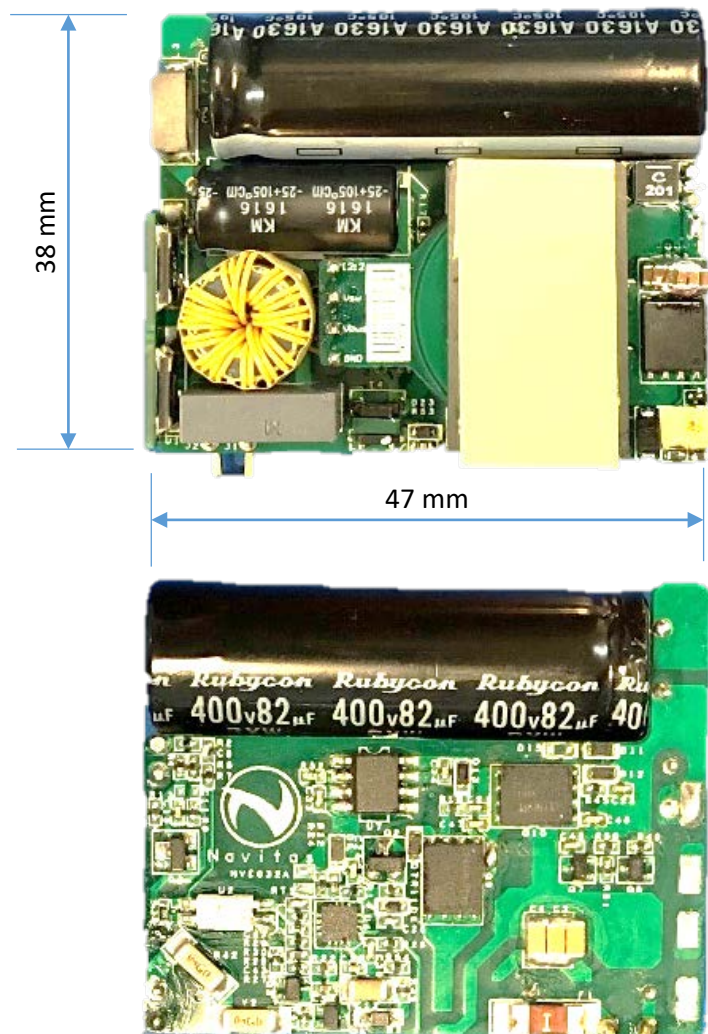
- Peak efficiency = 94.3% at 230 V_{AC}, full load (20V/3.25A)
- Lowest line efficiency = 93.4% at 90 V_{AC}, full load
- Standby: 25 mW at 115 V_{AC}, 40 mW at 230 V_{AC}
 - CoC Tier 2 spec is < 75mW, DoE Level VI spec <= 210 mW

Cool Performance

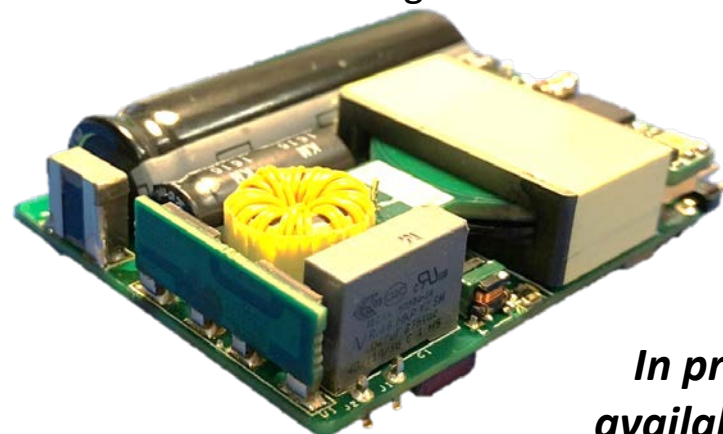
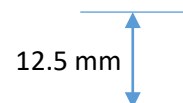


- Meets customer case specification of $\leq 50^{\circ}\text{C}$
- Conditions: 115V_{AC} , 20V_{DC} , 65W, 25°C ambient, no airflow, no heatsink

65W Planar Prototype

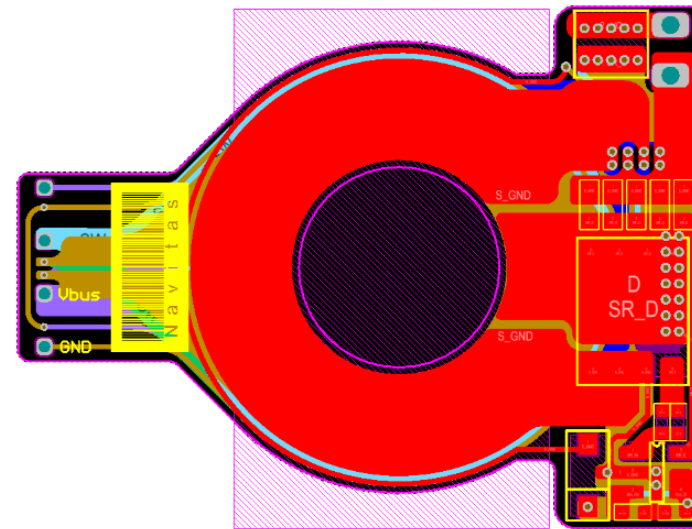
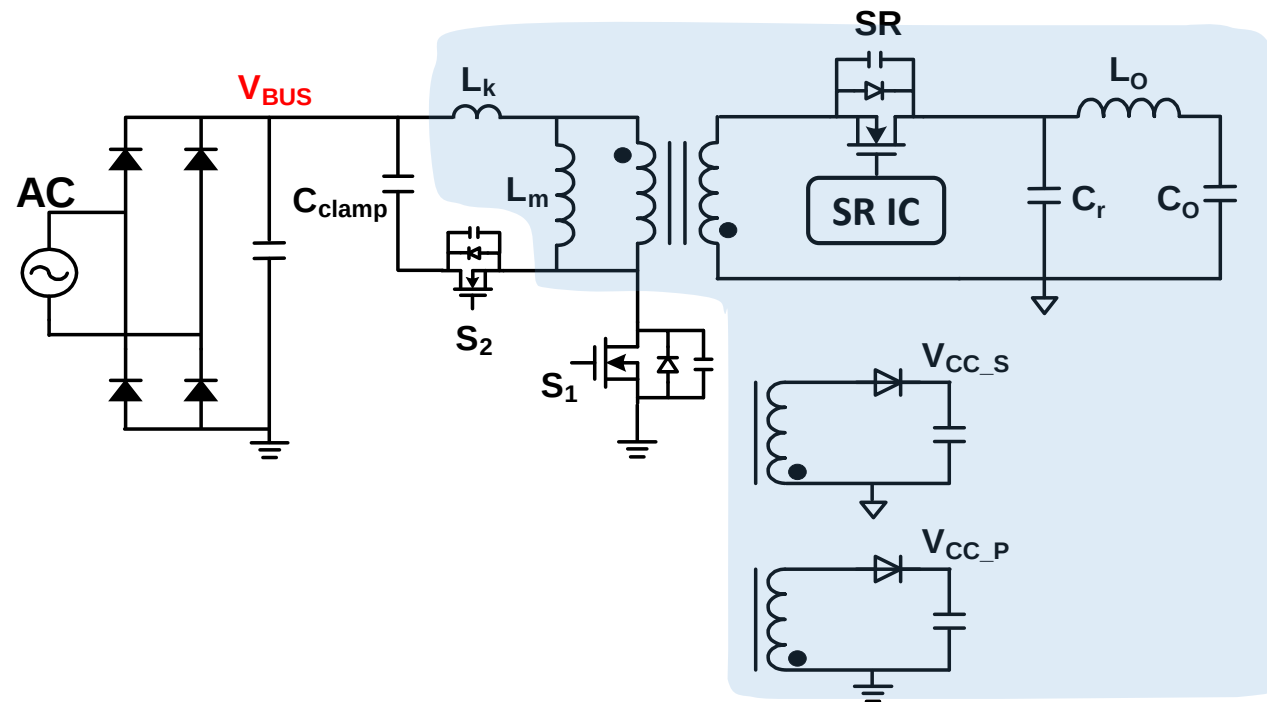


- Input : Universal AC (85-265V_{AC}, 47-63Hz)
- Output : Fixed 20 V (65W)
- Powertrain : NV6115 (160mΩ) + NV6117 (110mΩ) GaN Power ICs
- Control : ACF = TI UCC28780
- Frequency : 500-600 kHz
- Size : 38 x 47 x 12.5 mm = 22 cc uncased
43 x 52 x 17.5 mm = 39 cc with 2.5 mm case
- Power Density : 2.9 W/cc (47 W/in³) uncased
1.7 W/cc (27 W/in³) cased
- Construction : 4-layer, 2-oz Cu PCB, SMT powertrain
“No heatsink” design

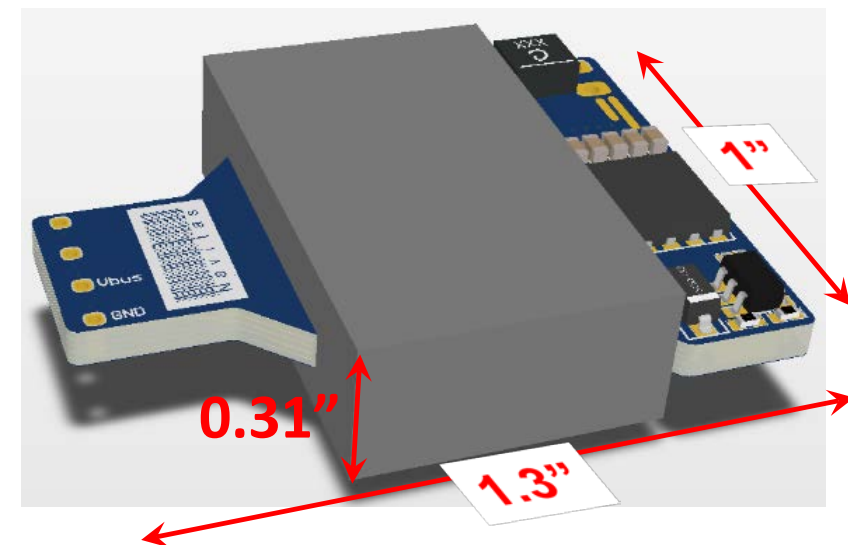


***In progress,
available Q2'18***

65W ACF Transformer (400~800kHz) (Preliminary)



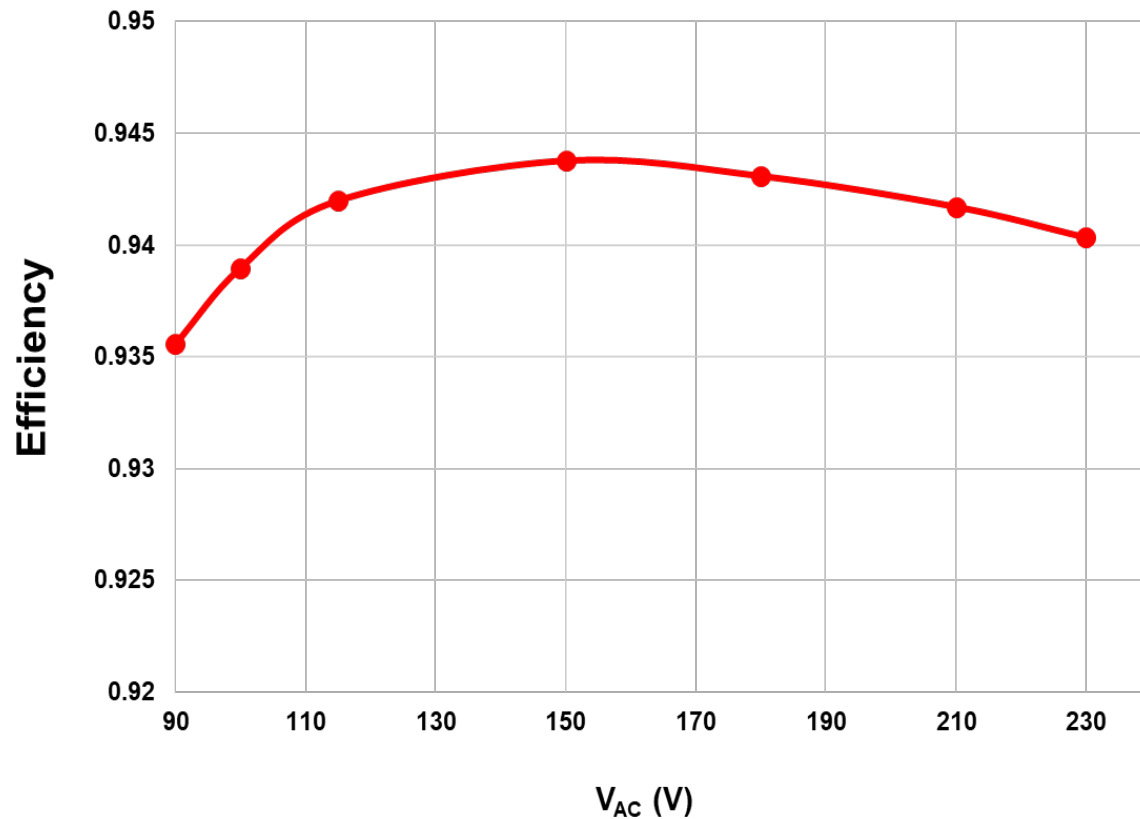
- 6-layer 'transformer+SR' mezzanine PCB
 - SR integrated onto secondary winding
 - EMI shielding integrated into primary winding
 - Uses buried vias / PCB core layers to comply with HV safety (creepage / clearance)



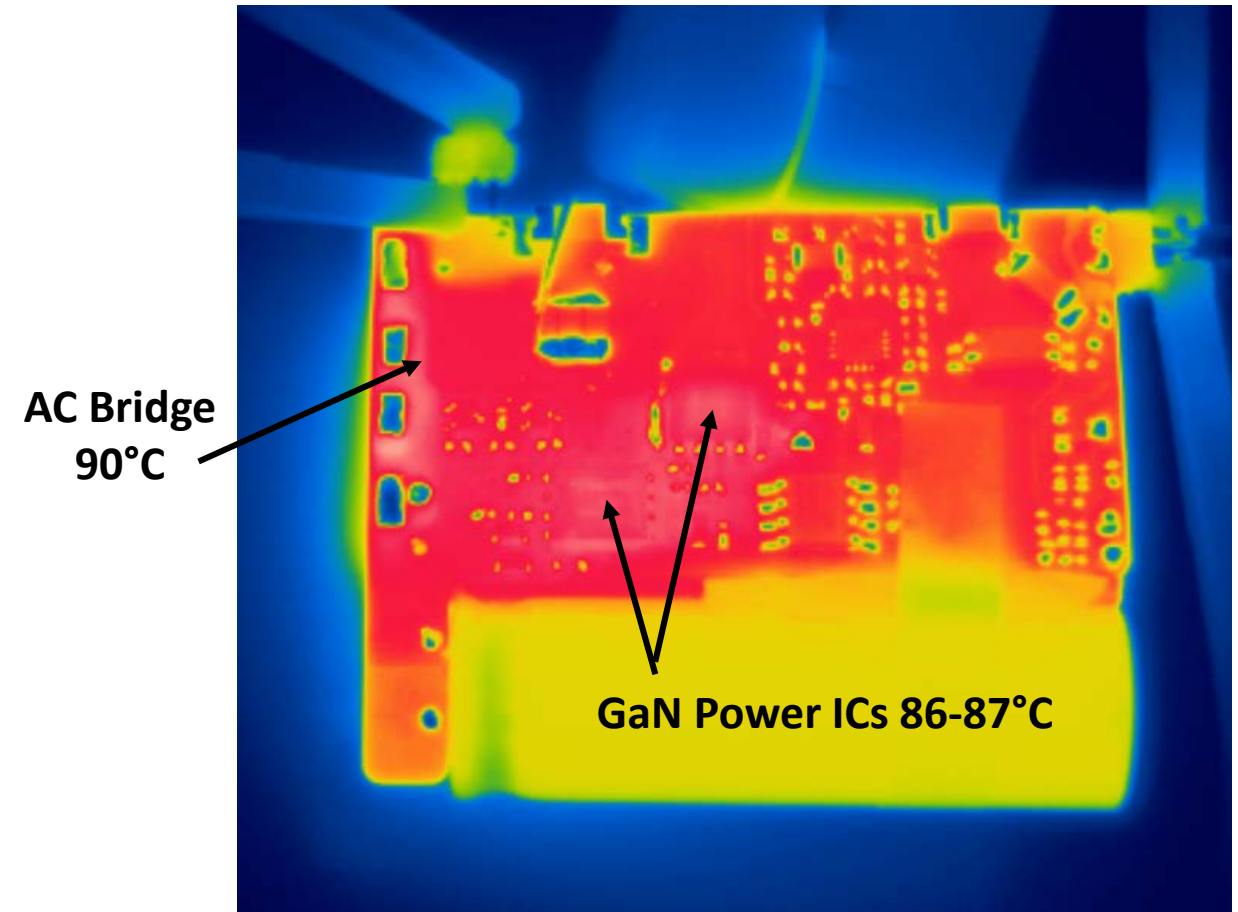
65W: High Efficiency, Runs Cool

(Preliminary) (fixed 20 V_{OUT})

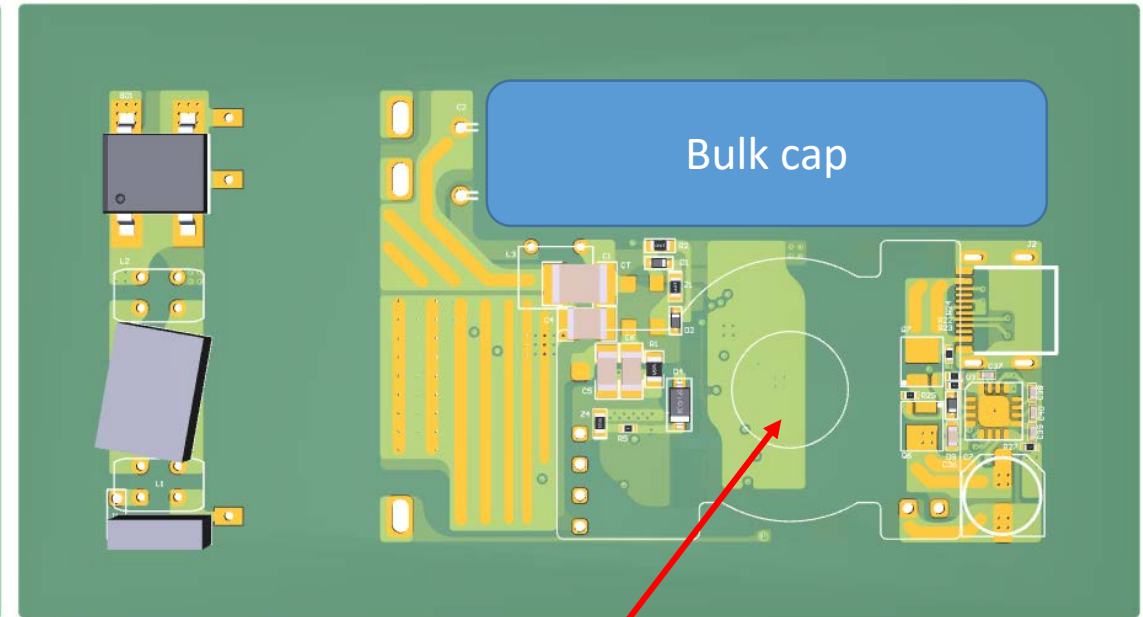
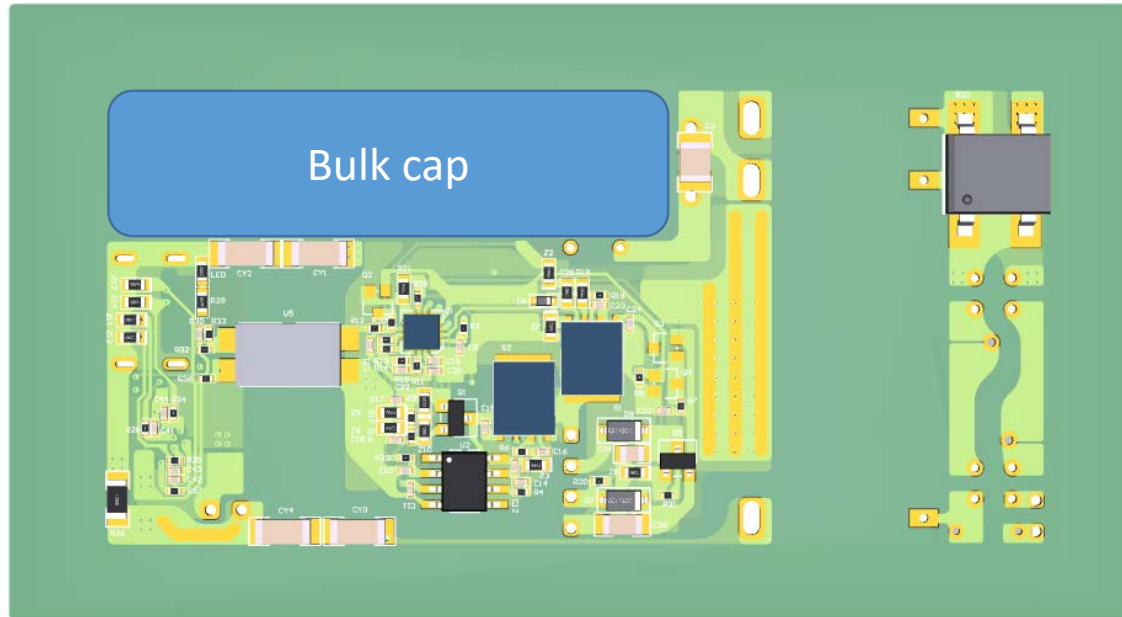
Efficiency vs. AC Voltage (full load, 25°C, no airflow)



Thermal Profile (full load, 90 V_{AC}, 25°C, no airflow)



65 W USB-PD (600 kHz, planar) – *in progress*

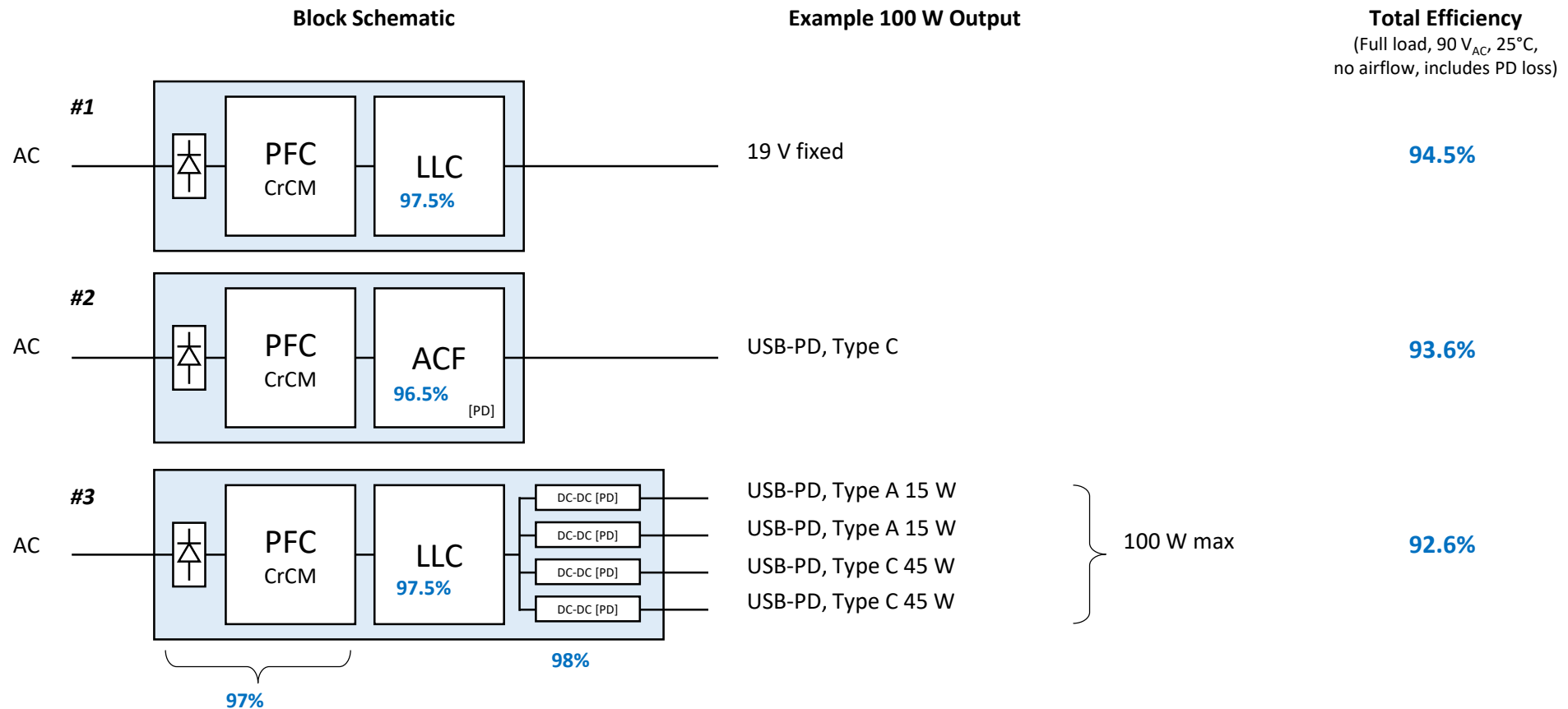


65W USB-PD 600kHz: Uncased size = 40 x 55 x 12.5 mm

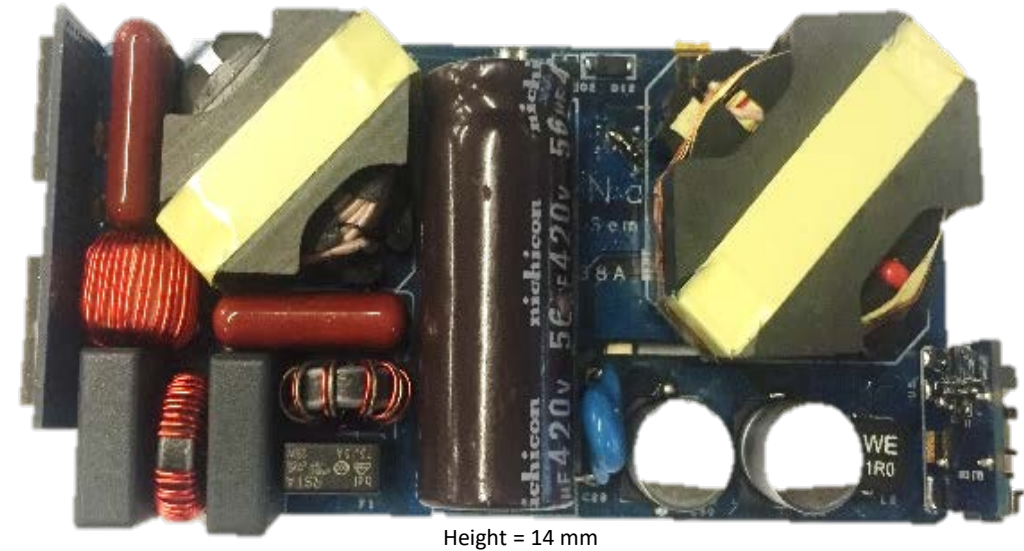
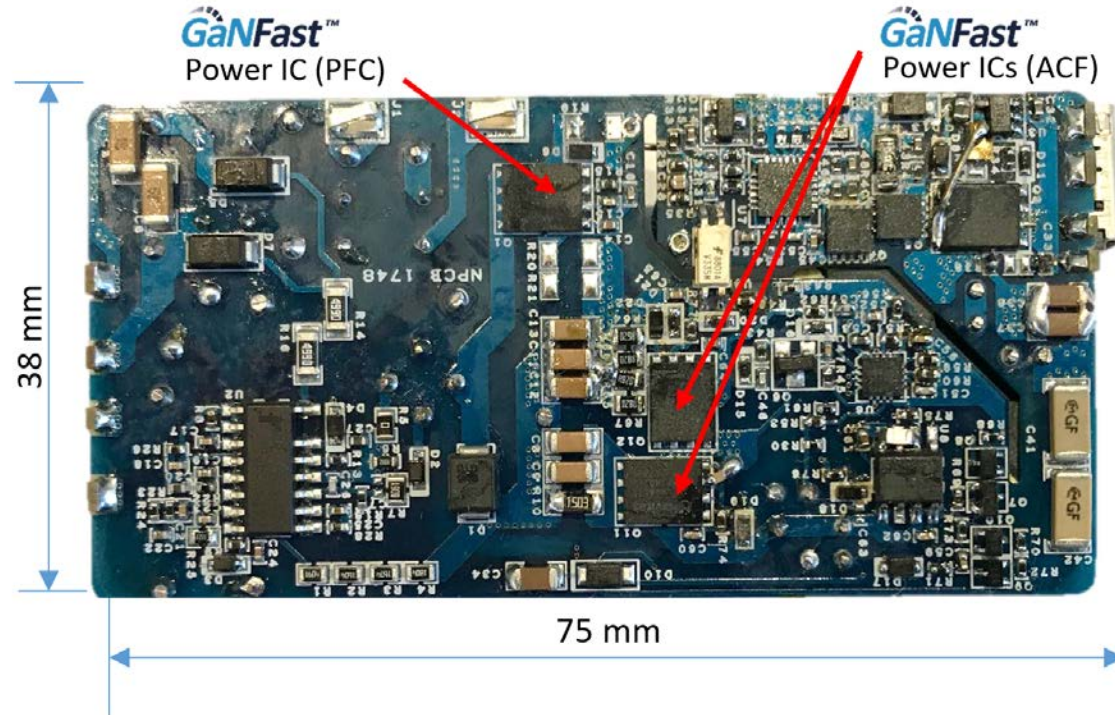
Planar transformer sub-assembly to sit over this area

100W: Topology?

- Fixed or variable output?
 - LLC best for fixed output
 - ACF best for variable (PD) output

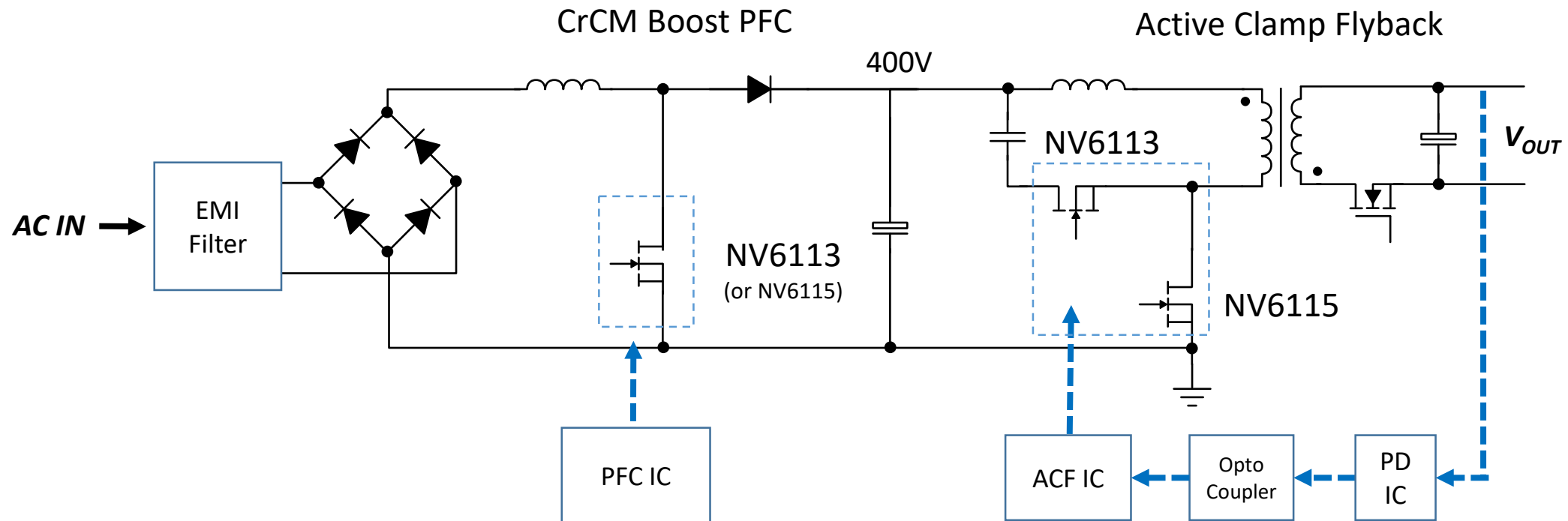


World's Smallest 100 W USB-PD



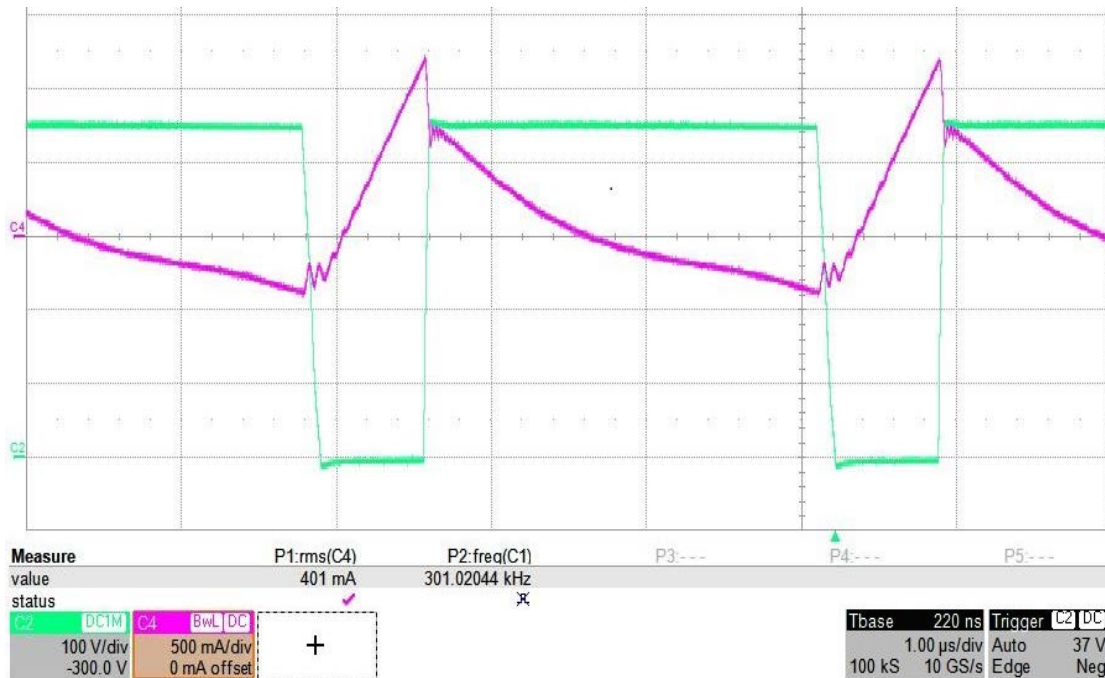
Power, Output	100 W USB-PD
Topology	CrCM PFC with NCP1615 and NV6115 GaNFast Power IC ACF with UCC28780 and NV6115, NV6117 GaNFast Power ICs
Frequency	PFC min. 200 kHz, ACF 300 kHz
Size	40 cc (65 cc with case)
Density	2.5 W/cc (41 W/in ³) (1.5 W/cc (25 W/in ³) cased
Efficiency	>93.7% peak, 92.1% (target >93%) at 90 V _{AC} , full load, DoE Level VI, Euro CoC (EuP) Tier 2

100W (PFC+ACF) USB-PD 3.0

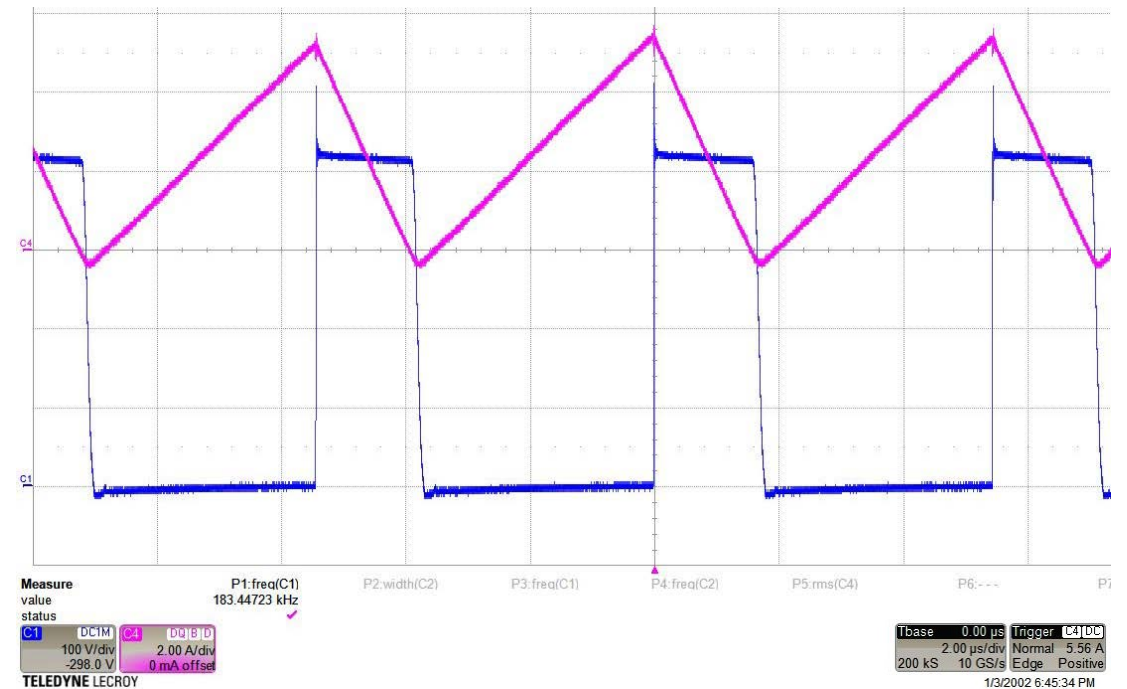


100 W USB-PD (CrCM PFC + ACF)

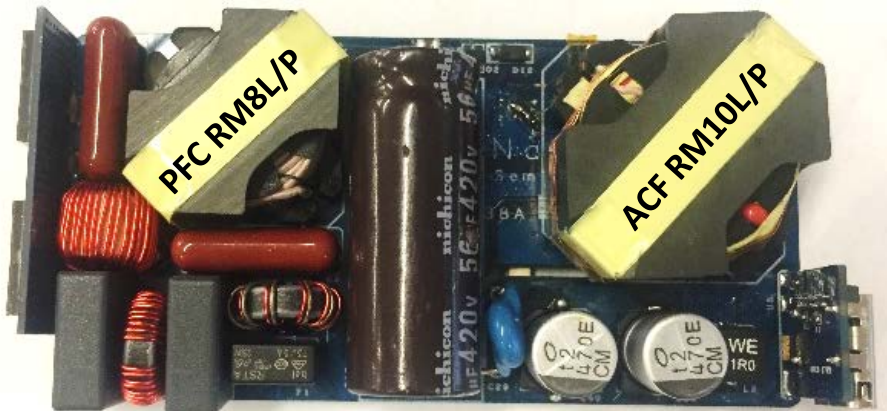
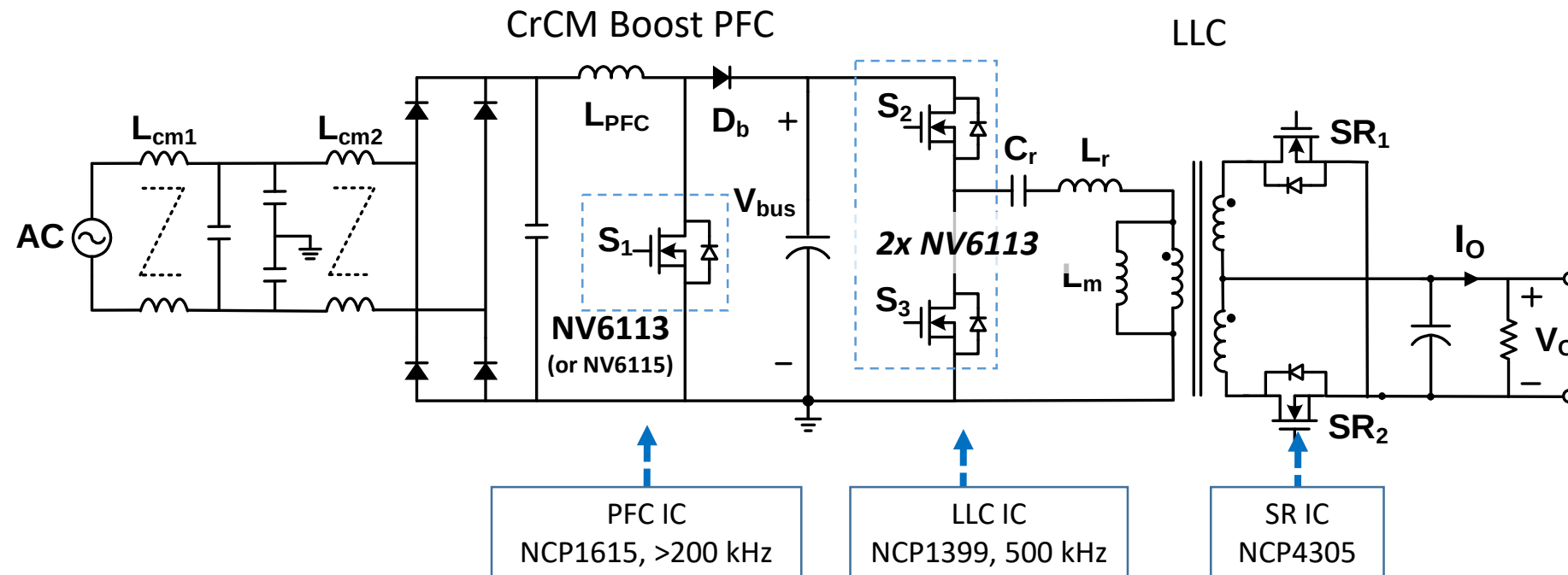
100 W PFC, 180 kHz, 90 V_{AC}
(Boost Current, PFC GaN Power IC VDS)



100 W ACF, 300 kHz
(Primary Transformer Current, Switch Node Voltage)

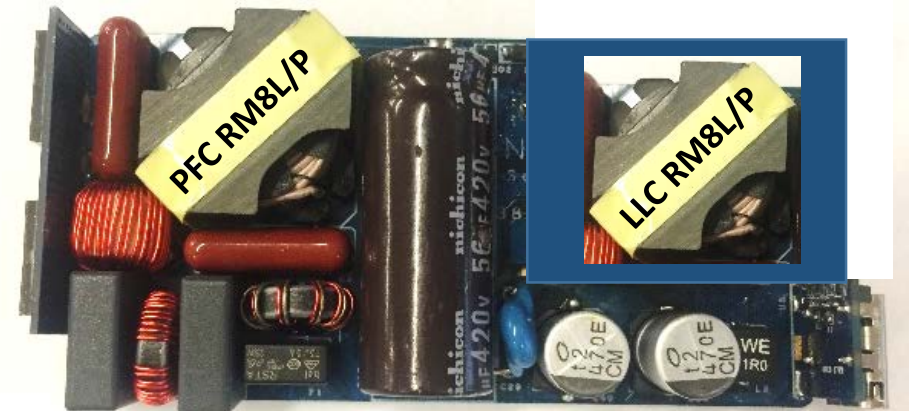


100W (PFC+LLC)



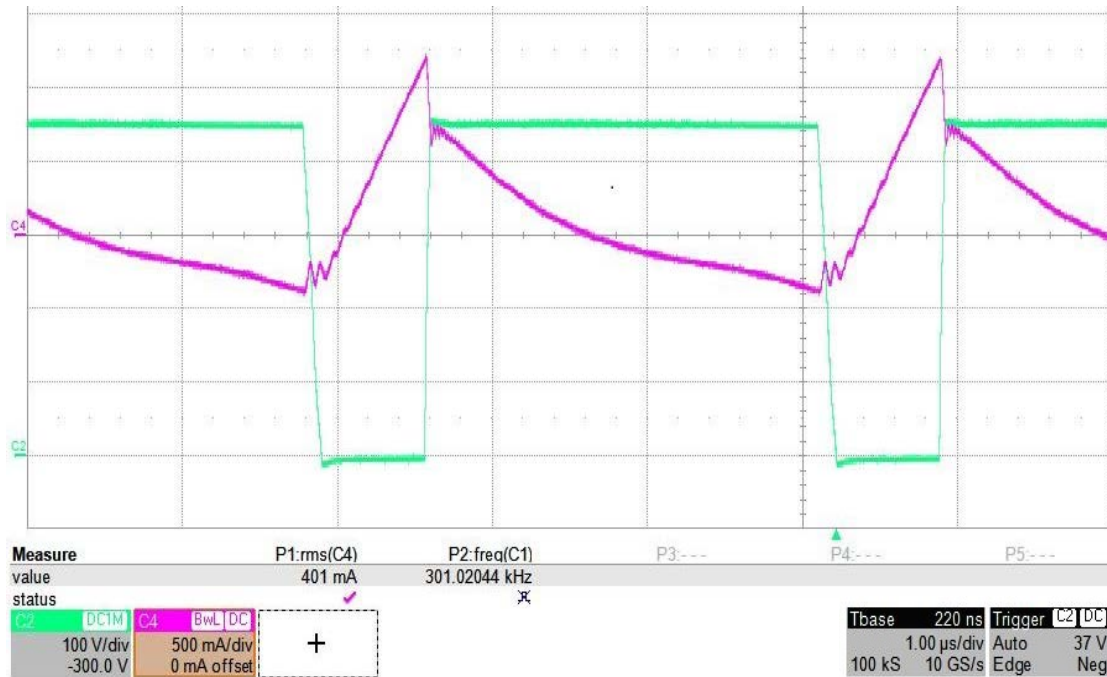
← 100W ACF = RM10/LP

100W LLC = RM8/LP→

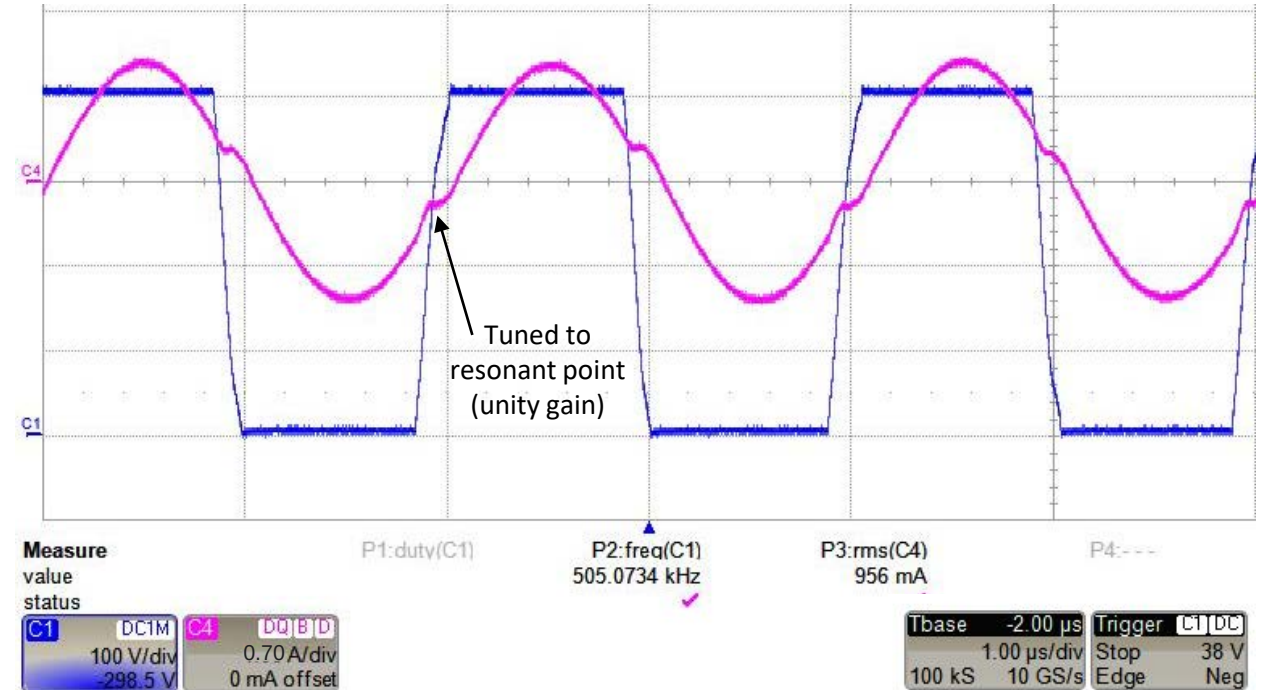


100 W, 19 V (CrCM PFC + LLC)

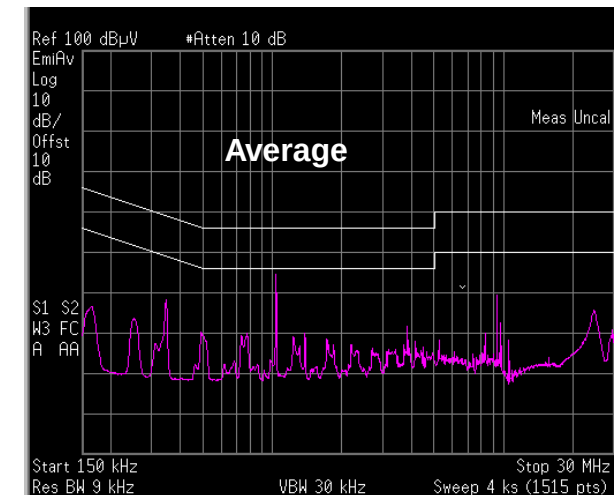
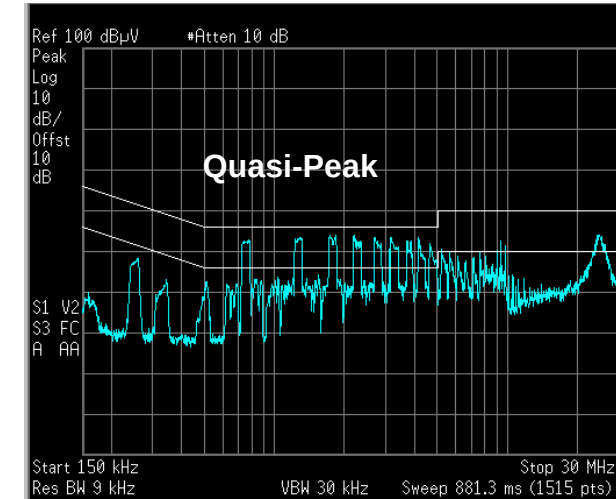
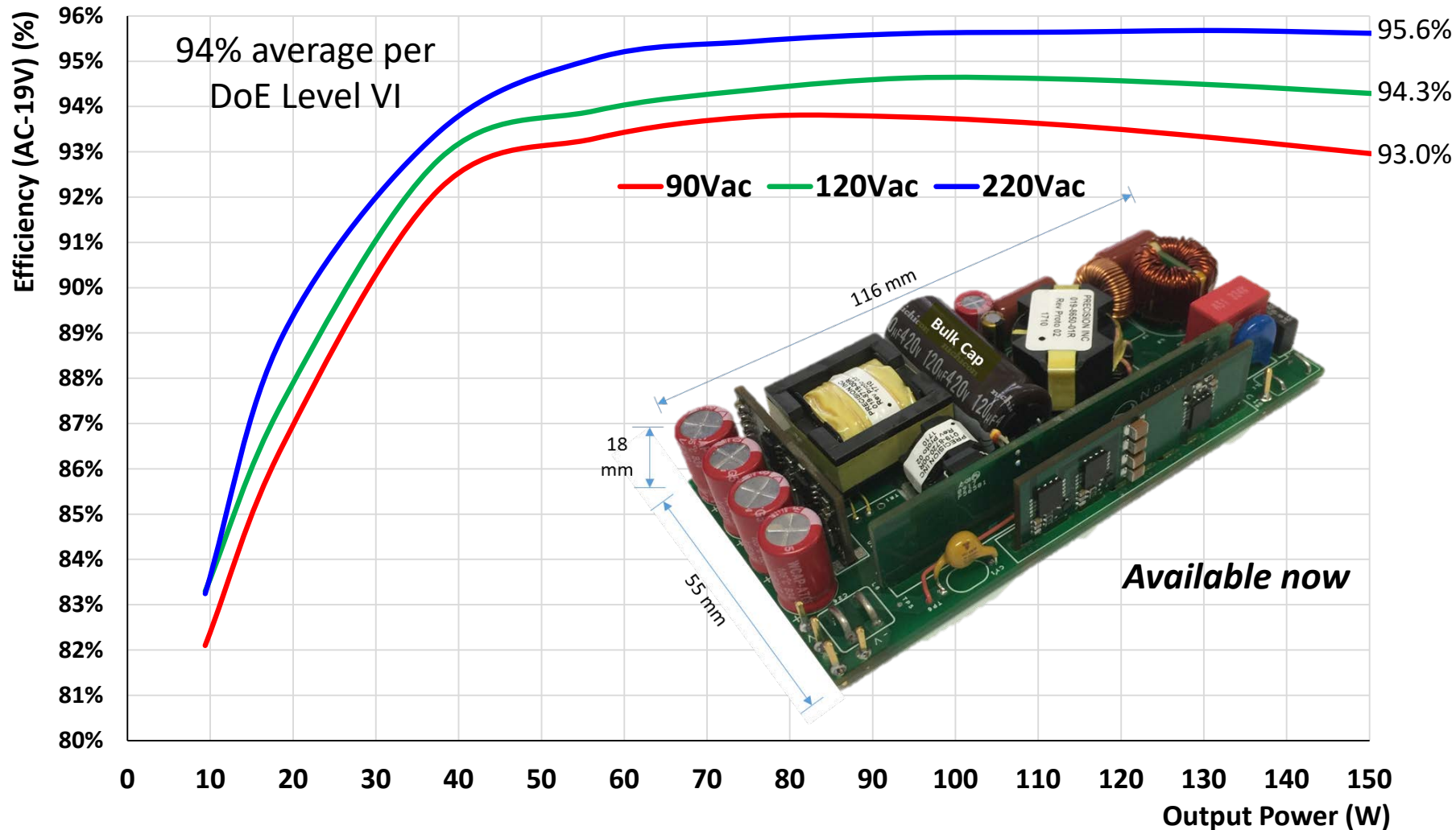
100 W PFC, min. 180 kHz, 90 V_{AC}
(Boost Current, PFC GaN Power IC V_{DS})



100 W LLC, 500 kHz
(Primary LLC Transformer Current, Switch Node Voltage)

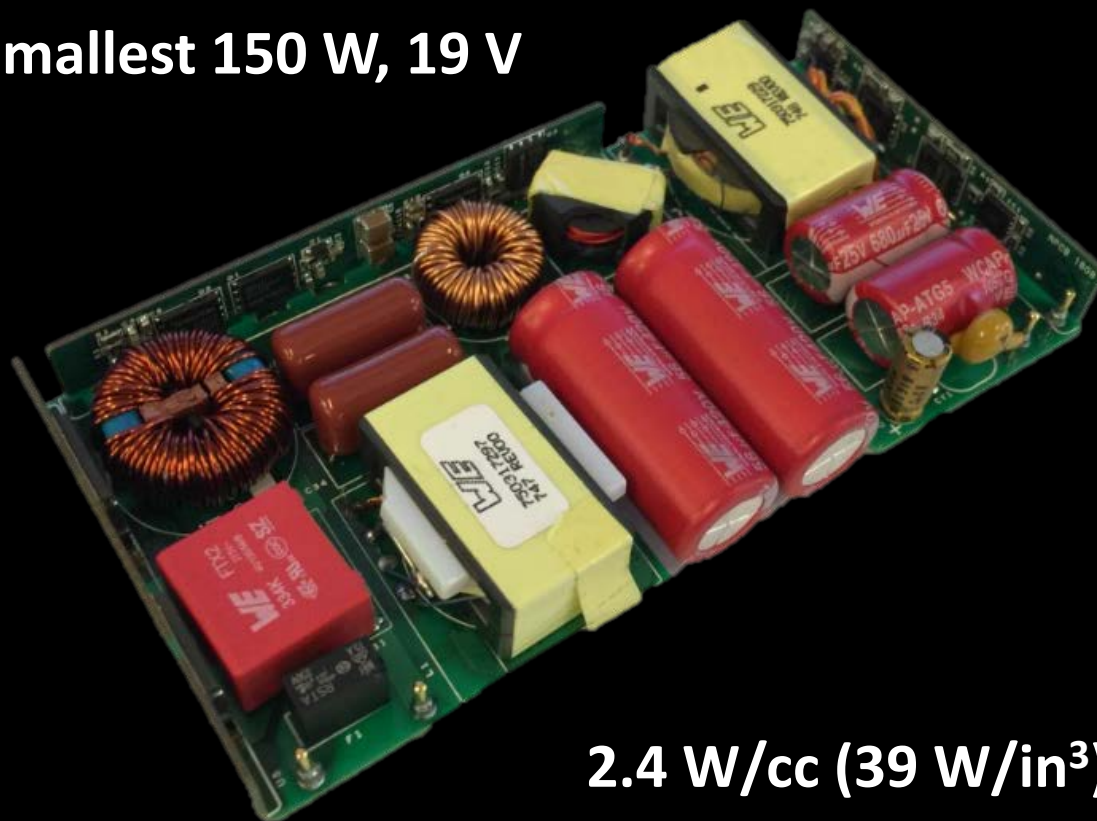


150W, 19V: 300 kHz, 21 W/in³



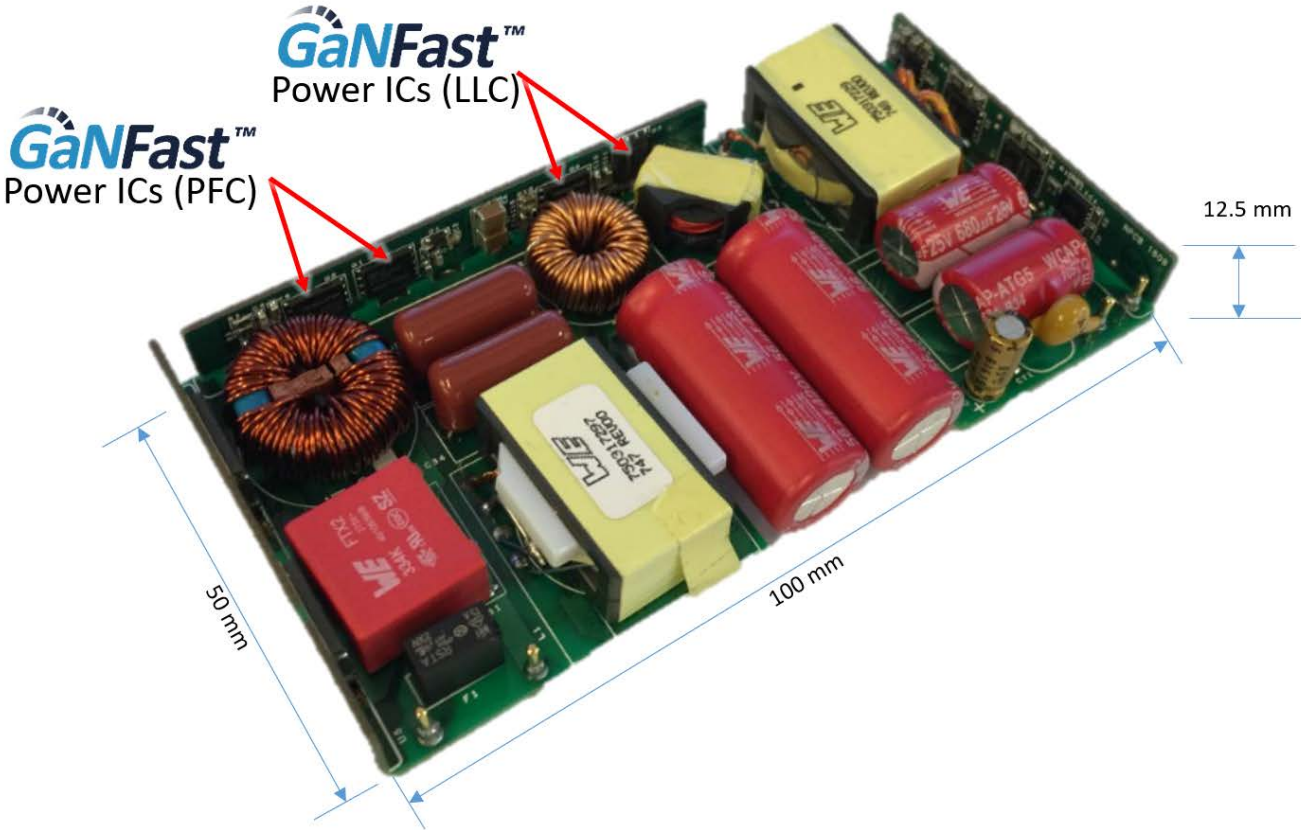


World's Smallest 150 W, 19 V



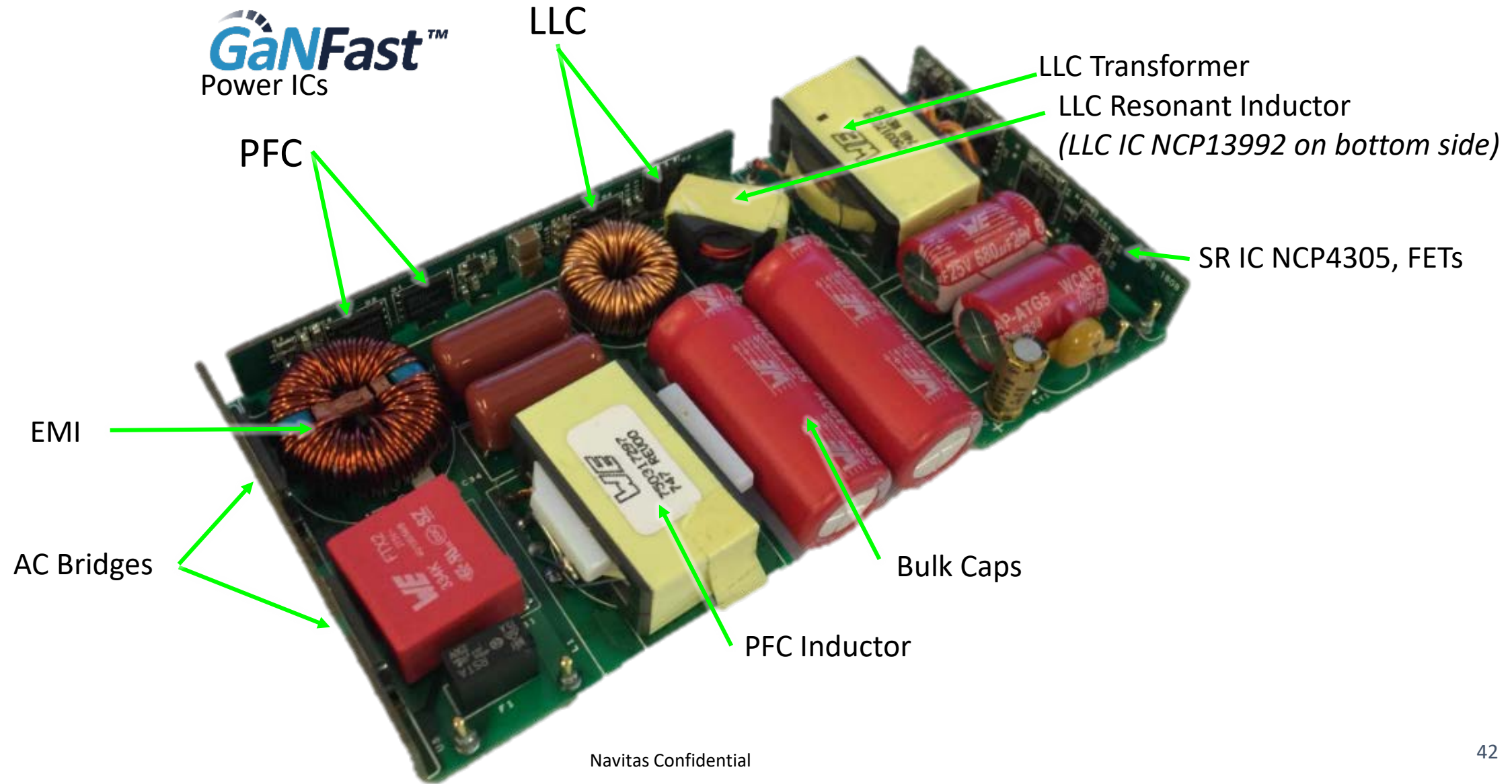
2.4 W/cc (39 W/in³)

150W, 19V: 200/500 kHz, 39 W/in³

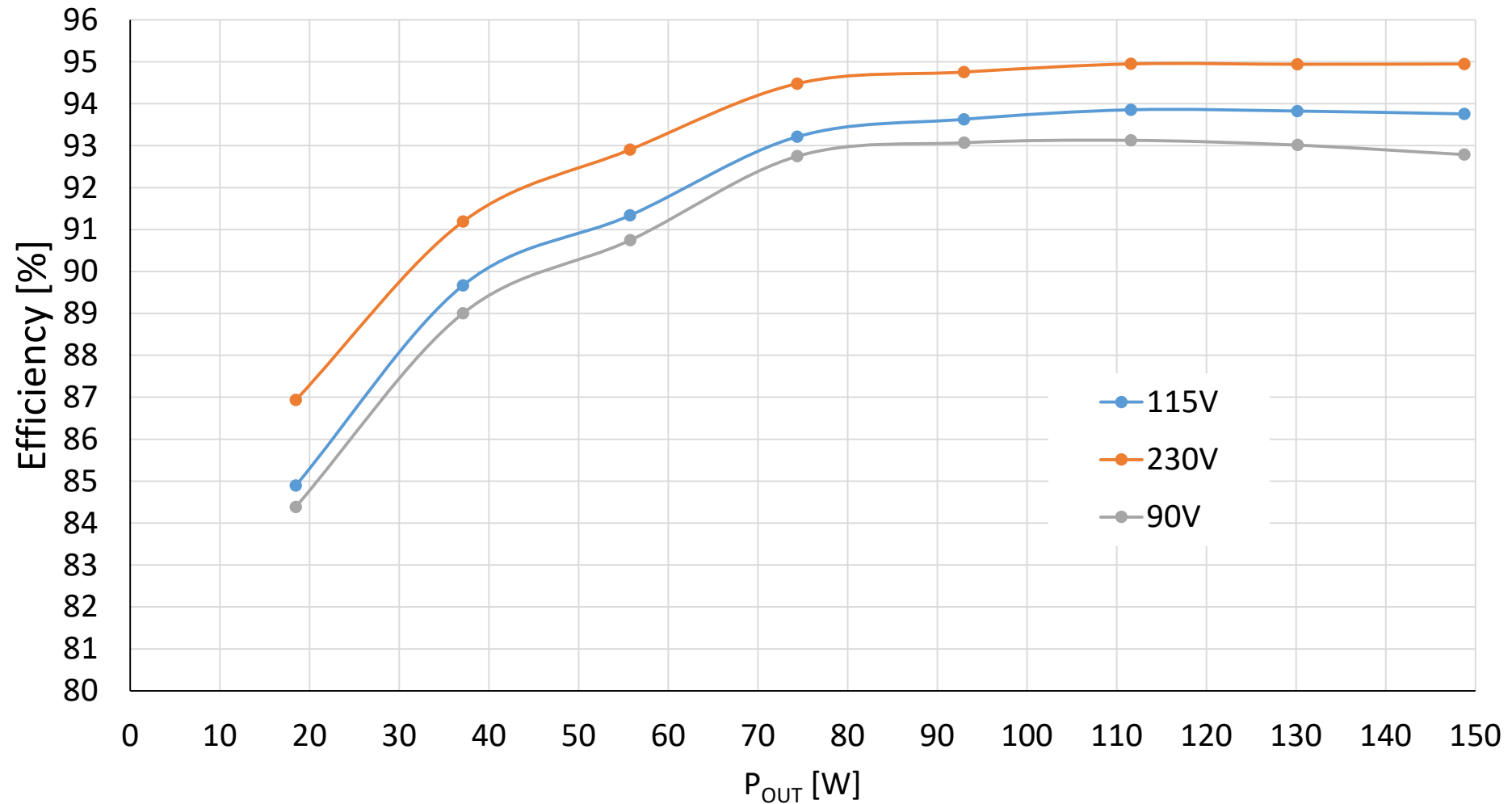


Power, Output	150 W, 19 V
Topology	CrCM PFC with NCP1615 and NV6115 GaNFast Power ICs LLC with NCP13992 and NV6115 GaNFast Power ICs
Frequency	PFC min. 200 kHz, LLC typ. 500 kHz
Size	63 cc (101 cc with case)
Density	2.4 W/cc (39 W/in ³) (1.5 W/cc (24 W/in ³) cased
Efficiency	95% peak, 93% at 90 V _{AC} , full load DoE Level VI, Euro CoC (EuP) Tier 2

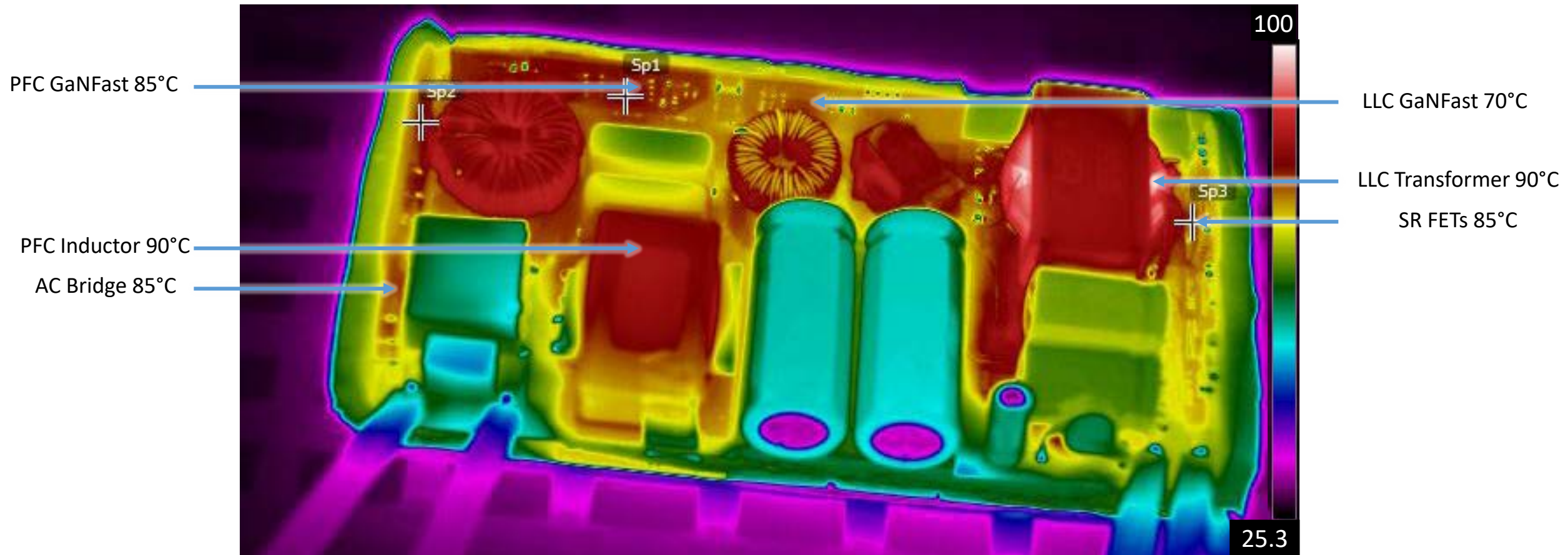
150W, 19V: PFC min 200 kHz, LLC 500 kHz



Highest Efficiency

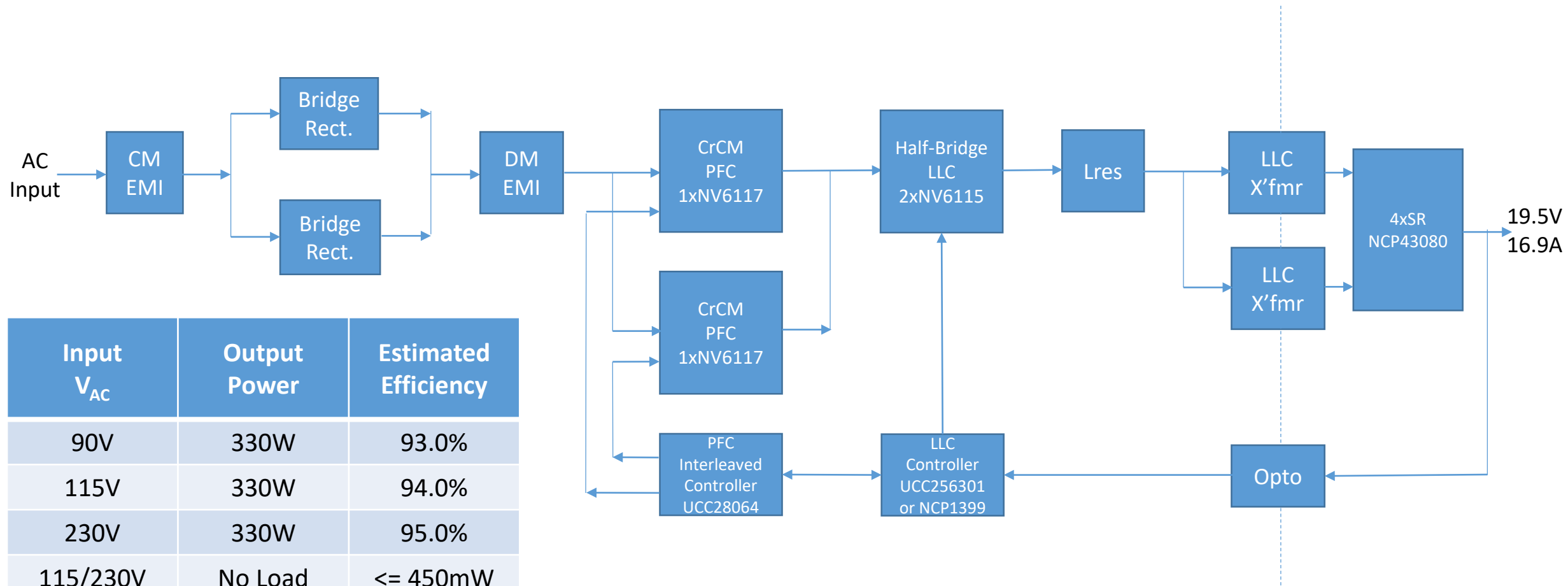


Cool Operation



90 V_{AC}, 150 W, 25 °C, uncased, no airflow

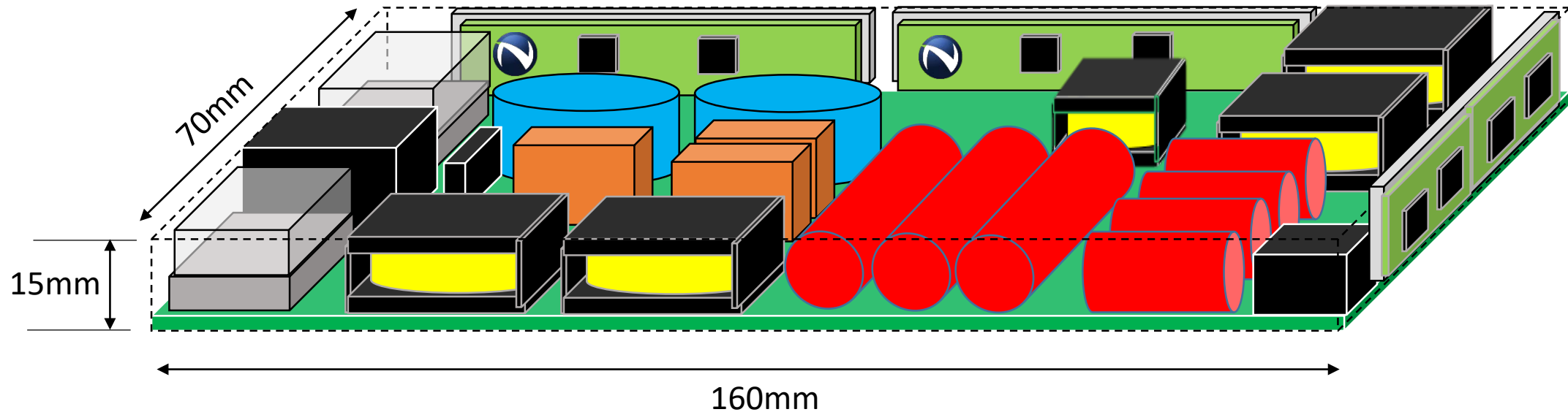
300W: Interleaved CrCM PFC + LLC



Input V_{AC}	Output Power	Estimated Efficiency
90V	330W	93.0%
115V	330W	94.0%
230V	330W	95.0%
115/230V	No Load	$\leq 450\text{mW}$
115/230V	0.25W	$\geq 50\%$
115/230V	0.5W	$\geq 50\%$

Preliminary 3D Concept

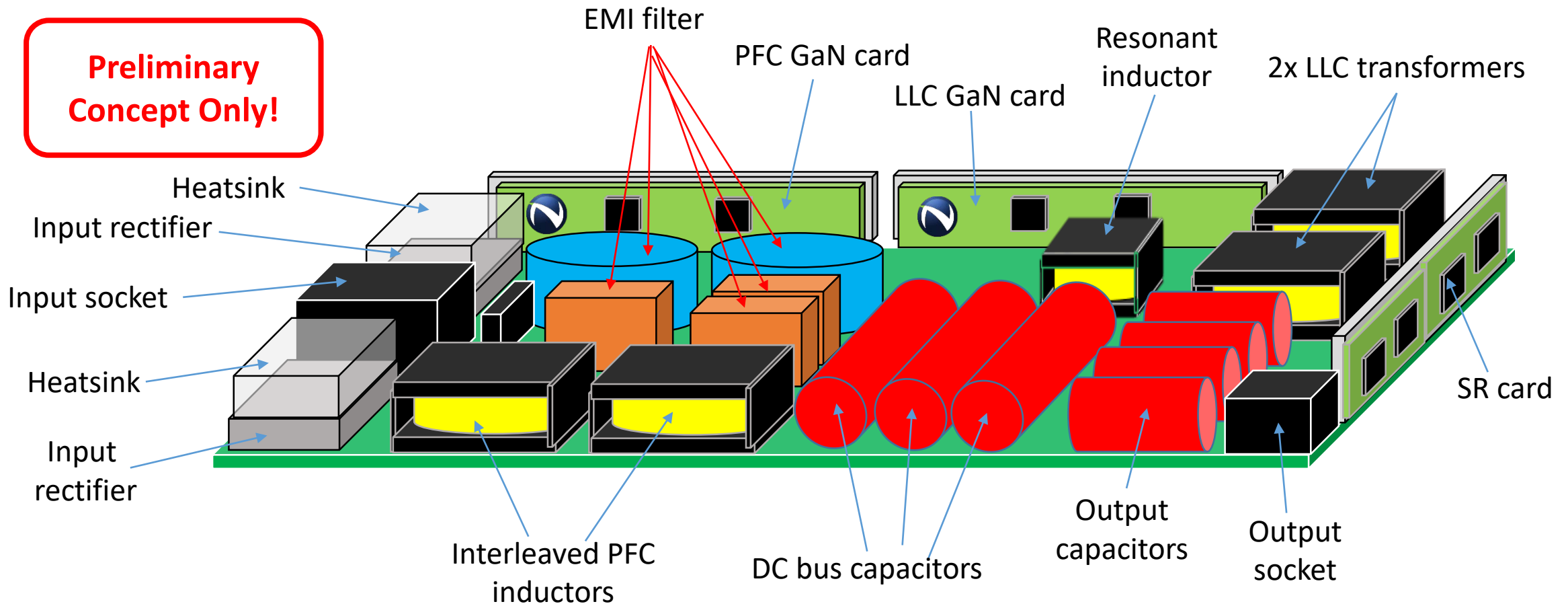
**Preliminary
Concept Only!**



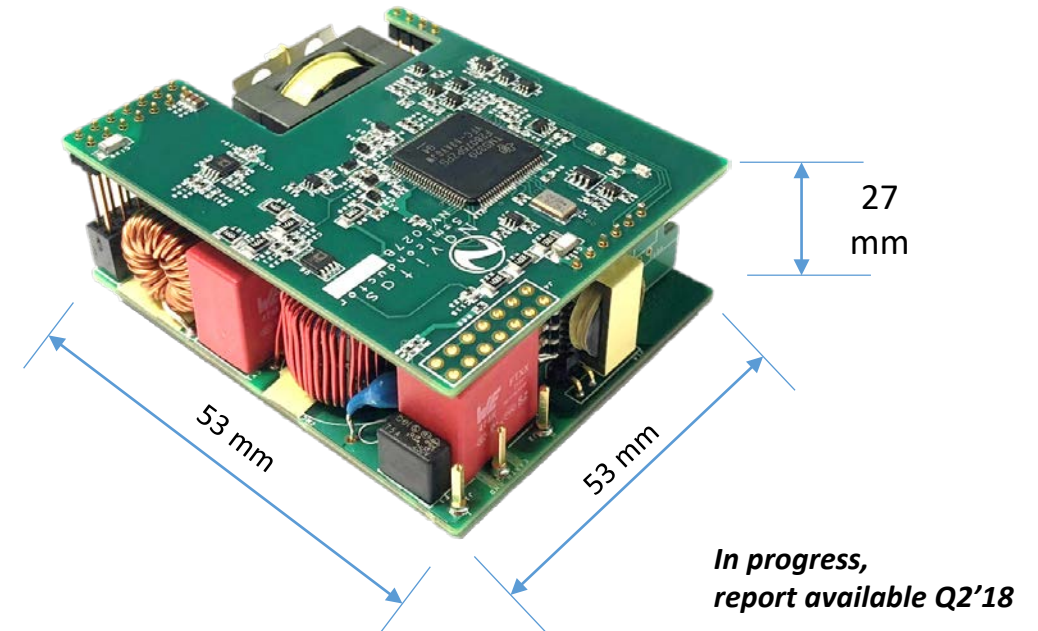
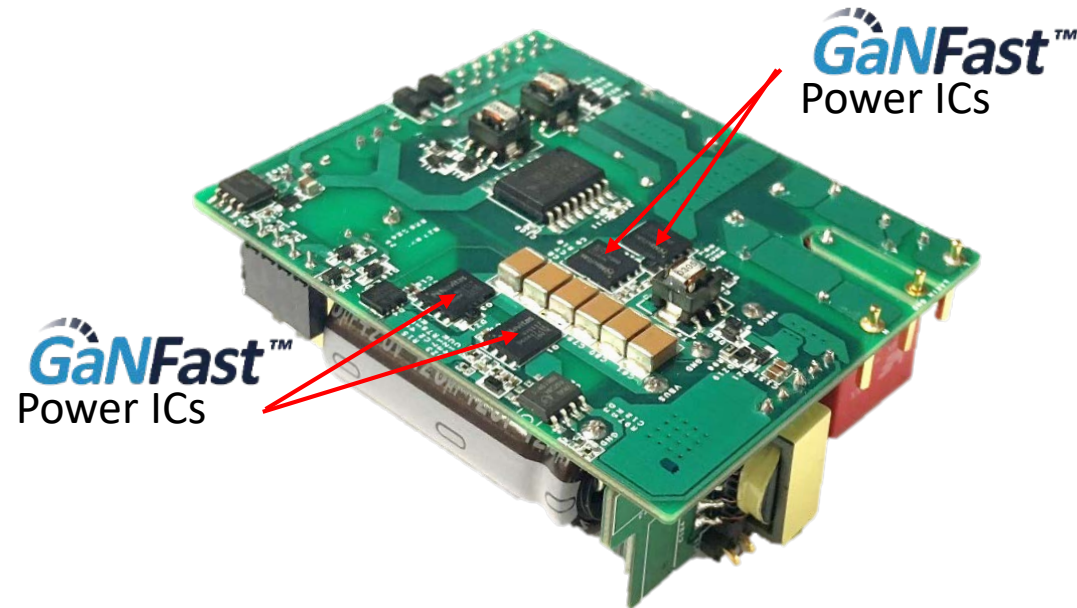
Power Density (uncased, estimate only)
 $15\text{mm} \times 70\text{mm} \times 160\text{mm} = 32.2 \text{ W/in}^3$

Requested Density: $165\text{mm} \times 75\text{mm} \times 35\text{mm} = 26.43 \text{ in}^3 \rightarrow 12.5 \text{ W/in}^3$ (cased)

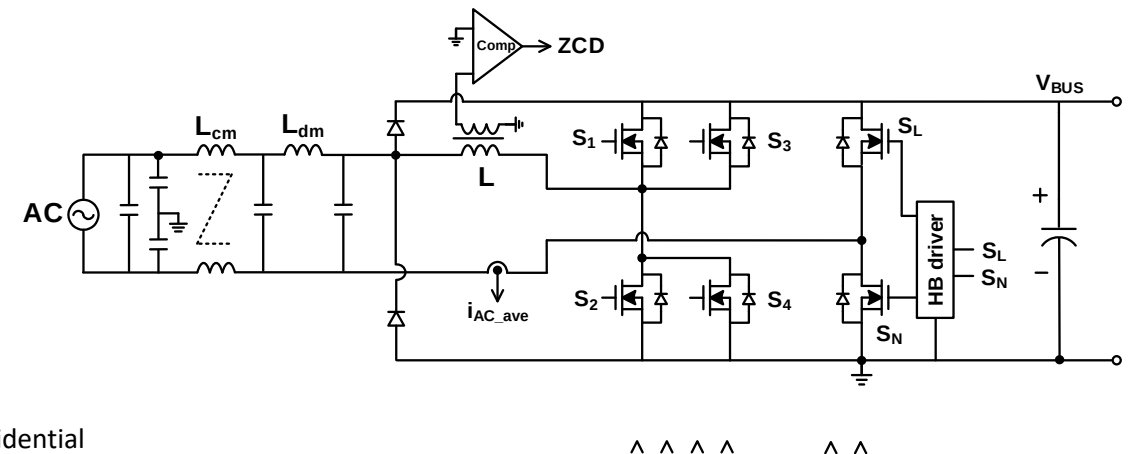
Preliminary 3D Concept



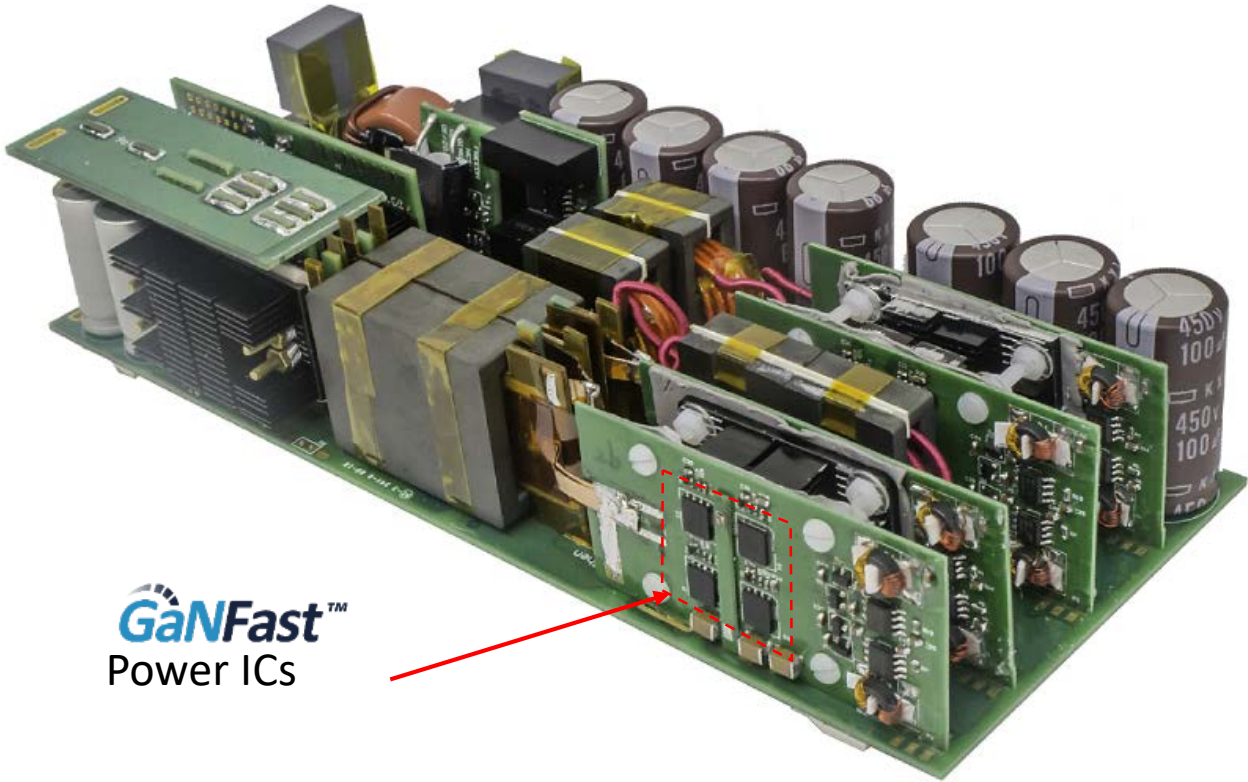
300 W, 1 MHz Totem-Pole PFC



Power, Output	300 W, 400 V
Topology	Totem-Pole CrCM PFC with NV6117 GaNFast Power ICs
Frequency	1 MHz (300 kHz – 1.2 MHz)
Size	97 cc (uncased)
Density	3.1 W/cc (80 W/in ³) uncased
Efficiency	98.5% peak, 97.5% at 90 V _{AC} , full load

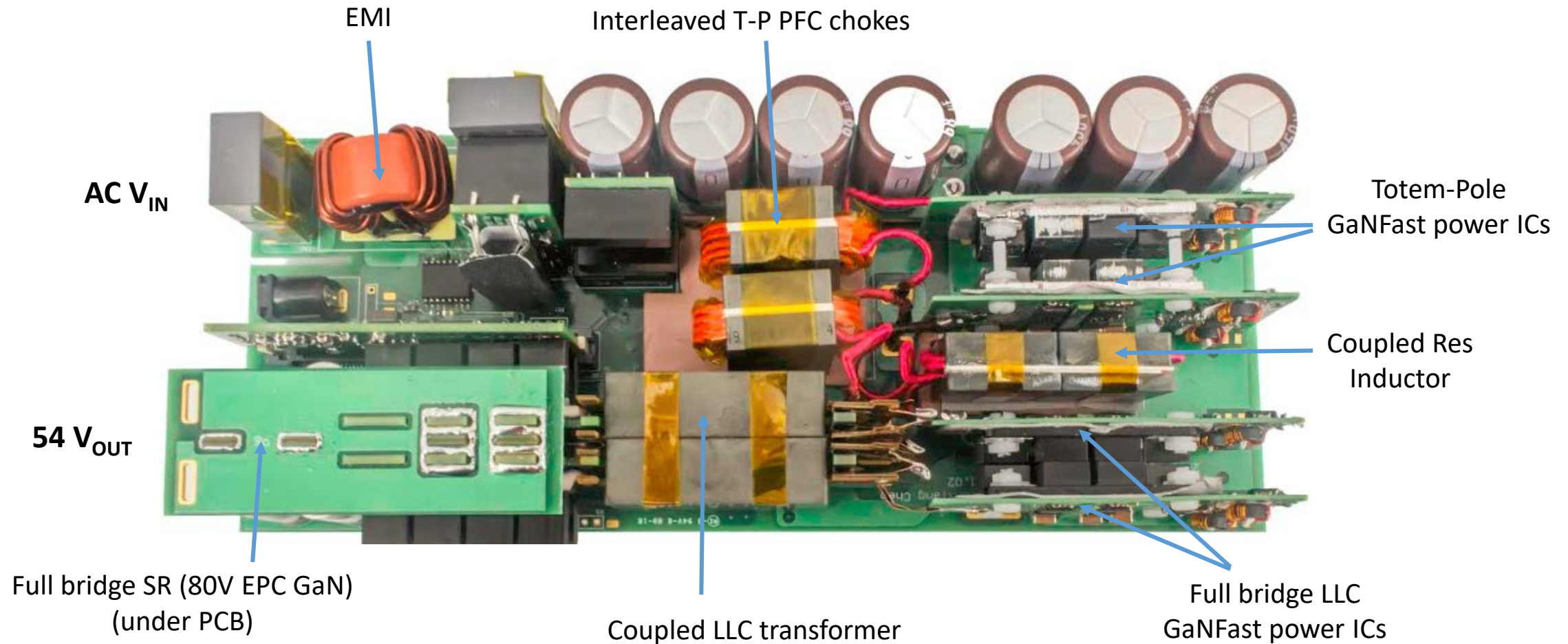


3.2 kW, 1 MHz Telecom



Power, Output	3,200 W, 54 V
Topology	Interleaved CrCM Totem-Pole PFC with NV6117 GaNFast Power ICs Paralleled ZVS LLC with NV6117 GaNFast Power ICs
Frequency	PFC = 1 MHz (350 kHz – 1.5 MHz), LLC = 500 kHz
Size	1U x 2U x 210 mm (800 cc)
Density	4 W/cc (65 W/in ³)
Efficiency	>97%* (PFC = 99%, LLC = >98%*)

1 MHz, 3.2 kW – 100% GaN



650V GaNFast™ Power IC Portfolio

Family	Part	Package (mm)	R _{DS(ON)} (typ, mΩ)	Samples	Release to Production	Typical Applications	F _{SW} (max)
Single	NV6112	5x6 QFN	600	TBD	TBD	Boost PFC, Totem-Pole PFC, LLC, Inverter	2 MHz
	NV6113		300	May	June		
	NV6115		170	Now	Now		
	NV6117		120	Now	Now		
Symmetrical Half Bridge	NV6250	6x8 QFN	600 + 600	Q1'19	Q2'19	LLC, Inverter	2 MHz
	NV6255		300 + 300	Q1'19	Q2'19		
	NV6260		200 + 200	Q1'19	Q2'19		
Asymmetrical Half-Bridge	NV6247		1200 + 600	Oct'18 (Eng) Jan'19 (final)	Apr'19	Active Clamp Flyback	
	NV6252		600 + 300	Now	July (risk) Sep'18		
	NV6257		300 + 200	Aug'18	Q4'18		
	NV6262		200 + 120	July'18	Q4'18		

Power per Topology

Partnumber	$R_{DS(ON)}$ (typ., m Ω)	85-264V AC-input ACF	400V DC-input ACF	400V DC-input LLC
NV6247	1,200+600	20W-30W	100W	
NV6250	600+600	25W-35W		150W
NV6252	600+300	30W-45W	150W	
NV6255	300+300	35W-50W		220W
NV6257	300+200	45W-60W	180W	
NV6260	200+200	55W-65W		280W
NV6262	200+120	65W+	230W	

Partnumber	$R_{DS(ON)}$ (typ., m Ω)	85-264V CrCM PFC
NV6113	300	90W-100W
NV6115	200	125W-150W
NV6117	120	150W+
2x NV6117	60	250W

Conditions / assumptions:

Temperature:
Device $T_{j-max} \leq 90^{\circ}\text{C}$

Power loss (no heatsink, no airflow):
Single iDrive < 0.6W
Half-Bridge < 1W