



Let's go **GaNFast™**

GaN Power IC Adoption Takes Off in Fast Charging Market

APEC 2019 PowerAmerica IS19, March 21, 2019

"Advances in the Adoption of Wide Bandgap Semiconductors in Commercial and Industrial Applications"

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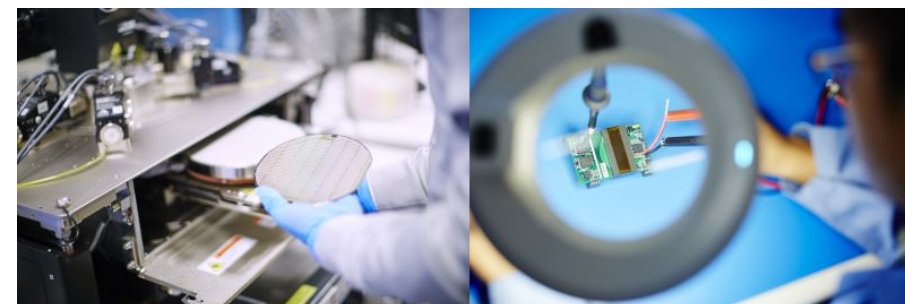


Navitas Semiconductor



GaNFast™

- World's first GaN power IC company
 - JEDEC qualified
 - Volume production with fast ramp
- Navitas: Latin for *Energy*
 - Bringing a new energy to power electronics
- Founded 2014 with HQ in El Segundo, CA
- Proven management team
 - 60+ employees
- Tier 1 manufacturing partners
 - TSMC wafer foundry, Amkor packaging
- Strong financial investors
 - Over \$1B capital under management



navitas
noun | en·er·gy

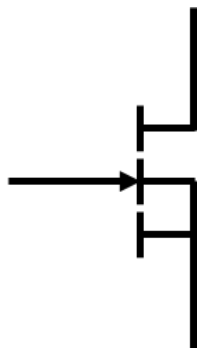




World's First GaNFast™ Power ICs



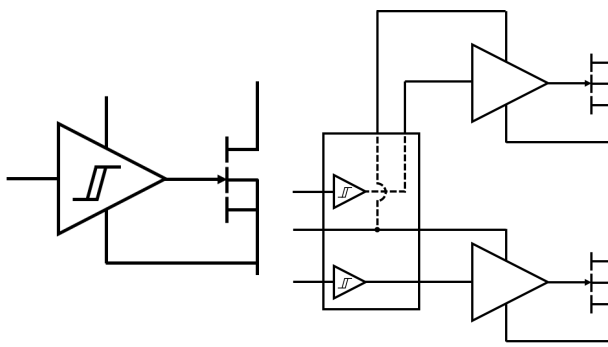
Fastest, most efficient
GaN Power FETs



- >20x faster than silicon
- >5x faster than cascoded GaN
- Proprietary design
- Gate is fragile and sensitive to noise



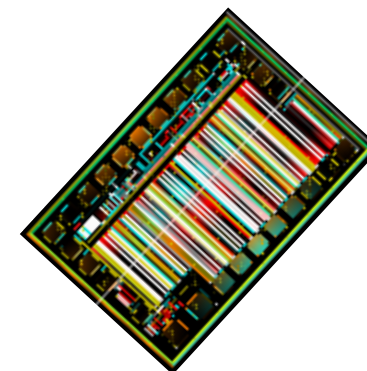
First & Fastest Integrated
GaN Gate Drivers



- >3x faster than any other gate driver
- Proprietary design
- 30+ patents granted
- Fast, protected gate, no need for negative drive



World's First
GaNFast™
Power ICs

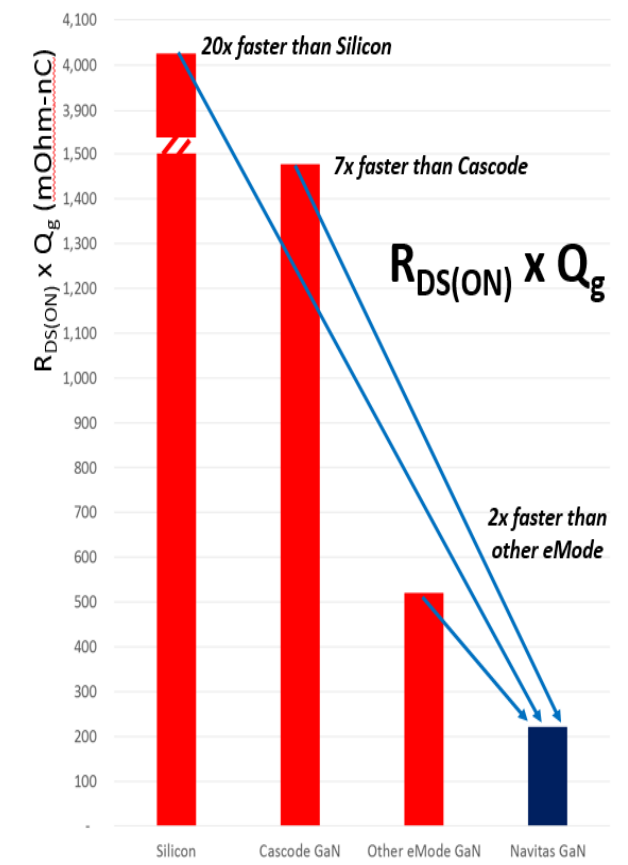
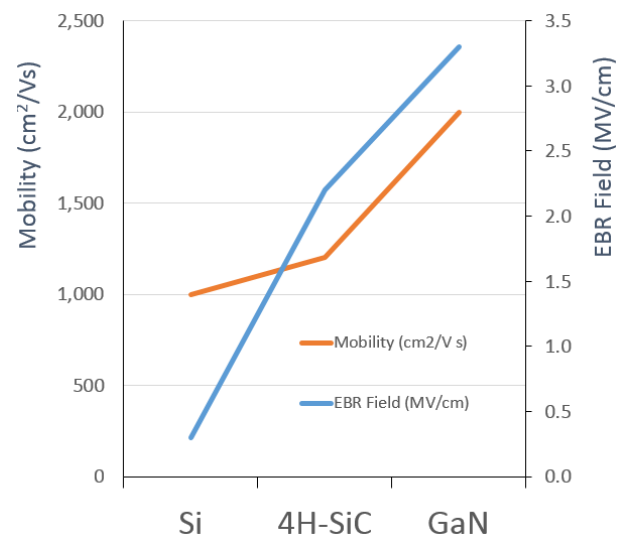
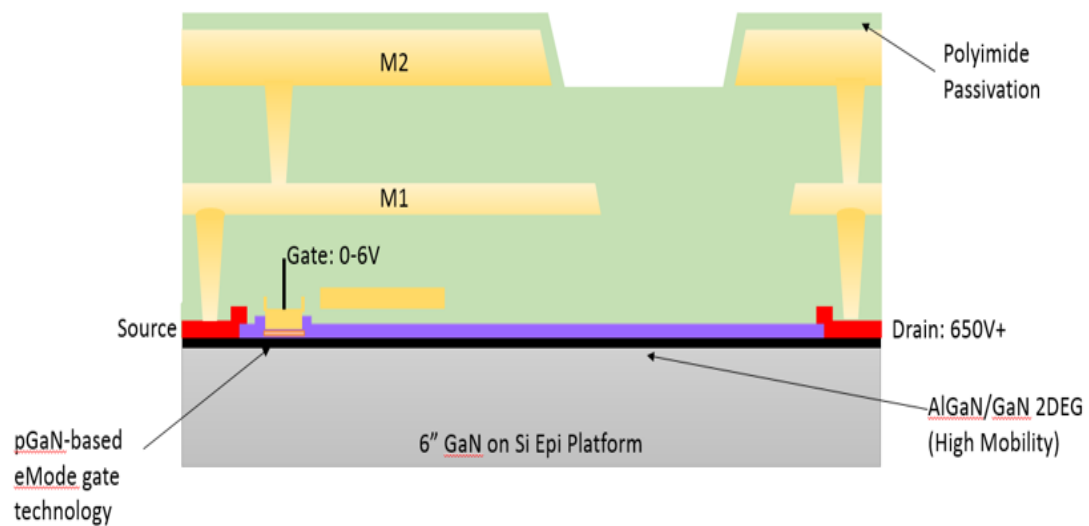


- Simple, fast and reliable
- Easy to use and package

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



Navitas eMode Power FET Technology



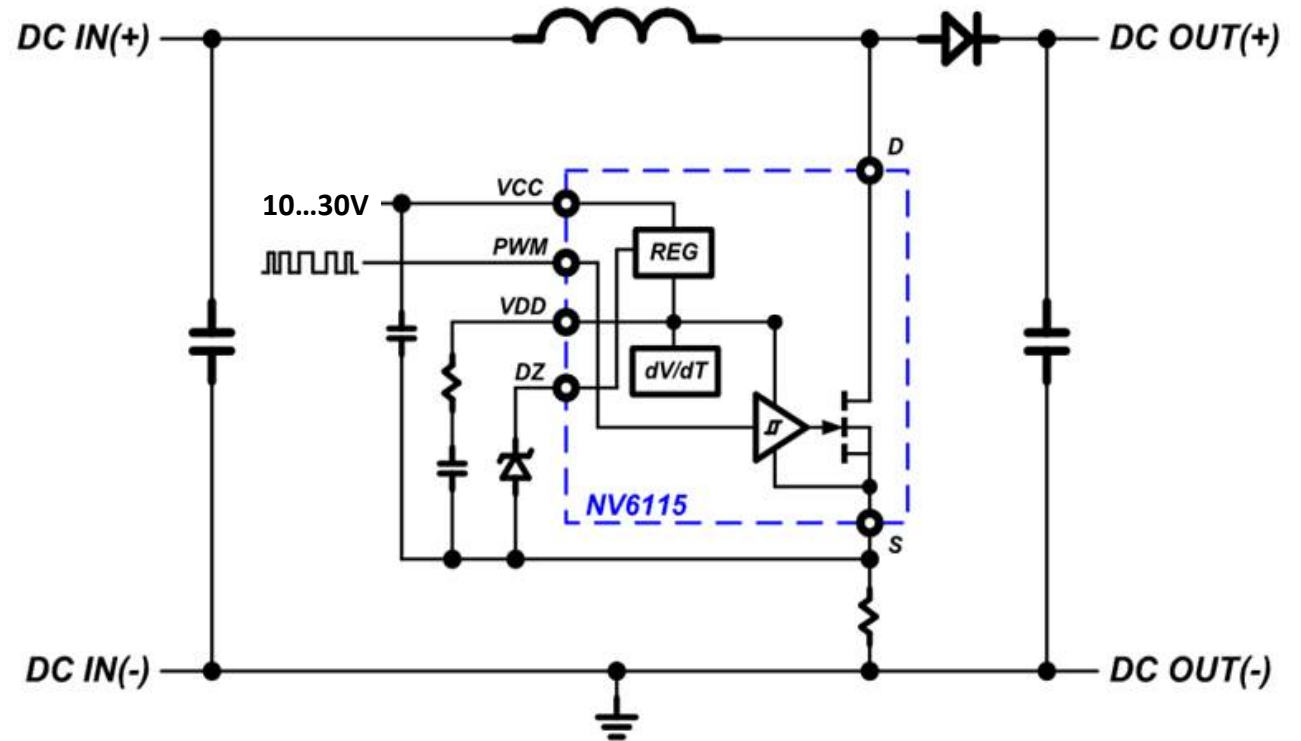
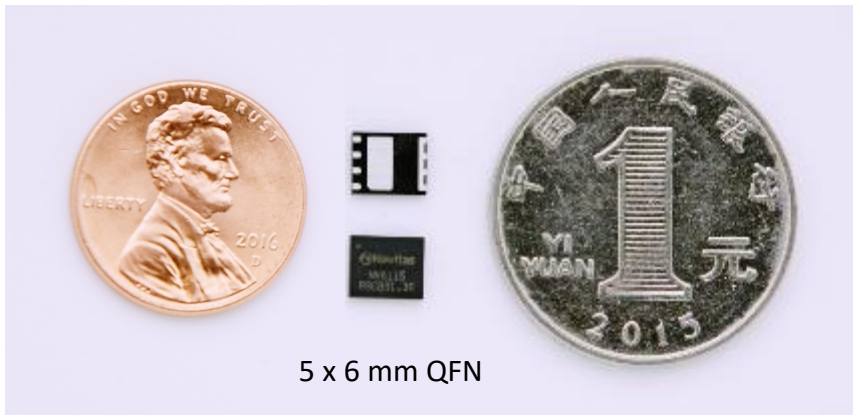
- Lateral device technology → Convenient isolation and easy voltage scaling
- High breakdown field (10X) and high mobility (2X) → Low $R_{DS(ON)}$, Low Q_{OSS}
- Lateral device technology → Low Q_G , easy to drive, easy to integrate
- Processed in established CMOS line → High yield, high capacity
- Multiple metal technology using standard CMOS processing equipment



Single Switch GaN Power IC

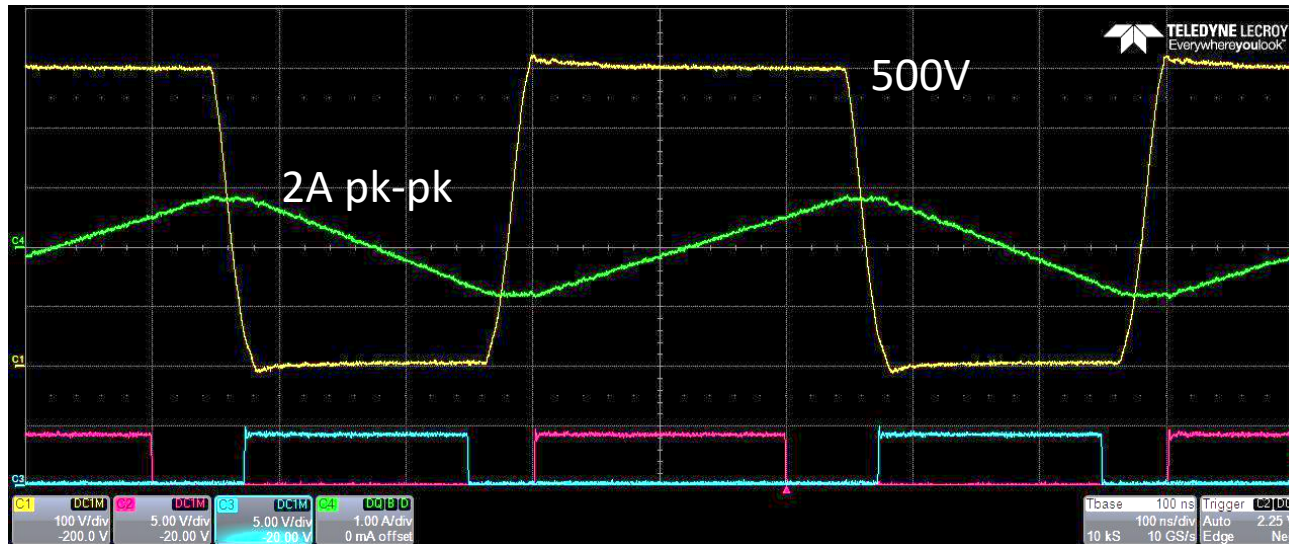
Monolithic integration at 650V

- GaN FET (range 120-300 m Ω)
- GaN gate driver (fast, no overshoot)
- Wide input voltage range (10-30V)
- GaN regulator (well controlled gate voltage)
- dV/dt control (programmable 10-100V/nsec)
- Hysteretic input, ESD, fault protection
- Fast and controlled start-up



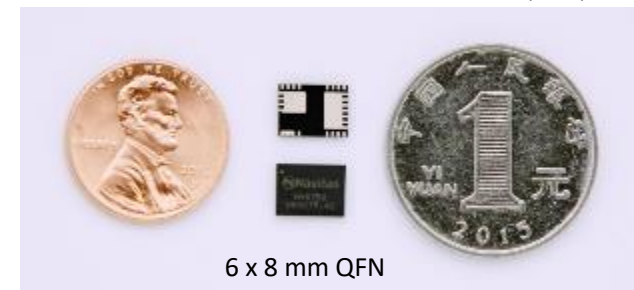
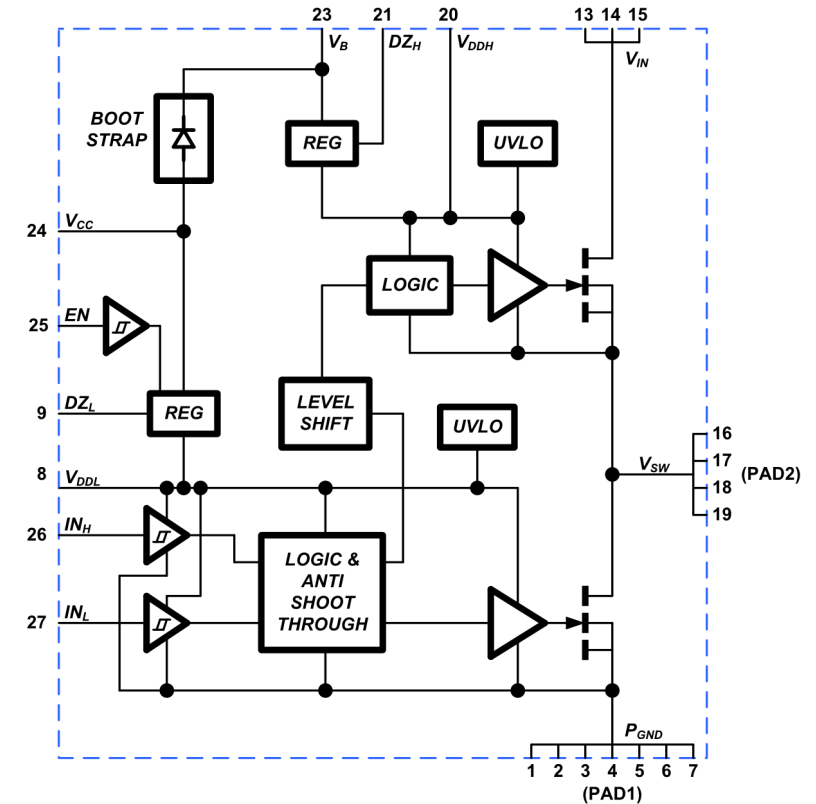


2 MHz Soft-Switching Operation



Monolithic integration at 650V

- 2x 650V eMode GaN FETs (*a/symmetrical range 120-600 mΩ*)
- 2x 6V GaN gate drivers
- 2x 30V to 6V GaN regulators and UVLO circuits
- 650V GaN level-shifters and bootstrap drivers
- GaN Logic (shoot-through protection, fault mgmt, ESD, etc...)

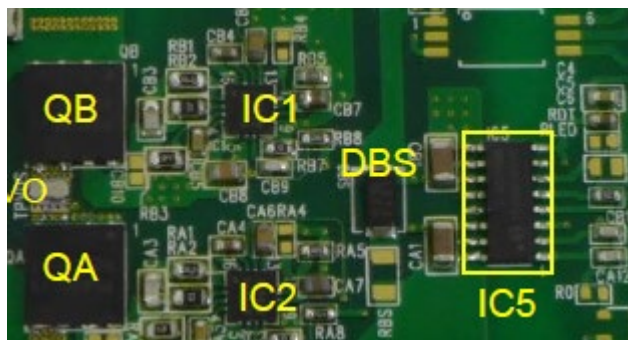
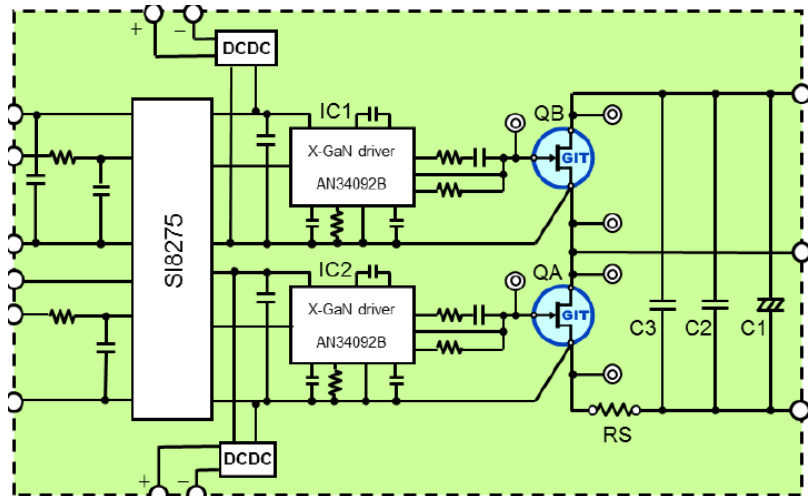


6 x 8 mm QFN



Complex Design → Made Simple

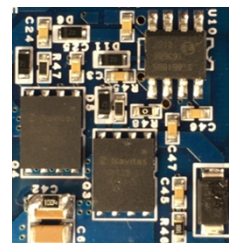
Half-Bridge *Discrete* GaN



PCB Area: 24 x 42 ~ 1,000 mm²

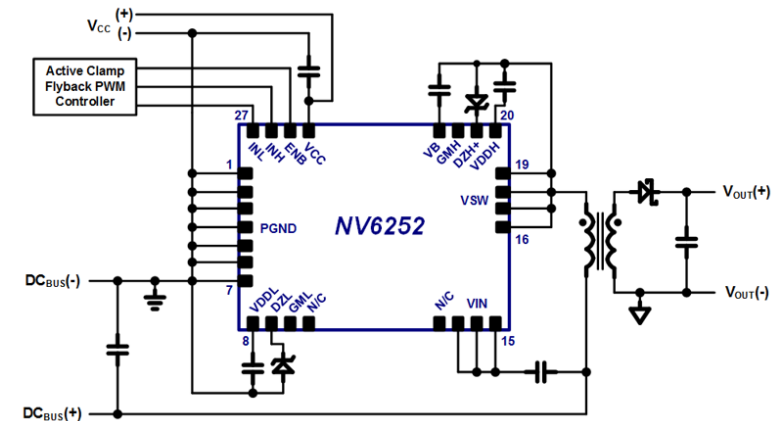
- 20x smaller PCB area
- 40+ fewer components
- Lower cost
- Robust & protected
- Simple
- Easy layout

Half-Bridge NV6115 GaN Power ICs + isolator and bootstrap diode



PCB Area: 18 x 20 = 360 mm²

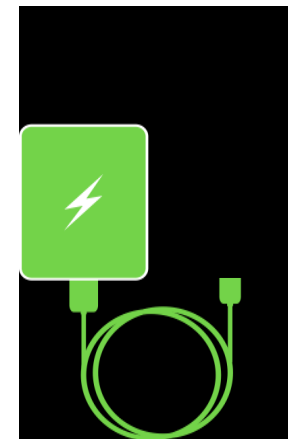
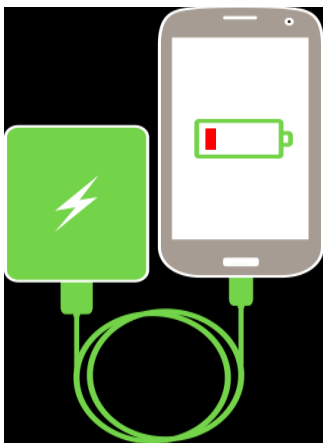
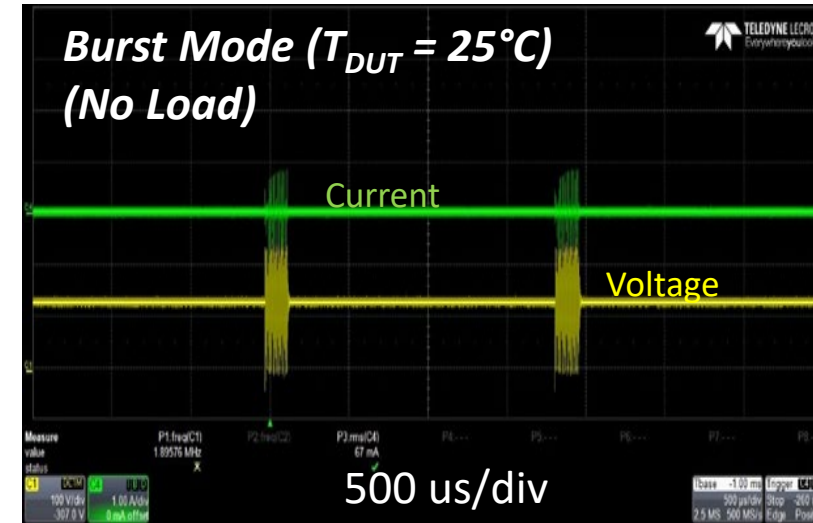
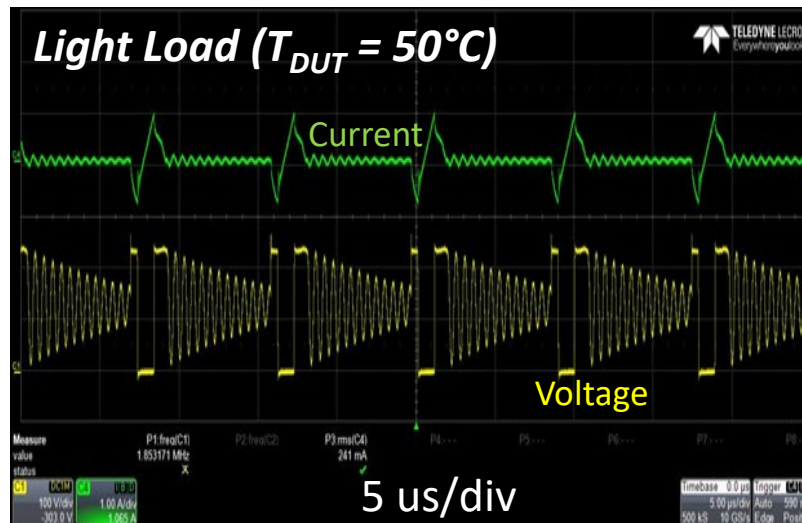
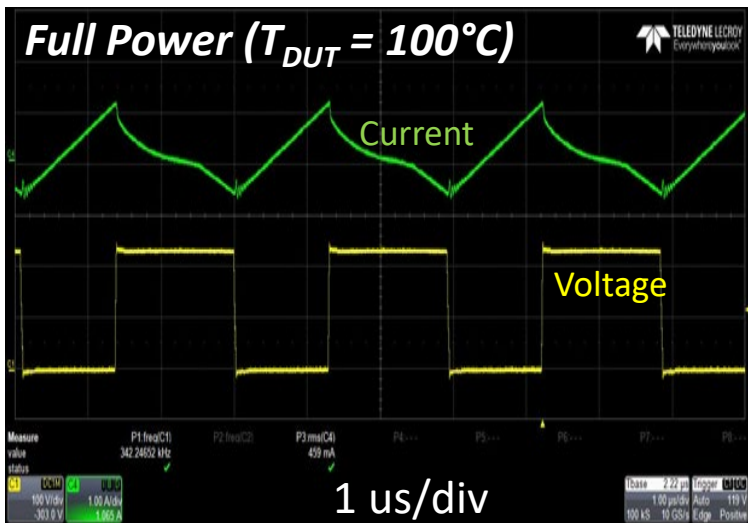
Half-Bridge NV6252 GaN Power IC



PCB Area: 6 x 8 = 48 mm²

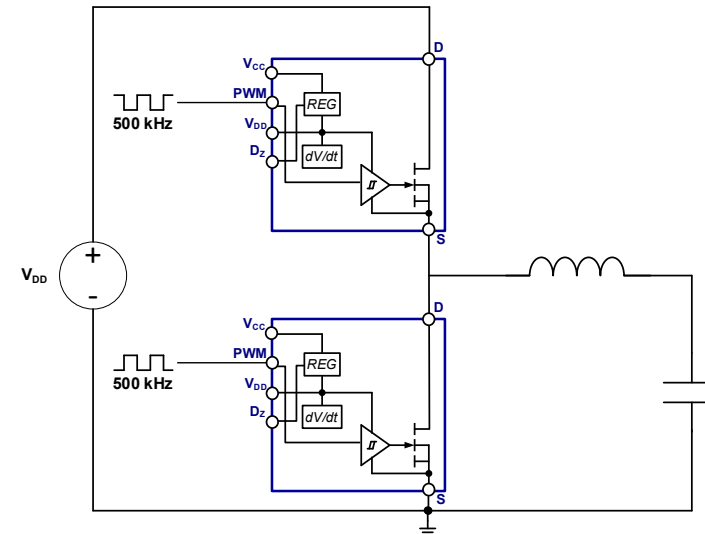
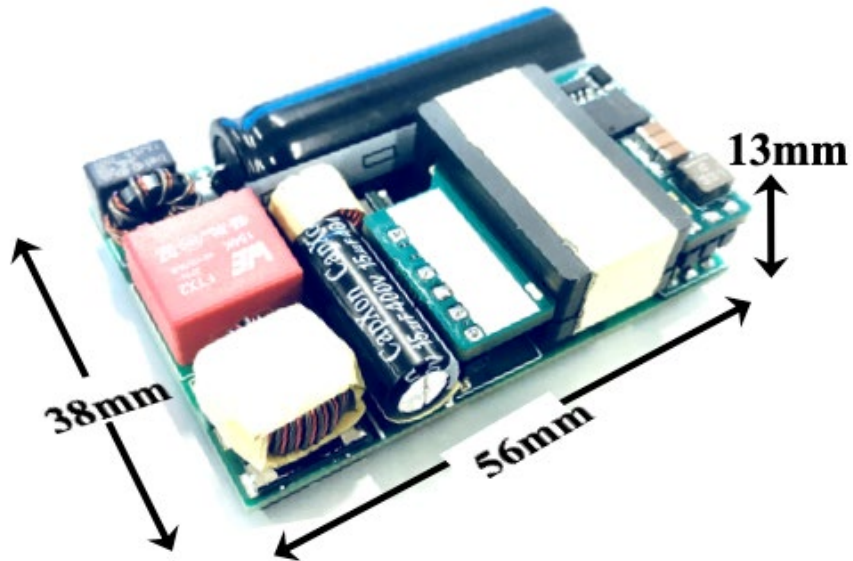
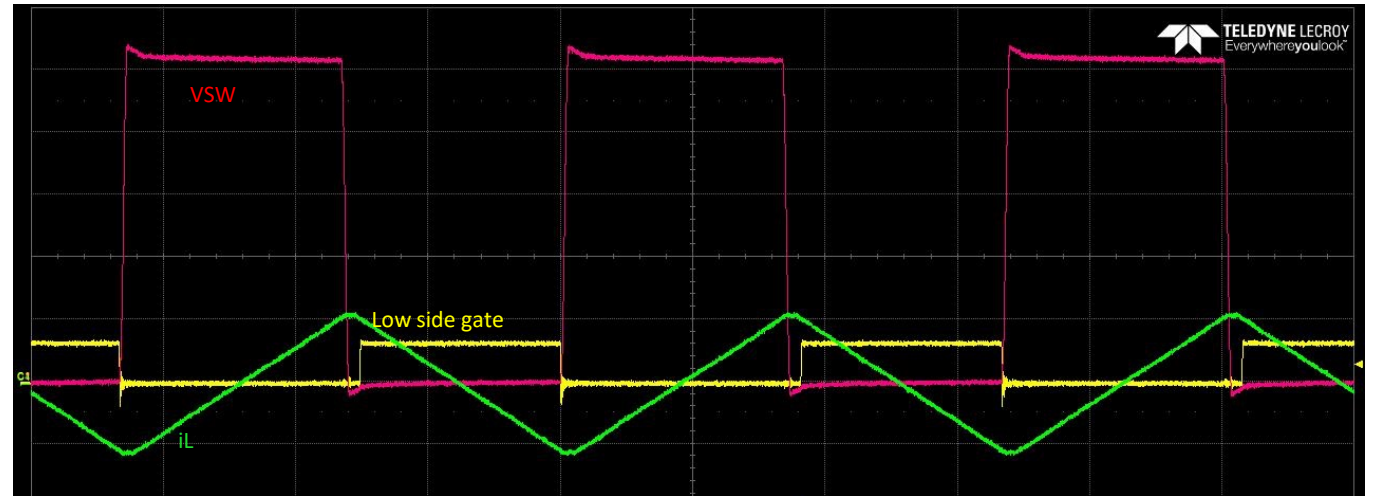
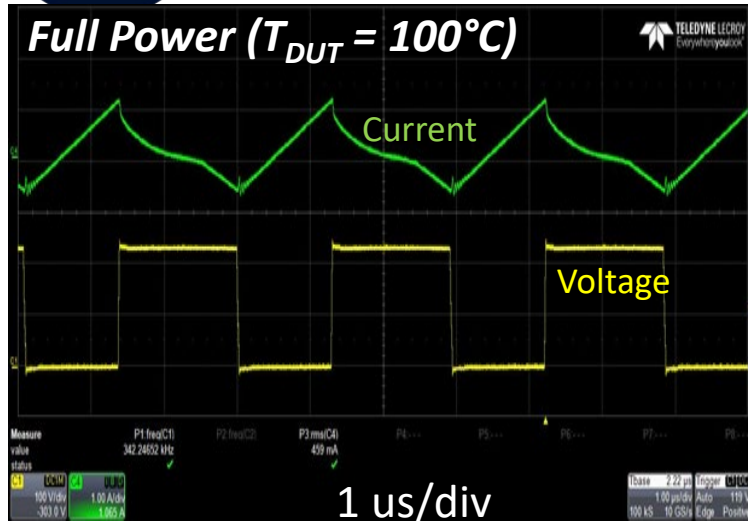


Application Profile for ACF Charger





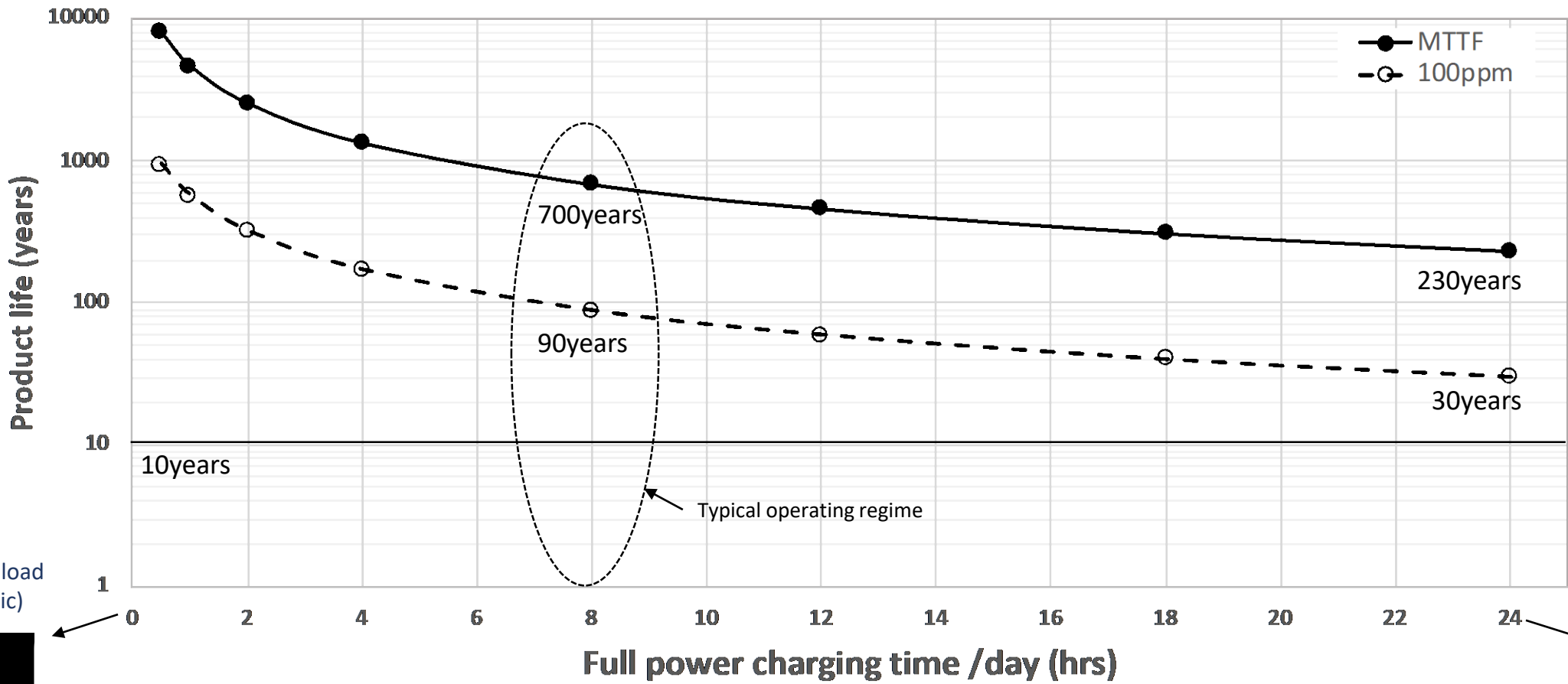
Mission Profile Driven HTOL (ZVS)



ZVS test bench replicates stresses seen in ACF application

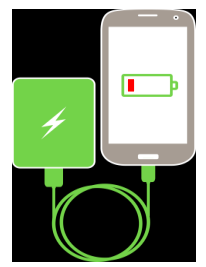
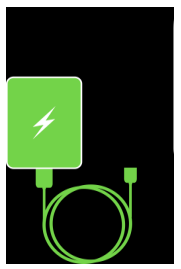


Lifetime Estimation in Charger Application



100% No load (unrealistic)

100% full power (unrealistic)



Significant built-in reliability margin → even at worst case conditions (exceeds 10+ year lifetime requirement)



Reliability → Qualification → Release



Reliability models on IC building blocks = Robust design

Mission profile driven reliability = Protected Customer

Comprehensive reliability monitoring

Reference	Test Conditions	Duration	Lots	S.S.	
JESD22-A113 J-STD-020	Preconditioning (MSL1): Moisture Preconditioning + 3x reflow: HAST, UHAST, TC & PC	N/A	3	308	PASS (0/308)
JESD22-A104	Temperature Cycle: -55°C / 150°C	1,000cy	3	77	PASS (0/231)
JESD22-A122	Power Cycle: Delta Tj = 100°C	10,000cy	3	77	PASS (0/231)
JESD22-A110	Highly Accelerated Stress Test: 130°C / 85%RH / 100V V _{DS}	96hrs	3	77	PASS (0/231)
JESD22-A108	High Temperature Reverse Bias: 150°C / 520V V _{DS}	1,000hrs	3	77	PASS (0/231)
JESD22-A108	High Temperature Gate Bias: 150°C / 6V V _{GS}	1,000hrs	3	77	PASS (0/231)
JESD22-A108	High Temperature Operating Life	1,000hrs	3	77	PASS (0/231)
JESD22-A108	Early Life Failure Rate	24 hrs	3	1,000	PASS (0/3,000)
JS-001-2014	Human Body Model ESD	N/A	1	3	PASS 0/3
JS-002-2014	Charged Device Model ESD	N/A	1	3	PASS 0/3

Metric	Results
Equivalent device hours tested*	1.5 billion hours
FIT*	0.6

*Statistics calculated from HTOL tests

GaNFast™
POWER ICs

Quality

Speed

Efficiency

Now in high volume production!



PowerAmerica Project Objectives



Project Title:

65W High-Efficiency High-Density Adapter with Improved Manufacturability

Objectives:

Create a commercially compelling platform that sets an industry standard in energy efficiency, power density & is manufacturing proven & volume ready (TRL≥8) for US OEMs.

Major Milestones:

Aug 2017 – 1st proto

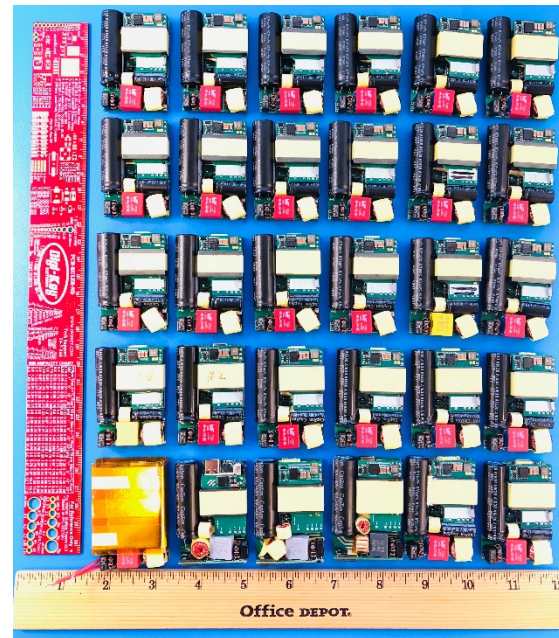
Nov 2017 – eval & optimization

Feb – final design

May – manufacturing validation

Deliverables:

30 adapter ref designs



1. Advances over silicon or conventional approaches: *Advancement & commercialization of Navitas GaN power ICs*

2. Markets impacts: *mobile chargers, travel adapters (consumer electronics)*

3. Timeframe for commercialization: *Q3 2018*

4. Quantitative benefits over state-of-the-art: *50% higher density, 30% improved energy efficiencies, improved manufacturability at a lower cost per watt*

5. Impact on the cost of WBG compared to Silicon: *A high-volume platform that demonstrates WBG superiority over silicon in performance and cost*

6. Potential for Job Creation Economic impact: *Significant job creation for US manufacturing partner(s) & US OEMs*

7.. Workforce Development and Education: *All R&D and manufacturing is 100% based in the US with significant workforce development and education with Navitas, suppliers, partners and customers*



Key Elements For New Adaptors

High Power Density Adaptors Needs

- GaN Power Device
- Higher Integration
- Advanced Magnetics
- High Frequency Controllers
- Soft Switching Topologies



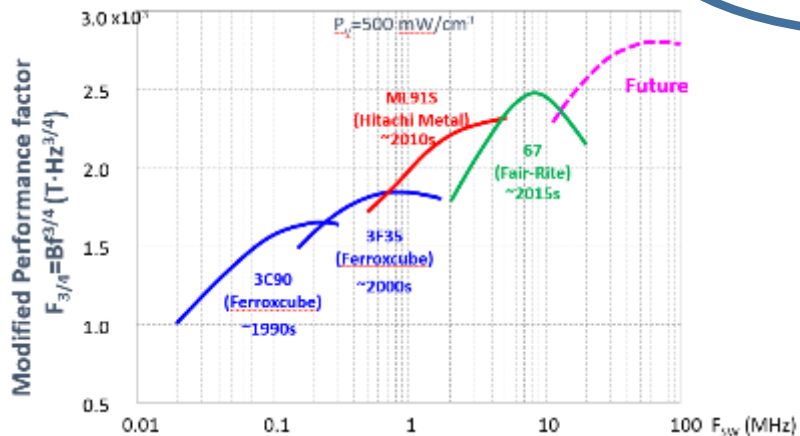
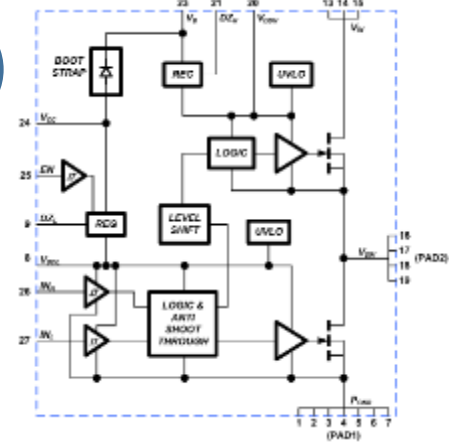
Higher Integration

GaN Power Device

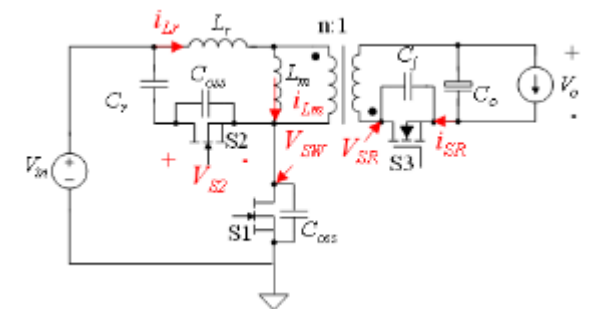
New Magnetics

New Control IC

New Topology

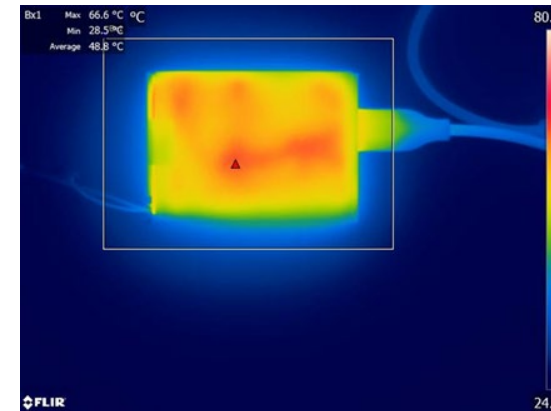
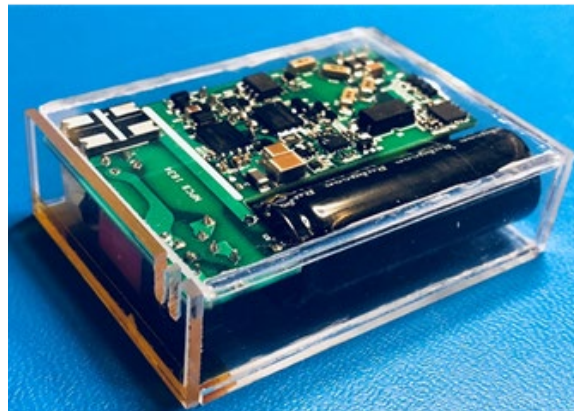
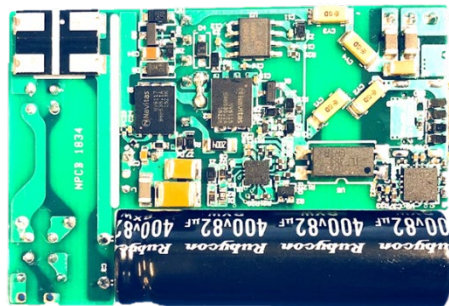
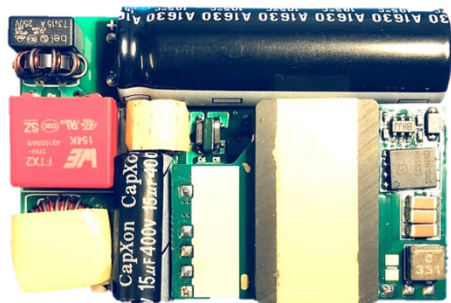
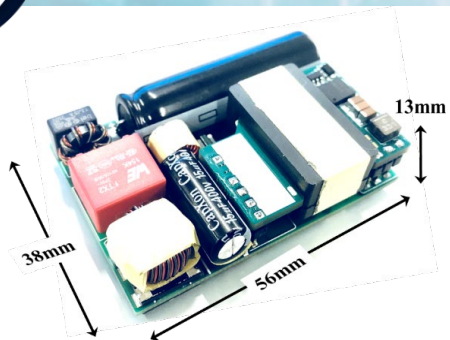


>500Khz controllers are ready!





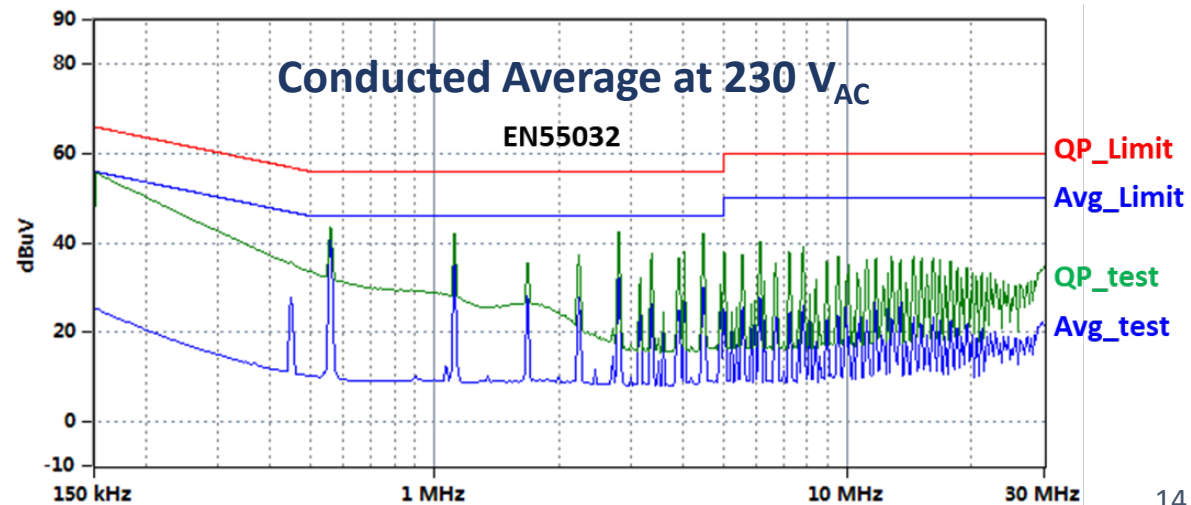
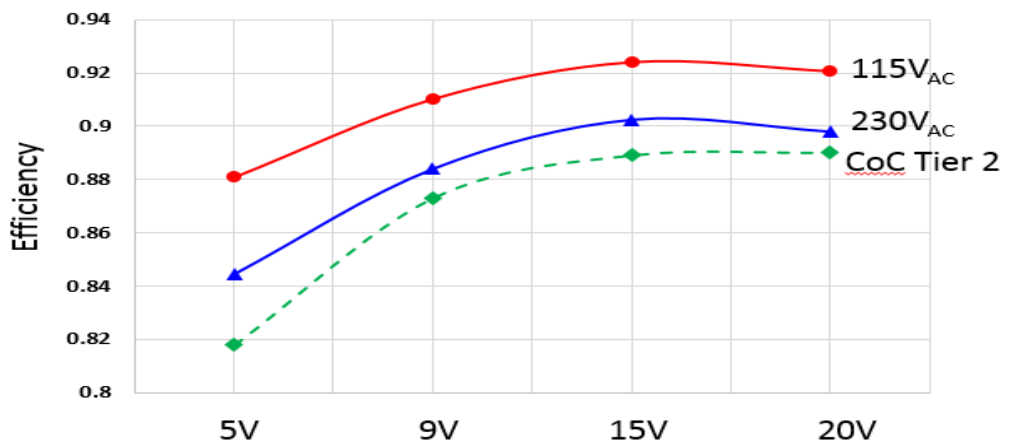
World's Smallest 65W USB-PD



Power, Output	65 W USB-PD
Topology	ACF with NV6115, NV6117 GaNFast Power ICs
Frequency	600 kHz
Size	27 cc (45 cc with case)
Density	2.4 W/cc (39 W/in ³) uncased 1.5 W/cc (24 W/in ³) cased
Efficiency	93.3% peak (115 V _{AC}) 93.2% at 90 V _{AC} full load DoE Level VI, Euro CoC (EuP) Tier 2

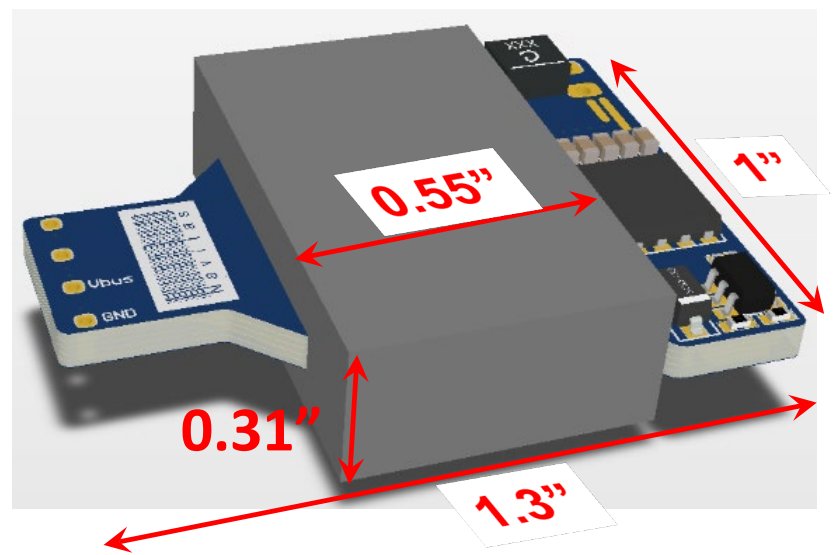
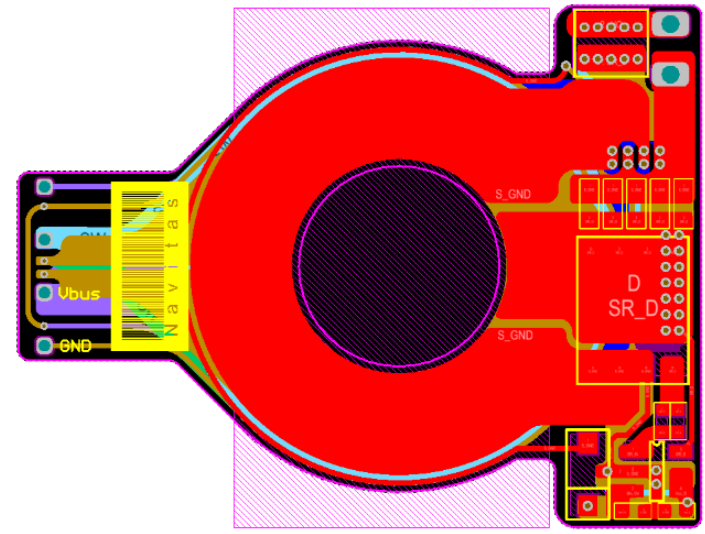
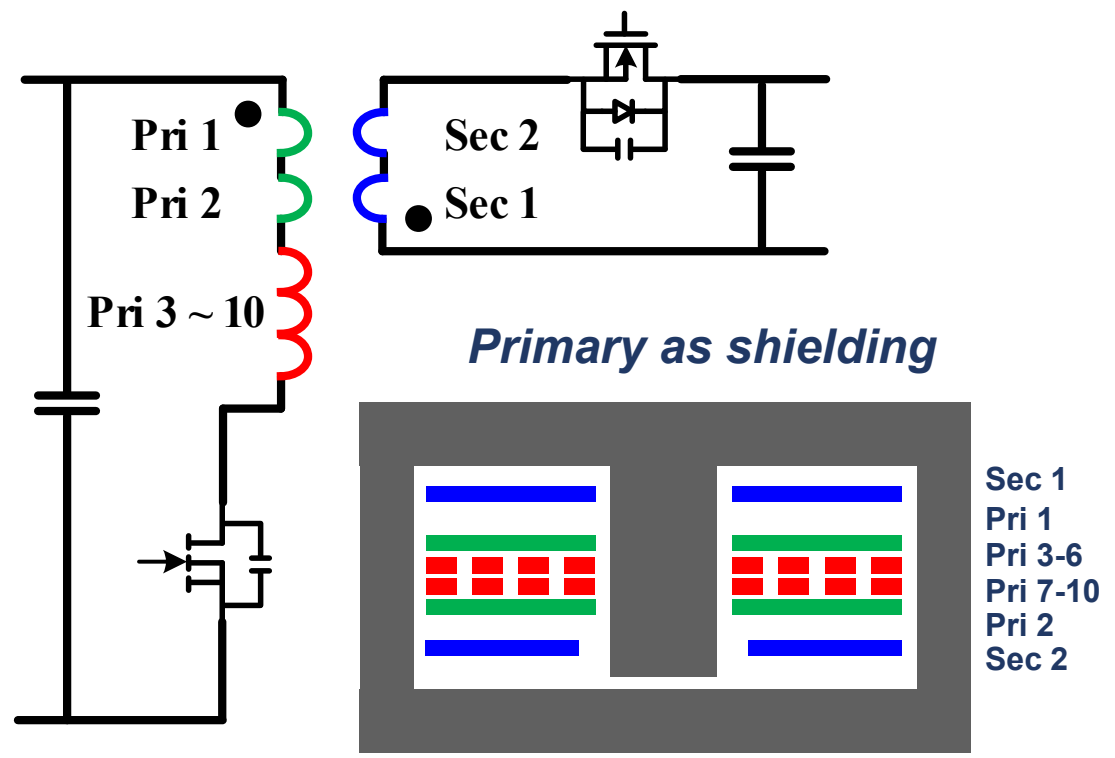
115 V_{AC}, 20 V / 3.25 A, 25°C ambient, no case, no airflow, no heatsink
20mins steady state operation. Maximum case <70°C

4-Point Average Efficiency





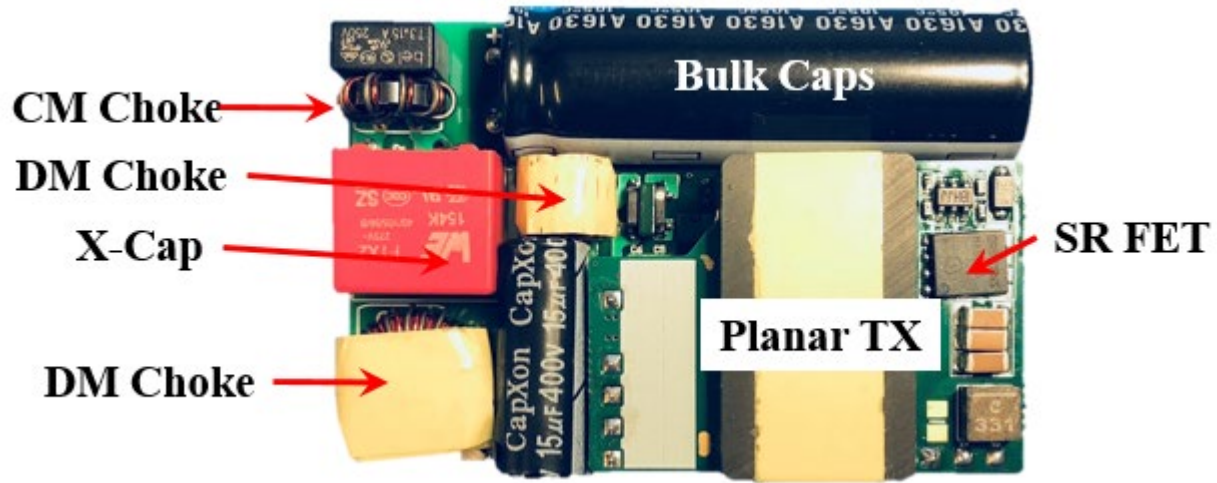
High Frequency Magnetics → Made Manufacturable



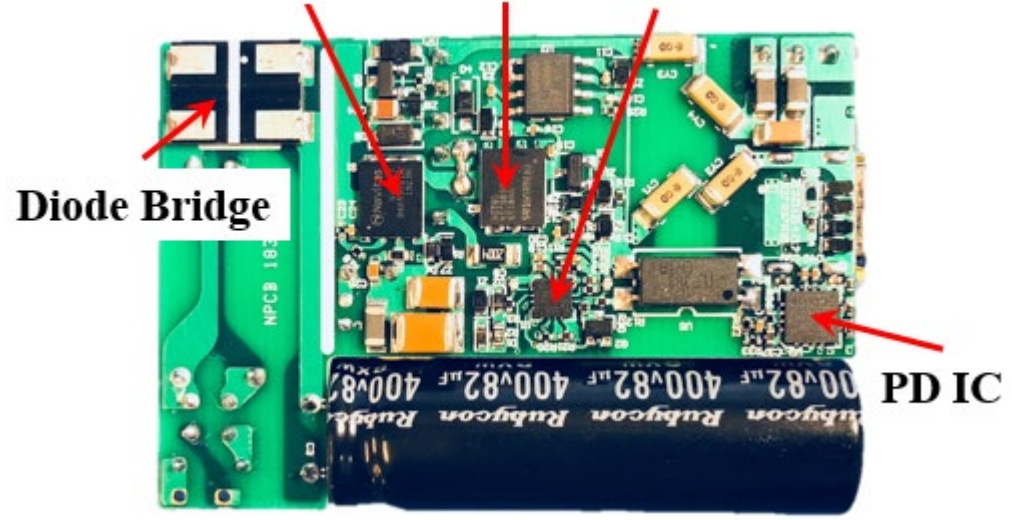
- SR on secondary winding, minimized L_k & R_{ac}
- Shielding integrated as primary winding
- Safety rule compliance



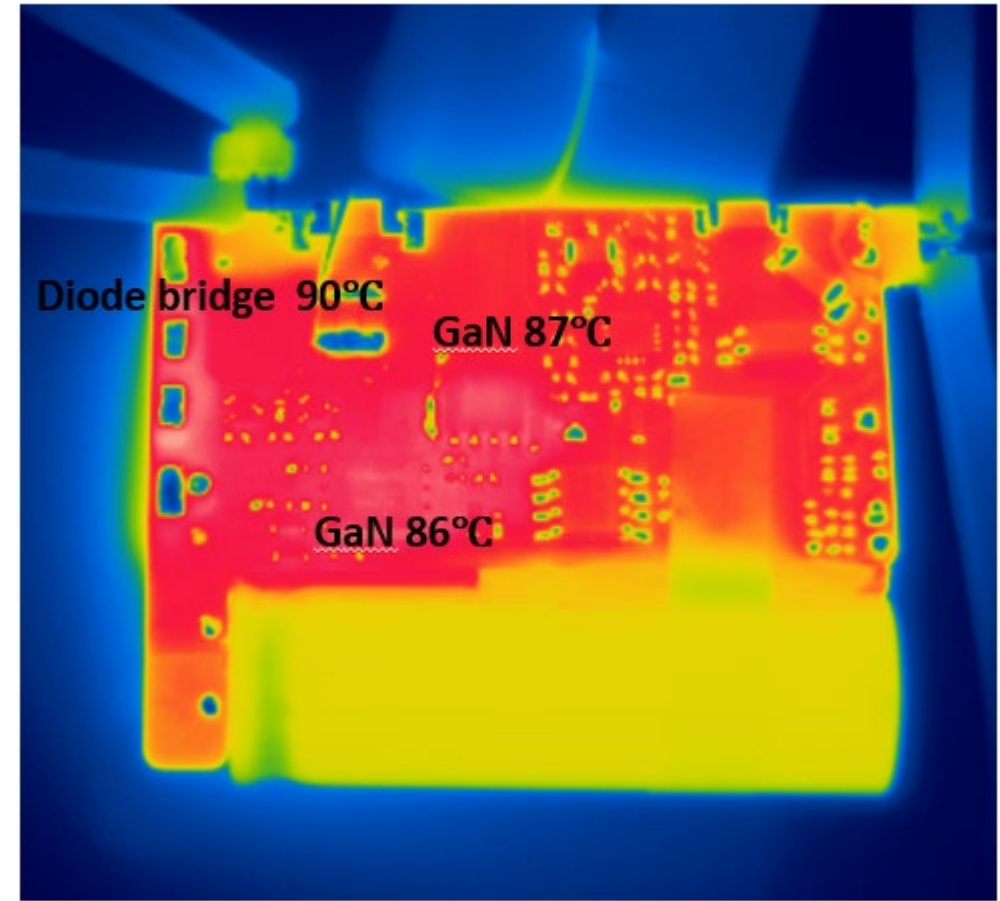
Design Details & Thermal Performance



NV6117 NV6115 ACF IC



65W/90Vac



Component max temperature is 90°C



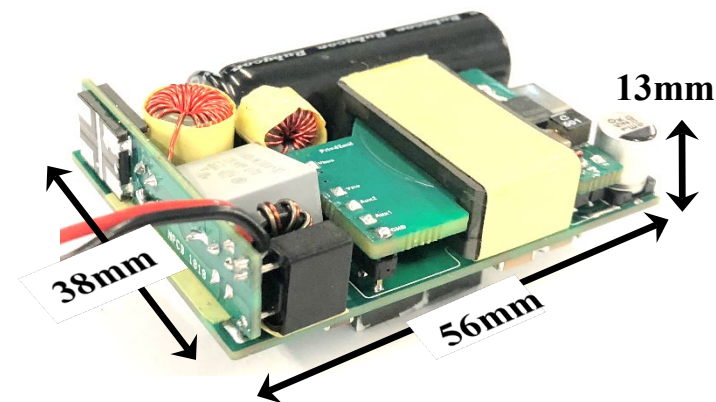
Accomplishments & Outcomes

• Accomplishments

- Completed 65W design
 - Verified efficiency, density, thermal, EMI, etc.
- Technology platform adopted and released to production
 - World's thinnest universal 45W adapter ([Mu One](#))

• US Manufacturing Impact

- Reduced labor content, costs
 - Fully automated transformer, reduced component count
- Reduced manufacturing costs
 - Improved manufacturing quality & consistency (yield)
 - Automated transformer assembly
 - Reduced re-work
- Significant US OEM interest to drive global adoption



PowerAmerica Project:
65W USB-PD 3.0, 27 cc, 2.4 W/cc (39 W/in³)



Commercial realization: Mu One
45W USB-PD 3.0, only 14 mm thin cased



Existing: "The Mu"

1.2 AMP 2x1.2 AMP / 2x6 WATT DUAL USB PORT

PATENTED FOLD-FLAT DESIGN **14MM**

COMPATIBLE WITH ALL TABLETS & SMARTPHONES
*SLOW CHARGE FOR TABLETS

AUTHENTIC DETECT FOR SAFE & EFFICIENT IOS CHARGING **AD**



- 14 mm profile
- CE, UL, etc.

- 90-264 V_{AC} input
- 2 x 6 W = 12 W (Type A)

Images courtesy Made-in-Mind



Challenge: Fast Charging “Mu One”



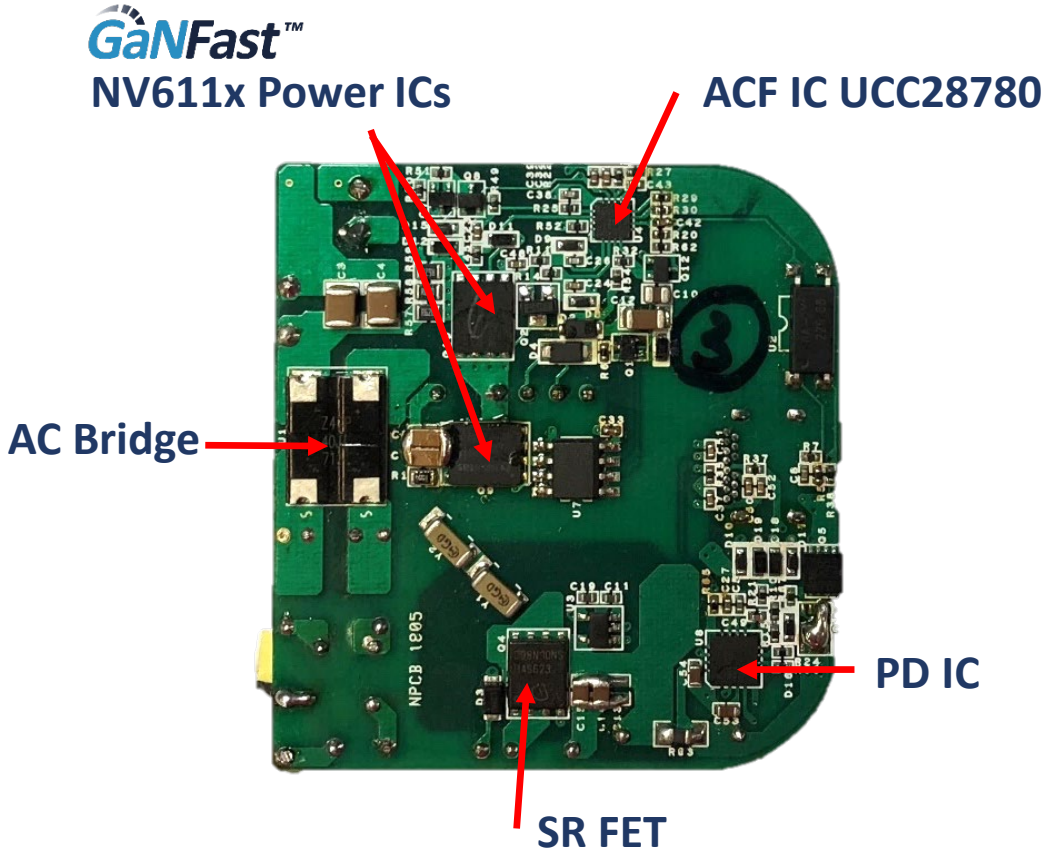
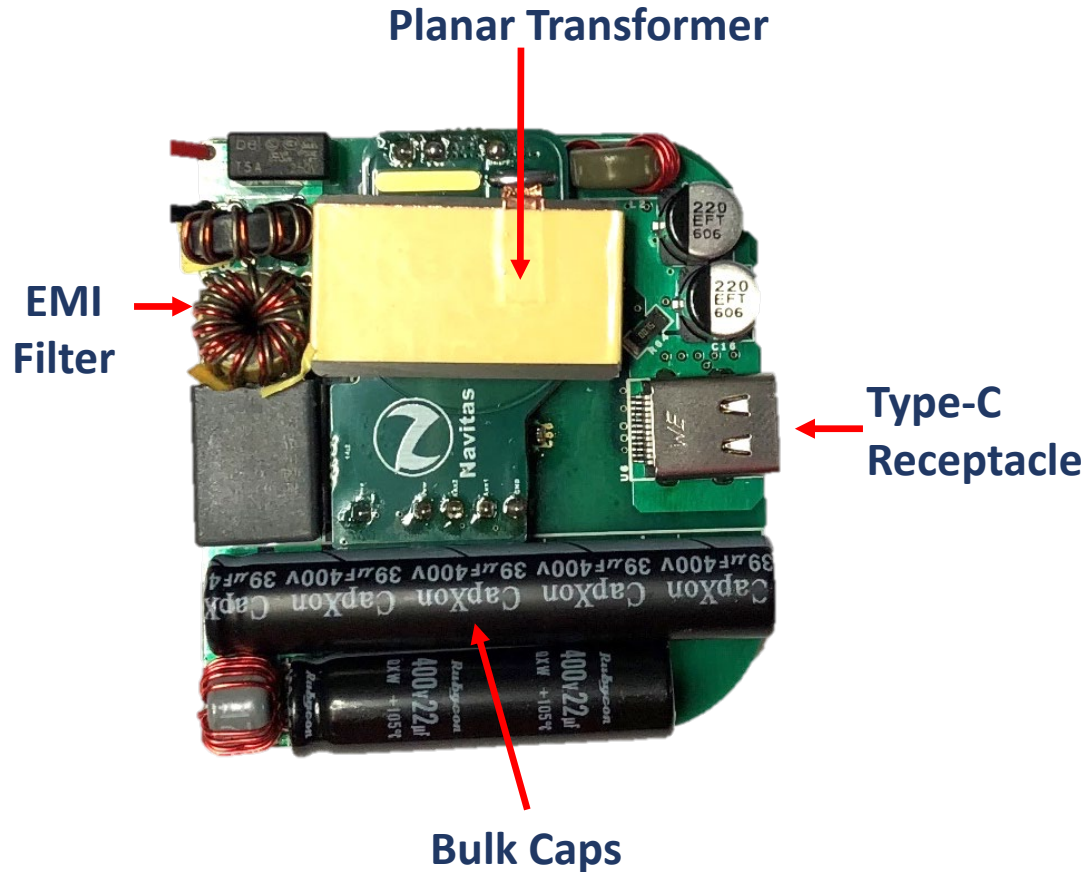
- 14 mm profile
- CE, UL, etc.

- 90-264 V_{AC} input
- ~~2 x 6 W = 12 W (Type A)~~
45 W (USB-PD Type C)

Images courtesy Made-in-Mind



45 W in 11 mm = HF Planar ACF





Cool Operation

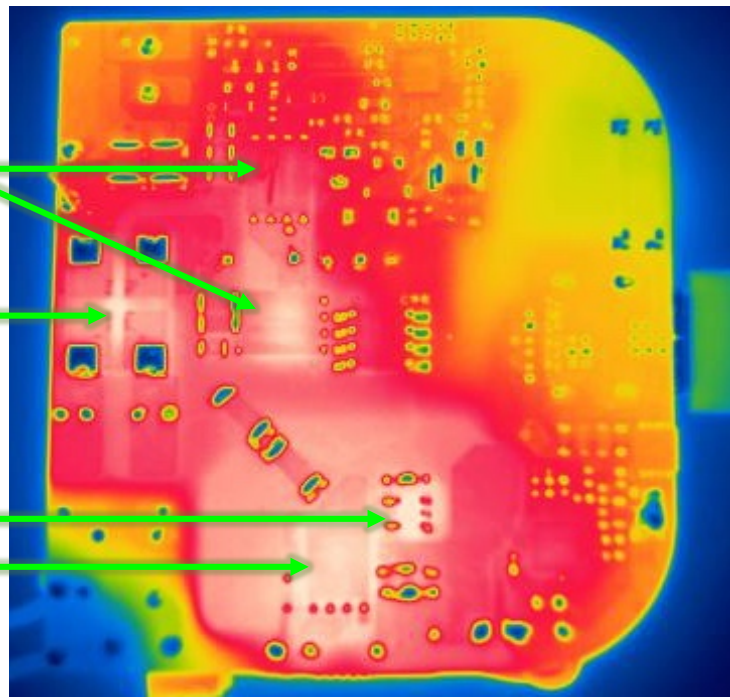
Top

Bottom

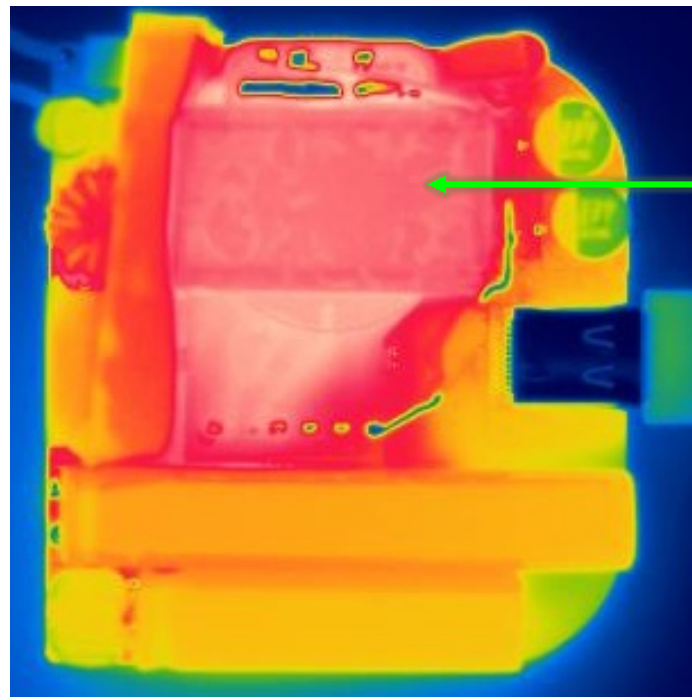
GaNFast
Power IC 75°C, 80°C

AC Bridge 80°C

SR IC 85°C
SR FET 85°C



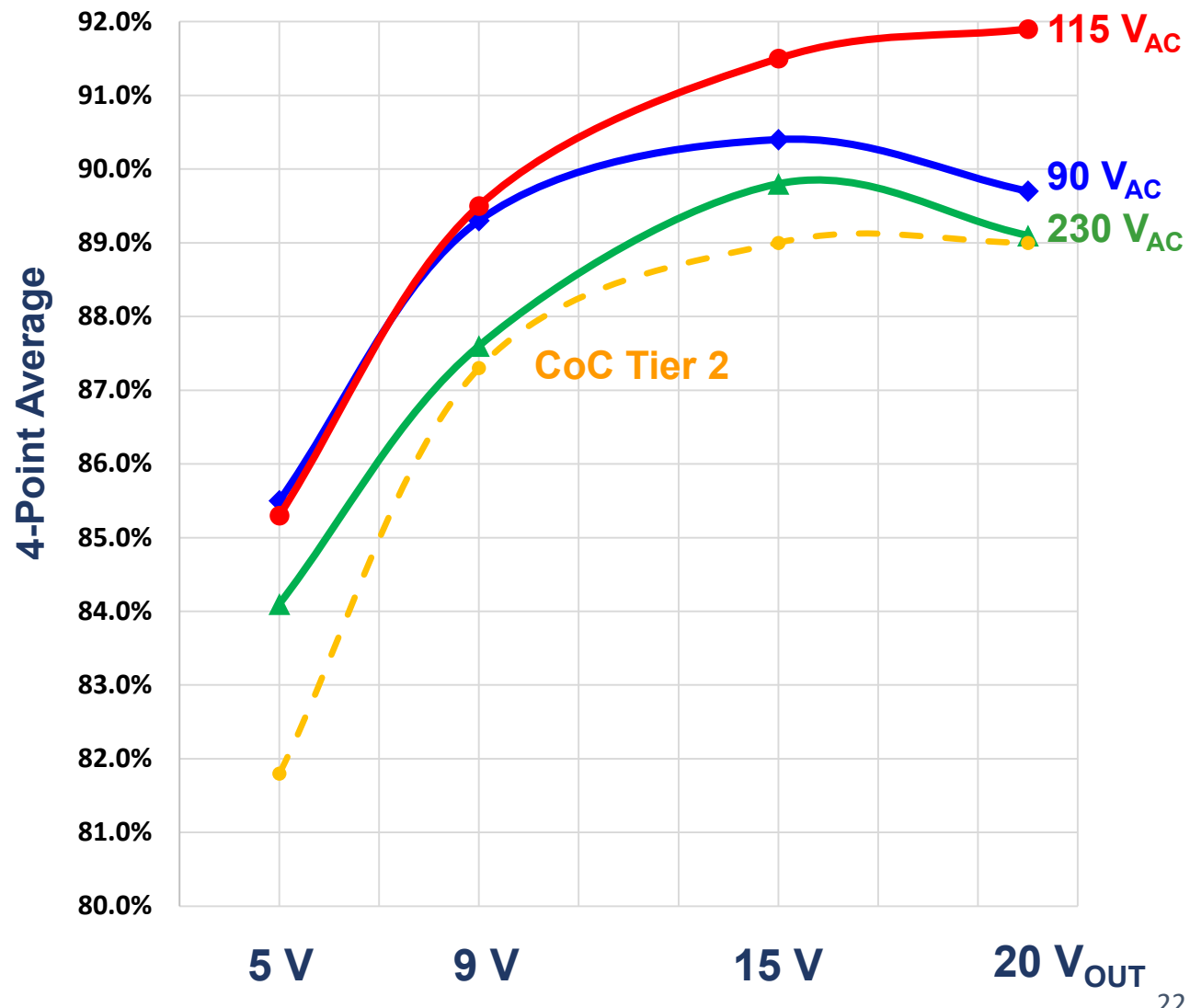
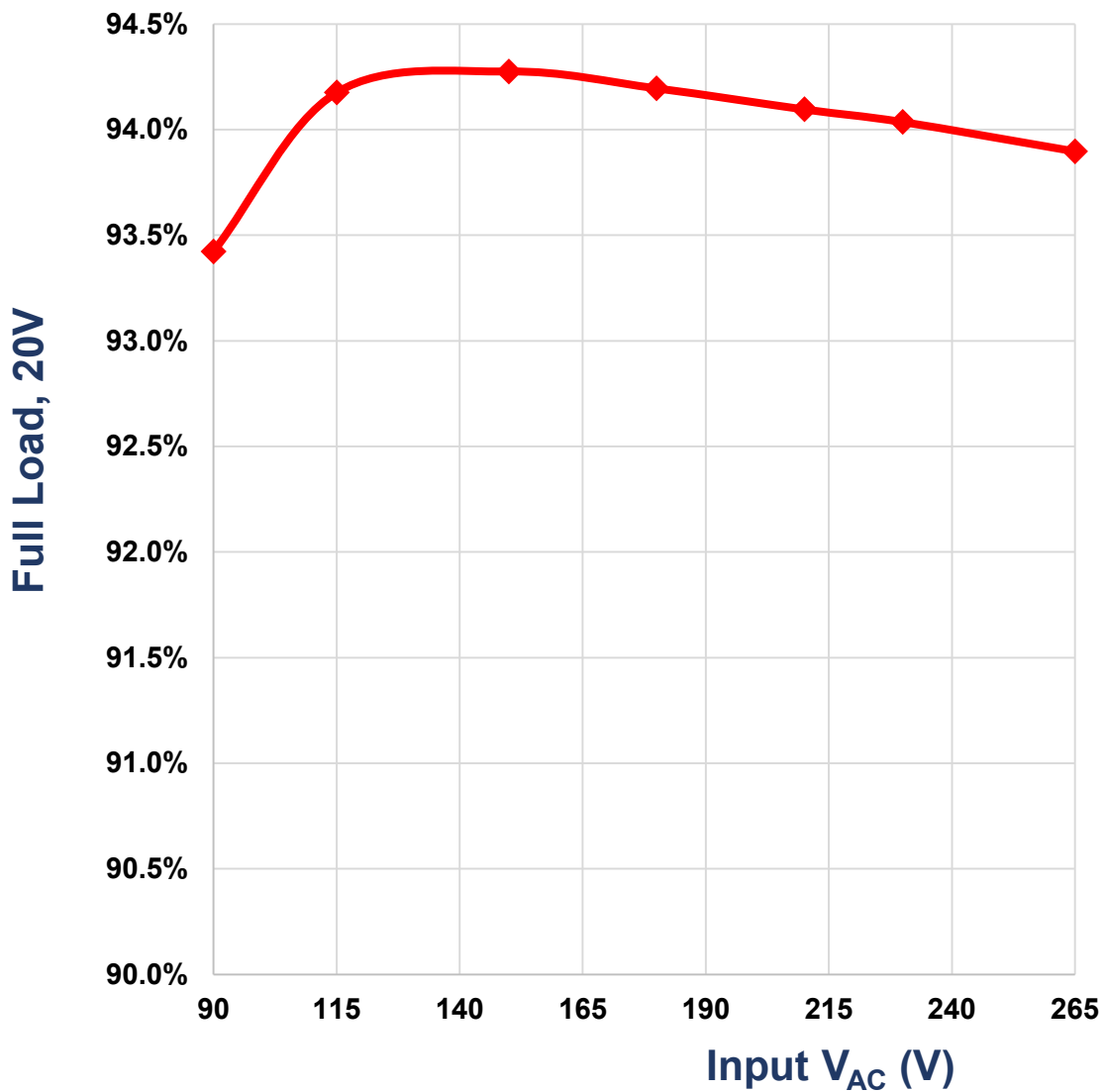
Transformer 80°C



90 V_{AC}, 45 W, 25 °C, uncased, no airflow,
no thermal compound / heatsinking

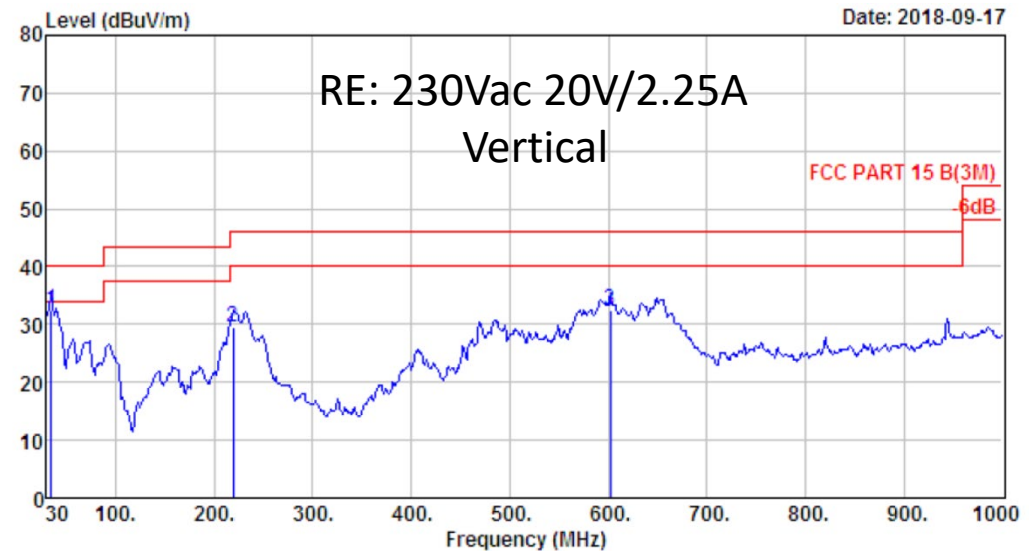
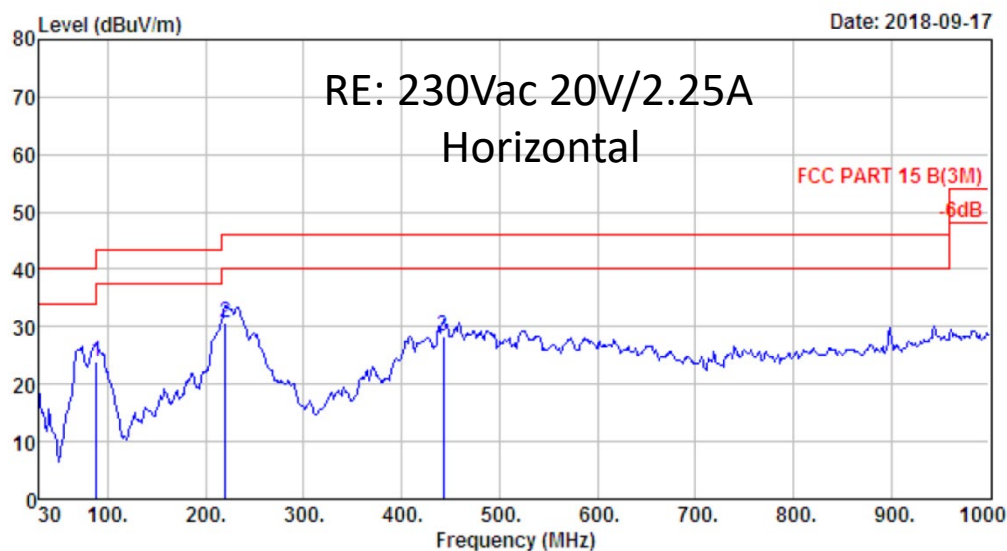
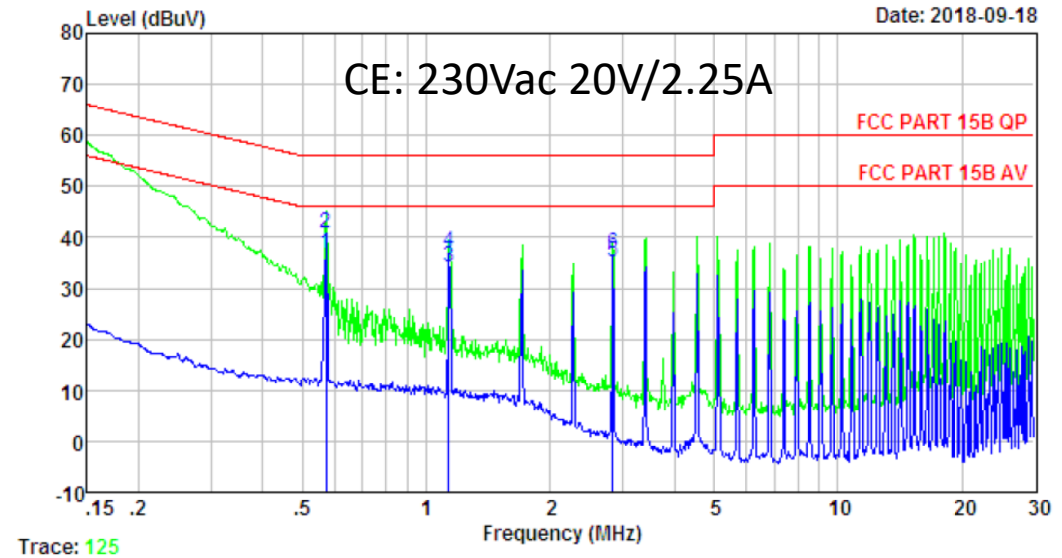
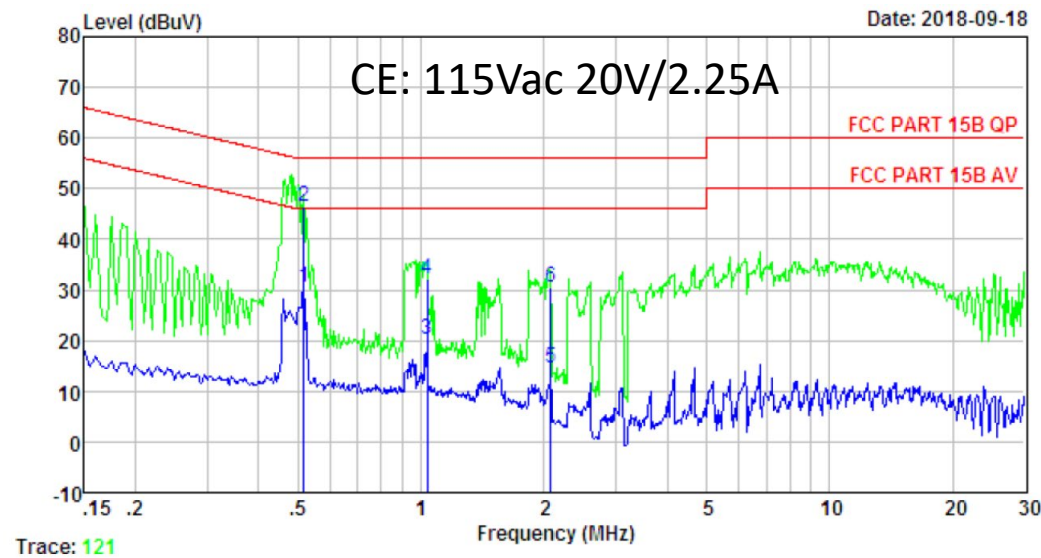


High Efficiency Across Line, Load, Output Voltage



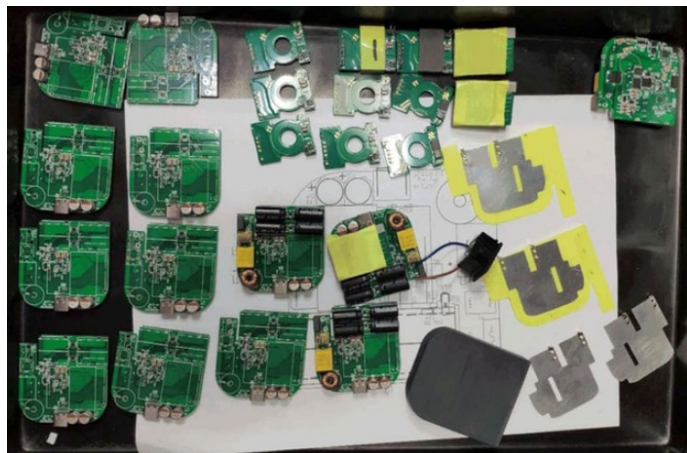


Quiet EMI (Conducted, Radiated)





Mu One: From Prototype to Mass Production



- Thanks to Matt Judkins, CEO of Made-in-Mind (Mu One)
- Available via www.kickstarter.com and www.amazon.com and airport stores

Images courtesy Made-in-Mind



RAVPower 45W: Same Platform

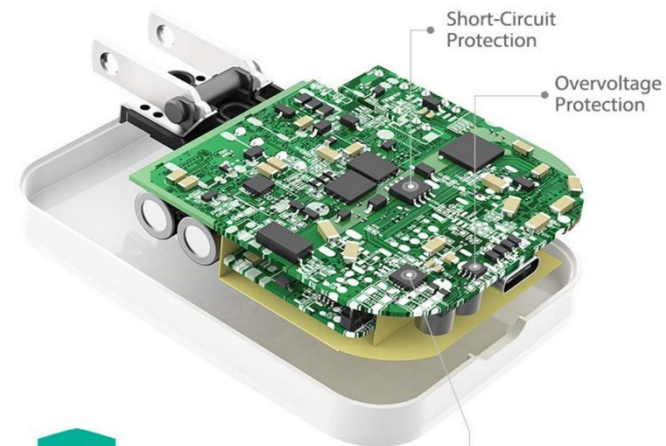
45W Power Delivery
2.5X Faster



Macbook 12"
2.0 hrs

iPhone XS Max
1.8 hrs

NOTE: Cable not included



UL Certificate

Available now on www.amazon.com

RAVPOWER



RAVPOWER

New Logo, New Image.
A Leap In Power Like Never Before.

Images courtesy RAVPower



AUKEY USB-C GaNFast Chargers



27W USB-C



12W x 2 USB-A



27W USB-C

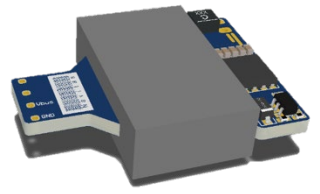
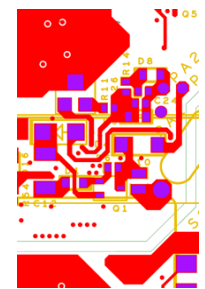
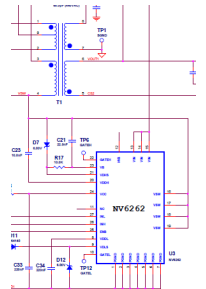
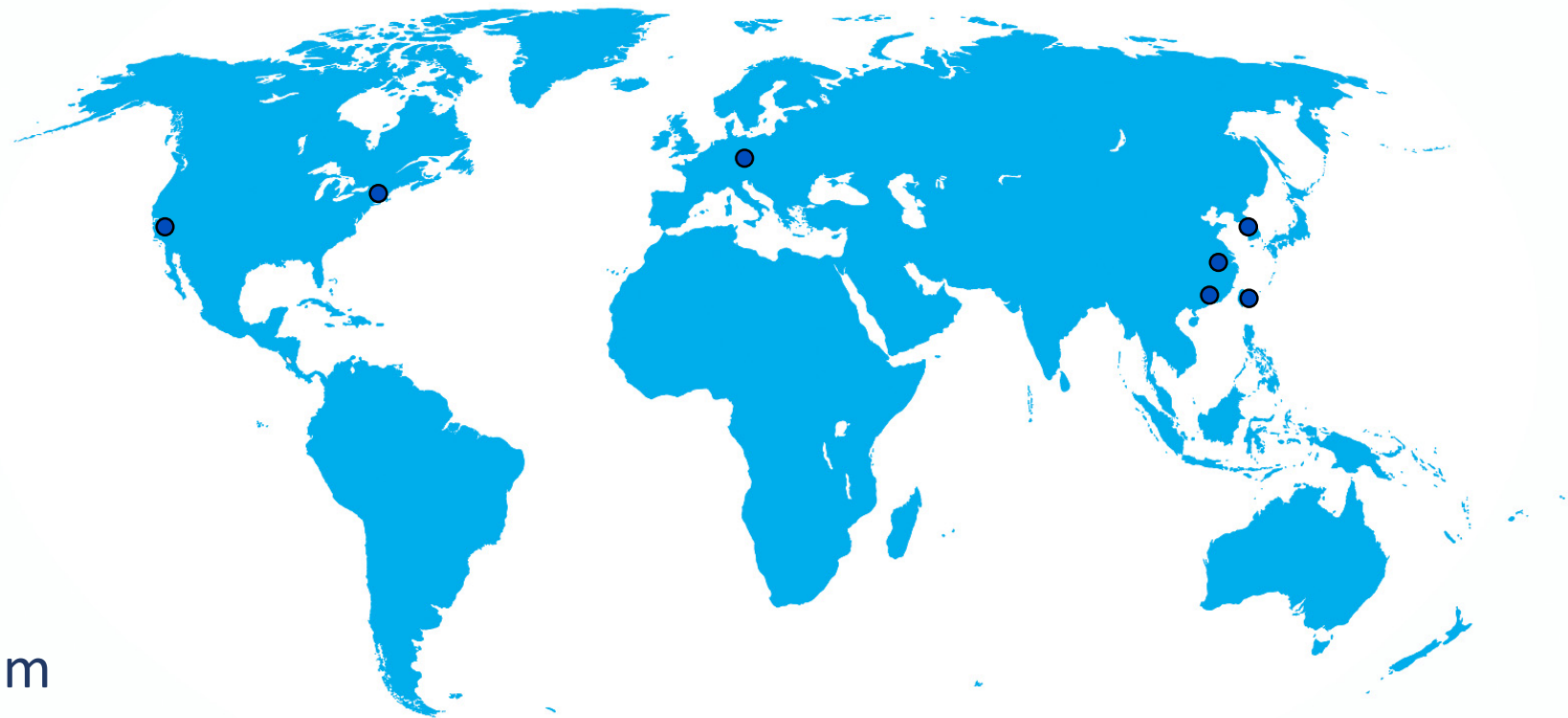
Available now on www.amazon.com

Images courtesy AUKEY



GaNFast Design Support

- Global technical support
 - Direct support
 - Partner support (VAR)
- Strong AE team
- Strong FAE team
- GaNFast Design Support Program
 - From schematic to EMI
 - Components, magnetics, PCB
 - Critical component support
 - System reliability support





GaNFast™



Let's go **GaNFast™**