



Let's go **GaNFast**[™]

Capacitors ... Going GaNFast

Opportunities and Challenges in High-Frequency Power Systems

Gene Sheridan, CEO
PSMA Capacitor Workshop
March 15, 2019

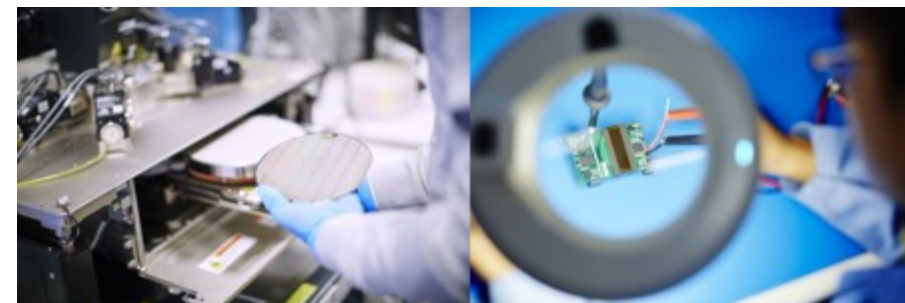


Navitas Semiconductor



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



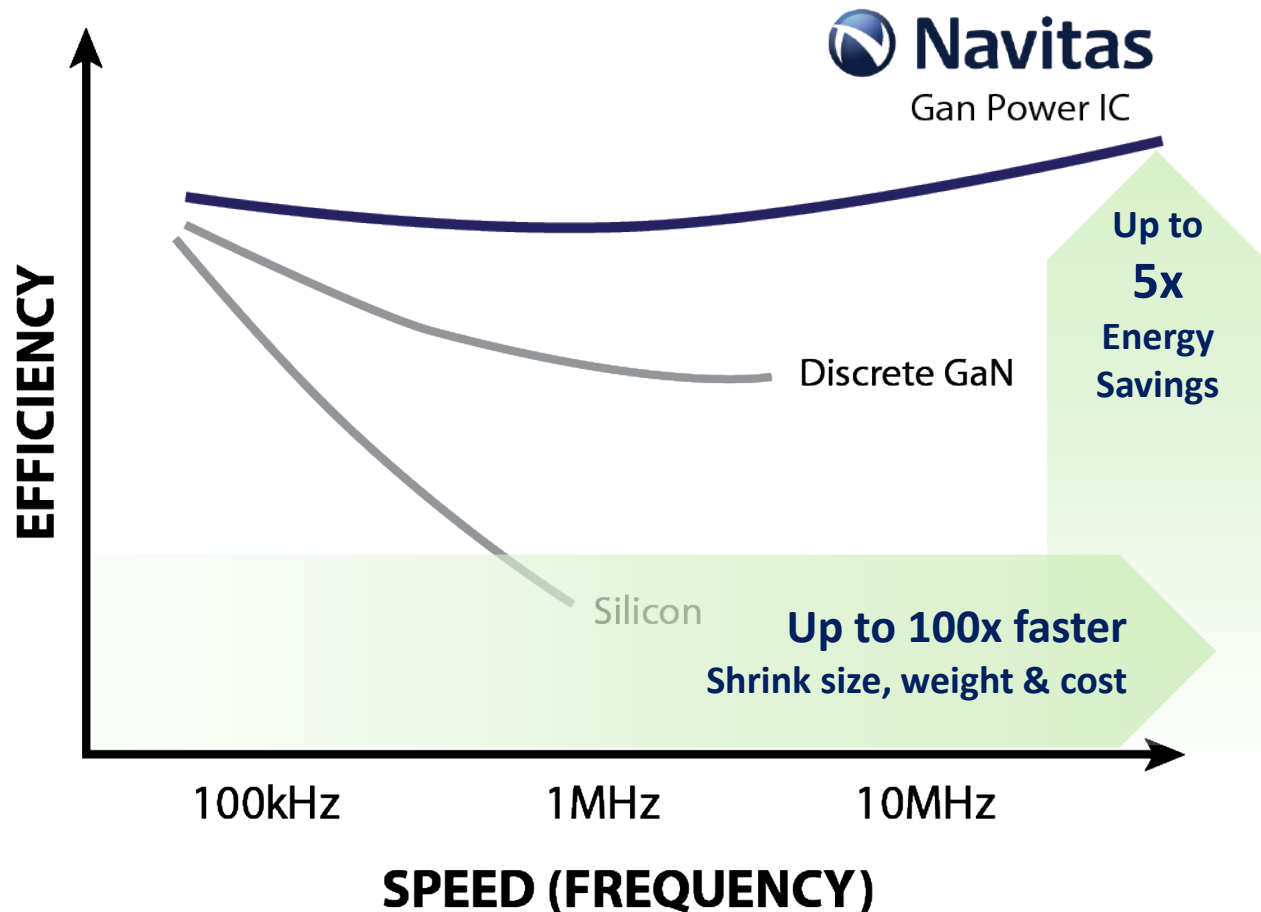
navitas
noun | en·er·gy





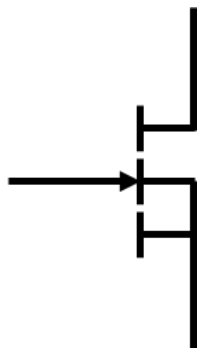
Speed & Efficiency are Key

- **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**, unequaled **Speed & Efficiency**





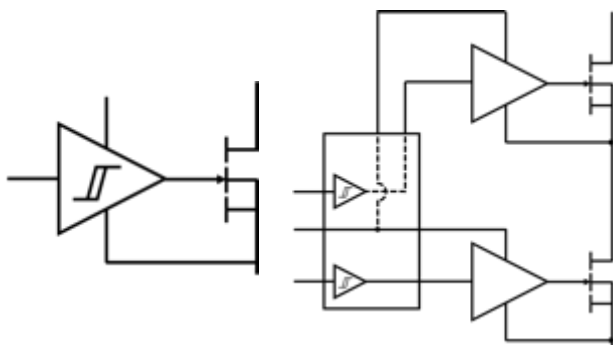
**Fastest, most efficient
GaN Power FETs**



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



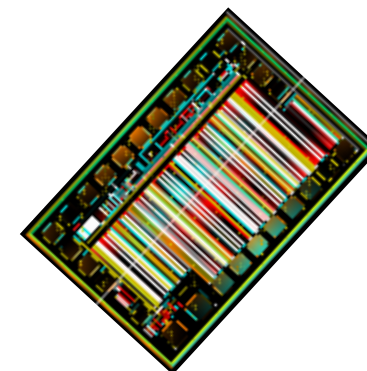
**First & Fastest Integrated
GaN Gate Drivers**



>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



The Power of GaN Power ICs

Unequaled Integration, Speed, Efficiency & Simplicity



Driver Circuits

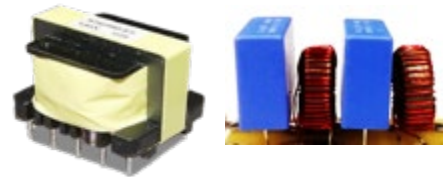
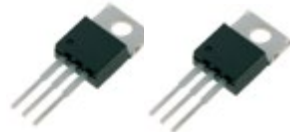
Power Devices

Passive Components

Switching Frequency

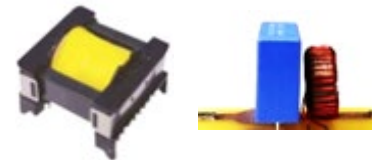
Energy Efficiency

Silicon



85-90%

Discrete GaN



88-92%

GaN Power ICs



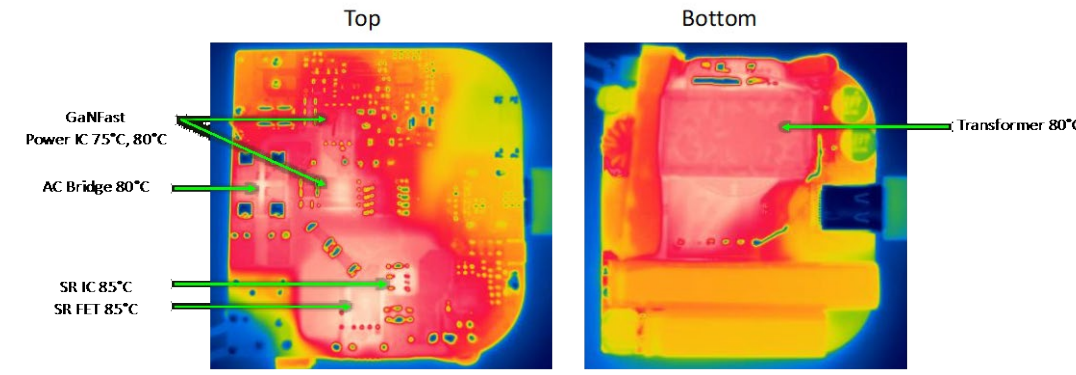
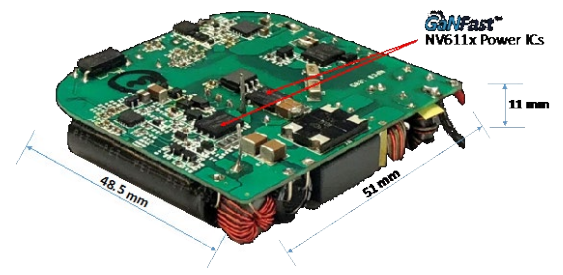
90-95%



Real World Benefits – 45W GaNFast Chargers

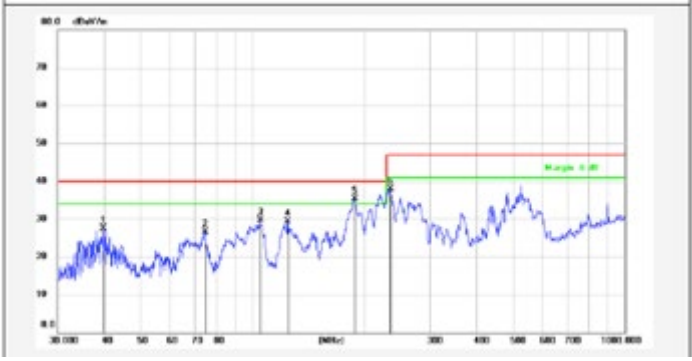


45W USB-C in 3x smaller size, weight and profile

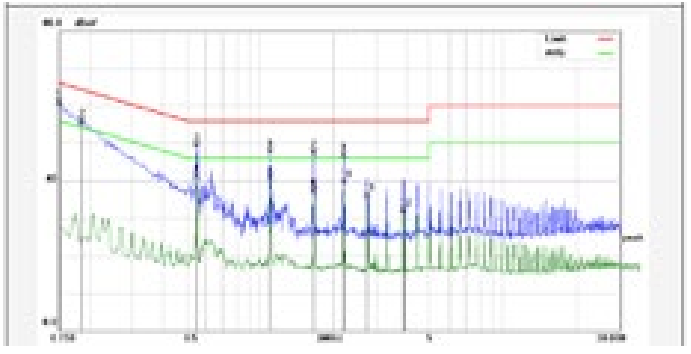


90 V_{AC}, 45 W, 25 °C, uncased, no airflow, no thermal compound / heatsinking

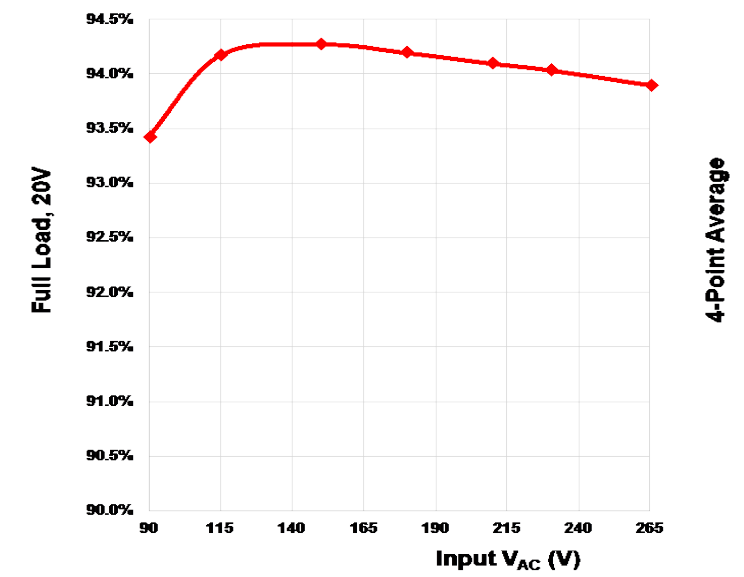
Radiated EMI
(230V, full 45W power)



Conducted EMI
(230V, full 45W power)



Full load Efficiency vs Input Voltage





Real World Benefits – 27W GaNFast Chargers

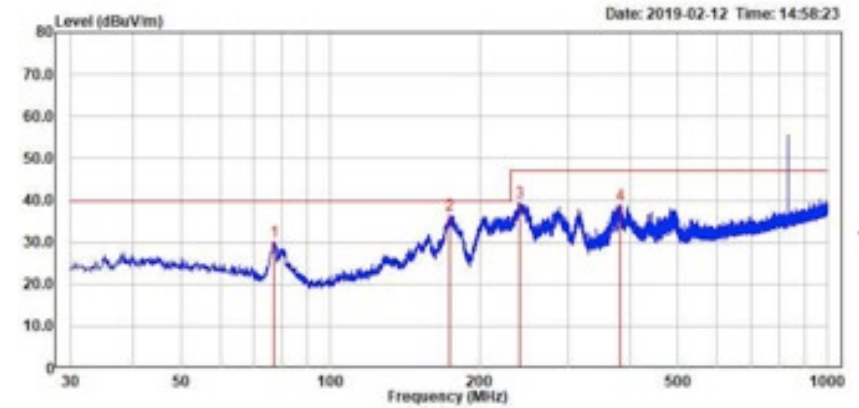


27W Silicon 65kHz
Size: 77cc

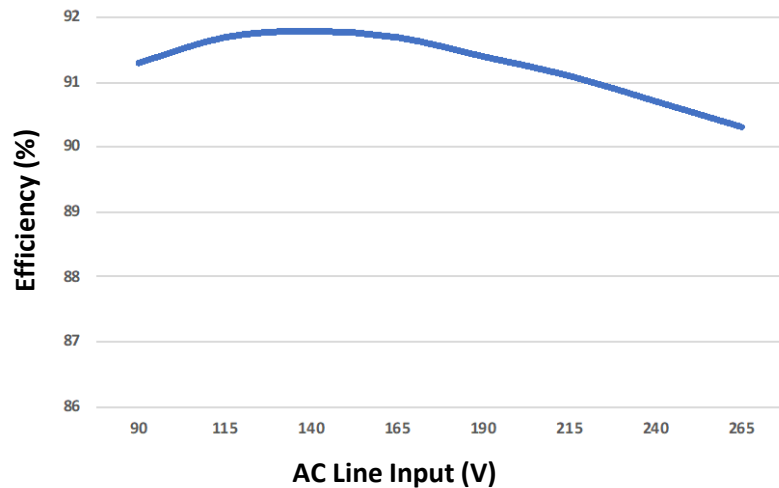


27W GaNFast 300kHz
Size: 42cc

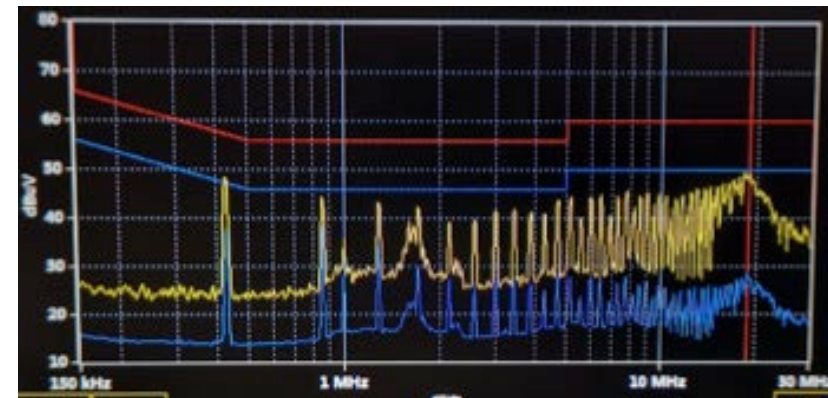
Radiated EMI (230V, Full 27W Power)



Full Load Efficiency vs Input Voltage



Conducted EMI (230V, Full 27W Power)

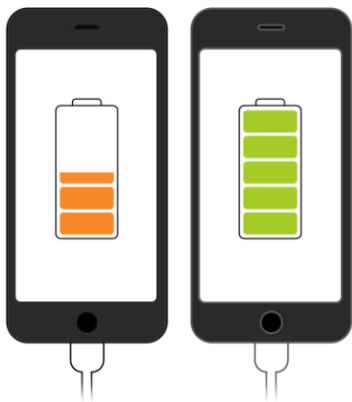




GaNFast USB-C Chargers Have Arrived

Fast

Up to 3x more power
Up to 3x faster charging



Mobile

Half the size & weight
of traditional chargers



Universal

One charger for **ALL** your devices
One and Done!!



Macbook 12"
Dell XPS 15/13

iPhone XS
Google Pixel 2

Nintendo Switch
And more...

AUKEY



27W



24W



30W

MADE IN MIND



45W

RAVPOWER®

45W

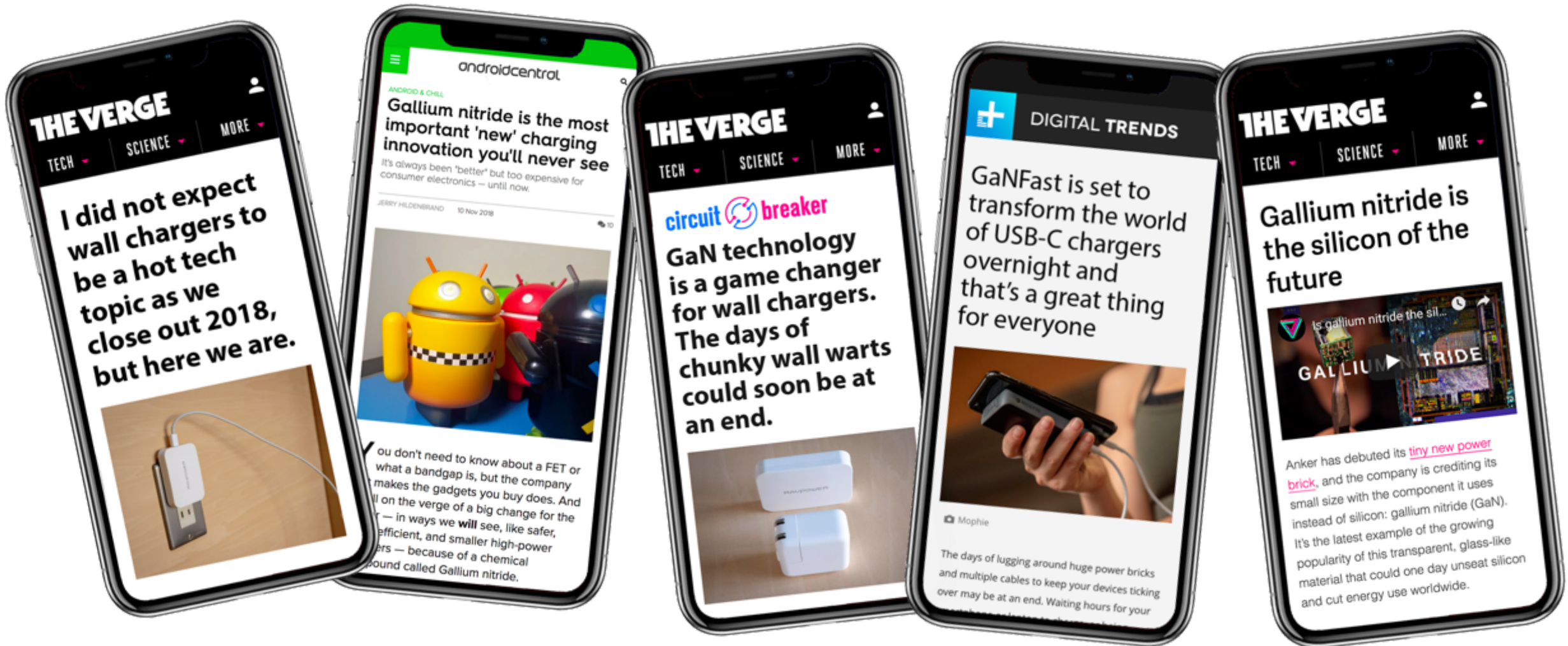




And the industry is taking notice ...

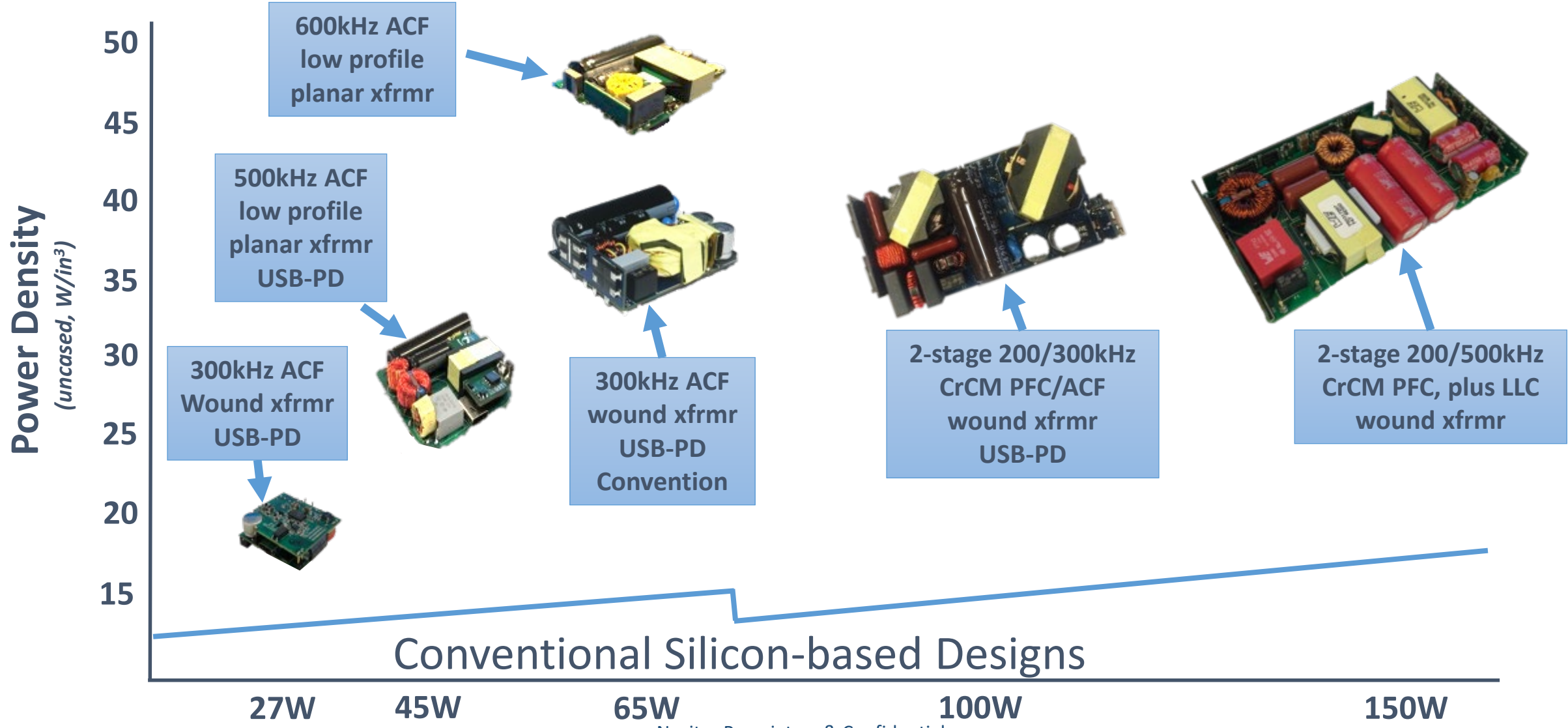


Here come the GaN chargers





The New World of GaNFast™ Chargers





Fast Growing GaNFast Eco-System



OEMs

GaNFast branding,
co-op marketing



ODMs

Mfg support, training



Technology

New products, reference designs,
joint marketing



Universities

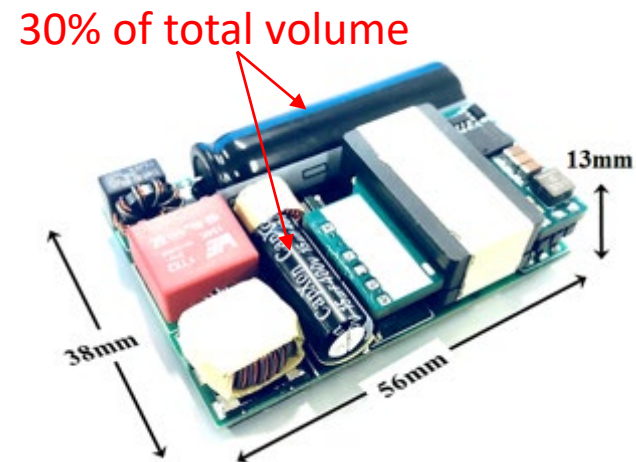
GaNFast education, branding



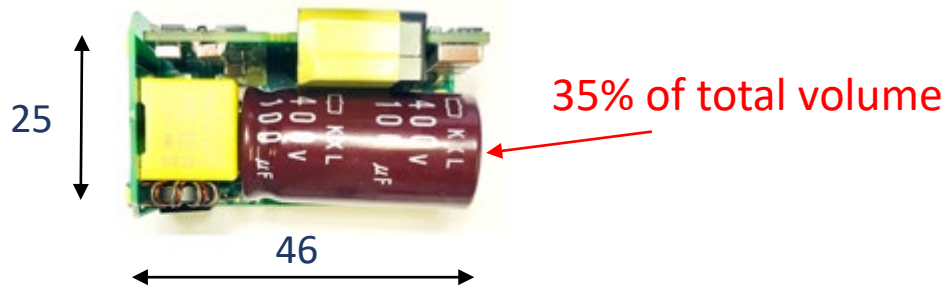


Bulk Cap: Biggest Component in HF Adapters

- Due to pulsating ac power, line frequency energy storage capacitor is required, and it doesn't shrink with frequency
- HF adapters are rapidly shrinking magnetics and filter capacitors
- Bulk caps are the bottleneck in HF adapters
 - It occupies **30-35%** of system volume
 - Usually dictates the form factor of an adapter
 - Sets max dimension in height, length or both
 - Design centers around bulk cap geometry, a highly inflexible process



65W PD, 39W/in³



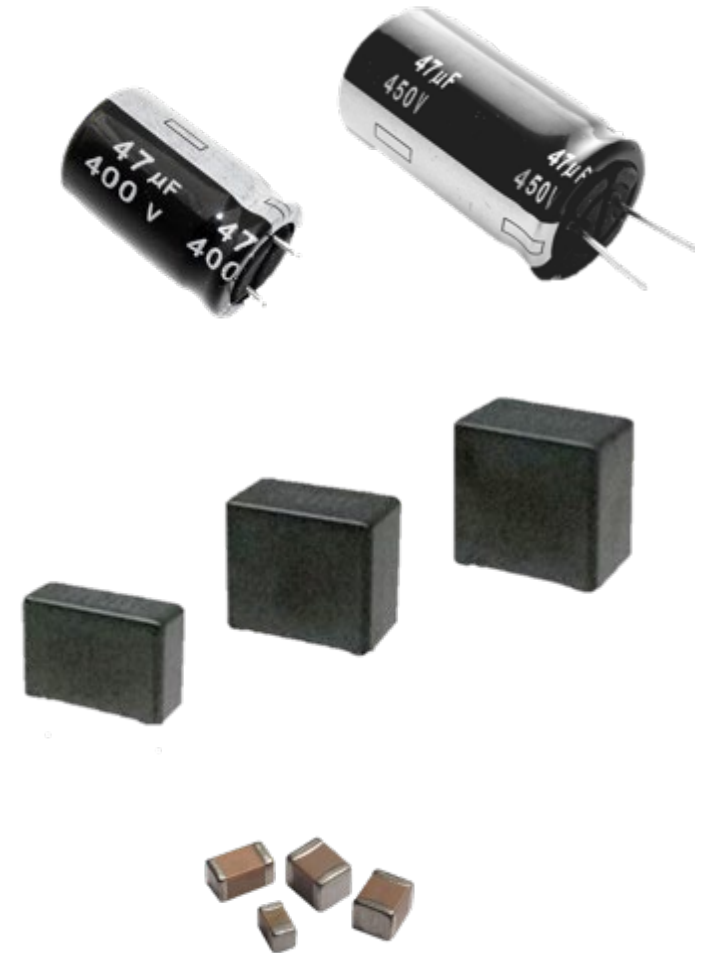
65W PD, 37W/in³





Electrolytic Cap: Low Cost Energy Storage

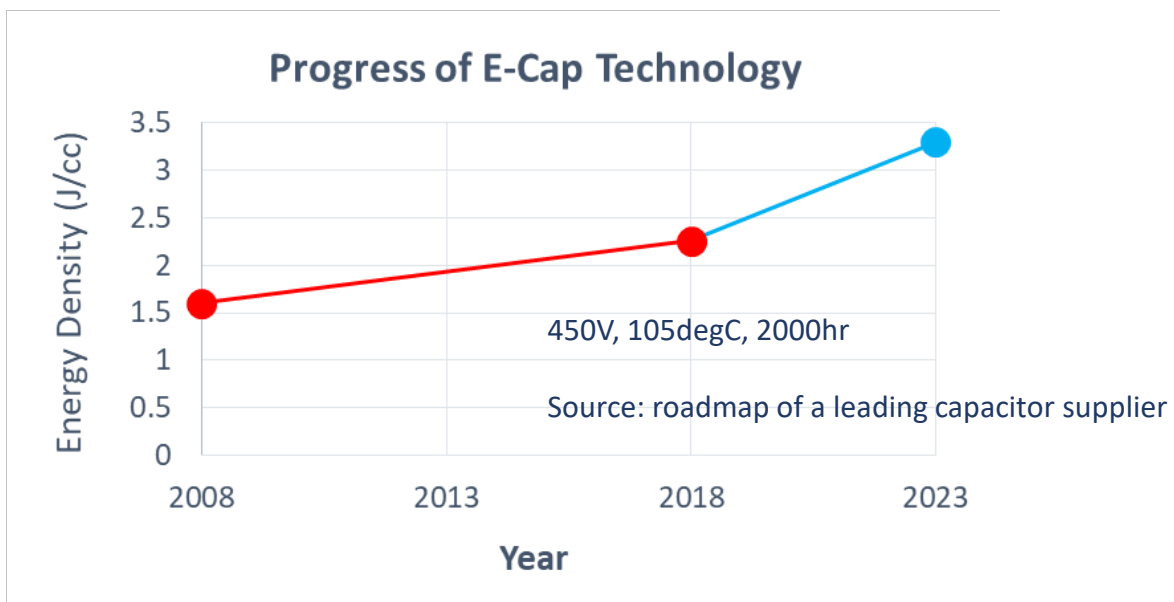
- Film capacitors making rapid progress in >500V dc link applications
 - Still lagging behind in cost and energy density in 200-450V ac/dc offline applications; at least by a factor of 3
- High voltage ceramic capacitors are excellent for HF filtering
 - Not economical as energy storage component
- Electrolytic capacitor dominates ac/dc offline power supplies
 - 400V E-Cap for non-PFC power supplies
 - 450V E-Cap for PFC power supplies





Electrolytic Caps Progress Slowly

- Some custom profile capacitors, i.e. low profile, slim & flat are introduced for TV and adapter applications
- Energy density progresses very slowly
 - 40% in last 10 years
 - Much slower than other capacitor technologies
 - Need next-gen faster (50% improvement)

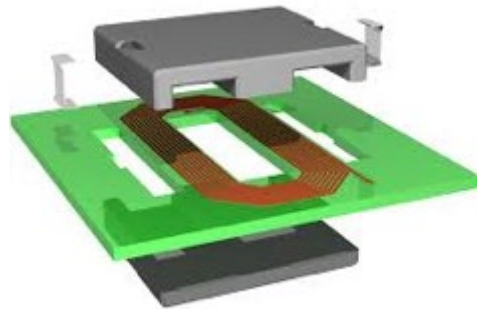




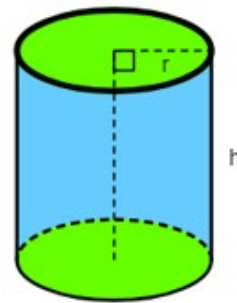
Space-Efficient Designs



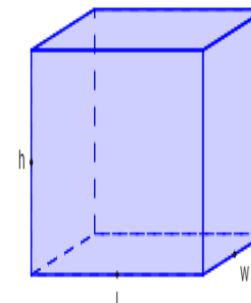
Radial bobbin
Transformer design



Flat planar
Transformer design



Volume of a
Cylinder
 $\pi r^2 h$



Volume of a
Rectangular Solid
 $= lwh$

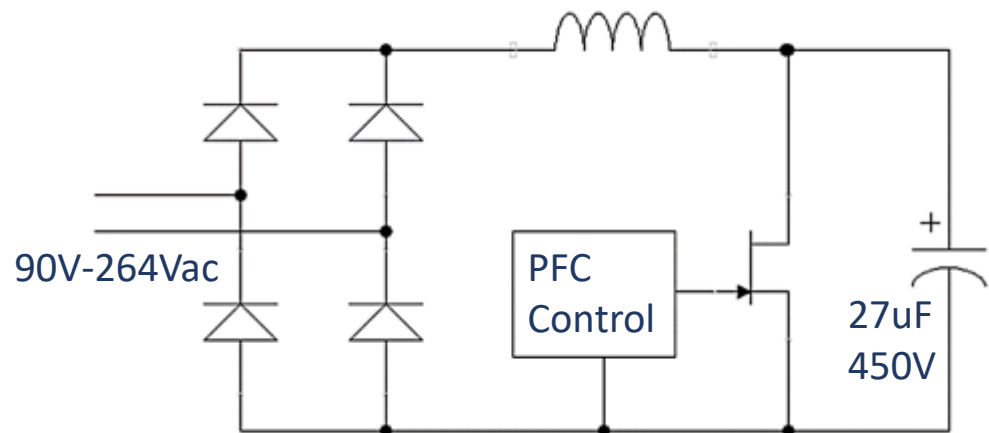
Transformers moving from radial bobbin to flat planar designs

Cylinder design is >20% less space efficient vs cubical design

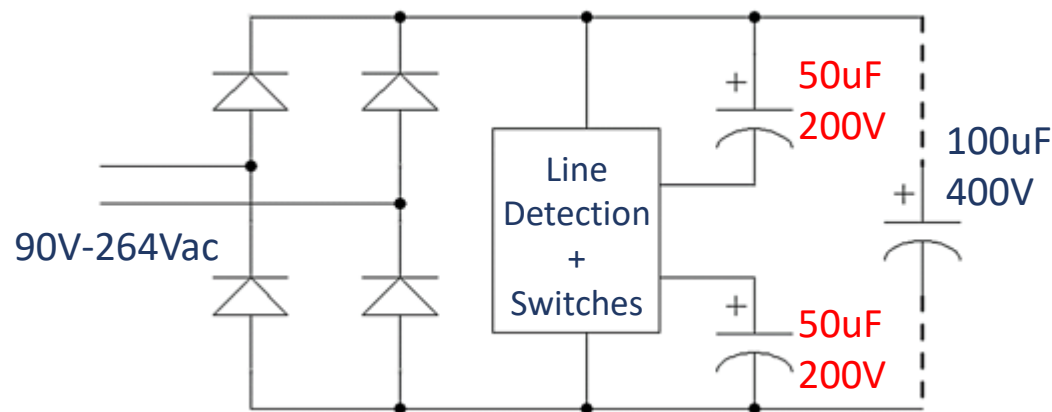
*In many high-frequency designs, the bulk cap is the tallest component;
20% profile reduction --> 20% volume reduction*



System Solutions to Reduce Bulk Cap



65W two stage: PFC + DC/DC



65W single stage: bridge rectifier + Flyback

- At 75W or less, bulk cap is not used efficiently
 - At 90Vac, capacitor voltage is 68% under utilized
 - At 264Vac, bulk capacitance is 3.5x over sized
- System approach: Boost PFC pre-regulator
 - 400V bus voltage: 90% voltage utilization
 - 3x bulk cap size reduction
 - Cost/size/efficiency penalty
- System approach: Use 200V Bulk Caps
 - At low line (90-132Vac), caps are in parallel
 - At high line (180-264Vac): caps are in series
 - **4x size reduction**, if 200V cap energy density is same as 400V (~2J/cc)
 - Today, 200V E-cap energy density is only 0.6J/cc
 - Low hanging fruit for size reduction?



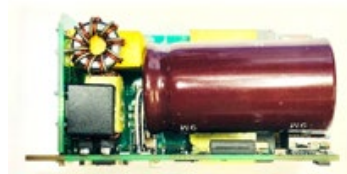
The Future of AC/DC Electronics



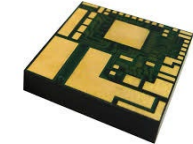
65kHz Silicon



300kHz GaNFast



600kHz GaNFast



1-5MHz GaNFast
New Capacitor Technologies



GaNFast™



Let's go **GaNFast™**