Capacitors ... Going GaNFast

Opportunities and Challenges in High-Frequency Power Systems

Gene Sheridan, CEO

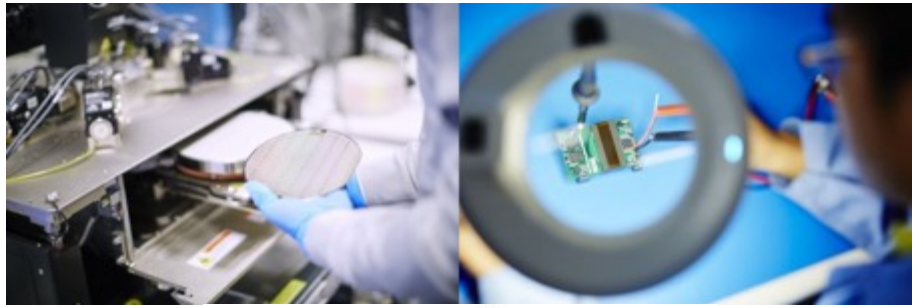
PSMA Capacitor Workshop

March 16, 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

tsmc

Amkor Technology®

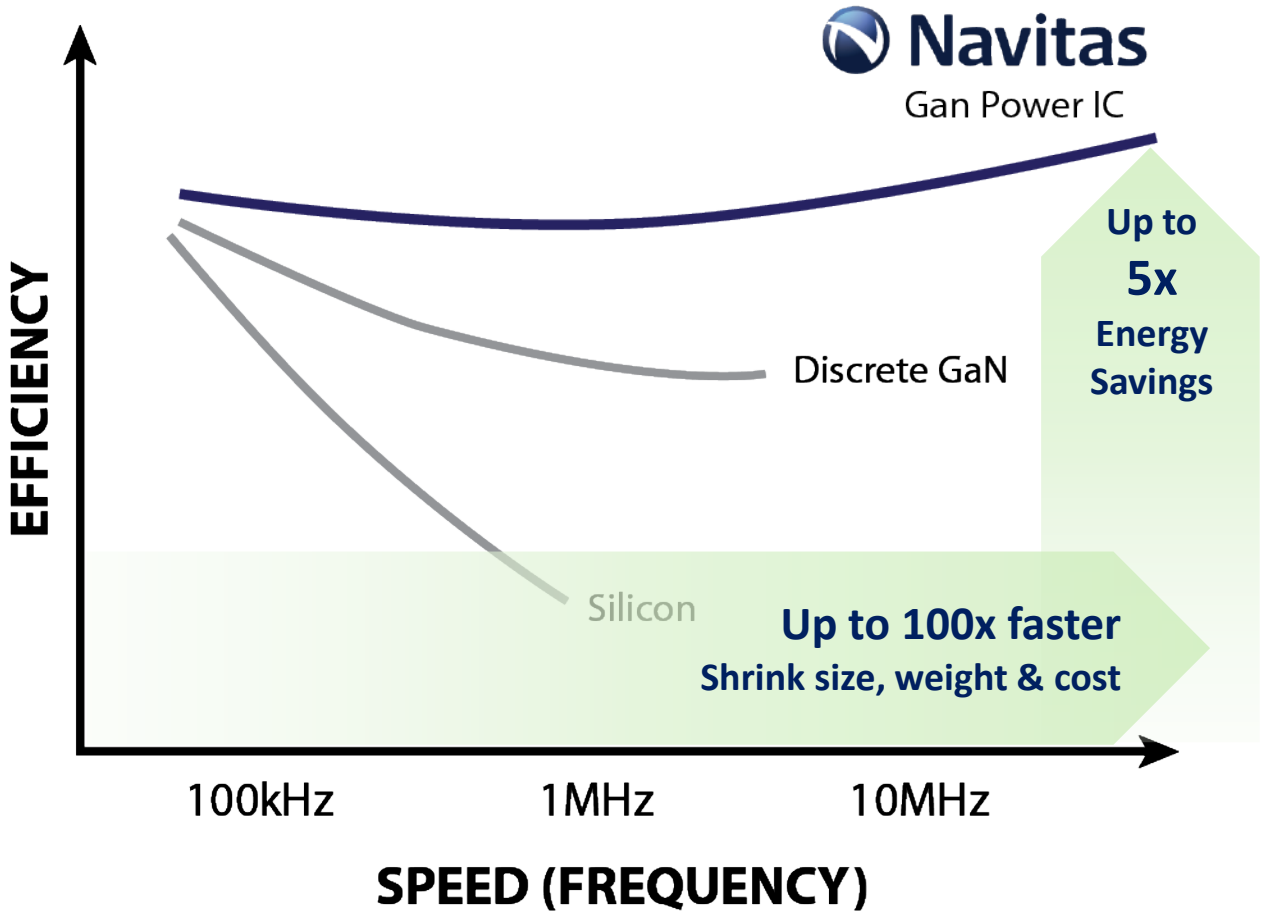
CAPRICORN INVESTMENTGROUP

ATLANTIC BRIDGE

Speed & Efficiency are Key

GaNFast™

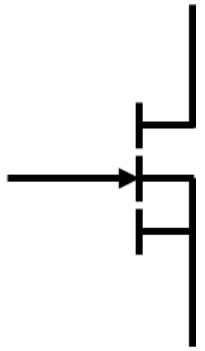
- **Speed** enables ***small size***, ***low-cost*** and ***faster charging***
- **Efficiency** enables ***energy savings***
- With Silicon or Discrete GaN power devices, you can get one ***or*** the other
- With GaN power ICs, you get ***both at the same time,*** unequaled **Speed & Efficiency**



World's First GaNFast™ Power ICs

GaNFast™

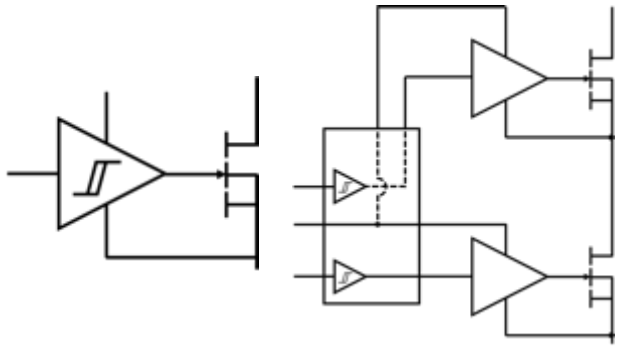
Fastest, most efficient GaN Power FETs



>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

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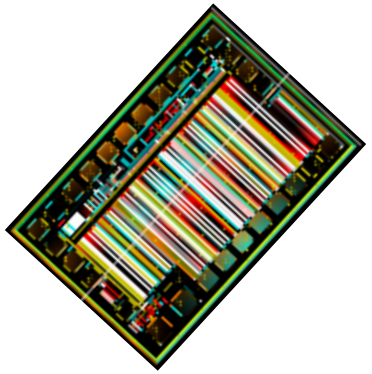
World's First GaNFast™ Power ICs

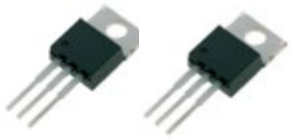
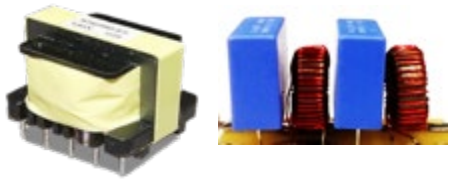
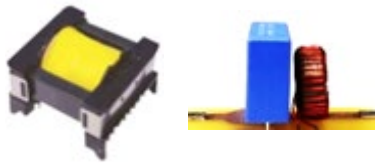


Up to 40MHz switching, 5x higher density & 20% lower system cost

The Power of GaN Power ICs

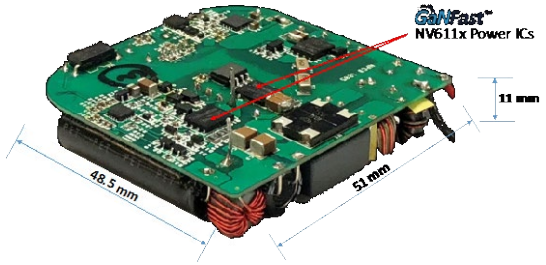
Unequaled Integration, Speed, Efficiency & Simplicity

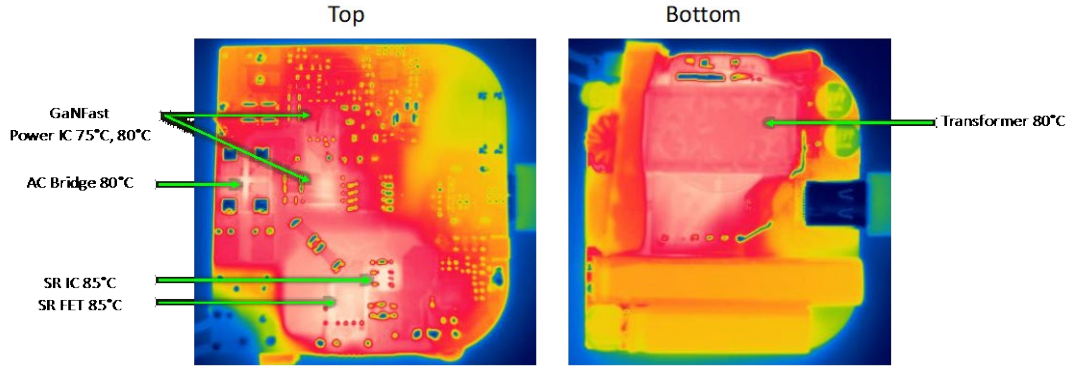
GaNFast™

	Driver Circuits	Power Devices	Passive Components	Switching Frequency	Energy Efficiency
Silicon				 *100kHz*	*85-90%*
Discrete GaN				 *500kHz*	*88-92%*
GaN Power ICs				 *1-10MHz*	*90-95%*

Real World Benefits – *45W GaNFast Chargers*

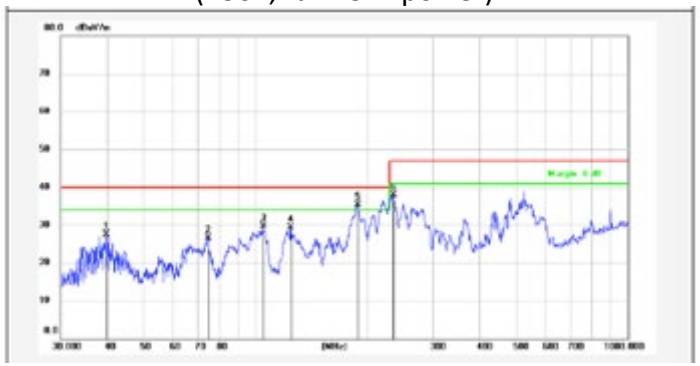
45W USB-C in 3x smaller size, weight and profile



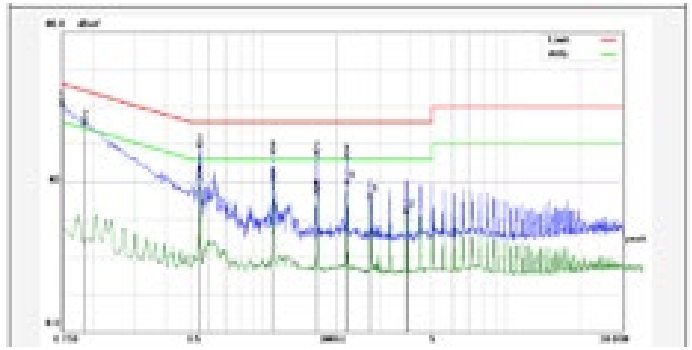


90 V_{AC}, 45 W, 25 °C, uncased, no airflow, no thermal compound / heatsinking

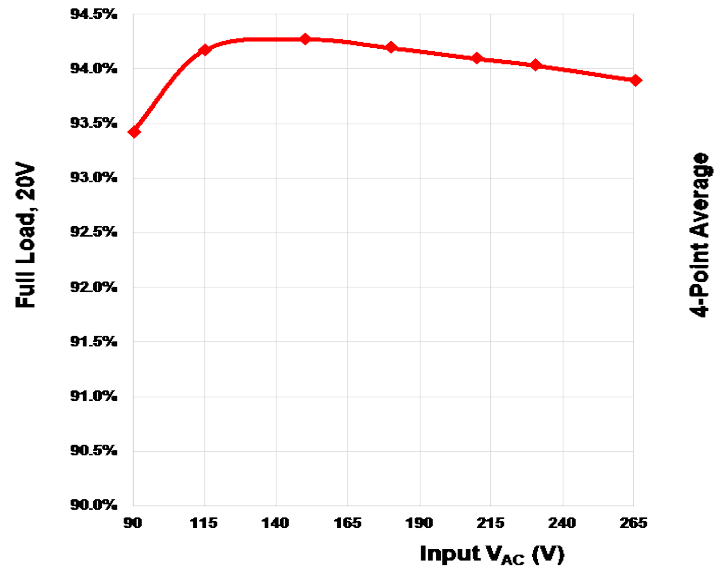
Radiated EMI
(230V, full 45W power)



Conducted EMI
(230V, full 45W power)



Full load Efficiency vs Input Voltage

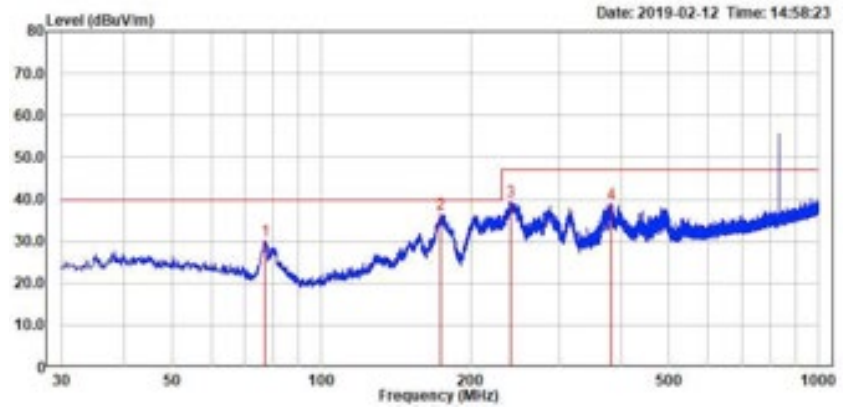


Real World Benefits – *27W GaNFast Chargers*

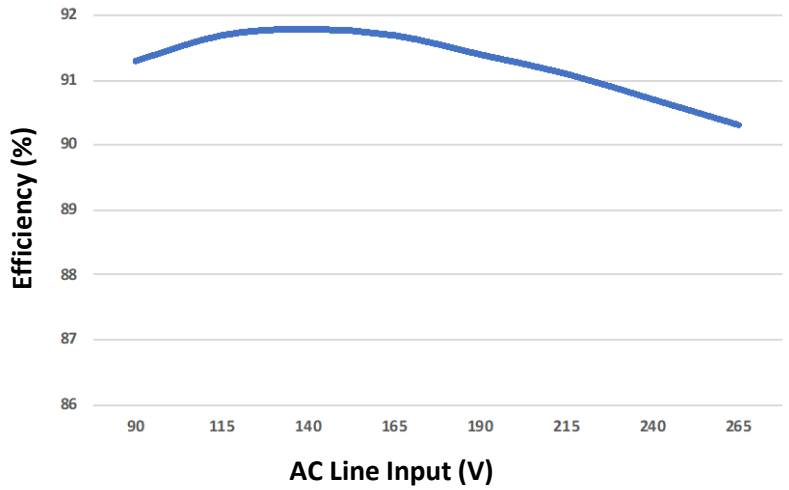
27W Silicon 65kHz
Size: 77cc

27W GaNFast 300kHz
Size: 42cc

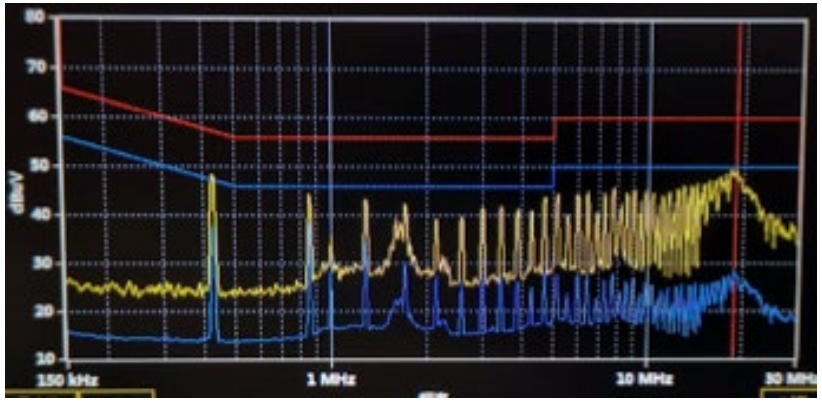
Radiated EMI
(230V, Full 27W Power)



Full Load Efficiency vs Input Voltage



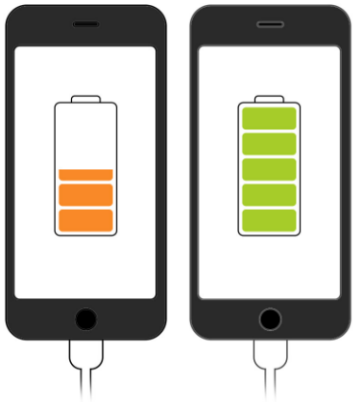
Conducted EMI
(230V, Full 27W Power)



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!!

AUKEY

27W

24W

30W

MADE IN MIND

45W

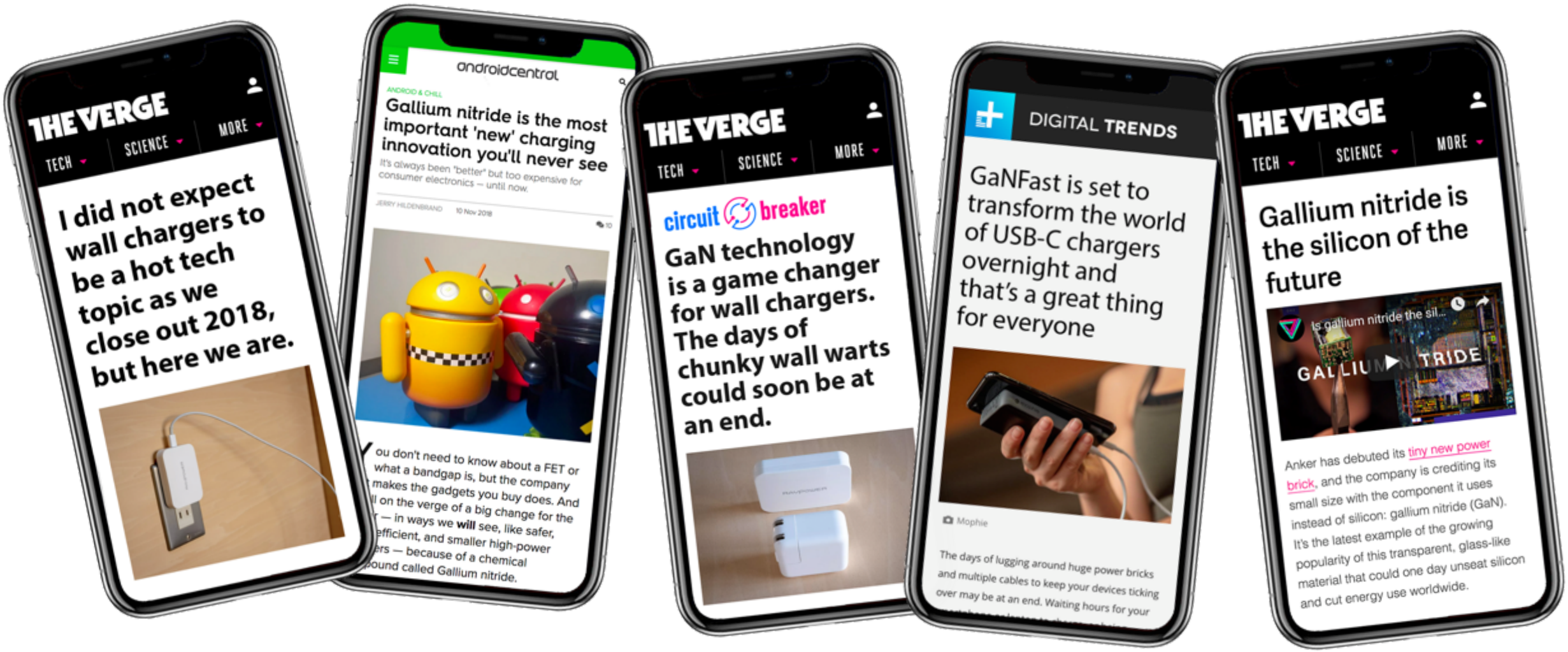
RAVPOWER®

45W

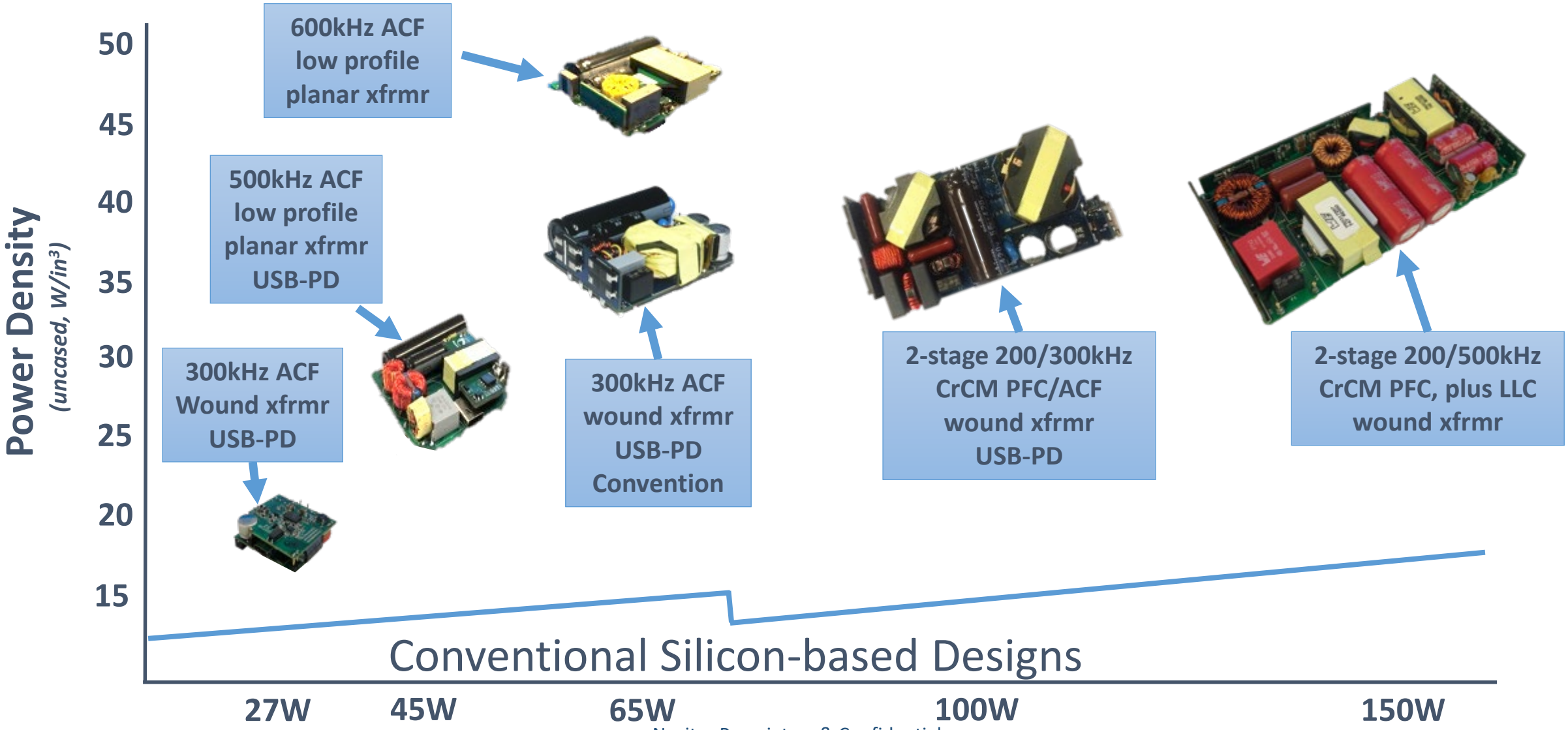
And the industry is taking notice …

GaNFast™

Here come the GaN chargers



The New World of GaNFast™ Chargers



Fast Growing GaNFast Eco-System

GaNFast™

OEMs

GaNFast branding, co-op marketing

ODMs

Mfg support, training

Technology

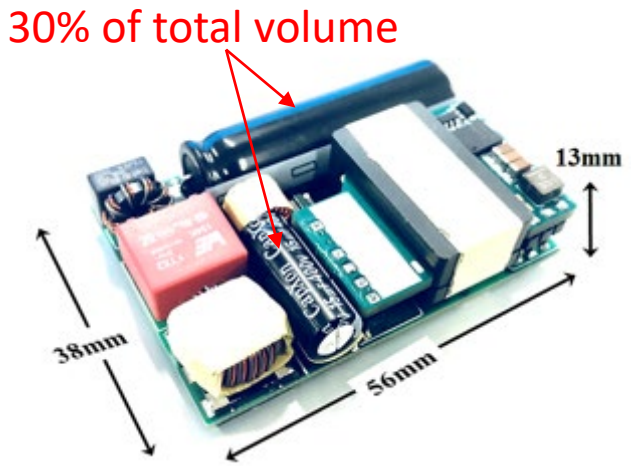
New products, reference designs, joint marketing

Universities

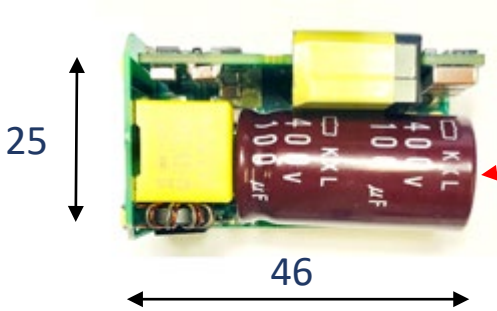
GaNFast education, branding

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



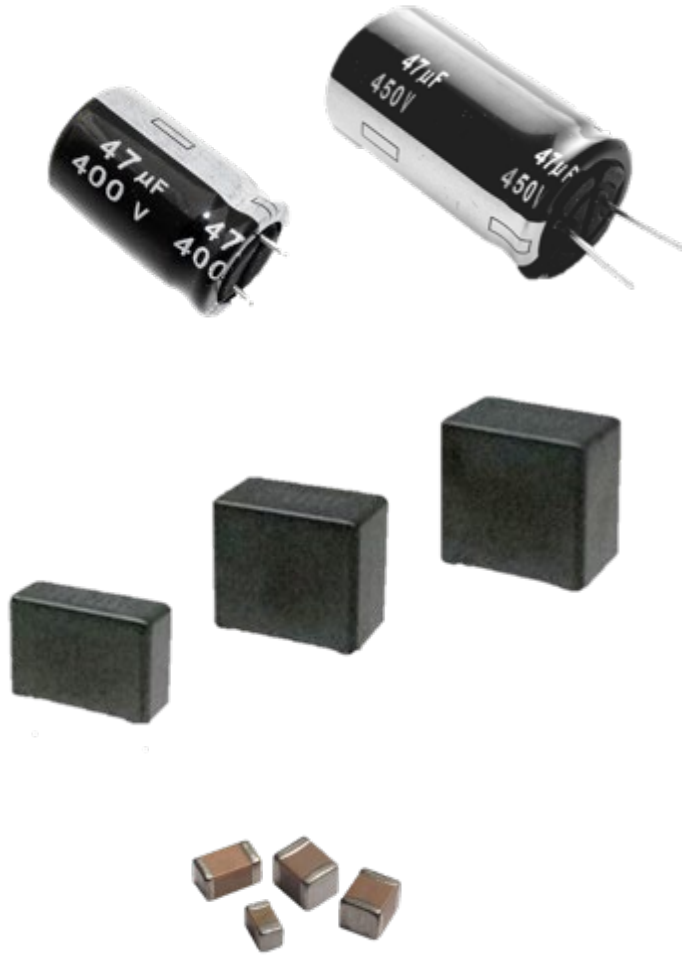
65W PD, 39W/in^3



65W PD, 37W/in^3

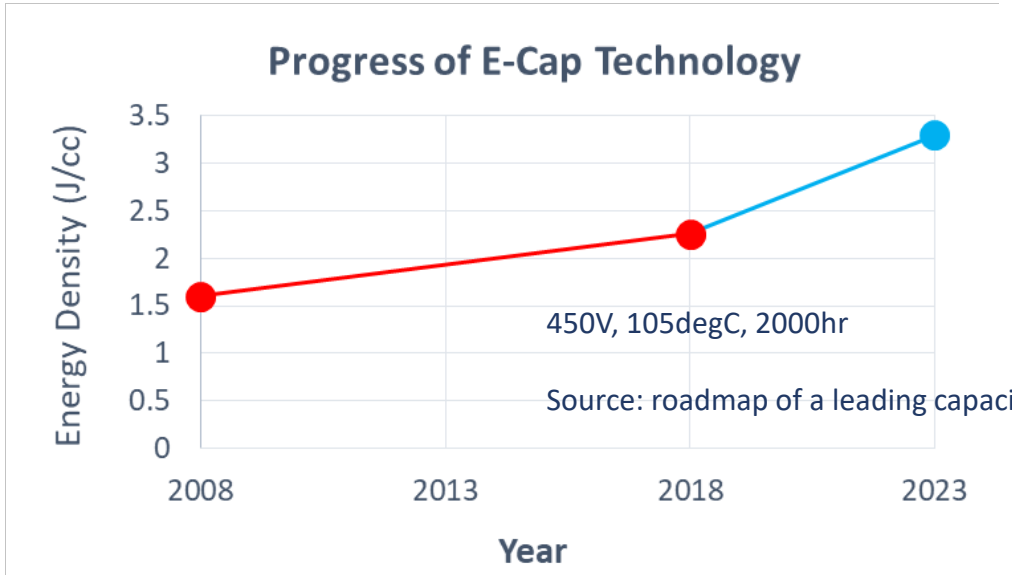
Electrolytic Cap: Low Cost Energy Storage

- 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



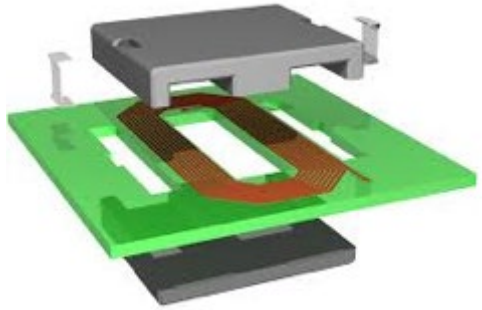
Electrolytic Caps Progress Slowly

- 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)

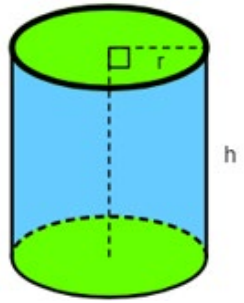


Space-Efficient Designs

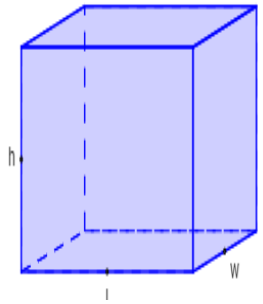
Radial bobbin
Transformer design



Flat planar
Transformer design



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



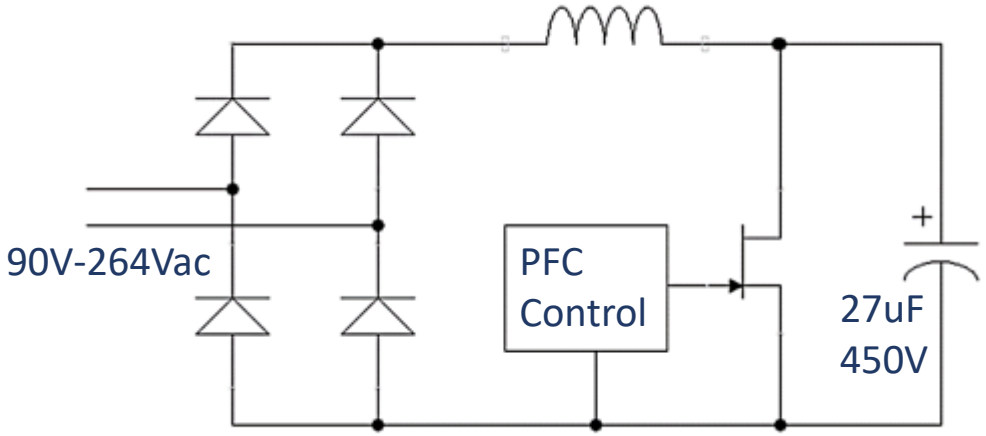
Volume of a
Rectangular Solid
$= lwh$

Transformers moving from radial bobbin to flat planar designs

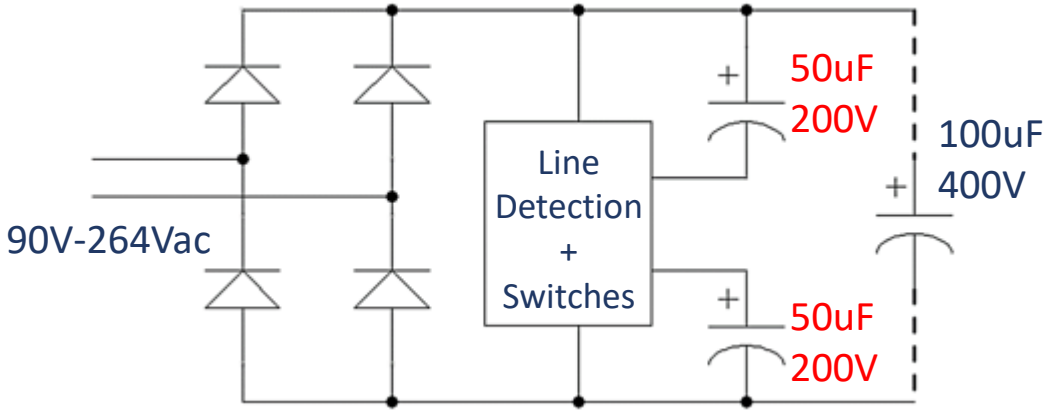
Cylinder design is >20% less space efficient vs cubical design

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

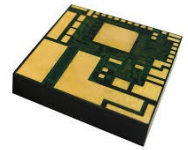
- At 75W or less, bulk cap is not used efficiently
  - At 90Vac, capacitor voltage is 68% under utilized
  - At 264Vac, bulk capacitance is 3.5x over sized
- System approach: Boost PFC pre-regulator
  - 400V bus voltage: 90% voltage utilization
  - 3x bulk cap size reduction
  - Cost/size/efficiency 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

Let's go GaNFast™