Capacitors … Going GaNFast
Opportunities and Challenges in High-Frequency Power Systems

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Navitas Semiconductor

- 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
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*
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 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

Discrete GaN

GaN Power ICs

100kHz

85-90%

500kHz

88-92%

1-10MHz

90-95%
Real World Benefits – 45W GaNFast Chargers

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

Radiated EMI
(230V, full 45W power)

Conducted EMI
(230V, full 45W power)

Full load Efficiency vs Input Voltage

90 V<sub>AC</sub>, 45 W, 25 °C, uncased, no airflow, no thermal compound / heatsinking
Real World Benefits – 27W GaNFast Chargers

27W Silicon 65kHz
Size: 77cc

27W GaNFast 300kHz
Size: 42cc

Full Load Efficiency vs Input Voltage

Radiated EMI
(230V, Full 27W Power)

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*!!

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**27W**  
**24W**  
**30W**  
**45W**  

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**AUKEY**

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**RAVPower®**

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And the industry is taking notice …

Here come the GaN chargers

I did not expect wall chargers to be a hot tech topic as we close out 2018, but here we are.

Gallium nitride is the most important ‘new’ charging innovation you’ll never see. It’s always been ‘hype’ but unimplemented for consumer electronics — until now. And the industry is taking notice — in ways we will see, like safer, efficient, and smaller high power bricks — because of a chemical compound called Gallium nitride.

GaN technology is a game changer for wall chargers. The days of chunky wall warts could soon be at an end.

GaNFast is set to transform the world of USB-C chargers overnight and that’s a great thing for everyone.

Gallium nitride is the silicon of the future.
The New World of GaNFast™ Chargers

Power Density (uncased, W/in³)

- 600kHz ACF low profile planar xfrmr
- 500kHz ACF low profile planar xfrmr USB-PD
- 300kHz ACF Wound xfrmr USB-PD
- 300kHz ACF wound xfrmr USB-PD Convention
- 2-stage 200/300kHz CrCM PFC/ACF wound xfrmr USB-PD
- 2-stage 200/500kHz CrCM PFC, plus LLC wound xfrmr

Conventional Silicon-based Designs

27W 45W 65W 100W 150W

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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

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• 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
• 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
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)

Progress of E-Cap Technology

- Energy Density (J/cc)
- 450V, 105degC, 2000hr
- Source: roadmap of a leading capacitor supplier
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
- 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