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*
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

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**

- 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

Radiated EMI
(230V, full 45W power)

Conducted EMI
(230V, full 45W power)

Full load Efficiency vs Input Voltage

90 V_{AC}, 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

Radiated EMI
(230V, Full 27W Power)

Conducted EMI
(230V, Full 27W Power)

Full Load Efficiency vs Input Voltage

Efficiency (%)

AC Line Input (V)
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

**RAVPower**

- 45W
And the industry is taking notice …

Here come the GaN chargers
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
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
• 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)
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
Let’s go GaNFast™