

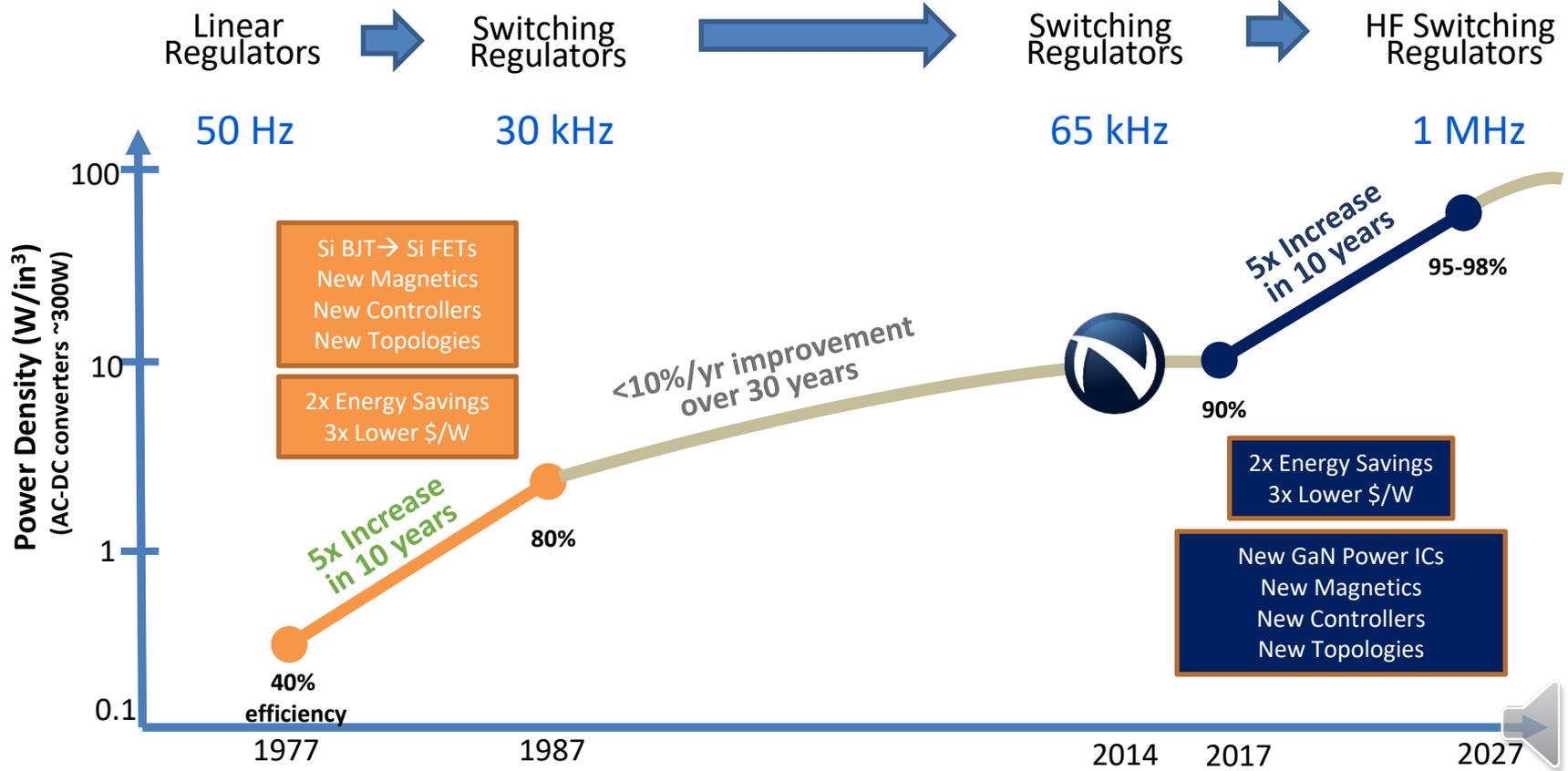
# Pulsed ACF for Low-Profile GaN Fast Chargers

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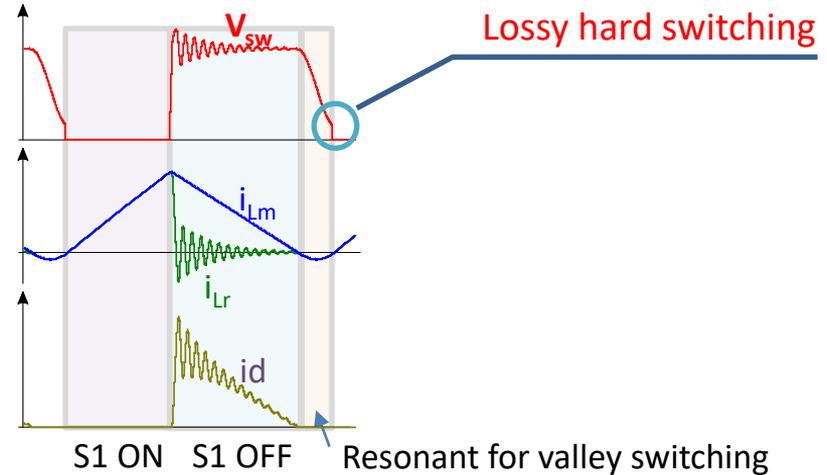
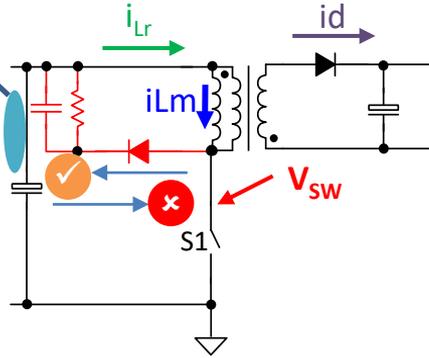


# Second Revolution in Power



# QR Flyback Losses

Lossy  $R_{CD}$  clamp

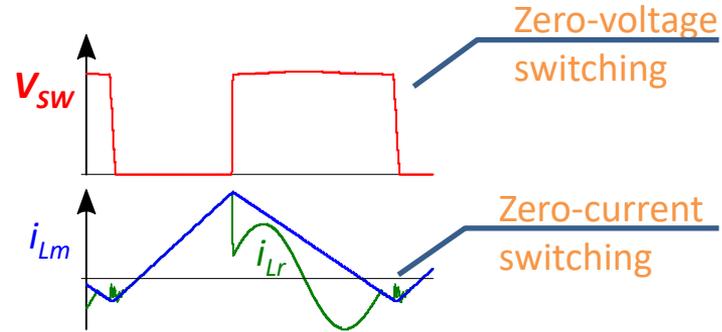
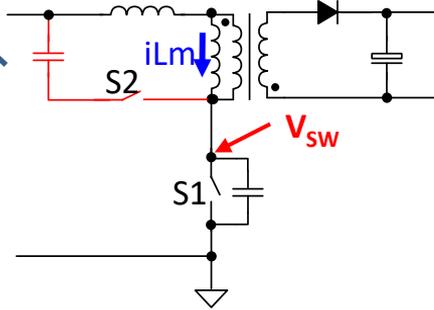


- Quasi-Resonant (QR) Flyback
  - Frequency-dependent **losses**
    - Leakage inductance
    - Snubber/clamp
    - Partial hard-switching at high line
    - Slow turn-on to minimize EMI
  - Difficult to improve efficiency at high frequency



# ACF Enables ZVS and High Frequency

Lossless snubber

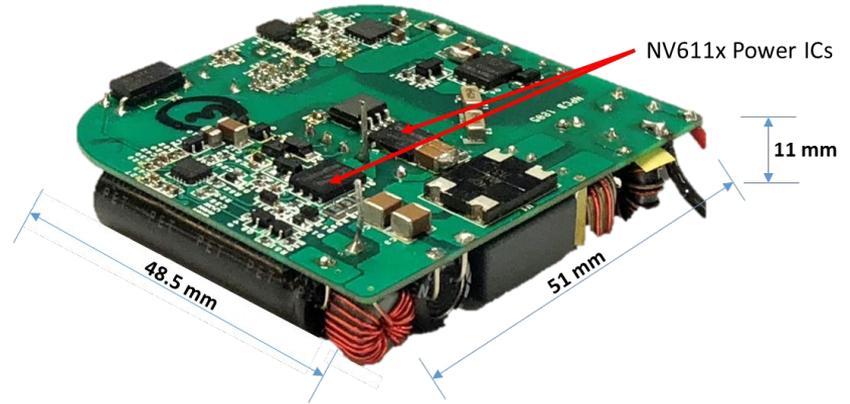


- Active-Clamp Flyback<sup>(1)</sup> (ACF)
  - No snubber losses, all leakage energy is recovered
  - ZVS soft switching over entire operation range
  - ZCS soft turn-off for output rectifier
  - Clean waveforms reduce EMI
  - Enable small adapter design with high-frequency switching

(1) R. Watson, F. C. Lee and G. C. Hua, "Utilization of an active-clamp circuit to achieve soft switching in flyback converters," in *IEEE Transactions on Power Electronics*, vol. 11, no. 1, pp. 162-169, Jan. 1996. doi: 10.1109/63.484429



# ACF in Mass Production: 2018



45W, 41 cc, 1.1 W/cc



# ACF in Mass Production: 2019



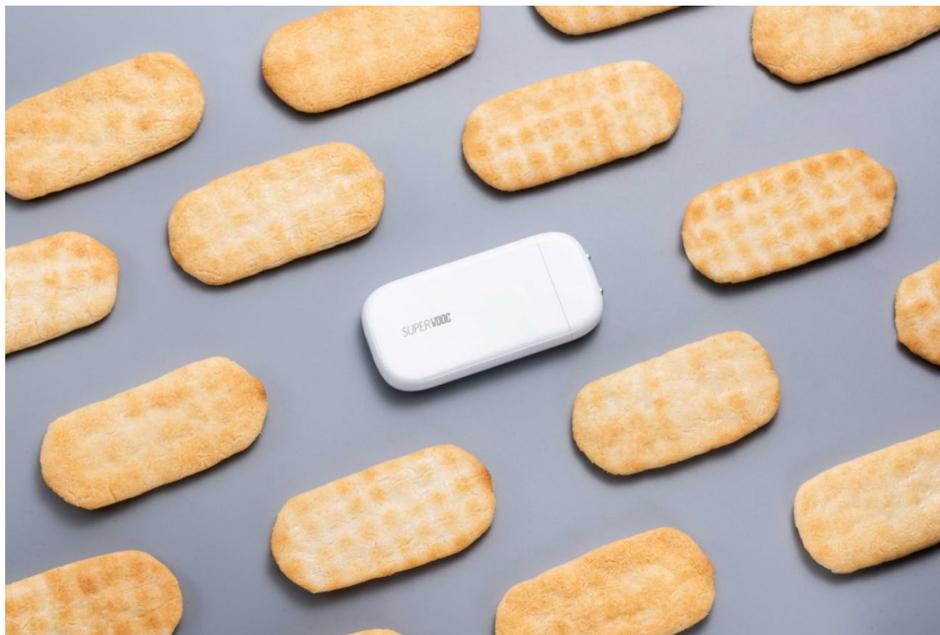
Xiaomi 65W, 53 cc, 1.2 W/cc

“Look how small this is! This charger is so coooooo!”  
Xiaomi CEO



*Pulsed*  
^

# ACF in Mass Production: 2020



The 'Cookie':  
OPPO 50W Mini SuperVOOC  
50W, 82 x 39 x 10.5 mm = 34 cc, 1.5 W/cc



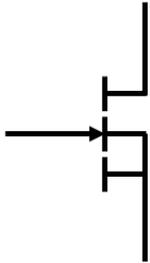
# Pulsed Active-Clamp Flyback (P-ACF)

- 3 major technology innovations:
  1. Powertrain
  2. Topology
  3. Transformer



# Powertrain: GaN Power ICs

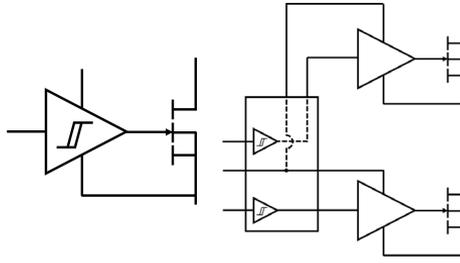
Fastest, most efficient  
GaN Power FETs



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



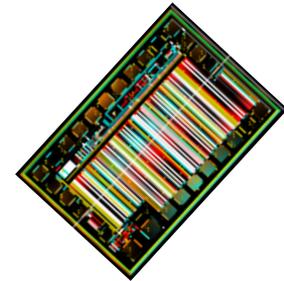
First & Fastest Integrated  
GaN Gate Driver  
with Control & Protection



>3x faster than any other gate  
driver  
Proprietary design  
120+ patents granted/applied



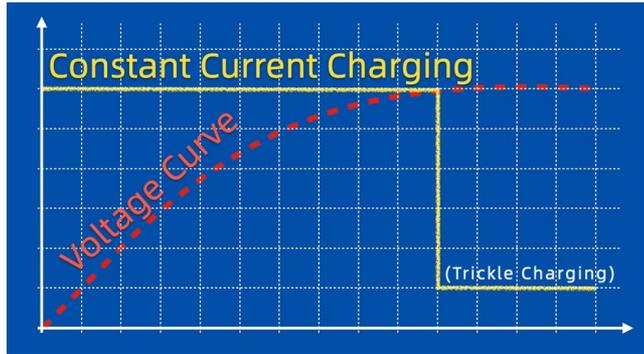
World's First  
**GaNFast™**  
Power ICs



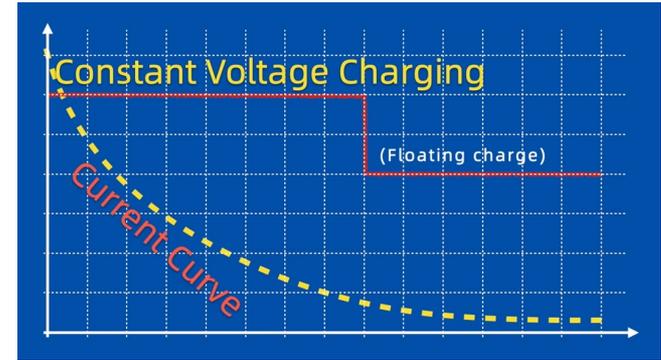
Up to 40 MHz switching, 5x higher density & 20% lower system cost



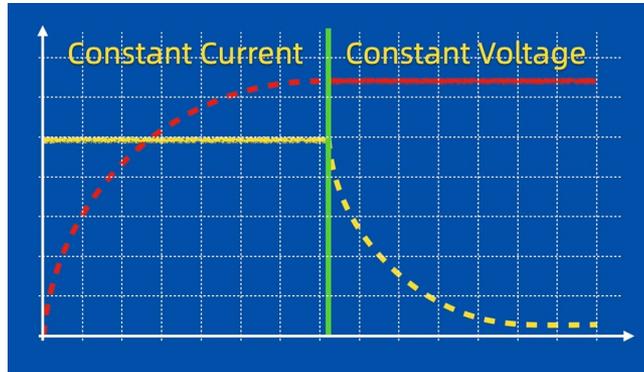
# Charging Progression



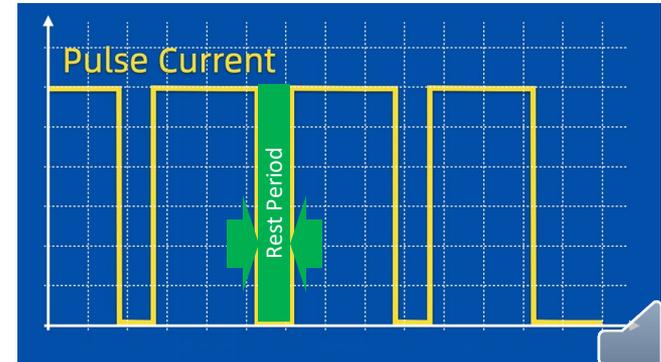
Constant  
Current



Constant  
Voltage



Mixed  
Mode



Pulsed  
Current  
Charging



# 100 Hz Pulsed Current

Current curve of  
OPPO 50W pulse charging  
*(P-ACF output current)*



Current curve of  
50W non-pulse charging



# Topology: Pulsed Active-Clamp Flyback

- OPPO 50W Mini
  - Powertrain: 2x Navitas NV6115 (170mOhm GaNFast power ICs)
    - Low resistance ( $R_{DS(ON)}$ ) to minimize 'on-state' losses
    - Minimal output capacitance ( $C_{OSS}$ ) for the best 'switching' performance
  - Control: TI UCC28782 ACF + On Semi NCP51530
    - High-speed, soft-switching (~400 kHz)
  - Proprietary innovation 'pulsed' power conversion
    - Eliminates electrolytic bulk capacitor
    - Rectified AC 100Hz feeds directly into the high-frequency ACF circuit
    - ACF can maintain a 100 Hz smooth pulse output to charge the phone's battery, even when the input voltage range is wide
    - Stability, and accurate measurement of current and voltage are critical
    - OPPO-proprietary 'direct-charge' approach means that during each pulse gap, the polarization effect in the phone battery is eliminated, reducing wear-out mechanisms and extending battery life



# Standard vs. Pulsed Charging

**Pulsed Current Charging**

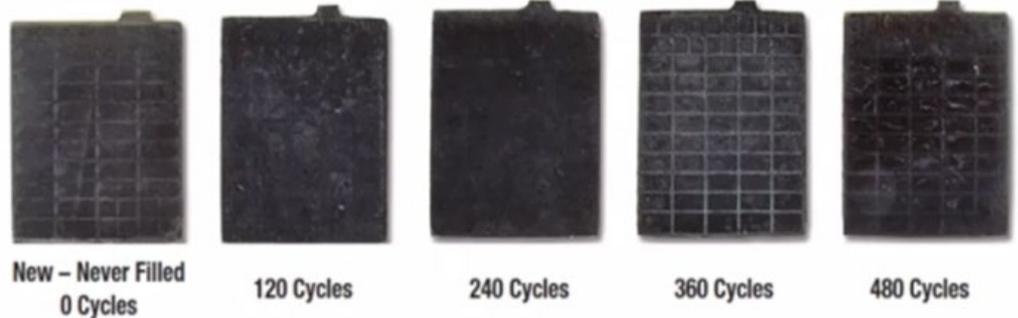
**Avoids Battery Polarization & heat.**

**Increase Charging Speed Without  
Sacrificing Battery Life**

**Traditional Charging**

**Battery Polarization Appears**

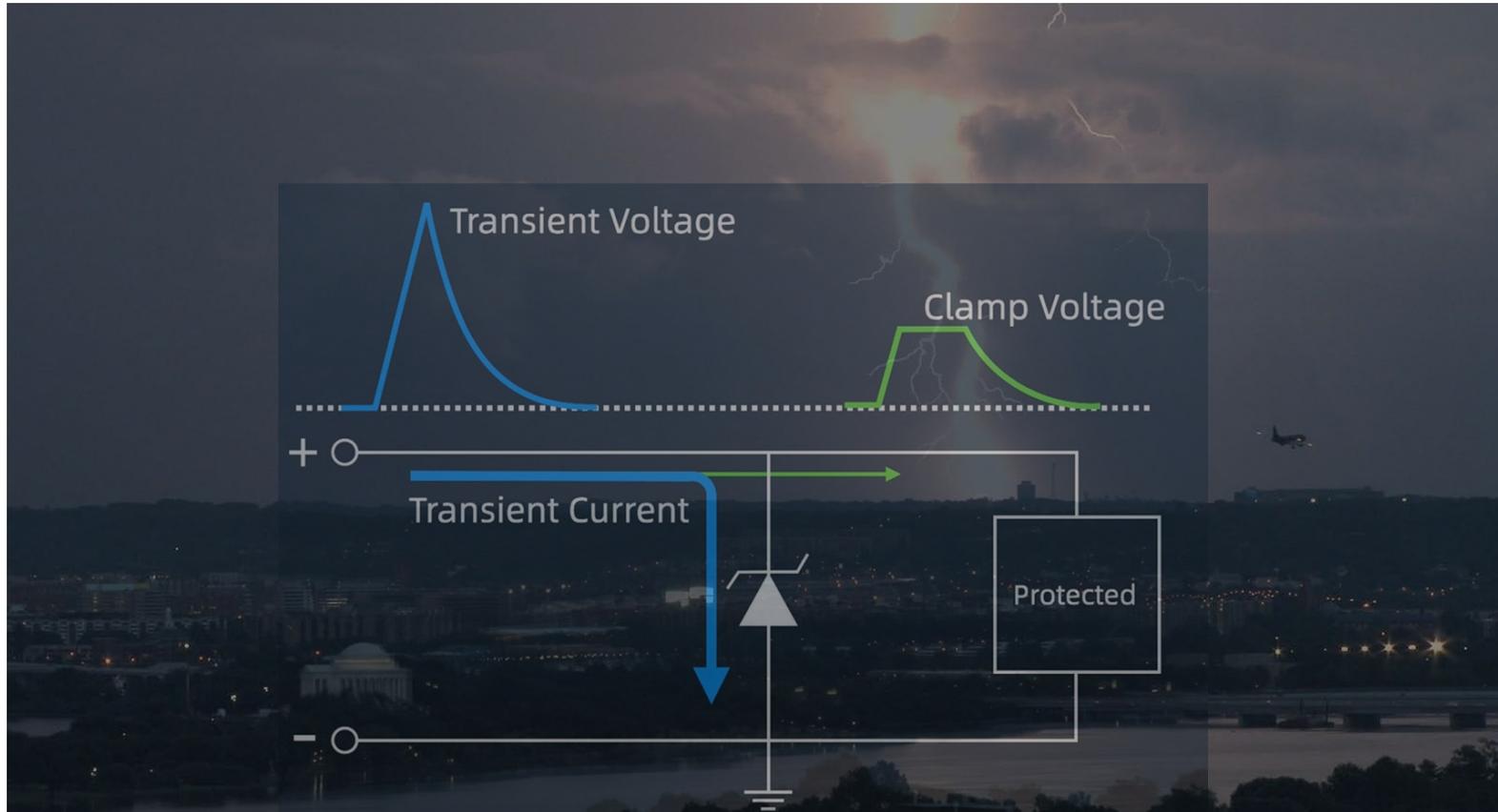
12-Volt Lead-Acid Batteries Charged with PulseTech Charger



12-Volt Lead-Acid Batteries Charged with Typical Charger



# Aircraft-Grade Protection



# P-ACF Results

- 60% thinner transformer
- 80% smaller output caps
- Easier EMI
  - 10x increased frequency
  - Planar shield layer
  - More consistent parameters

The image shows two transformer assemblies side-by-side. The left one is a traditional transformer with a large, bulky core and several large cylindrical capacitors. The right one is a high-frequency planar transformer with a much smaller, more compact core and a single large capacitor. Lines connect text labels to specific components in both transformers.

**Silicon, Low-Frequency**

**Traditional transformer**  
Thickness over 20mm

**Electrolytic capacitor**  
Accounting for about 1/4 of PCB

**Output Capacitors**

**GaN, High-Frequency**

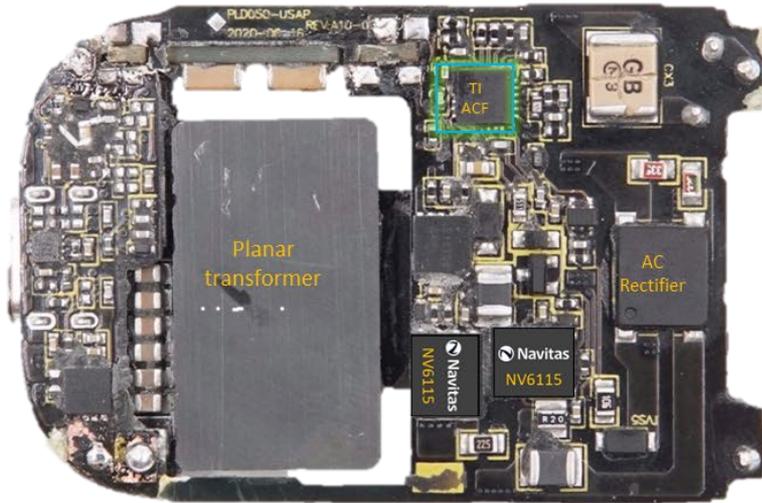
**Gallium nitride (GaN) high-frequency switch**  
3rd-generation wide-band gap semiconductor material

**Brand new Active Clamp Flyback**  
Switch wear and tear close to 0

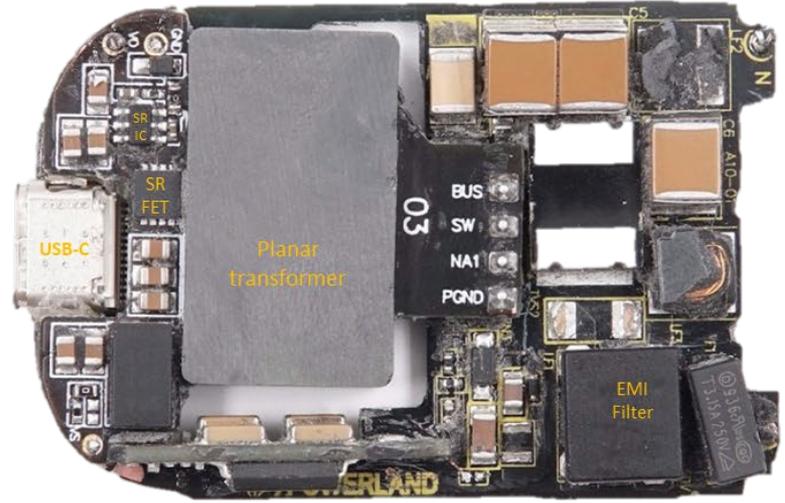
**High-frequency planar transformer**  
8mm Thickness only  
60% ↓ Thickness reduced by



# Spot the Bulk Cap?



Top

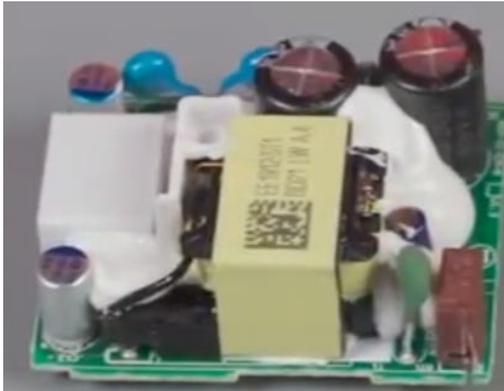


Bottom

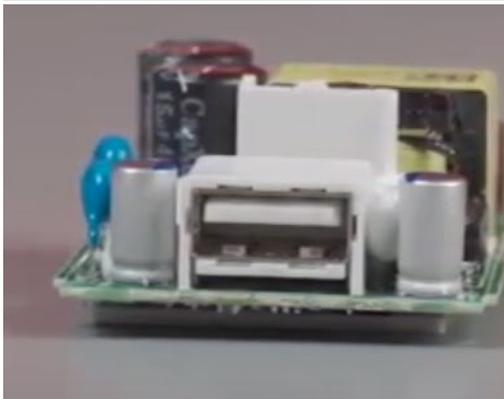


# 50W: Si vs GaN

QR Silicon



P-ACF GaN





“Using GaN to drive transformers to very high frequencies has been the dream of all technical workers for many years. GaN will trigger a technological revolution in the field of power supplies.”

Jialieng (Jeff) ZHANG, OPPO VOOC Super-Charging Chief Scientist



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