Pulsed ACF for Low-Profile GaN Fast Chargers

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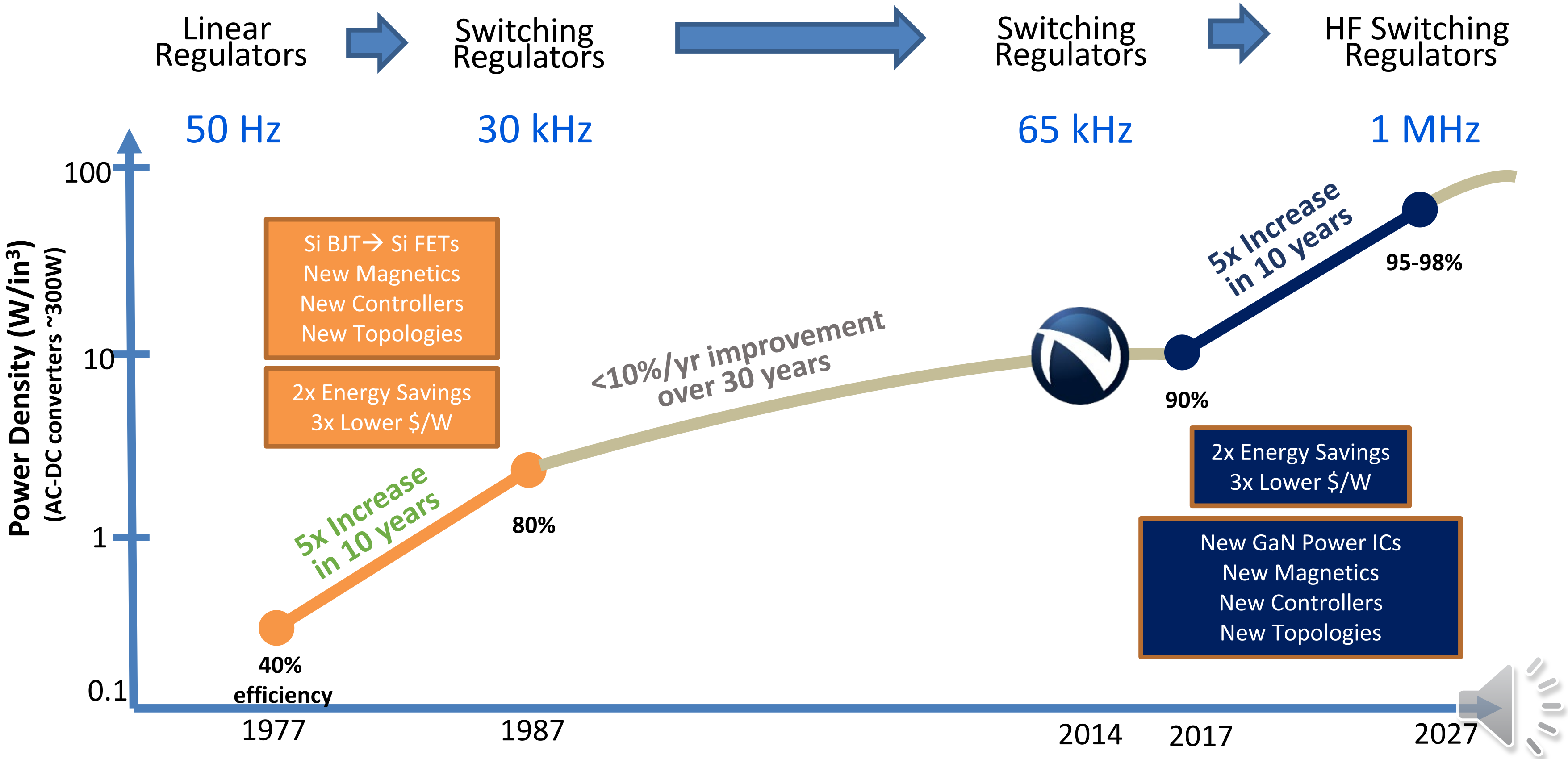
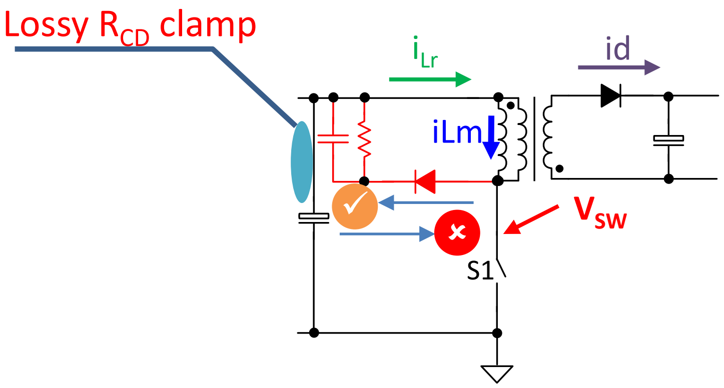
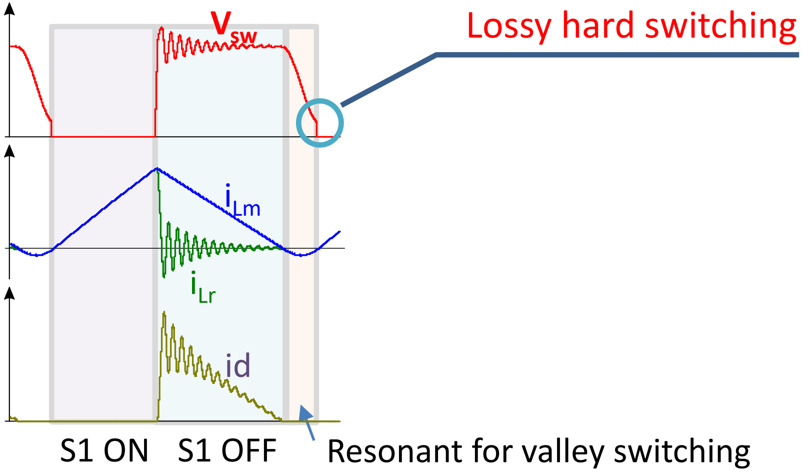
Paper #3060

Second Revolution in Power



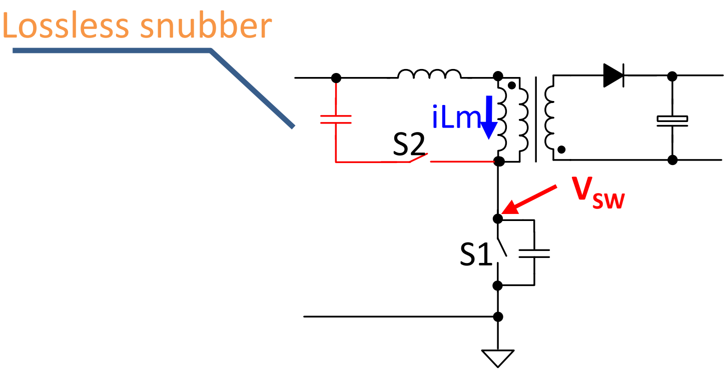
QR Flyback Losses

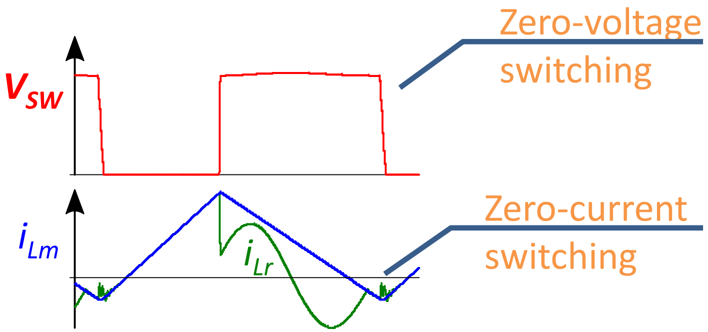




- Quasi-Resonant (QR) Flyback
  - Frequency-dependent ***losses***
    - Leakage inductance
    - Snubber/clamp
    - Partial hard-switching at high line
    - Slow turn-on to minimize EMI
  - Difficult to improve efficiency at high frequency

ACF Enables ZVS and High Frequency

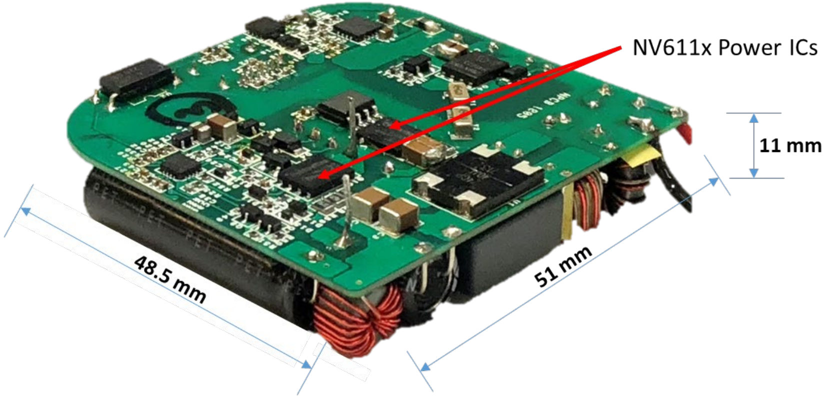




- Active-Clamp Flyback[1] (ACF)
  - No snubber losses, all leakage energy is recovered
  - ZVS soft switching over entire operation range
  - ZCS soft turn-off for output rectifier
  - Clean waveforms reduce EMI
  - Enable small adapter design with high-frequency switching

(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

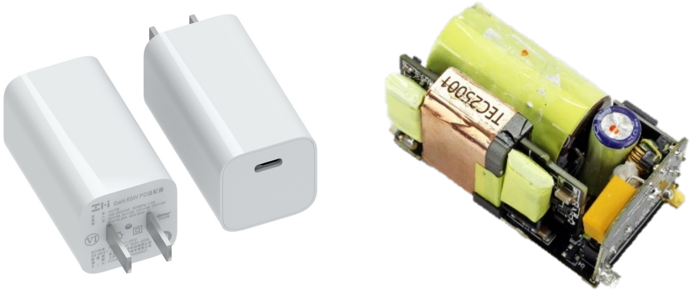
ACF in Mass Production: 2018



45W, 41 cc, 1.1 W/cc

ACF in Mass Production: 2019

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



Xiaomi 65W, 53 cc, 1.2 W/cc

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

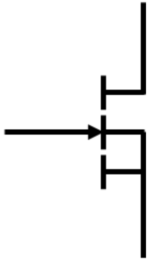
Pulsed Active-Clamp Flyback (P-ACF)

- 3 major technology innovations:

1. Powertrain
2. Topology
3. Transformer

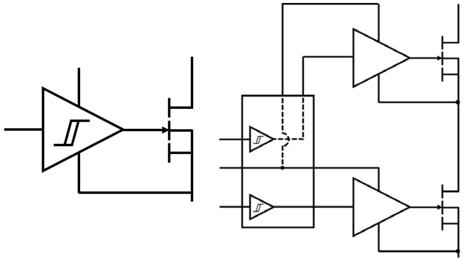
Powertrain: GaN Power ICs

Fastest, most efficient GaN Power FETs



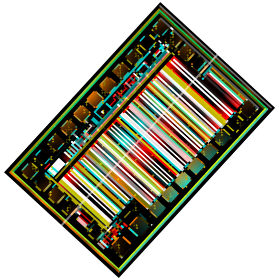
>20x faster than silicon
>5x faster than cascoded GaN
Proprietary design

First & Fastest Integrated GaN Gate Driver with Control & Protection



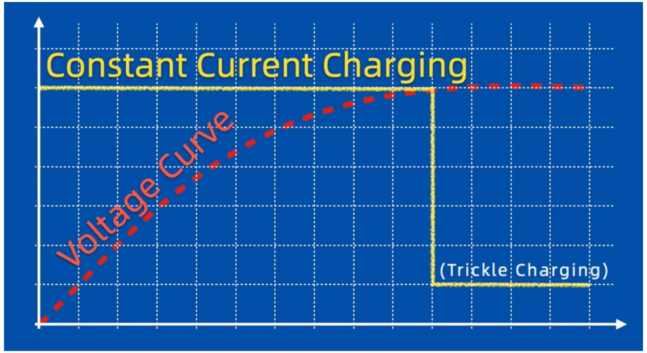
>3x faster than any other gate driver
Proprietary design
120+ patents granted/applied

World's First GaNFast™ Power ICs



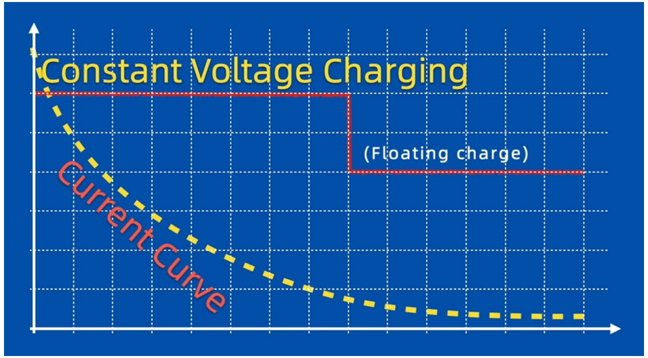
Up to 40 MHz switching, 5x higher density & 20% lower system cost

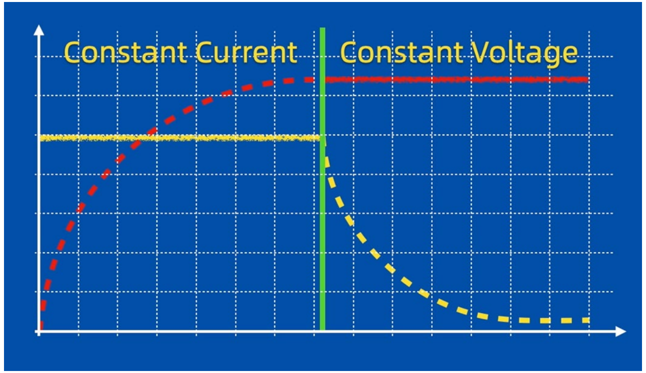
Charging Progression



Constant Current

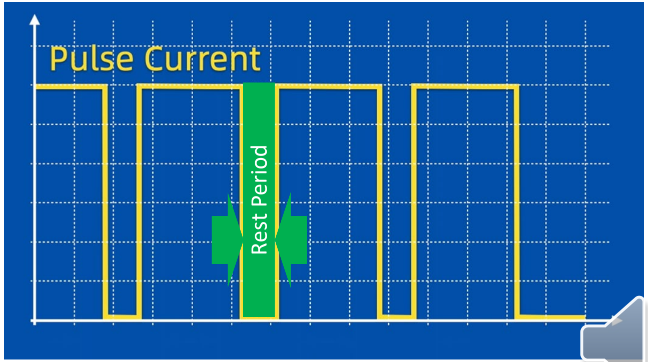
Constant Voltage



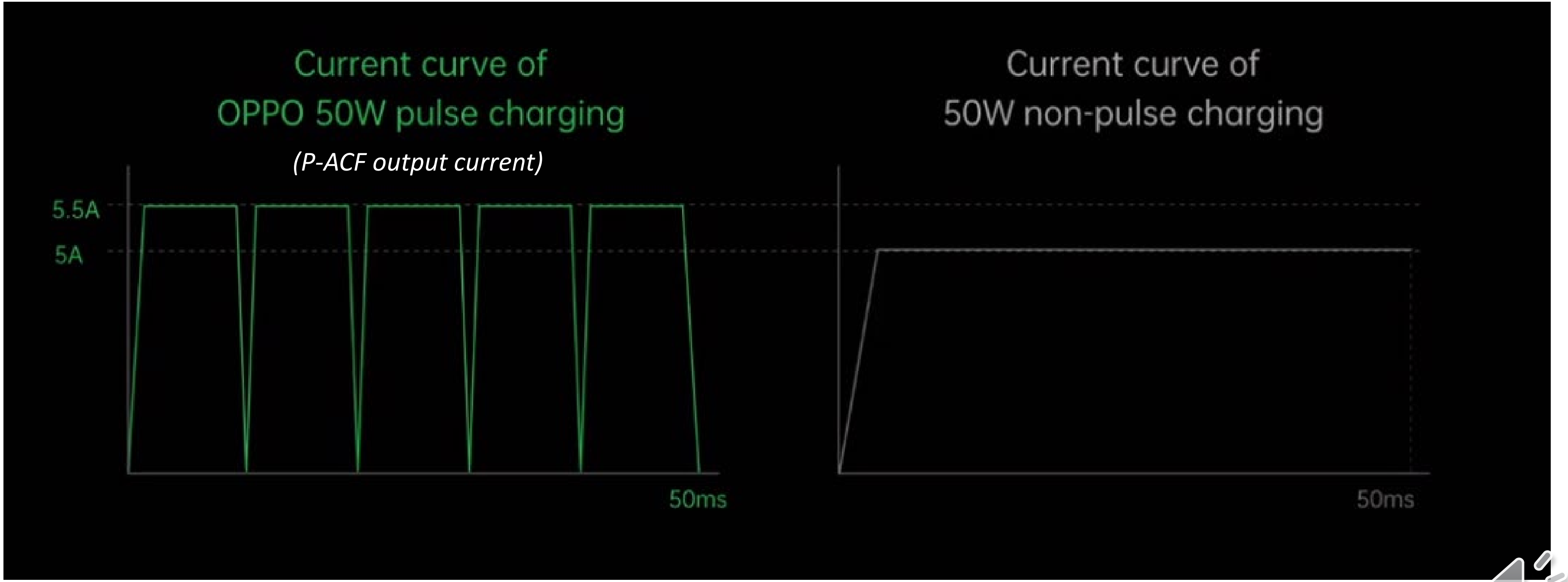


Mixed Mode

Pulsed Current Charging



100 Hz Pulsed Current



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

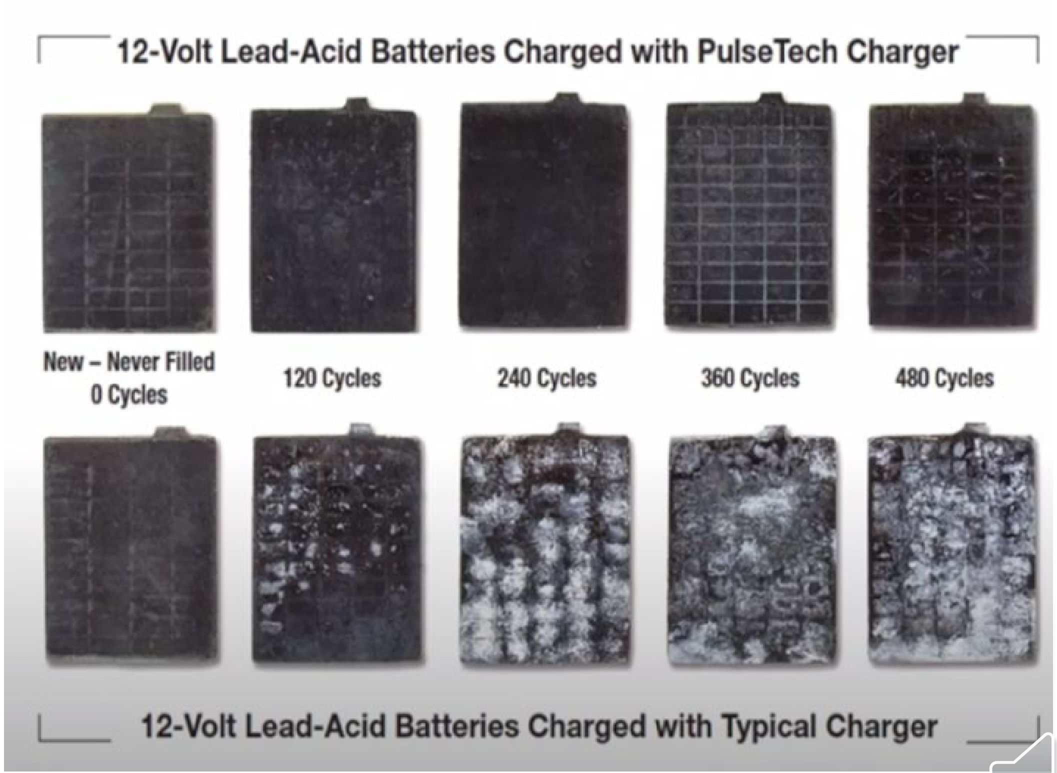
Pulsed Current Charging

<u>Avoids</u> Battery Polarization & heat.

Increase Charging Speed Without Sacrificing Battery Life

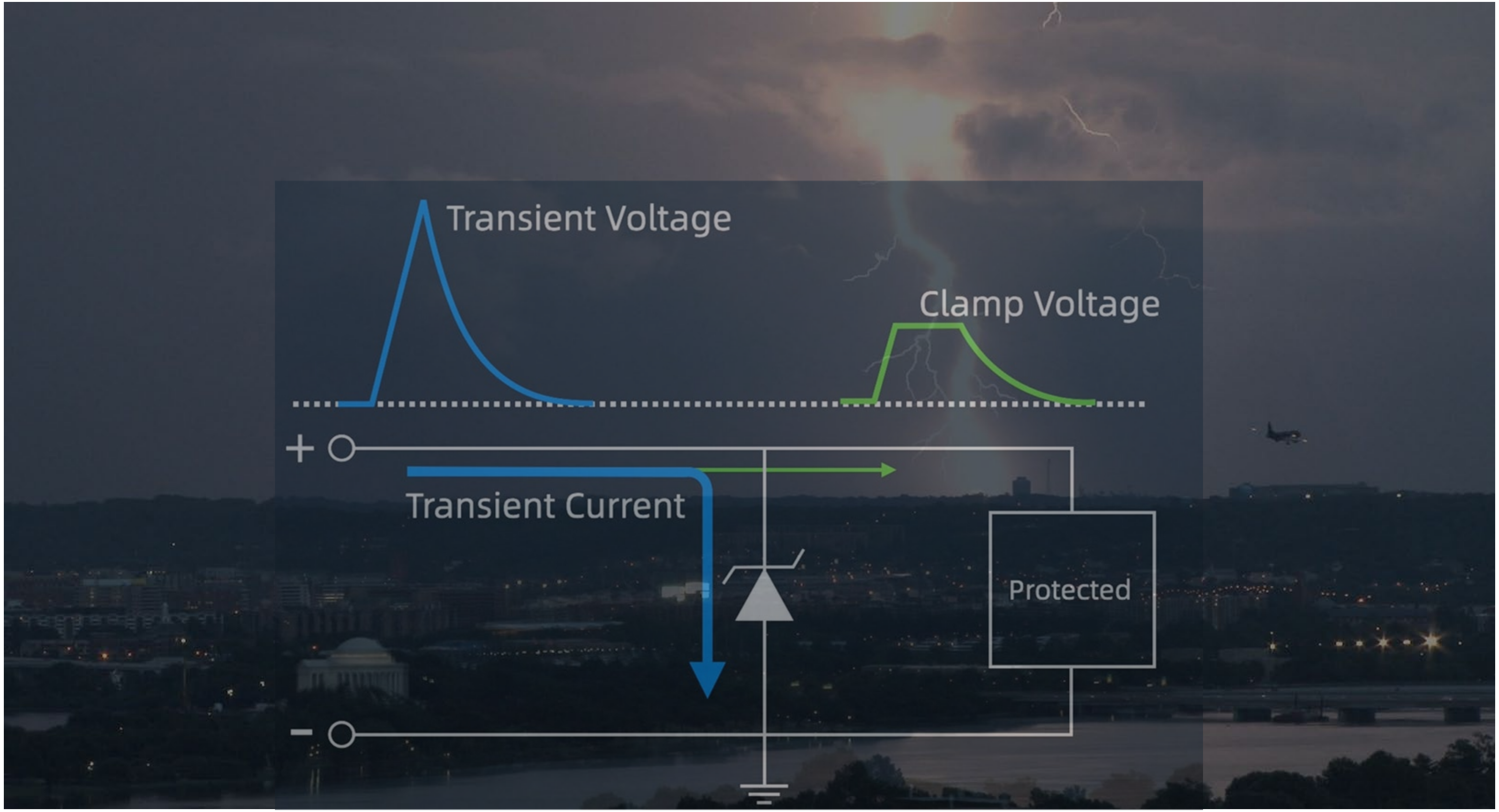
Traditional Charging

Battery Polarization Appears



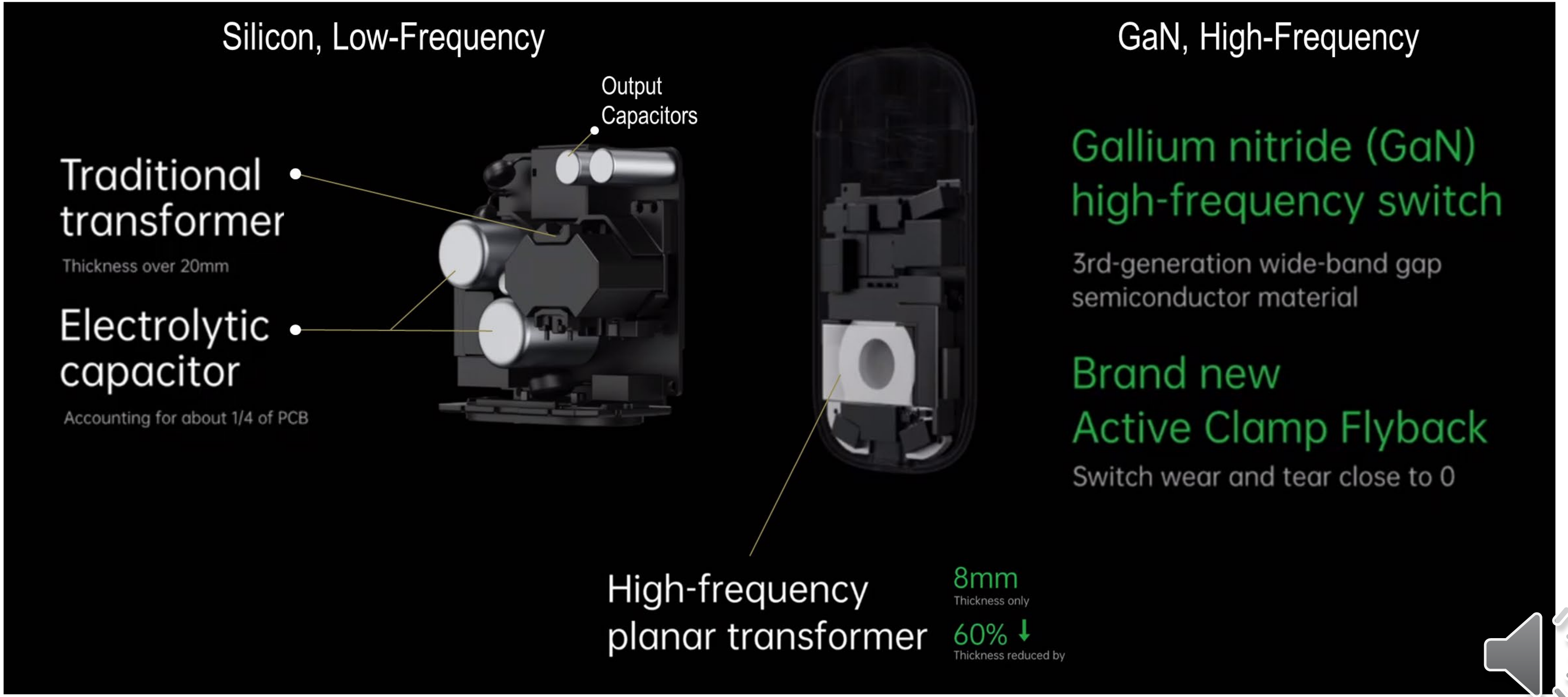
https://www.pulsetech.net/our-technology/pulse-technology.html

Aircraft-Grade Protection

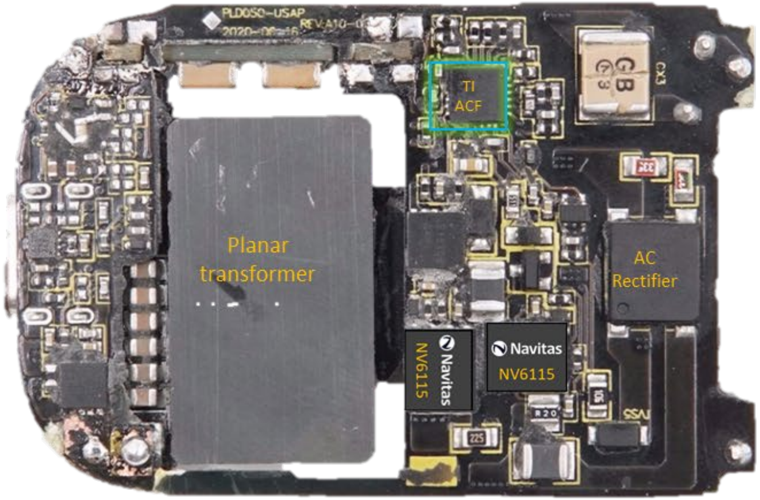


P-ACF Results

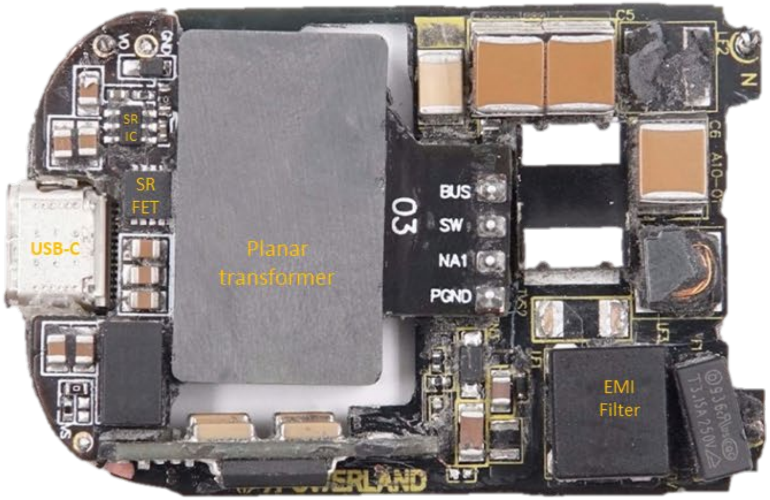
- 60% thinner transformer
- 80% smaller output caps
- Easier EMI
  - 10x increased frequency
  - Planar shield layer
  - More consistent parameters



Spot the Bulk Cap?



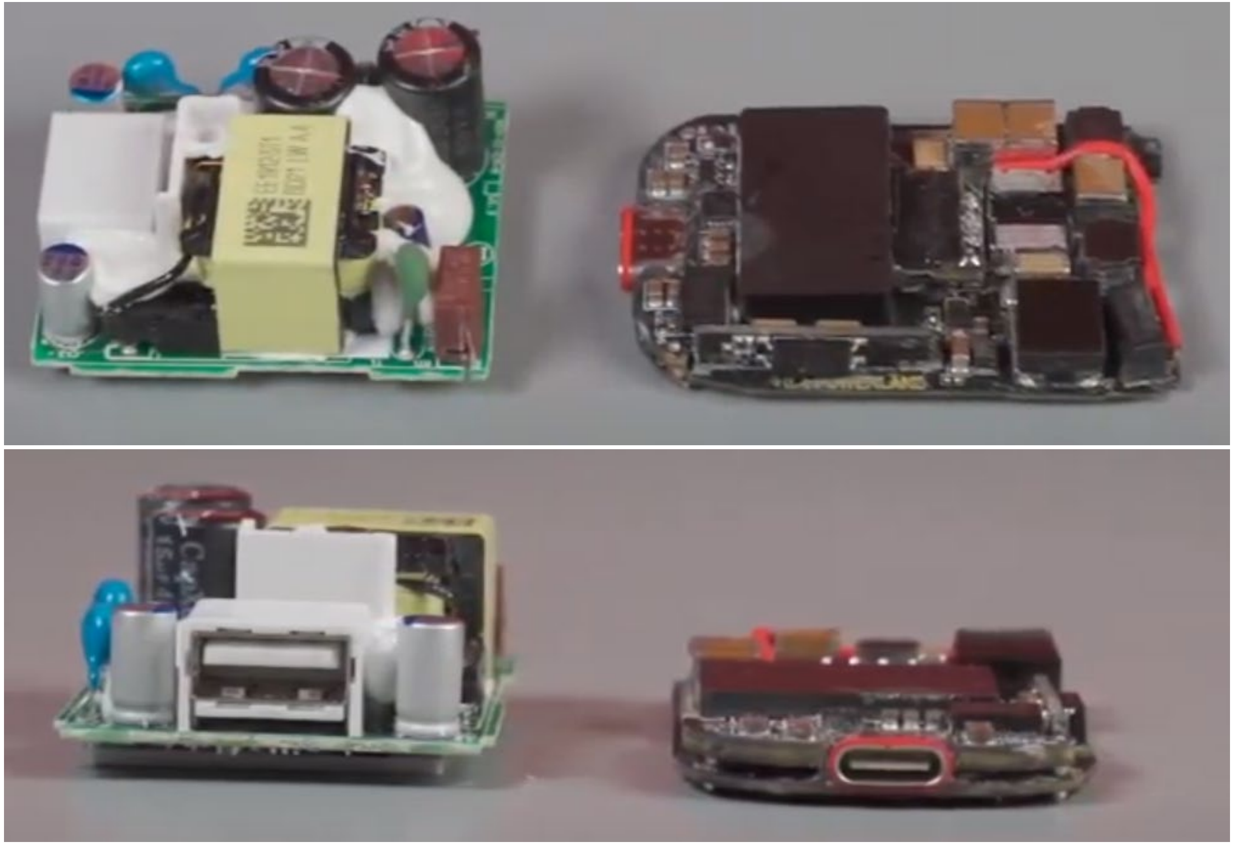
Top



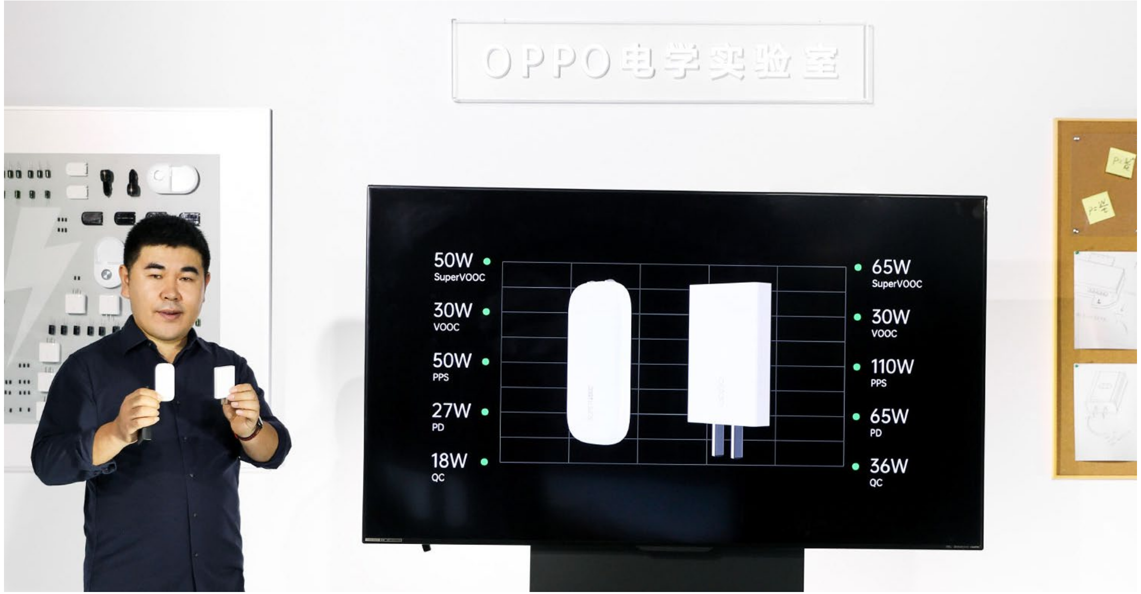
Bottom

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."

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

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