# Design Considerations of Highly-Efficient Active Clamp Flyback Converter Using GaNFast™ Power ICs

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# How to Improve Power Adapter Density?

Navitas

Traditional Travel Adapter and Chargers

5 W/in³
Samsung 25 W

7 W/in³
Apple 45 W

?

USB PD and Quick Charge

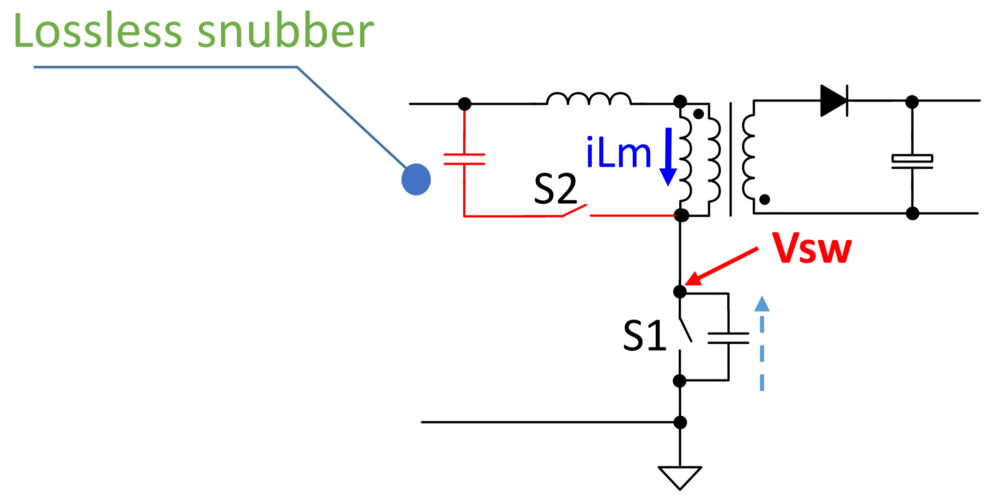
CERTIFIED USB™ CHARGER 45W

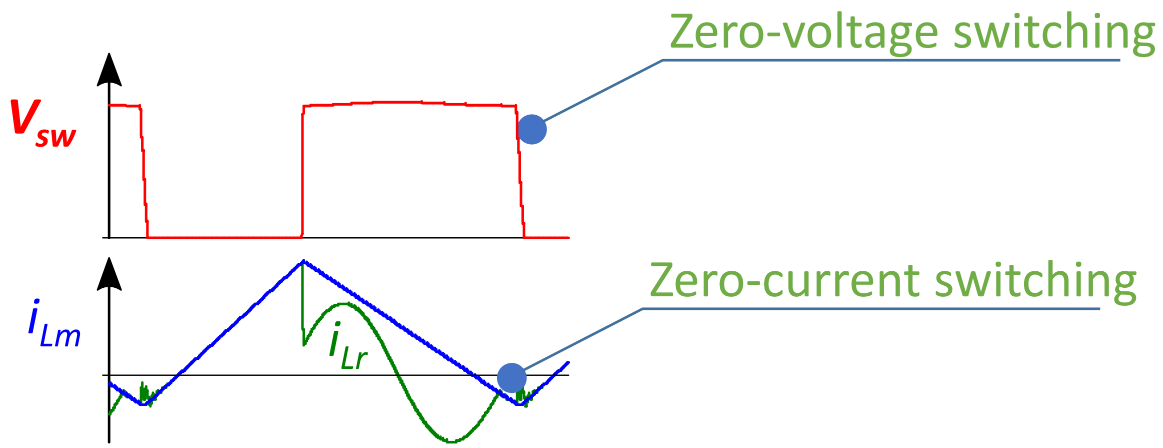
Qualcomm® Quick Charge™

> 20 W/in³

- Added power in USB PD and Quick Charge requires dramatically higher power density (>20 W/in³)
- Higher efficiency and lower power loss are required in high density adapters
- How to dramatically improve the power density?

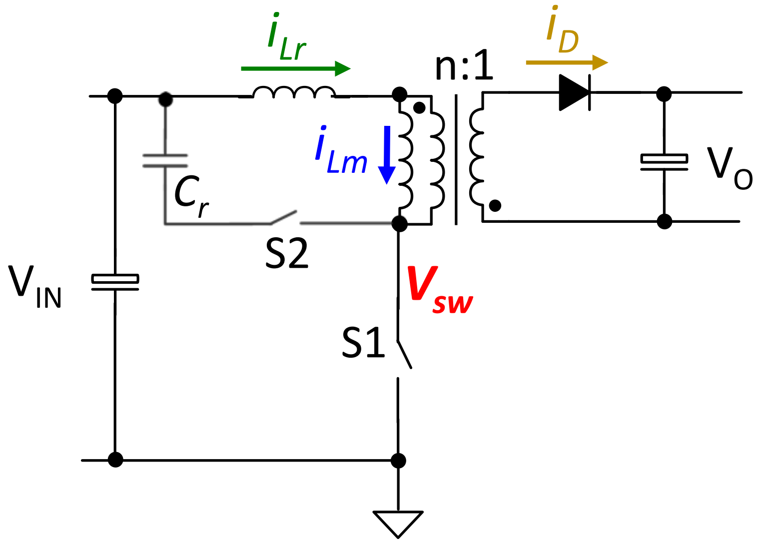
# ACF Enables ZVS and High Frequency Switching

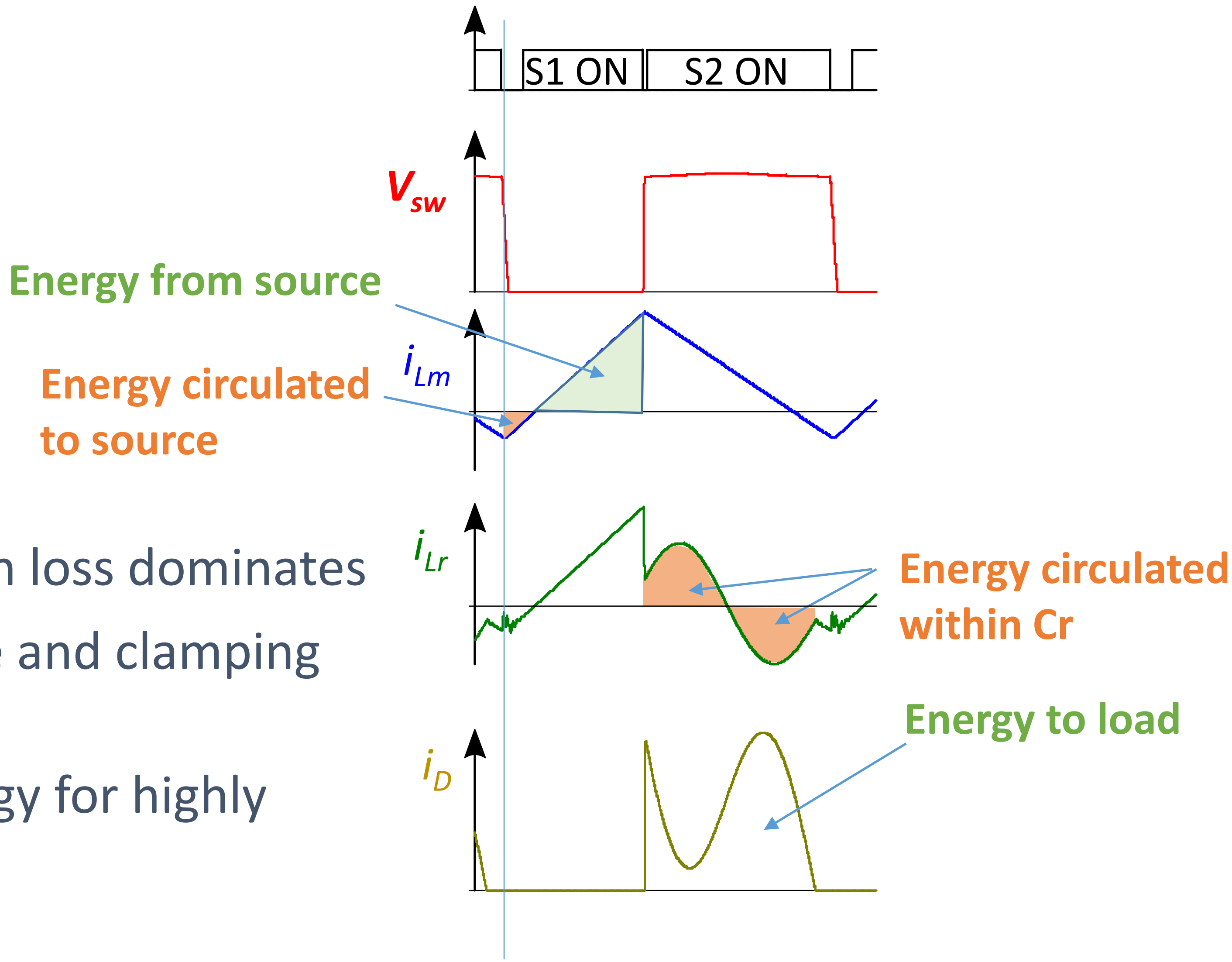



- No snubber losses, all leakage energy is recovered
- ZVS soft switching over entire operation range
- ZCS soft turn-off for output rectifier
- Clean waveforms reduce EMI
- Enable small adapter design with high-frequency switching

# Towards Highly Efficient ACF




- Soft-switching is achieved, conduction loss dominates
- Circulating energy to the input source and clamping capacitor Cr, increasing current RMS
- Reduce both parts of circulating energy for highly efficient ACF

# Minimizing Energy Circulated Back to Source

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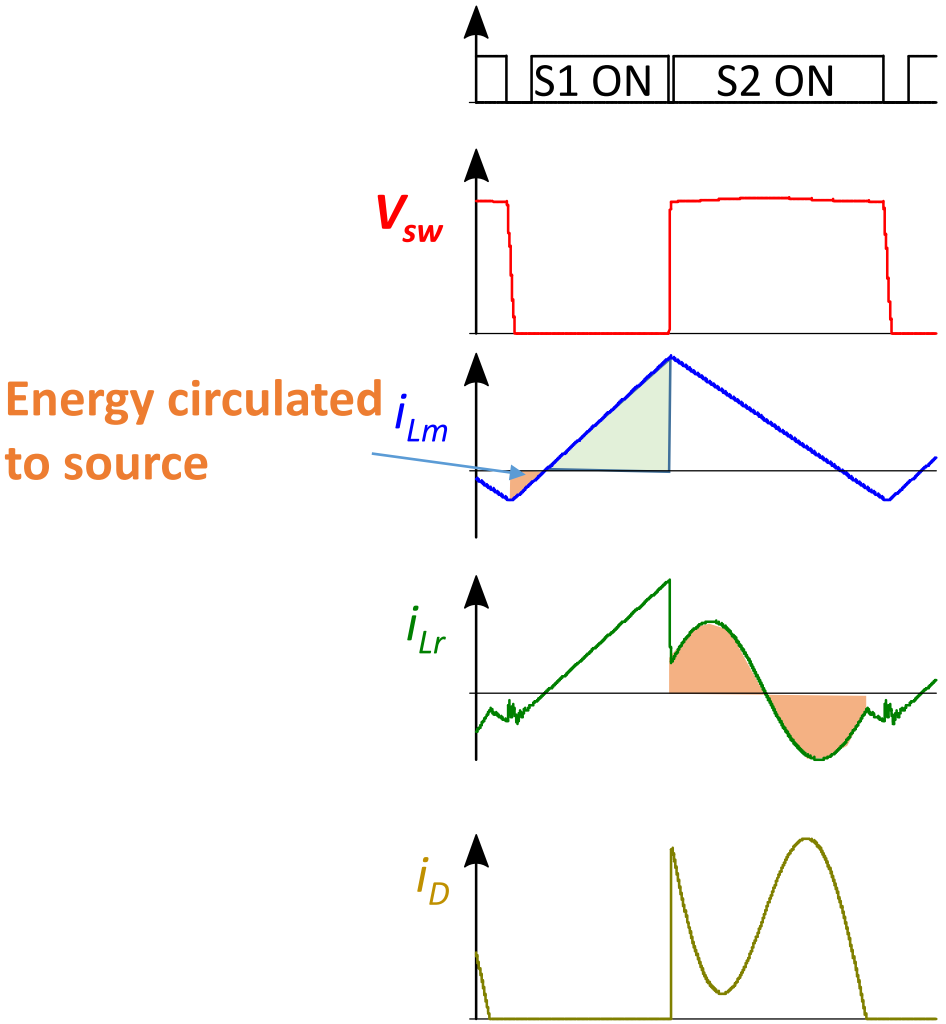
- Minimize negative $i_{Lm}$ for ZVS
  - → Depending on $C_o(tr)$
  - GaN has only ½ $C_o(tr)$ even with ½ $R_{DS(ON)}$
  - GaN needs less circulating energy

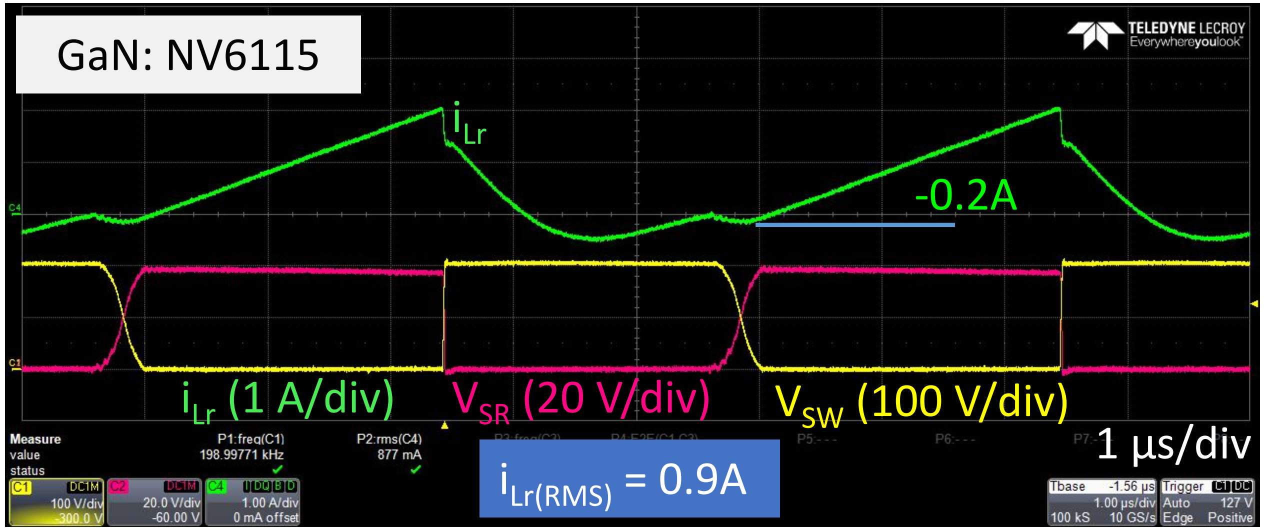
| | IPA60R299CP | IPA60R385CP | NV6115 |
|---|---|---|---|
| Voltage Rating (V) | 650 | 650 | 650 |
| $R_{DS(ON)}$ | 270 | 350 | 160 |
| $C_o(tr)$ (pF) | 120 | 96 | 50 |
| $Q_g$ (nC) | 22 | 17 | 2.5 |
| $Q_{rr}$ (nC) | 3900 | 3100 | 0 |

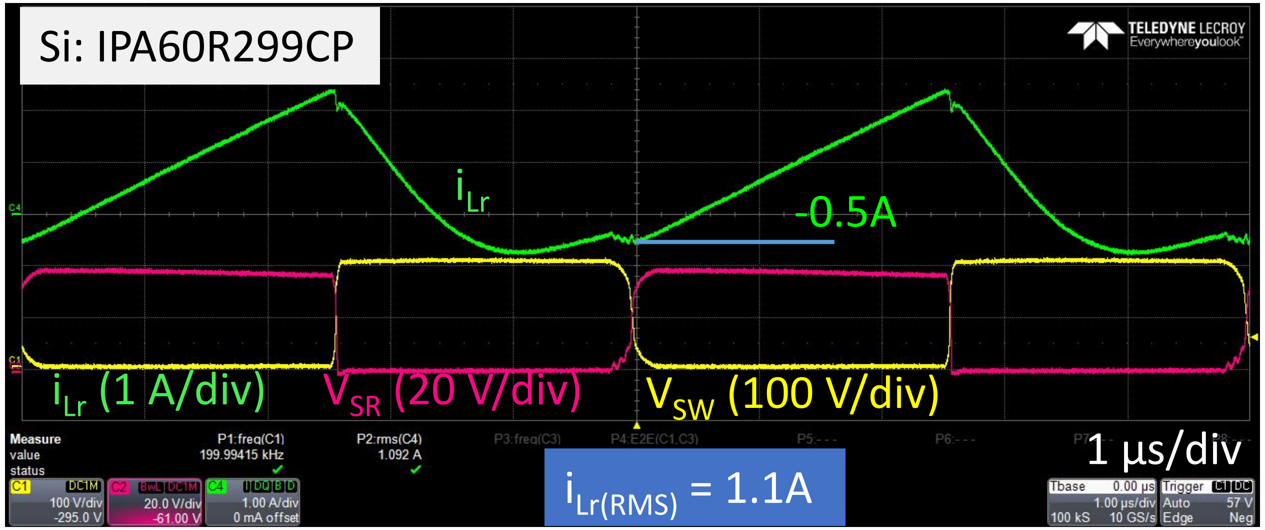





Dr. Lingxiao Xue, APEC 2018

# GaN ACF Minimized Negative $i_{Lm}$

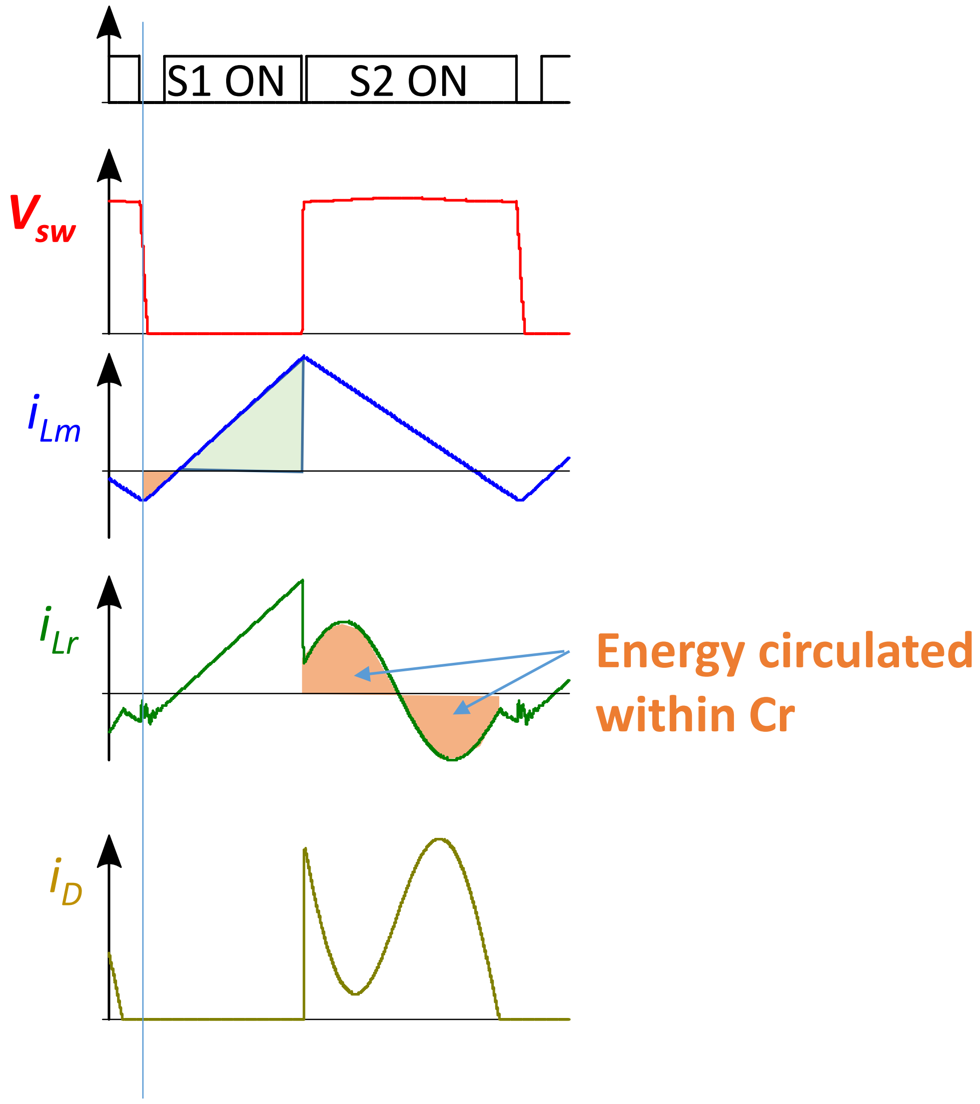



- GaN ACF needs only 0.2A negative current for ZVS vs. Si's 0.5A
- GaN ACF RMS is only 0.9A vs. Si's 1.1A
- Besides,
  - GaN has **no** body diode loss
  - Low high-frequency gate-charge loss

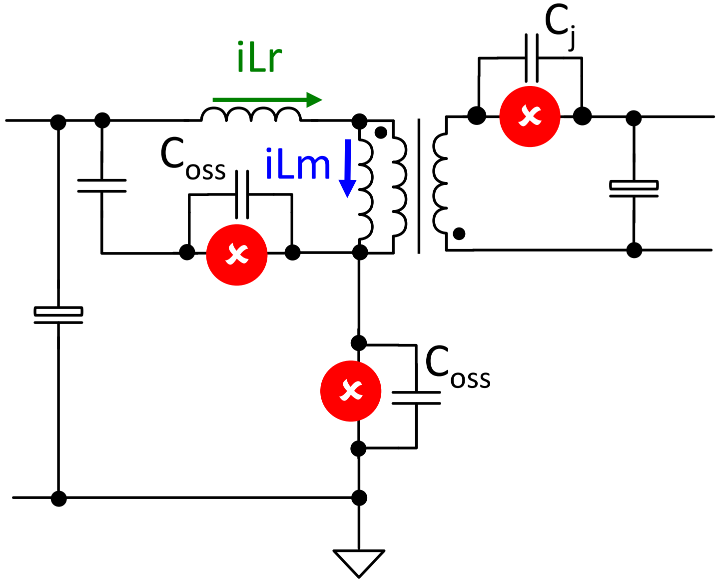
# Minimizing Energy Circulated in Cr

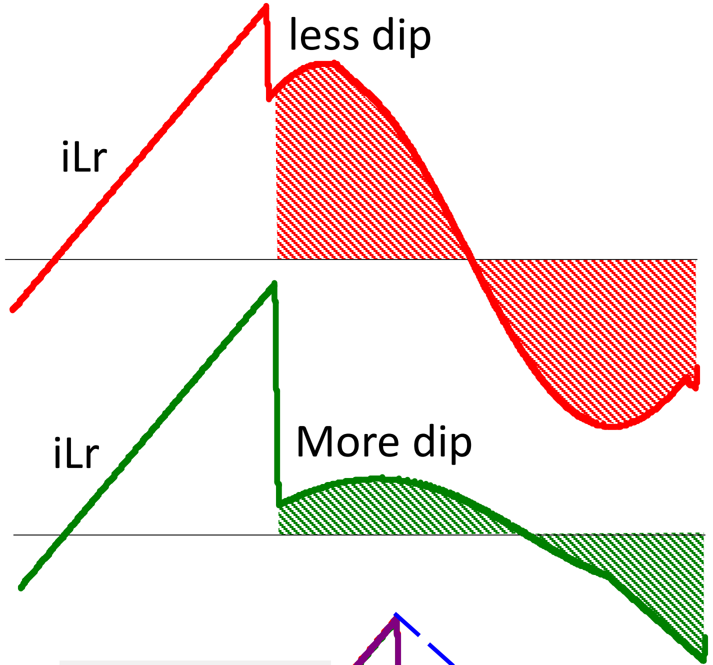
- Minimizing the shaded area
- Two methods identified
  - Creating deeper current dip
  - Using secondary resonant scheme

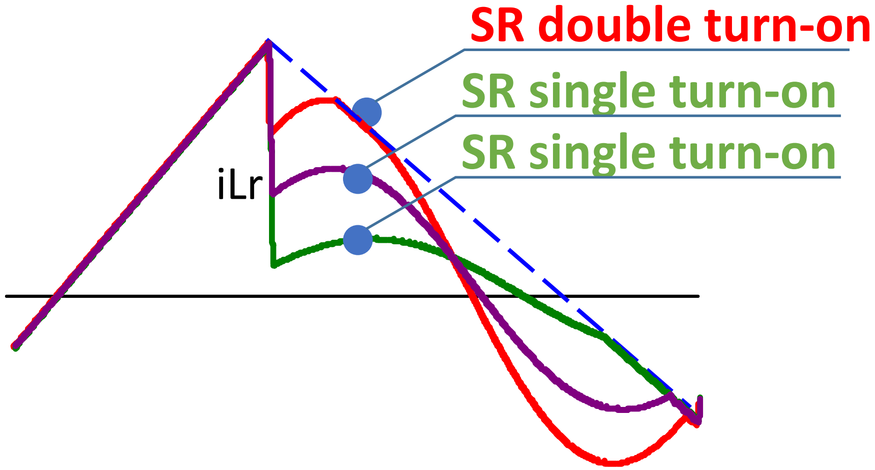


## Method 1

# GaN Increases Current Dip

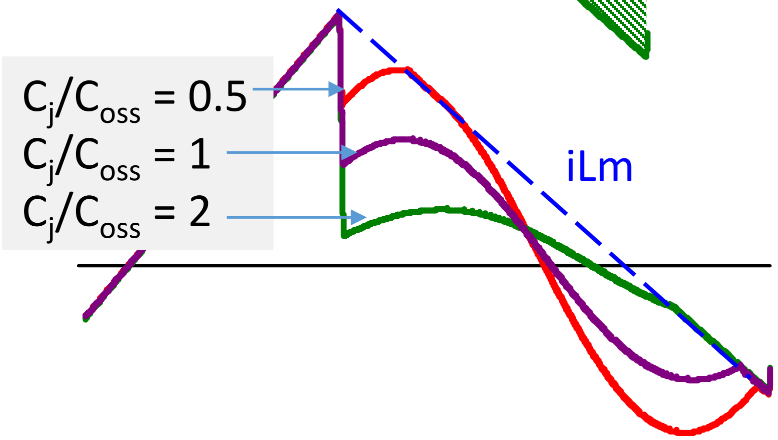


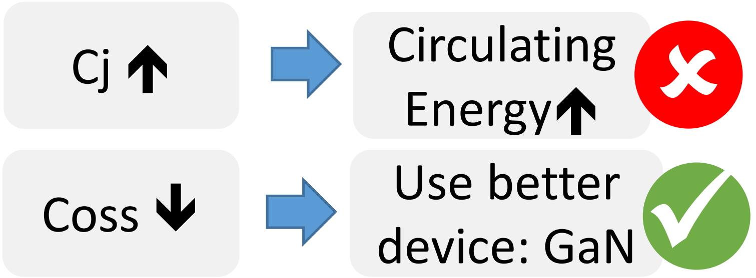




Current dip ↑

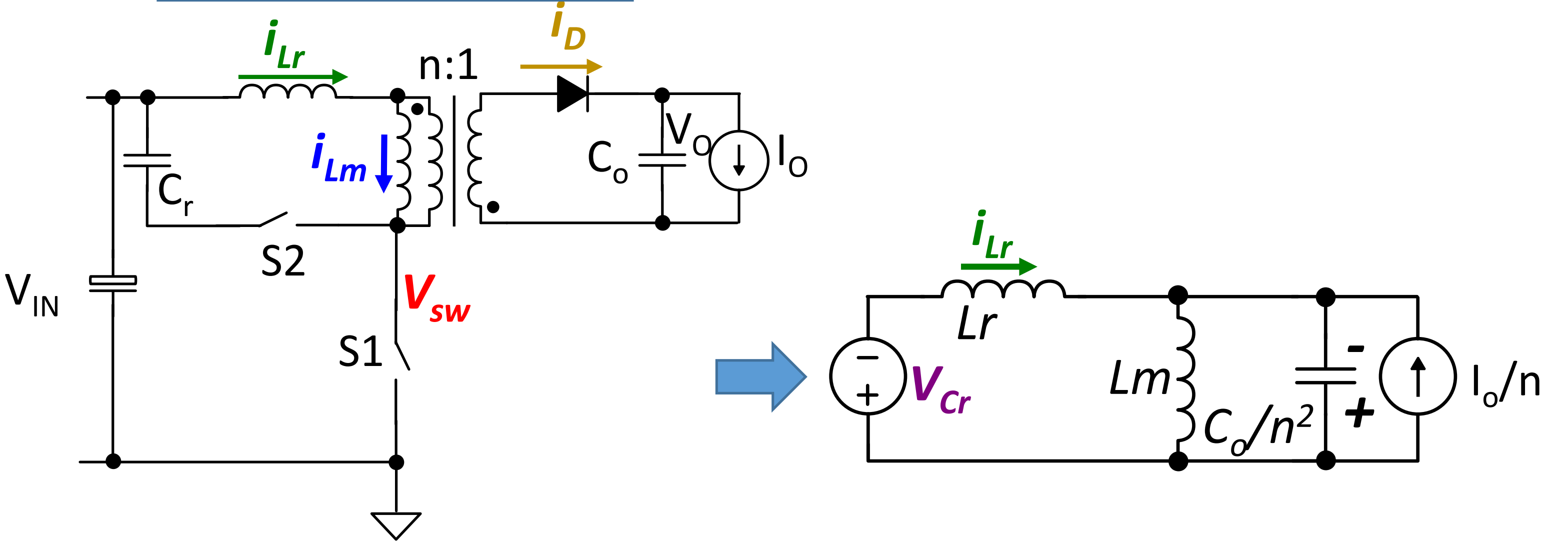
- RMS value $i_{Lr(RMS)}$ ↓
- Less SR double turn-on ↓

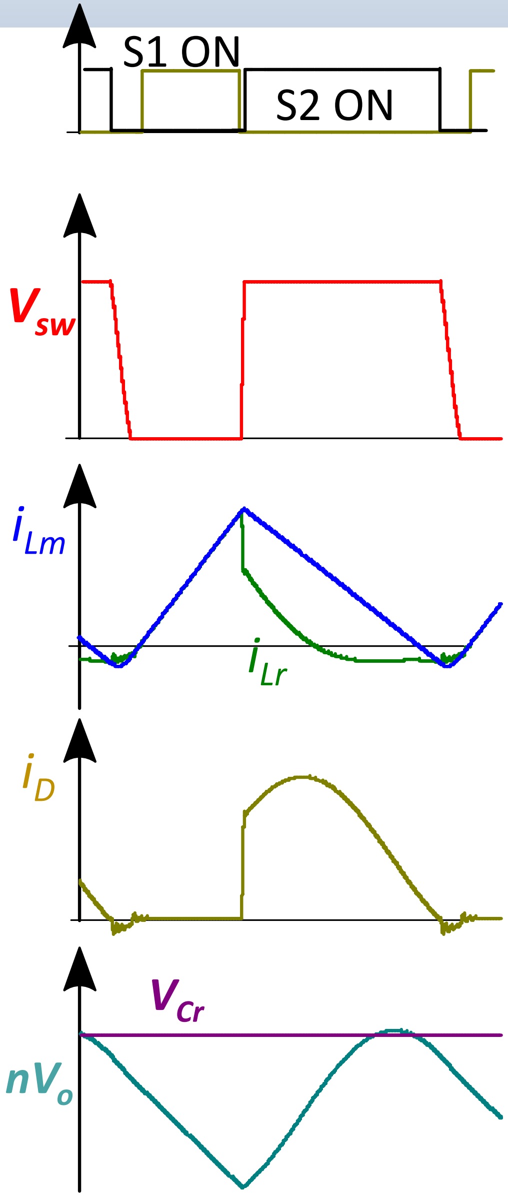


# Secondary Resonance Scheme*

Big Cr, small Co

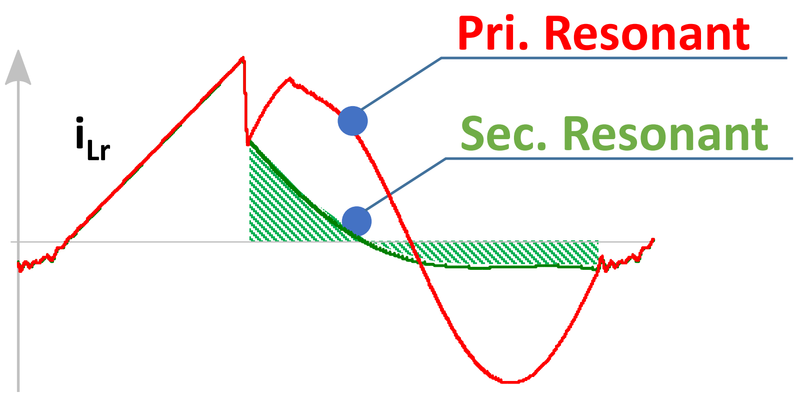


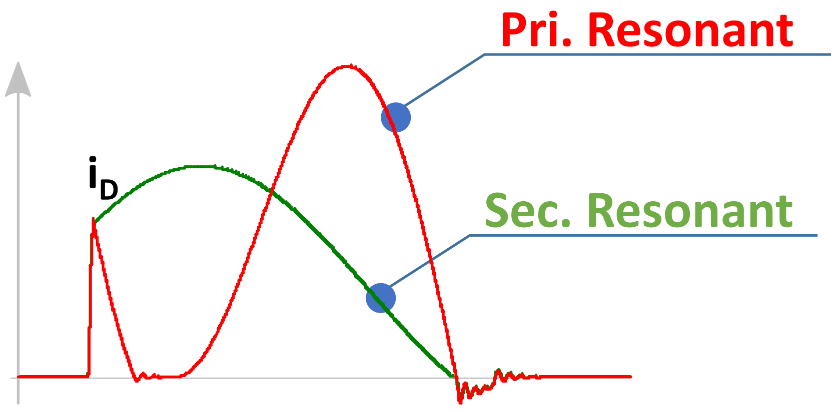



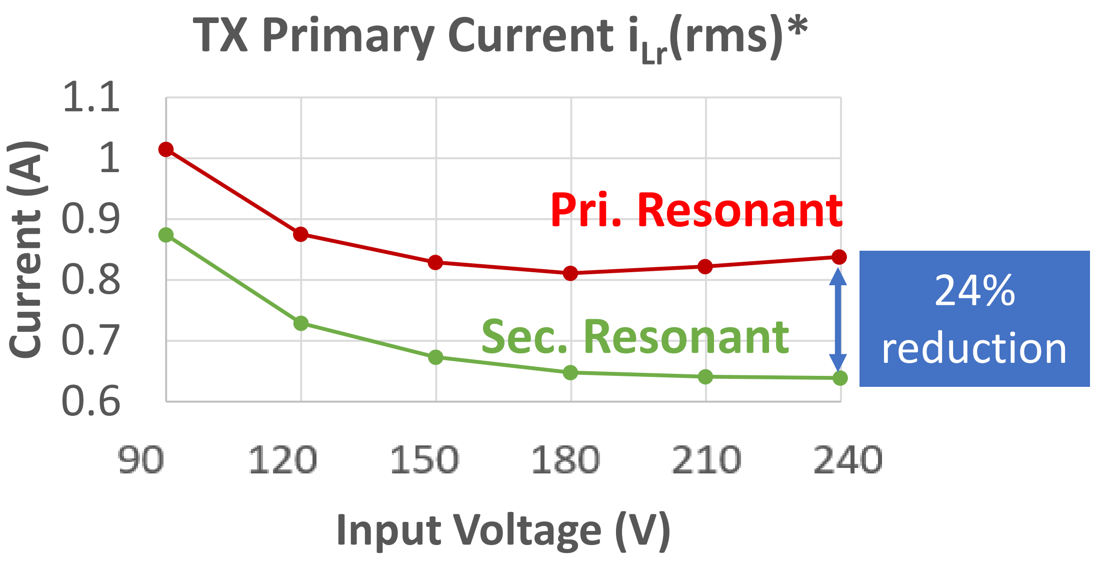

- Output capacitor to resonate with transformer leakage
- Clamping capacitor Cr has low voltage ripple
- More current pushed to the secondary side

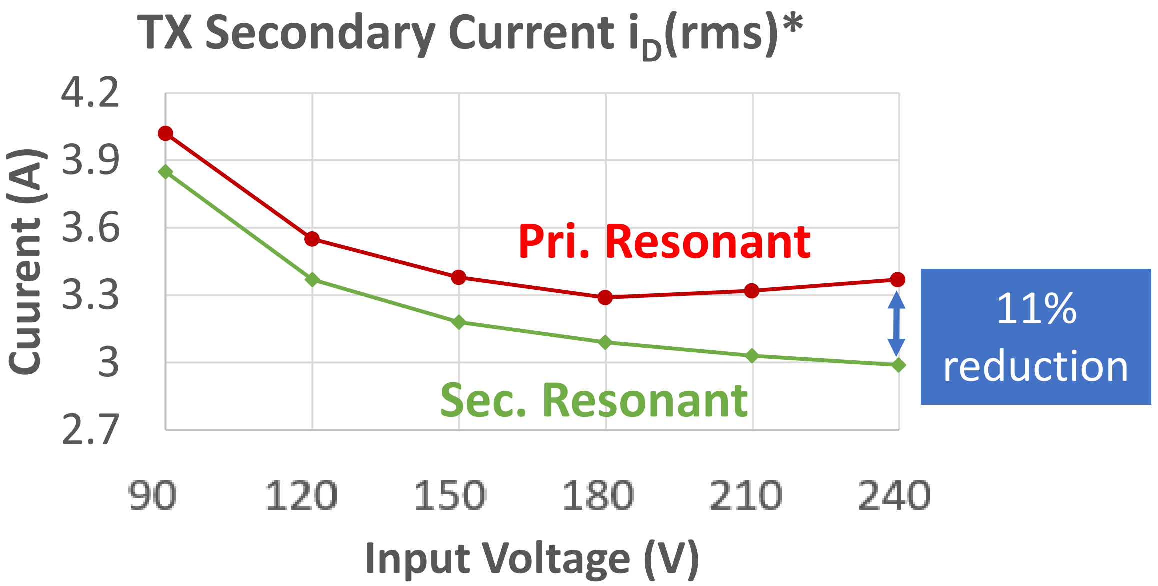
*Navitas Patent Pending

# Secondary Resonance Reduces Circulating Energy




*Measured results of 45W ACF

# 65W USB-PD ACF Using GaNFast™ Power ICs

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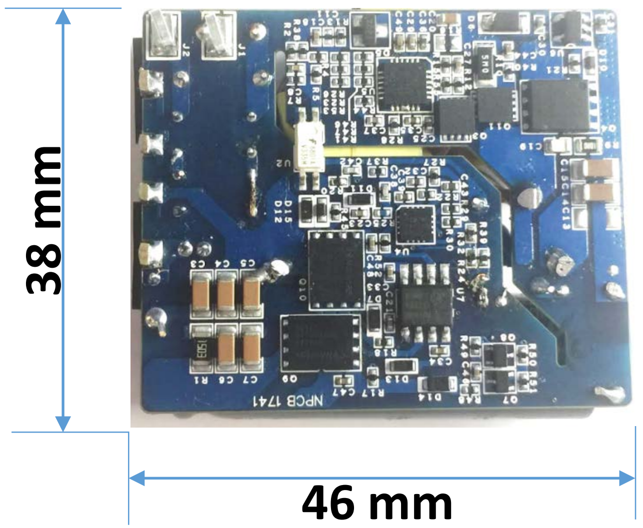
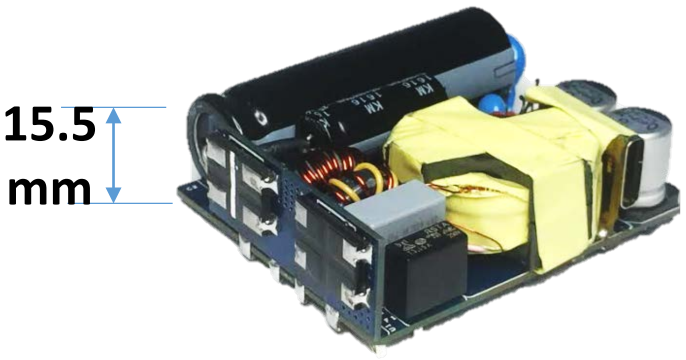
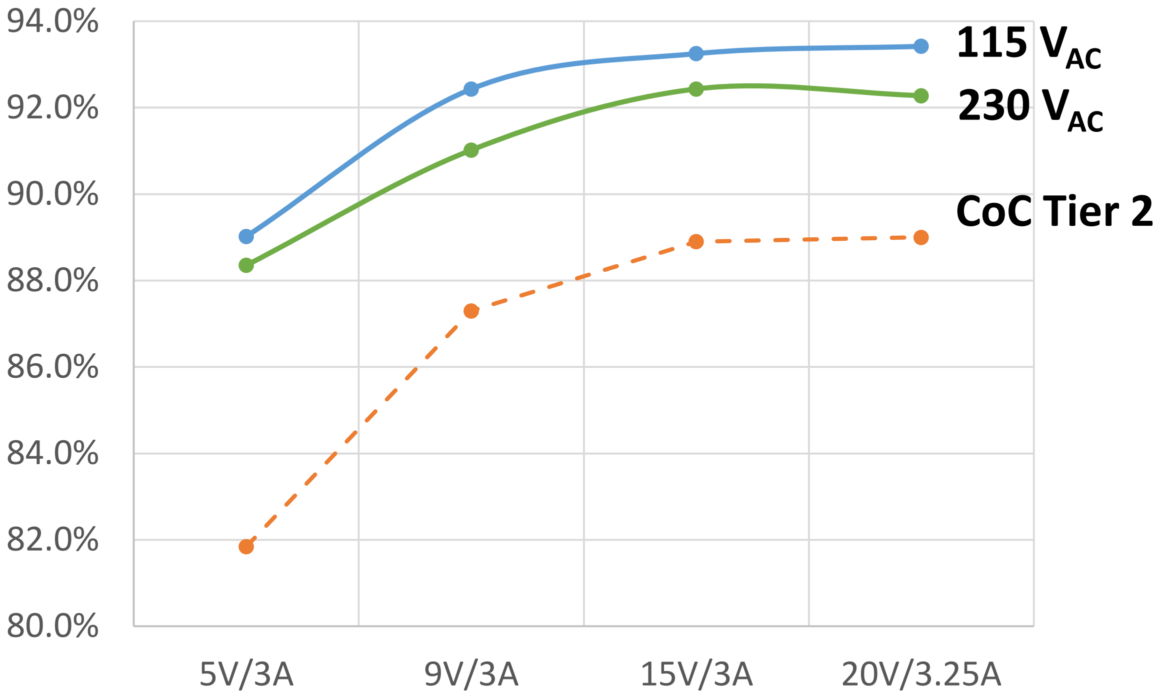


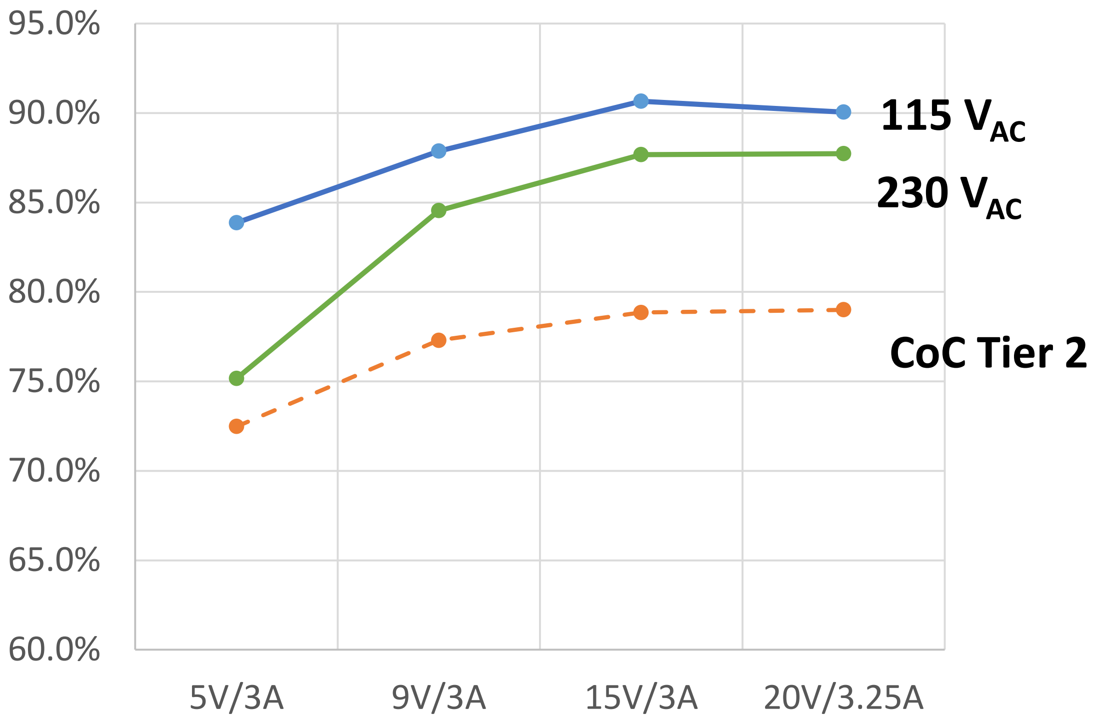

| | |
|---|---|
| **Input** | Universal AC (85-265$V_{AC}$, 47-63Hz) |
| **Output** | Type C, USB-PD 2.0 (5-20V) |
| **Frequency** | 250-350 kHz |
| **Power Density** | 2.4 W/cc (39 W/$in^3$) uncased<br>1.5 W/cc (24 W/$in^3$) cased |
| **Construction** | 4-layer, 2-oz Cu PCB,<br>“No heatsink” design |

# Efficiency Meets CoC Tier 2 and DOE LV VI

Efficiency: 4-Points Average




Efficiency: 10% Load



# Integration Eases ACF Design

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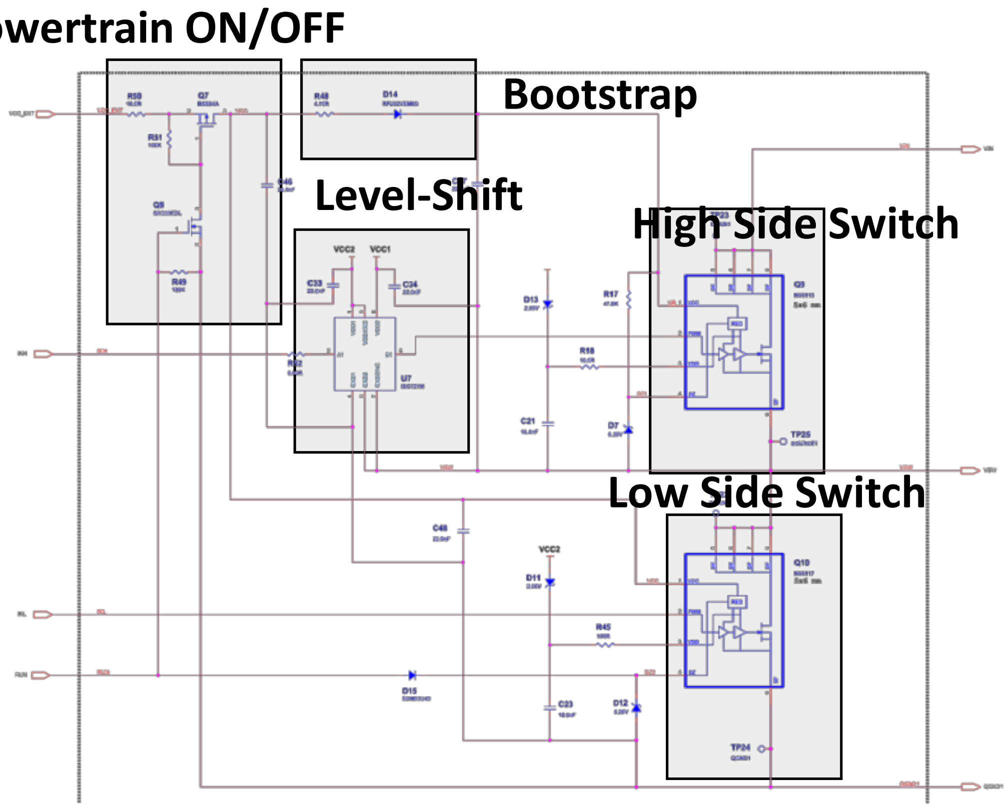
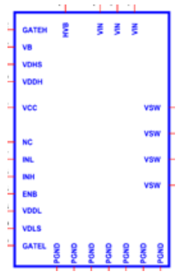
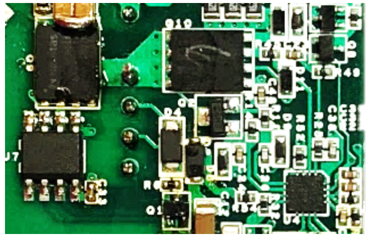



GaNFast™
NV6252 Half-Bridge



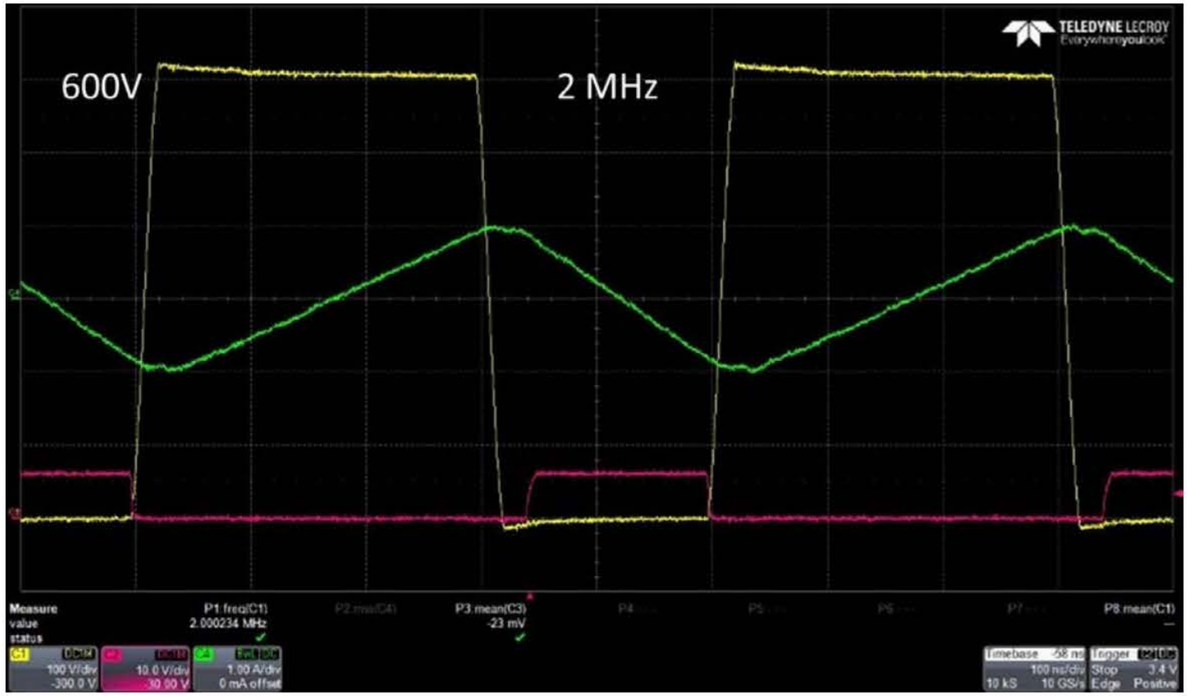



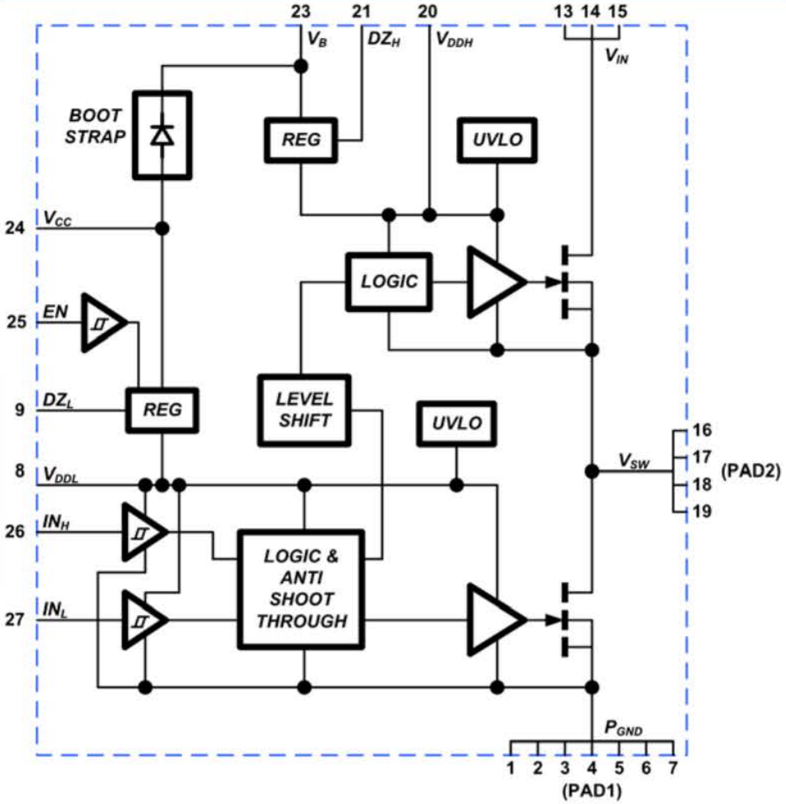
- Saved PCB space
- Avoided powertrain layout mistakes -> Noise confined
- Reduces standby loss

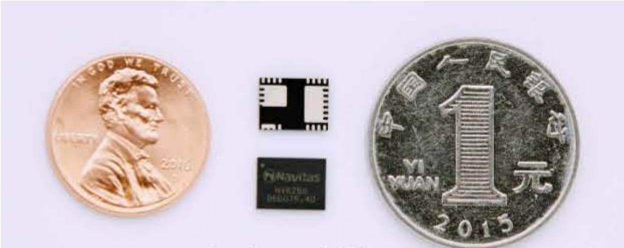
# GaNFast™ Half-Bridge Power IC



- Asymmetric Half-Bridge for ACF
  - 2x GaN FETs (High-side 600 mΩ + Low-side 300 mΩ)
  - 2x GaN drivers
  - GaN Logic (level-shift, bootstrap, UVLO, shoot-through, ESD)



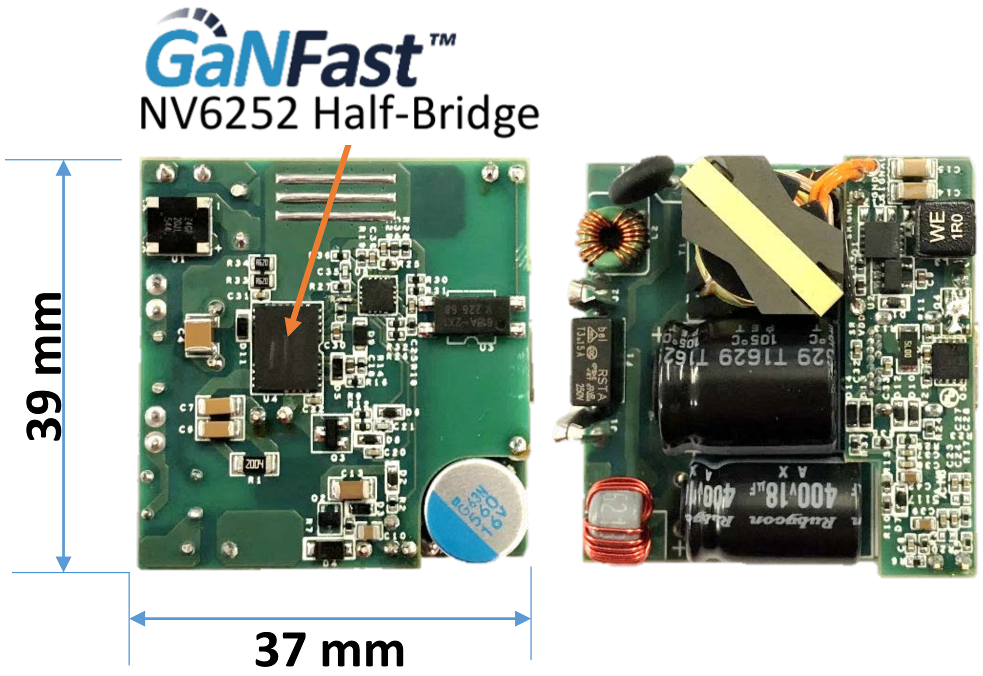



6 x 8 mm QFN

# 27W USB-PD 3.0 Using GaNFast™ HB Power IC

Navitas



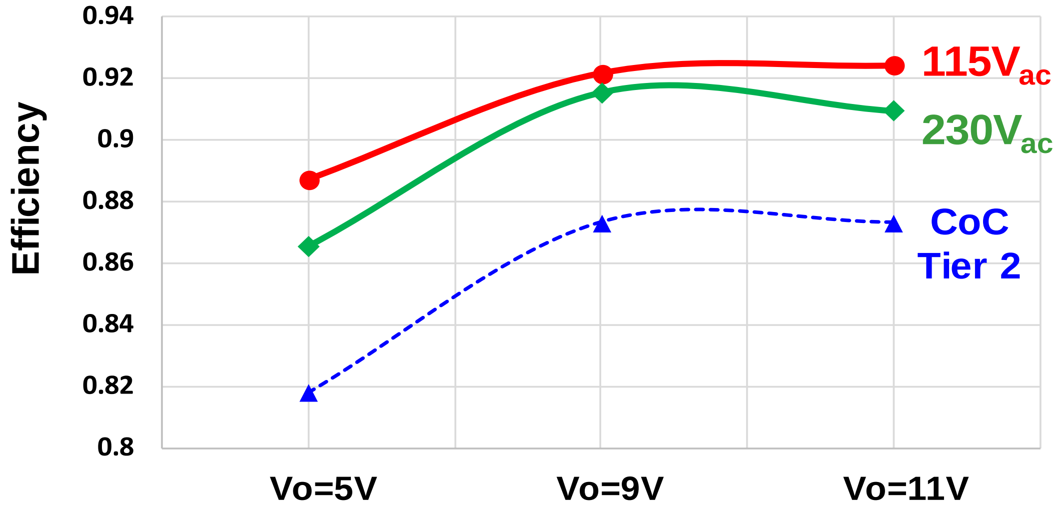


| | |
|---|---|
| **Input** | Universal AC (85-265$V_{AC}$, 47-63Hz) |
| **Output** | Type C, USB-PD 3.0 (27W) |
| **Frequency** | 200-400 kHz |
| **Power Density** | 1.2 W/cc (19 W/in$^3$) uncased<br>0.7 W/cc (11 W/in$^3$) cased |
| **Construction** | 4-layer, 2-oz Cu PCB,<br>“No heatsink” design |

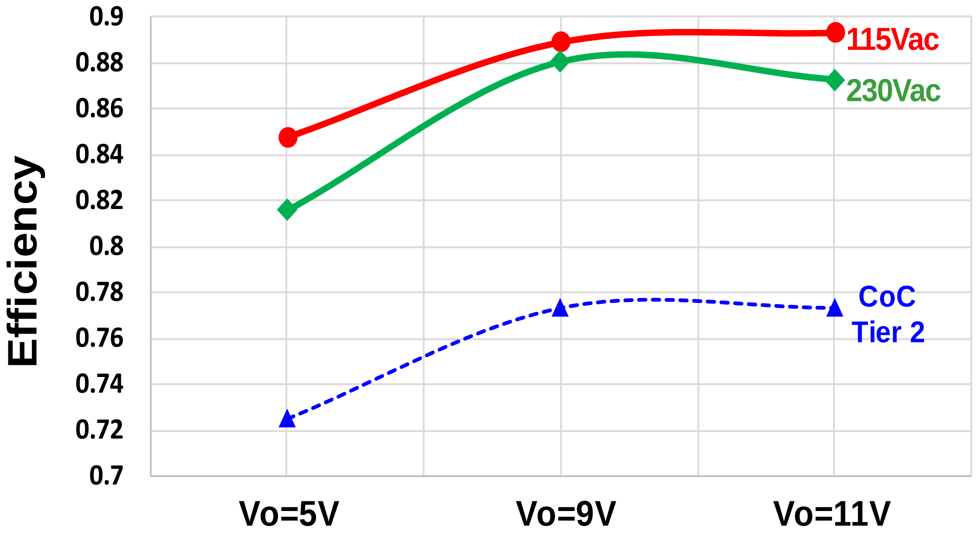
Efficiency:

# Meets CoC Tier 2 and DOE LV VI

## Efficiency: 4-Points Average




## Efficiency: 10% Load



# High Frequency 65W ACF with GaN ICs

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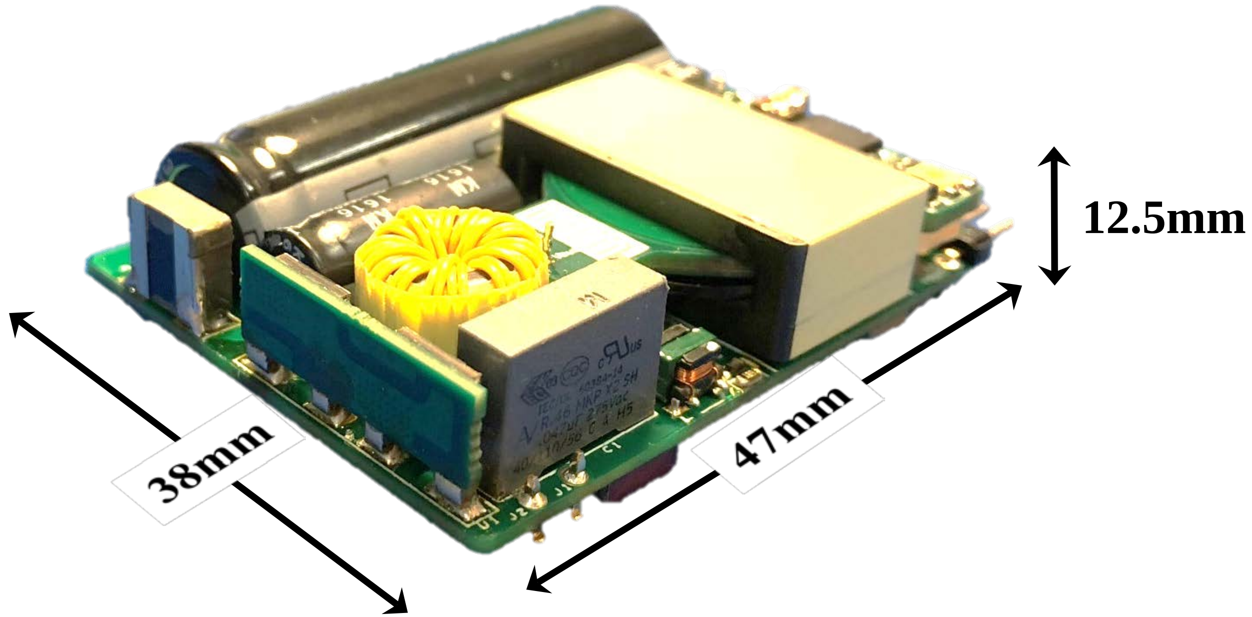


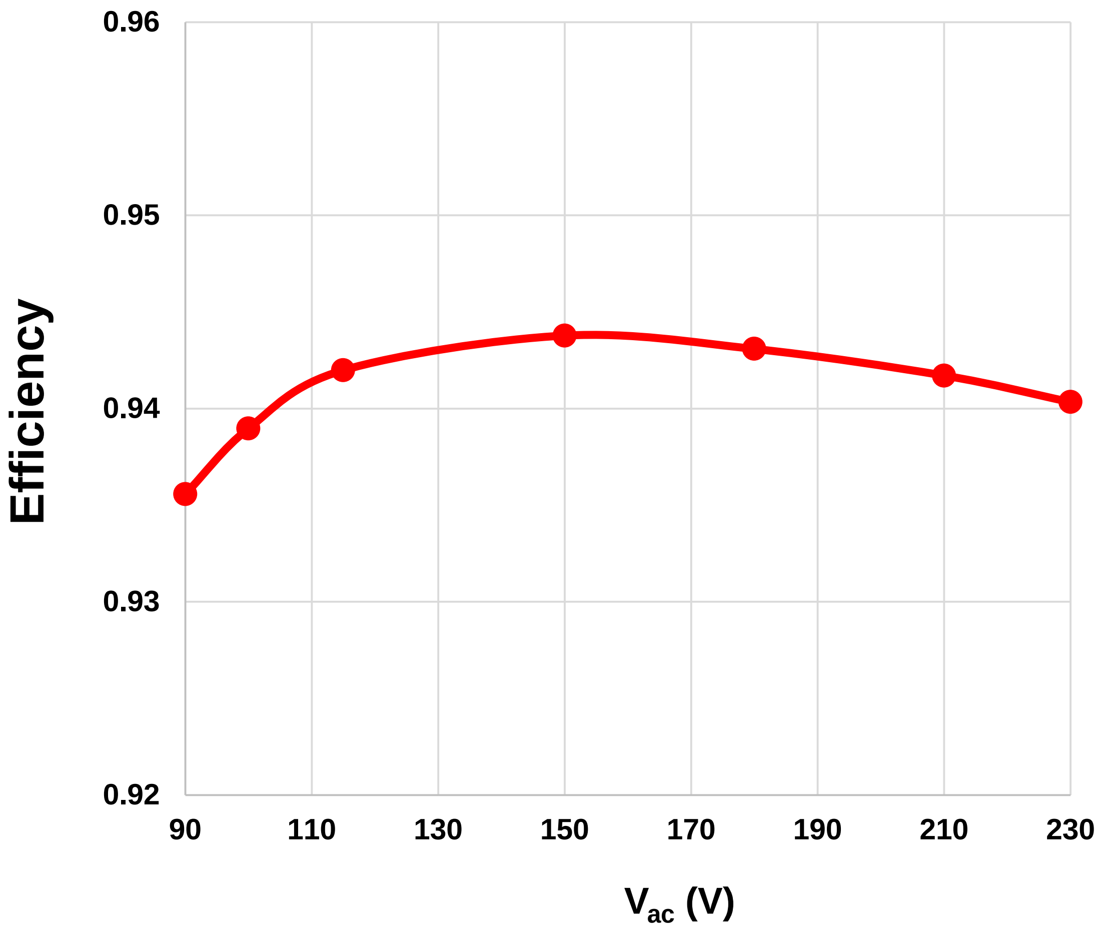


Full Load $F_{SW}$: 500-600 kHz

Power Density: 47 W/ in$^3$ (Uncased)

→ 26 W/ in$^3$ (2.5mm case)

**Average Efficiency= 93.4% @115 $V_{AC}$, 92% @230 $V_{AC}$**

# Conclusion

- Highly-efficient ACF should minimize the circulating energy
- GaN is uniquely suitable for high frequency ACF operation
- Half-Bridge GaNFast Power IC simplifies ACF design and improves density
- Examples of 27W and 65W PD designs are given showing high efficiency/density