



Active Clamp Flyback Using GaN Power IC for Power Adapter Applications

Linqxiao (Lincoln) Xue, Staff Applications Engineer, lingxiao.xue@navitassemi.com

Jason Zhang, VP Applications, jason.zhang@navitassemi.com

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How to Improve Power Adapter Density?

Traditional Travel Adapter and Chargers



USB PD and Quick Charge



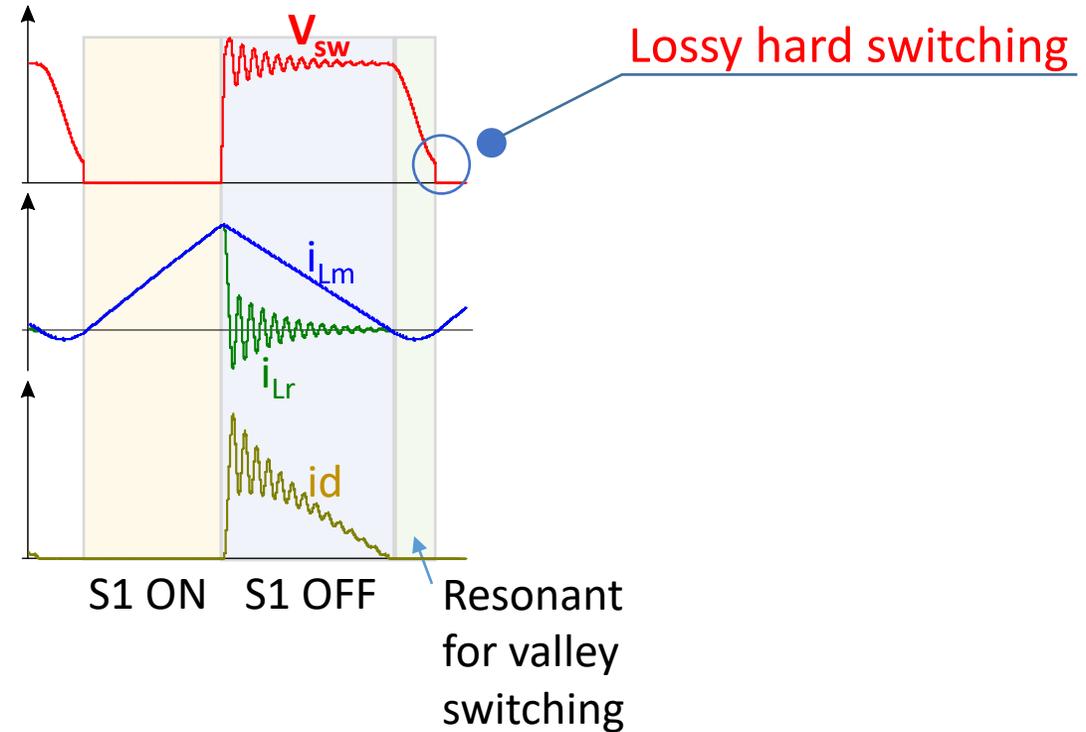
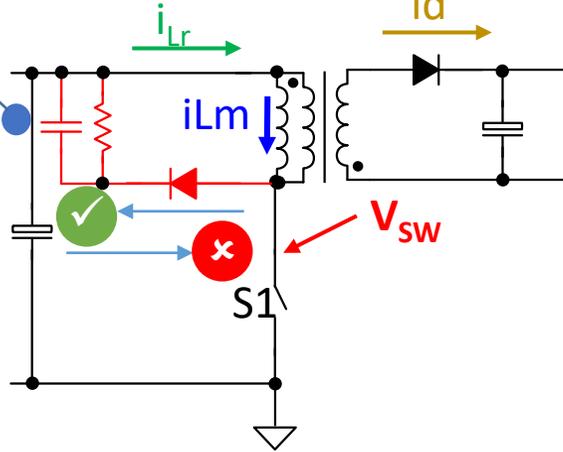
- Added power in USB PD and Quick Charge requires dramatically higher power density (>20 W/in³)
- Higher efficiency and lower power loss are required in high density adapters
- How to dramatically improve the power density?

Outline

- Limitations of standard flyback
- Active clamp flyback's benefits and drawbacks
- Improvement of active clamp flyback (ACF)
- GaN half-bridge power IC enables high density ACF
- Experimental results and conclusion

QR Flyback Hits Performance Ceiling

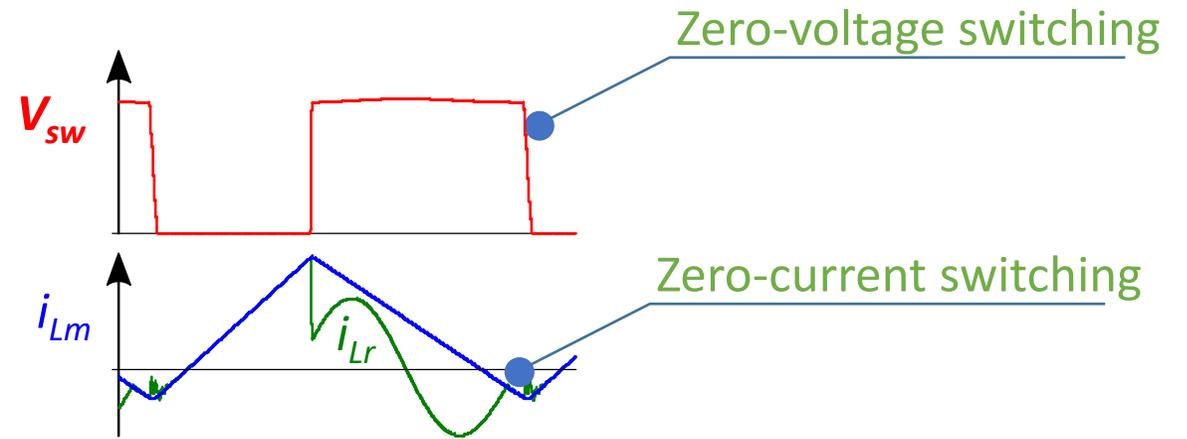
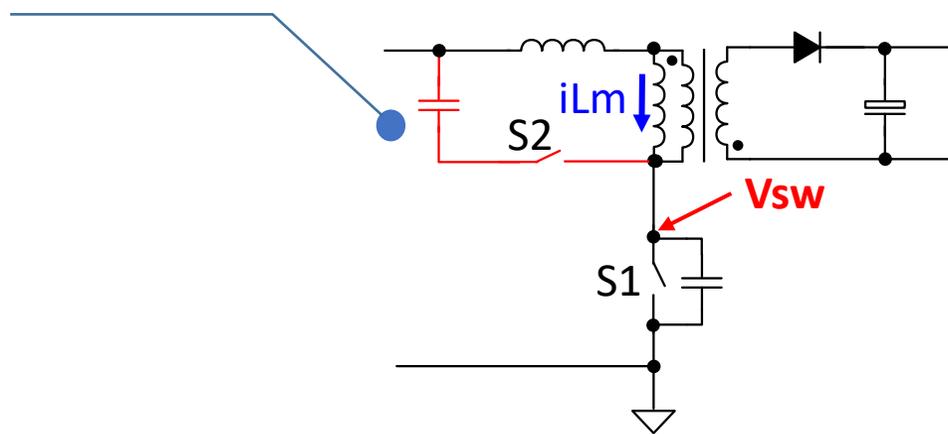
Lossy RCD clamp



- Frequency-dependent losses
 - Leakage inductance loss
 - Snubber/clamp losses
 - Partial hard-switching loss at high line
 - Slow turn-on loss to minimize EMI
- Difficult to improve efficiency at high frequency

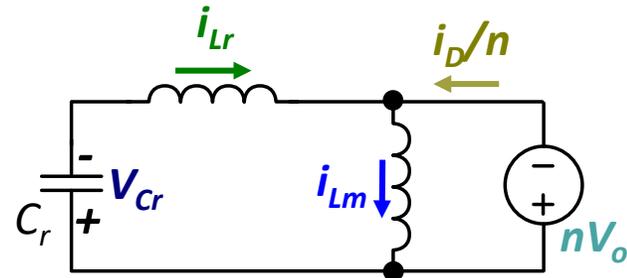
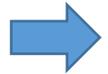
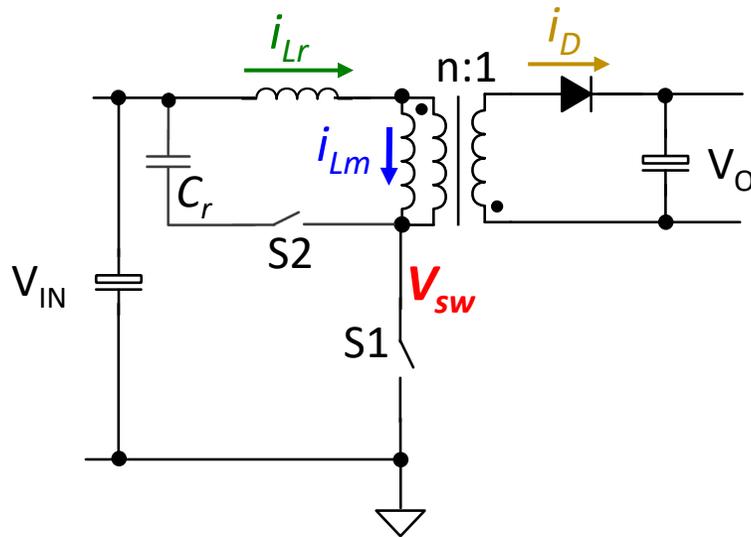
ACF Enables ZVS and High Frequency Switching

Lossless snubber

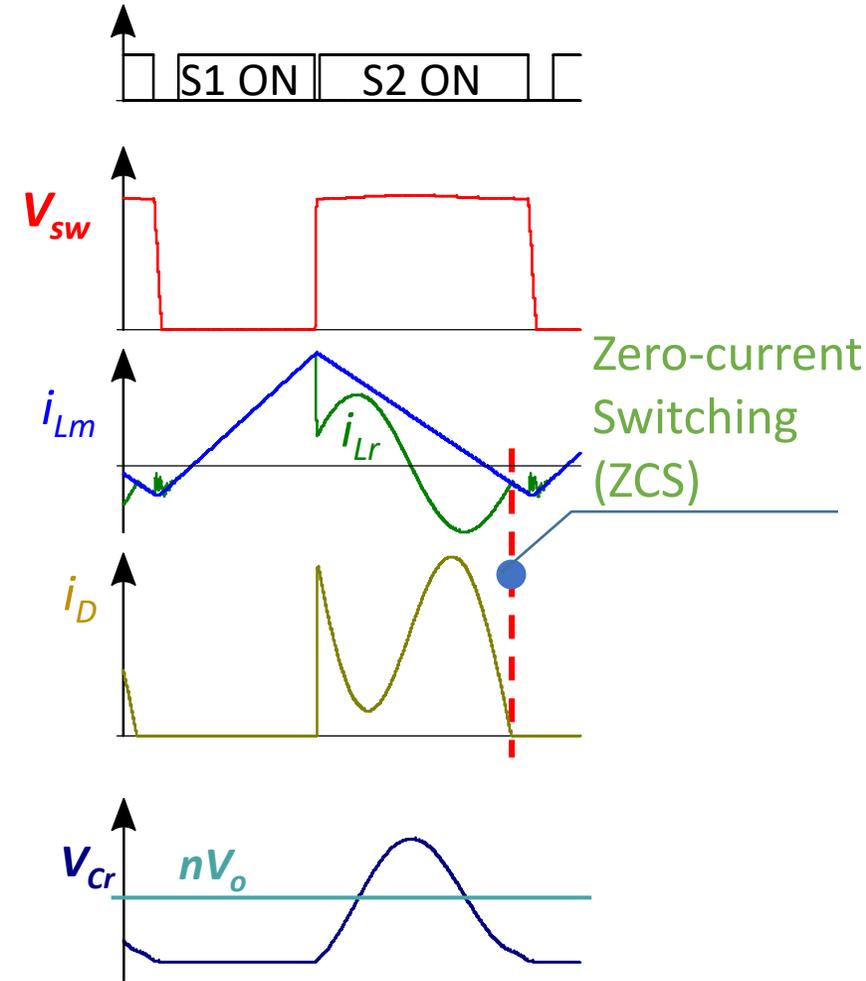
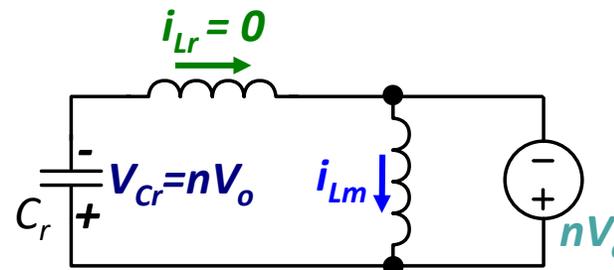


- No snubber losses, all leakage energy is recovered
- ZVS soft switching over entire operation range
- ZCS soft turn-off for output rectifier
- Clean waveforms reduce EMI
- Enable small adapter design with high-frequency switching

ACF Operation

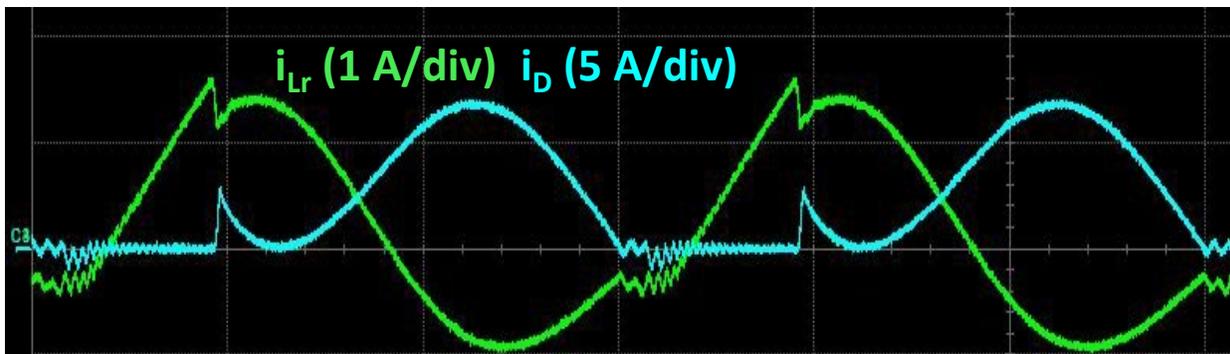
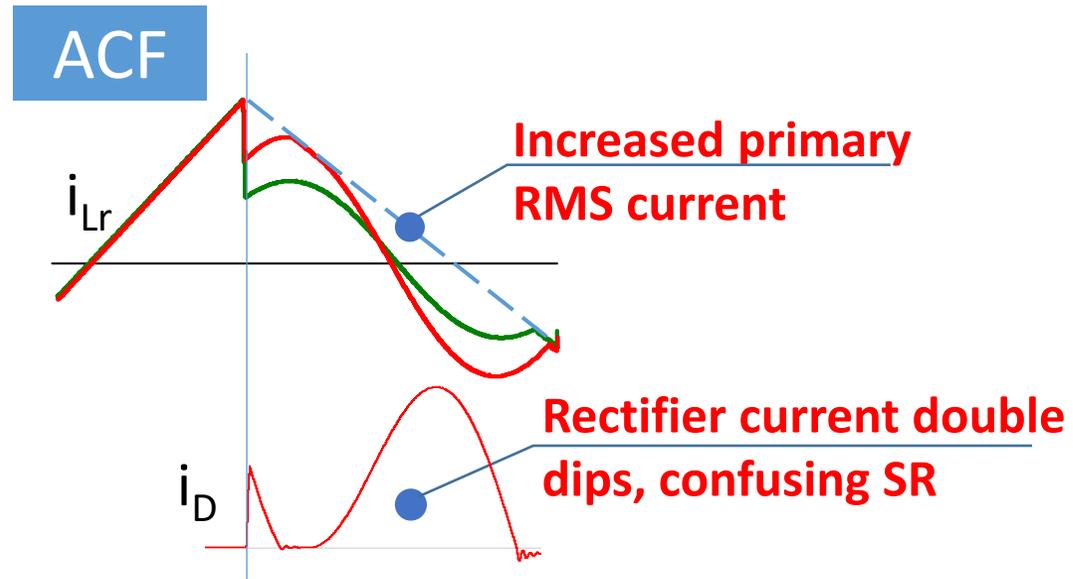
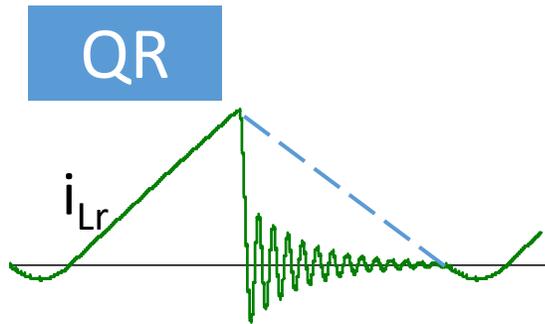


$t = \infty$



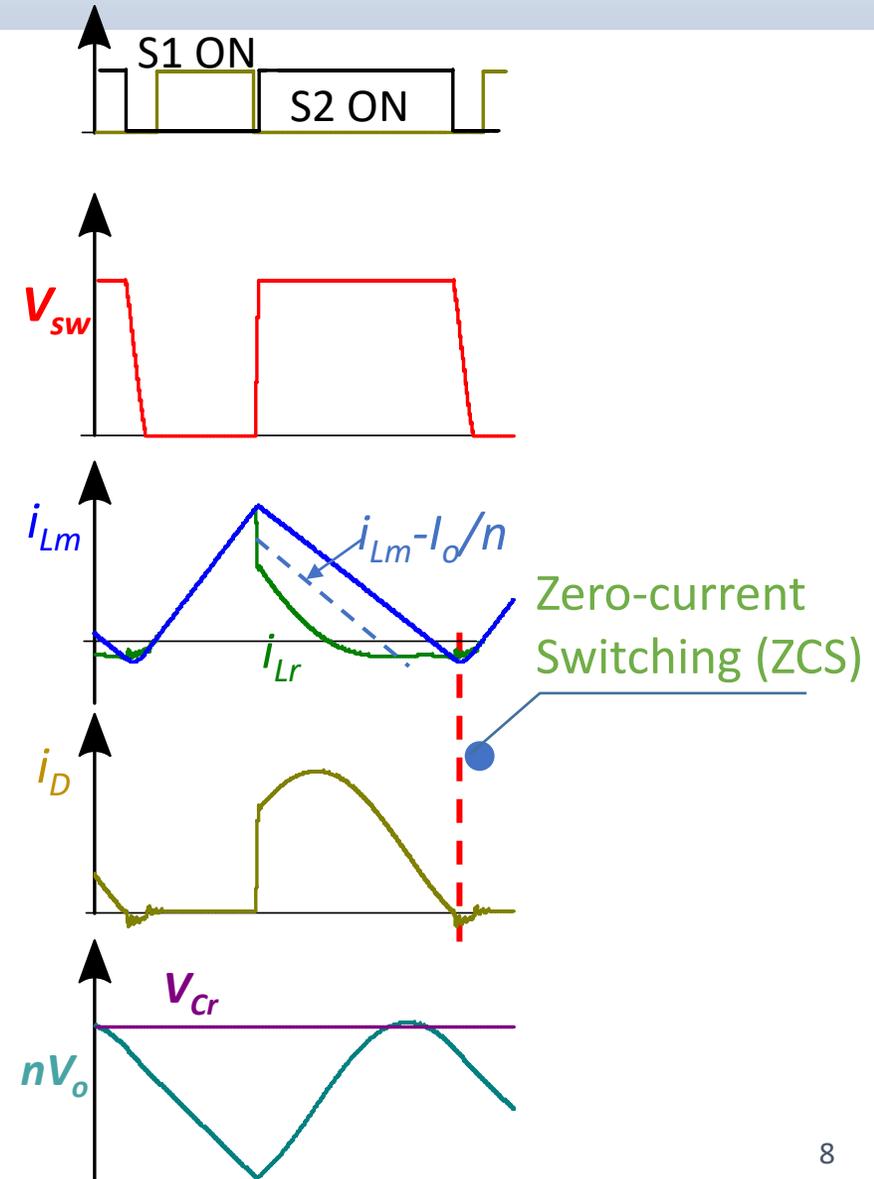
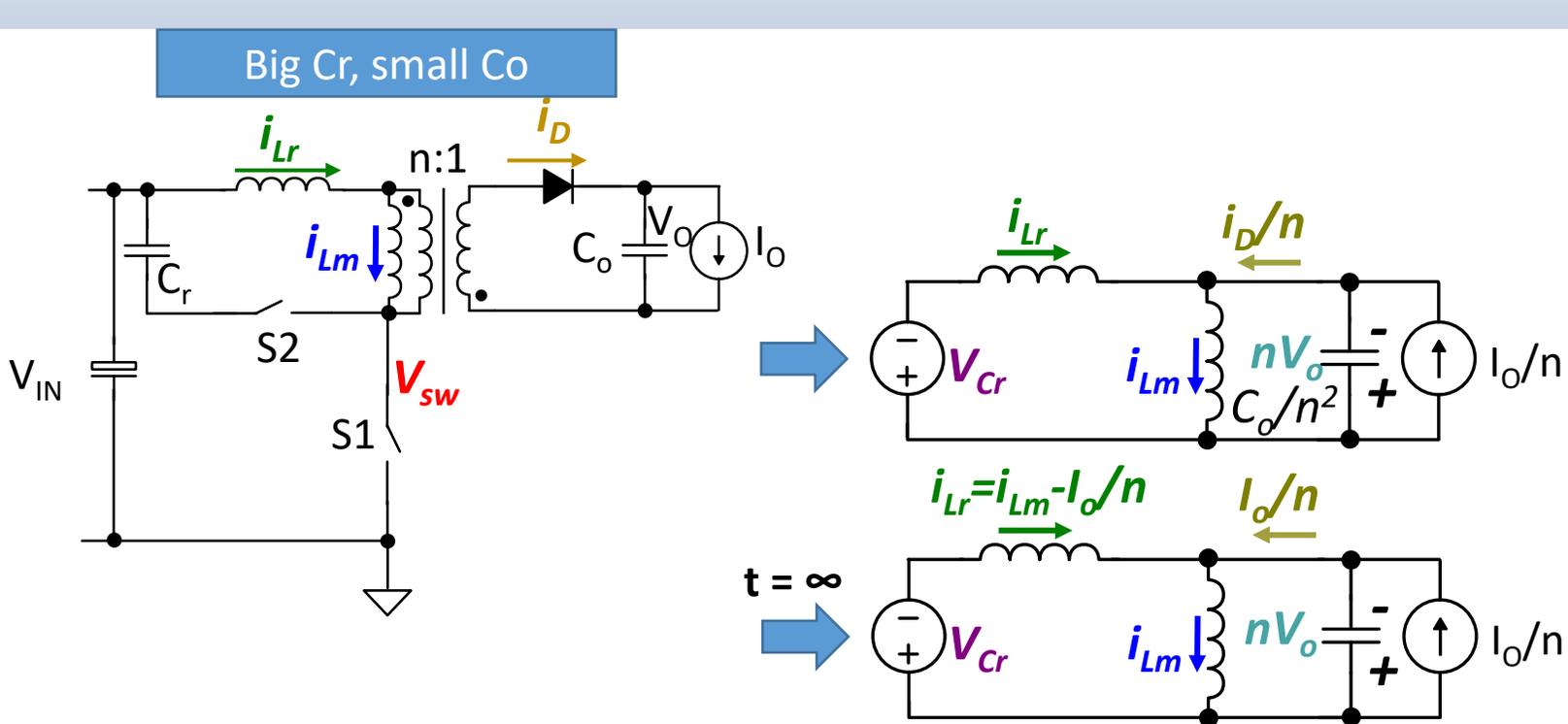
- L_r resonates with C_r during S2 ON interval
- ZVS is achieved by magnetizing inductance current
- Rectifier current is the difference between i_{Lm} and i_{Lr}
- i_{Lr} returns to i_{Lm} by the end of S2 ON interval for rectifier ZCS

Drawbacks of Traditional ACF



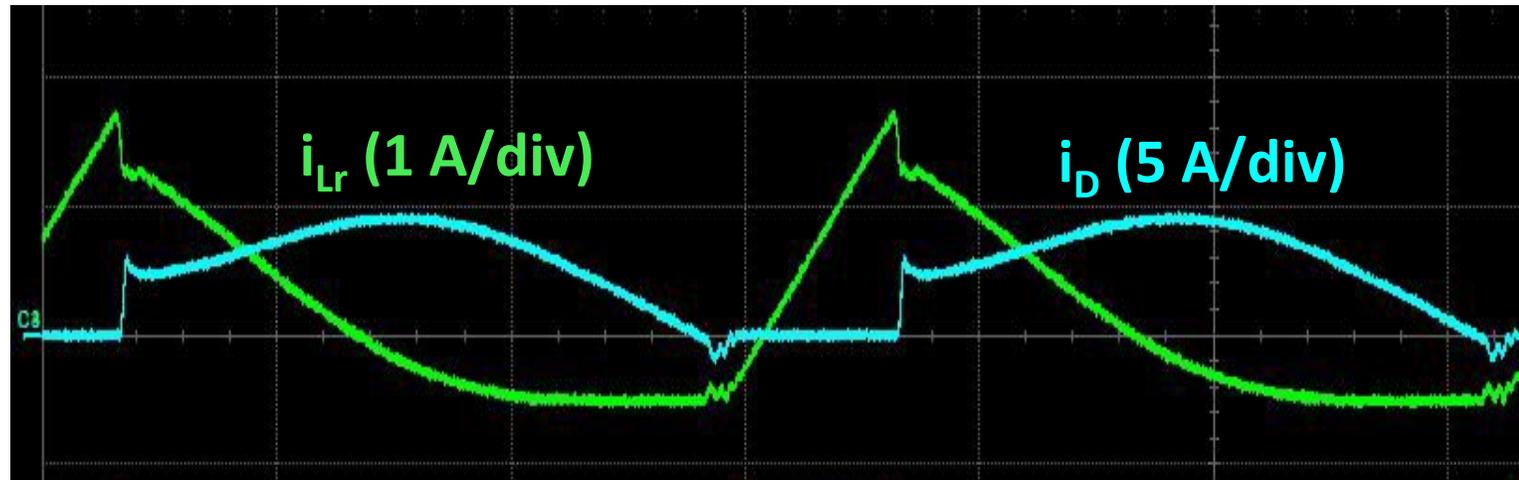
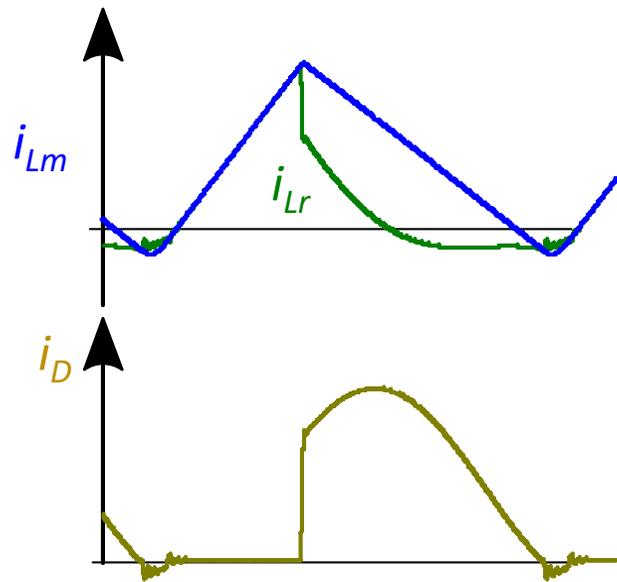
- Difficult to shape the current to achieve ZCS and minimize rms current
- Conduction loss is high
- Not compatible with SR controllers

New ACF Using Secondary Resonance



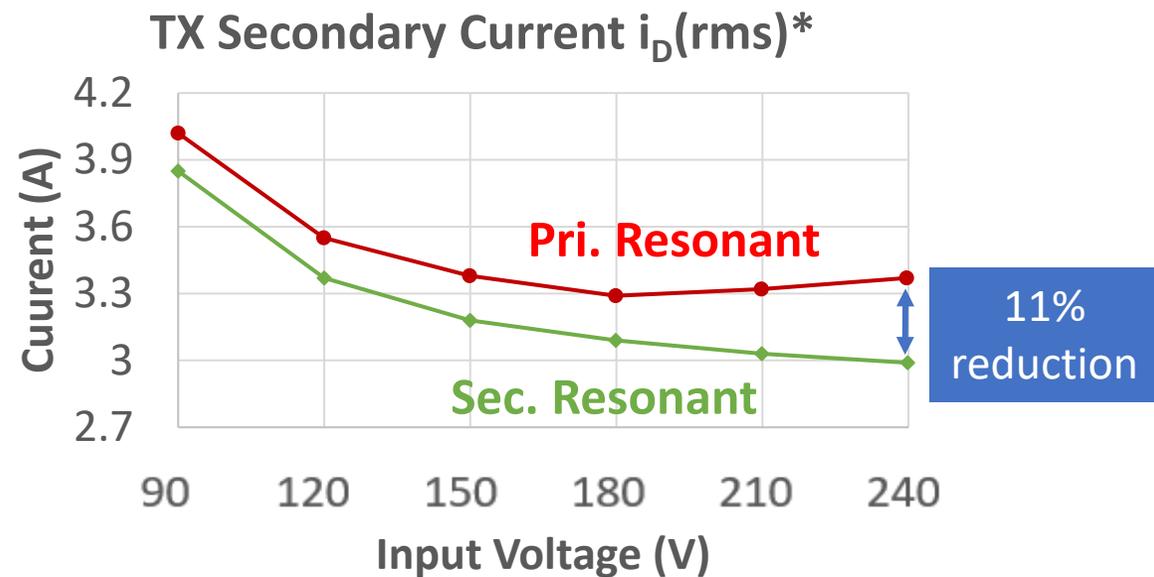
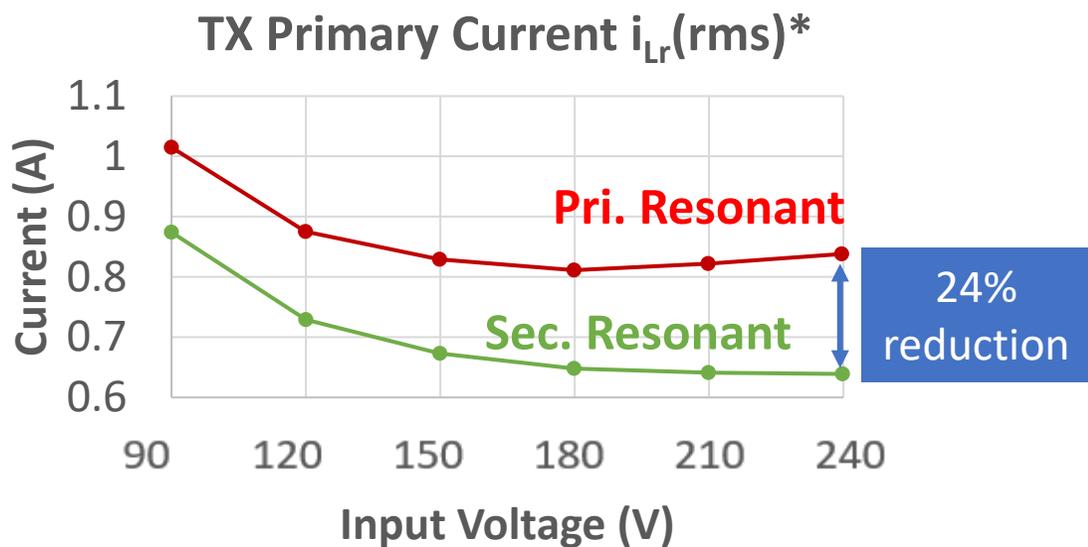
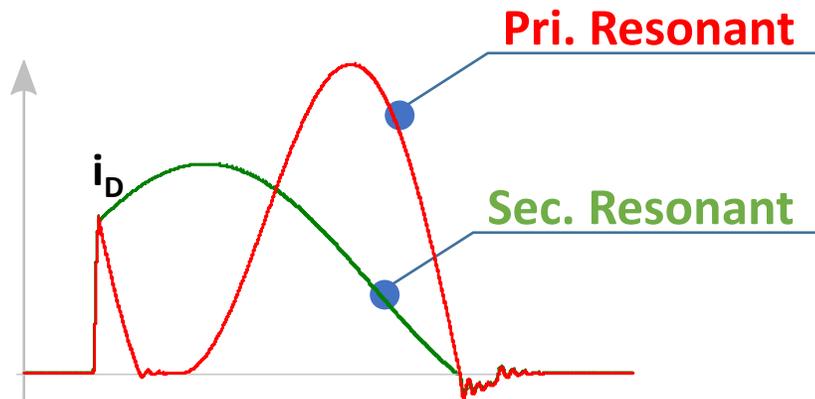
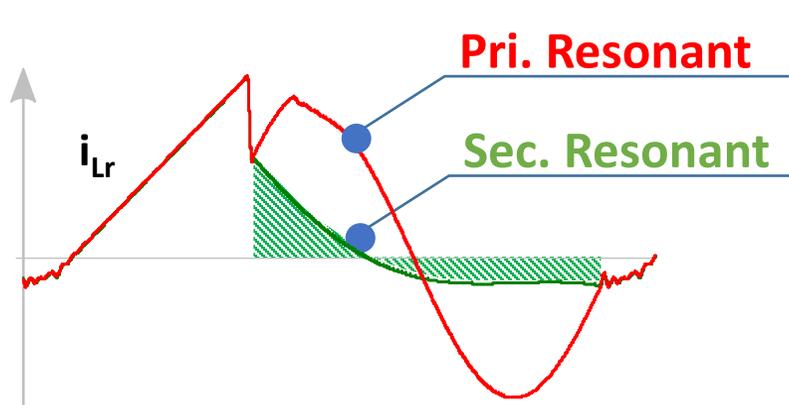
- S_1 ON interval is the same as primary resonant
- In S_2 ON interval
 - $C_o/n^2 \ll C_r$, C_o resonates with L_r
 - i_{Lr} centers around a line lower but in parallel with i_{Lm}
 - ZCS is easily achieved. No rectifier current double dipping

New ACF Simplifies SR and Reduces Current RMS



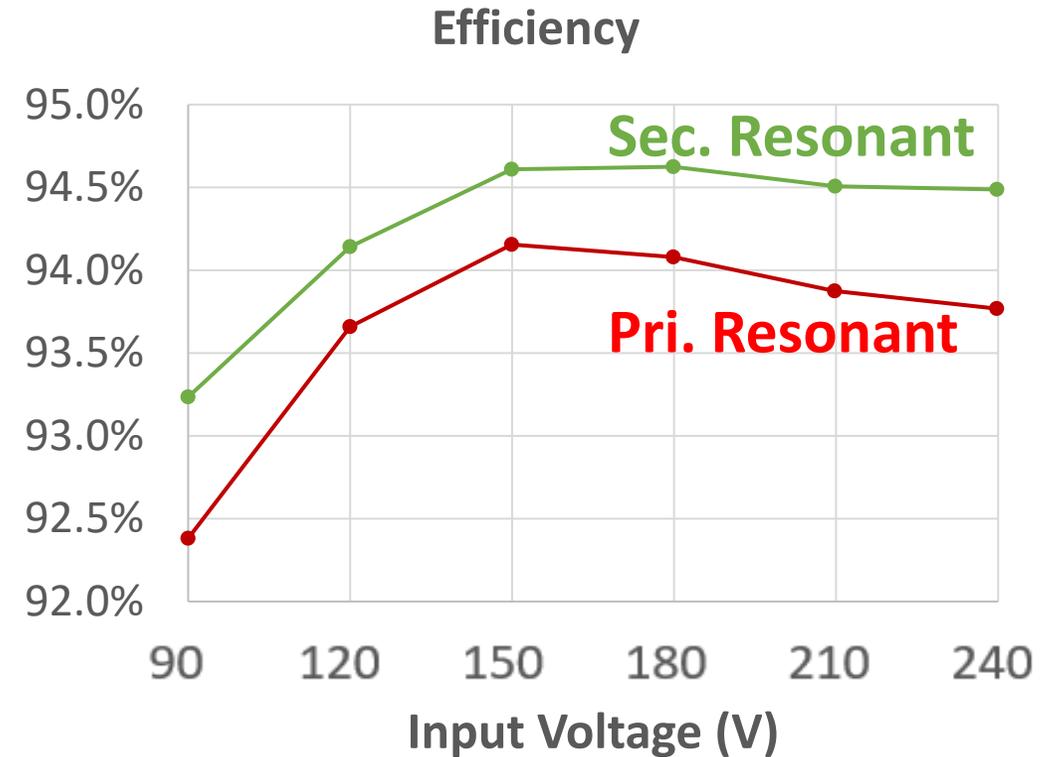
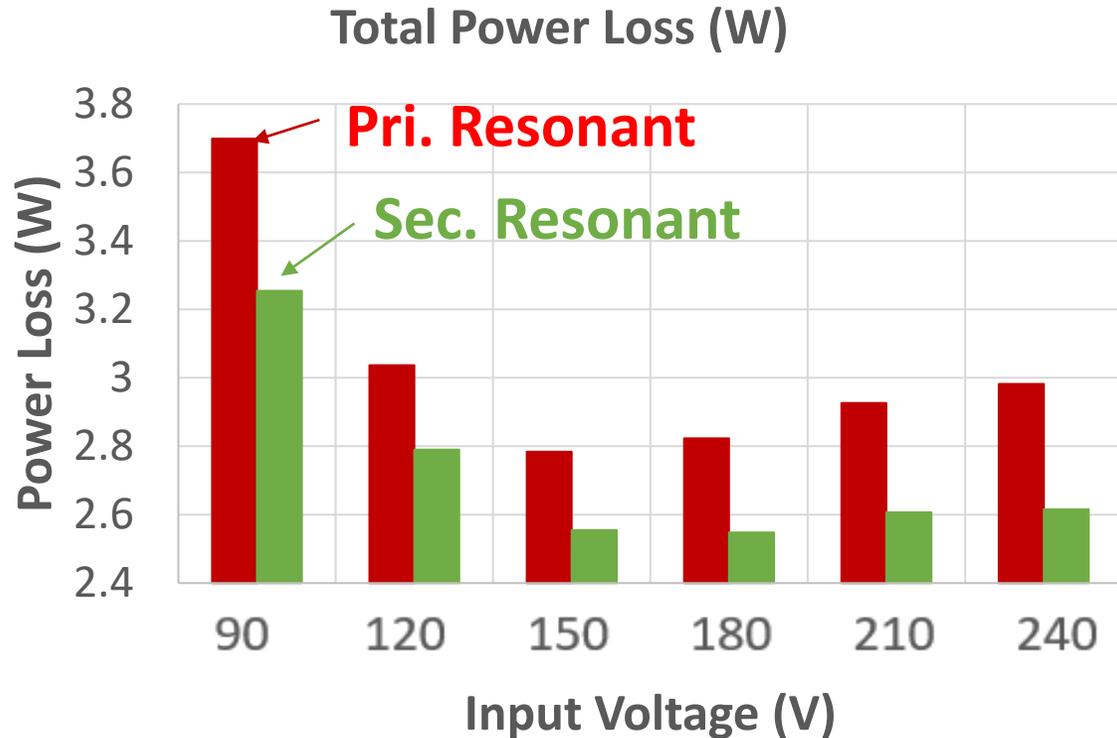
- i_{Lr} current can be easily shaped
- No rectifier current dipping issue. Simplifies SR
- Reduced rms current and conduction loss

Experimental Result of RMS Reduction



*Measured results of 45W ACF

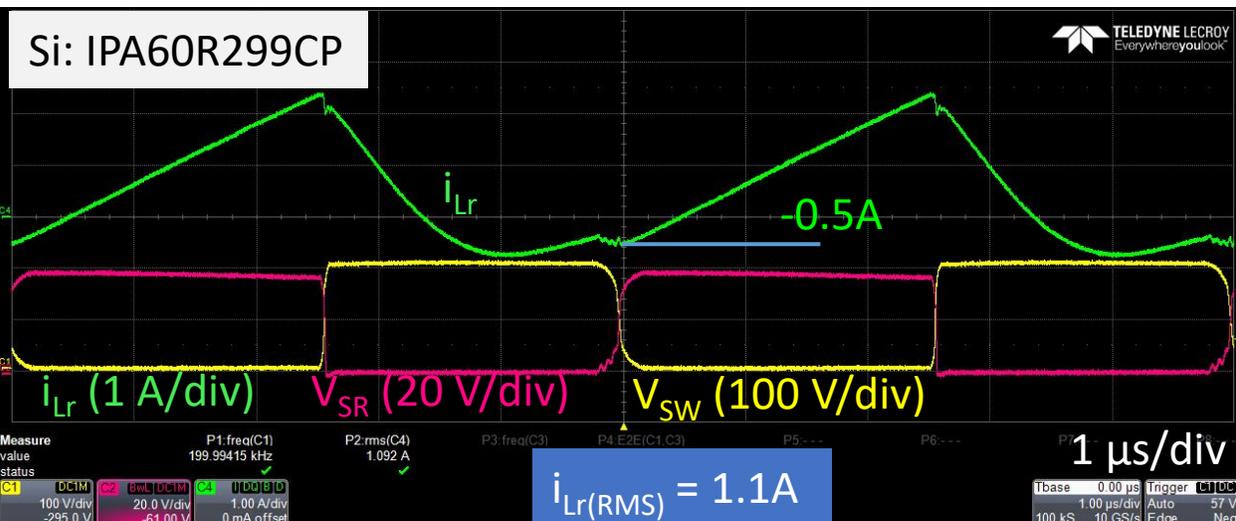
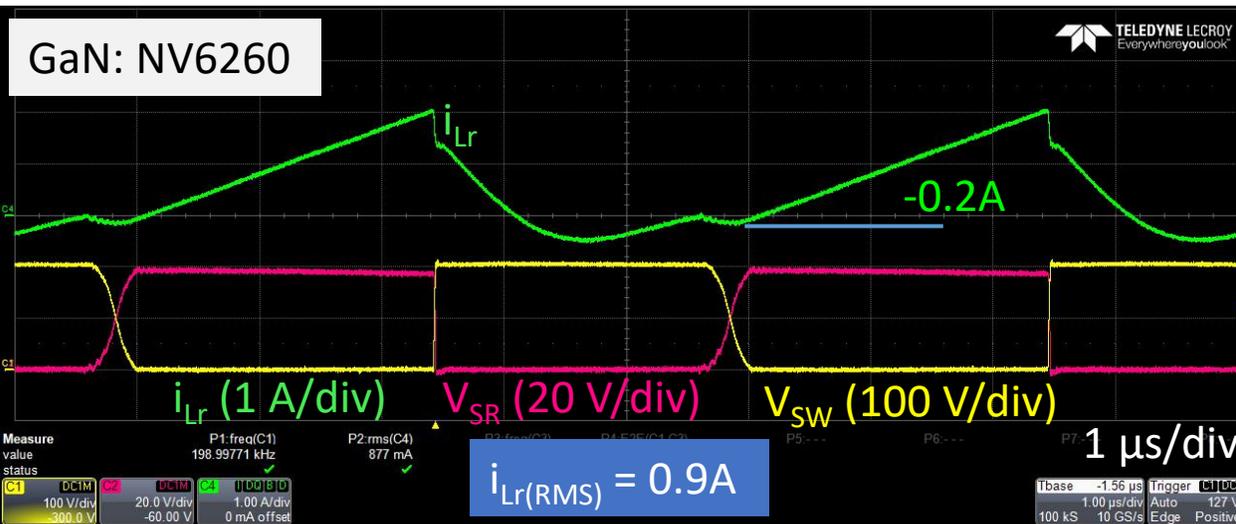
Efficiency Benefit of New ACF



- 0.4 W power loss reduction
- ~0.8% efficiency improvement

*Measured results of 45W ACF

Advantages of Using GaN in ACF



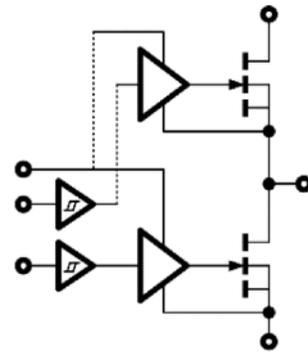
	IPA60R299CP	NV6260 (per FET)
Voltage Rating (V)	650	650
$R_{DS(ON)}$	270	160
$C_o(tr)$ (pF)	120	50
Q_g (nC)	22	2.5
Q_{rr} (nC)	3900	0

- 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
- GaN has no body diode loss
- Low high-frequency gate-charge loss

Half-Bridge iDrive GaN Power IC

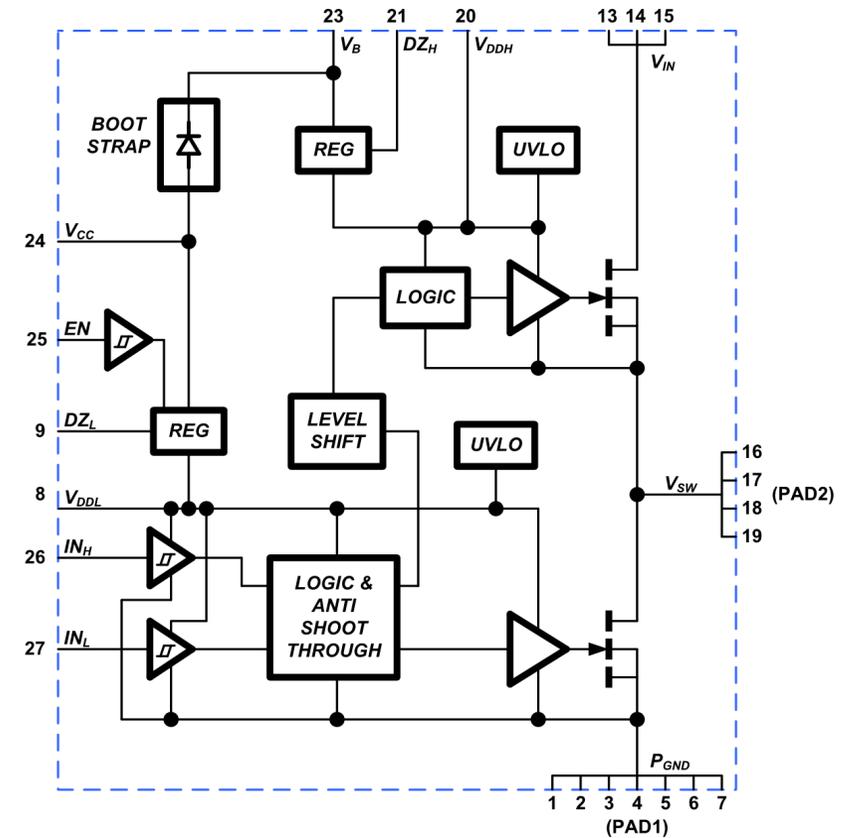


PQFN 6x8 mm

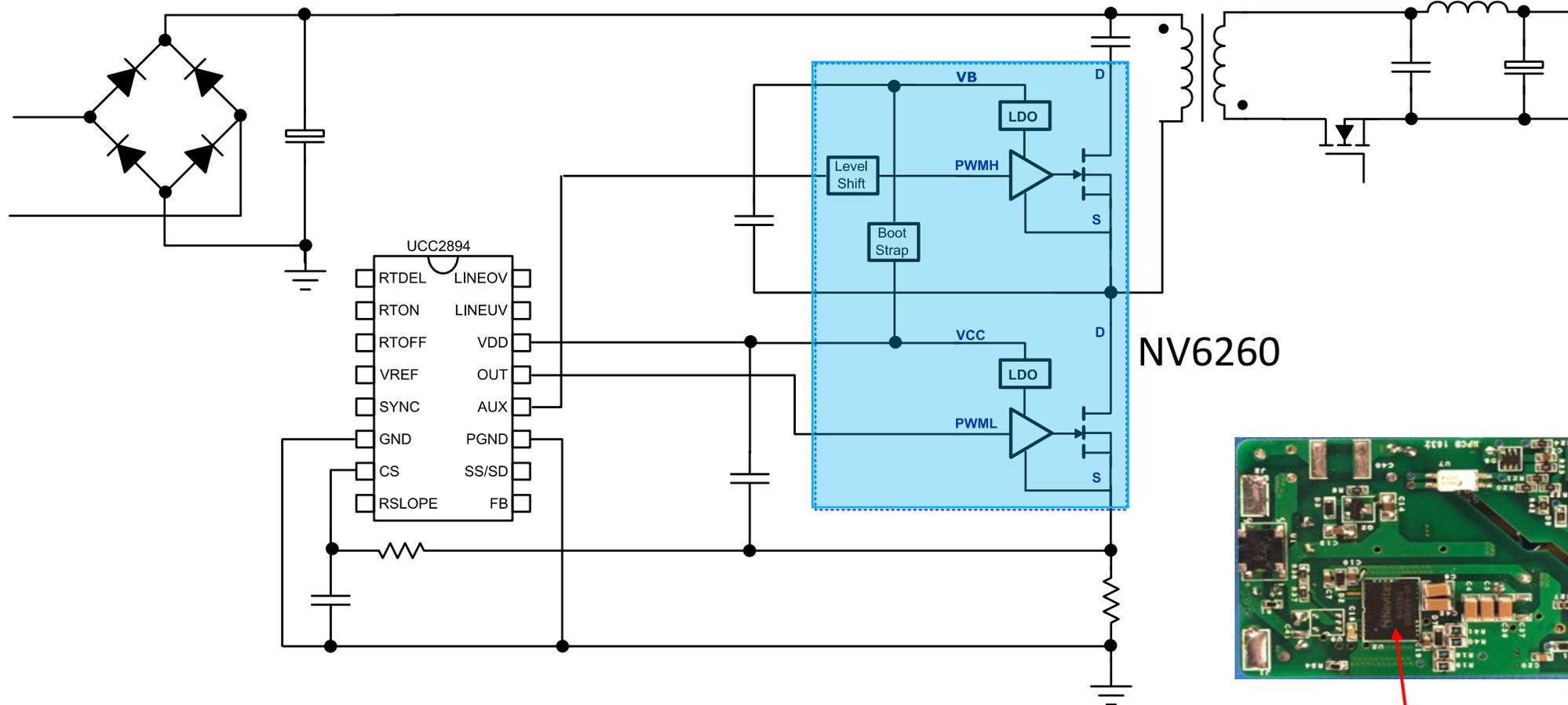


Simplified Schematic

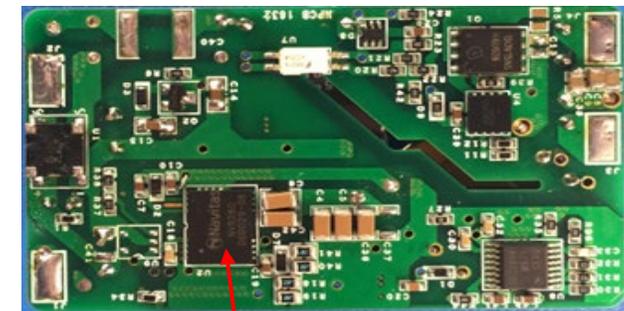
- Internal level-shift, bootstrap
- Range from 150-600 mOhm (650V)
- Single component
- Ground-referenced PWM signals
- Active Clamp Flyback, Half-Bridge, LLC, etc.



GaN Power IC Simplifies ACF



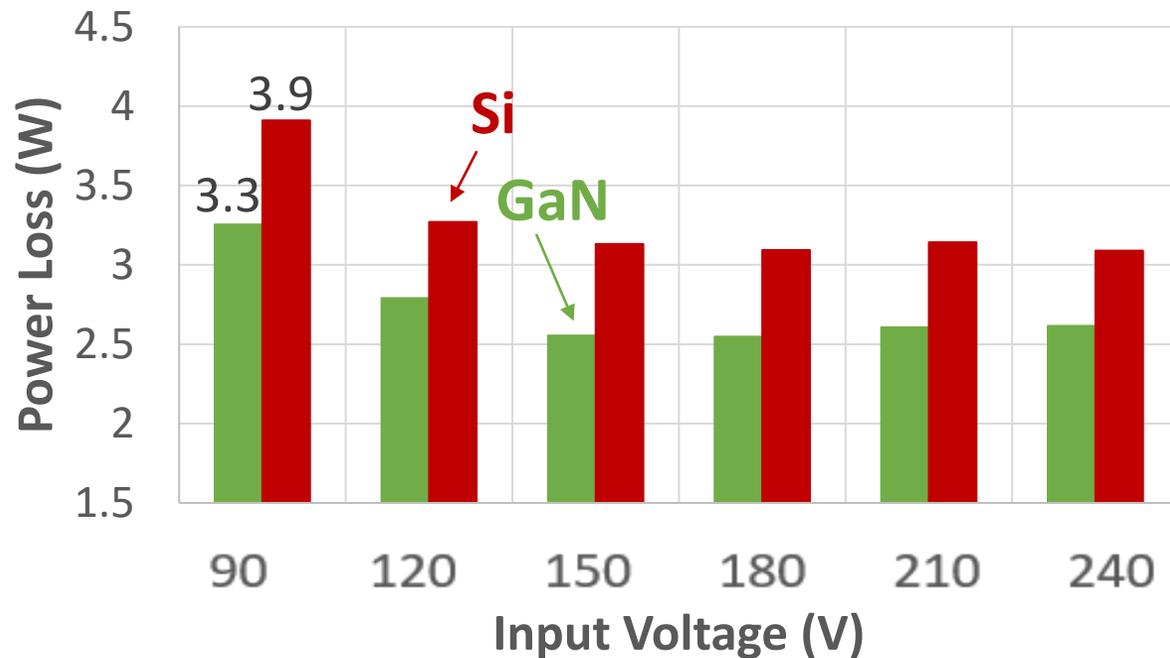
NV6260



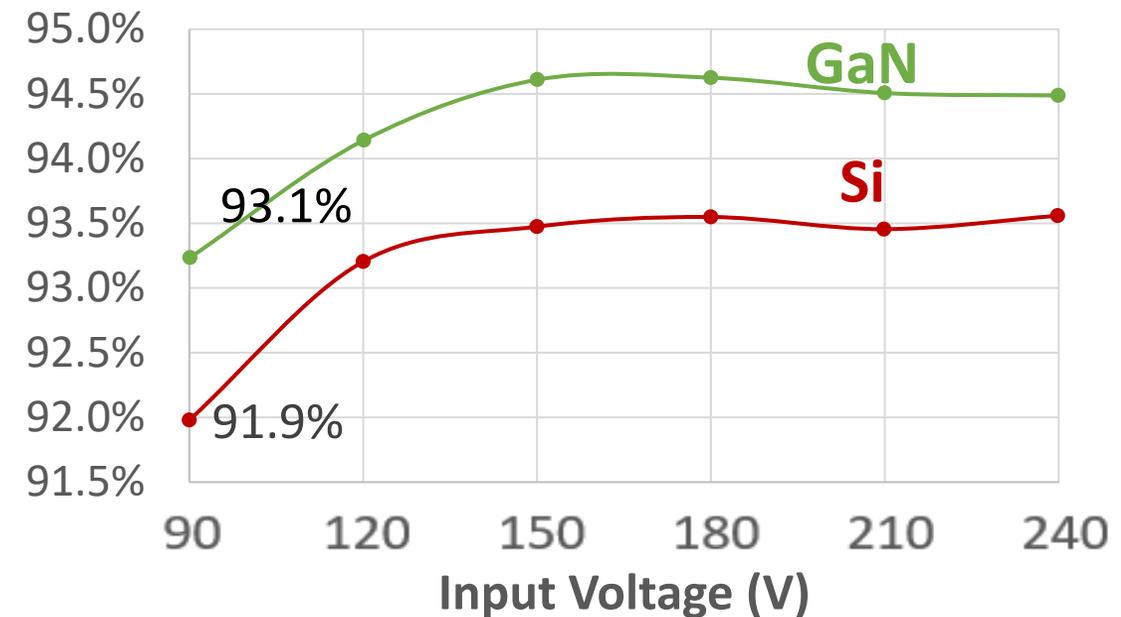
GaN IC

GaN Power IC Efficiency Advantage

Power Loss: GaN vs. Si



Efficiency: GaN vs. Si



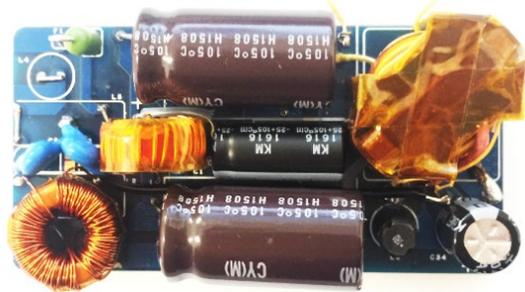
- GaN reduces power loss by 0.6W
- GaN boosts efficiency by 1.2%

*Measured results of 45W ACF

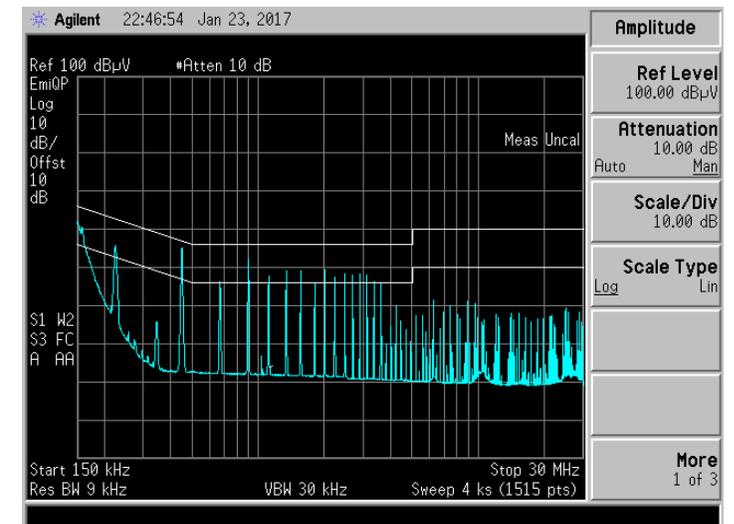
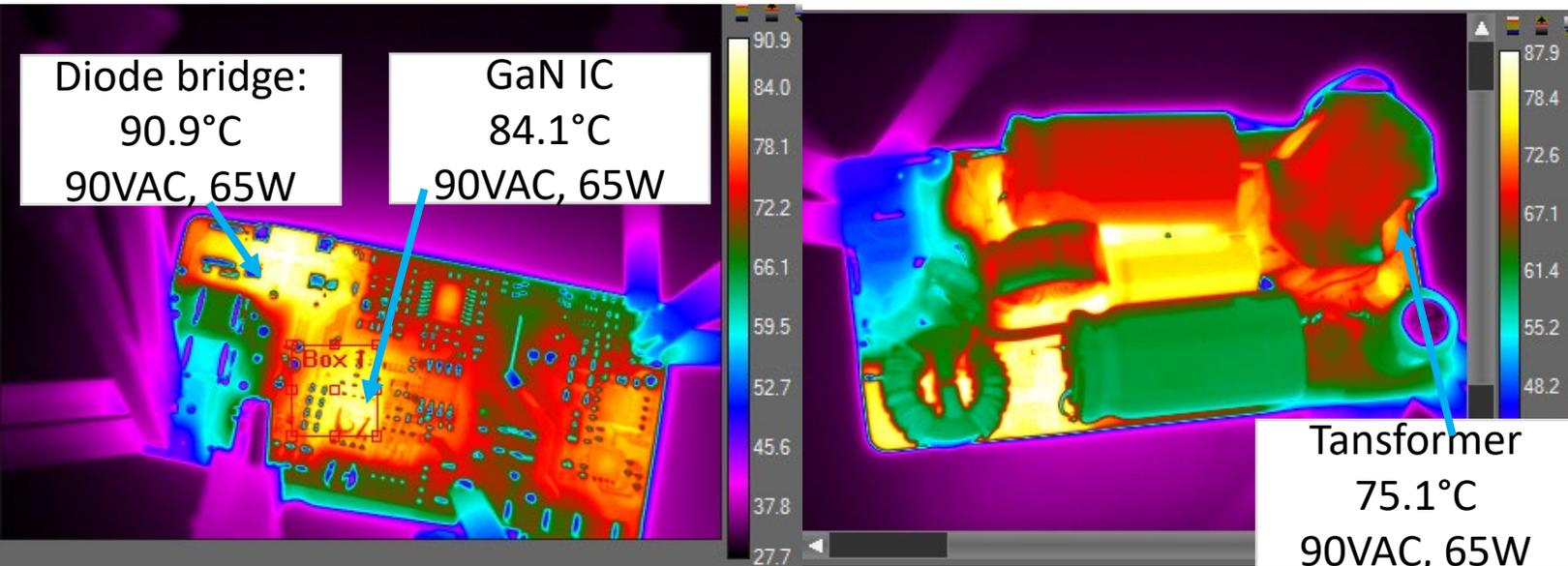
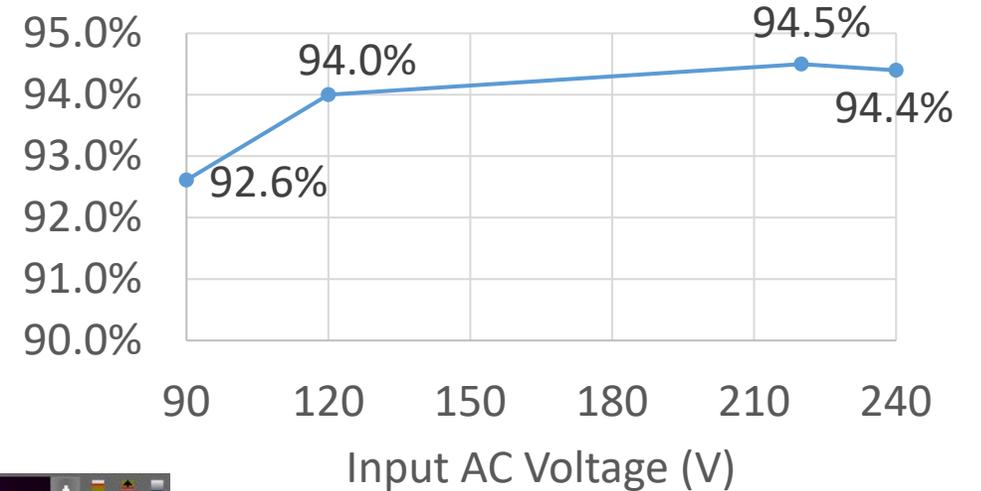
High Density 65W Adapter Using ACF and GaN

2.63 x 1.32 x 0.62 in

Power density 22 W/in³ (including case)



Efficiency at 65W



Conclusion

- USB-PD and QC demand high density solutions
- QR flyback hits performance ceiling
- ACF overcomes QR limitations and enables high frequency operation
- New ACF using secondary resonance improves ACF's operation and efficiency
- GaN is uniquely suitable for high frequency operation
- Half-Bridge GaN Power IC simplifies ACF design and improves density
- An example of 65W ACF adapter using GaN and secondary resonance achieves 22W/in³ density, while meeting thermal and EMI requirement



Active Clamp Flyback Using GaN Power IC for Power Adapter Applications

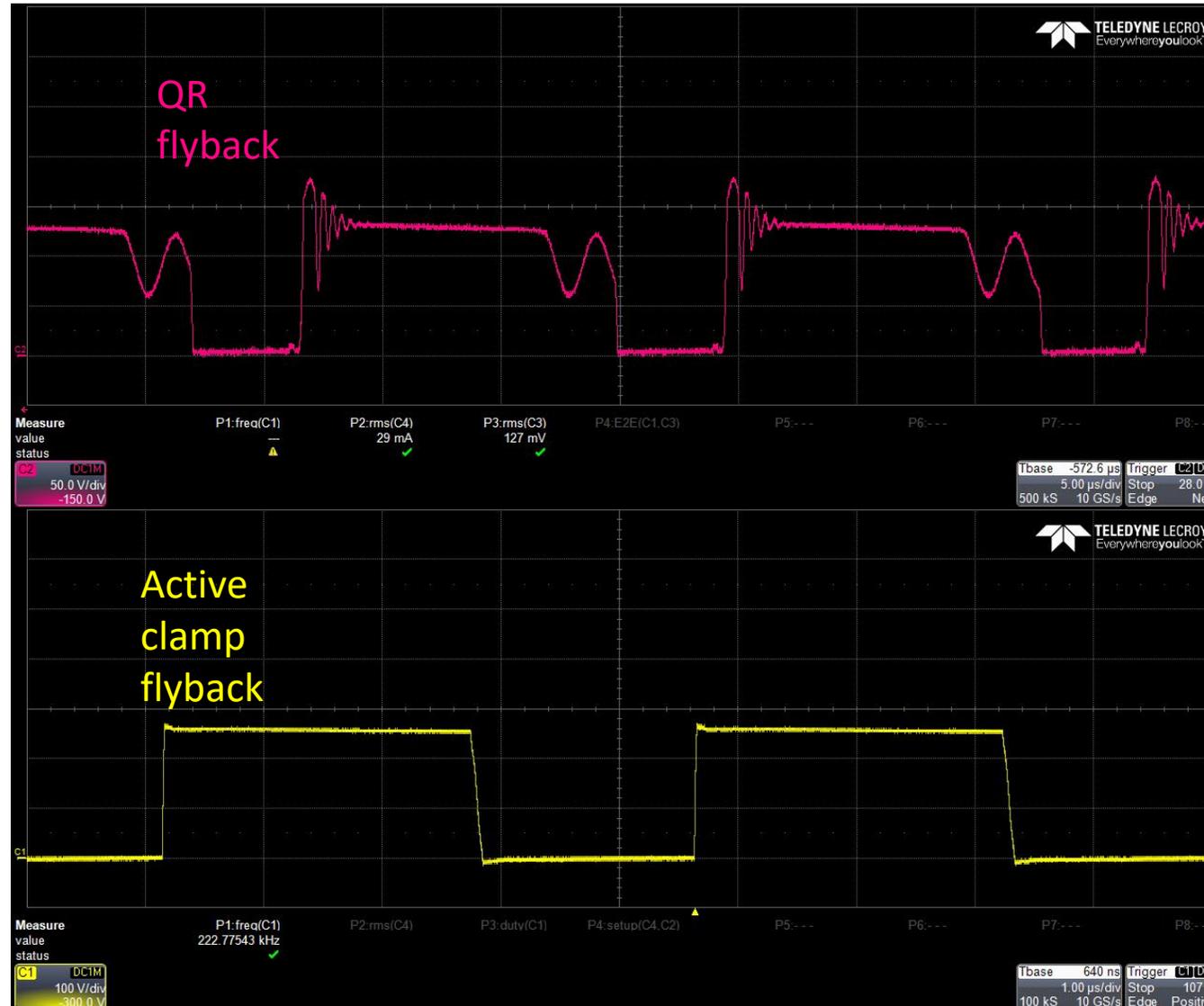
Linxiao (Lincoln) Xue, Staff Applications Engineer, linxiao.xue@navitassemi.com

Jason Zhang, VP Applications, jason.zhang@navitassemi.com

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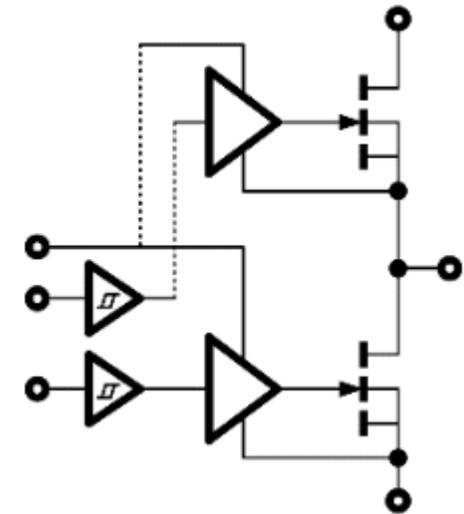
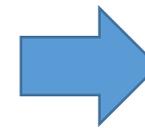
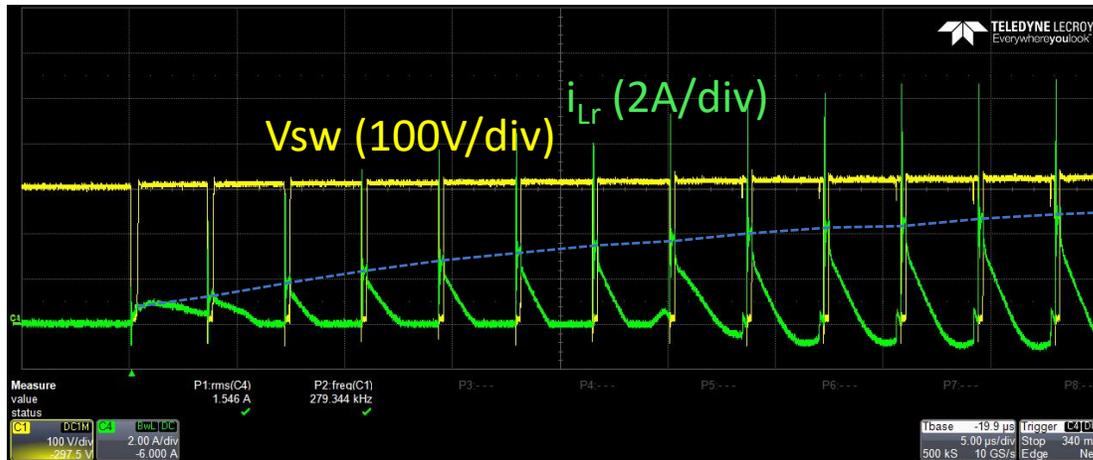
Backup

Waveform: QR vs. ACF



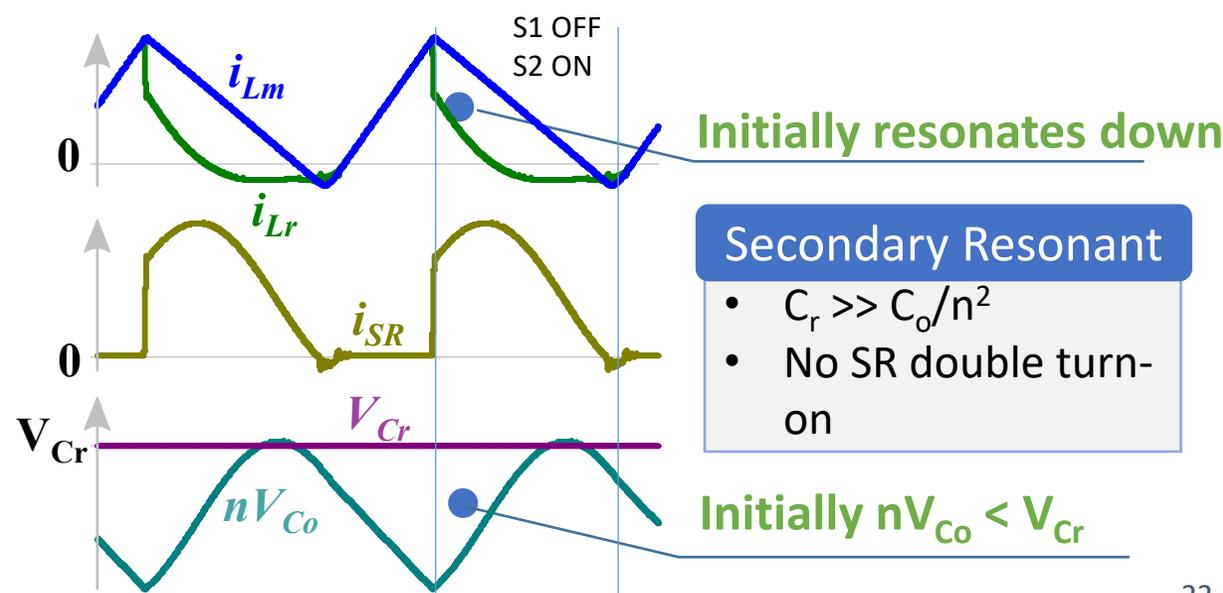
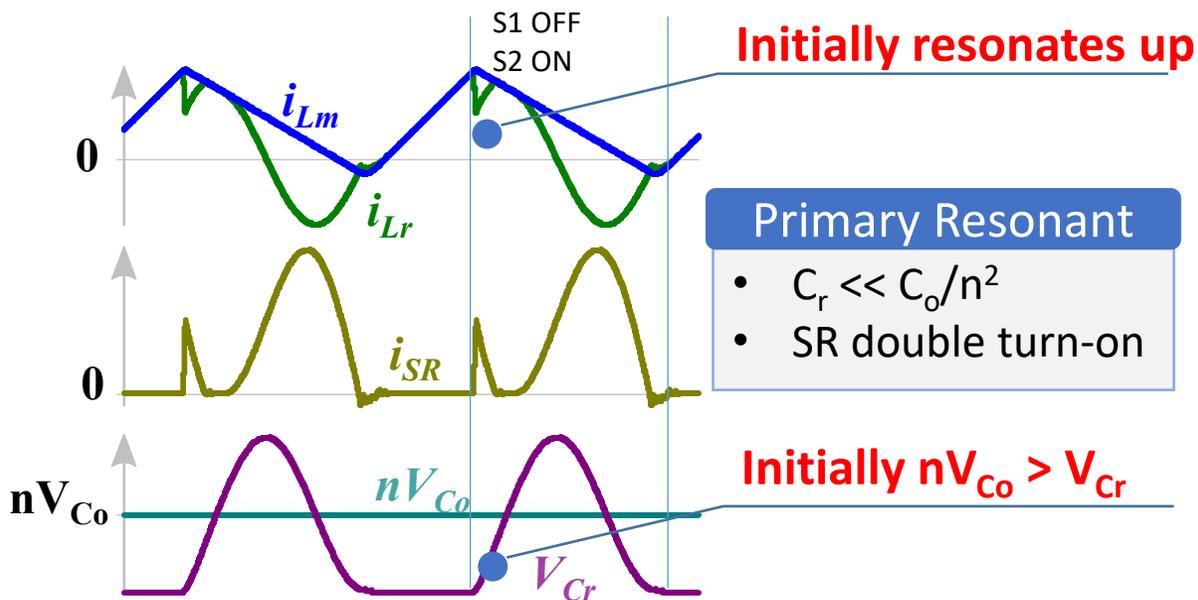
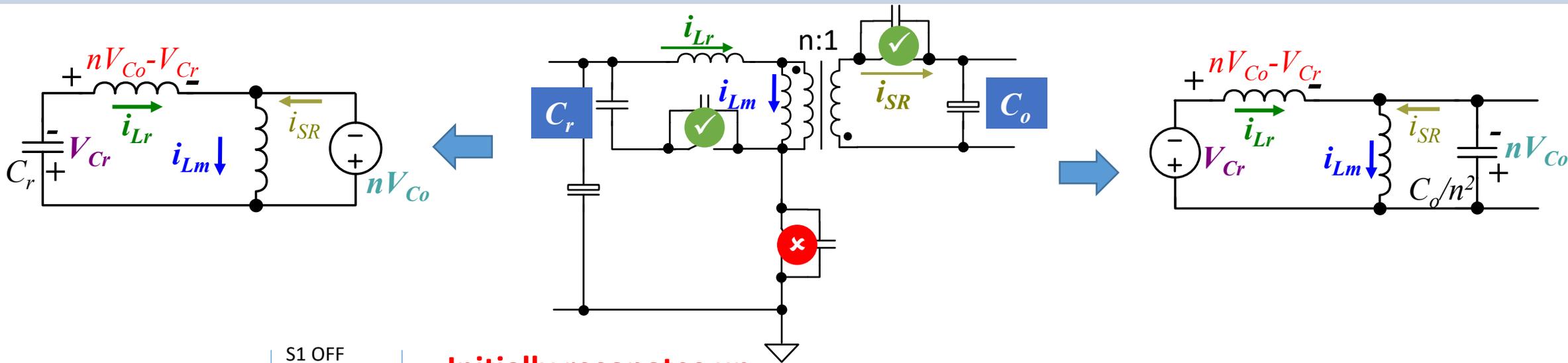
Startup in CCM and Hard-Switching

- Start-up in CCM: hard-switched, body diode reverse recovery..

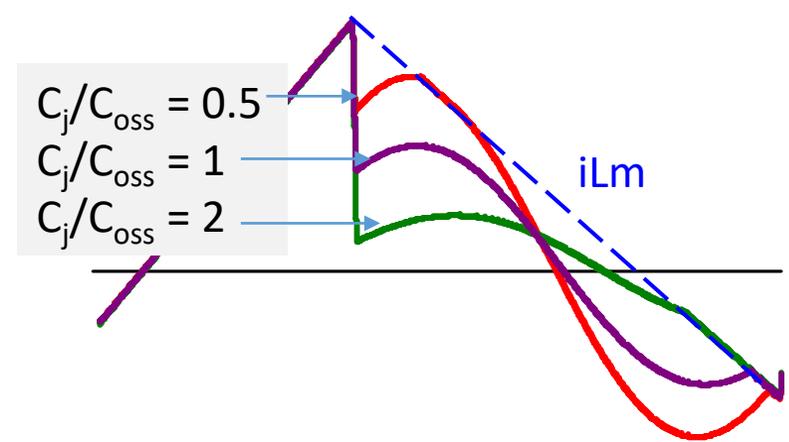
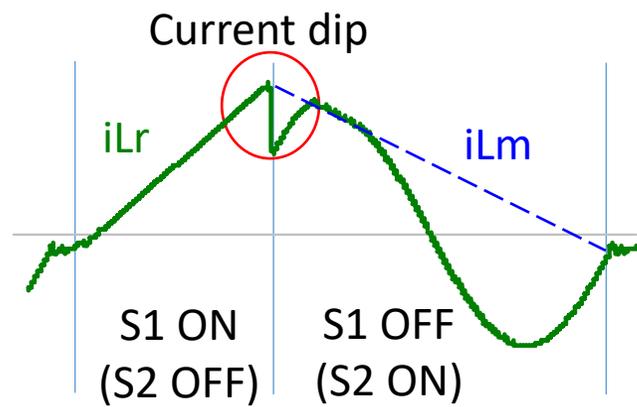
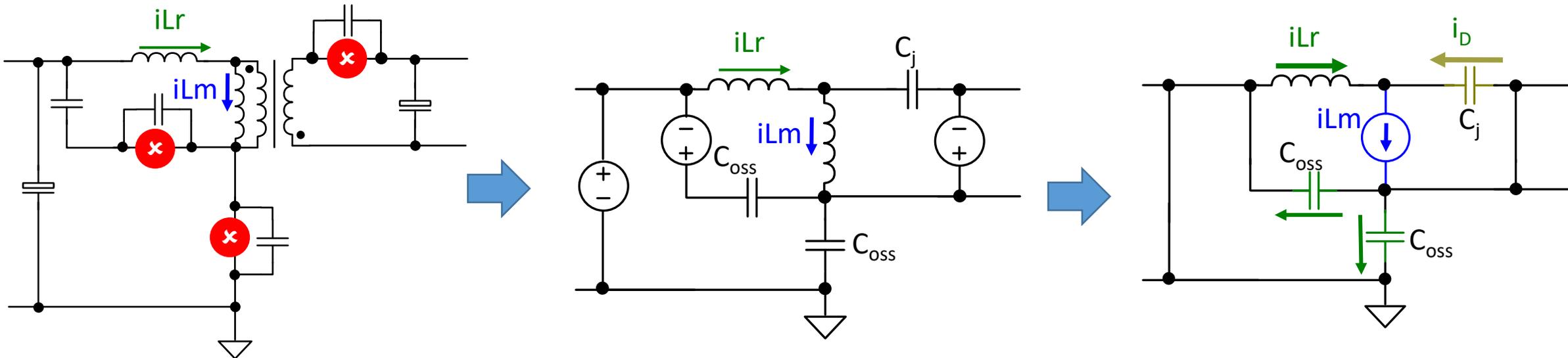


Navitas GaN
Half Bridge IC

Lr Resonant Interval

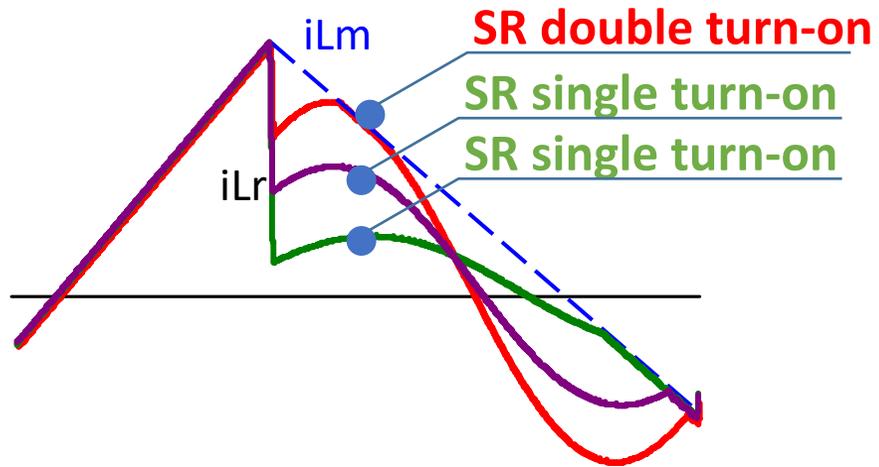


ACF Primary Current Dip

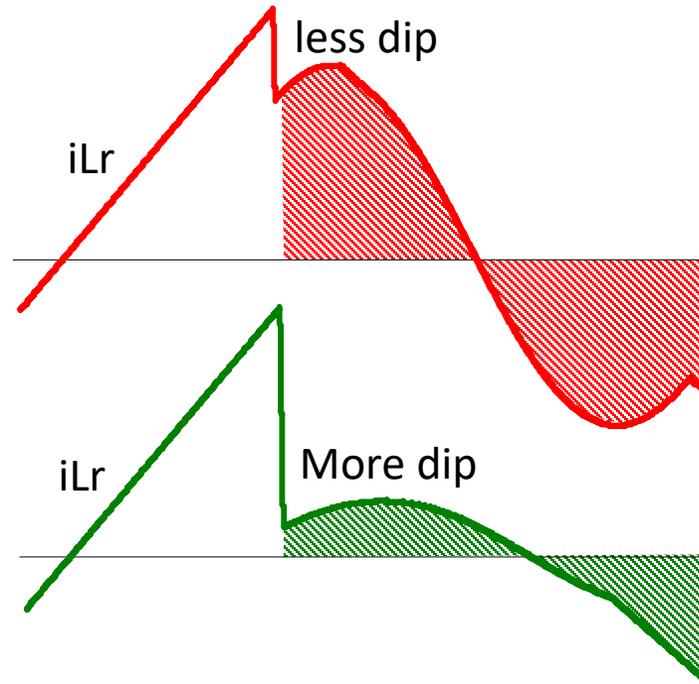


- Bigger C_j/C_{oss}
→ bigger current dip
- Why is current dip important?

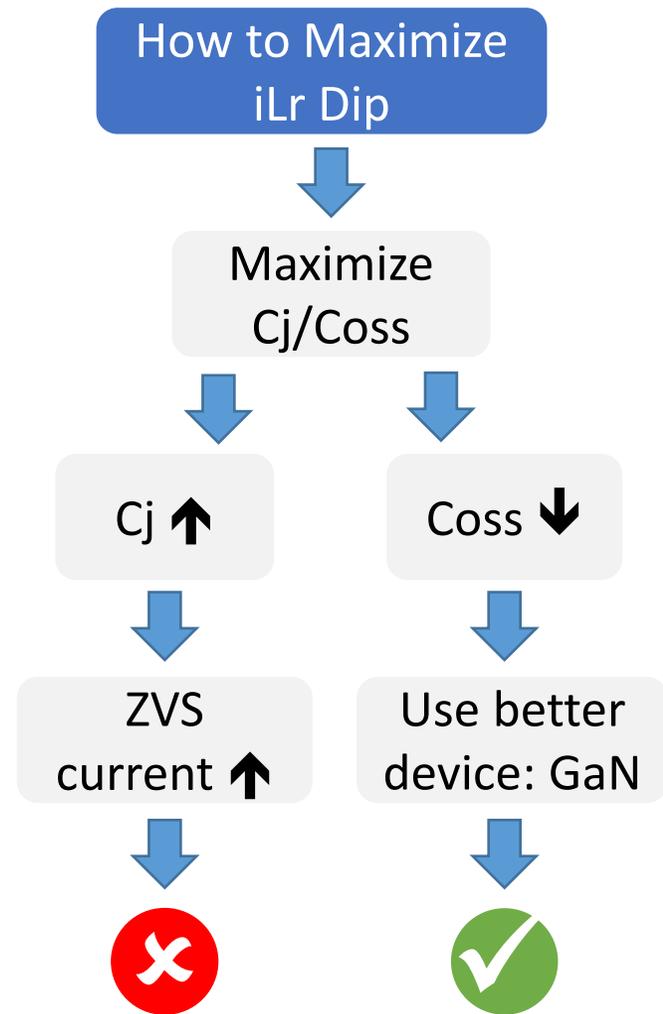
Current Dip Benefits



- Current dip \uparrow
- SR double turn-on \downarrow



- Current dip \uparrow
- RMS value $i_{Lr(RMS)}$ \downarrow



Current Dip: Adding 2.2nF Cj

