GaN Power HEMT Tutorial:
GaN Applications

GANPOWER INTERNATIONAL INC
(In collaboration with Digiq Power)

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Contents

Rough Comparison: GaN vs. MOSFET

	MOSFET	GaN	Comments
Switching speed	Slower	Faster	Very Good
R_{ds}	Larger	Smaller	Excellent
V_{gs} range	Wider (5- 20V)	Narrower (4.5 to 6.5V)	Bad
Avalanche	Yes	No	Bad
Price	Lower	Higher	Bad

Need new technologies optimized for GaN

- ✓ Take full advantages of GaN device
- ✓ Better Performance at higher / same cost

MOSFET as a Switch vs. GaN as a Switch

MOSFET used for past 30 years:

- All the problems ironed out
- All the lessons learned
- Very well understood
- Optimal topologies identified
- Application strategies found

30 years ago, initial MOSFET:

- As compared with BJT
- Very sensitive to noise
- Easy to get damaged
- Similar scenario as the GaN vs MOSFET

GaN as a new device:

- More expensive (- - -)
- Faster switching speed (+ +)
- Lower on resistance value (R_{ds}) (+ + +)
- Higher "body diode" voltage (-)
- No "body diode" reverse-recovery charge (++)
- Narrow V_{gs} Range (- -)

GaN is Expensive (- - -)

- How to justify the higher cost
  - Smaller sizes
  - Higher efficiency
  - Something that MOSFET cannot achieve
- Need a new eco-system for GaN switch
  - Topology
  - Control
  - Gate drive
  - Package

Faster Switching Speed (+ +)

Good:

- Lower switching loss
- Higher switching frequency

Bad:

- Large voltage ringing due to L*di/dt
- Coupled to gate signal causing higher GaN loss, even damage
- Increase gate resistor value

Consequence:

- Paramount to reduce AC loop (to reduce L)
- Extensive experience on layout
- Limited improvement for hard switching topology

Lower On Resistance (R_{ds}) (+ + +)

Good:

- Lower conduction loss
- Allow for higher conduction current

Bad: None

Consequence:

- Resonant converter is more advantageous
- Example: 250 – 400V, 12V / 500W

Example: 250 – 400V, 12V / 500W

	Conduction Loss	% of P_{out}
PSFB with MOSFET (0.11Ω)	1.70W	0.34%
LLC with MOSFET (0.11Ω)	2.75W	0.55%
LLC with GaN (0.05Ω)	1.25W	0.25%

Higher "Body Diode" Voltage (-)

Good:

- None

Bad:

- Higher loss when "Body Diode" Conducts

Consequence:

- Very important for dead time control
- Different (adaptive) dead time for different conditions
- Reduce the current through the "Body Diode"

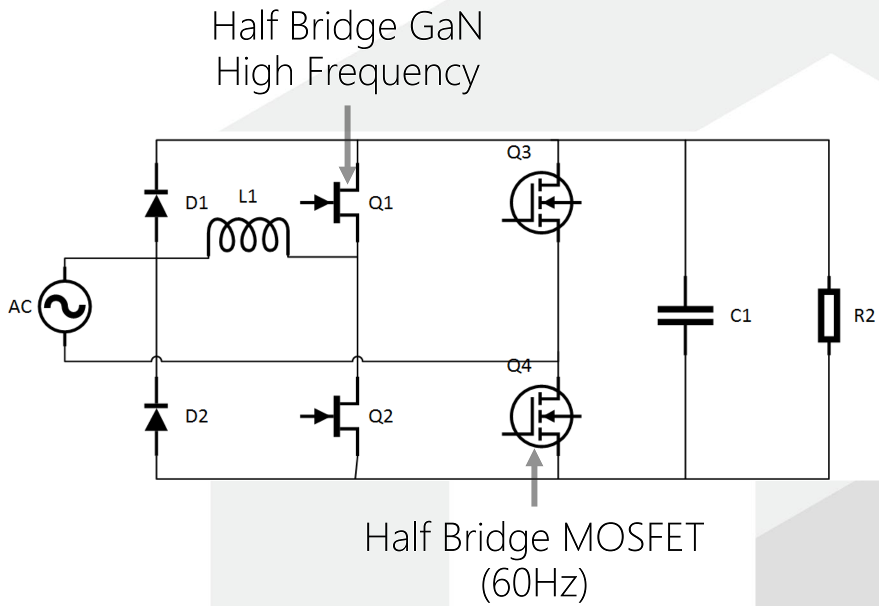
No "Body Diode" Reverse-Recovery (+)

Good:

- One less loss source

Bad:

- None



Consequence:

- For Totem-Pole Bridgeless Boost converter
- 99% + efficiency
- Only PWM converter with GaN

Narrow V_{gs} Range (- -)

Good: None

- 4.5V to 6.5V
- Reasonable for V_{cc} circuit

Bad:

- V_{gs} variation due to large L*di/dt
- Common source inductor (L_{cs}) impact

Consequence:

- Paramount to reduce L_{cs}
- Integrated driver + GaN switch in same die
- Topology not sensitive to L_{cs}

GaN: ZVS and LLC

Zero-Voltage Switching for GaN device:

- Best operating mode for GaN
- Maximize the benefit of GaN devices
- Higher switching frequency and low conduction loss

DCM operation for PWM converter:

- Making the inductor current negative
- Using negative current to achieve ZVS
- ZVS operation of PWM converter

Resonant converter:

- LLC resonant converter
- Achieving ZVS over entire operating range

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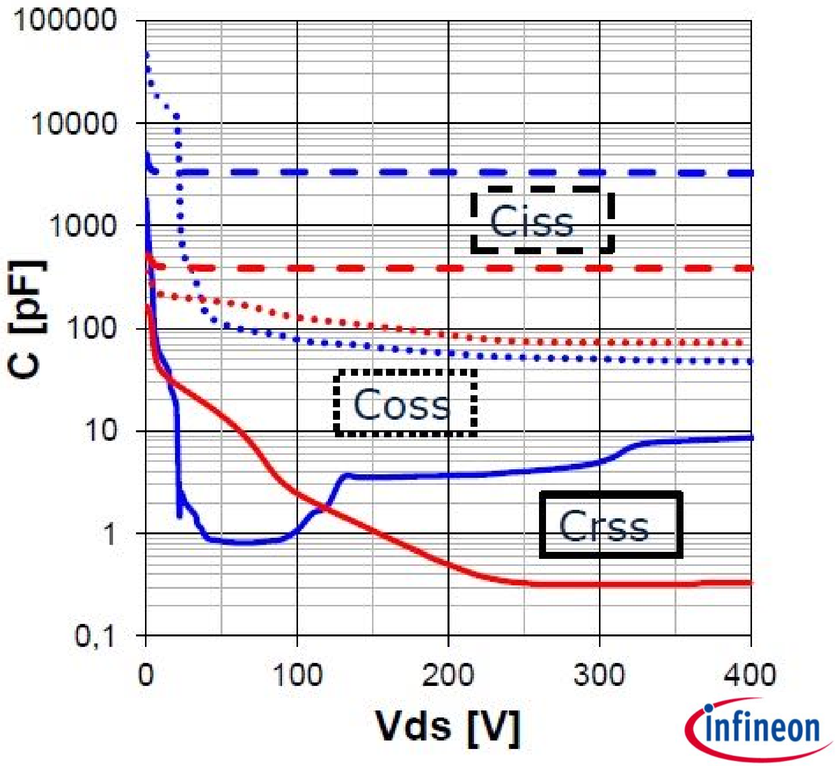
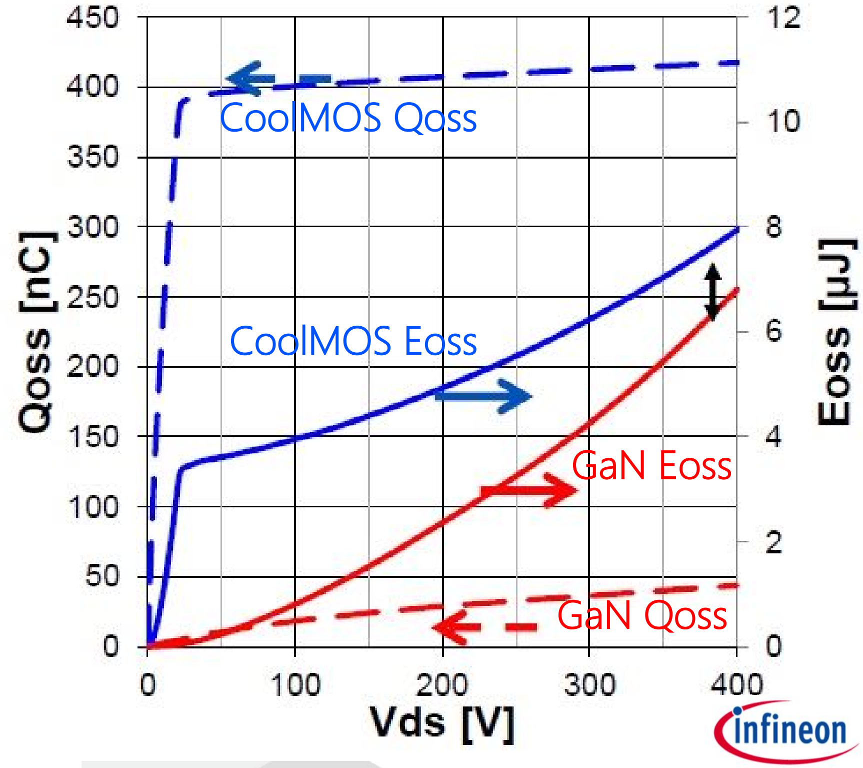
Why Hard-Switching is not for GaN?

Blue: Super Junction Red: E-mode GaN Both ~70 mΩ R_{dson}



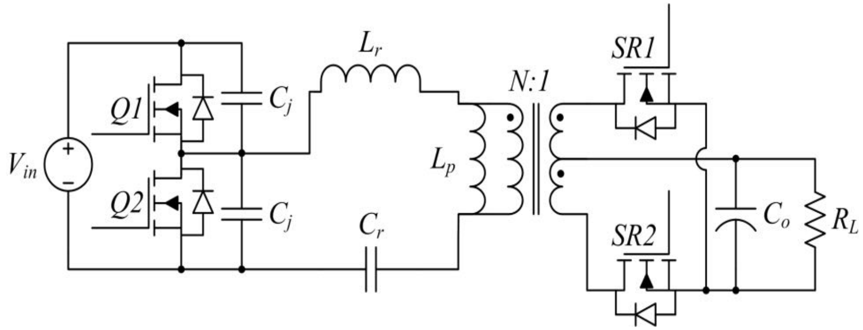


- ✓ Superjunction capacitances are much higher when compared to GaN
- ✓ Superjunction C_{oss} and C_{rss} behave very nonlinearly with voltage
- ✓ Output charge Q_{oss} difference is very large (up to 10x at 100 V)
- ✓ Difference in E_{oss} is much smaller (e.g: 20% at 400 V)

Source: Tim McDonald, GaN in a Silicon world: competition or coexistence? Infineon Technologies, APEC 2016

Why Should We Use ZVS Switching for GaN?

- There is no large difference in E_{oss} at 400V for GaN and SJ FET with same rated BV and comparable R_{dson}
- $C_{O(tr)}$ of GaN device is 10x lower than SJ FET, which can be leveraged in ZVS applications where it can result in lower power losses. This benefit grows with frequency (as a fixed deadtime grows in percentage of total switching cycle time)
- Hard switching turn-on loss is much higher than turn-off loss, use ZVS turn-on and fast hard turn-off can optimize the switching loss



Source: Tim McDonald, GaN in a Silicon world: competition or coexistence? Infineon Technologies, APEC 2016

Features of Resonant Converters

Frequency control

- Output voltage determined by ratio of F_s and F_r
- Around 50% duty cycle with dead time

Zero Voltage Switching (ZVS)

- ZVS over entire input and output voltage / load current range
- Very low switching loss
- L_{CS} is no long an impact

Higher Conduction Loss

- Higher circulating current through resonant tank
- Not an issue with GaN's lower R_{dson}

The Topology is Optimized for GaN Devices

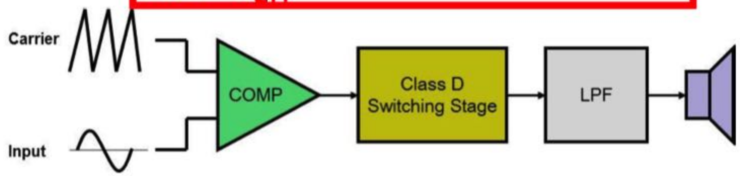
Contents

GaN Applications Survey

3b First use of GaN: 100 V cascode device for class D audio amplifier

Infineon

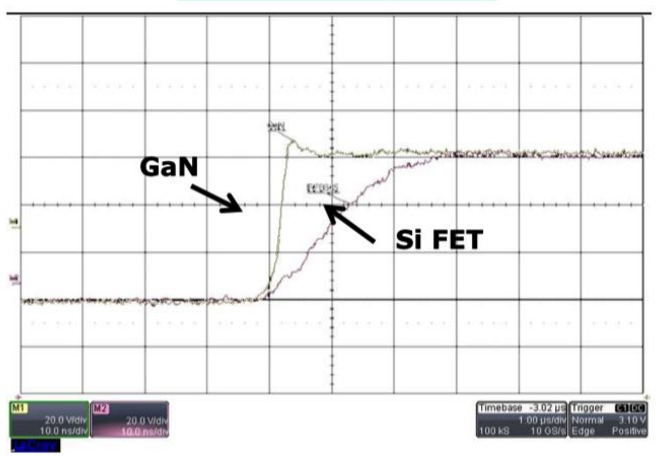
Leverages extremely low Q_{rr}



Improves Audio Quality

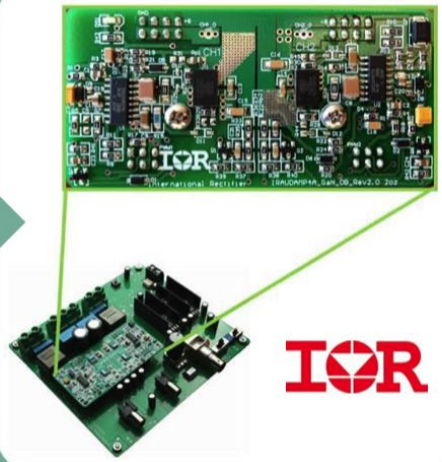
Key values	GaN benefit vs Silicon
Audio Quality	Lower - THD improves from faster/cleaner switching characteristics
Efficiency	Higher - from lower resistance
More channels, smaller size	Smaller – Full SMD w/o heatsink, high frequency for smaller LPF

Fast switching



MP: 2013

166W GaN Class D

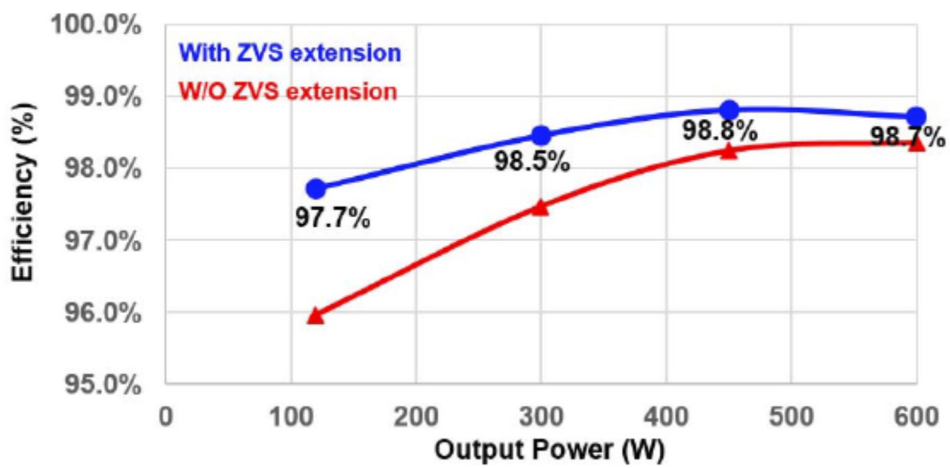


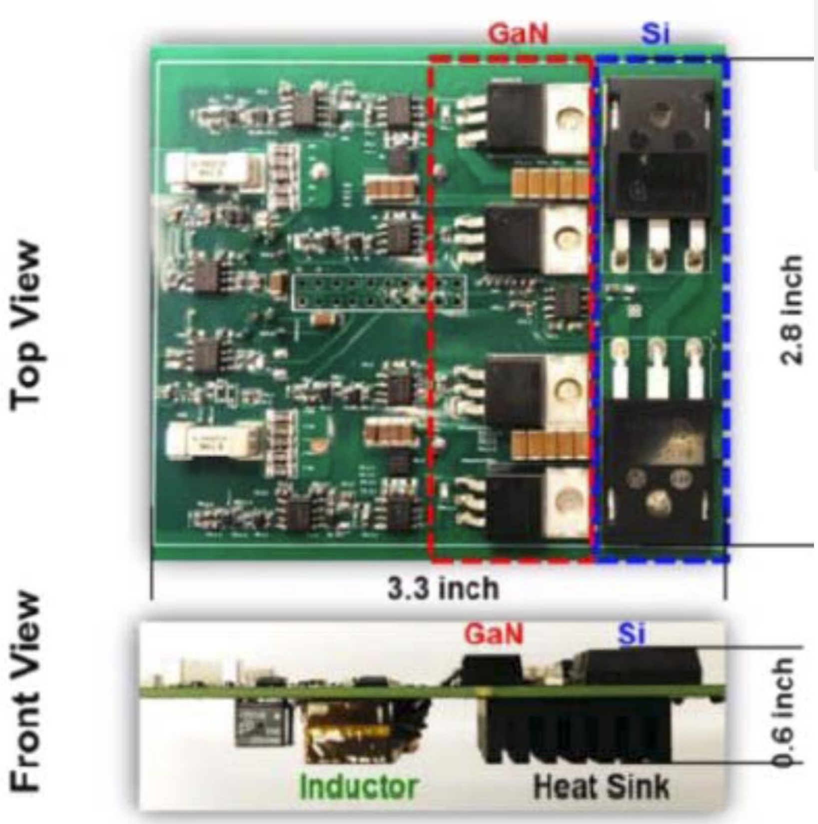
Source: Tim McDonald, GaN in a Silicon world: competition or coexistence? Infineon Technologies, APEC 2016

GaN Applications Survey:
Totem-Pole Bridgeless Boost at ZVS

Benefits:

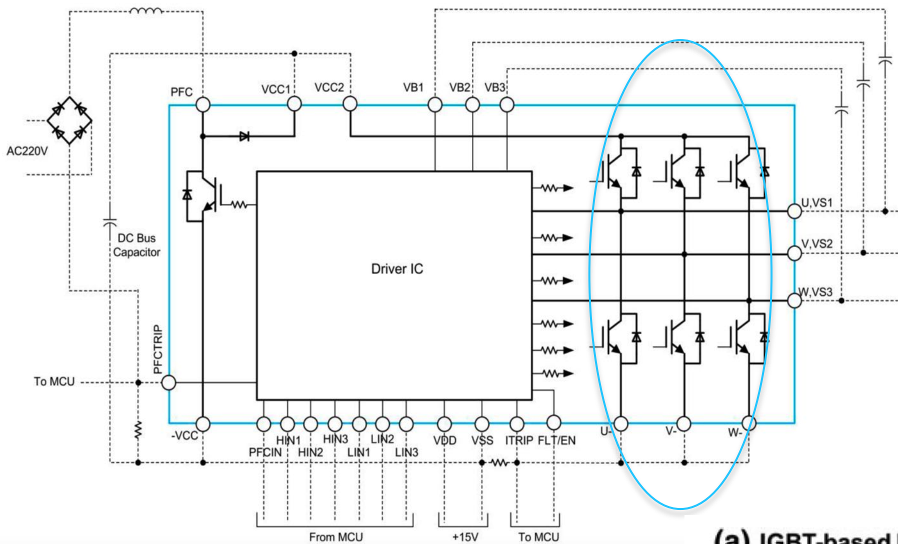
Smaller size and high efficiency

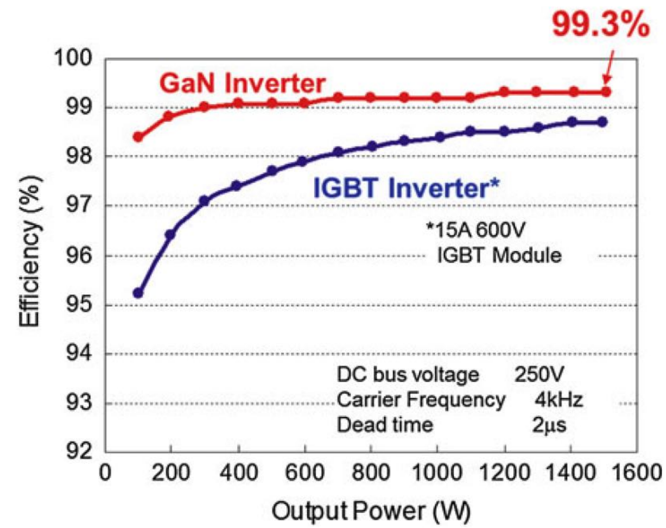


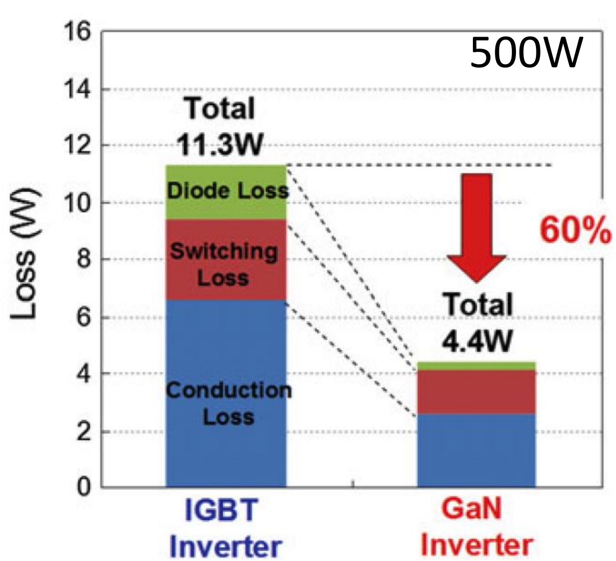


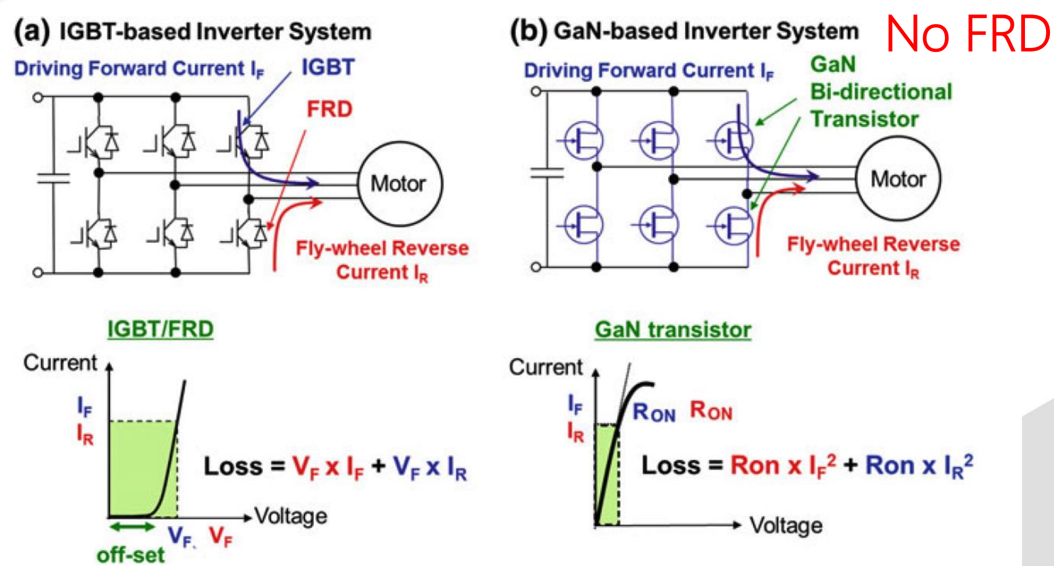
Z. Liu, FC Lee, etc, "Design of GaN-Based MHz Totem-Pole PFC Rectifier", JESTPE 2016

GaN Applications Survey: Air Conditioning Inverter





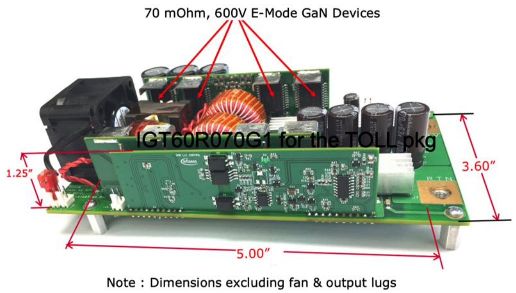




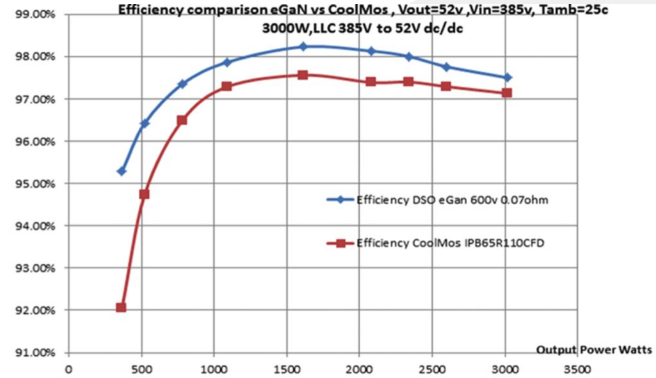
Source: Matteo Meneghini Gaudenzio Meneghesso Enrico Zanoni, Power GaN Devices: Materials, Applications and Reliability, Springer 2017

GaN Applications Survey:

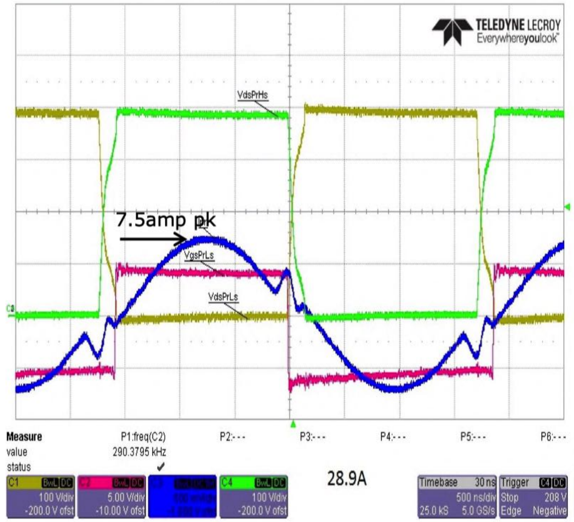
3600W LLC 380V to 52V Converter from Infineon



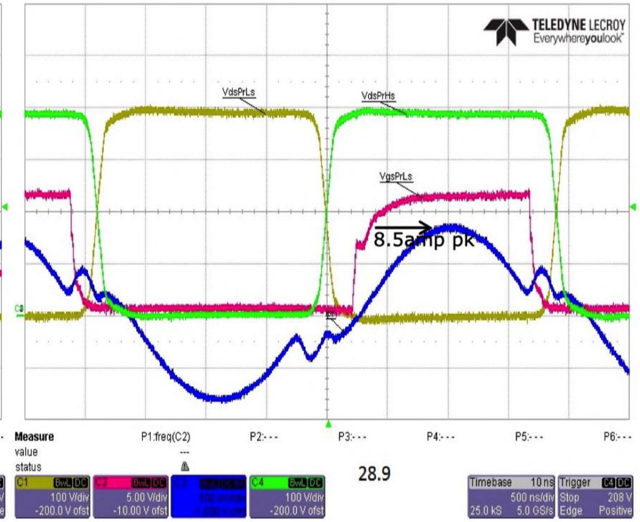
Power Density: 3600W/22.5 in.^{3}= **160 W/in.^{3}**



■ GaN 1500W, LLC



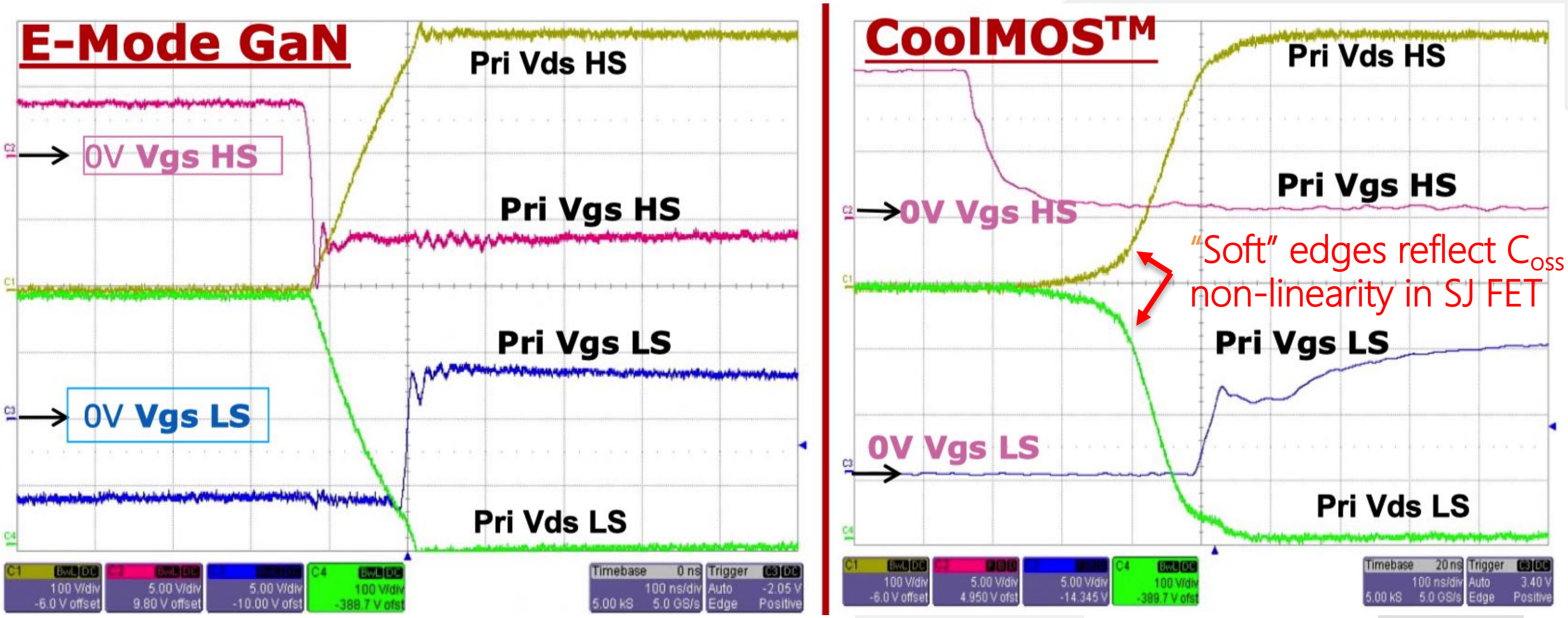
■ COOL MOS 1500W LLC



E-Mode GaN vs CoolMOS™ waveforms, I_{out}=30Amp, V_{out}=52V, V_{in}=385V

Moshe Domb, E-Mode GaN ,600V, 0.07Ohm, utilized in 3600W_ LLC 380V to 52V Converter, Infineon, APEC 2018

GaN Applications Survey:
3600W LLC 380V to 52V Converter from Infineon

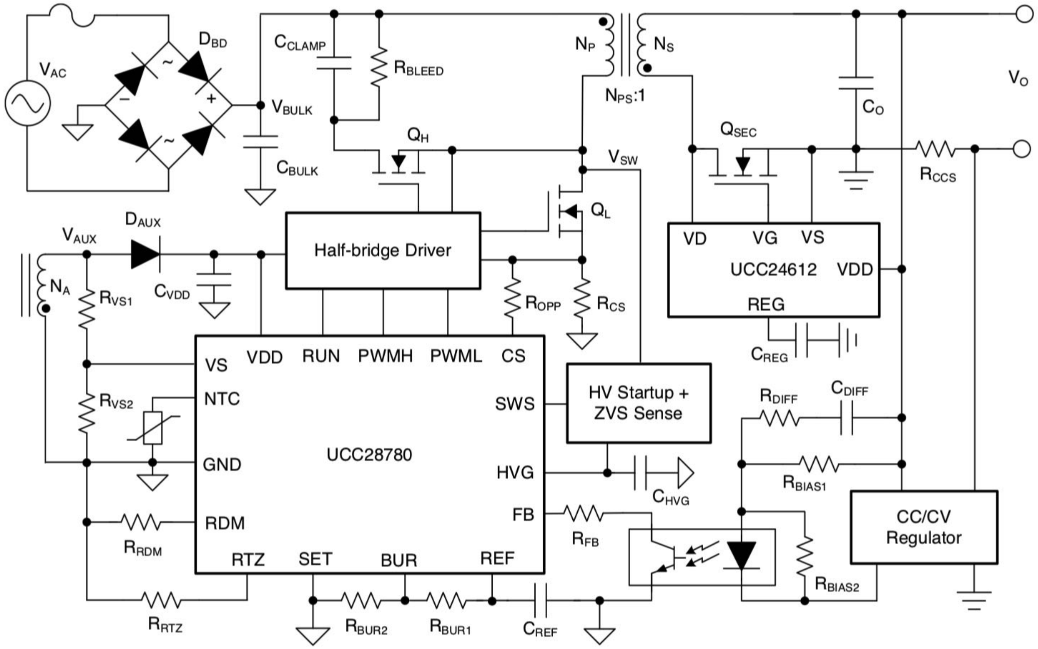


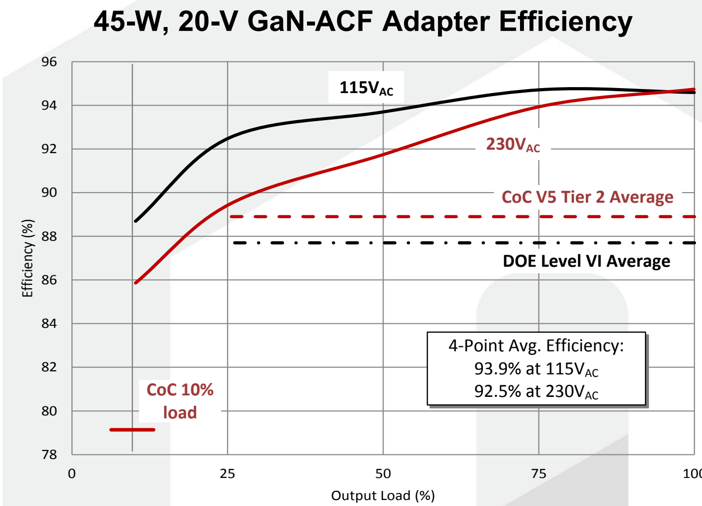
- CoolMOS requires much longer dead time between primary switches: 350ns compared to 130ns with GaN
- The longer dead time for CoolMOS also forces a higher primary & secondary peak current , compared to GaN to deliver the same output current, which causes more loss

Moshe Domb, E-Mode GaN ,600V, 0.07Ohm, utilized in 3600W_ LLC 380V to 52V Converter, Infineon, APEC 2018

GaN Applications Survey:

Active Clamp Flyback USB-PD Charger from TI and Navitas





- ✓ Zero voltage switching (ZVS) is achieved over a wide operating range with advanced auto-tuning techniques, adaptive dead-time optimization, and variable switching frequency control law.
- ✓ Using adaptive multimode control that changes the operation based on input and output conditions, UCC28780 enables high efficiency while mitigating audible noise.
- ✓ With a variable switching frequency of up to 1 MHz and accurate programmable over-power protection, which provides consistent power for thermal design across wide line range, the size of passive components can be further reduced and enable high power density.

Source: TI UCC28780 Datasheet

GaN Applications Survey:

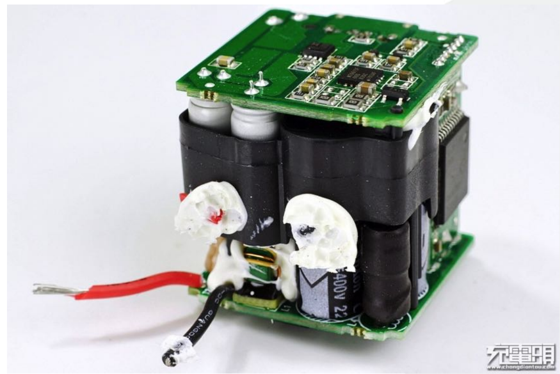
GaN applications that are in Mass Production: PC Gaming Power

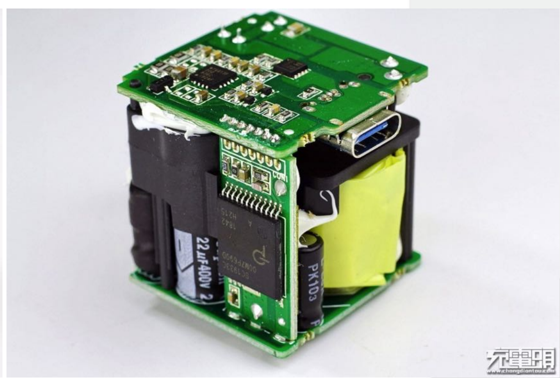
- ✓ The AX1600i uses Transphorm's TPH3205WS 650V FETs in a bridgeless totem-pole power factor correction (PFC)—the topology that complements GaN's performance and efficiency potential.
- ✓ With an increase of 6 percent within this topology, CORSAIR's PSU efficiency now earns a better-than an 80 PLUS® Titanium rating.
- ✓ Previous CORSAIR power supplies used Silicon (Si) super junction (SJ) MOSFETs in a 2-phased interleaved PFC, reaching 93 percent efficiency

Source: www.transphormusa.com

GaN Applications Survey:

GaN applications that are in Mass Production: 30W QR Adapters





- ✓ According to the teardown, this 30W power adapter is powered by Power Integrations InnoGaN
- ✓ Quasi-resonant Flyback topology is used in this adapter
- ✓ Input: 100 – 240V; output: 5V/3A, 9V/3A, 15V/2A, 20V/1.5A (30W)

Source: www.chongdiantou.com

GaN Applications Survey:

GaN applications that are in Mass Production: 45W ACF Adapters

- ✓ According to the teardown, this 45W power adapter is powered by Navitas NV6115 (650V 170 mΩ) and TI UCC28780 controller)
- ✓ Active Clamp Flyback (ACF) topology is used in this adapter
- ✓ Input: 100 – 240V; output: 5V/3A, 9V/3A, 12V/3A, 15V/3A, 20V/2.25A (45W)

Source: www.chongdiantou.com

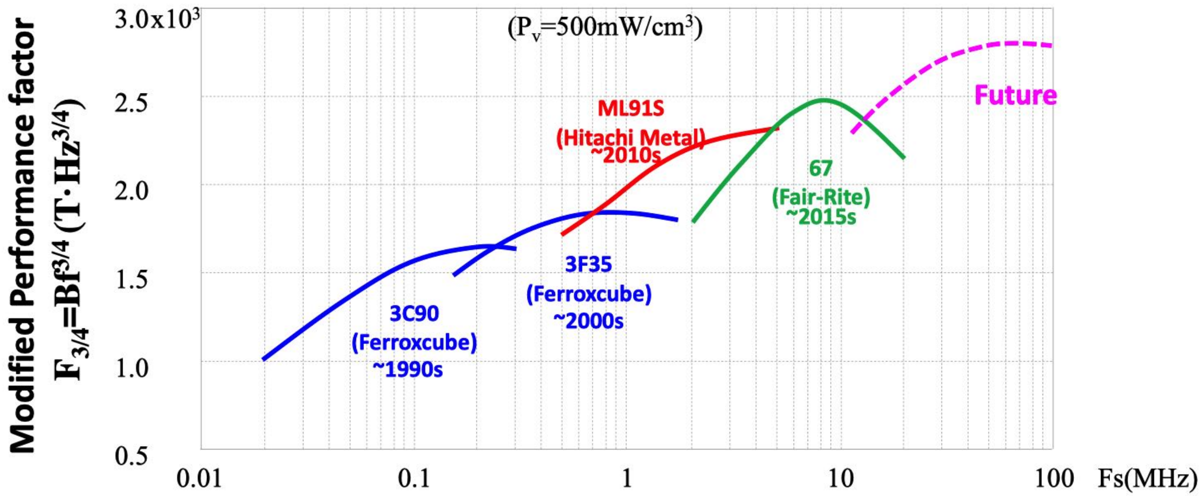
GaN Applications Survey:

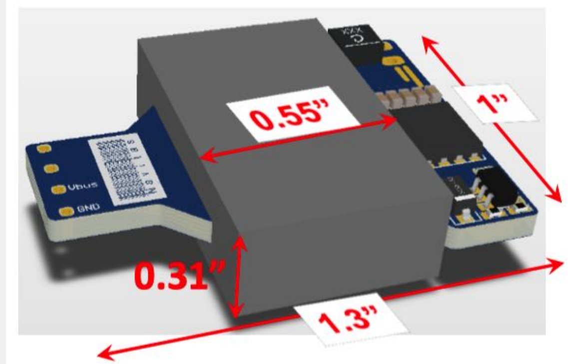
Commercially Available Ultra Compact 65W Adapters

65W Adapter	Lenovo ThinkPlus	Delta PowerGear 60C	Finsix Dart	Zolt	Mi CDQ07ZM	RAVPower GaN
Topology	Flyback	Flyback	3-level LLC	ACF	Flyback	QR
Power Switch	Si SJ MOS	Si SJ MOS	Si SJ MOS	SiC	Si SJ MOS	GaN
Size (Exclude Prongs)	35*74*30 mm	30*60*30 mm	28*70*28 mm	88.9*33*33 mm	60*57*28 mm	48 *48*30 mm
Weight	122g	88g	85g	100g	113g	175g
Max Power	20V/3.25A	20V/3A	20V/3.25A	20V/3.5A	20V/3.25A	20V/3A
USB-C/PD	Yes	Yes	No	No	Yes	Yes
Power Density	13.74W/in³	18.18W/in³	19.42W/in³	11.83W/in³	11.13W/in³	14.08W/in³
Date of Introduction	2018.11	2018.5	2016	2016	2018.6	2019
List Price	30 USD	109 USD	99 USD	49.99 USD	20 USD	37 USD
Product Pictures						

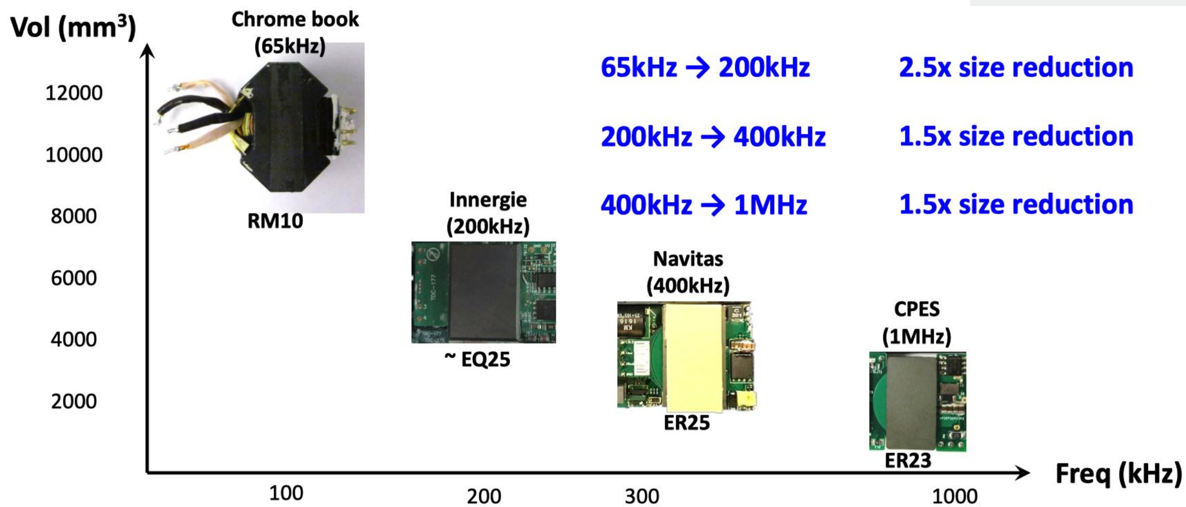
GaN Applications Survey:

High Frequency Magnetics





Planar Magnetics



GaN ICs Enabling Next-Gen ACF for Adapter/Charger Application; Navitas, APEC 2019

Contents

1kW LCLC-SCC* Converter Demo

(in collaboration with Digiq Power)

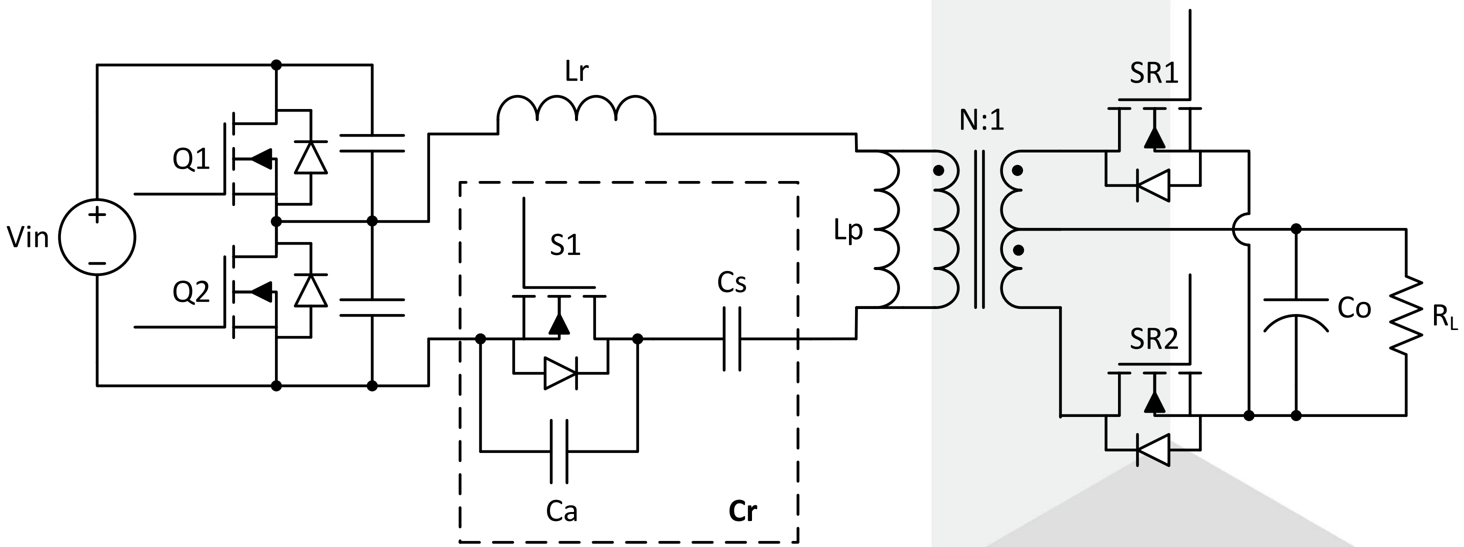
GaNPOWER digiq

*Switch-Controlled-Capacitor (SCC) is a GaNPower patented technology

Switch-Controlled-Capacitor (SCC) – LLC Converter

By compensating the resonant frequency due to L, C tolerance, Switch-Controlled-Capacitor (SCC) is designed to

- Achieve current sharing and interleaving for LLC
- Reduce the rms current and conduction loss
- Reduce the total system volume with higher switching frequency

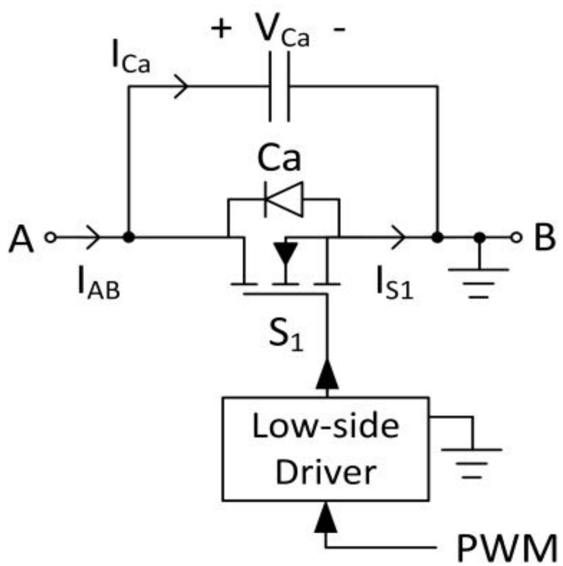


$$C_r = \frac{C_{SC} C_s}{C_{SC} + C_s} = \frac{2\pi C_a C_s}{2\pi C_a + 2\pi C_s - 2\alpha C_s + C_s \sin(2\alpha)}$$

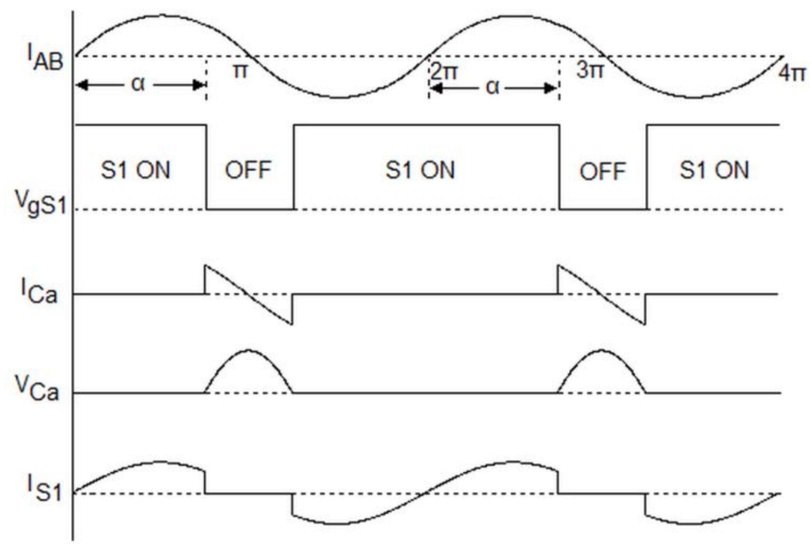
Switch Controlled Capacitor (SCC)

Interleaving	⇒	Same switching frequency		
Component tolerance	⇒	Different resonant frequency	⇒	Different voltage gain

Solution: Switch Controlled Capacitor (SCC) to equalize the resonant frequencies



Topology



Waveforms

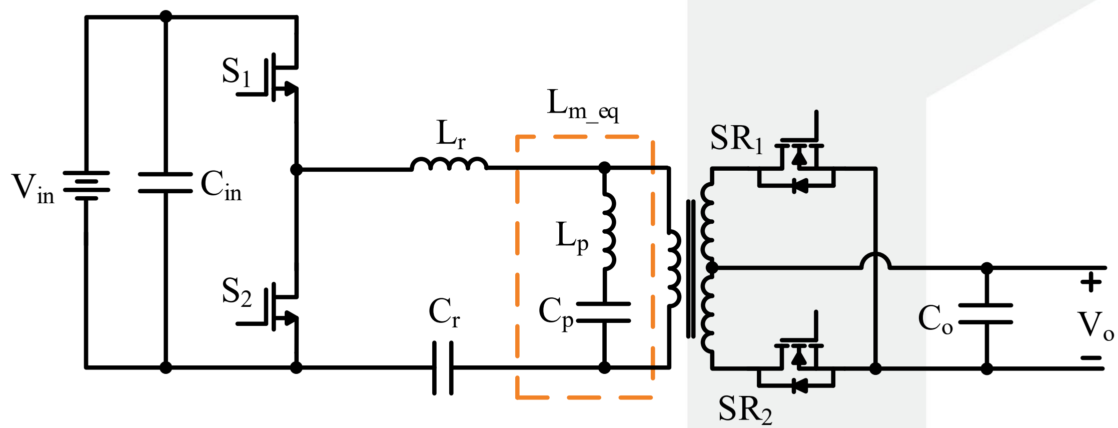
Equivalent capacitor value (C_{AB}) depends on the conduction time of S_1

Benefits of SCC Technology

- ✓ High efficiency at high load current
  - ➢ Through parallel operation with current sharing
  - ➢ Lower conduction loss
- ✓ Lower input and output ripple
  - ➢ Through interleaving operation
- ✓ High switching frequency
  - ➢ Because of lower current for each phase
- ✓ Achieving both (at same time)
  - ➢ Higher power density
  - ➢ Higher efficiency

Introduction to LCLC Resonant Converter

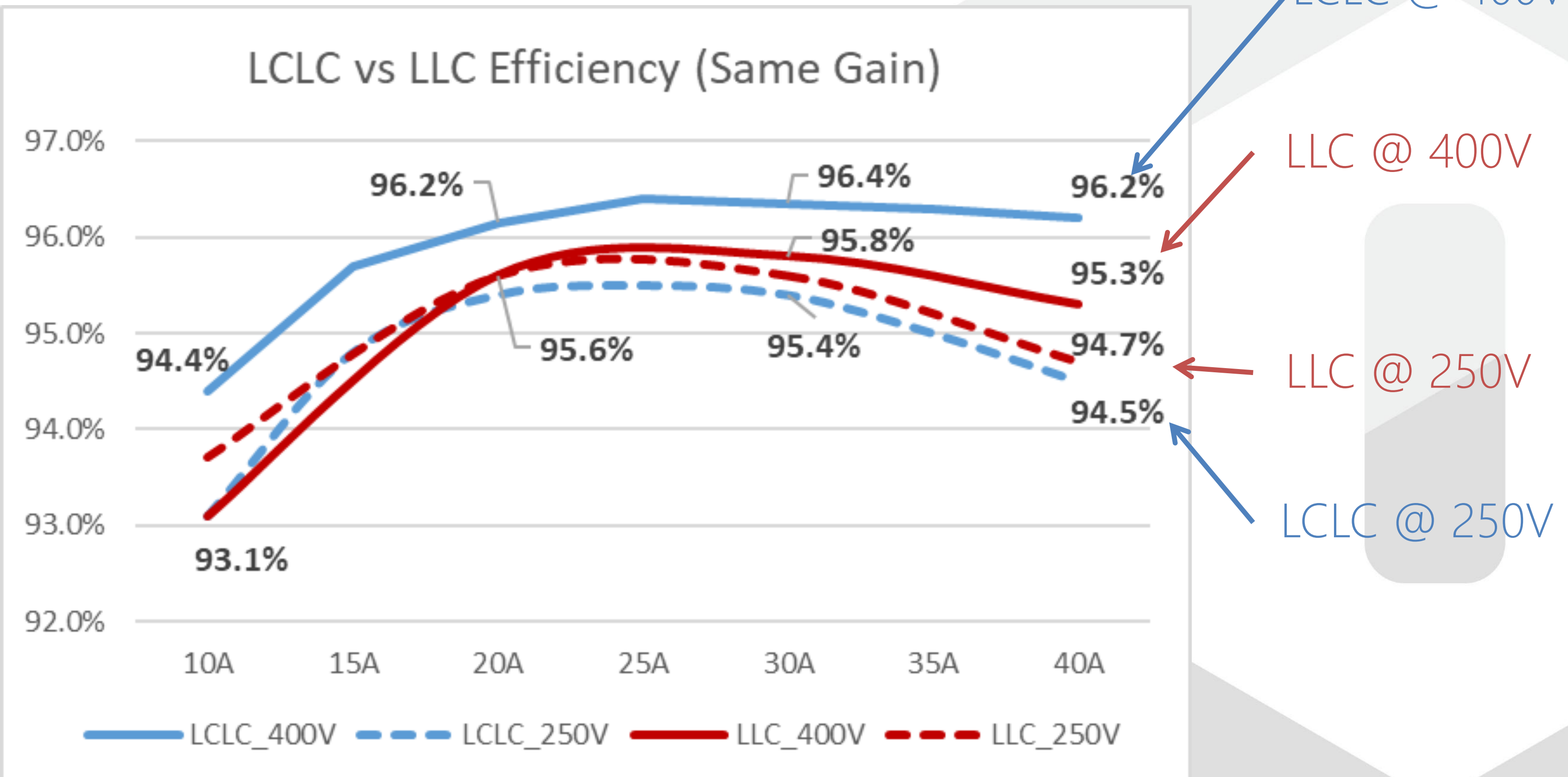
LCLC Resonant Tank → Modified LLC with Changeable L_m



High V_{in} →	High f_{sw} →	Large L_{m_eq} →	Small RMS Current
Low V_{in} →	Low f_{sw} →	Small L_{m_eq} →	High Voltage Gain

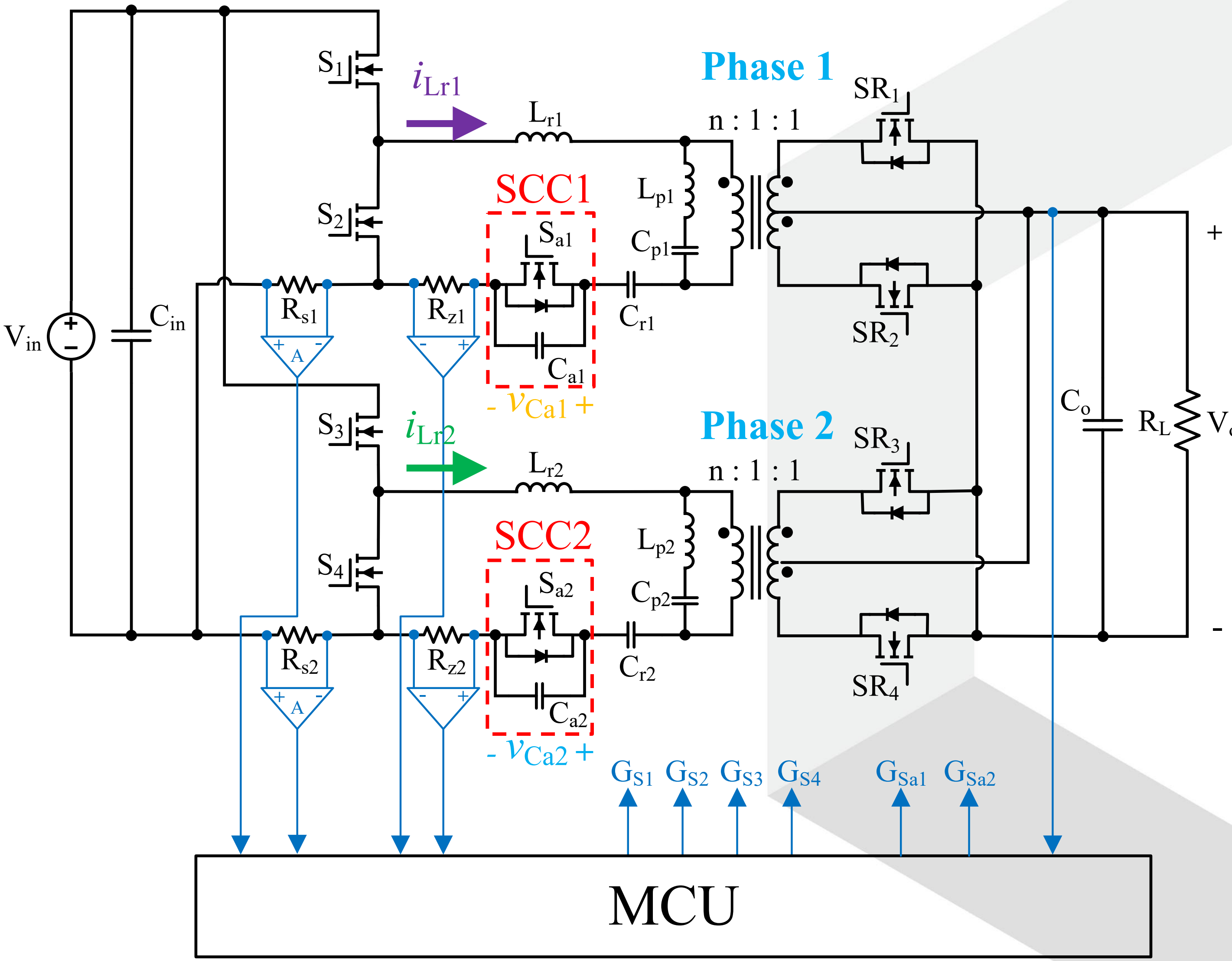
LCLC and LLC Efficiency Comparison

V_{in} = 250 – 400V, V_o = 12V / 500W



Much higher efficiency at 400V for LCLC

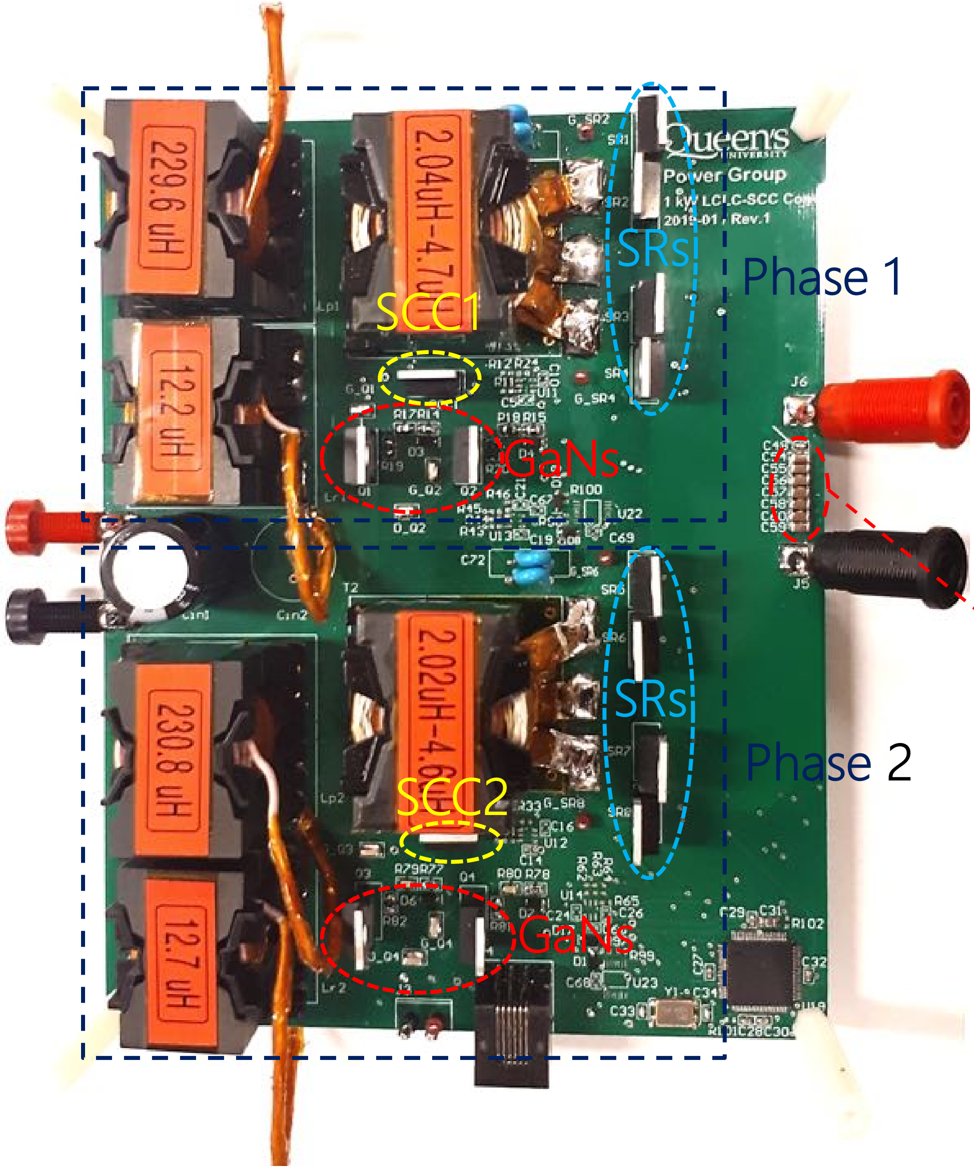
LCLC-SCC Resonant Converter

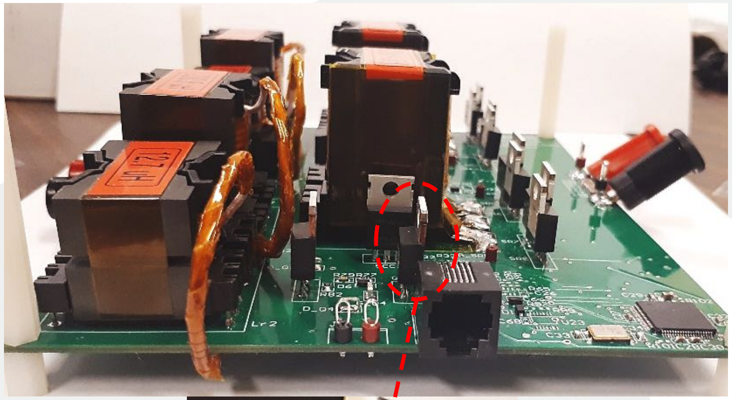


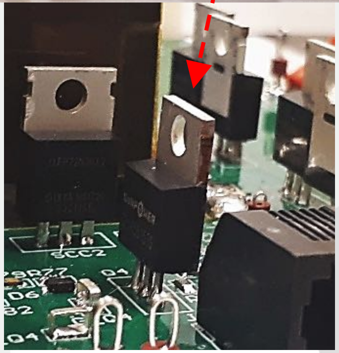
Design Parameters

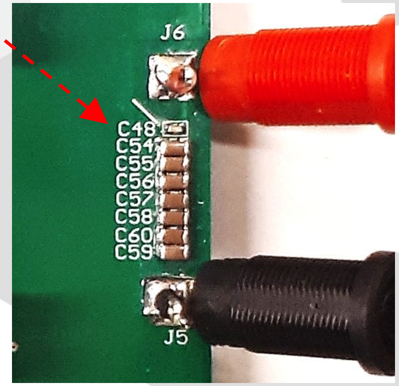
Description	Value
Input Voltage	250 – 400 VDC
Nominal Input Voltage	400 VDC
Output Voltage	12 VDC
Rated Output Current	84 A
Rated Output Power	1 kW
Series Resonant Frequency	320 kHz
Switching Frequency	170 – 240 kHz
Transformer Turns Ratio	18 : 1 : 1 (center tapped)
Resonant Inductor (L_r)	12.8 μH (Phase1) - 12.1 μH (Phase2)
Parallel Inductor (L_p)	230 μH (Phase1) - 223 μH (Phase2)
Resonant Capacitor (C_r)	20 x 1 nF = 20 nF ± 5%
Parallel Capacitor (C_p)	5 x 1 nF = 5 nF ± 5%
SCC Capacitor (Each Phase)	5 x 3.3 nF = 16.5 nF ± 5%
Input Capacitor (Electrolytic)	2 x 68 μF = 136 μF ± 5%
Output Capacitor (Ceramic)	20 x 47 μF = 940 μF ± 5%

Prototype with GaNPower HEMTs (TO-220)

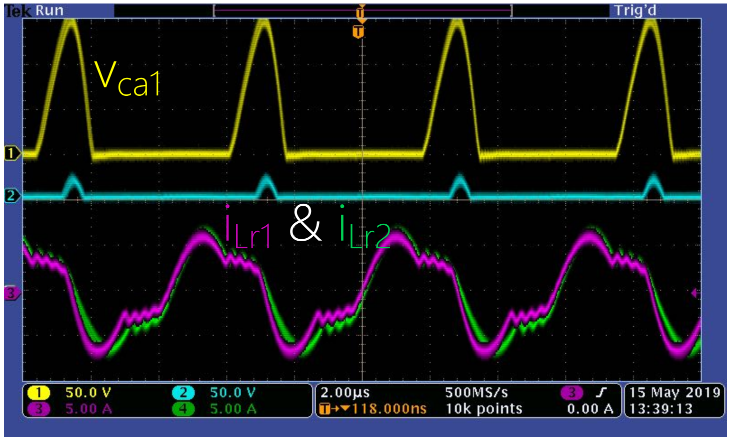




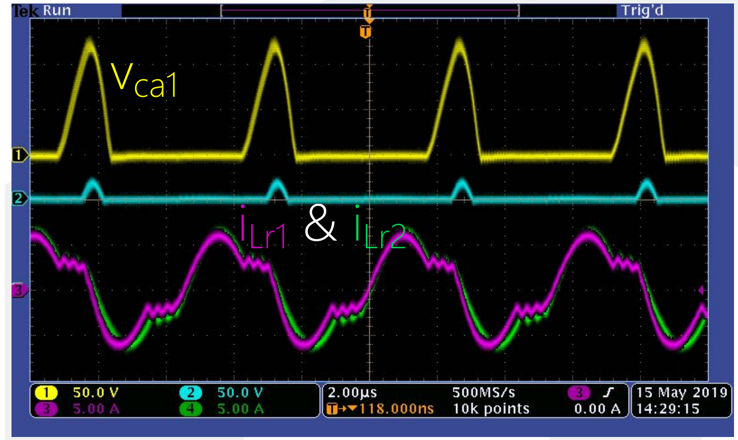




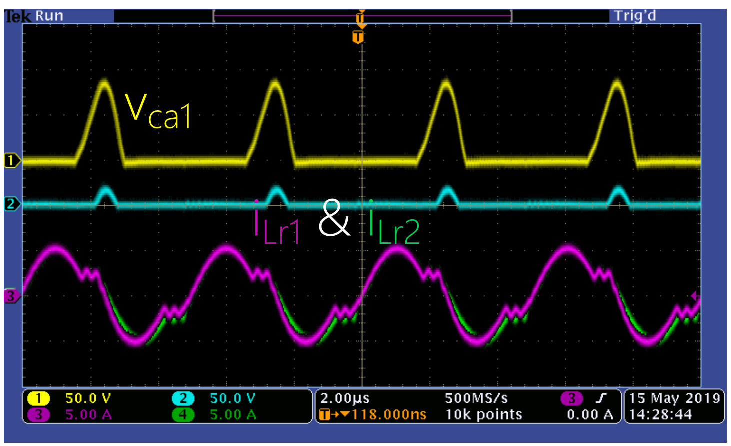
Waveforms of Non-Interleaved LCLC-SCC Resonant Converter



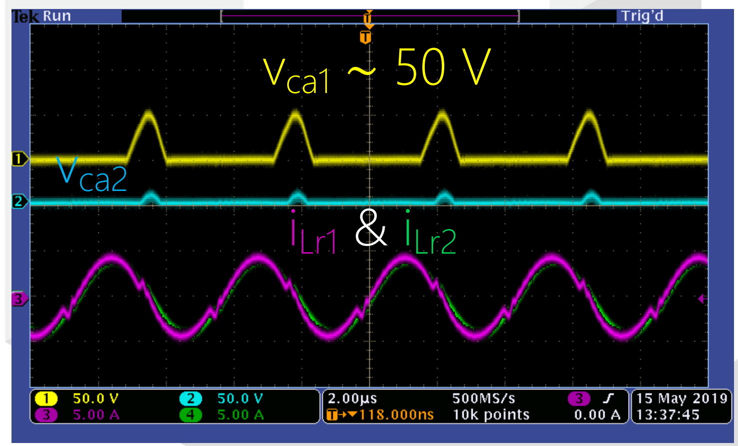
V_{in}=250 V - Load=70 A



V_{in}=300 V - Load=80 A

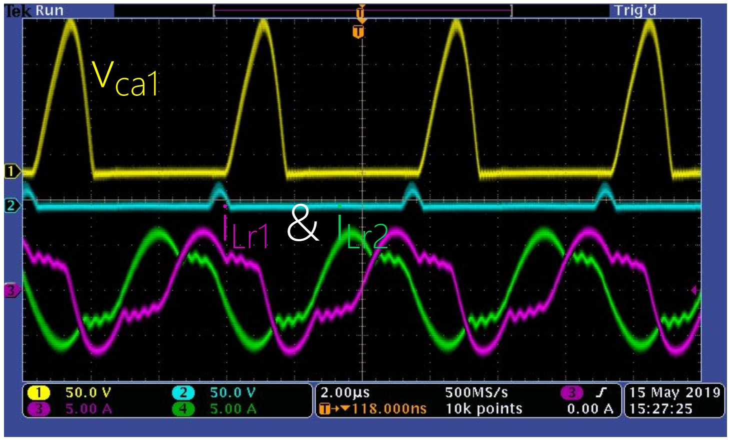


V_{in}=350 V - Load=80 A

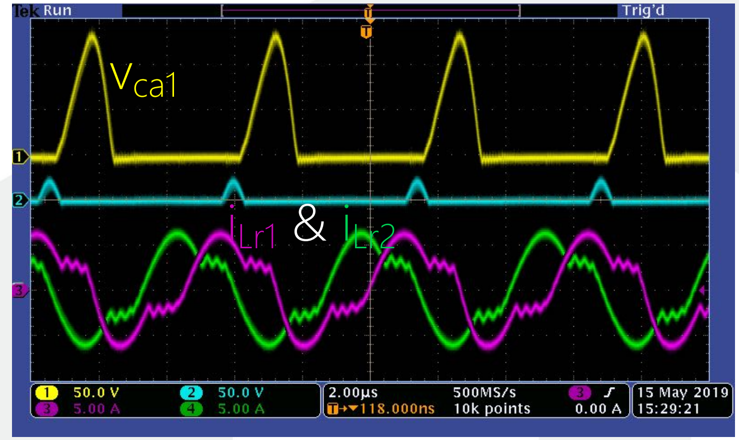


V_{in}=400 V - Load=80 A

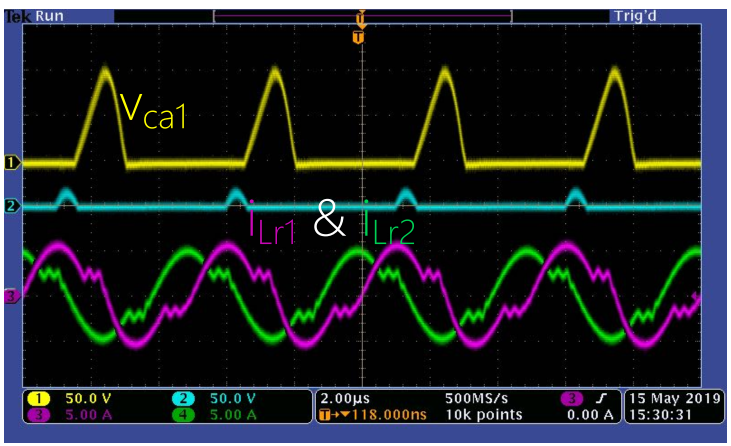
Waveforms of Interleaved LCLC-SCC Resonant Converter



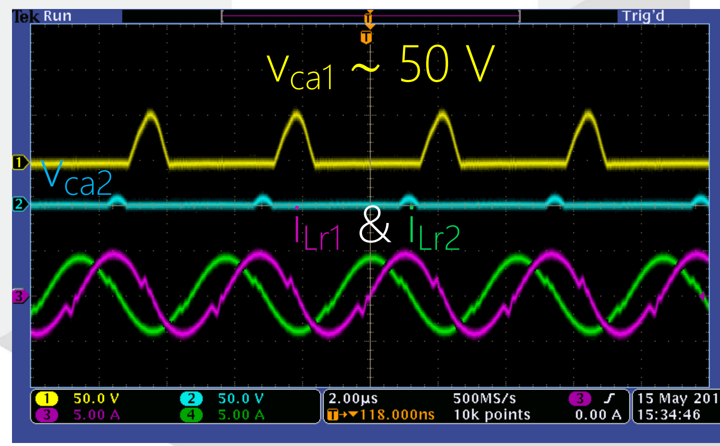
V_{in}=250 V - Load=70 A



V_{in}=300 V - Load=80 A

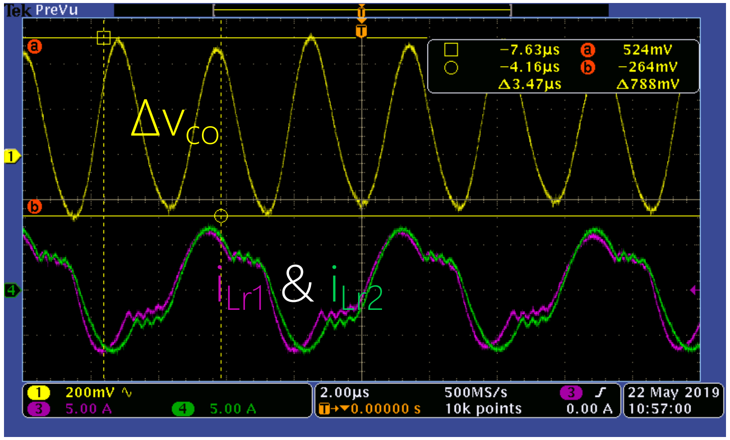


V_{in}=350 V - Load=80 A

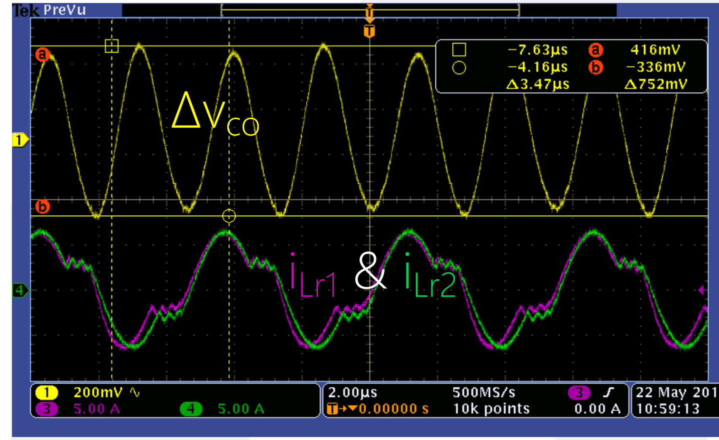


V_{in}=400 V - Load=80 A

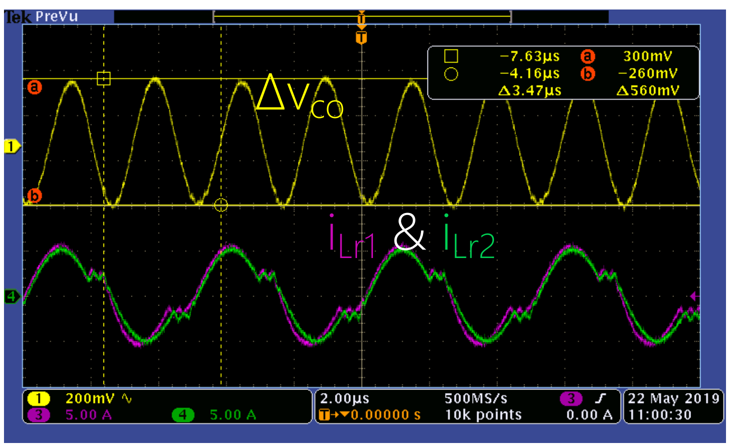
Output Voltage Ripple of Non-Interleaved LCLC-SCC Converter



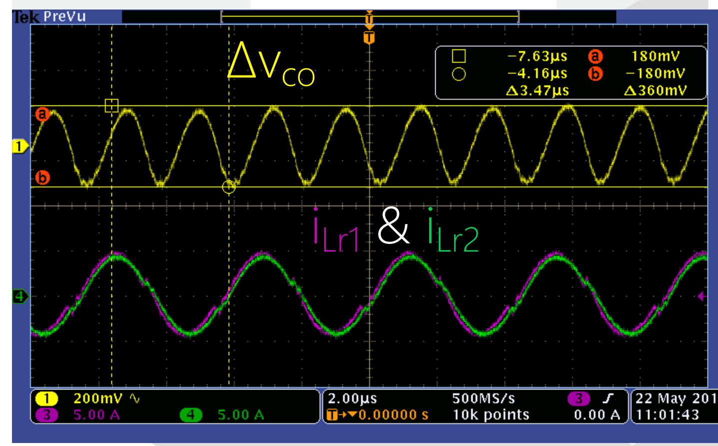
V$_{in}$=250 V - Load=70 A



V$_{in}$=300 V - Load=80 A



V$_{in}$=350 V - Load=80 A



V$_{in}$=400 V - Load=80 A

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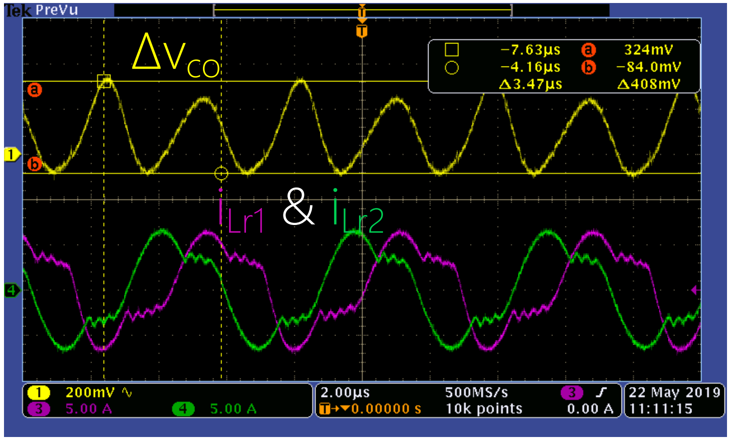
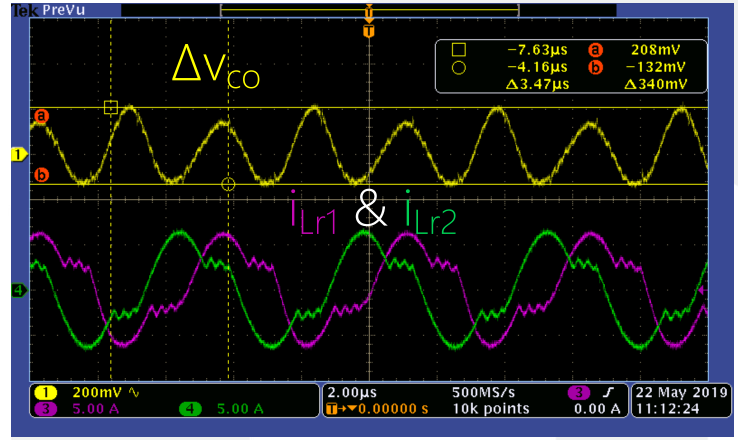
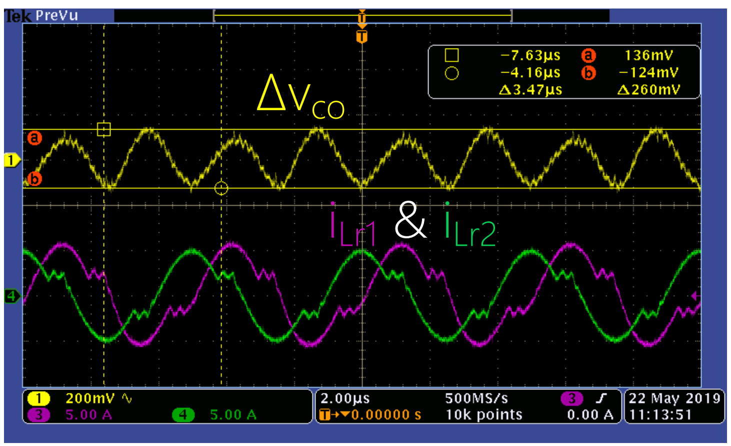
Output Voltage Ripple of Interleaved LCLC-SCC Converter



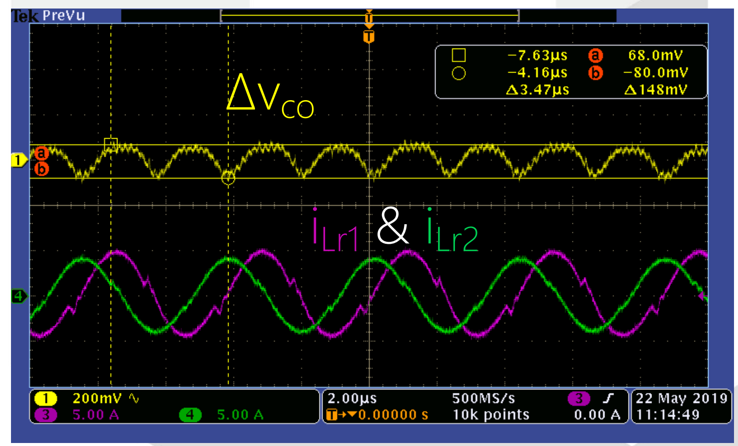
V_{in}=250 V - Load=70 A



V_{in}=300 V - Load=80 A



V_{in}=350 V - Load=80 A



V_{in}=400 V - Load=80 A

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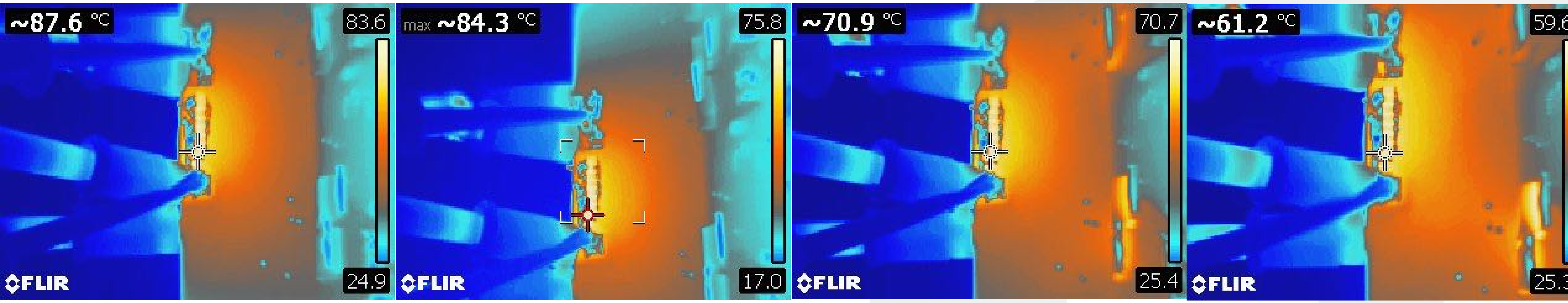
Thermal Images of Output Capacitor with Fan Cooling

Non-Interleaved

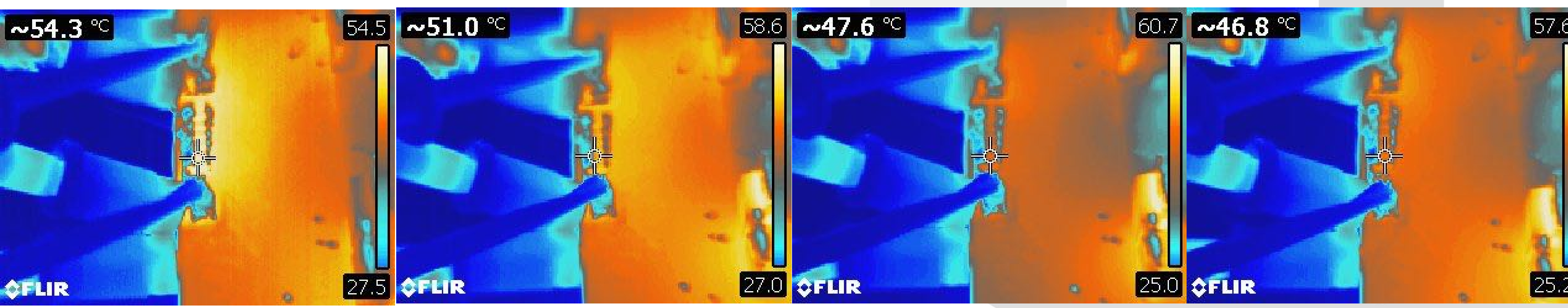


250 V - 70 A

300 V - 80 A

350 V - 80 A

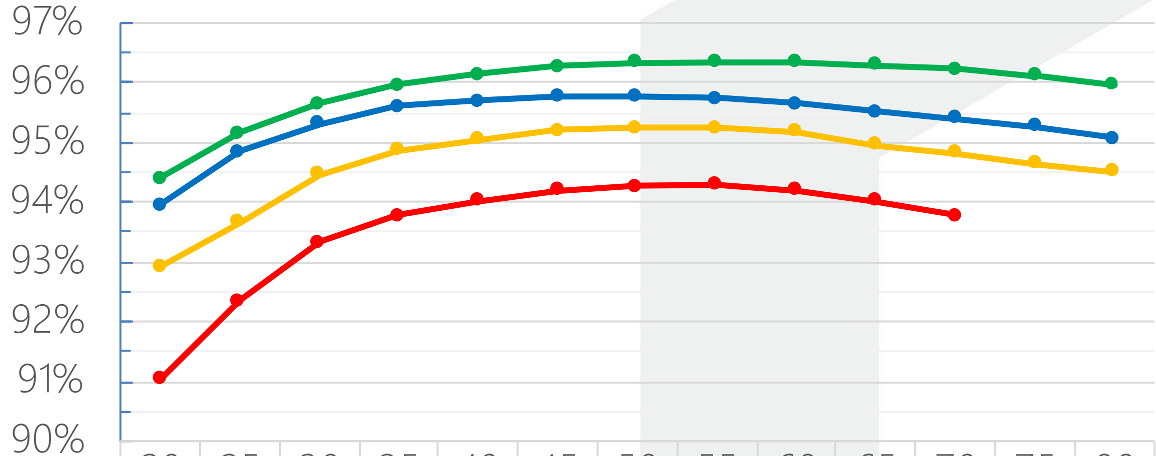
400 V - 80 A



Interleaved

Efficiency Curves (with 15 A GaN Power Devices)

1kW LCLC-SCC Converter (15A GaN Power TO-220)



	20	25	30	35	40	45	50	55	60	65	70	75	80
250 V	91.0	92.3	93.3	93.8	94.0	94.2	94.3	94.3	94.2	94.0	93.8		
300 V	92.9	93.7	94.5	94.9	95.1	95.2	95.3	95.3	95.2	95.0	94.8	94.7	94.5
350 V	94.0	94.8	95.3	95.6	95.7	95.8	95.8	95.7	95.7	95.5	95.4	95.3	95.1
400 V	94.4	95.2	95.7	96.0	96.1	96.3	96.3	96.3	96.3	96.3	96.2	96.1	96.0

Amps

Summary for the 1KW LCLC-SCC Converter

- Small Deadtime is Required for GaN Switches (100ns – 200ns)
- GaN Switches Operate Well for Wide Input Voltage Range
- TO-220 Package GaNs Work Without Heatsink Under Full-Load
- Perfect Current Sharing is Achieved by SCC Technology
- Only Ceramic Capacitors are Used at the Output Due to Interleaving
- Peak Efficiency of 96.3% is Recorded for LCLC-SCC Converter

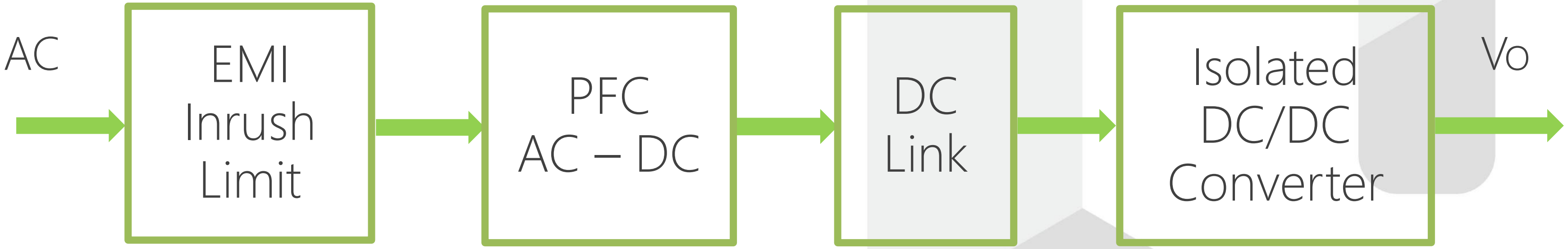
GaNPower SCC for EV OBC and DC/DC Converter

(in collaboration with Digiq Power)

SCC Technology for EV OBC with GaN

Requirements:

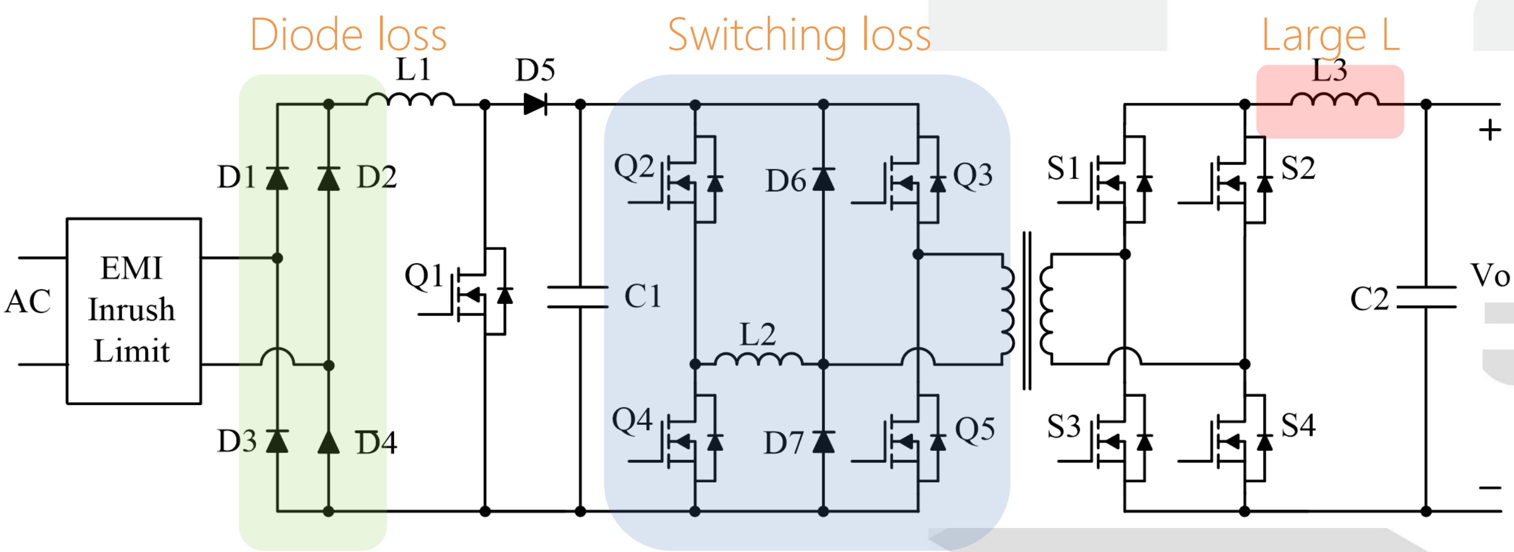
- Output power: 3.3kW and 6.6kW
- Wide input voltage range: 85 – 264V
- Wide output voltage range: 240 – 430V (battery)
- High output current: 14A for 3.3kW and 28A for 6.6kW



Block diagram of on-board EV charger

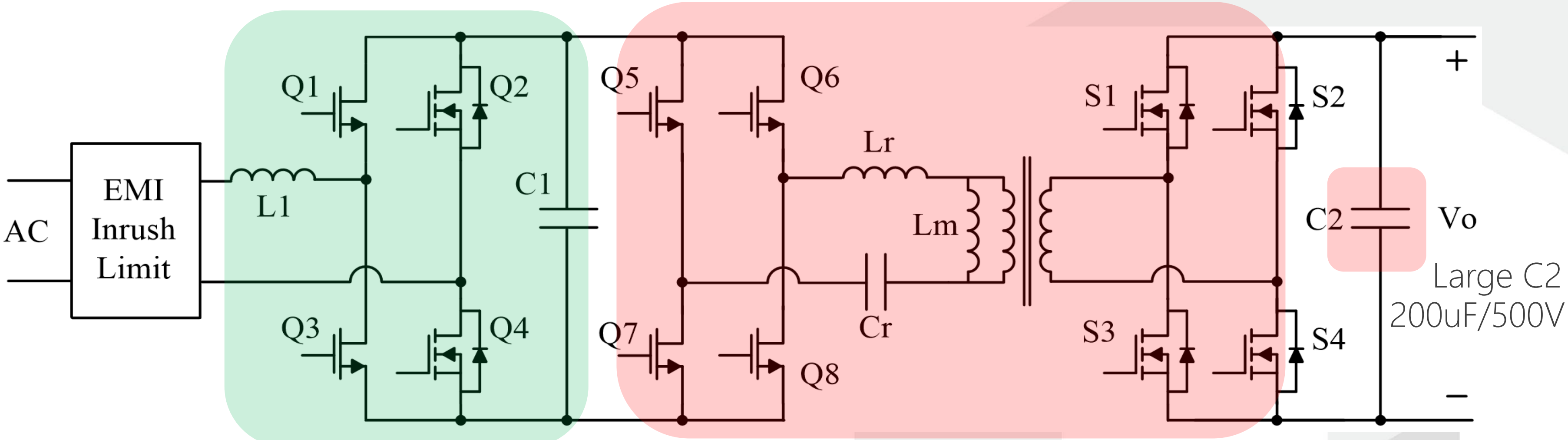
EV OBC Current Technology

- First Generation: Diode Bridge + Boost + Phase-Shift Full Bridge (PSFB)
- Efficiency: 92 – 93%, Power Density: 0.5 – 0.8 kW / L



EV OBC Current Technology

Bridgeless PFC LLC Resonant DC – DC



Good performance Not good for wide voltage gain range

Bridgeless Boost + LLC Resonant (in production)

- Current technology
- Efficiency: 94% (full load)
- Power Density: ~1 kW / L (16W / in^3)

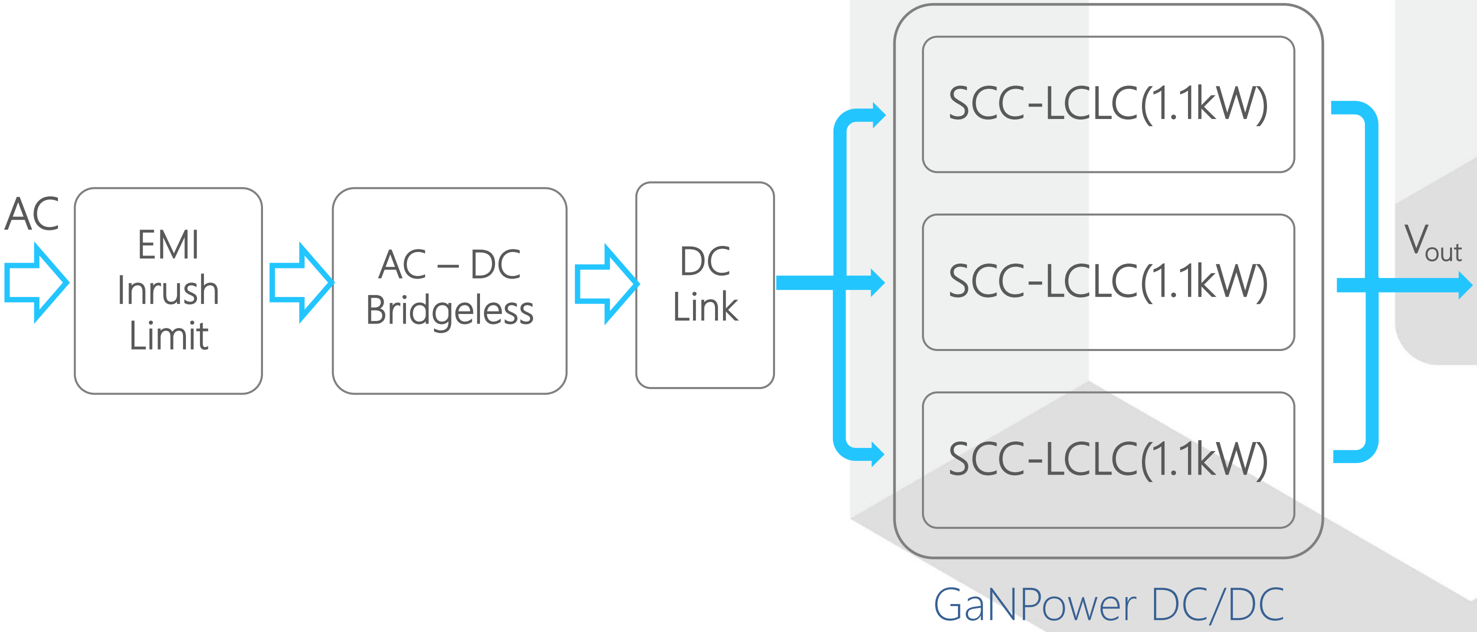
Bridgeless Boost + LLC Resonant (in lab, reported)

- Using GaN and / or SiC
- Efficiency: 95.7% (AC – DC: 98.2%, DC – DC: 97.5%)
- Power density: ~1.5 kW / L (24W / in^3)

GaNPower SCC EV OBC

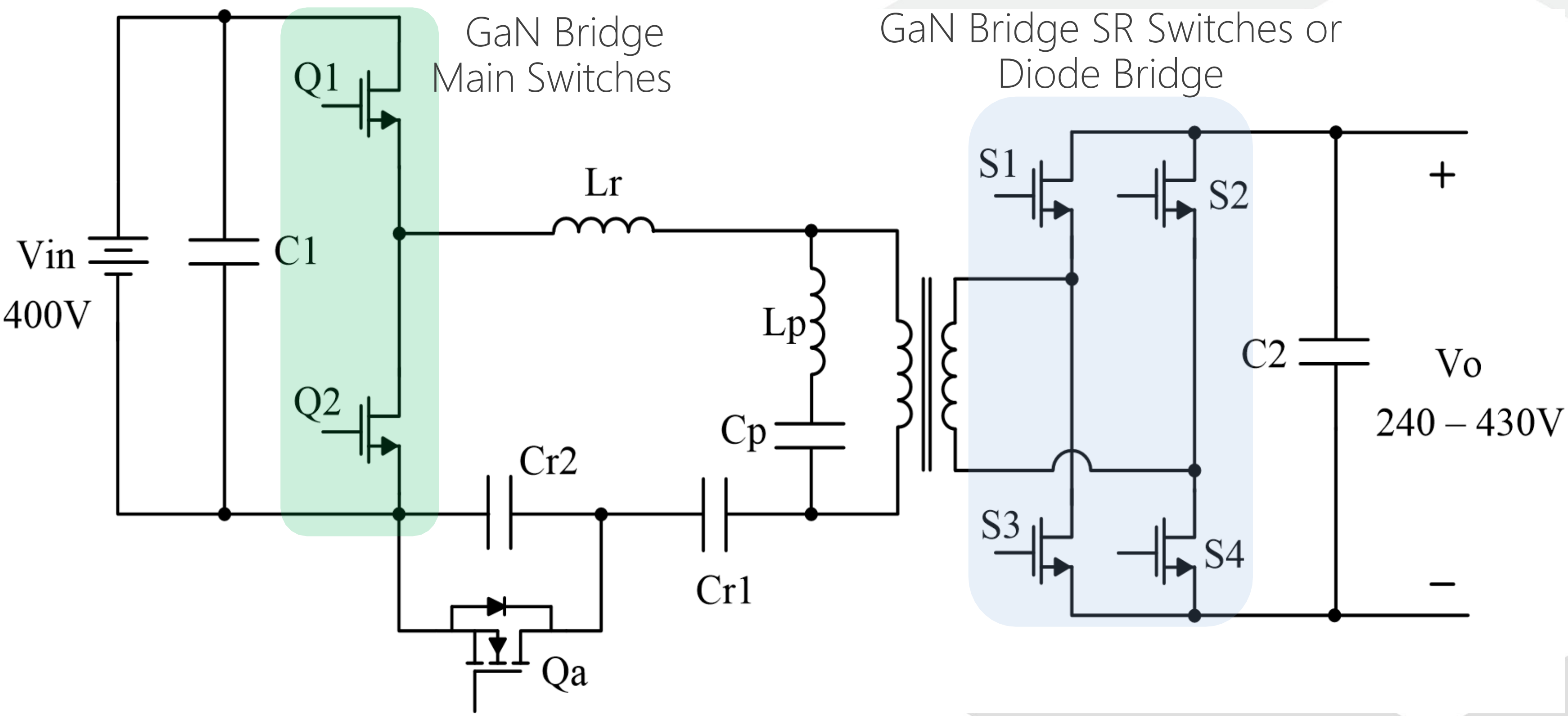
Bridgeless Boost PFC + 3-phase Interleaved LCLC (for 3.3kW)

- AC – DC stage: Bridgeless Boost, integrated GaN switches (similar)
- DC – DC: 3-phase interleaved SCC – LCLC for 3.3kW output (new)



GaNPower SCC EV OBC

SCC – LCLC topology for EV Battery charger



GaNPower SCC GaN Based EV OBC

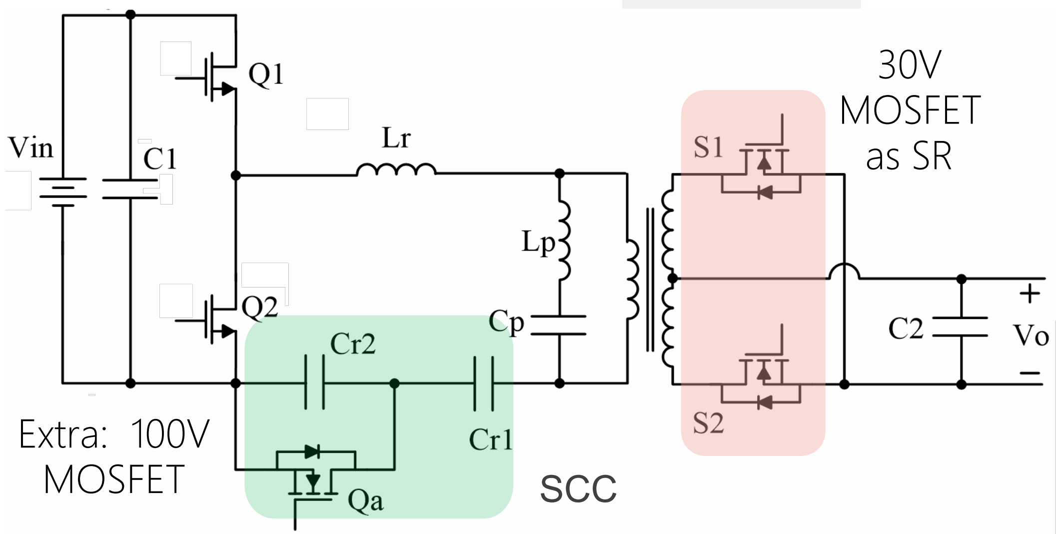
Advantages

- –Reduced output capacitor value, from 190uF / 500V to 12uF / 500V
  - ✓ Size reduction from 14 in^3 (two 100uF / 500V film cap, $28 x 2 = $56)
  - ✓ To 1 in^3 (one 12uF / 500V, film cap, $8)
- –Better thermal performance (no hot spot)
- –Efficiency: 96.5% (system, full load)
- –Size: ~ 1.2 Litre for 3.3kW
  - ✓ Power density: 2.5 – 3 kW / L (40 – 48W / in^3)

GaNPower SCC GaN Based EV DC/DC Converter

Requirements:

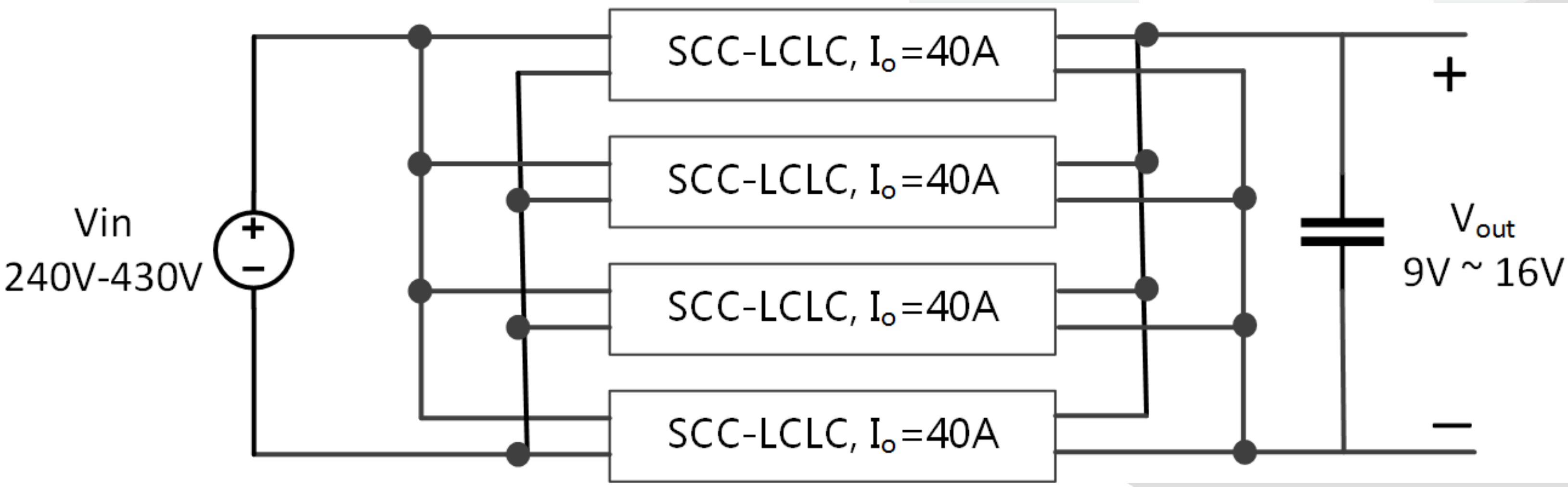
- High output power: 2kW
- Wide Input voltage range: 350V nominal, 240 –430V, from battery
- Wide output voltage range: 14V nominal, 9 – 16V
  - ✓ Voltage gain variation range: 15 to 48 (> 1:3)
  - ✓ Difficult to meet with LLC converter
- High load current: 150A
  - ✓ Needs bridge type converter with large inductor as a filter



GaNPower SCC GaN Based EV DC/DC Converter

- Four-phase interleaved SCC – LCLC in parallel
  - No need for large inductor
  - 40A each phase (~500W) to reduce the conduction loss
  - Interleaving to achieve very small output capacitor (< 500uF)

  Small output capacitor with interleave technology (~500uF for 150A)
- Conventional: 8,400uF output capacitor
- 100V MOSFET for SCC is cheap and almost no loss



OBC and DC/DC Solutions Using SCC Technology

EV On-board Charger (OBC)

	Current Design	Reported Design	GaNPower's Design I	GaNPower's Design II
Size / Volume	3.2 Litre	2.2 Litre	1.2 Litre	0.6 - 0.8 Litre
Power Density	1 kW / L	1.5 kW / L	2.5 - 3 kW / L	4 - 5.5 kW / L
Weight	Proportional to volume			
Efficiency	92%-94%	95.7%	96.5%	98%
Operating Temp Range	-45 - 105	-45 - 105	-45 - 105	-45 - 105
Transient Speed	No need to be fast			
Reliability	Same	Same	Same	Same
Durability	Same	Same	Same	Same
Power Devices / Cost	Large inductor	500V/200uF cap ($56)	500V / 12uF cap ($8)	500V / 12uF cap ($8)

Input：85-265VAC, Output：240-430VDC, 3.3KW, 14A

EV On-board DC/DC Converter

	Current Design	Reported Design	GaNPower's Design
Size / Volume	1.8 Litre	1.3 Litre	0.7 Litre
Power Density	0.7 - 1.1 kW / L	1.5 kW / L	3 - 4 kW / L
Weight	Proportional to volume		
Efficiency	94 - 95%	95 - 96%	97%
Operating Temp Range	-45 - 105	-45 - 105	-45 - 105
Transient Speed	Same	Same	Same
Reliability	Same	Same	Same
Durability	Same	Same	Same
Power Devices / Cost	MOSFET Large inductor	GaN 8,400uF cap	With GaN 500uF cap

Input：240-430VDC, Output：9-16VDC，2KW，150A

4X increase of power density using GaNPower's GaN devices and SCC design

Contents

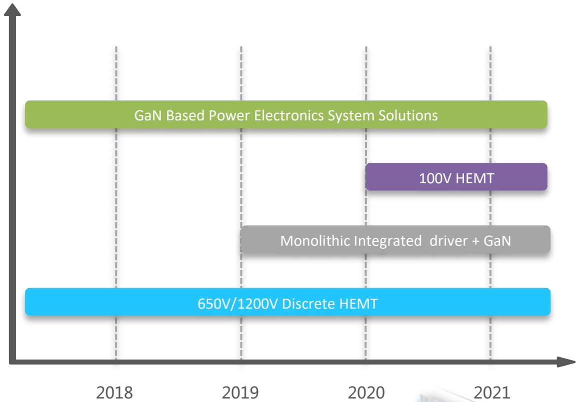
- Session 1: GaN devices basics
- Session 2: GaN Gate Driving
- Session 3: GaN Applications
  - GaN vs. Silicon, from application perspective
  - GaN Applications Survey
  - SCC Solution Demos (in collaboration with Digiq Power)
  - A brief introduction to GaNPower International

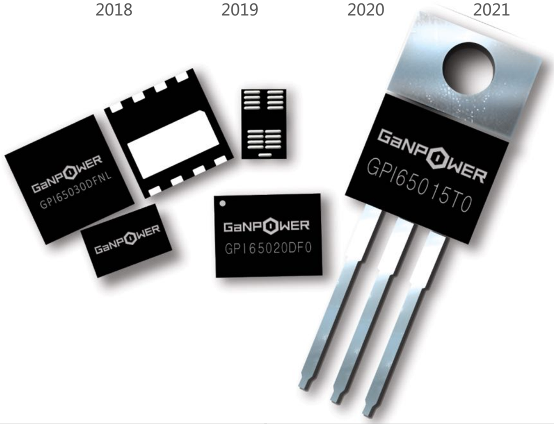
About GaNPower International Inc.

GaNPower Headquarters
(Vancouver, Canada)

GaNPower was established in June, 2015 by a group of professionals in Vancouver, Canada

Our GaN HEMT Products





Product Catalog	Current Ratings	Release date
650V GaN HEMT (TO220) (GPI650XXTO)	10A , 15A , 20A , 30A	2018 Q1
	40A , 60A , 80A	2018 Q3 ~ 2019 Q2
650V GaN HEMT (DFN 5X6) (GPI650XXDFI)	7.5A , 10A , IC	2019 Q2
650V GaN HEMT (DFN 6X8) (GPI650XXDFO)	15A, 20A, 30A, IC	2018 Q2 ~ 2019 Q2
650V GaN HEMT (DFN 8X8) (GPI650XXDFN)	15A , 30A	2018 Q3
	30A , 60A , Co-package , Monolithic IC	2019 Q1 ~ 2020 Q3
650V GaN HEMT (LGA) (iGaN650XX)	10A , 15A , 20A , 30A	2018 Q3
	LGA Half-bridge module: 60A , 120A	2019 Q3 ~ 2020 Q3
1200V GaN HEMT (TO252 DPAK) (GPIHVXXDDK)	15A , 30A	2018 Q3 ~ 2019 Q2
100V GaN HEMT (LGA) (iGaN100XXX)	7.5A , 10A , 30A , 60A , 80A , 100A	2020 Q1 ~ 2021 Q1

	GaNPower	Super Junction MOS	SiC	Cascode GaN	E-mode GaN
Product number	GPI65015TO	XXXXXXXC7	XXXXXXXXB3	XXXXXXLD	XXXXXX4B
Rated BV	650V	700V	650V	600V	650V
R_{dson}	92mΩ	125mΩ	100mΩ	150mΩ	100 - 130mΩ
Q_g	3.3nC	35nC	51nC	6nC	3nC
FOM=R_{dson}*Q_g	**304**	4375	5100	900	300 - 390

THANKS FOR WATCHING!

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