



APEC
2024

LONG BEACH
CALIFORNIA
CONVENTION CENTER

February 25th - 29th

Comparison of Silicon MOSFET vs GAN for 48V Input Intermediate Bus Conversion (IBC) Based on Multiphase Buck Controllers

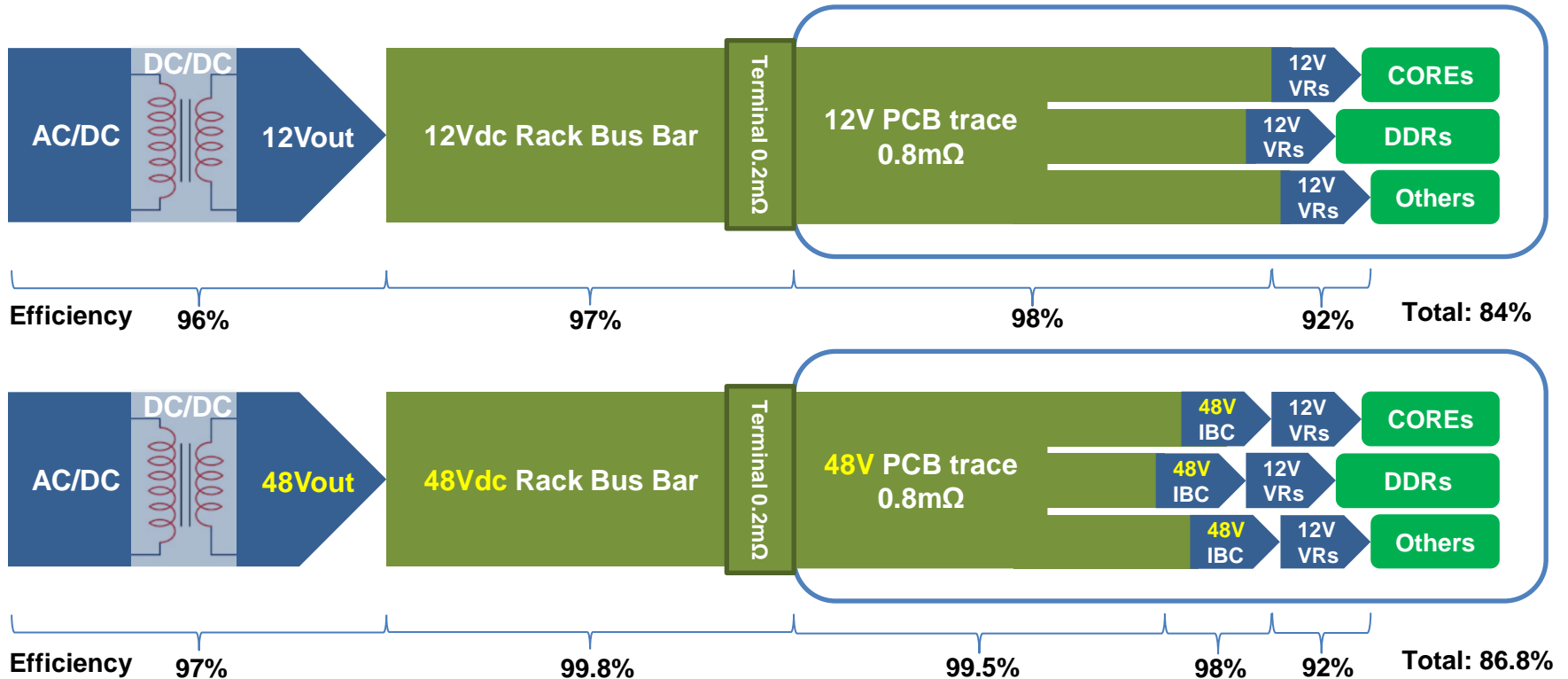
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1. 48V power structure for data center



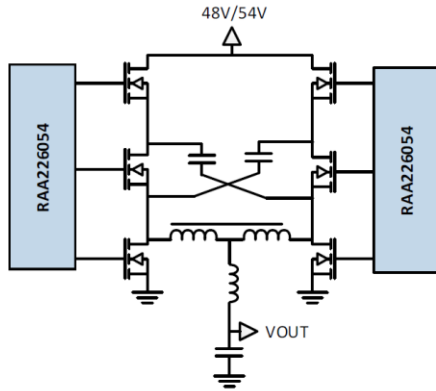
- Due to smaller I^2R loss, 48V power structure provides higher efficiency

2. 48V power structure

Solution 1: Hybrid Switched-Capacitor (HSC)

❑ Power train(PT):

- **Unregulated (4:1) operation**
 - Fixed 50% duty cycle
- **Regulated operation**
 - Fixed 12V output

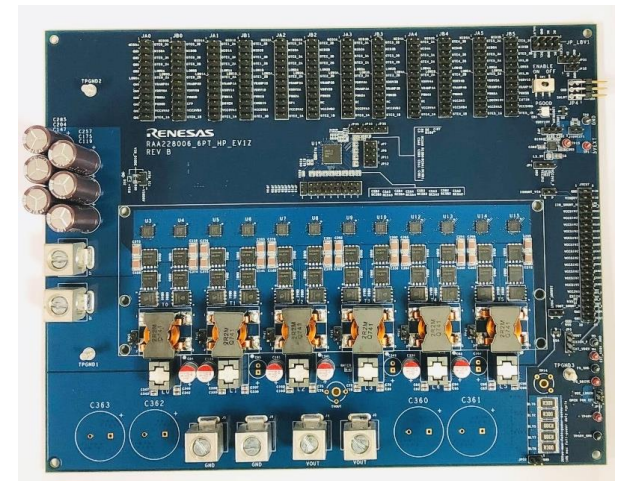
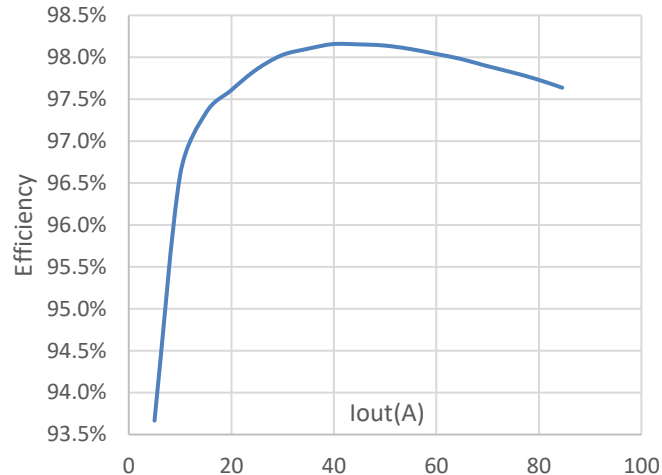


❑ Single PT:

- Output power: 1kW
- Size: 18*60*15 cm³
- Power density: 61W/cm³
- Peak efficiency: 98.2%
- Full load efficiency: 97.7%

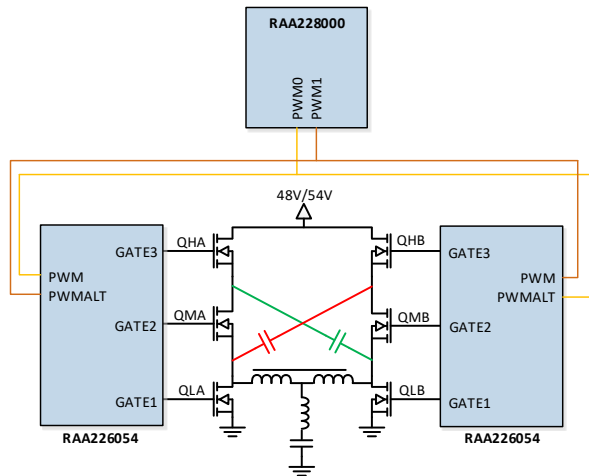
❑ Scalable design:

- 6*1kW = 6kW
- Current sharing and interleaving
- Size: 108*65*15mm³



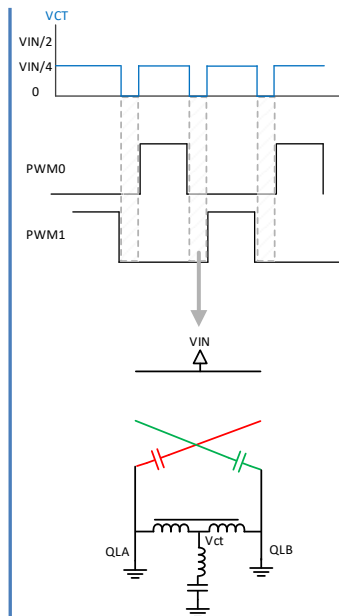
2. 48V power structure

Solution 1: Hybrid Switched-Capacitor (HSC)



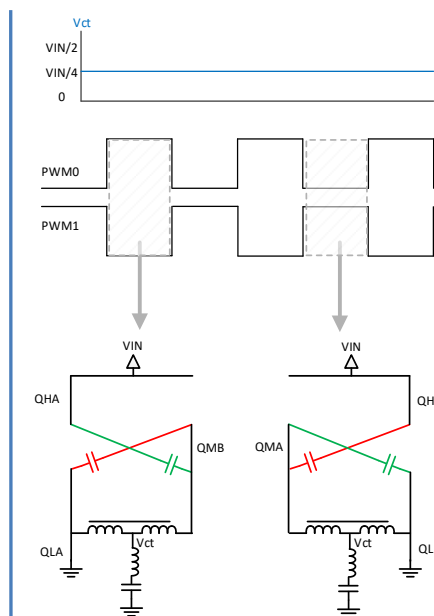
RAA226054 Truth Table

PWM	PWMALT	GATE1	GATE2	GATE3
0	0	1	0	0
0	1	0	1	0
1	0	1	0	1
1	1	0	0	1



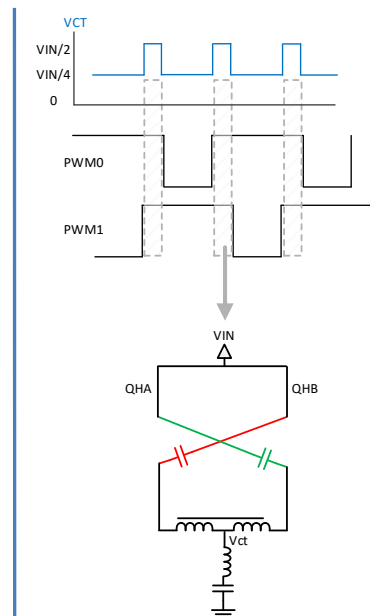
$D < 50\%$:

- Uses freewheeling
- Uses power delivery
- $V_{ct} = VIN/4$



$D = 50\%$:

- Uses only $V_{ct} = VIN/4$ power delivery states
- Allows output L to be removed



$D > 50\%$:

- Uses all power delivery states

2. 48V power structure

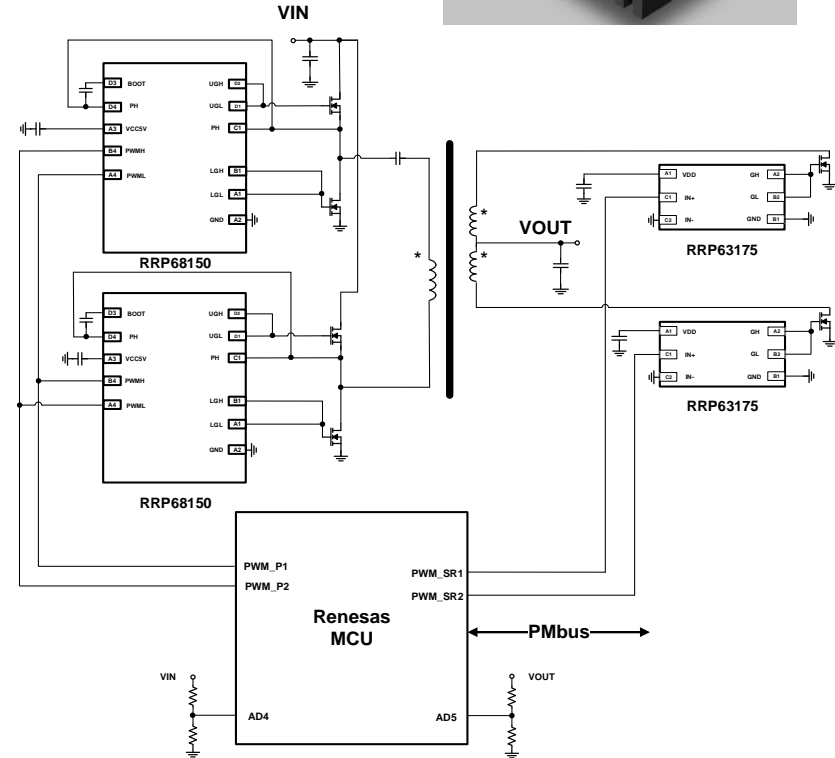
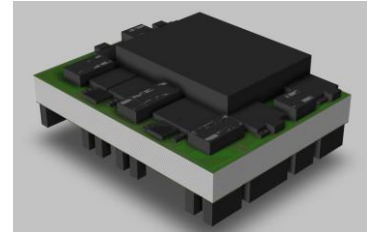
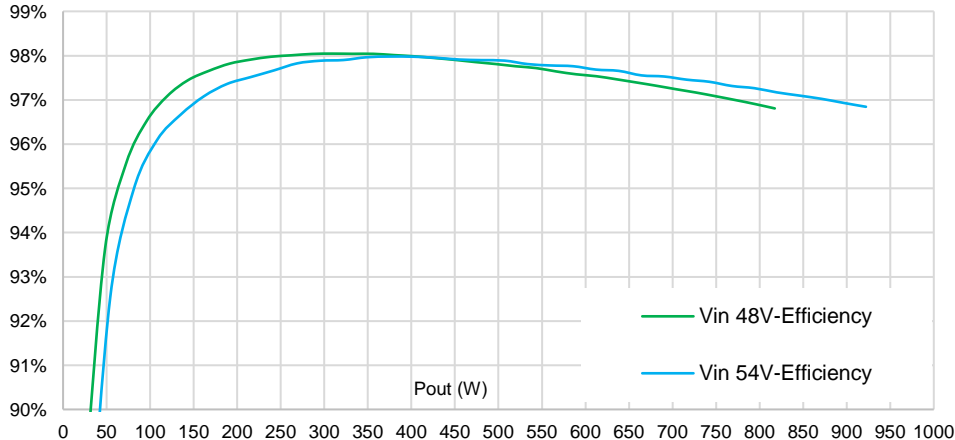
Solution 2: GaN based LLC(4:1)

□ Solution:

- Switching frequency: 1.5MHz
- Unregulated(open loop) with fixed input/output ratio: 4:1
- Planar transformer
- Size: 24*18*8 mm³
- Power density: 231W/cm³

□ Efficiency:

- Peak efficiency: 98%
- Full load efficiency: 97%



2. 48V power structure

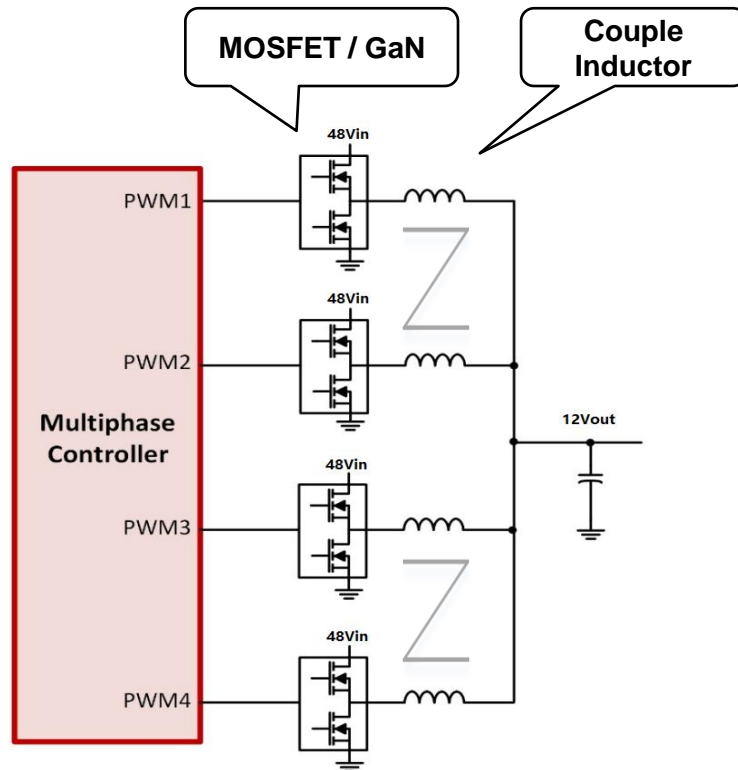
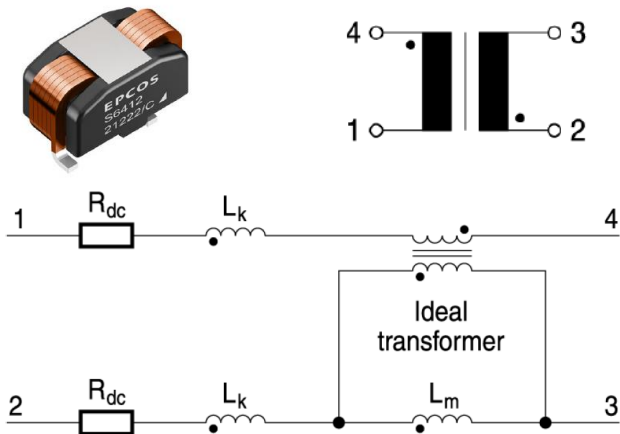
Solution 3: Multi-phase BUCK with Couple Inductor

□ Features:

- Multi-phase interleaving parallel working
- Regulated V_{out}
- Low cost
- Easy design and manufacture
- Acceptable efficiency and size

□ Multi-phase buck with couple inductor (CL):

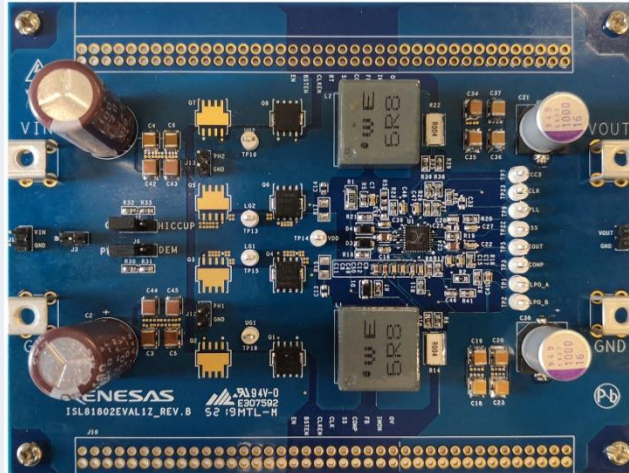
- 2 or 4 inductors are inversely coupled



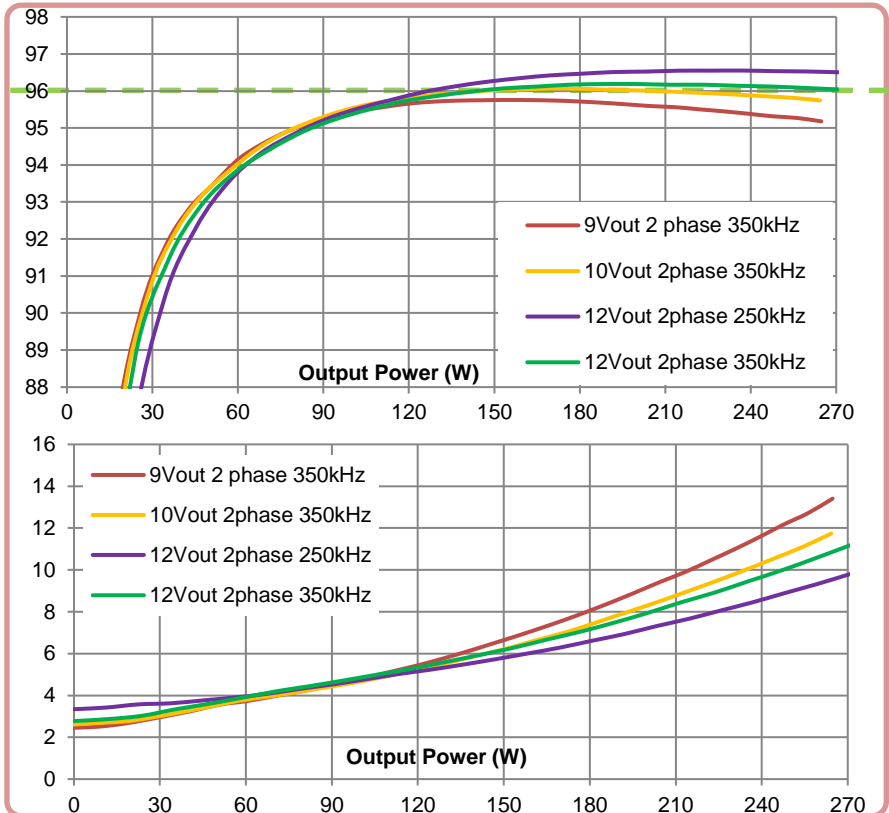
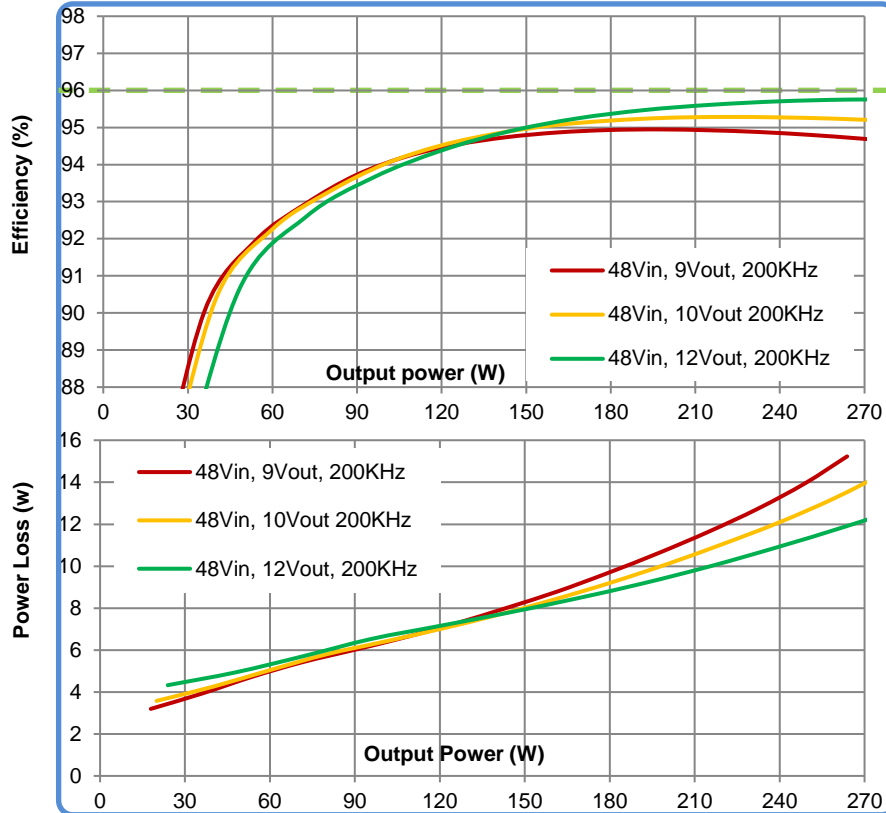
4. 2-Phase BUCK solution MOSFET vs GaN with none coupled inductor (NL)

48Vin/12Vout/270W	MOSFET @ 200kHz	GaN @ 350kHz
Controller	ISL81802*1	ISL81806*1
FET	1U/phase*2: IFX(<u>BSC072N08NS5</u>) 80V/7.2mΩ/5*6mm 1L/phase*2: IFX(<u>BSC030N08NS5</u>) 80V/3mΩ/5*6mm	1U1L/phase*2: <u>EPC2218</u> *4 100V/3.2mΩ/1.95*3.5mm
Inductor	Wurth <u>74439370068</u> *2 6.8uH (15.4*16.4*10mm) I _R =15A	TDK <u>SPM10065VT-4R7M-D</u> *2 4.7uH (10*10*6.5mm) I _R =11.7A

Demo



4. 2-Phase BUCK solution MOSFET vs GaN with none coupled inductor (NL)



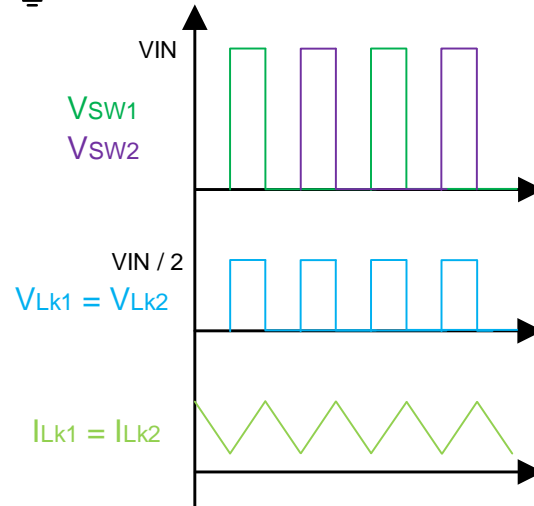
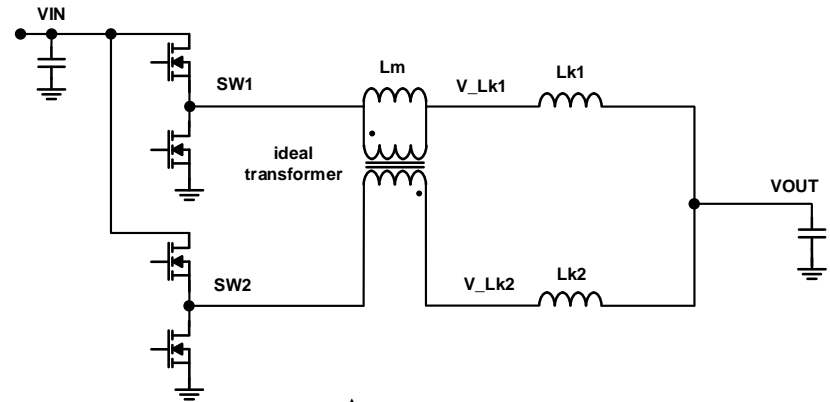
4. 2-Phase BUCK with coupled inductor (CL)

□ 2-phase buck with couple inductor(CL):

- $V_{in}=48V$, $V_{out}=12V$
- Ignore L_m
- $V_{Lk1} = V_{Lk2}$
- $I_{Lk1} = I_{Lk2}$
- Like f_s is doubled and halving V_{in}

□ 2-phase buck with couple inductor (CL) :

- Smaller inductor and C_{out} capacitor size
- Lower power loss
- Faster transient response



4. 4-Phase BUCK with coupled inductor (CL)

□ Design SPEC:

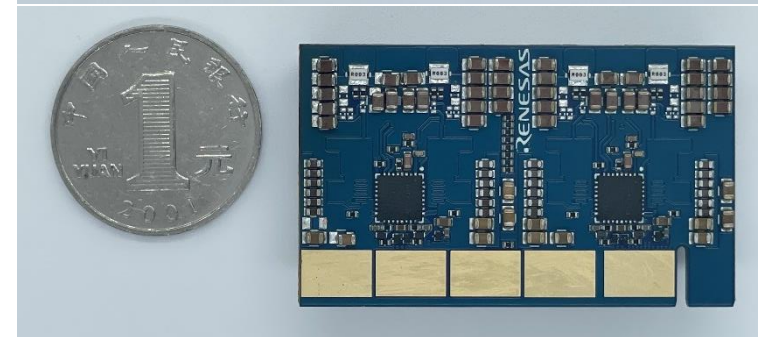
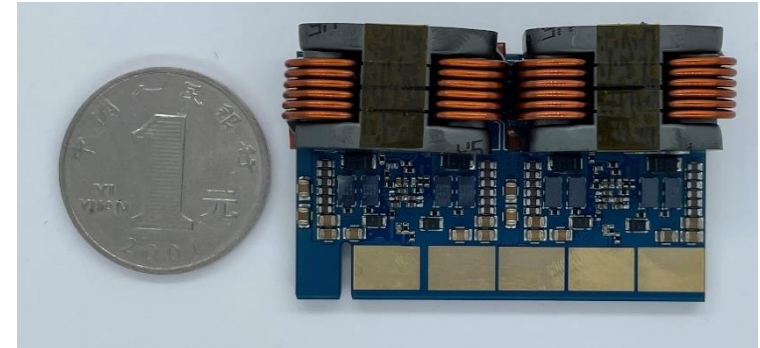
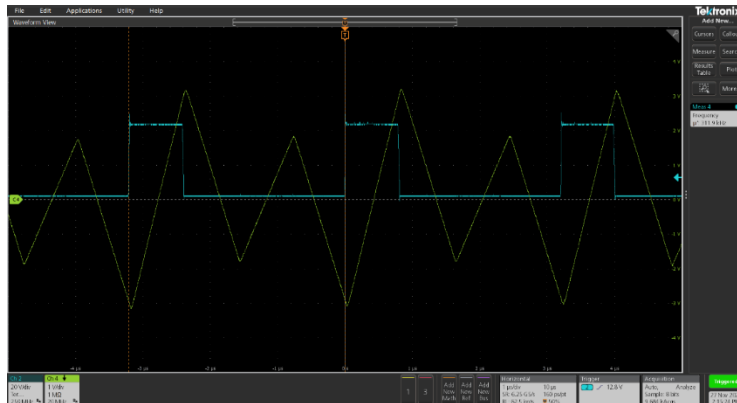
- 2 ISL81806 with 4-Phase 90° interleaving Buck with GaN
- Each phase 1U1L with GaN: EPC2088
- Inductor: TDK_B82559S6412M023 (Lk=2.05uH)
- Fs: 160kHz
- 48Vin/12Vout/80Aout peak efficiency: 97.7%
- 48Vin/12Vout/80Aout full load efficiency: 97%
- Board size: 23*54*17mm
- Support module level parallel to several kW's application.

□ Test waveform:

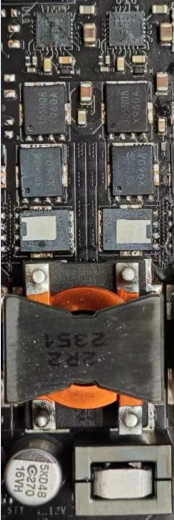
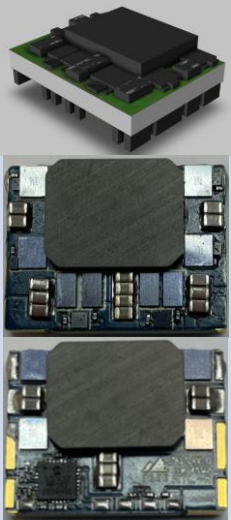
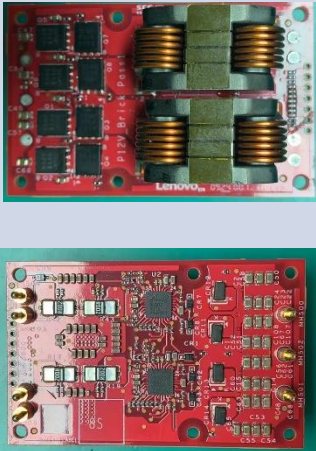
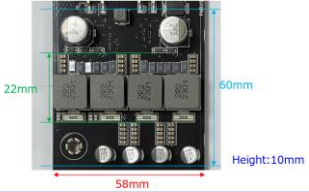
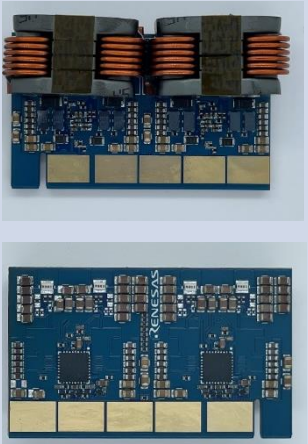
48VIN

C2: V_PH1

C4: I_PH1



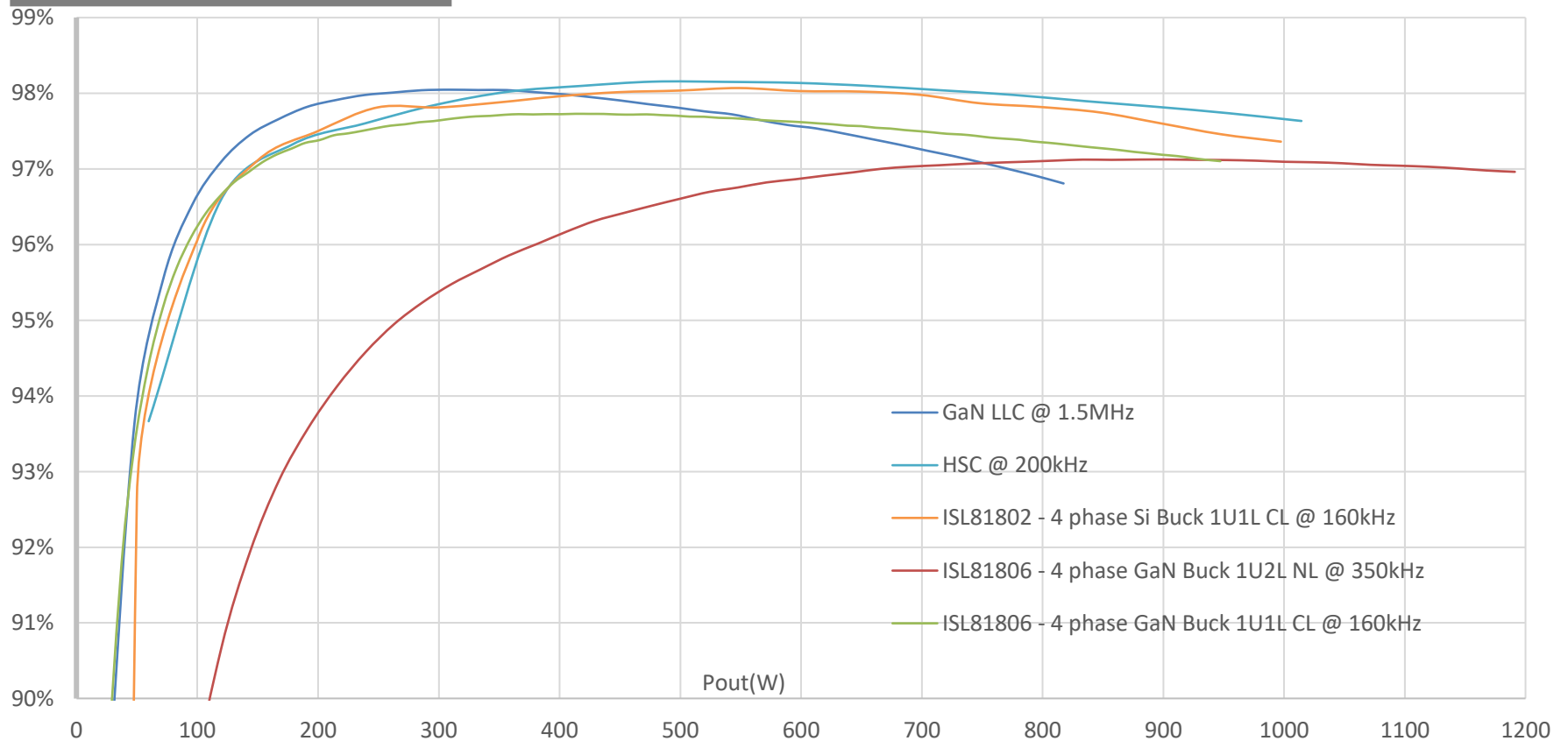
5. 48Vin/12Vout/1000W Size Comparison

	HSC @ 200kHz	LLC @ 1.5MHz	ISL81802 Si BUCK 4 phase @ 160kHz (CL)	ISL81806 GaN BUCK 4 phase @ 350kHz (NL)	ISL81806 GaN BUCK 4 phase @ 160kHz (CL)
Size	18*65*15 mm ³	24*18*8 mm ³	37*58*17 mm ³	35*58*10 mm ³	23*54*17 mm ³
Power density	61 W/cm ³	231 W/cm ³	28 W/cm ³	39 W/cm ³	47W/cm ³
Power	1000W	800W	1000W	1200W	1000W
Designed by	NVIDIA	RENESAS	Lenovo	ASUS	RENESAS
Demo					

5. 48Vin/12Vout/1000W BOM Comparison

Solution	HSC @ 200kHz	LLC @ 1.5MHz	ISL81802 Si BUCK 4 phase @ 160kHz (CL)	ISL81806 GaN BUCK 4 phase @ 350kHz (NL)	ISL81806 GaN BUCK 4 phase @ 160kHz (CL)
Controller	RAA228000 * 1	RLxx * 1	ISL81802 * 2	ISL81806 * 2	ISL81806 * 2
Driver	RAA226054 * 2	RAA68150 * 2 RAA63175 * 4	No need	No need	No need
FET	80V MOSFET * 4 60V MOSFET * 2	80V GaN*4 40V GaN*8	80V MOSFET * 8	80V GaN * 12(1U2L)	80V GaN * 8(1U1L)
Inductor/ transformer	Transformer * 1 (+ inductor * 1)	Transformer * 1	Couple inductor * 2	Inductor * 4	Couple inductor * 2

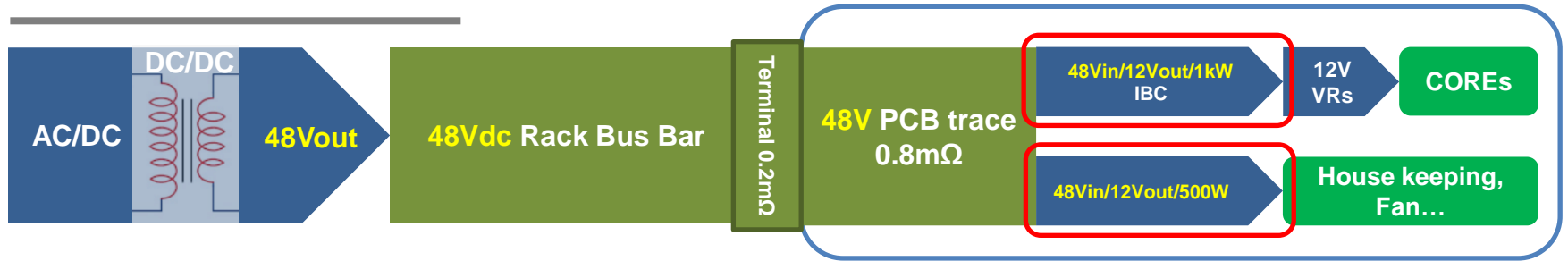
5. 48Vin/12Vout/1000W Efficiency Comparison



5. 48Vin/12Vout/1000W Overall Comparison

Solution	HSC @ 200kHz	LLC @ 1.5MHz	ISL81802 Si BUCK 4 phase @ 160kHz (L)	ISL81806 GaN BUCK 4 phase @ 350kHz (NL)	ISL81806 GaN BUCK 4 phase @ 160kHz (CL)
Cost	Low	High	Lowest	Low	Low
Size	Smaller	Smallest	Biggest	Small	Smaller
Power density	61W/cm ³	231W/cm ³	28W/cm ³	39W/cm ³	47W/cm ³
Manufacturability	Easy	Hard	Easiest	Easy	Easy
Regulated	Yes	No	Yes	Yes	Yes
Peak/Full load efficiency	Highest	High	High	High	High
Parallel	Yes	Yes	Yes	Yes	Yes

6. ISL81802/6 in datacenter application



□ Two types of 48Vin/12Vout power supplies are needed in datacenter

➤ Type 1: 48Vin/12Vout/1kW IBC for core

- Support parallel for several kW application.
- High efficiency and high power-density.
- Regulated is preferred.

➤ Type 2: 48Vin/12Vout/500W for house keeping, fan...

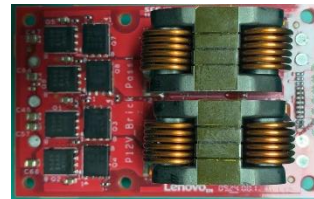
- Less than 500W
- Efficiency and power density are not need to be as high as IBC
- Regulated Vout

6. ISL81802 in datacenter application

□ Type 1: 48Vin/12Vout/1kW IBC for core

➤ ISL81802 48Vin/12Vout/1kW IBC regulated modular design with Mosfet

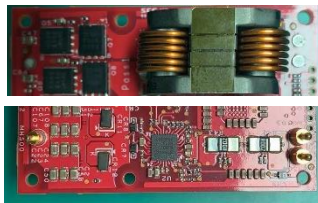
- 2*ISL81802 with 4-phase 90 degree interleaving parallel for each module
- Couple inductor
- 3 modules parallel for 3kW with 12-phases 30 degree interleaving
- Unlimited phases parallel supported (minimum 30 degree interleaving.)
- Lowest cost and high efficiency solution



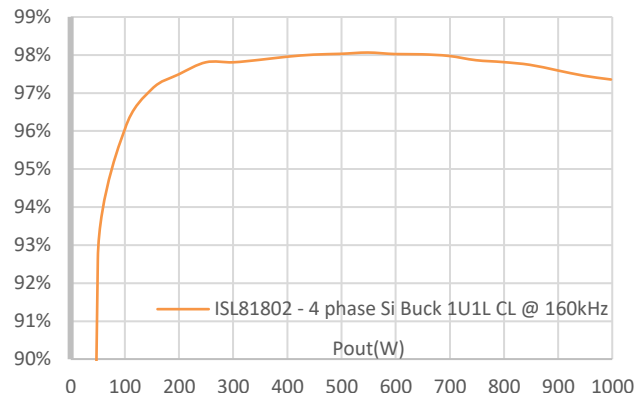
□ Type 2: 48Vin/12Vout/500W for house keeping, fan...

➤ ISL81802 48Vin/12Vout/500W regulated module solution with Mosfet

- 2-phase design with upper ISL81802 48Vin/12Vout/1kW IBC solution (a half design)
- ISL81802 with 2-phase 180 degree interleaving parallel
- Couple inductor



▪ 1kW / 4-phase / 37*58*17 mm³(1/4 brick)



▪ 500W / 2-phase / 19*58*17 mm³

6. ISL81806 in datacenter application

❑ Type 1: 48Vin/12Vout/1kW IBC for core

➤ ISL81806 48Vin/12Vout/1kW IBC regulated modular design with GaN

- 2*ISL81806 with 4-phase 90 degree interleaving parallel for each module
- Couple inductor
- 3 modules parallel for 3kW with 12-phases 30 degree interleaving
- Unlimited phases parallel supported (minimum 30 degree interleaving.)

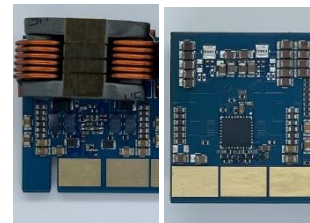
❑ Type 2: 48Vin/12Vout/500W for house keeping, fan...

➤ ISL81806 48Vin/12Vout/500W regulated module solution with GaN

- 2-phase design with upper ISL81806 48Vin/12Vout/1kW IBC solution (a half design)
- ISL81806 with 2-phase 180 degree interleaving parallel
- Couple inductor

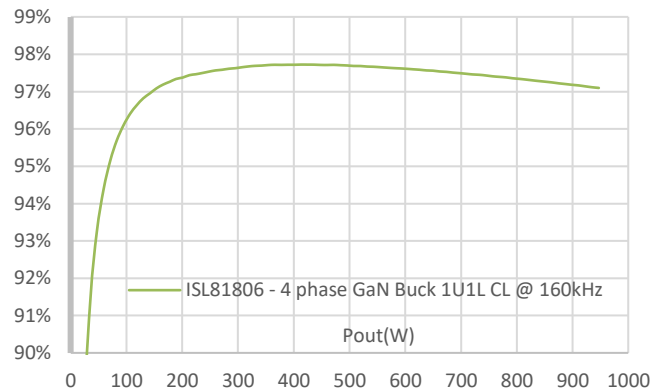
❑ Si Mosfet solution efficiency is even higher than GaN

- 80V Mosfet switching performance is good
- 80V Mosfet Rdson is small with standard 5*6mm package
- Mosfet efficiency can be higher than GaN with larger board space.



▪ 500W / 2-phase / 12*54*17 mm³

▪ 1kW / 4-phase / 23*54*17 mm³



Acknowledgment

- Thanks to the following companies for their data and information: **INTEL, NVIDIA, EPC, RECOM, Lenovo** and **ASUS**.

Q&A

Thanks