

INNAD140B1

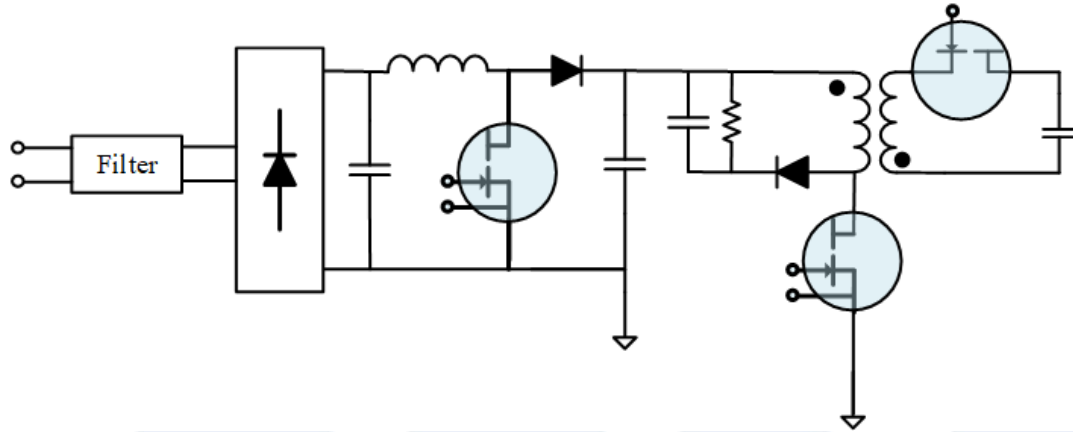
Demo Manual
140W All-GaN PD3.1 (PFC+QR)



140W PFC+QR

● PFC + QR

140W PFC+QR evaluation board is a high efficiency, high power density and low cost AC/DC power module with PD3.1 protocol support. Input voltage: 90Vac-264Vac, output: 5-28V, maximum output power: 140W, and peak efficiency up to 94.8%.



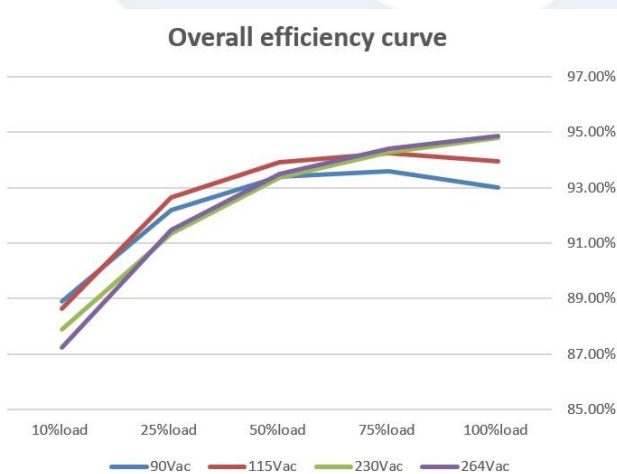
● Highlighted Products

- INN650D150A
- INN150LA070A

● Target Applications

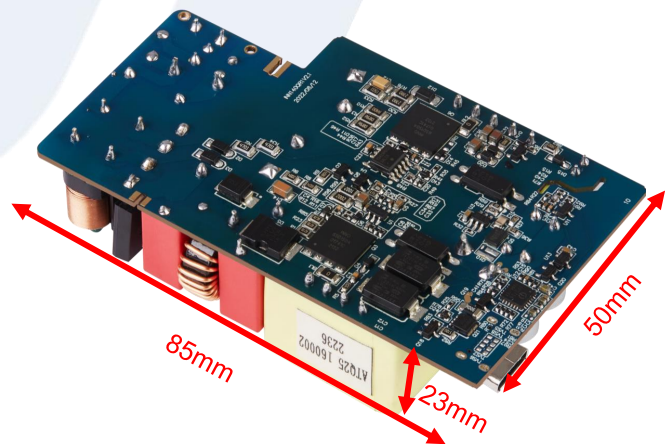
- Mobile Phone Charger
- Laptop power supply

● Test Results



Peak Efficiency 94.8%

● Photo



23.5W/in³

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Revision History21

1. Overview

1.1. Description

140W PFC+QR evaluation board is a high efficiency, high power density and low cost AC/DC power module with PD3.1 protocol support. The specific parameters are input voltage 90Vac-264Vac, output 5-28V, maximum output power 140W, and peak efficiency up to 94.8%. With double-layer PCB design, single-sided SMT, the processing of the evaluation board is simple and the cost is low.

Both PFC and QR consist of one Innoscience 650V enhancement mode GaN field effect transistors INN650D150A and one Innoscience 150V enhancement mode GaN field effect transistors INN150LA070A are adopted in the SR synchronous rectifier. The switching advantages brought by the high electron mobility and smaller parasitic junction capacitance of the third generation semiconductor GaN transistors are better reflected in the high frequency application.

1.2. Features and Advantages

■ Main features and Advantages

- > High efficiency : 94.8%(230Vac), 93%(90Vac)
- > Small size : 85*50*23mm (PCBA)
- > High power density : 23.5W/in³ (PCBA)
- > PD3.1 protocol support
- > Easy to manufacture and low cost

■ Protection Function

- > Short circuit protection
- > Over temperature protection
- > Input under voltage protection
- > Output over voltage/current protection

1.3. Applications

- Mobile phone fast charger
- Laptop power supply

2. Parameters

Table 1 Electrical Characteristic (Ta=25°C)

Symbol	Parameters	Test Conditions	Min	Nom	Max	Units
System Spec						
VIN	Input voltage		90	230	264	Vac
Fac,Lin	Input frequency			60		Hz
Fac,Hin				50		Hz
VOUT	Output voltage		5		28	V
POUT	Output power			140		W
Demo Performance						
Pstandby	Standby power	230Vac			0.070	W
Fsw,PFC	Working frequency	Vin=115Vac , Full load	70	100	125	kHz
Fsw,PFC		Vin=230Vac , Full load	90	160	220	kHz
Fsw,QR		Vin=115Vac , Full load	90	95	105	kHz
Fsw,QR		Vin=230Vac , Full load	105	115	125	kHz
Vripple	Output voltage ripple	Full load			220	mV
Eff,pk	Peak efficiency	Vin=230Vac		94.8		%
Eff	Full load efficiency	Vin=90Vac		93		%

3. Demo Solutions

3.1. System Solutions

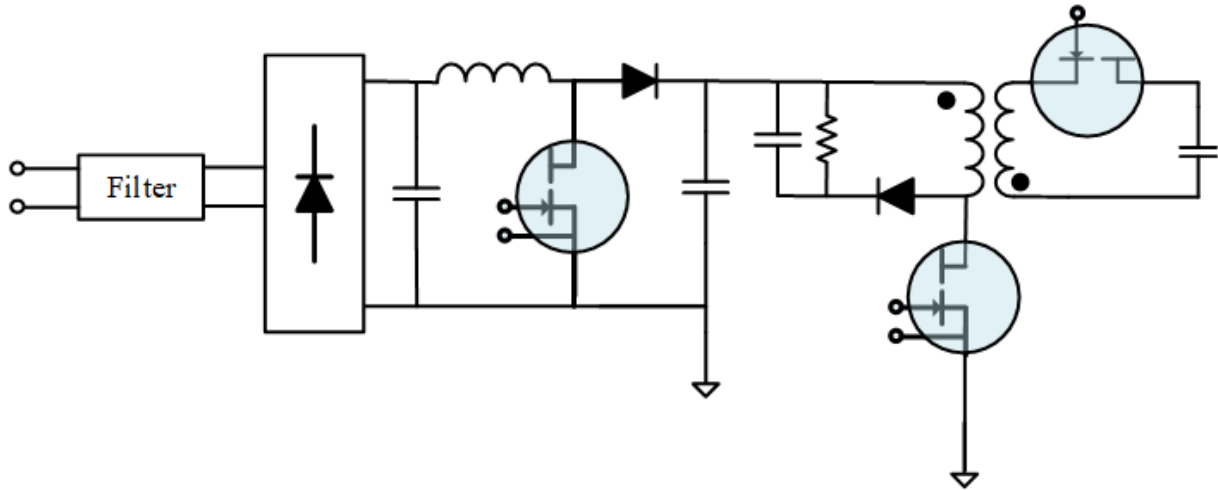


Figure 1 140W evaluation board topology

■ PFC stage

In the scheme, the PFC adopts a staged PFC topology, while $V_{in}=90Vac\sim 150Vac$, $V_{out}=270V$, which further increase the efficiency at low voltage. The power switch for PFC is InnoGaN INNO650D150A.

■ QR stage

QR used InnoGaN INNO650D150A as primary power switch while INN150LA070A as the synchronous rectifier.

3.2. Value of GaN

Two GaN field effect transistors INN650D080B with QFN 8×8 package, drain-source voltage 650V, and the maximum conduction resistance of 80mΩ are adopted in the PFC fast bridge leg and slow bridge leg, respectively.

■ Lower Switching Losses

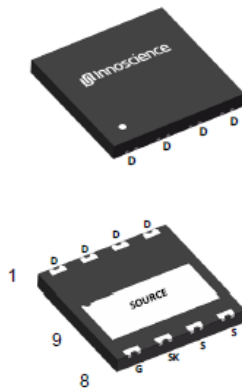
The parasitic capacitance of GaN is smaller, where C_{iss} and C_{rss} are 1/10 and 1/8 of that of Si CoolMOS, respectively. So GaN has faster switching speed. In the BTPPFC fast-bridge arm, the current and voltage overlap time is reduced by more than 88%, and the Miller plateau time is almost zero, so the total switching loss is reduced by at least 70%.

Table 2 Ciss/Crss Comparison (InnoGaN vs Si CoolMOS)

Parameter	InnoGaN	Si CoolMOS	
Ciss(pF)	110	1150	1/10
Crss(pF)	0.46	3.8	1/8

3.3. Highlighted Products

3.3.1. InnoGaN INNO650D150A



4. Key performance parameters

Table 1 Key performance parameters at $T_j = 25\text{ }^\circ\text{C}$

Parameter	Value	Unit
$V_{DS,max}$	650	V
$R_{DS(on),max}$ @ $V_{GS} = 6\text{ V}$	150	m Ω
$Q_{G,typ}$ @ $V_{DS} = 400\text{ V}$	3	nC
$I_{D,pulse}$	32	A
Q_{OSS} @ $V_{DS} = 400\text{ V}$	28	nC
Q_{rr} @ $V_{DS} = 400\text{ V}$	0	nC

5. Pin information

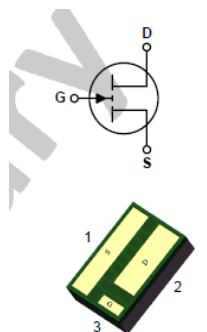
Table 2 Pin information

Gate	Drain	Kelvin Source	Source
8	1,2,3,4	7	5,6,9

Figure 2 InnoGaN INNO650D150A

InnoGaN INNO650D150A is QFN 8x8 package, 650V rated voltage, maximum 150 m Ω Rdson. When Vds=400V, Qoss is 28nC, Eoss is 4.2 μ J. Comparing to conventional Si MOSFET, it has lower turn on losses which is suitable for PFC and QR application.

3.3.2. InnoGaN INNO150LA070A



Package: FCLGA
Size: 3.2 mm x 2.2 mm

4. Key performance parameters

Table 1 Key performance parameters at $T_j = 25\text{ }^\circ\text{C}$

Parameter	Value	Unit
$V_{DS,max}$	150	V
$R_{DS(on),max}$ @ $V_{GS} = 5\text{ V}$	7	m Ω
$Q_{G,typ}$ @ $V_{DS} = 85\text{ V}$	7.6	nC
$I_{DS,Pulse}$	120	A
$Q_{OSS}@ V_{DS} = 85\text{ V}$	46.8	nC

5. Pin information

Table 2 Pin information

PIN	Pin Description	Pin Function
1	Source	Power Source
2	Drain	Power Drain
3	Gate	Driver Gate

Figure 3 InnoGaN INNO150LA070A

InnoGaN INNO650LA070A is FCLGA 3.2×2.2 package, 150V rated voltage, maximum 7mΩ R_{dson}. Comparing to Si MOSFET, at 150V, it has lower R_{dson} and lower conduction losses. And the Q_g for INNO650LA070A is 7.6nC which brings lower driver losses. When it is applied in high side synchronous rectifier, there is no need for the auxiliary winding for the transformer which simplified the design of transformer.

4. Hardware Implementation

4.1. Photos

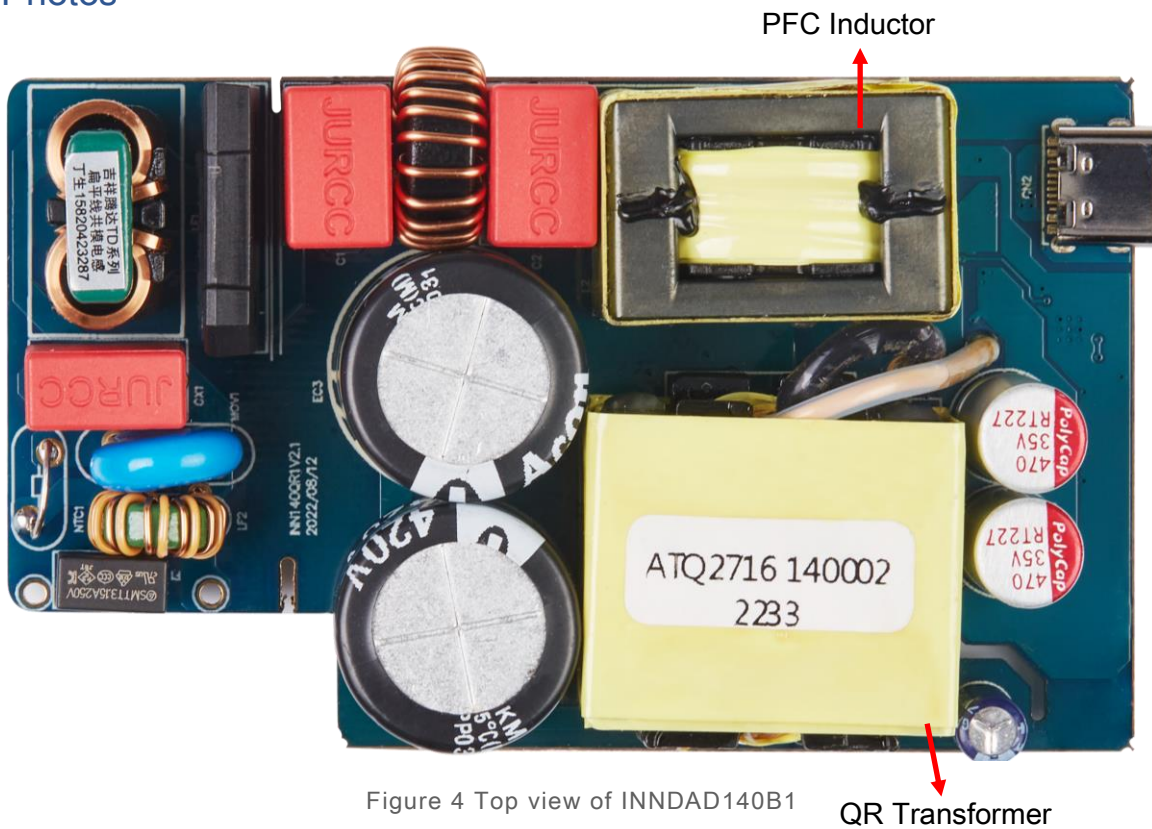


Figure 4 Top view of INNDAD140B1

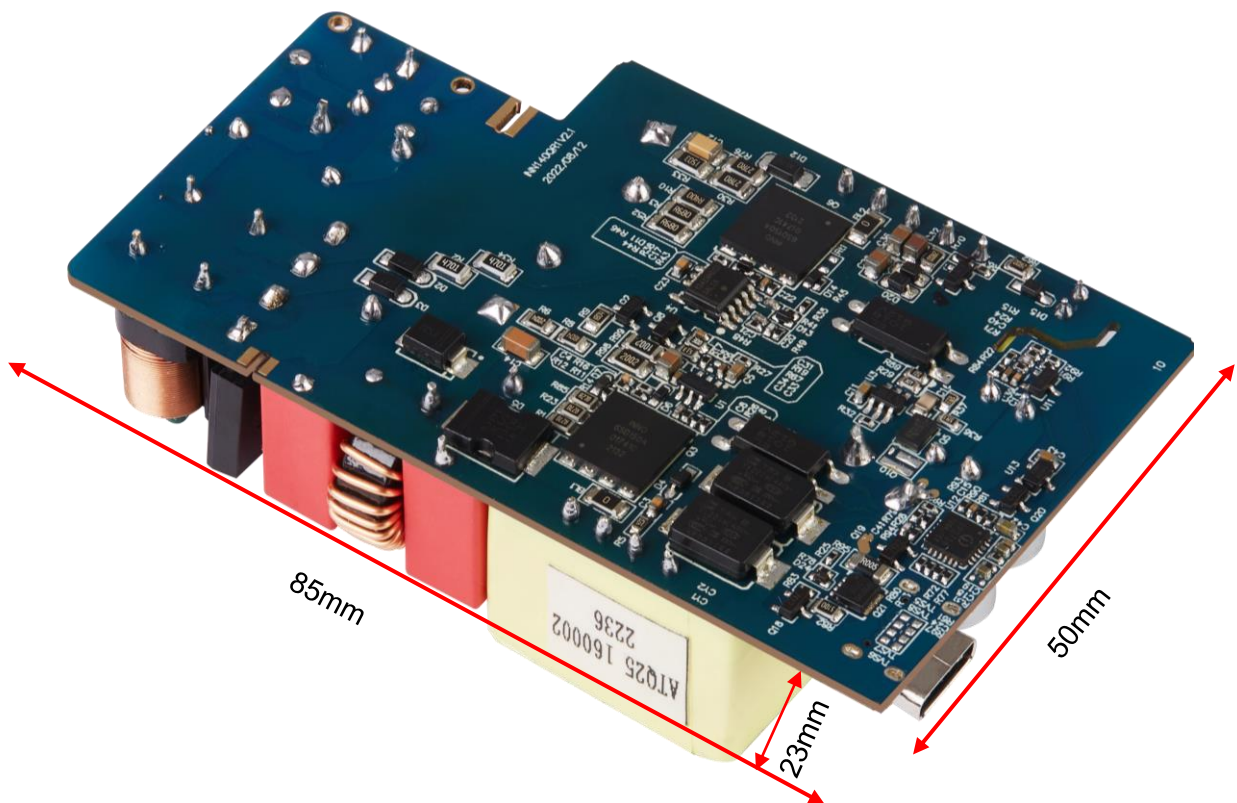
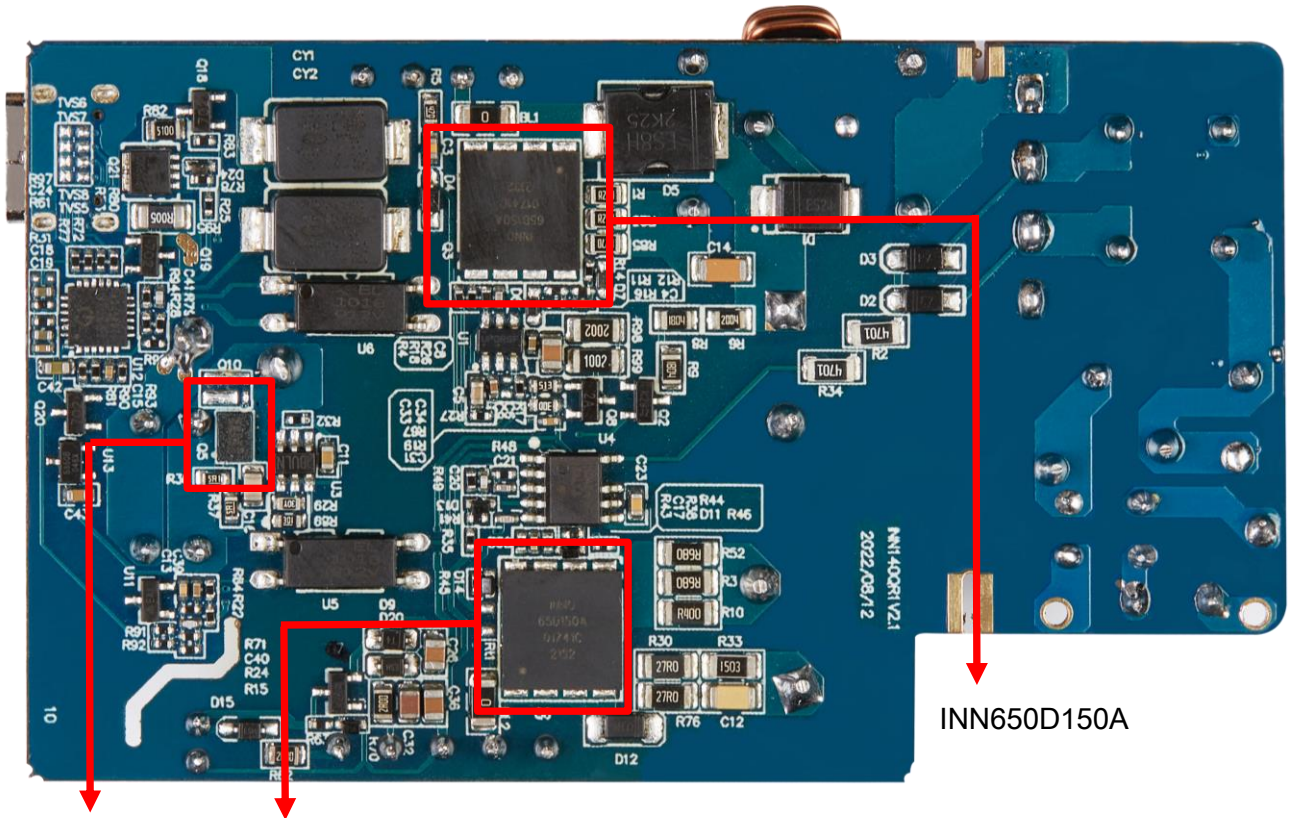


Figure 5 Bottom view of INNDAD140B1



INN150LA070A INN650D150A

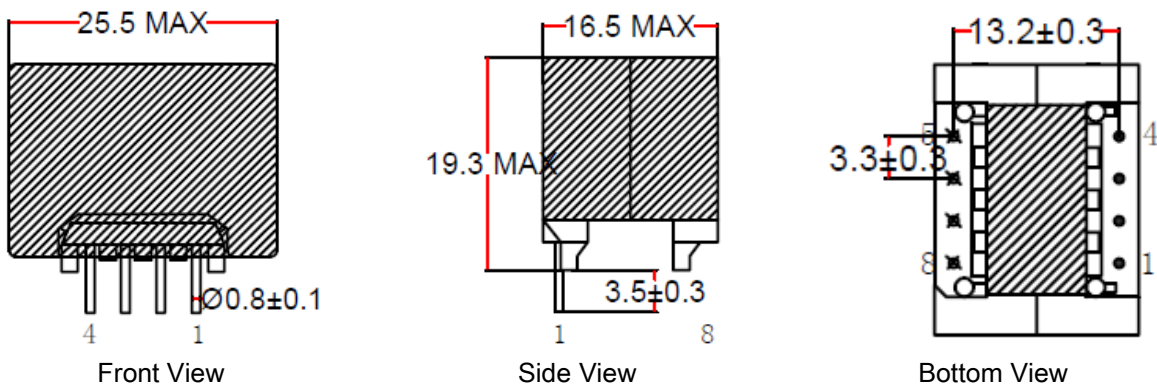
Figure 6 Mother Board

4.2. Design Considerations

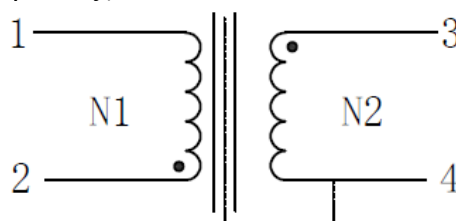
4.2.1. PFC Inductor

Dimension Diagram

Unit: mm



Schematic Diagram ('·' indicates the polarity)



Magnetic Core

No.	Name	Core Size/Material	Vendor
1	Core	ATQ25/16	/
2	Material	JPP-95/3C95	安磁/天通/Ferroxcube

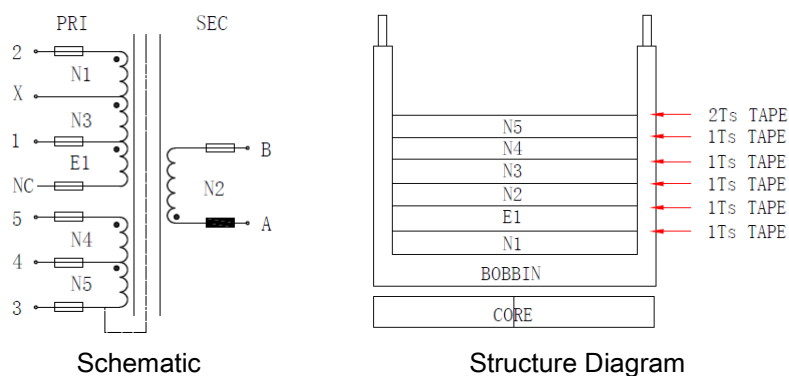
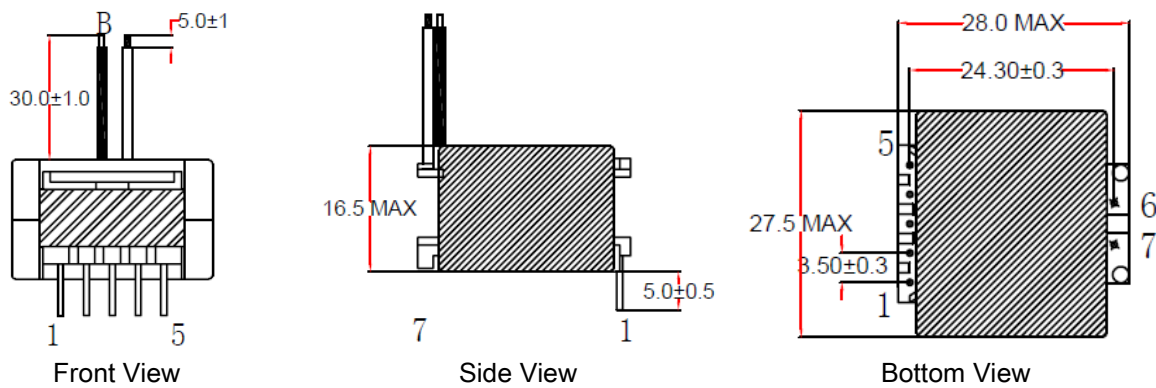
Parameters

No.	Winding	Turns	Inductance	Test Case
1	N1	32	180uH ± 5%	1V/100KHz
2	N2	3	/	/

4.2.2. QR Transformer

Dimension Diagram

Unit: mm



Magnetic Core

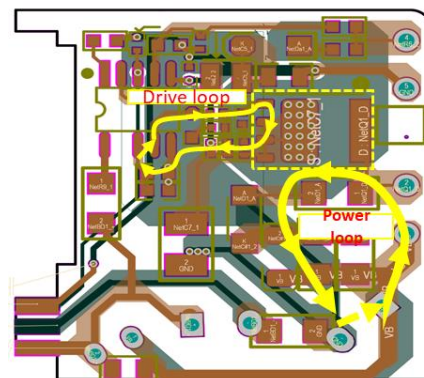
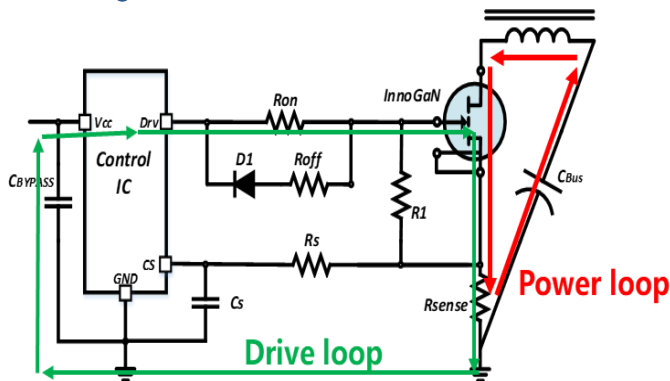
No.	Name	Core Size/Material	Vendor
1	Core	ATQ27/16	/
2	Material	JPP-95/3C95	安磁/天通/Ferroxcube

Parameter

No.	Winding	Turns	Inductance	Test Case
1	N1	11	230uH±5%	1V/100KHz
2	E1	10.5		/
3	N2	5	/	/
4	N3	11	/	/
5	N4	12	/	/
6	N5	3	/	/

4.2.3. Layout

■ Single switch



- a) Set CBYPASS close to the IC
- b) Place the driver loop close to InnoGaN

- a) CBUS, Transformer, InnoGaN loop should be minimize

Figure 7 Single Switch Layout Recommendation

■ Half Bridge

Using Kelvin design, the power loop and drive loop are decoupled; the drive circuit is placed close to InnoGaN to reduce parasitic inductance. The current flow loop is transient, if the alignment is too long, the switch off moment will generate large voltage spikes as well as EMI impact, so the loop path is required to be as short as possible and the loop area is as small as possible. At the same time, the main power loop to avoid taking sensitive signal lines, sensitive alignment to avoid HB moving point.

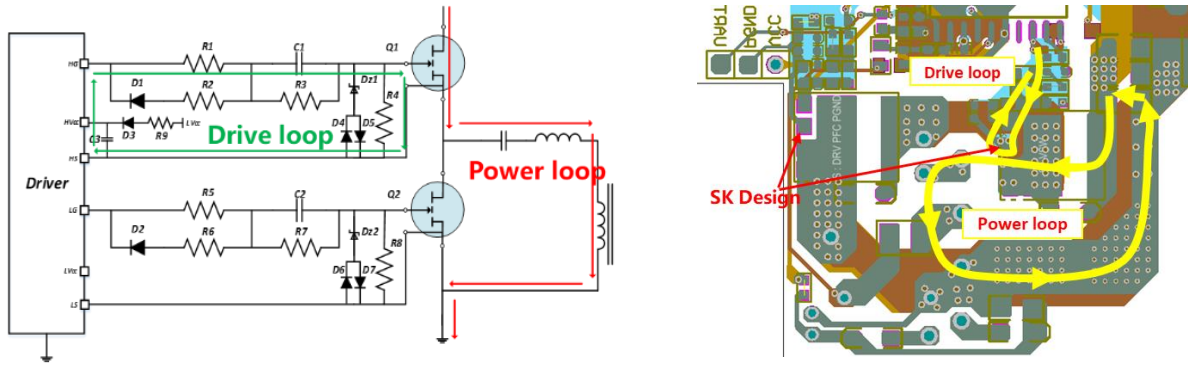


Figure 8 Half Bridge Layout Recommendation

5. Testing & Results

5.1. Test Setup

Input Power Meter: ZLG PA310

Output load: ITECH IT8512

Oscilloscope: Tektronix MSO44 200MHz

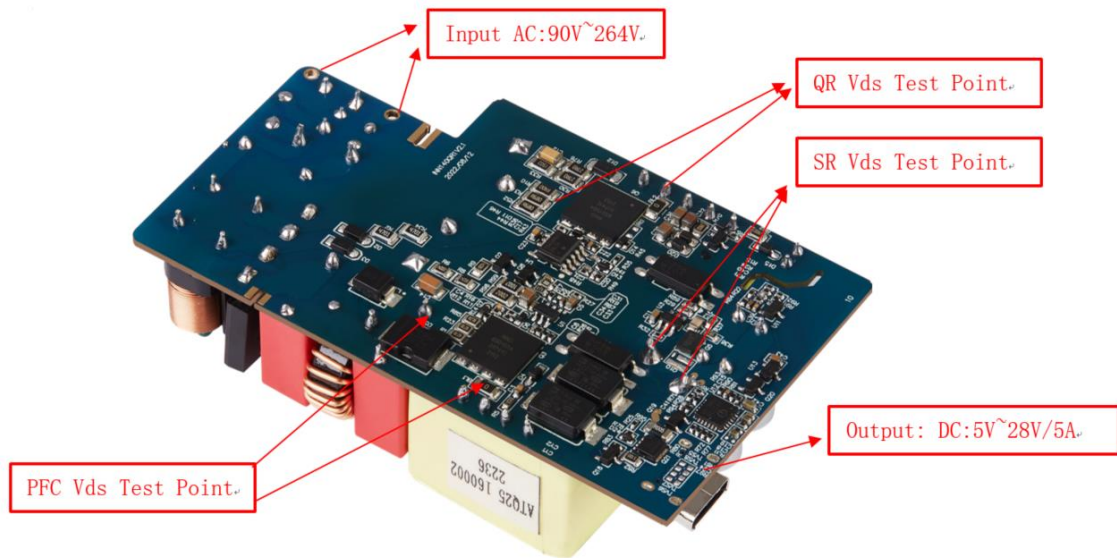


Figure 9 Test points



Figure 10 Test setup

5.2. Test results

5.2.1. Efficiency

Overall efficiency

Vin (V)	100%load η (%)	75%load η (%)	50%load η (%)	25%load η (%)	10%load η (%)	Average η (%)
90Vac	93.01	93.58	93.38	92.19	88.90	92.21
115Vac	93.97	94.23	93.93	92.63	88.62	92.68
230Vac	94.80	94.29	93.35	91.33	87.88	92.33
264Vac	94.86	94.40	93.50	91.47	87.23	92.29

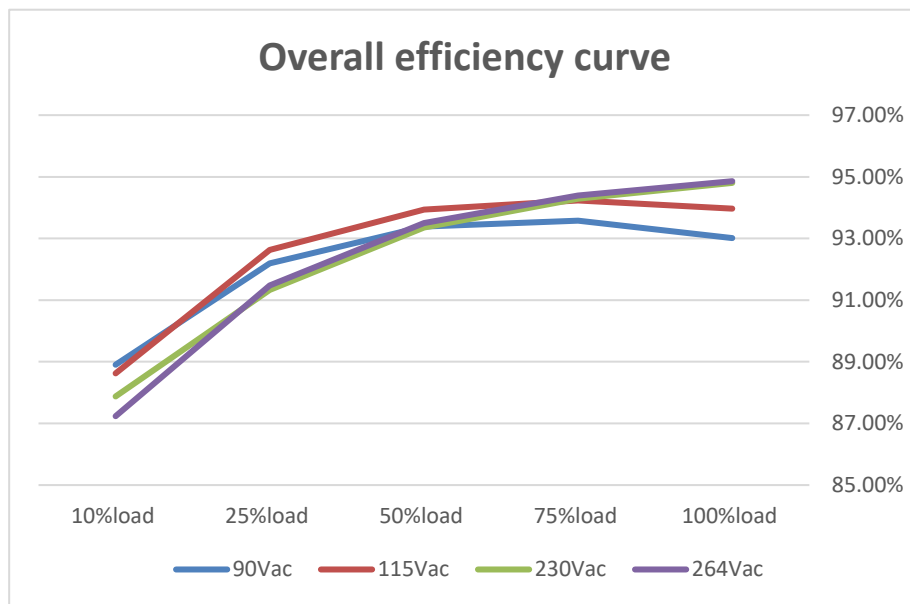


Figure 11 Overall efficiency curve

5.2.2. Switching Waveforms

CH4=PFC_VDS

Measure	P1:max(C4)	P2:---	P3:---	P4:---	P5:---	P6:---
value	445 V					
mean	444.833333333333 V					
min	445 V					
max	445 V					
sdev	7.629 μ V					
num	64					
status	✓					

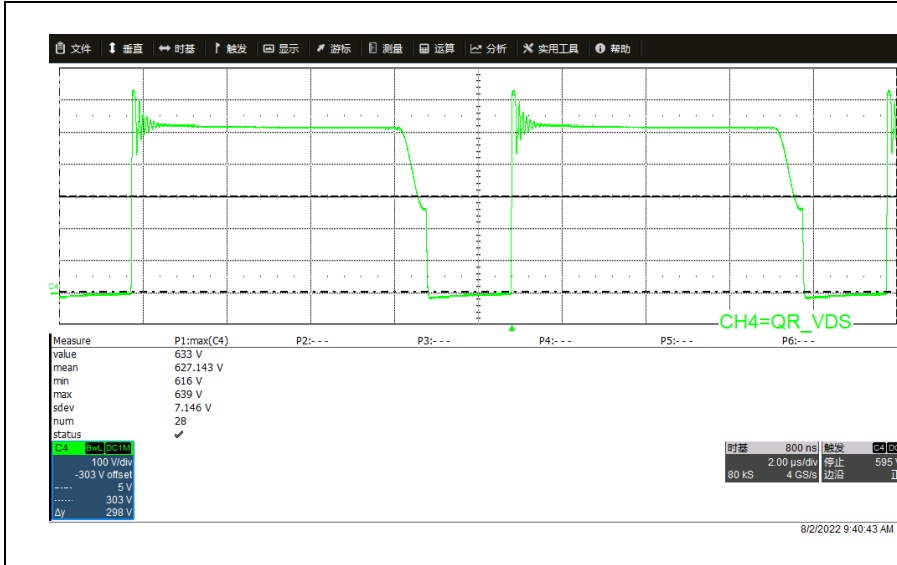
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Test conditions

Vin=264Vac/50Hz
 Vout=28V
 Full load

Result

Vds_maxPFC=445V



Test conditions

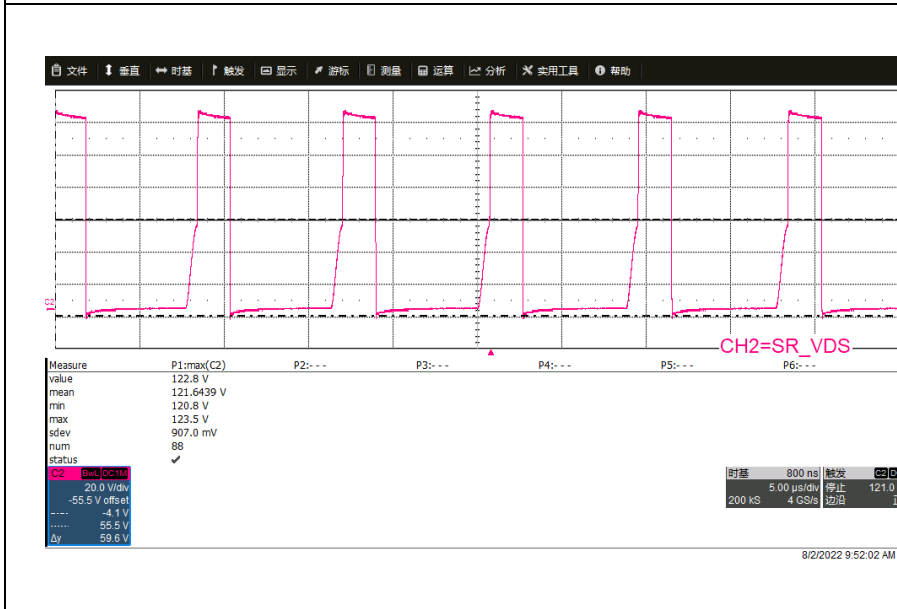
Vin=264Vac/50Hz

Vout=28V

Full load

Result

Vds_maxQR=639V



Test conditions

Vin=264Vac/50Hz

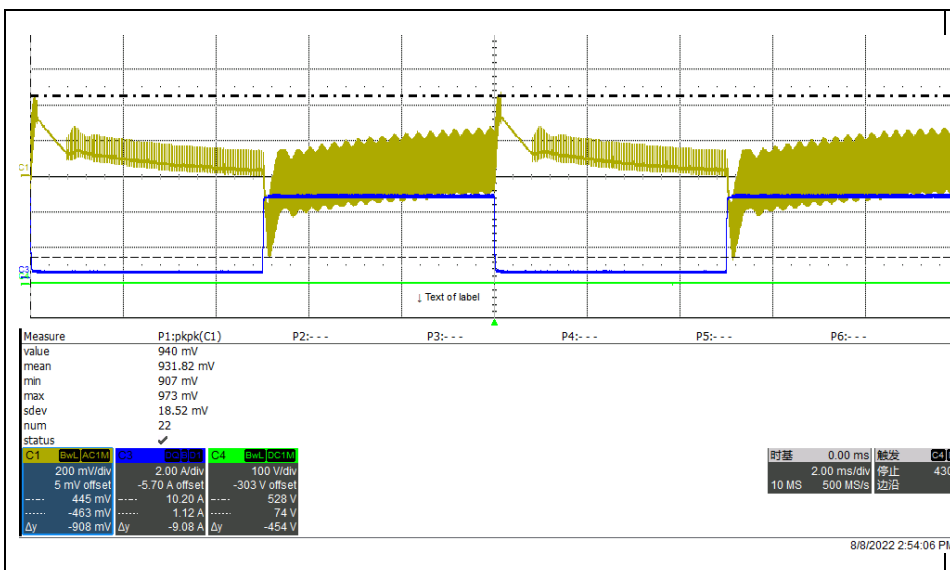
Vout=28V

Light load to Full load

Result

Vds_maxSR=123.5V

5.2.3. Dynamic Performance



Test conditions

Vin=90Vac/60Hz

Vout=28V

10%~90%load

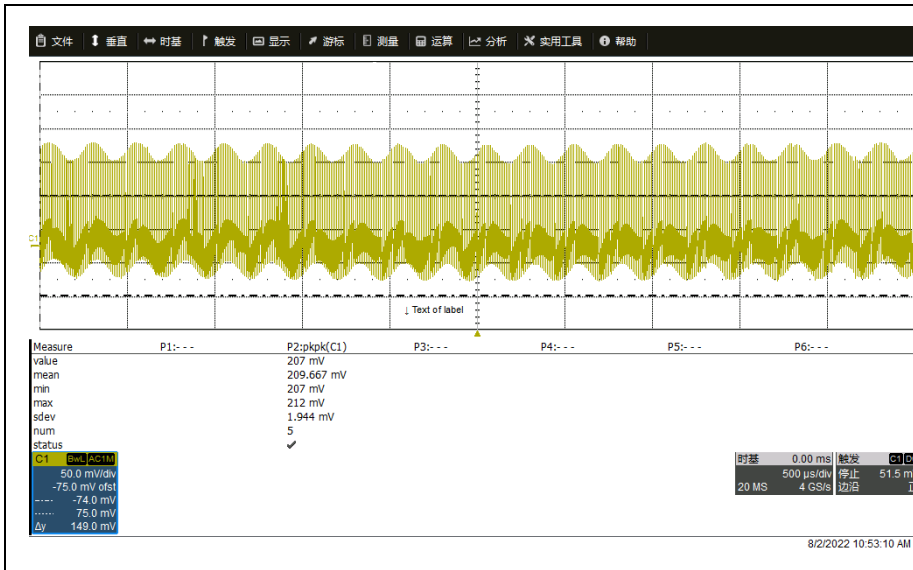
0.25A/us

T1=T2=5ms

Result

Vpp<5%

5.2.4. Ripple



Test conditions

Vin=90Vac/60Hz

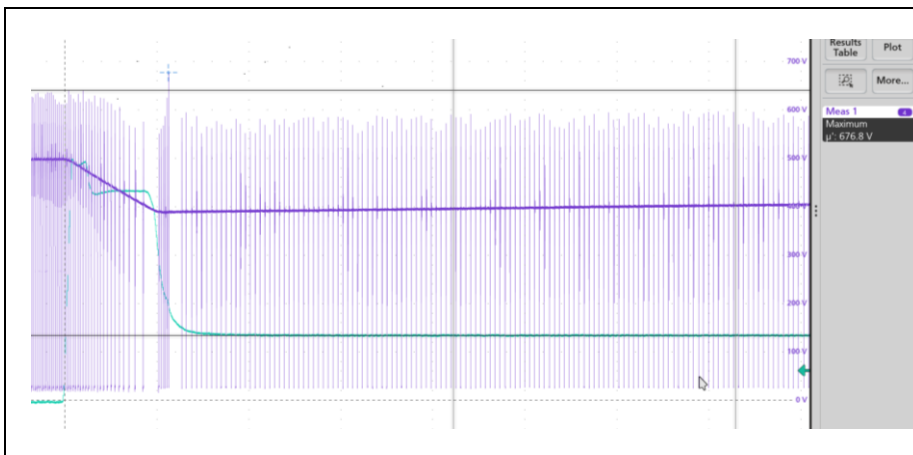
Vout=28V

Full load

Result

Vo_ripple < 220mV

5.2.5. Short



Test conditions

Vin=264Vac/50Hz

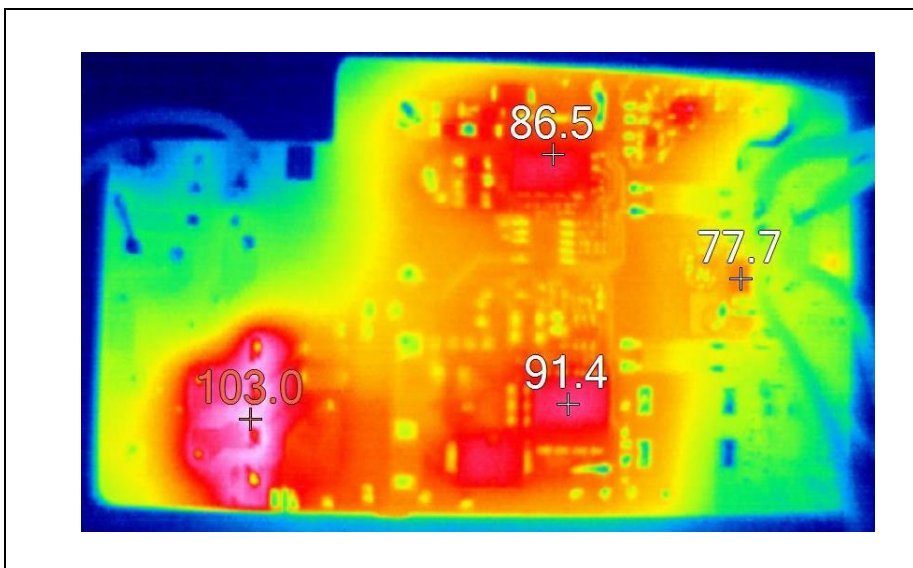
Vout=28V

Full load

Result

Vds_maxQR=675V

5.2.6. Thermal



Test conditions

Vin=90Vac/60Hz

Vout=28V

Full load

Ambient temp 25°C

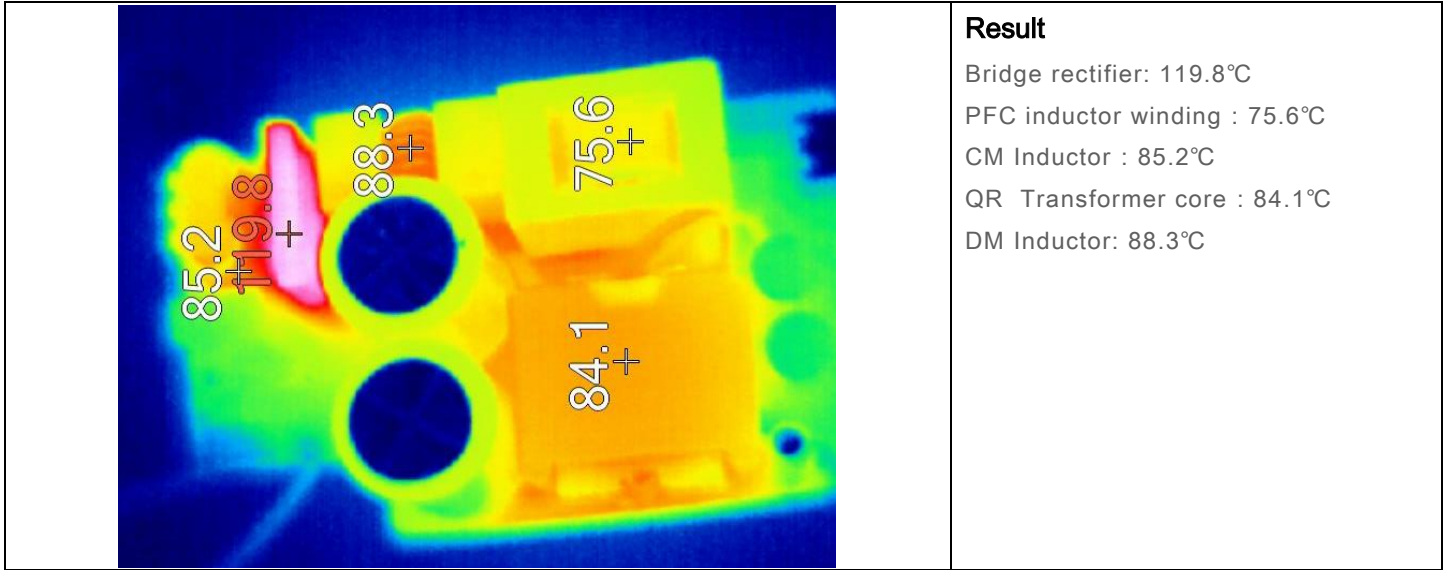
Run for 1h

Result

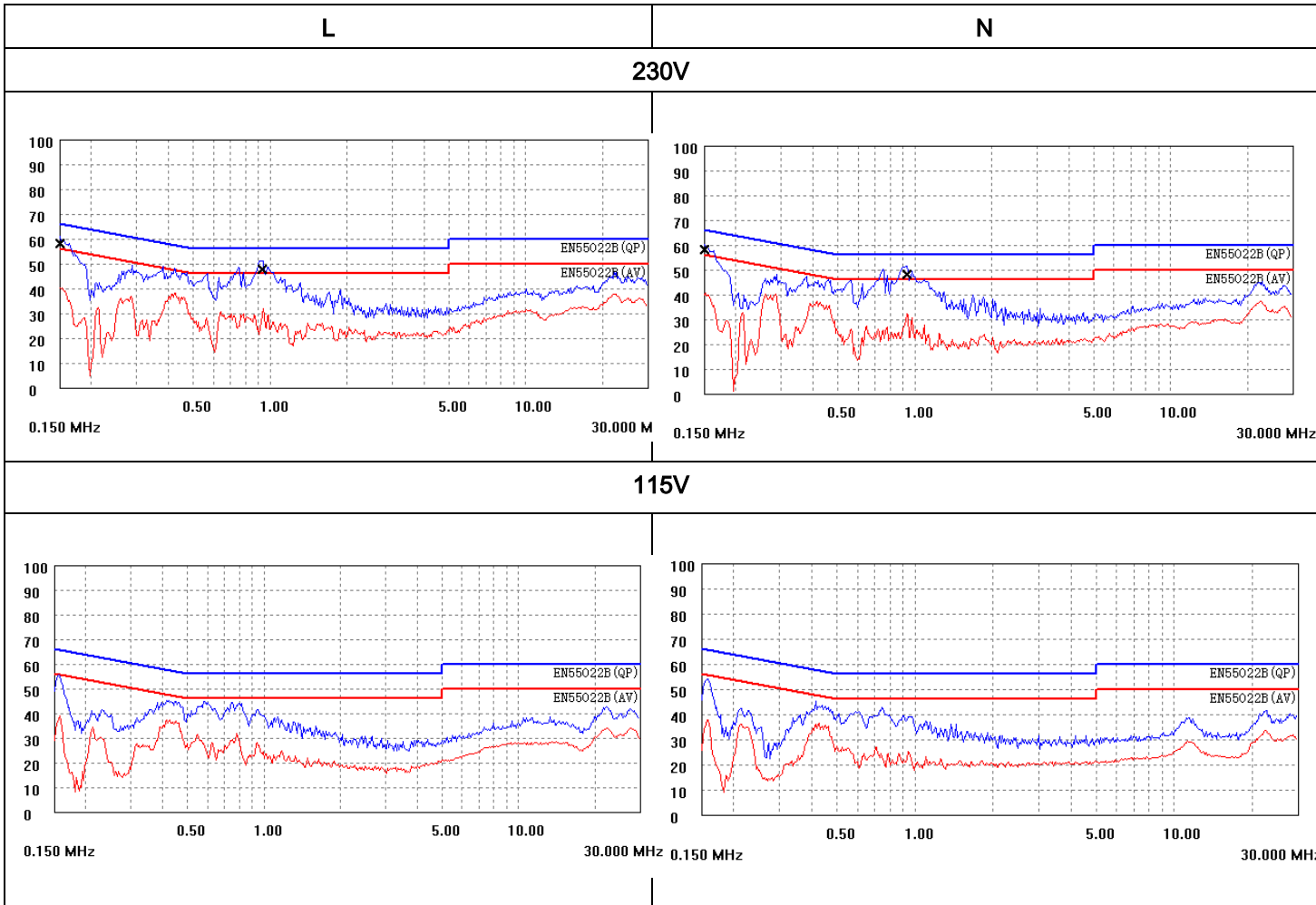
PFC GaN : 91.4°C

QR GaN : 86.5°C

SR GaN : 77.7°C



5.2.7. EMI



Appendix

Appendix A. Schematics

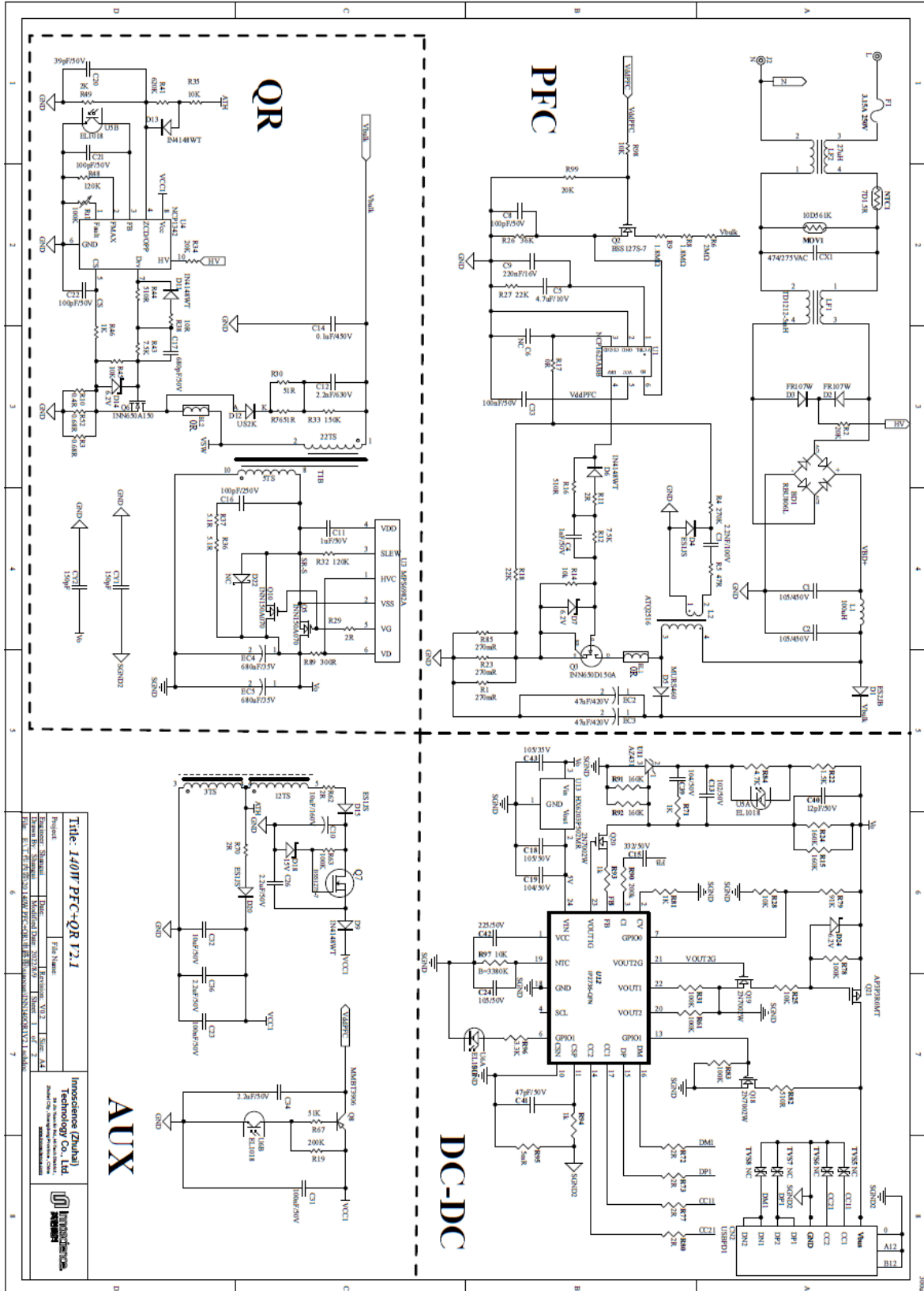


Figure 12 Schematic

Appendix B. BOM

Table 3 BOM

Comment	Description	Designator	Footprint	Quantity
0R	Resistor 1%	BL1, BL2	1206L	2
2.2NF/100V	Capacitor X7R 10%	C3	0603C	1
1nF/50V	Capacitor X7R 10%	C4, C13	0402C	2
4.7uF/10V	Capacitor X7R 10%	C5	0603C	1
100pF/50V	Capacitor NP0 5%	C8, C21, C22	0402C	3
220nF/16V	Capacitor X7R 10%	C9	0402C	1
1uF/50V	Capacitor X7R 10%	C11, C43	0603C	2
2.2nF/630V	Capacitor NP0 5%	C12	1206C	1
0.1uF/450V	Capacitor X7R 10%	C14	1206C	1
3.3nF/50V	Capacitor X7R 10%	C15	0402C	1
100pF/250V	Capacitor NP0 5%	C16	0805C	1
680pF/50V	Capacitor NP0 5%	C17	0402C	1
1uF/50V	Capacitor X7R 10%	C18, C24	0402C	2
100nF/50V	Capacitor X7R 10%	C19, C31, C33, C39	0402C	4
39pF/50V	Capacitor NP0 5%	C20	0402C	1
100nF/50V	Capacitor X7R 10%	C23	0603C	1
2.2uF/50V	Capacitor X7R 10%	C26, C34, C36	0805C	3
10uF/50V	Capacitor X7R 10%	C32	0805C	1
12pF/50V	Capacitor NP0 5%	C40	0402C	1
47pF/50V	Capacitor X7R 10%	C41	0402C	1
2.2uF/50V	Capacitor X7R 10%	C42	0603C	1
USBPD1	SMT 16P Type-C	CN2	PD-03	1
150pF	Y-Cap TRX SMD Y1	CY1, CY2	CY SMD TRX	2
ES2JB	Ultra-Fast Recovery Diode, 800V/2A	D1	SMB	1
FR107W	Fast Recovery Diode /1000V/1A ,SOD-123F	D2, D3	SOD-123	2
ES1JS	Fast Recovery Diode , 800V1A /35ns	D4, D15, D20	SOD-323	3
PES8H	Ultra-Fast Recovery Diode, 500V/8A VF=1.45V trr=35ns	D5	SMC	1
1N4148WT	Diode 100V/150mA	D6, D11	SOD-523	2
MM5Z6V2ST1G	MM5Z6V2ST1G, 6.2V ZENER	D7, D14, D24	SOD-523	3
1N4148WS	Diode 100V/150mA	D9	SOD-323	1
US1KW	Fast Recovery Diode , 800V1A /35ns	D12	sod-123	1
BAV21WT	Diode 200V/200mA	D13	SOD-523	1
BZX584C18	18V ZENER	D18	SOD-523	1
56uF/420V	中元电子 KM 420V56 D18X18max	EC2, EC3	EC18*35.5*7.5	2
470uF/35V	Solid-state Aluminum electrolytic capacitor Polycap RT35V470 D8*35mm	EC4, EC5	EC8*11.5*3.5	2
BSS127S-7	N-MOS 600V 50mA DIODES	Q2, Q7	SOT23-3L	2
INN650D150A	GaN , 650V/150mΩ , DFN 8*8 , Innoscence	Q3, Q6	DFNWB8x8-8L-K	2
INN150A070	GaN , 150V/7mΩ , FCLGA , Innoscence	Q5	FCLGA 3.2*2.2	1
MMBT3906	PNP,45V 100mA	Q8	SOT23-3L	1
2N7002	NMOSFET 60V/150mA	Q18, Q19, Q20	SOT23-3L	3
CQY03P7R8	PMOS CQAOS 30V/34A 7.8mR	Q21	DFN3*3	1
270mR	Resistor 1%	R1, R23, R85	0805R	3
20K	Resistor 1%	R2, R34, R99	1206R	3
0.68R	Resistor 1%	R3, R52	1206R	2
270K	Resistor 1%	R4	0402R	1
47R	Resistor 1%	R5	0603R	1
2MΩ	Resistor 1%	R6	R0805	1

1.8MΩ	Resistor 1%	R8, R9	R0805	2
0.4R	Resistor 1%	R10	1206R	1
2R	Resistor 1%	R11, R72, R73, R77, R80	0402R	5
7.5K	Resistor 1%	R12, R43	0402R	2
10k	Resistor 1%	R14, R25, R28, R35, R45	0402R	5
160K	Resistor 1%	R15, R24, R91, R92	0402R	4
510R	Resistor 1%	R16, R44	0402R	2
0R	Resistor 1%	R17	0402R	1
22K	Resistor 1%	R18, R27	0402R	2
200K	Resistor 1%	R19	0603R	1
1.5K	Resistor 1%	R22	0402R	1
36K	Resistor 1%	R26	0402R	1
2R	Resistor 1%	R29	0603R	1
27R	Resistor 1%	R30, R76	1206R	2
100K	Resistor 1%	R31, R61, R63, R78, R83	0402R	5
120K	Resistor 1%	R32, R48	0402R	2
150K	Resistor 1%	R33	1206R	1
5.1R	Resistor 1%	R36, R37	0603R	2
10R	Resistor 1%	R38	0402R	1
620K	Resistor 1%	R41	0402R	1
1K	Resistor 1%	R46, R71, R81, R93, R94	0402R	5
2K	Resistor 1%	R49	0402R	1
2R	Resistor 1%	R62, R70	0805R	2
51K	Resistor 1%	R67	0603R	1
91K	Resistor 1%	R79	0402R	1
510R	Resistor 1%	R82	0805R	1
4.7K	Resistor 1%	R84	0402R	1
300R	Resistor 1%	R89	0603C	1
200k	Resistor 1%	R90	0402R	1
5mR	Resistor 1%	R95	1206R	1
3.3K	Resistor 1%	R96	0402R	1
10K	Resistor 1%	R98	1206R	1
NCP1623ABB	PFC Controller, TSOP-6, ON	U1	SOT23-6L	1
MPS6982A	MPS Synchronize Rectifier IC	U3	SOT23-6N	1
NCP1342AMD	ON QR IC	U4	SOP10_L	1
EL1018	Optocoupler	U5, U6	SOP4-W2.54_L	2
AZ431	ADJUSTABLE PRECISION SHUNT REGULATORS	U11	SOT23-3L	1
IP2736-QFN	Injoinic Protocol IC	U12	QFN24 4x4_N	1
HX6203P502MR	LDO 35V to 5V	U13	SOT23-3L	1
RBU806L	Low VF Rectifier Bridge 沃尔德 600V/8A	BD1	RBU	1
105/450V	JURCC红色 310V/VAC P=10 12*8*15	C1, C2	CX 12.0X8*15	2
4.7uF/160V	Aluminum electrolytic capacitor D5*11 P=2.5	C10	EC5*11*2.5	1
474/275VAC	JURCC红色 310V/VAC P=10 12*6*12	CX1	CX 12X6*12	1
3.15A 250V	Fuse, 3.15A 250V, 8X4mm	F1	FUSE4X8.4R	1
33uH	DM inductor, 40125 线径 0.8mm	L1	T11.5X8	1
ATQ2516	ATQ2516 180uH 32:3	L2	ATQ-2501	1
TD1212-4mH	Flat CM Inductor 80mR 0.2*1.0 37T 立式 吉祥腾达	LF1	TD1212H	1
27uH	Nickel-zinc inductors T9*4*5 绿色磁环 Wire diameter 0.3mm	LF2	T09X5X4 O	1
10D561K	VDR 560V	MOV1	RV-10D471	1
7D1.5R	NTC	NTC1	RV-7D471	1
ATQ27	ATQ27 5+0 Im=230uH 22:5:12:3	T1	ATQ-27	1
NC	Capacitor NP0 5%	C6	0402C	1
NC	NTC B=3380K	R97	0402R	1
NC	Schottky Diode 150V/1A	D22	SOD-123	1

L	Wiring terminals	J1	M4X39	1
N	Wiring terminals	J2	M4X39	1
NC	GaN , 150V/7mΩ , FCLGA , Innoscience	Q10	FCLGA 3.2*2.2	1
NC	Resistor 1%	Rt1	0603R	1
NC	TVS	TVS5, TVS6, TVS7, TVS8	SOD-523	4

Revision History

Date	Author	Versions	Description	Check
2022.11.1	Shangui Ou/Bingwei Jing	1.0	First edition	AE Team



Note:

There is a dangerous voltage on the demo board, and exposure to high voltage may lead to safety problems such as injury or death.

Proper operating and safety procedures must be adhered to and used only for laboratory evaluation demonstrations and not directly to end-user equipment.



Reminder:

This product contains parts that are susceptible to electrostatic discharge (ESD). When using this product, be sure to follow antistatic procedures.



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