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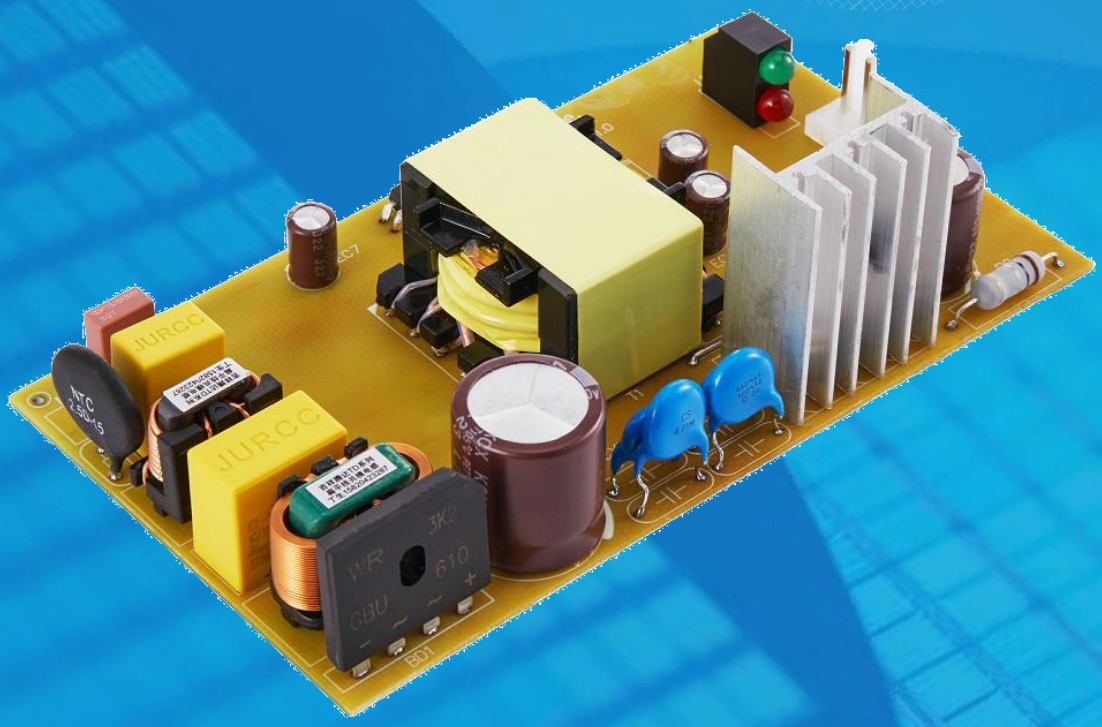
INNDAD120B4

120W E-Bike Charger Demo Manual



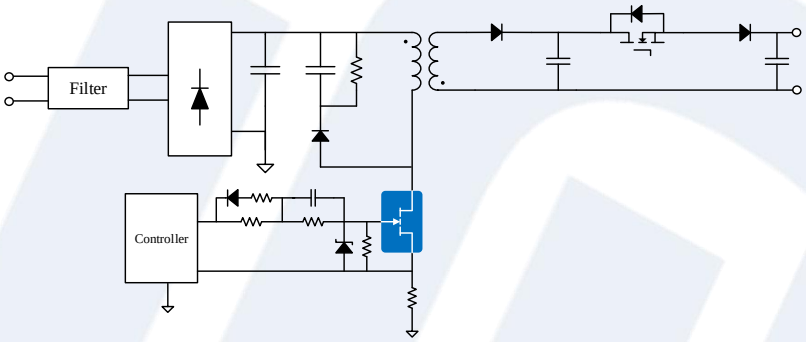
120W E-Bike Charger

The Introduction

120W E-Bike charger evaluation board is a highly efficient, highly reliable, no fan and low-cost AC/DC power supply.No heatsink for the power dissipation of Primary GaN.Its application is for E-Bike.

Input voltage:165Vac-275Vac Output voltage,55V-60V, Output maximum current:1.8A

The peak efficiency:91.8%.



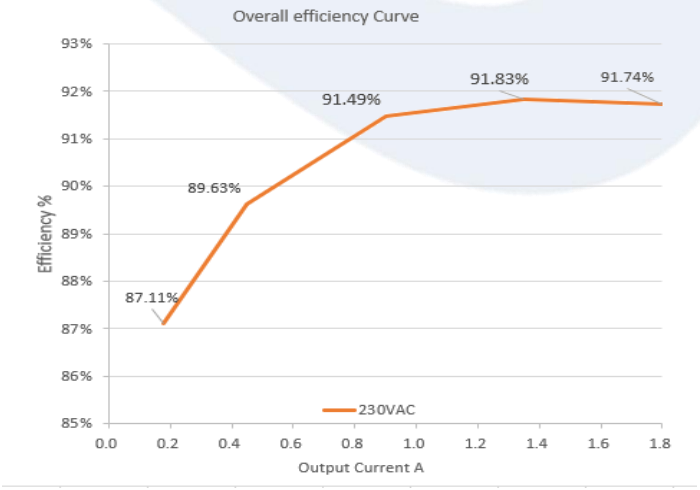
Highlighted Products

- INN700TK350B

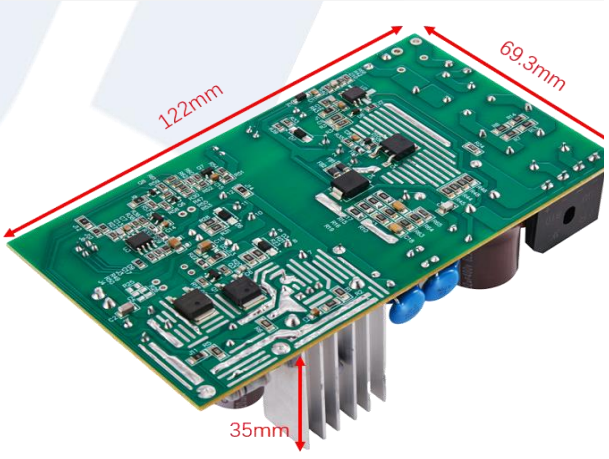
Target Applications

- E-Bike Charger

Test Results



Photo



List of Content

1. Overview

1.1. Description

120W E-Bike-Charger evaluation board is a high efficiency, no fan and low-cost AC/DC power supply. The specific parameters are input voltage 165Vac-275Vac, output 55V-60V, maximum output current 1.8A, and the peak efficiency up to 91.8%. With single-layer PCB design, single-side SMT, the processing of the evaluation board is simple and the cost is low.

QR consists of an Innoscience enhanced GaN field-effect transistor named INN700TK350B and a transformer.The switching advantages brought about by the high electron mobility and small parasitic junction capacitance of third-generation semiconductor GaN transistors are better reflected in high-frequency applications.

1.2. Features and Advantages

- **Main features and Advantages**
  - > High efficiency: 91.7%(Full load@230Vac)
  - > PCBA size: 122*69.3*40mm
  - > high reliability (No fan)
  - > Easy to manufacture and low cost
- **Protection Function**
  - > Cycle by cycle OCP
  - > Input under voltage protection
  - > Output over voltage
  - > Output short circuit protection
  - > Over power protection (OPP)

1.3. Applications

- **E-bike charger**

2. Parameters

Table 1 Electrical Characteristic（Ta=25℃）

Symbol	Parameters	Test Conditions	Min	Nom	Max	Units
System Spec						
VIN	Input voltage		165	230	275	Vac
F_AC	Input frequency			50		Hz
Fsw,QR		Vin=230Vac，Full load	110	112	123	kHz
Output	Output Voltage	Io<0.6A		55		V
		0.6A≦Io≦1.8A		59		V
POUT	Output power			106		W
Demo Performance						
Pstandby	Standby power	230Vac			0.5	W
Vripple	Output voltage ripple	Full load		500		mV
Eff,pk	Peak efficiency	Vin=230Vac		91.8		%
Eff	Full load efficiency	Vin=230Vac		91.7		%

3. Application Solutions

3.1. Block Diagram

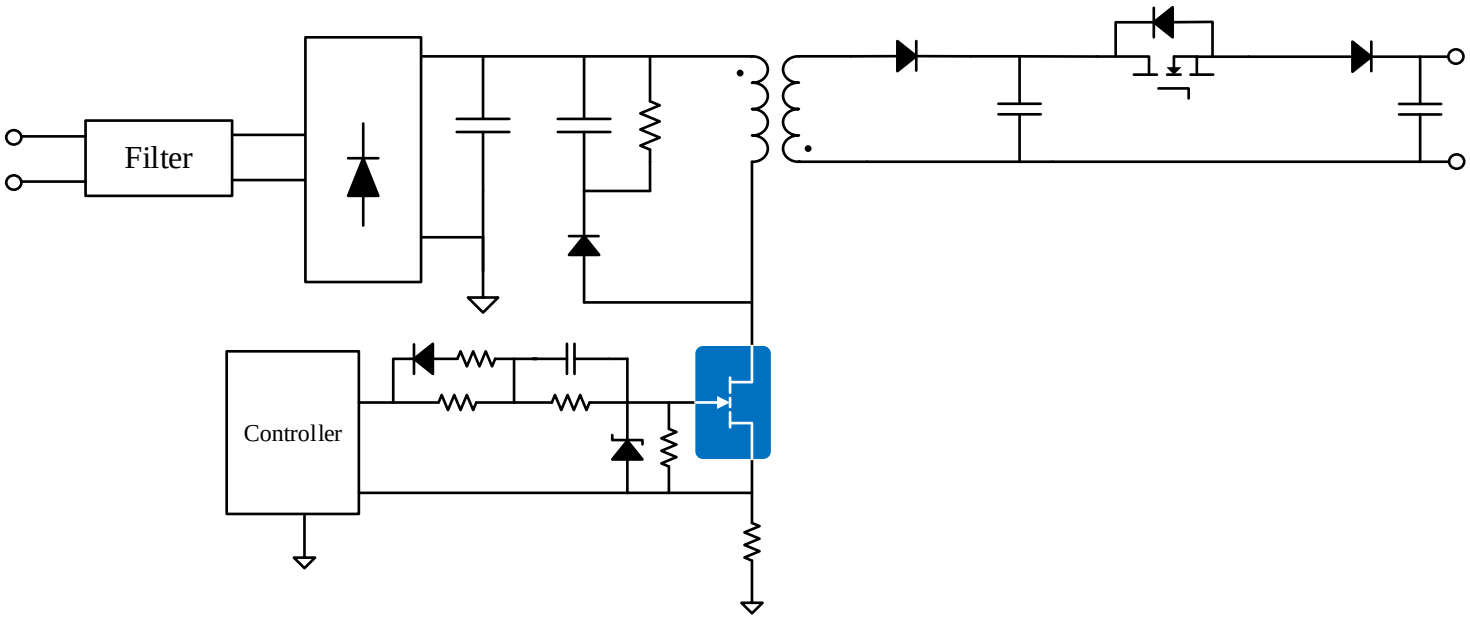


Figure 1 INNDAD120B4 System Block Diagram

3.2. INN700TK350B Introduction

INN700TK350B is a 700V silicon-based gallium nitride enhanced power transistor from Innoscience packaged in a TO-252 package.Compared to Si-MOSFET devices with the same conduction resistance, INN700TK350B has advantages such as lower Qg and Coss,zero reverse recovery charges, etc, which can reduce the switching and driving losses of the system.

Table 2 INN700TK350B Key performance parameters(Tj=25℃)

Parameter	Value	Unit
Vds,max	700	V
Rds(on), max@Vg=6V	350	mΩ
Qg, typ@Vds=400V	1.5	nC
Id, pulse	10	A
Qoss@Vds=400V	13	nC
Qrr@Vds=400V	0	nC

4. Hardware Implementation

4.1. Photos

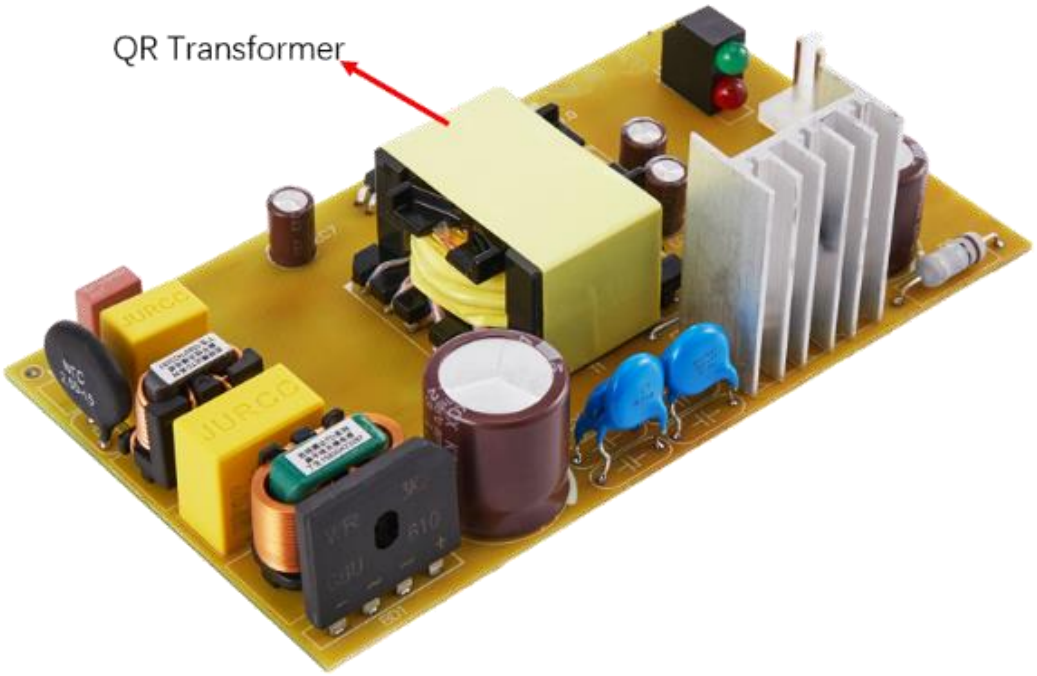


Figure 2 Top view of INNDAD120B4

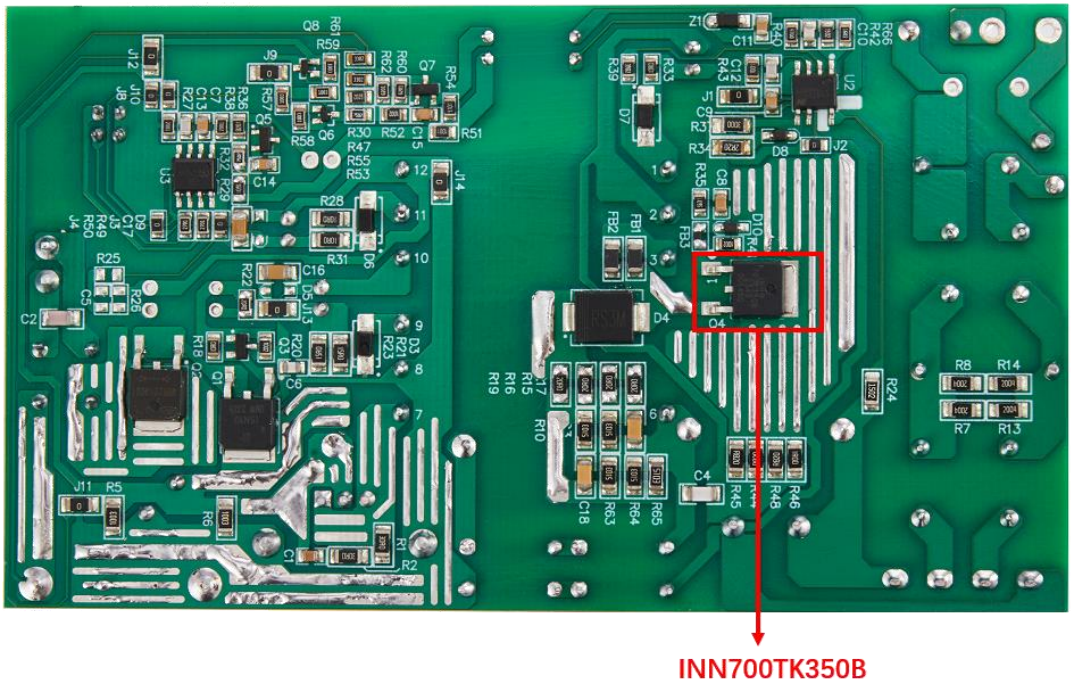
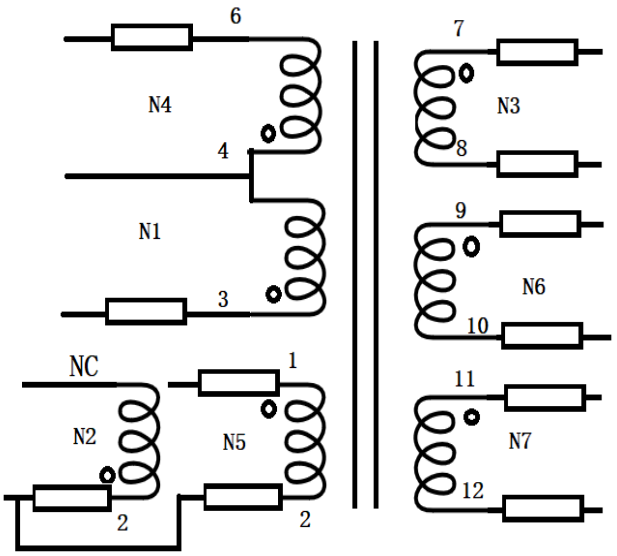


Figure 3 Bottom view of INNDAD120B4

4.2. Design Considerations

4.2.1. QR Transformer

Electrical diagram



Construction diagram

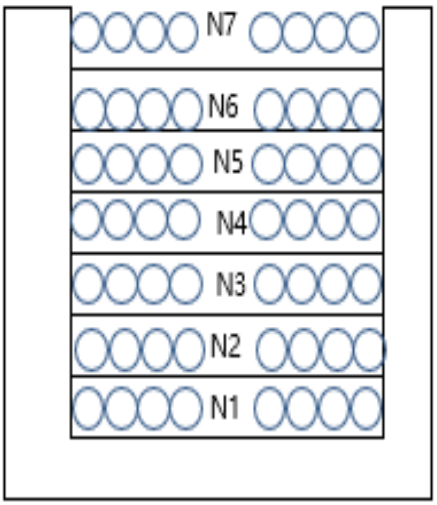


Table 3 Magnetic Core

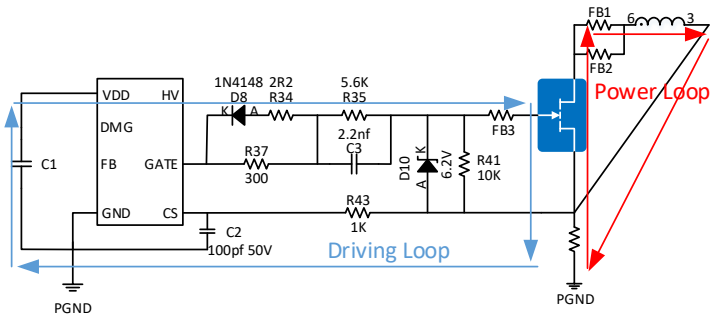
No.	Name	Core Size/Material	Vendor
1	Core	PQ3220	
2	Bobbin	Bobbin：PQ3220 (6+6PIN)	
3	Material	PC44	A-CORE/TDG/

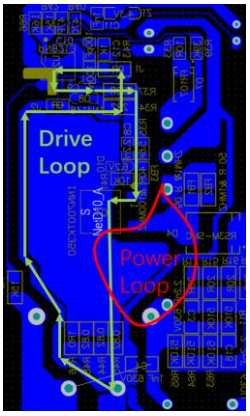
Table 4 Parameter

No.	Winding	Turns	Inductance	Test Case
1	N1	14	330uH±5%	1V/100KHz
2	N2	20		/
3	N3	9	/	/
4	N4	9	/	/
5	N5	3	/	/
6	N6	2	/	/
7	N7	2		
Short 7-8,9-10,11-12			L3-6_max=3.3uH	

4.2.2. Layout

- **Single switch**





a) Set CBYPASS close to the IC

b) Place the driver loop close to InnoGaN

a) CBUS,Transformer,InnoGaN circuits loop should be minimized

Figure 4 Single Switch Layout Recommendation

4.2.3. Thermal design guidance

120W E-Bike-Charger evaluation board is designed with single-layer PCB. One INN700TK350B with To-252 package is soldered on bottom side. No heatsink for power dissipation. So Leave as much PCB area as possible for heat dissipation. As below figure shows, PCB area size is about 385 mm2(30.6mm*12.6mm).

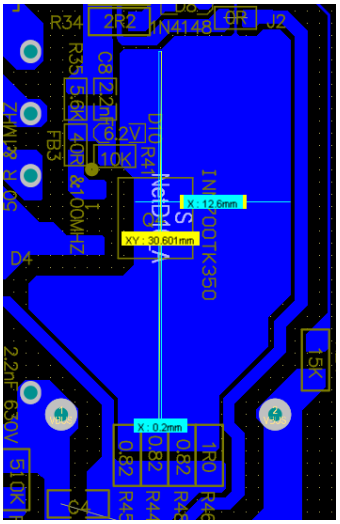


Figure 5 PCB area for the heat dissipation of INN700TK350B

5. Testing & Results

5.1. Test Setup

- Input Power Meter: ZLG PA310
- Output load: ITECH IT8732
- Oscilloscope: Tektronix MSO44 500MHz
- Input AC Power Source: eec EAB-120

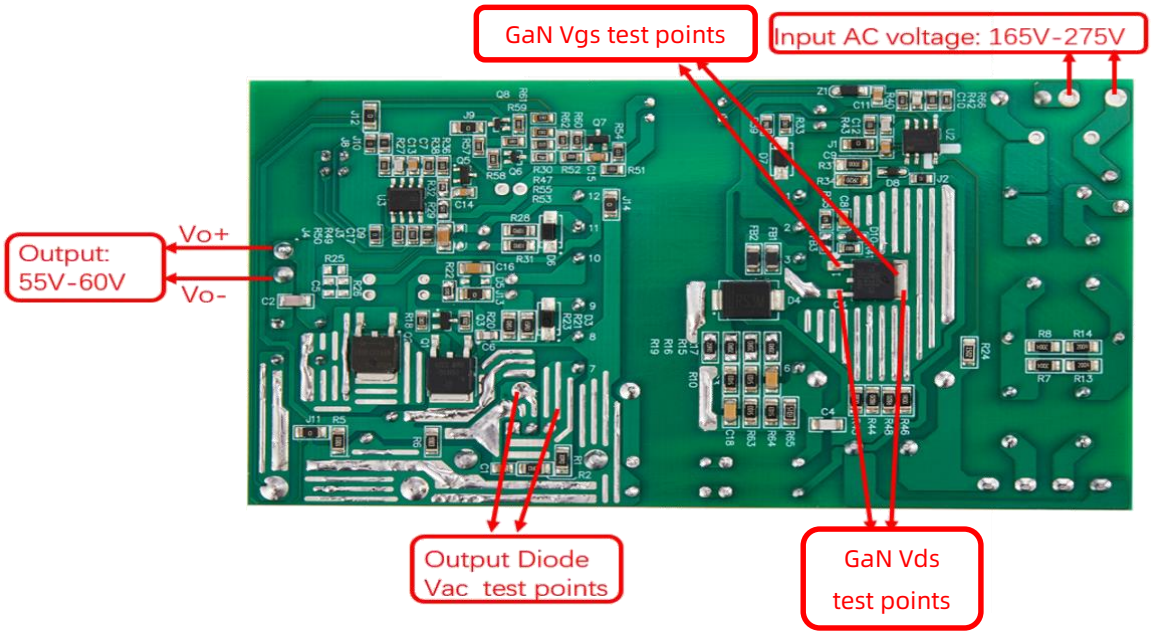


Figure 6 Test points

Figure 7 Test setup

5.2. Test results

5.2.1. Efficiency

Table 5 Overall efficiency

Vin（V）	100%load η (%)	75%load η (%)	50%load η (%)	25%load η (%)	10%load η (%)	Average η (%)
165Vac	91.10	91.58	91.58	90.45	88.19	91.18
230Vac	91.74	91.83	91.49	89.63	87.11	91.17
275Vac	91.73	91.59	91.02	88.67	85.90	90.75

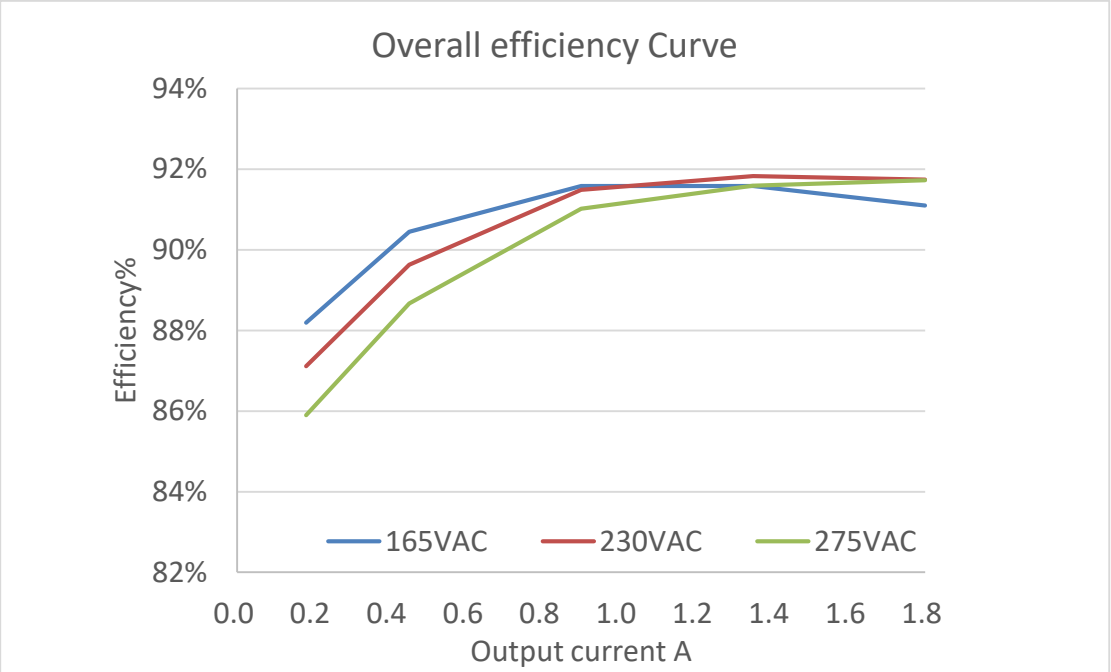
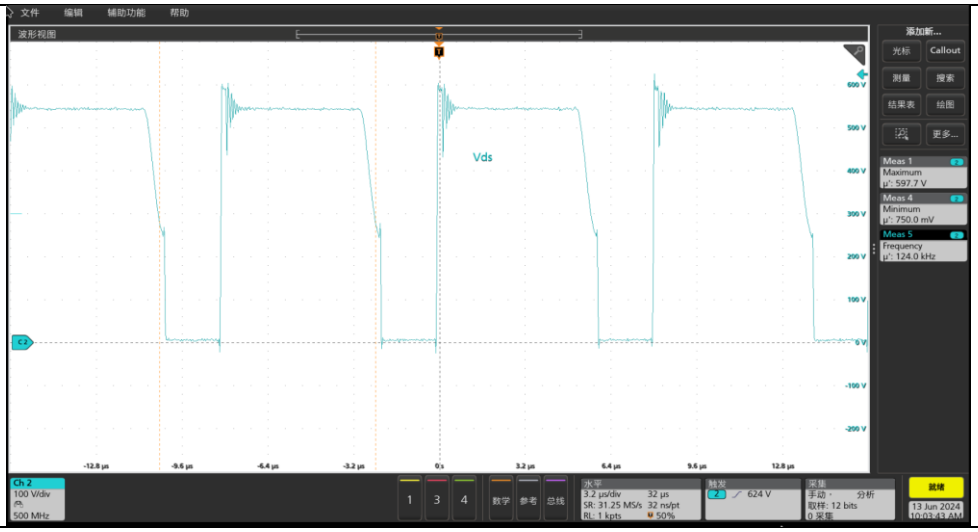
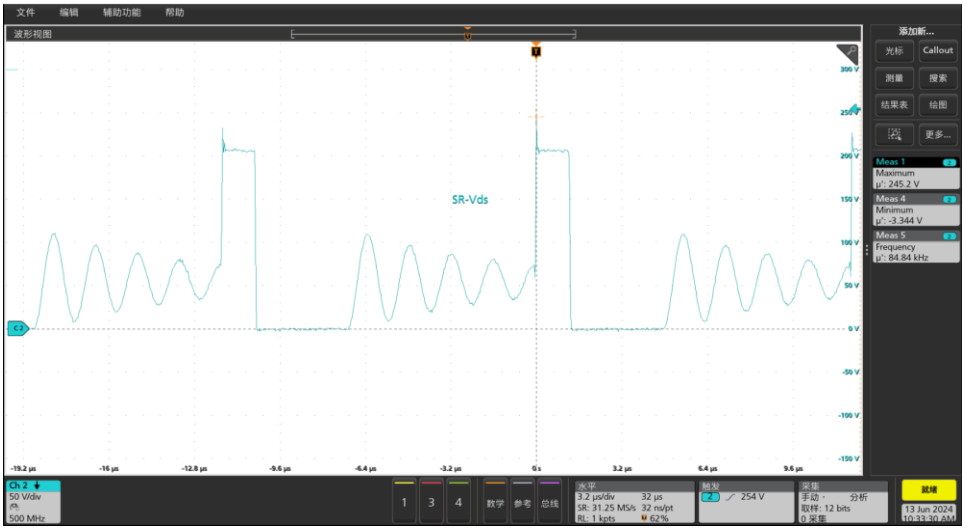
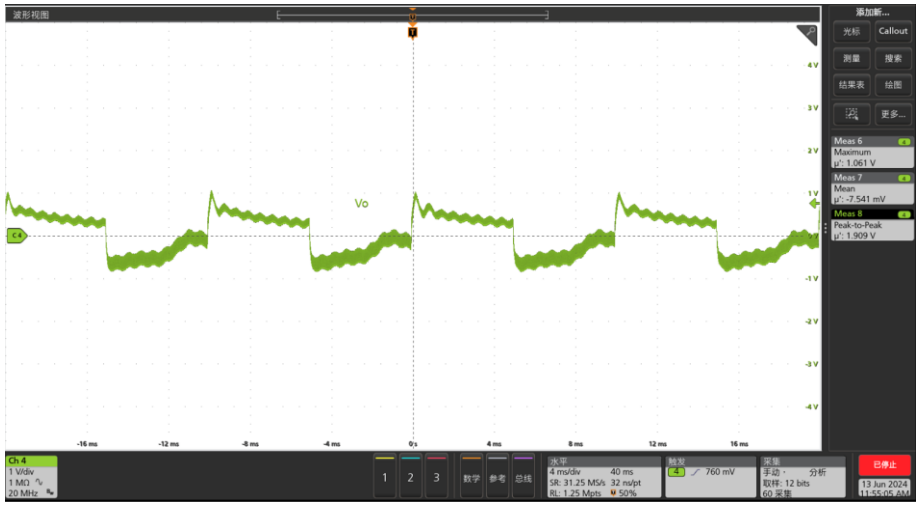


Figure 8 Overall efficiency curve

5.2.2. Switching Waveforms

	**Test conditions** Vin=275Vac/50Hz Vout=60V Full load **Result** Vds_max=598V
	**Test conditions** Vin=275Vac/50Hz Vout=60V light load to Full load， Record the maximum SR voltage stress **Result** Vds_max_SR=245V

5.2.3. Dynamic Performance



Test conditions

Vin=90Vac/60Hz

Vout=60V

33%(0.6A) ~100%(1.8A) load

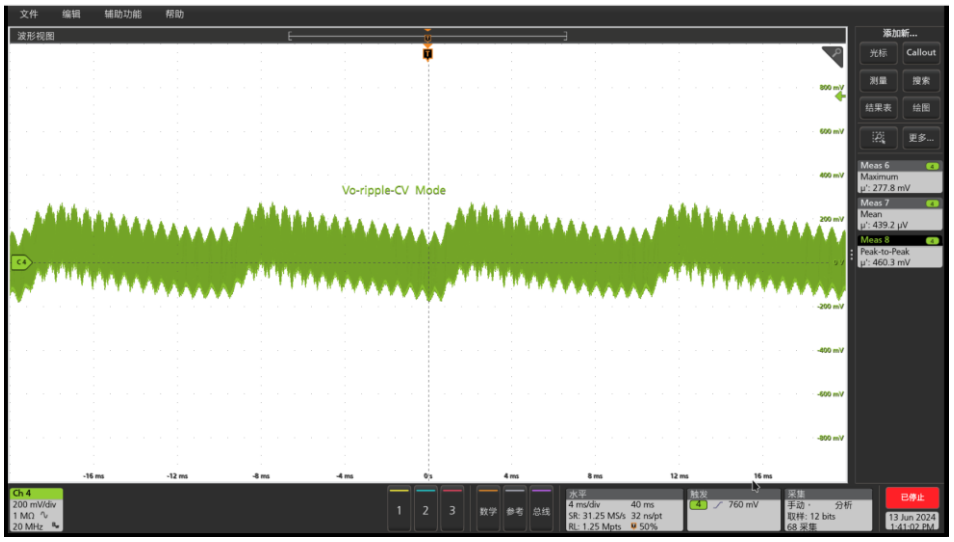
0.25A/us

T1=T2=5ms

Result

Vpp<5%

5.2.4. Output Ripple waveform



Test conditions

Vin=165Vac/50Hz

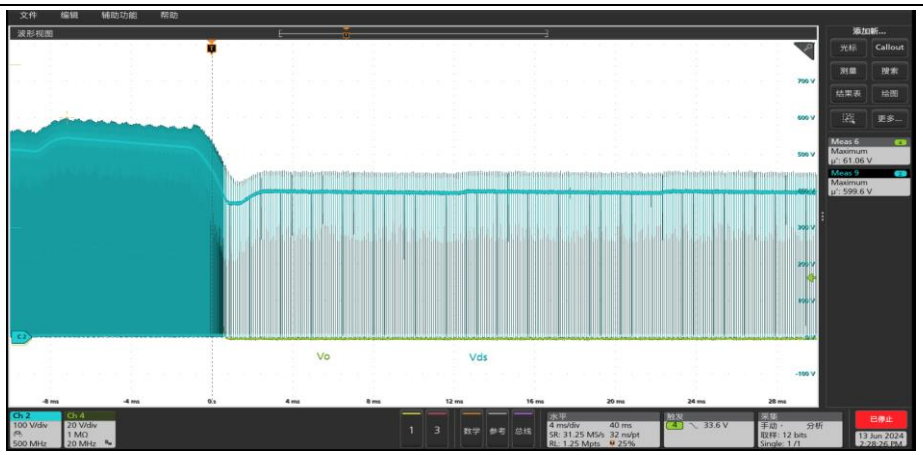
Vout=60V

Full load CV

Result

Vo_ripple=460 mV < 600mV

5.2.5. Short



Test conditions

Vin=275Vac/50Hz

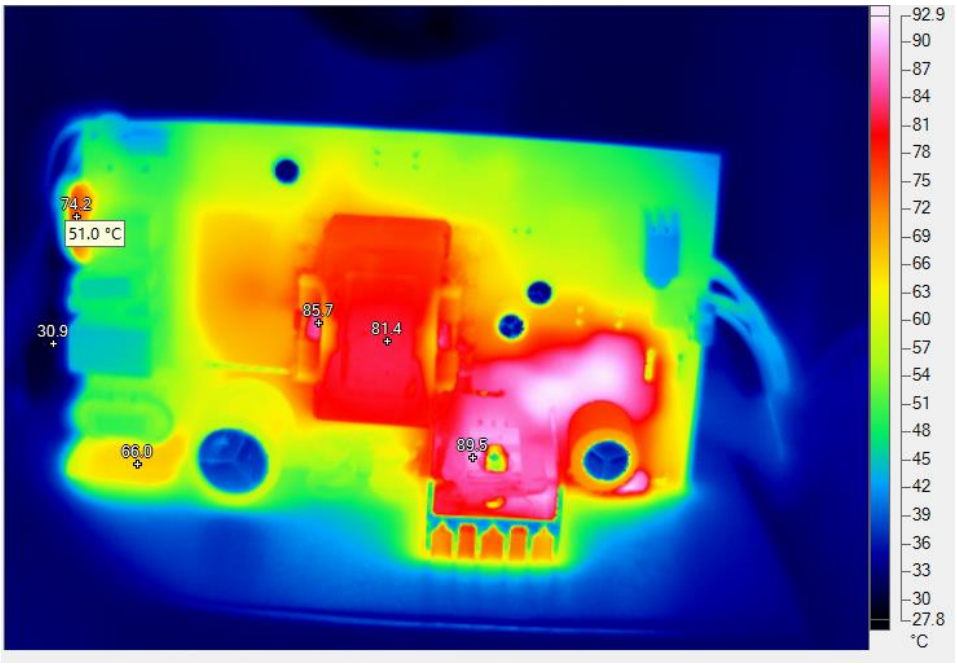
Vout=60V

Output full load, then short-circuit output

Result

Vds_max_QR=599.6V

5.2.6. Thermal



TOP

Test conditions

Vin=165Vac/50Hz

Vout=60V

Full load

Ambient temp 31°C

Run for 1h

Result

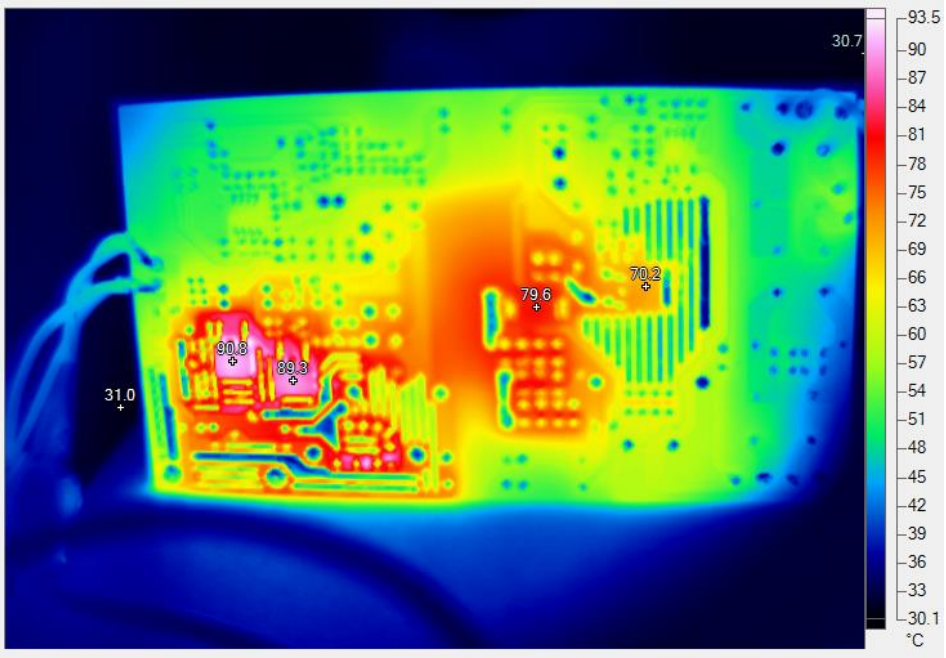
Transformer: Winding:85.7℃

Core: 81.4℃

Rectifier Diode:89.5℃

NTC:74.2℃

Rectifier Bridge:66℃



Bottom

Test conditions

Vin=165Vac/50Hz

Vout=60V

Full load

Ambient temp 31°C

Run for 1h

Result

GaN: 70.2℃

Snubber Diode: 79.6℃

Back-to-back diode:90.8℃

Back-to-back MOSFET:89.3℃

Test conditions

Put PCBA into the case and test components' temperatures

The inside of the case is semi glued for heat dissipation

Devices	Unit:℃	Equivalent to 55 ℃
Output rectifier diode	93.07	122.07
Wingding of the Transformer	80.52	109.52
Core of the Transformer	89.91	118.91
Rectifier Bridge	87.13	116.13
Output Reverse MOSFET	96.4	125.4
GaN(INN700TK350B)	86.8	115.8
Snubber circuit Diode	92.07	121.07
Output reverse Diode	90.32	119.32
Top side of the case	51.16	80.16
Bottom side of the case	61.9	
Bottom side of the case	60.2	

Test conditions

Vin=165Vac/50Hz

Vout=60V

Full load

Ambient temp 26°C

Run for 3h

Result

Pass

Devices	Unit: ℃	Equivalent to 55 ℃
Output rectifier diode	91.6	119.6
Wingding of Transformer	79.96	107.96
Core of Transformer	90.72	118.72
Rectifier Bridge	71.42	99.42
Output Reverse MOSFET	95.2	123.2
GaN(INN700TK350B)	81.28	109.28
Snubber circuit Diode	89.44	117.44
Output reverse Diode	89.21	117.21
Top side of the case	49.86	
Bottom side of the case	60.2	

Test conditions

Vin=275Vac/50Hz

Vout=60V

Full load

Ambient temp 27°C

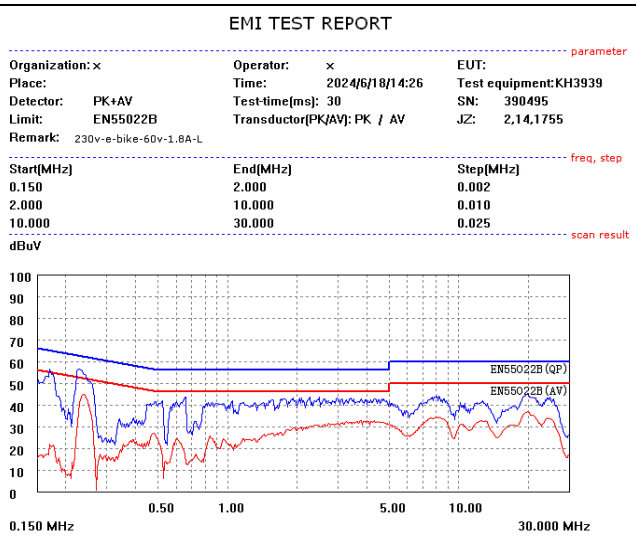
Run for 3h

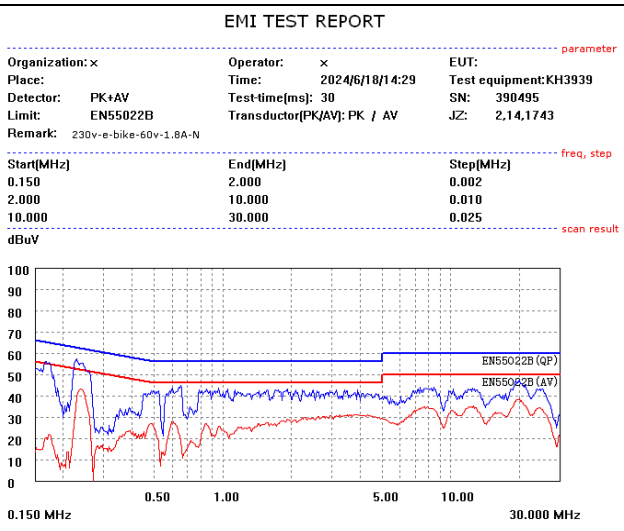
Result

Pass

5.2.7. EMI

L	N
230V	





Appendix

Appendix A. Schematics

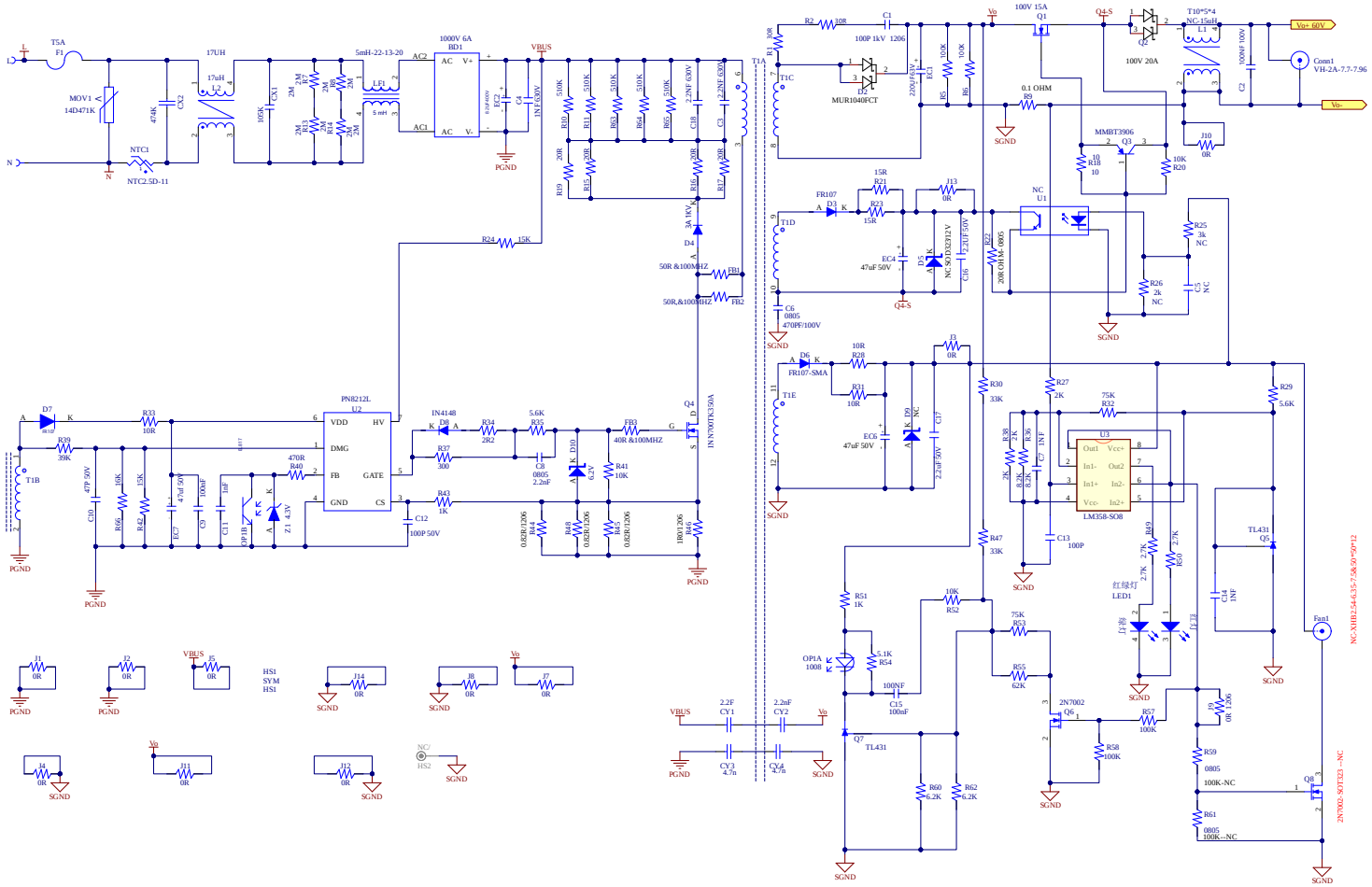


Figure 9 Schematic

Appendix B. BOM

Table 6 BOM

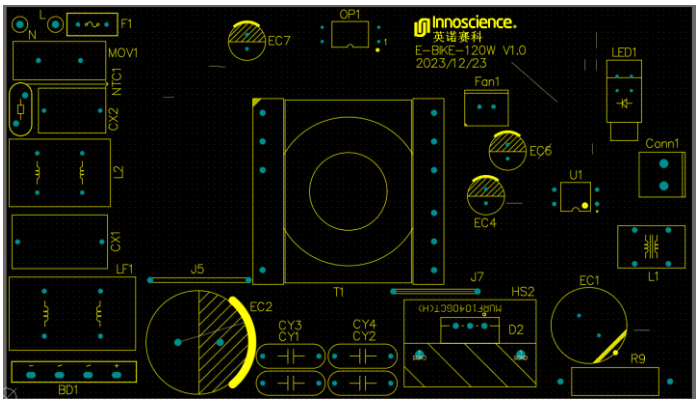
Comment	Description	Designator	Footprint	Quantity
WRGBU610	Rectifier Bridge World 1KV/6A	BD1	GBU_4P-L22.0-W3.5-P5.08	1
100P 1KV	Capacitor X7R 10%	C1	C1206R	1
100NF 100V	Capacitor X7R 10%	C2	C1206R	1
2.2NF 630V	Capacitor X7R 10%	C3,'C18	C1206R	2
1NF 630V	Capacitor X7R 10%	C4	C1206R	1
100P 100V	Capacitor X7R 10%	C6,	C0805R	1
2.2N 50V	Capacitor X7R 10%	C8	C0805R	1
1NF 50V	Capacitor X7R, 10%	C7, C11, C14	C0805R	3
100nF 50V	Capacitor X7R, 10%	C9, C15	C0805R	2
47P 50V	Capacitor X7R, 10%	C10	C0805R	1
100P 50V	Capacitor X7R, 10%	C12'C13	C0805R	2
2.2UF 50V	Capacitor X7R, 10%	C16, C17	C1206R	2
105K X2	JURCC yellow X2 105K MPX/MKP 275VAC305VAC	CX1	17*9.5*6.5 PIN=15mm	1
474K X2	JURCC yellow X2 474K MPX/MKP 275VAC305VAC	CX2	12*8*15 PIN=10mm	1
2.2nF Y2	AJC 222M 400VAC	CY1, CY2	pitch 7.5mm	2
4.7n Y2	KNSCHA JT 472M 400VAC	CY3, CY4	pitch 7.5mm;	2
220UF 63V	Aluminum electrolytic capacitor Yongming LK '220UF 63V	EC1	EC 13*26.5*5	1
82 UF 400V	Aluminum electrolytic capacitor Yongming KCX 82UF 400V	EC2	EC18*35.5*7.5	1
47UF 50V	Aluminum electrolytic capacitor Yongming LK 47UF 50V	EC4, EC7,'EC6	EC6.3*11.2*2.5	3
MUR1040FCT	YFW fast recovery/High efficiency diode/Voltage: 400V	D2	TO-220	1

	Current: 5A tube installation 10A VF=1.15V			
FR107	VDSS 1KV if=1A, tr=500 n s	D6 D7 D3	SMA	3
RS3M	3A 1KV GOODWORK	D4	SMC	1
IN4148	SOD323_SMD 1N4148	D8	SOD-323	1
BZT52C6V2S	6.2V Zener diode	D10	SOD-323	1
BZT52C4V3S	4.3V Zener diode	Z1	SOD-123	1
SQT3.15M	300VAC 3.15APlastic sealed square slow break Fuse	F1	FUSED-4X8-	1
50R &100MHZ	SMD Bead 50Ω@100MHz	FB1，'FB2	R1206	2
40R &100MHZ	SMD Bead 40Ω@100MHz	FB3	R0805	1
0R	0R,±1%,	J1, J9, J11, J12, J13, J14	R1206	6
0R	0R,±1%	J2, J3, J4, J8, J10	R0805	5
0R	Φ1.0mm*15	J5	JUMP_DIP_17.5	1
0R	Φ1.0mm*15	J7	JUMP_DIP_15	1
LT-10X13-SCH	LT-10X13-short	L1	LF 12*7.5*12	1
17UH	CM Inductor Lucky Tenda TD1212NY-17UH vertical	L2	L 18*12*16.5	1
5mH	'CM Inductor Lucky Tenda达TD1515-5mH vertical	LF1	8*10	1
红绿灯	Typical RED GaAs LED	LED1	14.3*6.2*12.4 (L*W*H)	1
NTC2.5D-15	NTC Resistor/ 2.5Ω 2.5D-15 / Dip P=7.5mm	NTC1	2.5D-15	1
OPTO EL817(C)-G	Optocoupler EVERLIGHT EL817(C)-G	OP1	DIP-4	1
15N10	N-mosfet 100V 15A Rdson=95 mohm &Vgs=10V	Q1	TO-252	1
MBR20100DT	Schottky Rectifiers 100V 20A VF=0.85V	Q2	TO-252	1
MMBT3906	PNP Bipolar Transistor	Q3	SOT-23B_N	1

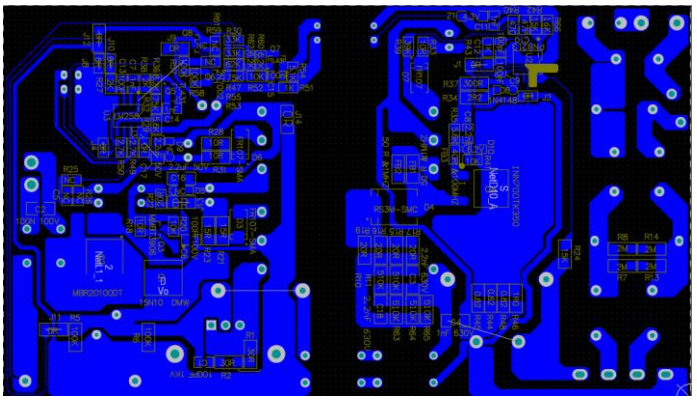
	MMBT3906			
INN700TK350B	GaN,700V/350 mΩ Innoscience	Q4	TO-252	1
TL431	ADJUSTABLE PRECISION SHUNT REGULATORS	Q5, Q7	SOT23	2
2N7002	N-Channel MOSFET 2N7002	Q6	SOT323	1
30R	Resistor 1%	R1, R2	R1206	2
100K	Resistor 1%	R5, R6	R1206	2
2M	Resistor 1%	R7, R8, R13, R14	R1206	4
0.1R	0.1R 1W DIP	R9	RES-TH_BD5.0-L15.5-P19.50-D0.7	1
510K	Resistor 1%	R10, R11, R63, R64, R65	R1206	5
20R	Resistor 1%	R15, R16, R17, R19	R1206	4
10	Resistor 1%	R18	R0805	1
10K	Resistor 1%	R20, R41, R52	R0805	3
15R	Resistor 1%	R21, R23	R1206	2
20R	Resistor 1%	R22	R0805	1
15K	Resistor 1%	R24	R1206	1
2K	Resistor 1%	R27, R38	R0805	2
10R	Resistor 1%	R28, R31	R1206	2
5.6K	Resistor 1%	R29, R35	R0805	2
33K	Resistor 1%	R30, R47	R0805	2
75K	Resistor 1%	R32, R53	R0805	2
10R	Resistor 1%	R33	R0805	1
2R2	Resistor 1%	R34	R1206	1
8.2K	Resistor 1%	R36	R0805	1
300	Resistor 1%	R37	R1206	1
39K	Resistor 1%	R39	R0805	1
470R	Resistor 1%	R40	R0805	1
15K	Resistor 1%	R42	R0805	1
1K	Resistor 1%	R43, R51	R0805	2
0.82R	Resistor 1%	R44, R45, R48	R1206	3
1R	Resistor 1%	R46	R1206	1
2.7K	Resistor 1%	R49, R50	R0805	2

5.1K	Resistor 1%	R54	R0805	1
62K	Resistor 1%	R55	R0805	1
100K	Resistor 1%	R57, R58	R0805	2
6.2K	Resistor 1%	R60, R62	R0805	2
16K	Resistor 1%	R66	R0805	1
PQ3220	Transformer: PQ3220 Lm=330uH 23:3:9:2:2	T1	34*33*25.1(L*W*H)	1
PN8212L-SOP7	Chipown PN8212L-SOP7 QR PWM IC	U2	SOP7	1
LM258-SO8	Low-power dual operational amplifiers ST	U3	SO8	1
VH-2A-7.7-7.96	Output connector	Conn1	7.7*7.96*13.3 (L*W*H)	1
HS1	Heatsink	HS1	26.3mm（L） *15.4mm (W)*35mm(H)	1
NC	connect to one fan	Fan1	50mm*50mm*12mm (L*W*H)	1
NC	VCR 14D471KA	MOV1	MOV 16.5*6.8*21.5	1
NC	N-Channel MOSFET	Q8	SOT323	1
NC	Resistor 1%	R25, R26	R0805	2
NC	Resistor 1%	R59, R61	R0805	2
NC	4-Pin Phototransistor Optocoupler	U1	DIP-4	1
NC	Capacitor X7R 10%	C5	C0805R	1
NC	Zener diode/BZT52-B12S,12V ZENER, SOD-323, PANJIT	D5 D9	SOD-323	2

Appendix C. PCB Layouts



(a) Top Layer Layout



(b) Bottom Layer Layout

Revision History

Date	Version	Description	Author
2024/6/27	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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