Reference Design Report for a 5W (5V/1A NO Y) Cell Phone Charger Solution Using SF6010

Specification	90-265VAC Input; 5V/1A output
Application	Cell Phone Charger
Author	System Engineering Department
Document Number	SF6010_ CHRG _5W_5V1A
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Key Features

- NC-Cap/PSR ™ with Multi Mode Control
- Direct Drive Low Cost BJT
- No-Y Capacitor Solution
- Less than 70mW standby power @ 230VAC
- Meet 4-Start Cell Phone Charger Standby Requirement
- Pass Energy Star EPS2.0
- ±5% Constant Current (CC) and Constant Voltage (CV) Accuracy
- Pass EN55022 class B and FCC Part 15 Class B with over 6dB margin
- OCP/ OPP/SCP protection features
- Low Components Count

Contents

1. Introduction

SF6010 is a high precision, highly integrated DCM (Discontinuous Conduction Mode) Primary Side Regulation (PSR) controller for offline small power converter applications. It can directly drive power BJT, which can further lower system cost.

SF6010 uses Multi Mode Control to improve efficiency and reliability and to decrease audio noise energy @ light loadings. Around the full load, the system operates in PWM+PFM mode, which improve the system reliability. Under light load conditions, the IC operates in PFM mode to achieve excellent regulation and high efficiency, and to achieve less than 70mW standby power. SF6010 also integrates the function of "Max. Frequency Clamping @ Output Short Circuit" to limits power BJT Vce spike when output short circuits occurs.

SF6010 has built-in proprietary **NC-Cap/PSR™** control for CV control, which eliminates external compensation or filtering capacitor. It has built-in cable drop compensation function, which can provide excellent CV performance.

SF6010 integrates functions and protections of Under Voltage Lockout (UVLO), VDD Over Voltage Protection (VDD OVP), Output Over Voltage Protection (Output OVP), Soft Start, Cycle-by-cycle Current Limiting (OCP), Pin Floating Protection, VDD Clamping.

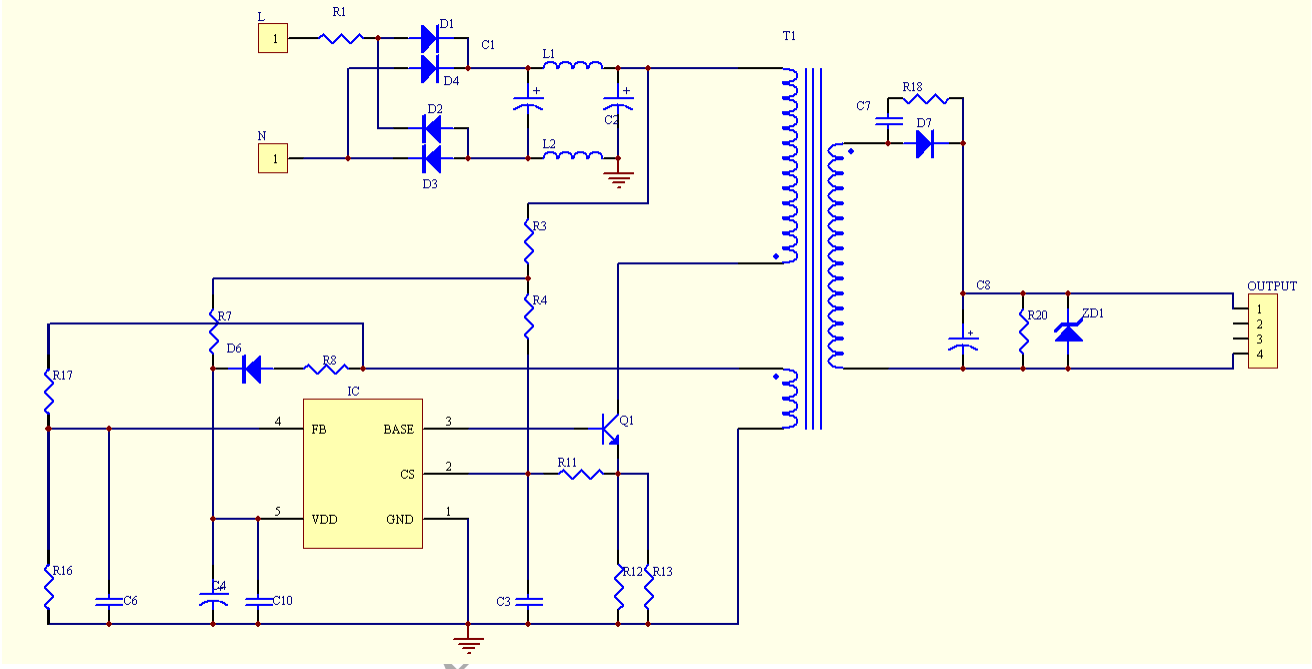
This document also contains the power supply specifications, schematic, bill of materials, transformer specifications, and typical performance characteristics for this reference design.

2. Specifiction

Description	Min	Typ	Max	Units	Remark
Input					
Voltage Frequency No Load Input Power	90 47	 50/60	264 64 100	VAC Hz mW	2 Wire Measure at 230VAC
Output (Measure at the end of Cable)					
Output Voltage Output Current Line Regulation Load Regulation Continuous Output Power	4.75 0	5.0 1 5	5.25 2 5	V A % % W	±5%
Efficiency(Measure at the end of Cable)					
Required average efficiency in Energy Star EPS2.0 (Low voltage mode)	68.17 %			%	115VAC/230VAC
Time Sequence					
Turn-on Delay Time Output Voltage Rise Time		2850 3.535	3000 5.26	ms ms	90VAC with full load
Protection Feature					

Short Circuit Protection Over Voltage Protection Open Loop Protection	Output shut down with automatic recovery			
Environmental, Surge and ESD				
Ambient Temperature	0		40	℃
Operating Humidity	20		90	% R.H
Storage Temperature	-40		60	℃
Storage Humidity	0		95	% R.H
EMI Test	Pass EN55022 Class B and FCC Part15 Class B with 6dB margin			

3. Schematic



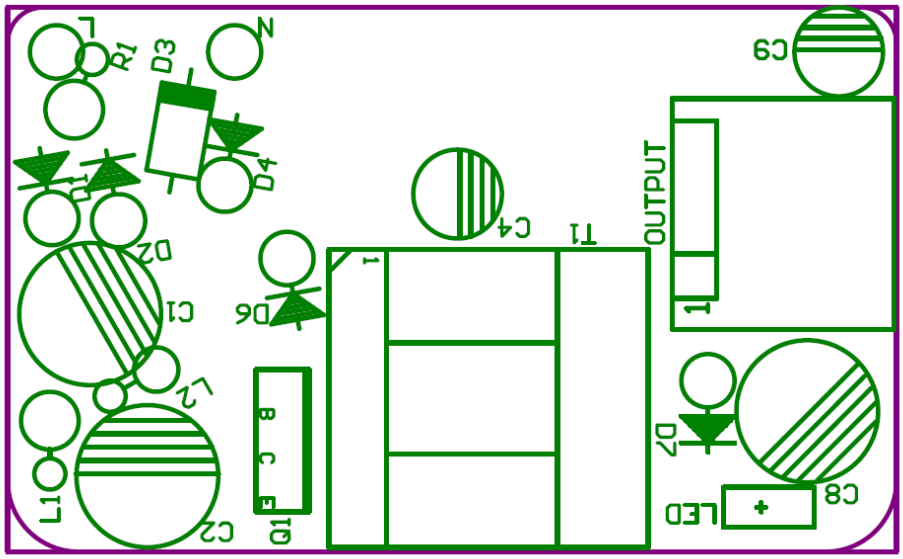
4. PCB Layout

Print circuit board (PCB) layout and design are very important for switching power supply where the voltage and current change with high dv/dt and di/dt. Good PCB layout minimizes excessive EMI and prevents the power supply from being disrupted during surge/ESD tests. The PCB layout guidelines are highlighted as following:

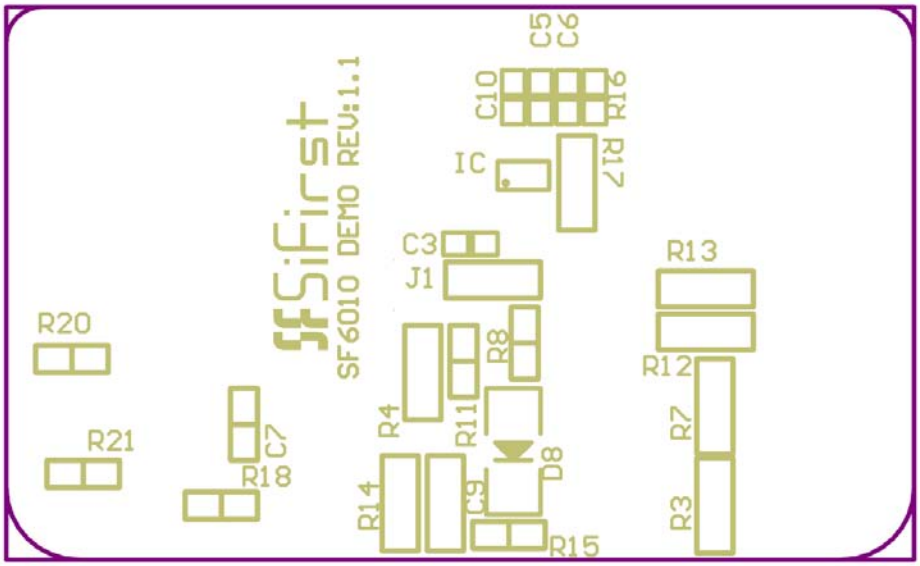
1. The area enclosed by the transformer auxiliary winding, Ddd and Cdd should be kept short path.
2. The ground of the control circuits should be connected first, then to the other circuitry.
3. Regarding the ESD discharge path, put in the shortcut pad between AC line and DC output (which is the best way). The other method is to discharge the ESD energy to AC line through the primary main ground. Because ESD energy is delivered from secondary to primary through the transformer stray capacitor, the controller circuit should not be placed on the discharge path.
4. For the surge path, select fusible resistor type with wire wound type to reduce inrush current and surge energy, using π input filter (two bulk capacitor and one inductance) to share the surge energy.
5. The drain trace length should be minimized to reduce EMI.

6. RCD Clamp and output rectifier diode loop areas should be minimized to reduce EMI

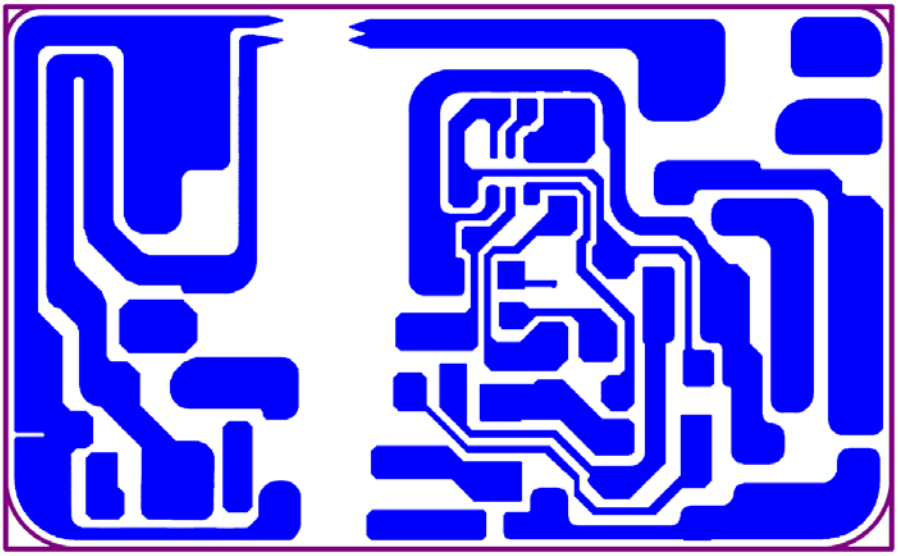
7. The AC input is located away from switching nodes to minimize noise coupling that may bypass input filtering.



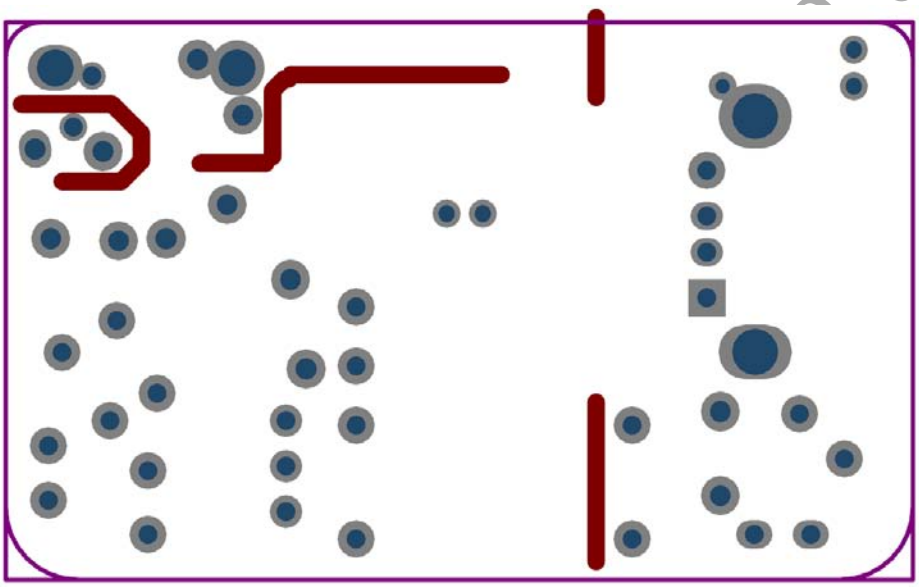
PCB Layout (Top view)



PCB Layout (Assembly Drawing，Bottom view)

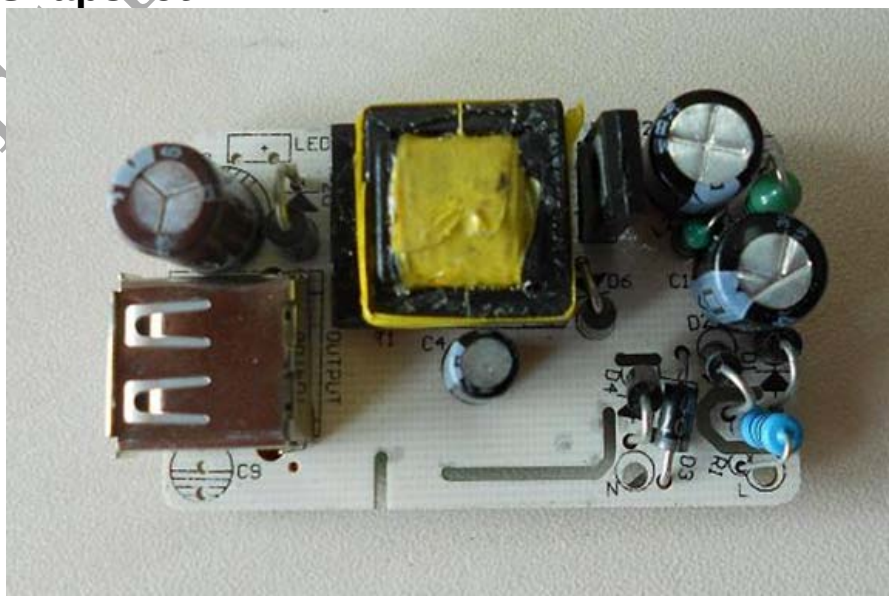


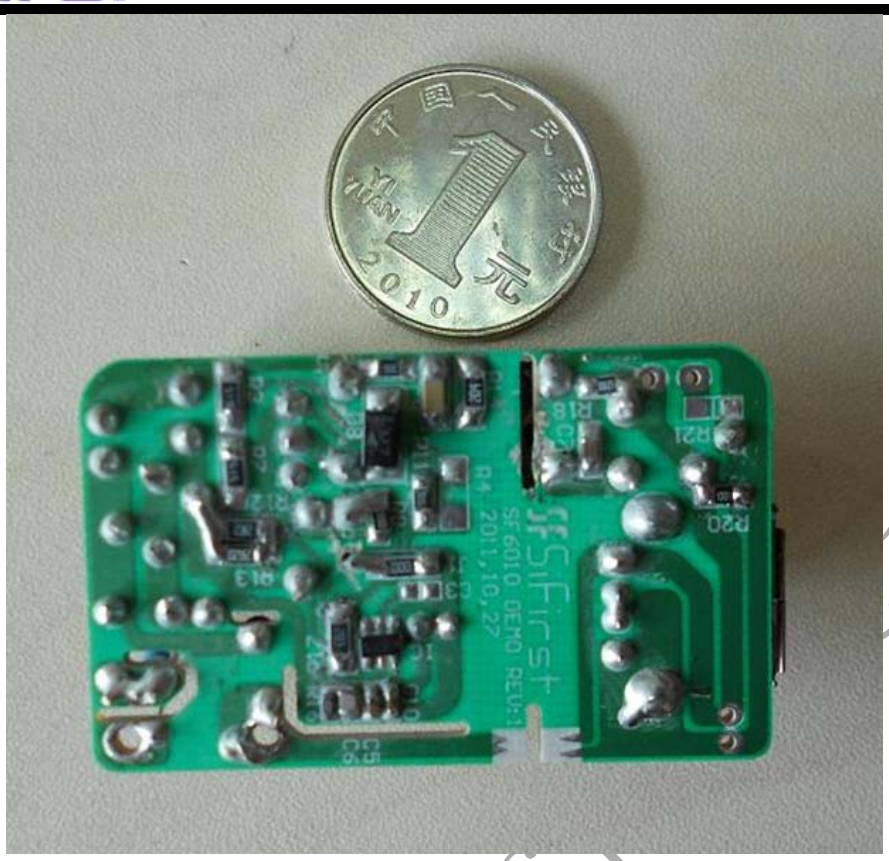
PCB Layout (Bottom Copper，Bottom view)



PCB Layout (multilayer, Top view)

5. Module Snapshot





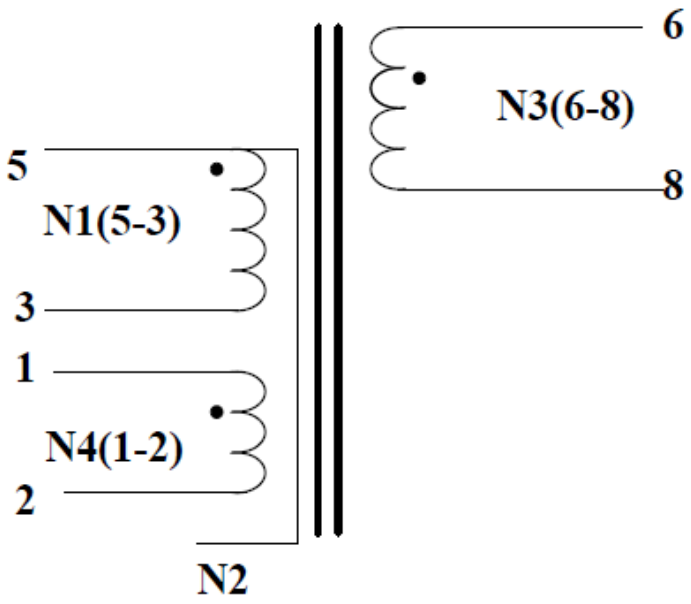
6. Bill of Materials

REFDES	DESCRIPTION	QTY
R16	0603 3.3K±1%	1
R8	0805 0R±5%	1
R18	0805 47R±5%	1
R15	0805 100R±5%	1
R20	0805 510R±5%	1
R11	0805 1K±5%	1
J1	1206 0R±1%	1
R12/R13	1206 2.2R±1%	2
R17	1206 20K±1%	1
R14	1206 200K±5%	1
R3/R4/R7	1206 2M±5%	3
C6	0603 100pF 50V	1
C3	0603 100nF 50V	1
C7	0805 1nF 200V	1
C10	1206 1nF/1KV	1
D8	M7 SMA	1
R1	10R±5% 1/2W	1
C4	4.7uF/50V 5*11	1
C8	680uF/10V 8*12(low ESR)	1
C1/C2	2.2uF/400V 8*12	1
D1/D2/D3/D4/D6	1N4007 DO-41	1
D7	SR160 DO-41	1

Q1	13003 TO-126	1
T1	EE16 SF5922S	1
L1	1mH±10% 1W	1
L2	5.6uH±10% 1/4W	1
U1	SF6010 SOT23-5	1
OUTPUT	USB	1
PCB	SF6010 DEMO	1

7. Transformer Specifications

7.1 Electrical Diagram



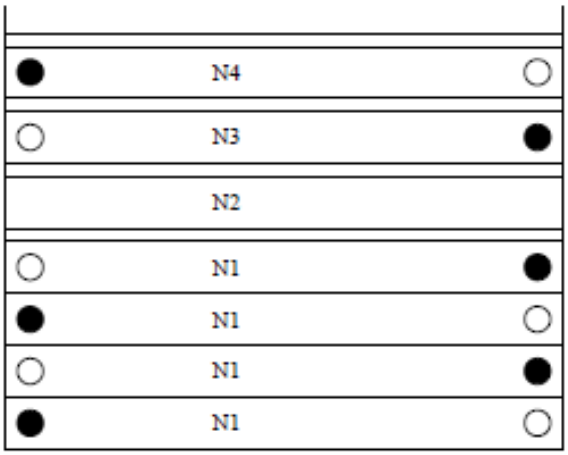
7.2 Electrical Specifications

Primary Inductance	Pin 5-3, all other windings open, measured at 1KHz, 0.4Vrms	2mH, ±5%
Primary Leakage Inductance	Pin 5-3, with Pins 6-8 shorted, measured at 1KHz, 0.4Vrms	100uH(max)
Electrical Strength	60 seconds, 60Hz, from Pin 1-5 to Pin 6-10	3750Vac

7.3 Materials

Item	Description
[1]	Core: EE16, TDK PC40 or equivalent
[2]	Bobbin: EE16, 10 pins (5+5). row spacing is 15.5mm
[3]	Magnet Wire: Φ0.2mm, for the Shield Winding
[4]	Magnet Wire: Φ0.2mm, for the Auxiliary Winding
[5]	Copper foil: 0.05mm thick, 7mm wide， for the Shield winding
[6]	Triple Insulated Wire: Φ0.35mm, for the Secondary Winding
[7]	Tape: 0.05mm thick, 8mm wide

7.4 Transformer Build Diagram



7.5 Transformer Winding Specification

No	Winding	Material	Start	Turns	Finish
1	N1	0.2mm*1 2UEW	5	130	3
2	TAPE	TAPE W=8mm		2	
3	N2	Copper foil: 0.05mm thick, 7mm wide	5	1.1	NC
4	TAPE	TAPE W=8mm		2	
5	N3	0.35mm*1 triple insulated wire	6	12	8
6	TAPE	TAPE W=8mm		2	
7	N4	0.2mm*1 2UEW	1	30	2
8	TAPE	TAPE W=8mm		2	

8. Performance Data

Test Equipments

Item	Vender	Vender
AC Source	Gwinstek	APS9501
Electrical Load	Prodigit	3314F
Digital Power Meter	Voltech	PM1000
Oscilloscope	LeCroy	Wavesufer24Xs
Thermal	Agilent	34970A

8.1 Summary of Testing Results

Description	Test Results			Units	Remark
Input					
No Load Input Power @ 230VAC	69.33			mW	Pass
Output (Measure at the end of Cable)					
Output Voltage	4.75	5.0	5.25	V	<±5%
Output Ripple Voltage	263			mV	Pass
Max. Output Current	1050	1100	1150	mA	Pass
Min. Output Current	0			mA	Pass
Line Regulation	±0.3%			%	Pass
Load Regulation	±1.5%			%	Pass
Continuous Output Power	5			W	Pass
Average Active Mode Efficiency(Measure at the end of Cable)					
@115VAC		70.59%		%	Pass EPS2.0 68.17%
@230VAC		69.94%		%	
Time Sequence					
Turn-on Delay Time@90VAC	2850			ms	Pass
Output Voltage Rise Time	3.535			ms	Pass
Protection Feature					
Short Circuit Protection	OK				
Open Loop Protection	OK				
EMI					
EMI Test	Pass EN55022 Class B and FCC Part15 Class B with 6dB margin				Pass

8.2 Active Mode Efficiency

Input Voltage	Percent of Full Load				Average Efficiency	EPS2.0 Spec
	25%	50%	75%	100%		
90VAC/60Hz	68.79%	69.43%	69.09%	68.48%	68.95%	
115VAC/60Hz	69.88%	70.93%	70.90%	70.64%	70.59%	68.17%
230VAC/50Hz	67.84%	70.17%	70.82%	70.93%	69.94%	
264VAC/50Hz	66.26%	69.07%	69.77%	69.97%	68.77%	
Note: Efficiency was measured at the end of an AWG20 cable with length of 1.5m. (Cable resistance =0.25 Ohm)						

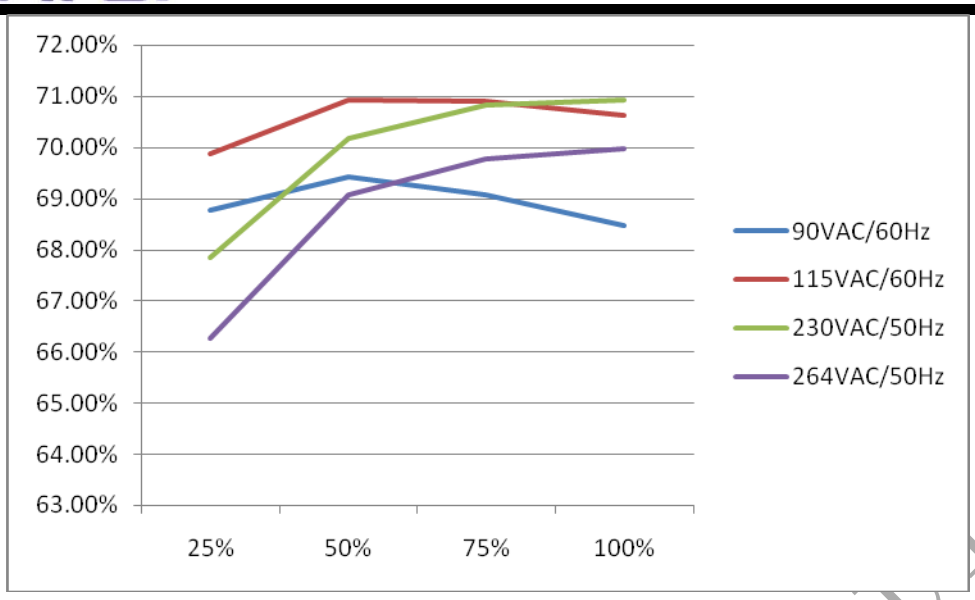


Fig.1 Efficiency vs. Percent of Rated Output Power

8.3 No Load Power

Input Voltage	Pin (mW)	Specification	Test Result
90VAC/60Hz	60.18	<100mW@/264VAC	Pass
115VAC/60Hz	60.65		
230VAC/50Hz	69.33		
264VAC/50Hz	74.60		
Note: Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz.			

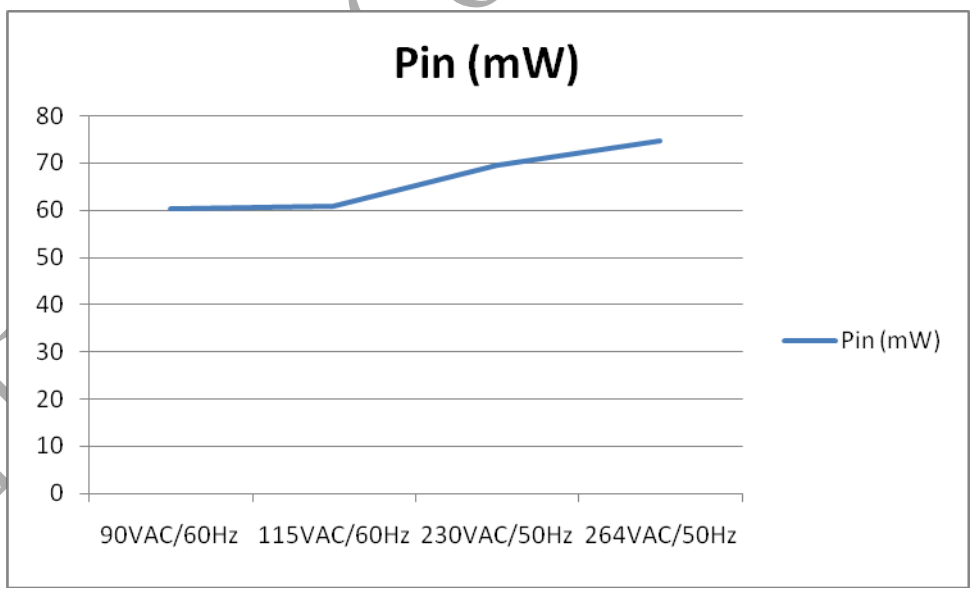


Fig.2 No Load Input Power vs. Line Voltage

8.4 Line and Load Regulation

Input Voltage	Vout (V) vs Load (percent of full load) and Line					Spec
	0%	25%	50%	75%	100%	
90VAC/60Hz	5.13	5.02	5	4.98	4.97	
115VAC/60Hz	5.14	5.04	5.01	4.99	4.98	
230VAC/50Hz	5.14	5.04	5.01	5	4.99	
264VAC/50Hz	5.15	5.04	5.01	4.99	5	
Line Regulation	±0.2%	±0.2%	±0.2%	±0.2%	±0.3%	<±2%
Load Regulation	±1.5%					<±5%
Note: Efficiency was measured at the end of a AWG20 cable with length of 1.5m. (Cable resistance =0.25 Ohm)						

9. Waveforms and Testing Results

9.1 Ripple and Noise

Input Voltage	Ripple & Noise		Waveform
	No Load	Full Load	
90VAC/60Hz	135mV	263mV	Fig.3, Fig.4
264VAC/50Hz	132mV	243mV	Fig.5, Fig.6
Note: Ripple and noise are measured at cable end with a 0.1uF/50V ceramic cap connected in parallel with a 10uF/50V aluminum electrolytic cap. The oscilloscope bandwidth is limited to 20MHz.			

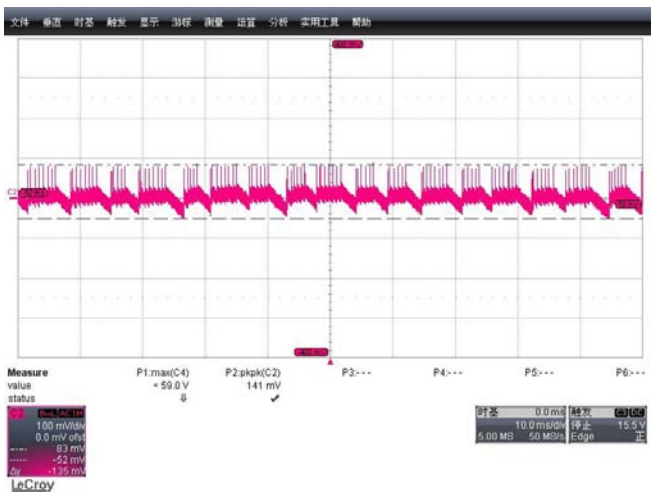


Fig.3 Ripple & Noise @90VAC/60Hz, no load

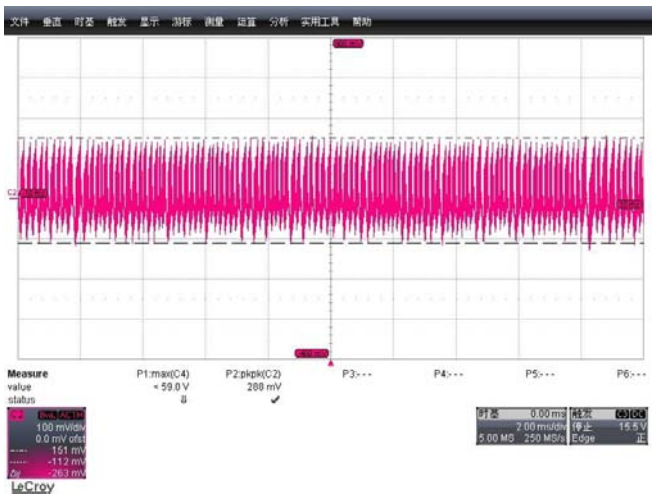


Fig.4 Ripple & Noise @ 90VAC/60Hz, full load

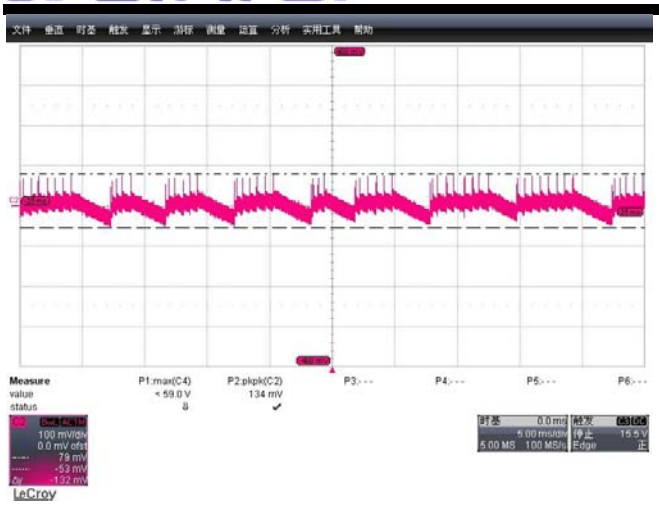


Fig.5 Ripple & Noise @264VAC/50Hz, no load

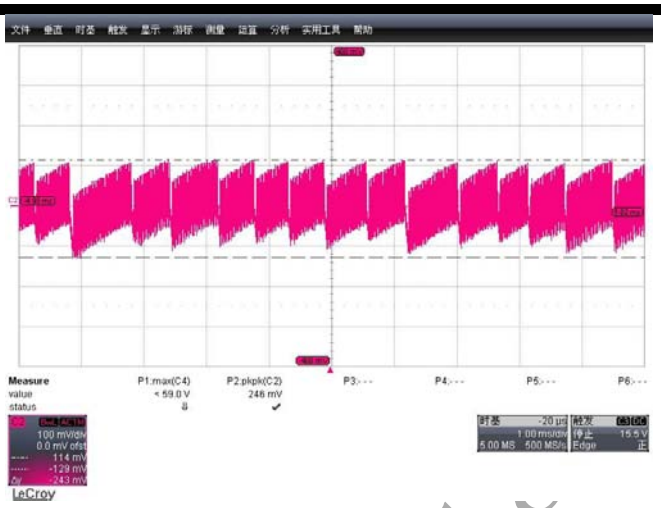


Fig.6 Ripple & Noise @ 264VAC/50Hz, full load

9.2 Dynamic Test

Input Voltage	Output Voltage Ripple	Waveform
90VAC/60Hz	±352mV	Fig.7
264VAC/50Hz	±352mV	Fig.8
Note: A dynamic loading with low load set at 10% full load lasting for 50ms and high load set at 90% full load lasting for 50ms is added to output. The ramp is set at 0.25A/us at transient. Measurements are done at cable end		

Fig.7 Output voltage waveform (90VAC dynamic)

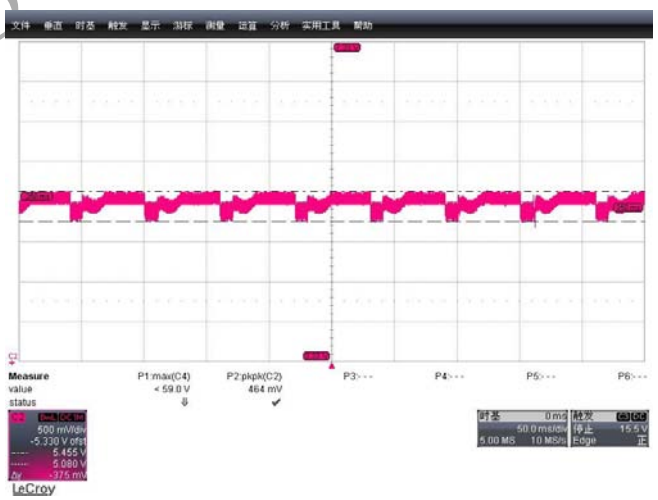


Fig.8 Output voltage waveform (264VAC dynamic)

9.3 Vce, VDD and Vcs Waveform @ Nomal Operation

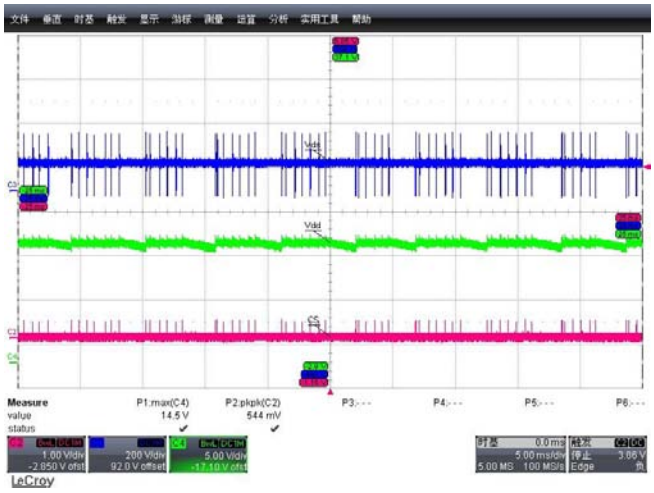


Fig.9 Vce, VDD and Vcs waveform (90VAC, no load)

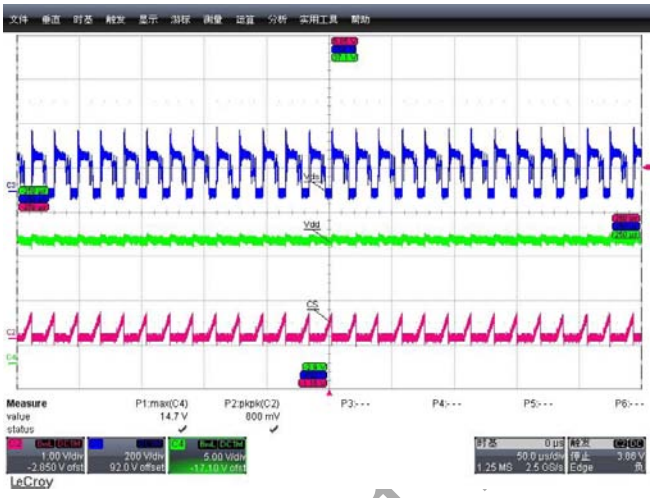


Fig. 10 Vce, VDD and Vcs waveform (90VAC full load)

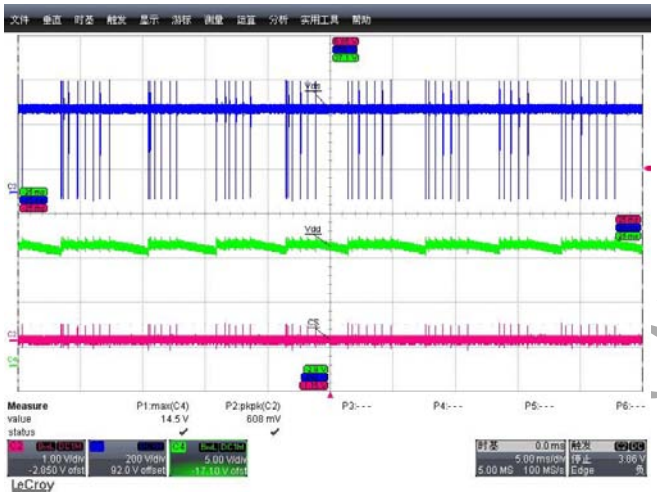


Fig.11 Vce, VDD and Vcs waveform (264VAC, no load)

Fig.12 Vce, VDD and Vcs waveform (264VAC full load)

9.4 Time Sequence (Full Load)

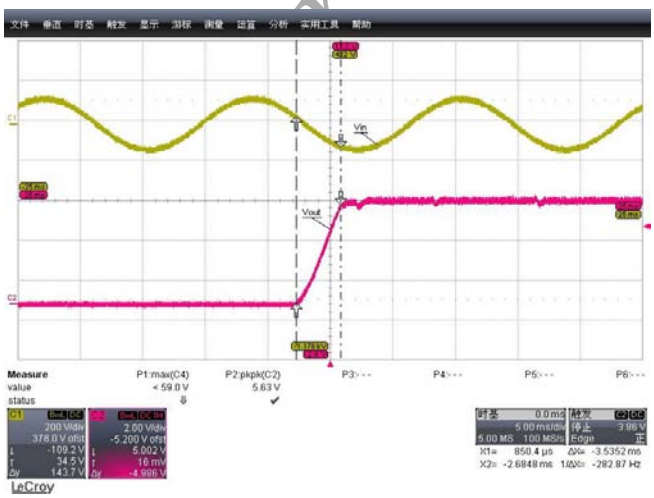


Fig.13 Output rise time 3.535ms (90VAC, full load)

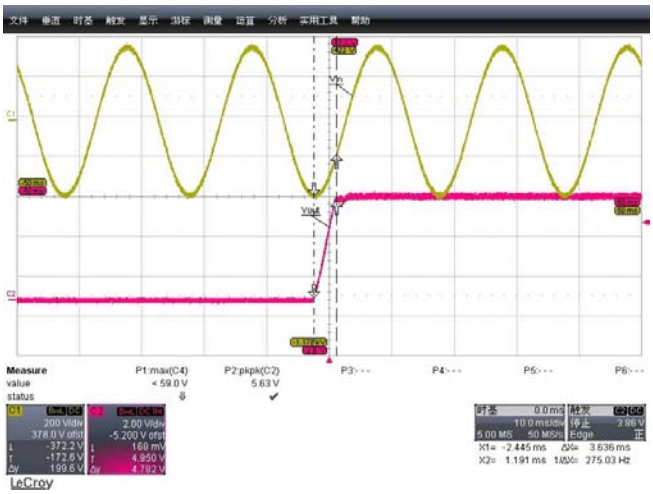


Fig.14 Output rise time3.636ms (264VAC full load)

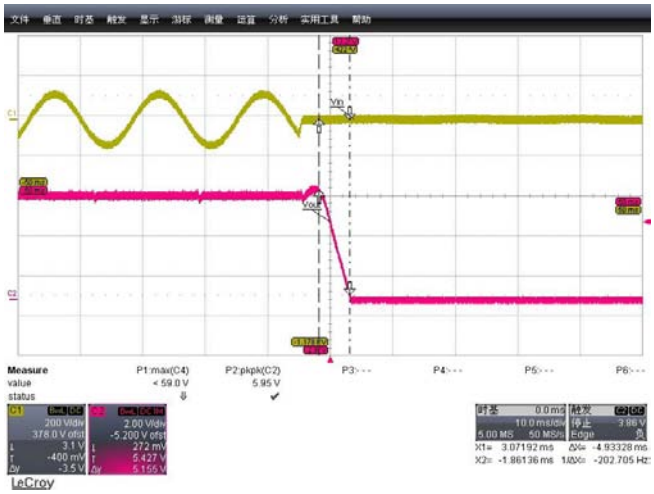


Fig.15 Output fall time 4.933ms (90VAC, full load)

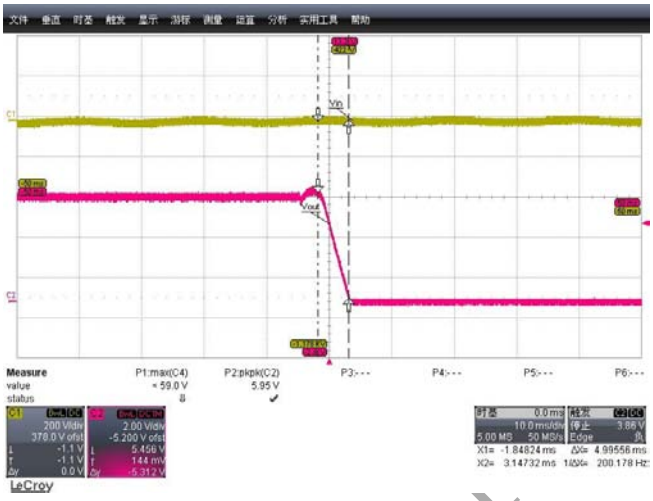


Fig.16 Output fall time 4.996ms (264VAC, full load)

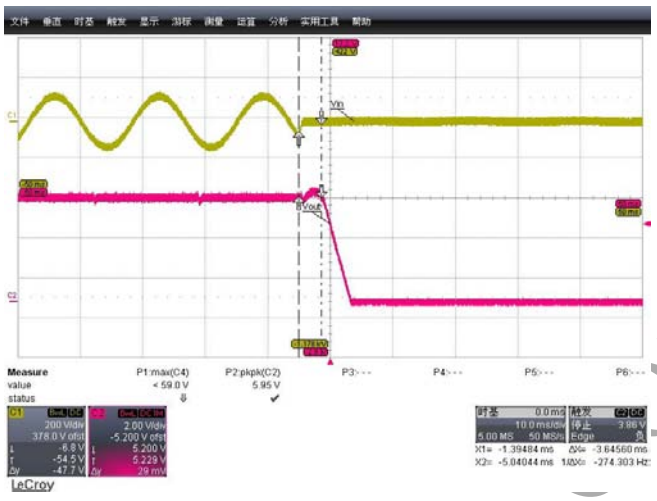


Fig.17 Holdup time 3.646ms (90VAC, full load)

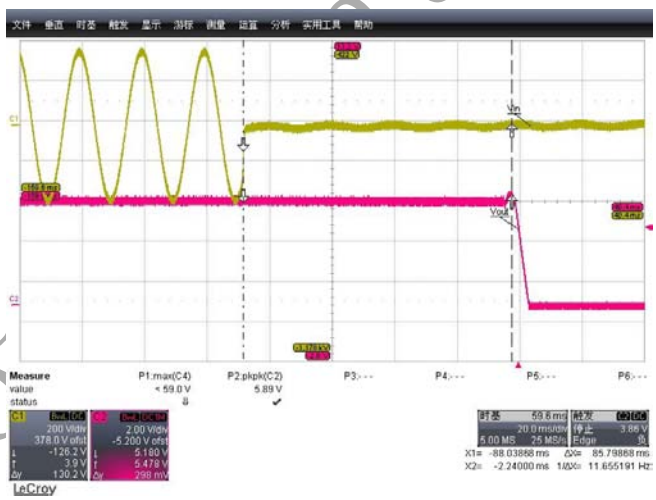


Fig.18 Holdup time 85.80ms (264VAC, full load)

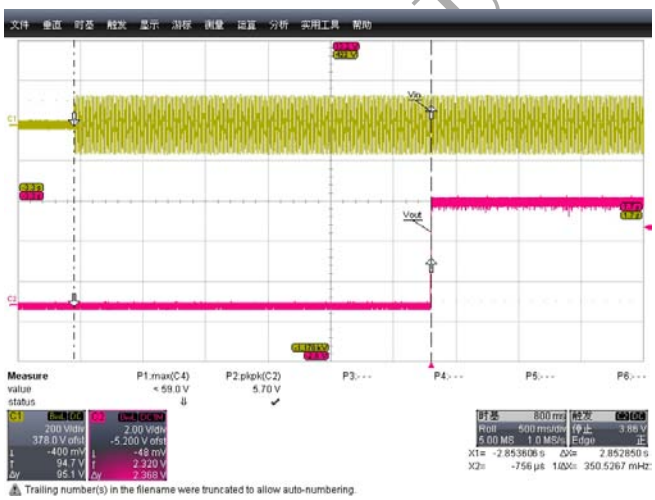


Fig.19 Turn on delay time 2.85s (90VAC, full load)

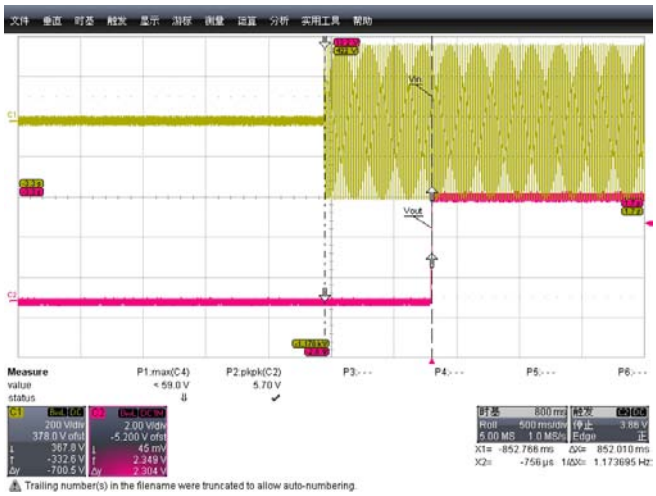


Fig.20 Turn on delay time 0.852s (264VAC, full load)

9.5 Max Vce of Power BJT

Test Condition	Max. Vce (V)	Remark
Output Short @ 264V/50Hz	480V	Fig.23
Normal full load @ 264V/50Hz	536V	Fig.24
Full load Startup @ 264V/50hz	546V	Fig.24

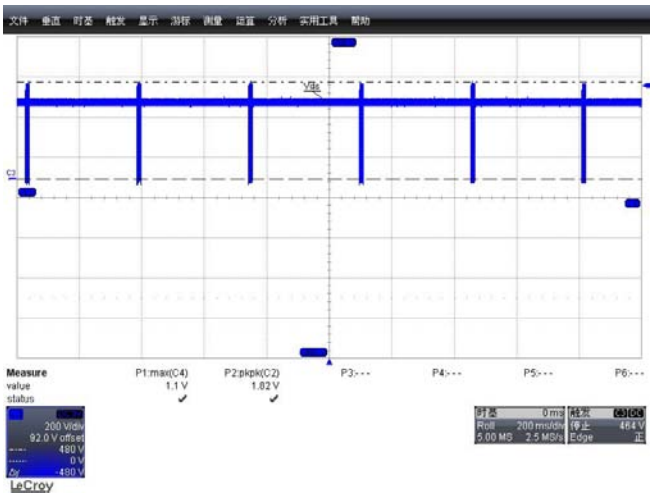


Fig.21 Vce (264VAC, Output Short)

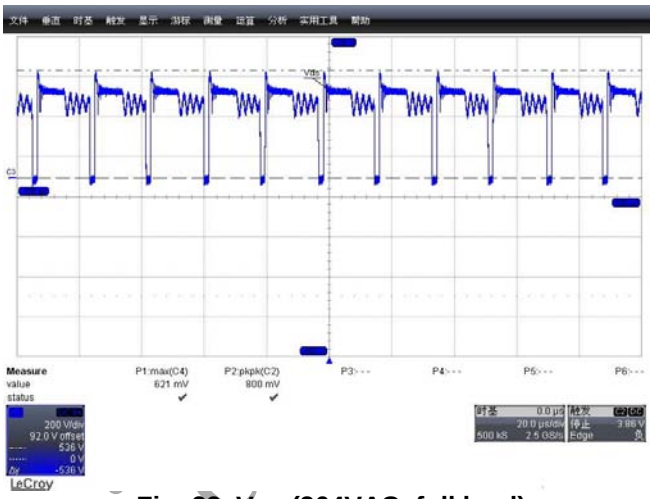


Fig. 22 Vce (264VAC, full load)

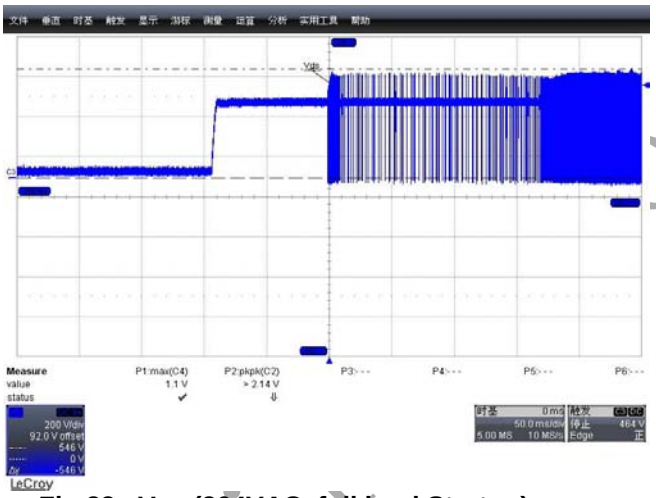


Fig.23 Vce (264VAC, full load Startup)

10. Protections

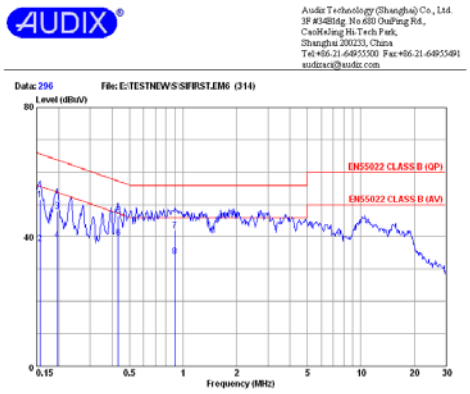
10.1 OCP Protection:

Input	90V60HZ	115V60HZ	230V50HZ	264V50HZ
OCP	1.05A	1.08A	1.07A	1.07A

11. EMI Testing Results

11.1 Conduction EMI Test

EN55022 @ Full Load Report

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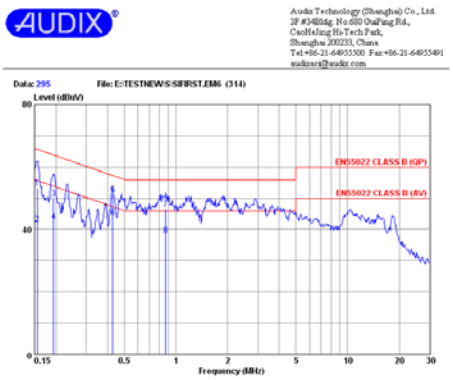
Site                : Audix(Shanghai) Shielded1
Condition           : EN55022 CLASS B (QP) ESH2-Z5-11.03.22 NEUTRAL
Project No.         :
Applicant           :
EUT                 :
M/N                 : SF6010 5V 1A
S/N                 :
Power Supply        : 230V/50Hz
Ambient             : 22'C 48%RH
Test line           : N
Test Mode           : FULL LOAD
Test Engineer       : Lvy
Memo                :
```

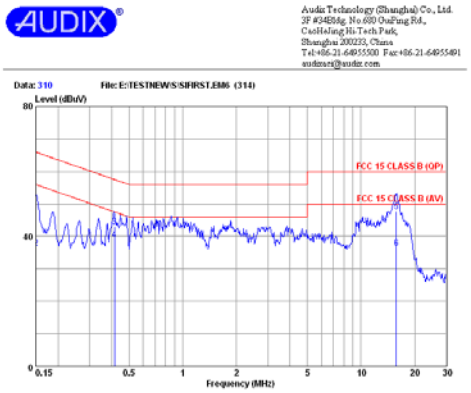
	Freq	Level	Read Level	Cable Loss	LISN Factor	Factor	Limit Line	Over Limit	Remark
	MHz	dBuV	dBuV	dB	dB	dB	dBuV	dB	
1	0.156600	51.45	51.26	0.03	0.16	0.19	65.64	-14.19	QP
2	0.156600	37.79	37.60	0.03	0.16	0.19	55.64	-17.85	Average
3	0.196400	47.82	47.63	0.03	0.16	0.19	63.76	-15.94	QP
4	0.196400	38.89	38.70	0.03	0.16	0.19	53.76	-14.87	Average
5	0.432000	46.59	46.35	0.04	0.20	0.24	57.21	-10.62	QP
6	0.432000	39.74	39.50	0.04	0.20	0.24	47.21	-7.47	Average
7	0.899500	41.96	41.54	0.07	0.35	0.42	56.00	-14.04	QP
8	0.899500	33.92	33.50	0.07	0.35	0.42	46.00	-12.08	Average




```
Site                : Audix(Shanghai) Shielded1
Condition           : EN55022 CLASS B (QP) ESH2-Z5-11.03.22 LINE
Project No.         :
Applicant           :
EUT                 :
M/N                 : SF6010 5V 1A
S/N                 :
Power Supply        : 230V/50Hz
Ambient             : 22'C 48%RH
Test line           : L
Test Mode           : FULL LOAD
Test Engineer       : Lvy
Memo                :
```

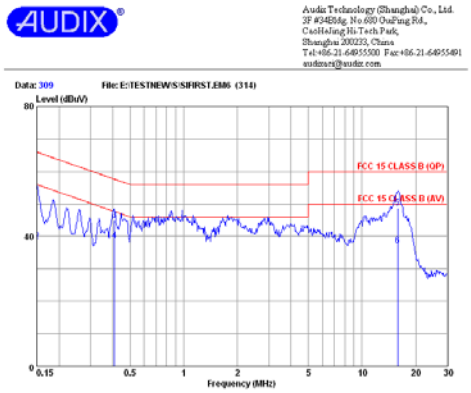
	Freq	Level	Read Level	Cable Loss	LISN Factor	Factor	Limit Line	Over Limit	Remark
	MHz	dBuV	dBuV	dB	dB	dB	dBuV	dB	
1	0.155600	53.32	53.10	0.03	0.19	0.22	65.70	-12.38	QP
2	0.155600	41.72	41.50	0.03	0.19	0.22	55.70	-13.98	Average
3	0.193500	49.81	49.58	0.03	0.20	0.23	63.88	-14.07	QP
4	0.193500	42.53	42.30	0.03	0.20	0.23	53.88	-11.35	Average
5	0.428400	51.28	50.97	0.04	0.27	0.31	57.28	-6.00	QP
6	0.428400	44.00	43.69	0.04	0.27	0.31	47.28	-3.28	Average
7	0.872400	46.49	46.11	0.07	0.31	0.38	56.00	-9.51	QP
8	0.872400	38.08	37.70	0.07	0.31	0.38	46.00	-7.92	Average

FCC Class B @ Full Load Report




```
Site                : Audix(Shanghai) Shielded1
Condition           : FCC 15 CLASS B (QP) ESH2-Z5-11.03.22 NEUTRAL
Project No.         :
Applicant           :
EUT                 :
M/N                 : SF6010 5V 1A
S/N                 :
Power Supply        : 120V/60Hz
Ambient             : 22'C 48%RH
Test line           : N
Test Mode           : FULL LOAD
Test Engineer       : Lvy
Memo                :
```

	Freq	Level	Read Level	Cable Loss	LISN Factor	Factor	Limit Line	Over Limit	Remark
	MHz	dBuV	dBuV	dB	dB	dB	dBuV	dB	
1	0.150010	47.88	47.70	0.03	0.15	0.18	66.00	-18.12	QP
2	0.150010	36.42	36.24	0.03	0.15	0.18	56.00	-19.58	Average
3	0.414200	43.08	42.84	0.04	0.20	0.24	57.56	-14.48	QP
4	0.414200	38.93	38.69	0.04	0.20	0.24	47.56	-8.63	Average
5	15.750000	47.69	46.53	0.35	0.81	1.16	60.00	-12.31	QP
6	15.750000	36.36	35.20	0.35	0.81	1.16	50.00	-13.64	Average

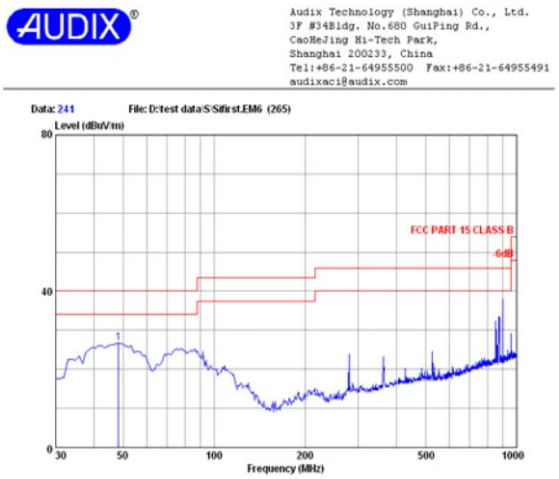



```
Site                : Audix(Shanghai) Shielded1
Condition           : FCC 15 CLASS B (QP) ESH2-Z5-11.03.22 LINE
Project No.         :
Applicant           :
EUT                 :
M/N                 : SF6010 5V 1A
S/N                 :
Power Supply        : 120V/60Hz
Ambient             : 22'C 48%RH
Test line           : L
Test Mode           : FULL LOAD
Test Engineer       : Lvy
Memo                :
```

	Freq	Level	Read Level	Cable Loss	LISN Factor	Factor	Limit Line	Over Limit	Remark
	MHz	dBuV	dBuV	dB	dB	dB	dBuV	dB	
1	0.150010	50.34	50.12	0.03	0.19	0.22	66.00	-15.66	QP
2	0.150010	38.52	38.30	0.03	0.19	0.22	56.00	-17.48	Average
3	0.407800	45.05	44.76	0.03	0.26	0.29	57.69	-12.64	QP
4	0.407800	38.70	38.41	0.03	0.26	0.29	47.69	-8.99	Average
5	15.820000	48.78	47.91	0.35	0.52	0.87	60.00	-11.22	QP
6	15.820000	37.27	36.40	0.35	0.52	0.87	50.00	-12.73	Average

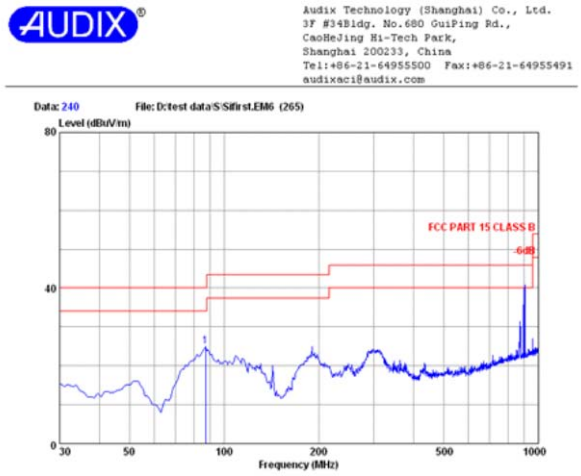
11.2 Radiation EMI Test

EN55022 @ Full Load Report



Site : Audix(Shanghai) Chamber3
Condition : FCC PART 15 CLASS B VERTICAL
Project No. :
Applicant :
EUT :
M/N : SF6010
S/N : 5V 1A
Power Supply : 120V/60Hz
Ambient : 22°C 60%RH
Test Mode :
Test Engineer: Raven
Memo :

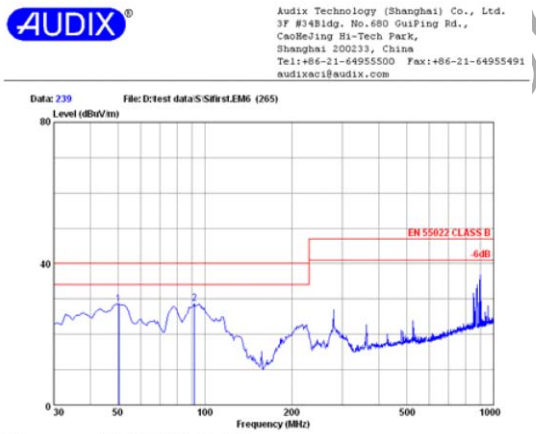
	Freq	Level	ReadAntenna Level	Antenna Factor	Cable Loss	Limit Line	Over Limit	Remark
	MHz	dBuV/m	dBuV	dB/m	dB	dBuV/m	dB	
1	48.43	26.77	16.85	9.02	0.90	40.00	-13.23	Peak



Site : Audix(Shanghai) Chamber3
Condition : FCC PART 15 CLASS B HORIZONTAL
Project No. :
Applicant :
EUT :
M/N : SF6010
S/N : 5V 1A
Power Supply : 120V/60Hz
Ambient : 22°C 60%RH
Test Mode :
Test Engineer: Raven
Memo :

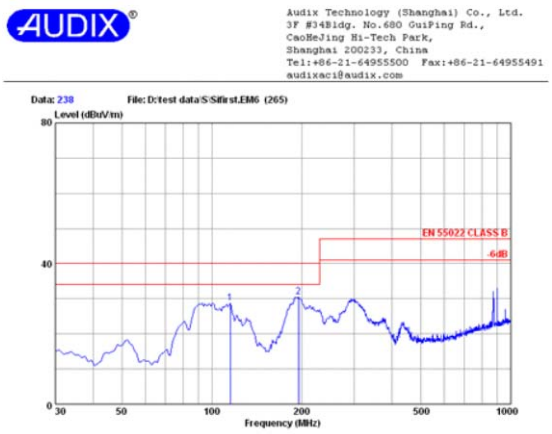
	Freq	Level	ReadAntenna Level	Antenna Factor	Cable Loss	Limit Line	Over Limit	Remark
	MHz	dBuV/m	dBuV	dB/m	dB	dBuV/m	dB	
1	87.23	24.95	12.37	10.88	1.70	40.00	-15.05	Peak

FCC Class B @ Full Load Report



Site : Audix(Shanghai) Chamber3
Condition : EN 55022 CLASS B VERTICAL
Project No. :
Applicant :
EUT :
M/N : SF6010
S/N : 5V 1A
Power Supply : 230V/50Hz
Ambient : 22°C 60%RH
Test Mode :
Test Engineer: Raven
Memo :

	Freq	Level	ReadAntenna Level	Antenna Factor	Cable Loss	Limit Line	Over Limit	Remark
	MHz	dBuV/m	dBuV	dB/m	dB	dBuV/m	dB	
1	50.37	28.59	19.15	8.51	0.93	40.00	-11.41	Peak
2	92.08	28.64	15.81	11.08	1.75	40.00	-11.36	Peak



Site : Audix(Shanghai) Chamber3
Condition : EN 55022 CLASS B HORIZONTAL
Project No. :
Applicant :
EUT :
M/N : SF6010
S/N : 5V 1A
Power Supply : 230V/50Hz
Ambient : 22°C 60%RH
Test Mode :
Test Engineer: Raven
Memo :

	Freq	Level	ReadAntenna Level	Antenna Factor	Cable Loss	Limit Line	Over Limit	Remark
	MHz	dBuV/m	dBuV	dB/m	dB	dBuV/m	dB	
1	115.36	28.70	15.63	11.09	1.98	40.00	-11.30	Peak
2	194.90	30.47	18.22	9.84	2.41	40.00	-9.53	Peak