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Chapter 1. Summary

1.1 General Description

The AP3984 stands out as an extremely low standby-power (<10mW) Primary Side Regulation (PSR) switcher for power supplies based on optimal cost-effectiveness, efficiency, Constant Voltage (CV) & Constant Current (CC) accuracy, and versatile protection functions.

The AP3984, with built-in Bipolar Junction Transistor (BJT), regulates the output voltage and current in the primary side by piece-wise Pulse Frequency Modulation (p-PFM) and primary current peak Amplitude Modulation (AM) in discontinuous conduction mode (DCM). The system operating frequency reduces linearly from heavy load to light load in each interval of the p-PFM, and operating frequency is fixed at medium load by varying primary current peak amplitude.

The AP3984 has good transient characteristics in combination with the secondary side IC like AP4341/AP43410 (PSR Accelerator). Typically, minimal voltage of 4.3V at PCB side can be achieved for dynamic test of 5V application system.

The AP3984 provides operating frequency dithering function to improve EMC performance of power supply. The AP3984 also has programmable cable voltage drop compensation function by external resistor.

1.2 Key Features

- Primary Side Control for Eliminating Opto-coupler
- Built-in 700V BJT
- Excellent Transient Characteristics
- High Voltage and Super-speed Start up
- External Adjustable Output Cable Voltage Drop Compensation
- Ultra-low No-load Power Consumption(<10mW)
- Multiple PWM/PFM Mode to Improve Audio Noise and Efficiency
- Valley-on for Higher Efficiency and Better EMI
- Multiple Protections:
- Over Voltage Protection (OVP)
- Output Short Circuit Protection (SCP)
- Over Temperature Protection (OTP)
- Totally Lead-free & Fully RoHS Compliant (SO-7)
- Halogen and Antimony Free. “Green” Device

1.3 Applications

- Chargers
- Auxiliary Supplies
- Set Top Boxes
- Appliances

1.4 Main Power Specifications (CV & CC Mode)

Parameter	Value
Input Voltage	90 to 264V_{AC}
Input standby power	10mW
Main output Vo / Io	5V / 1A
Efficiency	~ 76%
Total Output Power	5W
Protections	OCP, OVP, OLP,OTP
XYZ Dimension	41x 31 x15 mm
ROHS Compliance	Yes

1.5 Evaluation Board Picture:

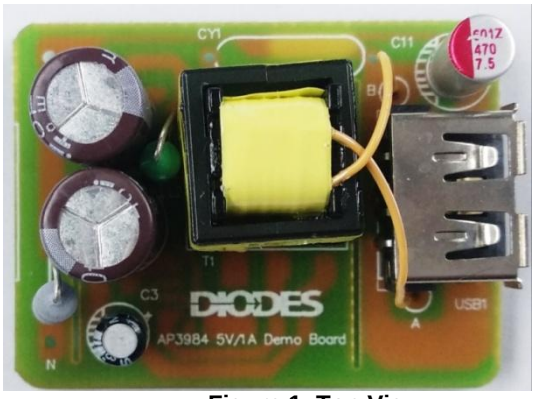


Figure 1: Top View

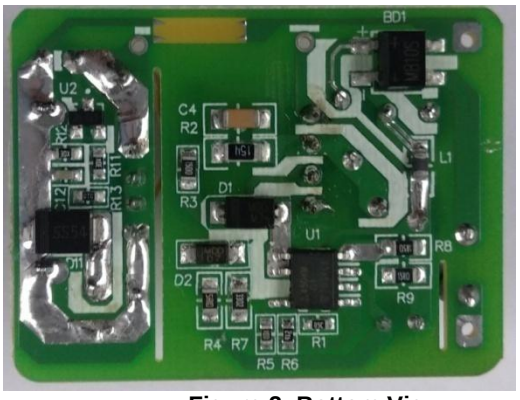


Figure 2: Bottom View

Chapter 2. Power Supply Specification

2.1 Specification and Test Results

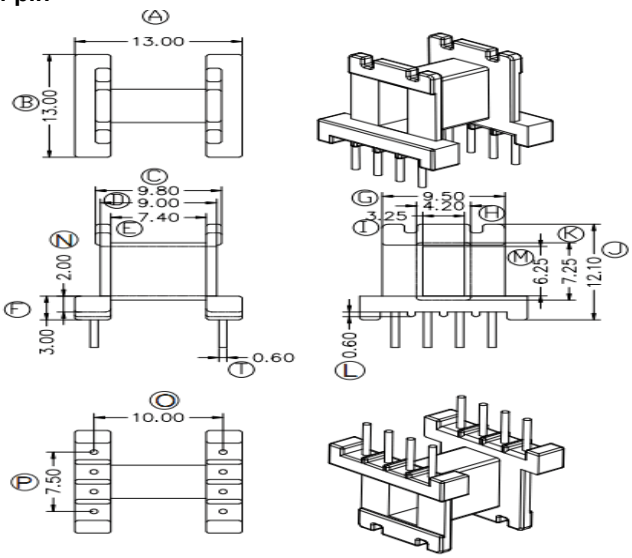
Parameter	Test conditions	Min	Nom	Max	Eff /DOE Level VI	Eff /CoC V5 Tier2	Test Summary
V_{ACIN} Input Voltage	-	90 V_{RMS}	115/230	264 V_{RMS}	-	-	-
F_{LINE} Frequency	-	47Hz	50/60	64Hz	-	-	-
I_{IN} Input Current	-	-	-	$0.13A_{RMS}$	-	-	Pass
No load Pin	At 230Vac/50Hz, @ 5V, Pin < 10mW	-	-	10mW	-	-	Pass, 230Vac: 6.3mW
5VDC / 1A @115Vac/230Vac Average efficiency	Board end	-	5V/1A	-	73.62%		Pass, 115Vac: 76.5% 230Vac: 76.8%
Thermal Performance	5V-1A @ 90Vac	@AP3984 IC =86.4C @85Vac		@AP3984 IC=88.0C @264Vac			Pass
EMI Scan Data	5V-1A @115Vac		Under Limit line < -6db				Pass
	5V-1A 230Vac		Under Limit line < -6db				Pass

- **DoE VI Eff ≥ 0.0834xLn(Po)-0.0014xPo+0.609 <Vo<6V**
- **DoE VI Eff ≥ 0.071xLn(Po)-0.0014xPo+0.67 Vo>6V**

2.1 Transformer Specification

AP3984 (90V_{AC} ~ 265V_{AC} one outputs 5W Transformer Spec.)

1) C o r e & Bobbin: EE13, 4+4 pin



2) Transformer Parameters

1. Primary Inductance (Pin4-Pin2), all other windings are open Lp = 1.75mH ±7% @1KHz

EE13 （Ae = 17.1mm^2）						
NO Winding	NAME	TERMINAL NO.		WINDING		
		START	FINISH	WIRE	TURNS	Layers
1	Np	4	2	Φ 0.14mmx1	132Ts	1
2	Nfb	3	1	Φ 0.15mm x 1	23Ts	3
3	Shield	1	Nc	Φ 0.15mm x 2	7.5T	1
4	Ns	B	A	Φ 0.5mm x 1	10Ts	1
		1-core				

Primary Inductance	Pin 4-2,all other windings open, measured at 1kHz, 0.4VRMS	1.75mH ± 7 %
Primary Leakage Inductance	Pin 4-2, all other windings shorted, measured at 10kHz, 0.4VRMS	80 uH (Max.)

Chapter 3. Schematic

3.1 Evaluation Board Schematic

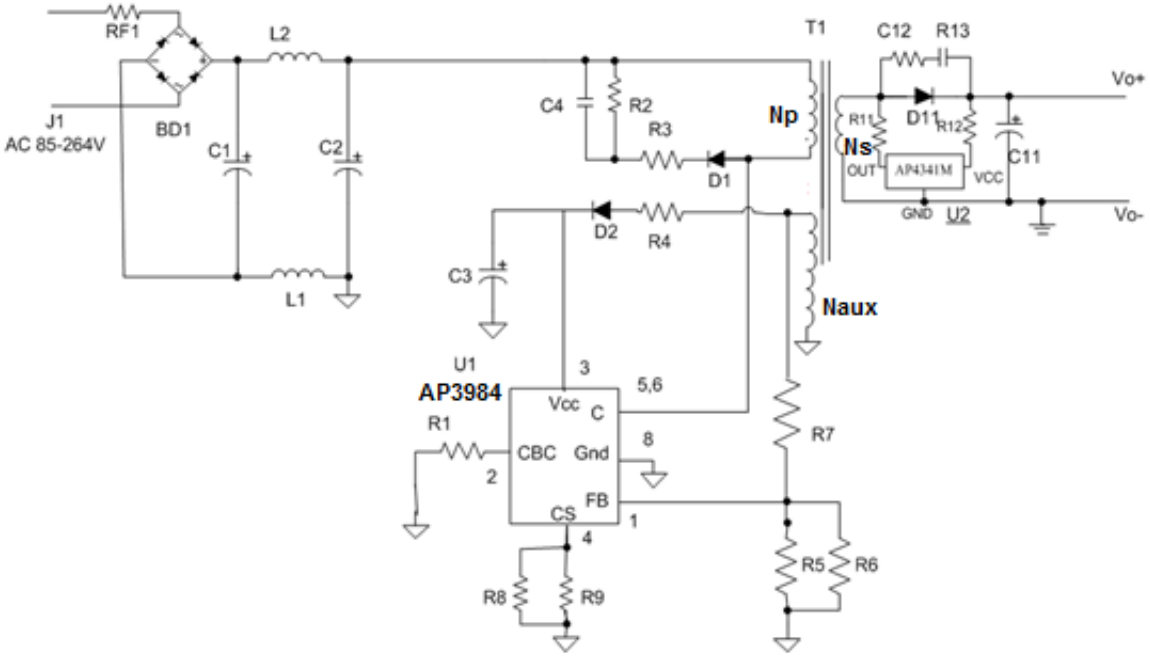


Figure 3: Evaluation Board Schematic

3.2 Bill of Material (BOM)

Item	QTY per board	REF. DES.	Description	MFG or Supplier	MFG P/N or Supplier P/N Digi key #
1	2	C1,C2	6.8uF/400V, electrolytic	AISHI	
2	1	C3	3.3uF/50V, electrolytic	AISHI	
3	1	C4	1nF/1kV, 1206	MURATA	
4	1	C12	1nF/50V, 0603	MURATA	
5	1	C11	470uF/7.5V, solid state cap	AISHI	
6	1	BD1	MB10S,1000V/0.8A,MBS	Diodes	
7	1	D1	S1M-13-F, rectifier diode, SMA	Diodes	
8	1	D2	S1MWF, rectifier diode,SOD123-FL	Diodes	
9	1	L1	4.7uH , inductor ,1206	TDK	
10	1	L2	330uH, color ring inductor		
11	1	U1	AP3984MTR-G1, SOIC-7	Diodes	
12	1	U2	AP4341SNTR-G1, SOT-23	Diodes	
13	1	FR1	10ohm, 1W		
14	1	D11	Schottky,SS54,5A/40V,SMB	Diodes	
15	1	R1	75kohm, 0603 5%	Yageo	
16	1	R2	150kohm, 1206 5%	Yageo	
17	1	R3	150ohm , 0805 5%	Yageo	
18	1	R4	5.1ohm, 0805,1%	Yageo	
19	1	R5	150kohm, 06031%	Yageo	
20	1	R6	9.1kohm, 0603 1%	Yageo	
21	1	R7	33kohm, 0805 1%	Yageo	
22	1	R8	1.5ohm, 0805 1%	Yageo	
23	1	R9	15ohm, 0805 1%	Yageo	
24	1	R11	20ohm, 0603 5%	Yageo	
25	1	R12	20ohm, 0603 5%	Yageo	
26	1	R13	51ohm, 0603 5%	Yageo	
27	1	T1	EE13 core, PC40, transformer		
28	1	USB	Horizontal connector		

Chapter 4. The Evaluation Board (EVB) Connections

4.1 Evaluation Board PCB Layout

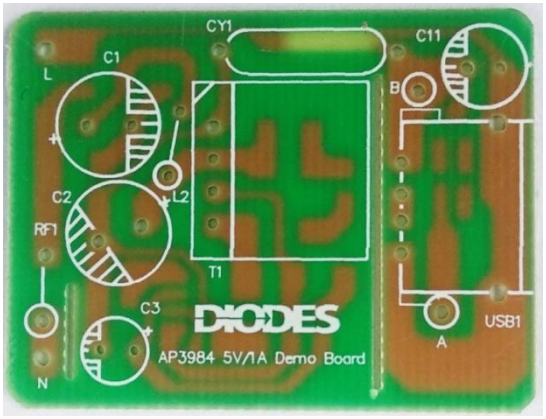


Figure 4: PCB Board Layout Top View

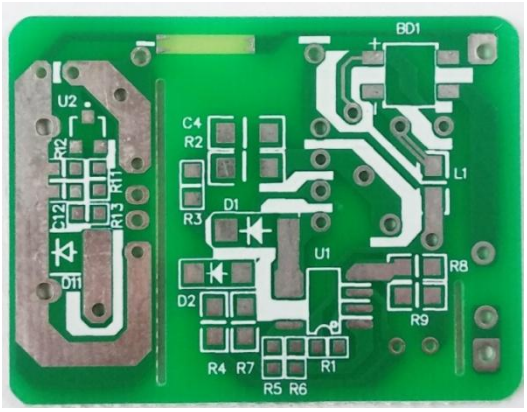


Figure 5: PCB Board Layout Bottom View

4.2 Quick Start Guide Before Connection

1. The evaluation board is preset at 5V/1A from output + & -
2. Ensure that the AC source is switched OFF or disconnected before doing connection.
3. Connect the AC line wires of power supply to “L and N” on the left side of the board.
4. Turn on the AC main switch.
5. Measure Red & Black wires to ensure correct output voltages at 5V respectively.

Chapter 5. Testing the Evaluation Board

5.1 Input & Output Characteristics

5.1.1 Input Standby Power

Input Voltage	115Vac/60Hz	230Vac/50Hz	Note
Pin (w)	3.5mW	6.3mW	At no loading

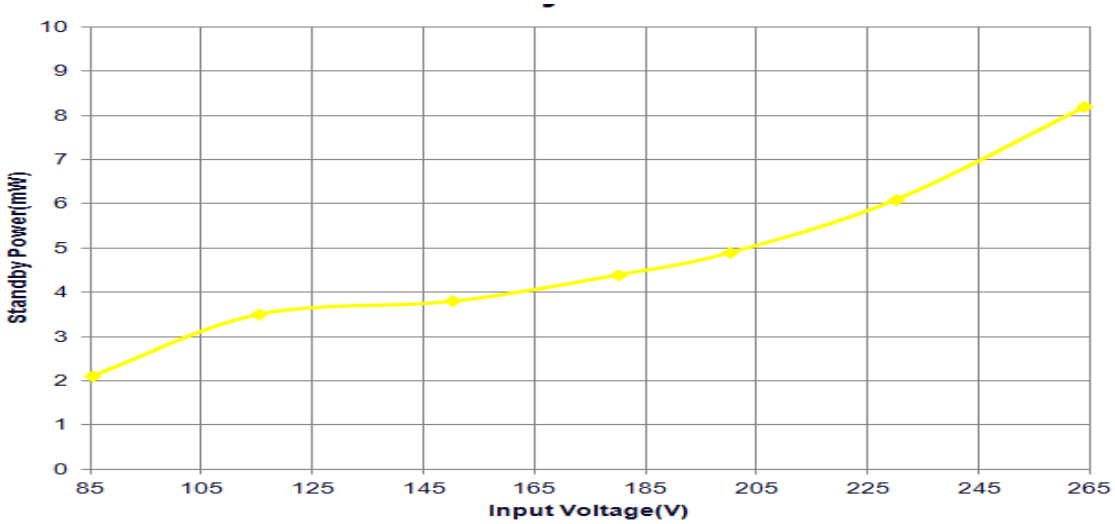


Figure 6: The Efficiency curve with at different AC input

5.1.2 Input Power Efficiency at Different Loading

AC input	Efficiency (%)					Avg. Efficiency
	10%	25%	50%	75%	100%	
90VAC/60Hz					75.13	
115VAC/60Hz	72.63%	76.79%	76.6%	76.47 %	76.30%	76.54%
230VAC/50Hz	68.21%	75.3%	76.94%	77.35%	77.5%	76.77%
264VAC/50Hz					77.59%	
Avg. Efficiency						

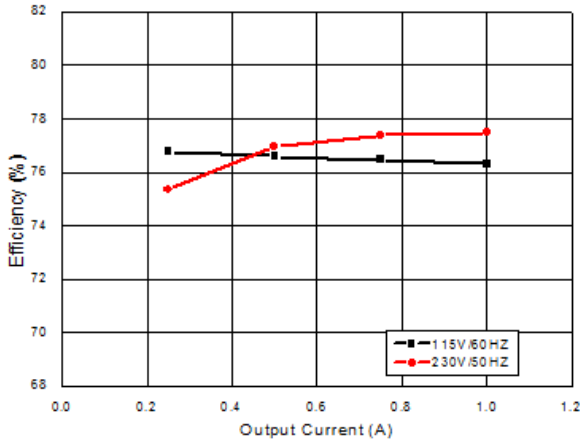


Figure 7: The efficiency curve with different loading

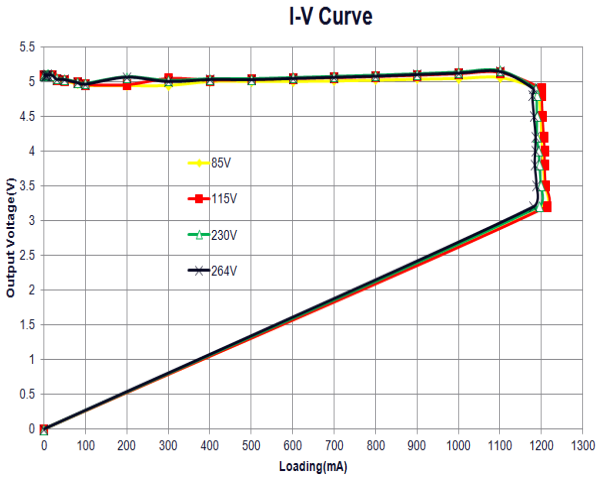


Figure 8: CV & CC Curve at OCP set points

5.1.3 OCP Current set point with at different AC line

AC input	90VAC	115VAC	230VAC	264VAC	Note
I _max	1.202A	1.208A	1.194A	1.185A	

5.1.4 PSU Output Characteristics:

Line Regulation (at full loading condition):

AC input Voltage	90VAC/60Hz	115VAC/60Hz	230VAC/50Hz	265VAC/50Hz	Note
5.00Vo	5.094V/1.0A	5.103V/1.0A	5.117V/1.0A	5.124V/1.0A	0.6%<1%

Cross Load Regulation (at nominal line AC input voltage):

AC input Voltage	115VAC/60Hz	230VAC/50Hz
5V Full Load	5.103V / 1.0A	5.117V/1.0A
5V 10% of FL	4.957V /0.10A	4.965V/0.10A
Note	2.9%	3.04%

Note: All output voltages are measured at output PCB END.

5.2 Key Performance Waveforms:

5.2.1 System start - up time

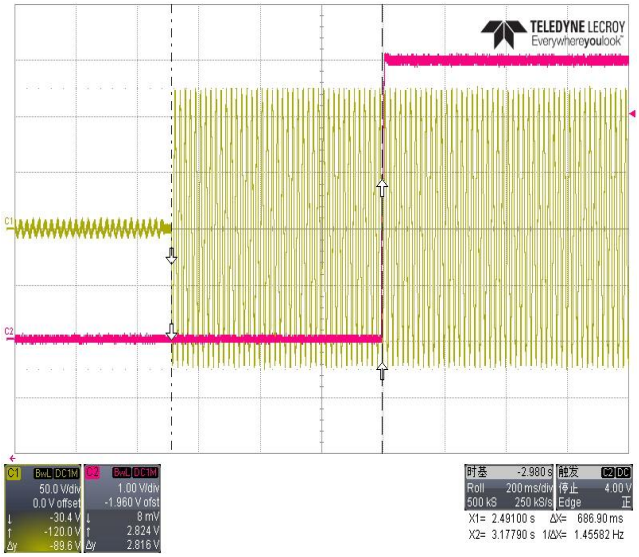


Figure 9: AP3984 Start up time is 0.68S at 90Vac

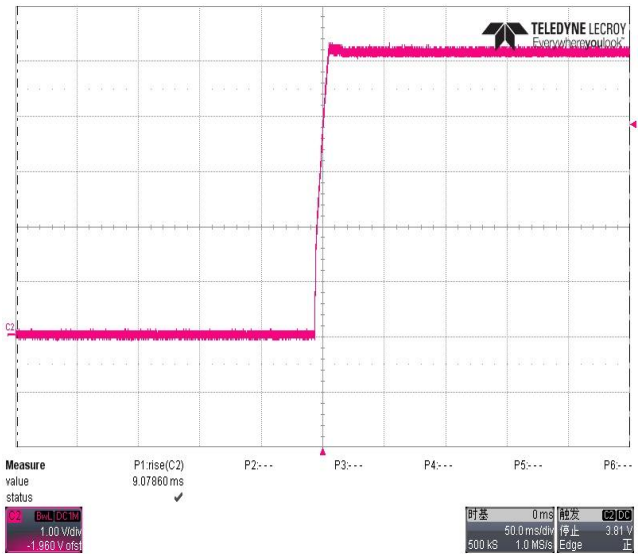


Figure 10: AP3984 Rising time 9.08mS, at 90Vac

5.2.2 System performance-Voltage Stress

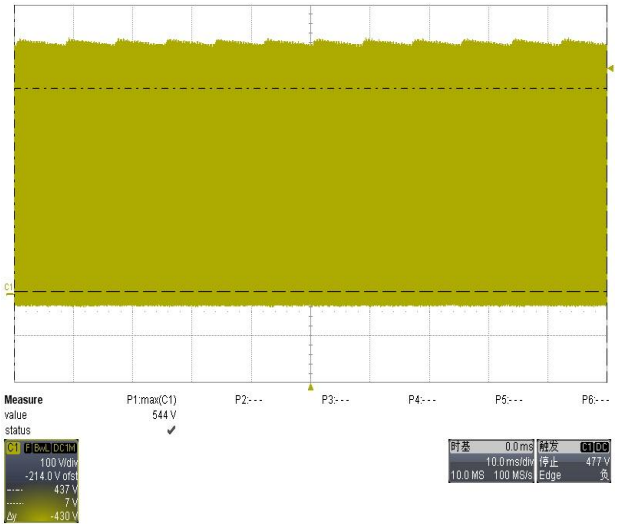


**Figure 11: BJT Q1: Vce=544V;
264VAC/50Hz, load level: 1A**

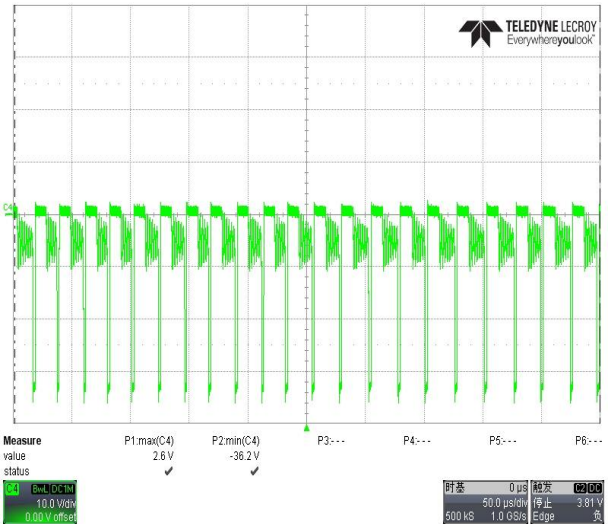


**Figure 12: Output schottky: Vak=36.2V;
264VAC/50Hz, load level: 1A**

5.2.3 Short-circuit protection of full load

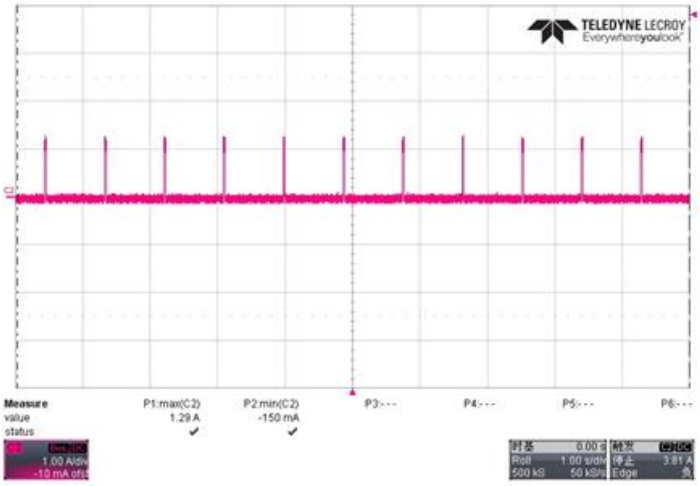


Figure 13:

90VAC/60Hz，1.29A

Pin=8.9mW

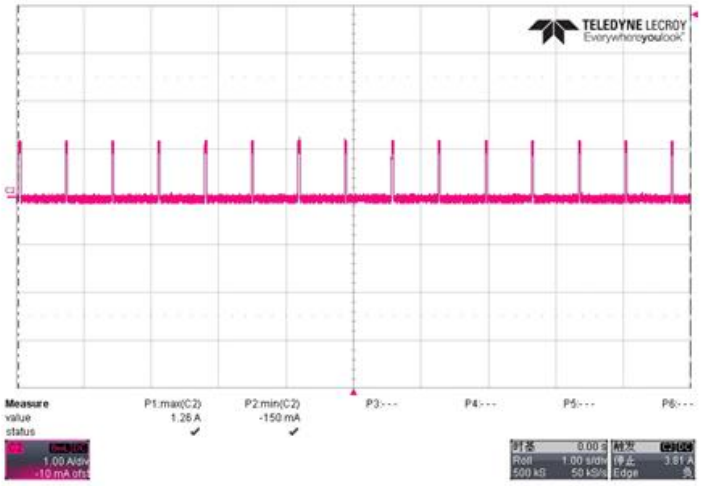


Figure 14:

264VAC/50Hz，1.26A

Pin=130mW

5.2.4System output Ripple performance

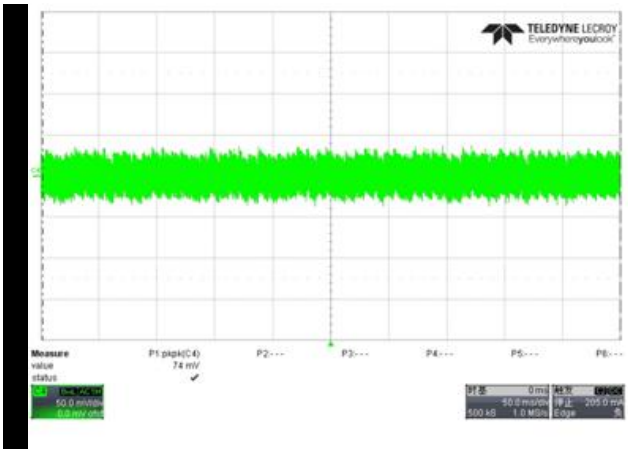


Figure 15: The Ripple at 90Vac_in Vpp=74mv FL

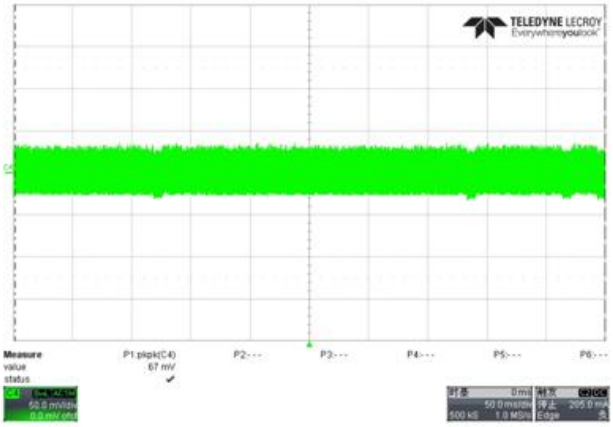


Figure 16: The Ripple at 230Vac_in Vpp=67mv FL

5.2.5 System Dynamic Response performance

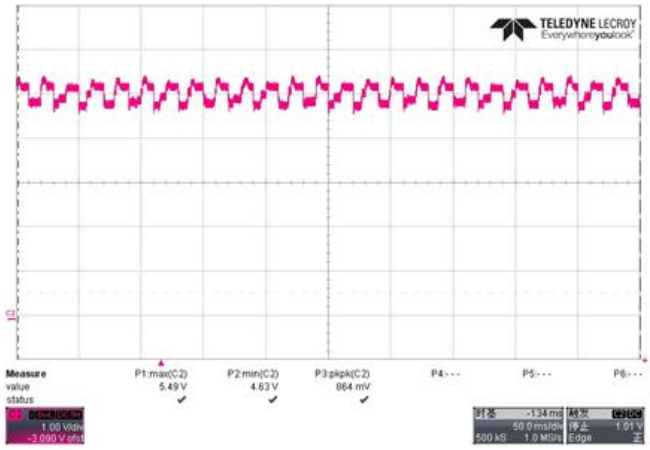


Figure 17:

Vout: 5.55~4.69V

90VAC/50Hz; Load level: 0~1A;

Frequency: 10mS-10mS. Slew rate: 250mA/us

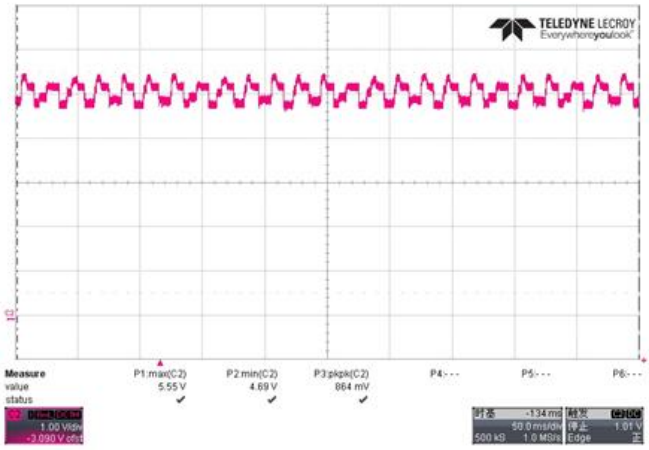


Figure 18:

Vout: 5.55~4.69V

264VAC/50Hz; Load level: 0~1A;

Frequency: 10mS-10mS. Slew rate: 250mA/us

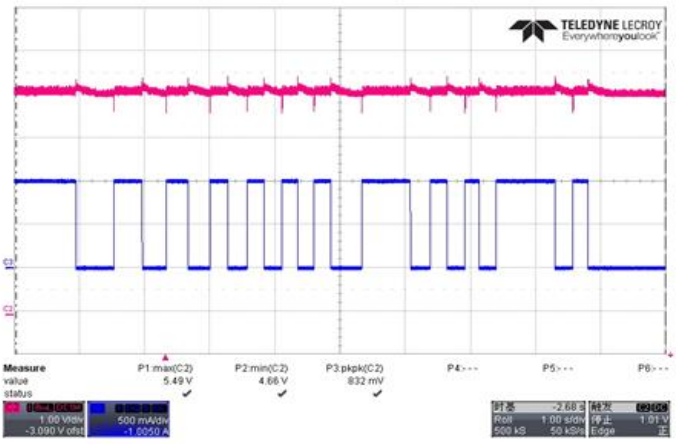


Figure 19:

Vout: 5.49~4.66V

90VAC/60Hz; Load level: 0~1A;

Frequency: manually. Slew rate: 250A/us

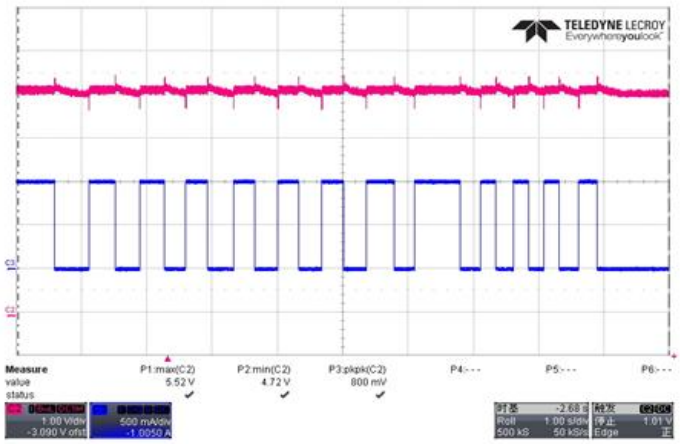


Figure 20:

Vout: 5.52~4.72V

264VAC/50Hz; Load level: 0~1A;

Frequency: manually. Slew rate: 250A/us

5.3 Thermal Test data at room Temperature after running 1 hr

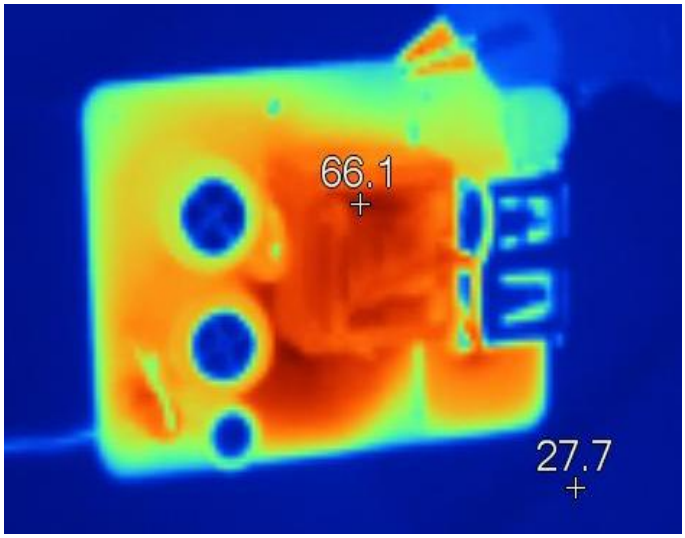
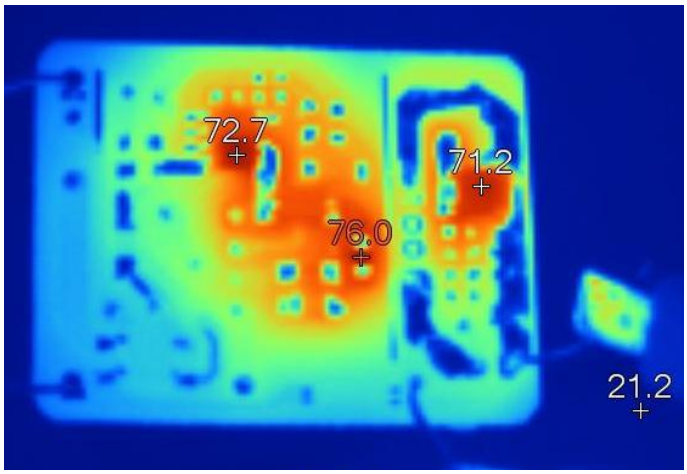


Figure21:

85Vac/60Hz, 1A AMB temp: 27.7℃

IC temp: 73.6℃ Core Temp :66.1 ℃ Schottky Temp :74.6℃



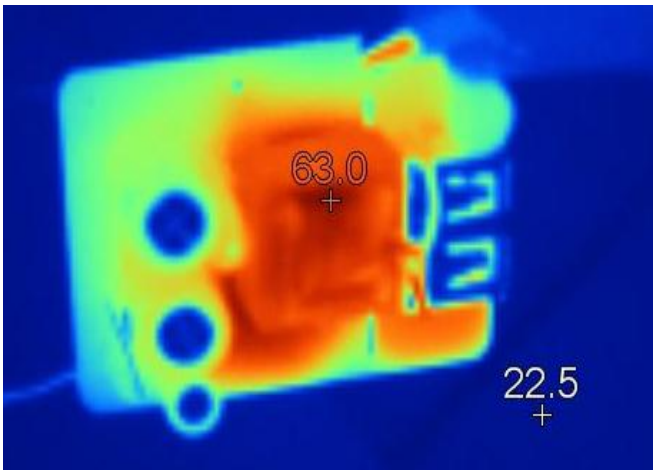


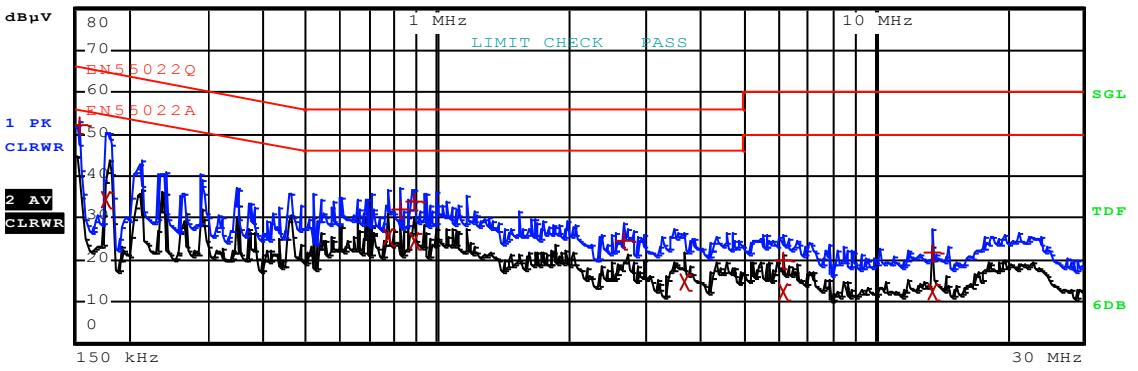
Figure 22:

264Vac/60Hz, 1A IC temp: 72.7℃

AMB temp: 22.5℃ Core Temp :63 ℃ Schottky Temp :71.2℃

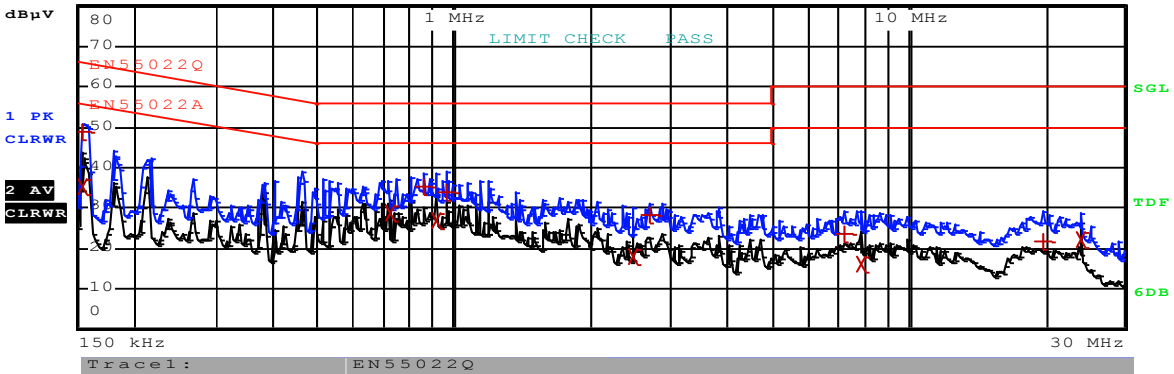
5.4 System EMI Scan

5.4.1 System EMI L & N -Line Scan Data @115Vac



Trace1:	EN55022Q			
Trace2:	EN55022A			
Trace3:	---			
TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1	Quasi Peak	154 kHz	52.00	-13.78
2	Average	178 kHz	34.27	-20.30
2	Average	774 kHz	25.48	-20.51
1	Quasi Peak	822 kHz	32.19	-23.80
1	Quasi Peak	886 kHz	33.84	-22.16
2	Average	886 kHz	24.39	-21.60
1	Quasi Peak	2.67 MHz	24.48	-31.51
2	Average	3.666 MHz	14.58	-31.41
1	Quasi Peak	6.17 MHz	19.87	-40.12
2	Average	6.17 MHz	12.22	-37.77
1	Quasi Peak	13.562 MHz	21.80	-38.19
2	Average	13.562 MHz	12.58	-37.41

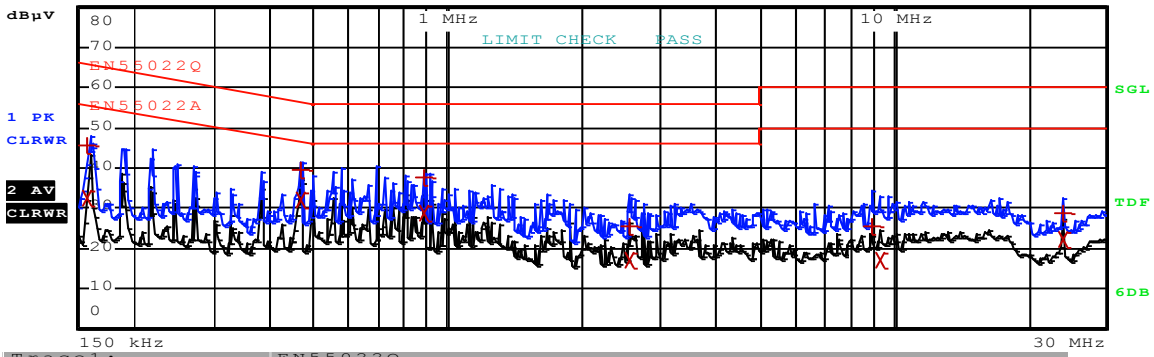
Figure 23: EMI Scan at 115Vac @ L - line



Trace1:	EN55022Q			
Trace2:	EN55022A			
Trace3:	---			
TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1	Quasi Peak	154 kHz	48.66	-17.11
2	Average	154 kHz	35.17	-20.61
2	Average	722 kHz	28.94	-17.05
1	Quasi Peak	854 kHz	35.52	-20.47
2	Average	918 kHz	26.68	-19.31
1	Quasi Peak	966 kHz	34.08	-21.91
2	Average	2.486 MHz	17.96	-28.03
1	Quasi Peak	2.694 MHz	28.16	-27.83
1	Quasi Peak	7.218 MHz	23.48	-36.51
2	Average	7.994 MHz	16.26	-33.73
1	Quasi Peak	19.802 MHz	21.76	-38.23
2	Average	24.002 MHz	22.20	-27.80

Figure 24: EMI Scan at 115Vac @ N - line

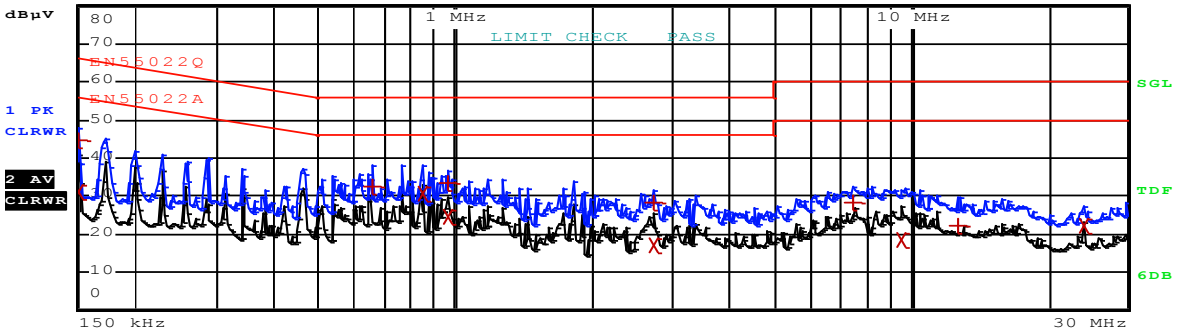
5.4.2 System EMI L & N -Line Scan Data @230Vac



Trace1:	EN55022Q
Trace2:	EN55022A
Trace3:	---

TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1	Quasi Peak	158 kHz	45.64	-19.92
2	Average	158 kHz	32.41	-23.15
1	Quasi Peak	466 kHz	39.61	-16.97
2	Average	466 kHz	32.25	-14.33
1	Quasi Peak	890 kHz	37.50	-18.49
2	Average	890 kHz	28.99	-17.01
1	Quasi Peak	2.558 MHz	25.50	-30.49
2	Average	2.558 MHz	17.23	-28.76
1	Quasi Peak	8.958 MHz	25.69	-34.30
2	Average	9.342 MHz	17.27	-32.72
1	Quasi Peak	24.002 MHz	28.77	-31.22
2	Average	24.002 MHz	22.26	-27.74

Figure 25: EMI Scan at 230Vac @ L- line



Trace1:	EN55022Q
Trace2:	EN55022A
Trace3:	---

TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1	Quasi Peak	150 kHz	44.62	-21.37
2	Average	150 kHz	31.06	-24.93
1	Quasi Peak	654 kHz	32.74	-23.25
2	Average	846 kHz	30.79	-15.20
1	Quasi Peak	962 kHz	33.24	-22.75
2	Average	962 kHz	24.57	-21.42
1	Quasi Peak	2.73 MHz	28.14	-27.85
2	Average	2.73 MHz	17.24	-28.75
1	Quasi Peak	7.51 MHz	28.21	-31.78
2	Average	9.546 MHz	18.25	-31.74
1	Quasi Peak	12.738 MHz	22.42	-37.57
2	Average	24.002 MHz	22.01	-27.98

Figure 26: EMI Scan at 230Vac @ N - line

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