Universal AC input, Primary Side Regulation High Eff 69W AP3781 23V-3A EV Board User Guide

General Description

Based on Flyback topology, the Primary side Regulated AP3781 EV board is designed to serve as an example for High Efficiency, low cost & less components for consumer home appliance and power tools system. This system output is 70W with 23V-3A. It can meet DOE VI and CoC Tier 2 energy efficiency requirement.

Key Features

- 90 ~264V_{AC} wide input range
- Use the Primary side control to eliminate the Opto-coupler.
- PFM method operations.
- With Valley on detection. the switching stays at Valley. So that will realize good system efficiency & EMI performance, and above 90% efficiency can be reached at full load.
- Low start-up operating quiescent currents, 150mW low standby input power can be achieved.
- Accurate constant voltage (CV)& constant current (CC) regulation performance.
- Good EMI performance with IC Jittering Frequency function
- Internal Auto Recovery OCP, OVP, OLP, OTP Power Protection, cycle by cycle current limit.
- Adjustable cable Compensation.
- With a Brown out Protection.

Applications

- Switching AC-DC Adaptor & Charger
- Home Appliances systems
- Power Tools
- Battery charger

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Universal AC input PSR 23V-3.0A Power Specifications (CV & CC mode)

Parameter	Value
Input Voltage	90 to 264V_{AC}
Input standby power	150mW
Main output Vo / Io	23V – 3A
Efficiency	~ 90%
Total Output Power	70W
Protections	OCP, OVP, OLP,OTP
XYZ Dimension	84 x 53 x 20 mm
ROHS Compliance	Yes

Evaluation Board Picture:

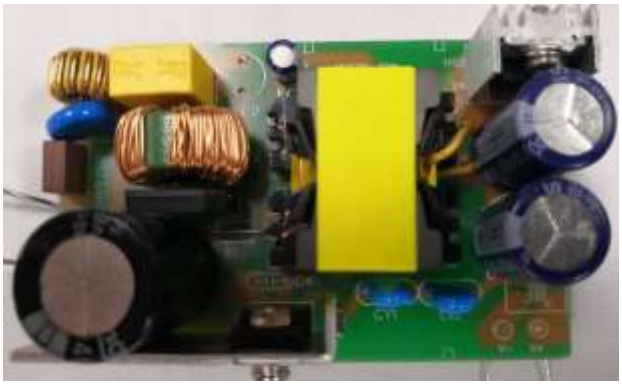


Figure 1: Top View

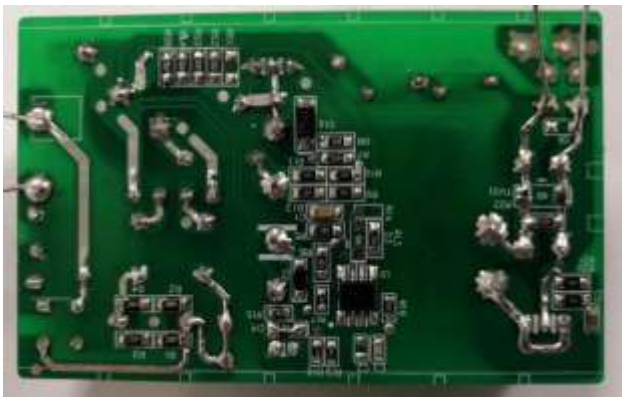
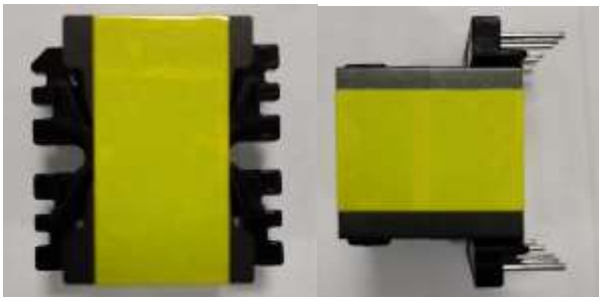


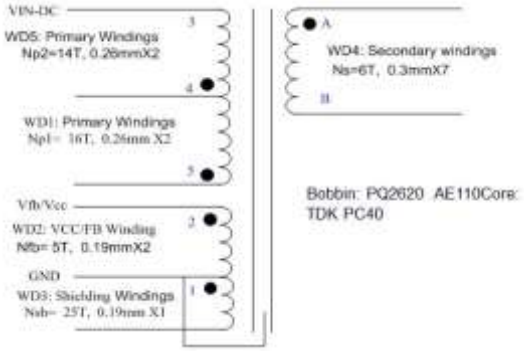
Figure 2: Bottom View

AP3781 (90V_{AC} ~ 265V_{AC} one outputs 70W Transformer Spec.)

1) Core& Bobbin: PQ26/20, 5+2 pin



2) Electrical Diagram:



3) Transformer Parameters

1. Primary Inductance (Pin5-Pin3), all other windings are open Lp =0.35 mH ±7% @10KHz

PQ2620 （Ae = 110mm^2）						
NO Winding	NAME	TERMINAL NO.		WINDING		
		START	FINISH	WIRE	TURNS	Layers
1	Np1	5	4	Φ 0.26mm X 2	16 Ts	2
2	Na	2	1	Φ 0.19mm X 2	5 Ts	2
3	Ns	A	B	Φ 0.30mm X 7	6 Ts	2
4	Shield	1（GND）	NC	Φ 0.19mm X 1	25 Ts	2
5	Np2	4	3	Φ 0.26mm X 2	14 Ts	2

Primary Inductance	Pin 5-3,all other windings open, measured at 10kHz, 0.4VRMS	0.35mH ± 7 %
Primary Leakage Inductance	Pin 5-3, all other windings shorted, measured at 10kHz, 0.4VRMS	25 uH (Max.)

Evaluation Board Schematic

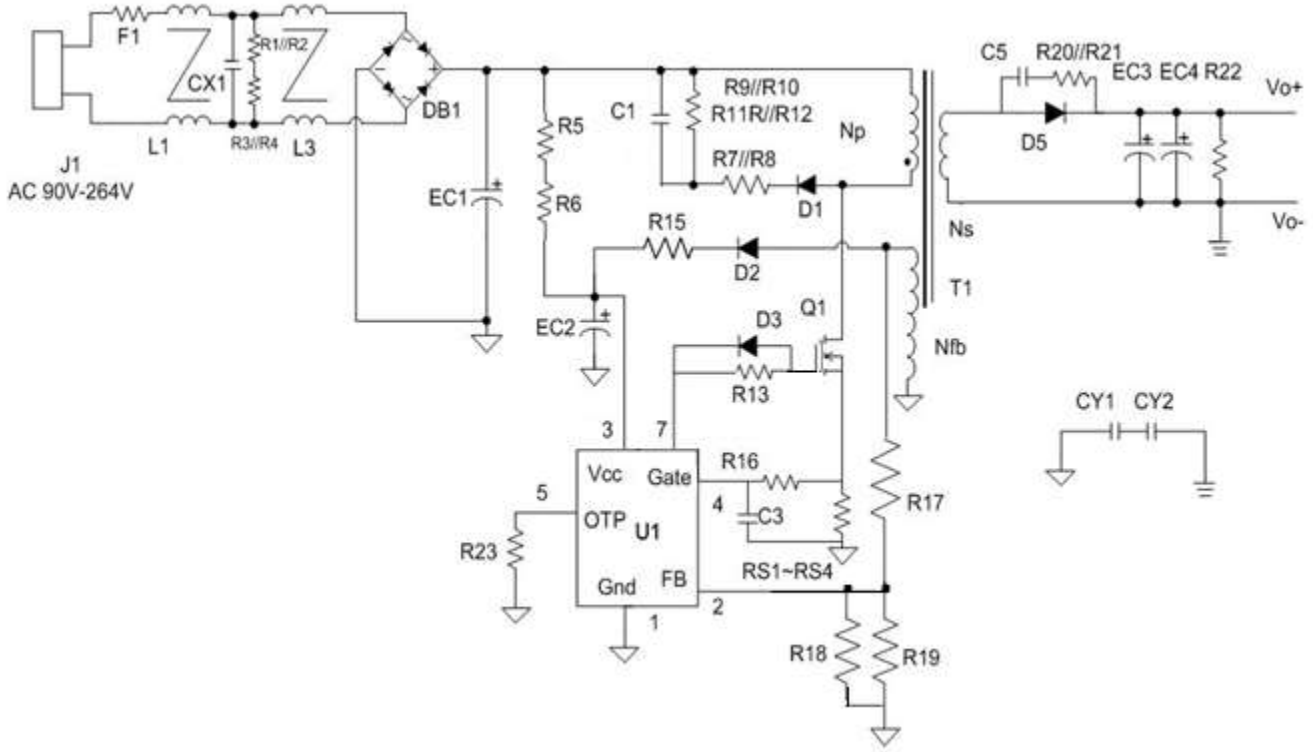


Figure 3: Evaluation Board Schematic

Evaluation Board PCB Layout

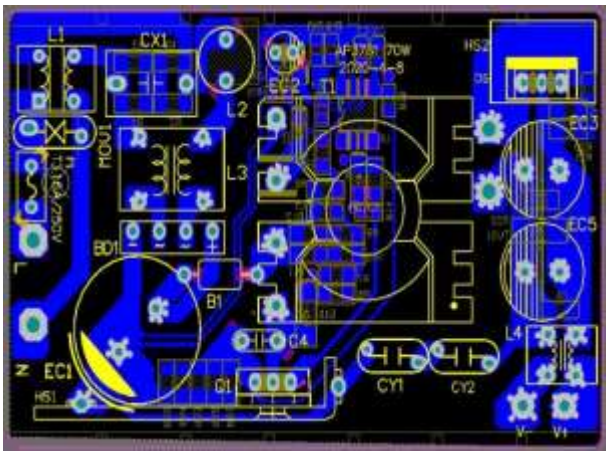


Figure4: PCB Board Layout Top View

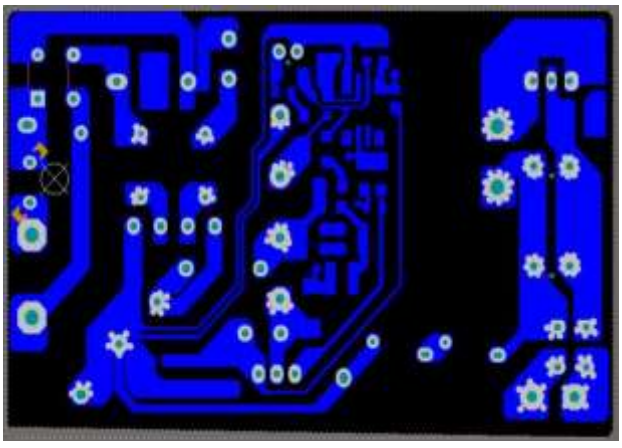


Figure5: PCB Board Layout Bottom View

PCB Layout Consideration

As shown in Figure 6, there are four major high frequency current loops:
1. The current path from bulk capacitor, transformer, MOSFET, Rcs returning to bulk capacitor
2. The path from GATE pin, MOSFET, Rcs returning to the ground of IC
3. The RCD clamp circuit is a high frequency loop
4. Transformer, rectifier diode, and output capacitor also a high frequency current loop

The loops must be as short as possible to decrease the radiate area for a better EMI, and if the MOSFET And Schottky diode have heat sink, the heat sink should be connected to their ground separately.

Ground Layout Consideration

1. A proper “Ground” layout is important to decrease unknown noise interference and EMI issue in the switching power supply.
2. A so-called “Star” connection is highly recommended for primary GND. As shown in Figure 6, the ground of MOSFET, auxiliary winding, Y-cap and control IC are separated and finally connected together on bulk capacitor ground. The width of these grounds should be kept as large as possible. The primary side of Y-cap could also be connected to the high voltage pin

Evaluation Board PCB Layout

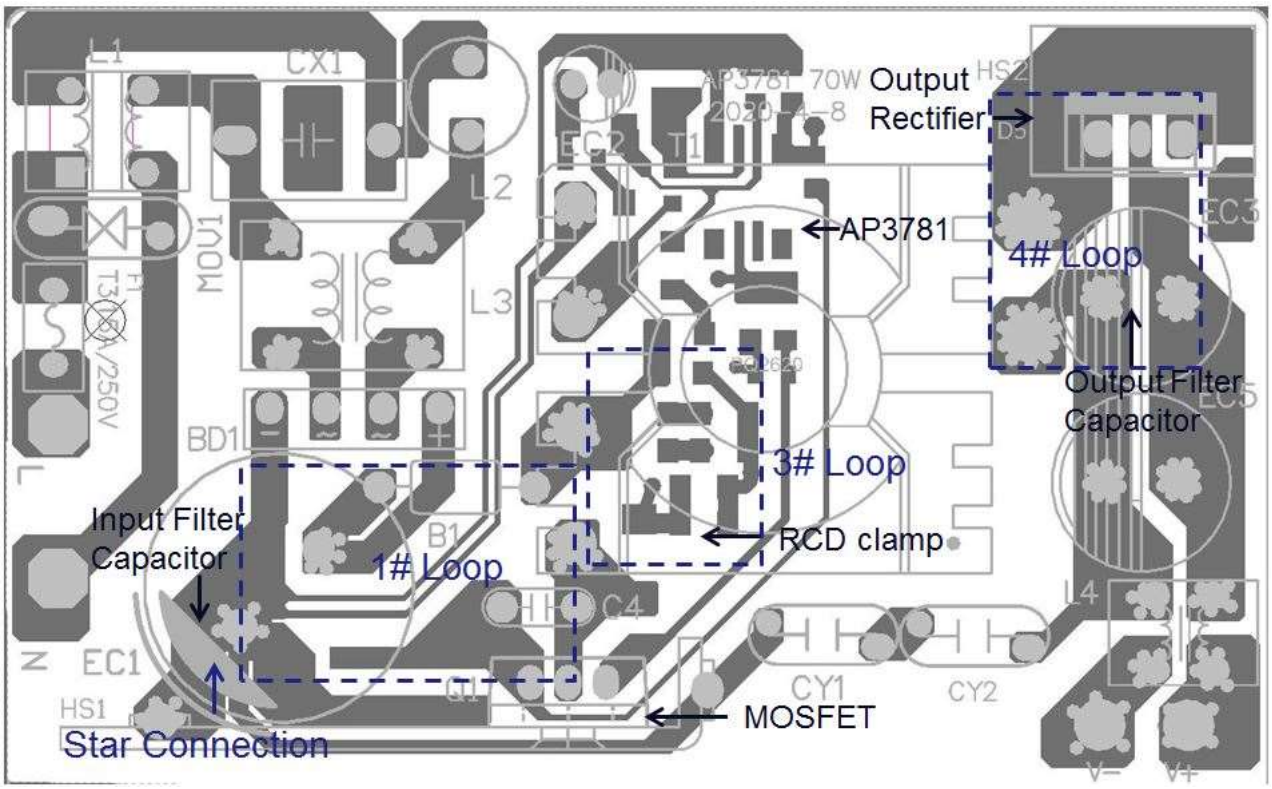


Figure6: High Current Loop & Star Connection

Quick Start Guide

1. The evaluation board is preset at 23V/3A 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 23V respectively.

Build of Material

			AP3781 23V-3A BOM 6-5-2020		
Item	QTY per board	REF. DES.	Description	MFG or Supplier	MFG P/N or Supplier P/N Digi key #
1	1	EC1	120uf /400V 16 x 32mm	Aishi Electro	
2	1	EC2	10uF/50V 5 x 10mm	Aishi Electro	
3	2	EC3, EC4	1000uf /35V 12 x 16mm	Aishi Electro	
4	1	C1	1nf / 1KV, 1206 X7R	Holy Stone	
5	1	C3	33pf / 25V, 0805 X7R	Holy Stone	
6	1	C5	1nf / 200V, 0805 X7R	Holy Stone	
7	4	R1,R2,R3,R4	2M ohm 1206	Yageo	
8	2	R5,R6	1M ohm 1206	Yageo	
9	2	R7,R8	51R ohm 1206	Yageo	
10	4	R9,R10,R11,R12	180K ohm 1206	Yageo	
11	1	R13	20R ohm 1206	Yageo	
12	1	R15	1R ohm 0805	Yageo	
13	1	R16	1K ohm 0805	Yageo	
14	1	R17	47.5K ohm 0805	Yageo	
15	1	R18	7.5K ohm 0805	Yageo	
16	1	R19	82.5K ohm 0805	Yageo	
17	4	RS1,RS2.RS3,RS4	1.0R ohm 1206	Yageo	
18	2	R20,R21	10R ohm 1206	Yageo	
19	1	R22	12K ohm 1206	Yageo	
20	1	BD1	KBP410G	Diodes	
21	1	D1	S2MA SMA	Diodes	
22	1	D2	RS1MSWF SOD-123	Diodes	
23	1	D5	SDT40A120CT	Diodes	
24	1	F1	3.15A330V	Fuse	
25	1	L1	1mH 8X10mm	Inductor	
26	1	L2	20mH 10X20mm	Inductor	
27	2	CY1,CY2	3.3nf/250Vac Y1	Holy Stone	
28	1	U1	AP3781 sop-7	Diodes	
29	1	Q1	250N65S3	ONsemi	
30	1	T1	PQ26/20	Transformer	

AP3781 23V-3A BOM 6-5-2020

Notes: 1. D2 diode type selection, we propose standard or fast diode (not schottky or super fast recovery diode).

Input Standby Power

Input Voltage	115Vac/60Hz	230Vac/50Hz	Note
Pin (w)	90mW	140mW	At no loading

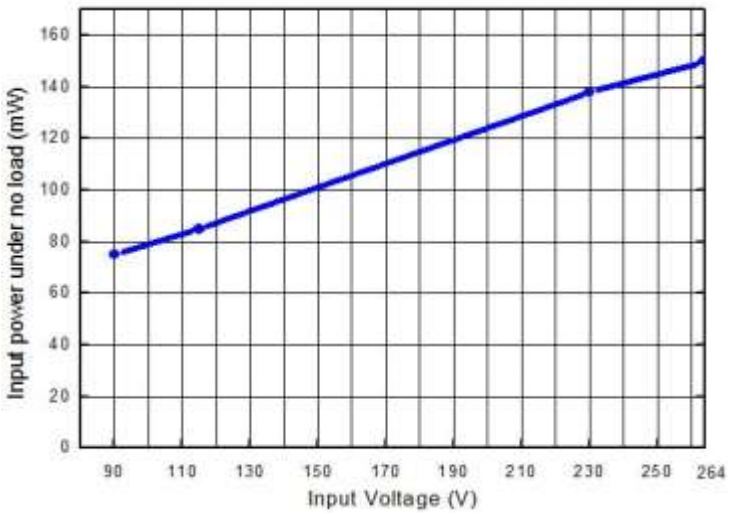
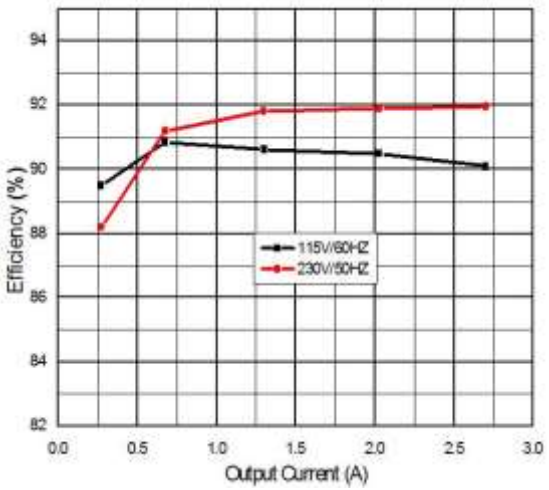


Figure 8: The Efficiency curve with at different AC input

Input power Efficiency at different loading

AC input	Efficiency (%)					Eff_avg at four conditions
	10%	25%	50%	75%	100%	
115VAC/60Hz	**89.49%**	**90.84%**	**90.61%**	**90.49%**	**90.09%**	**90.50%**
230VAC/50Hz	**88.22%**	**91.20%**	**91.80%**	**91.89%**	**91.96%**	**91.71%**
Eff_avg						



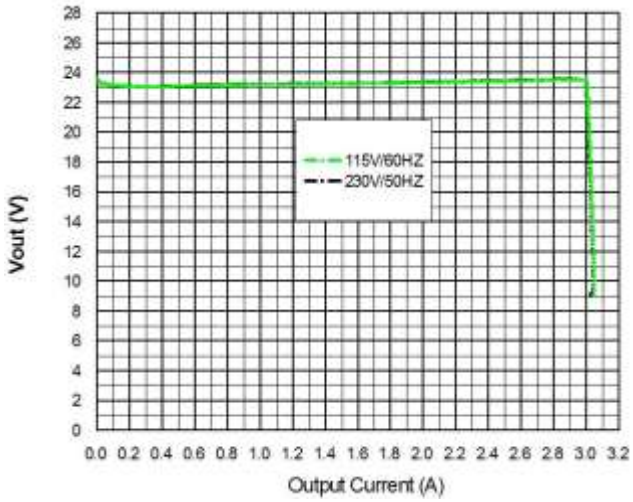


Figure 9: The efficiency curve with different loading

Figure 10: CV & CC Curve at OCP set poits

OCP Current set point with at different AC line

AC input	90VAC	115VAC	230VAC	264VAC	Note
I _max	3A	3A	3A	3A	

PSU Output Characteristics:

Line Regulation (at full loading condition):

AC input Voltage	90VAC/60Hz	115VAC/60Hz	230VAC/50Hz	265VAC/50Hz	Note
23.00Vout	23.43V/2.7A	23.47V/2.7A	23.51V/2.7A	23.51V/2.7A	0.34%<1%

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

AC input Voltage	115VAC/60Hz	230VAC/50Hz
23V Full Load	23.46V / 2.7A	23.50V/2.7A
23V 10% of FL	23.04V /0.27A	23.05V/0.27A
Note: cable compensation	1.82%	1.95%

Note: All output voltages are measured at output PCB board Edge. Internal Cable Compensation 4%

Key Performance Waveforms:

System start - up time

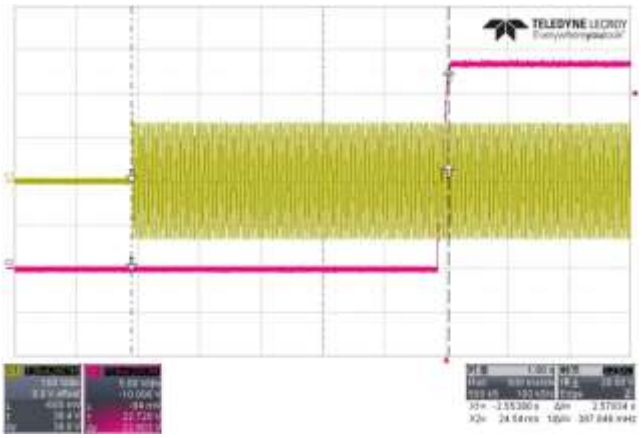


Figure 11:AP3781 turn on time 2.57sFL at 90Vac

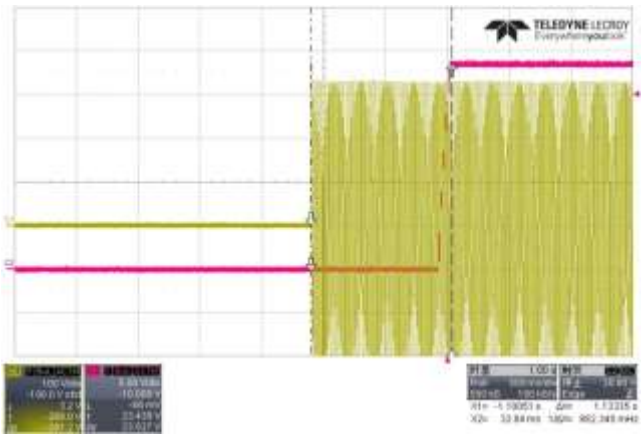


Figure 12: AP3781 turn on time 1.13s at FL, at 230Vac

System main switching Voltage Stress on Q1 D-S

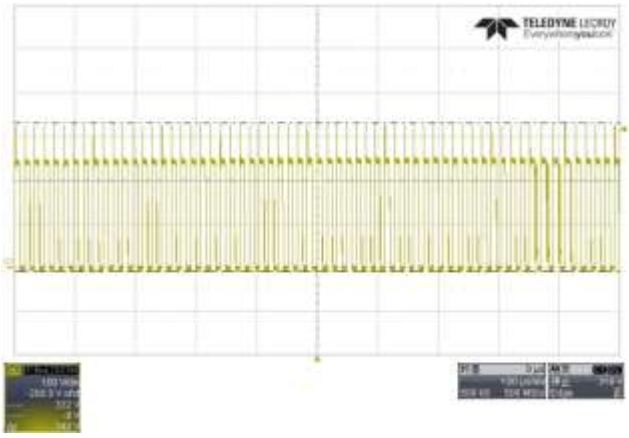


Figure 13:AP3781 Vds at FL at 90Vac Vds=340Vp-p

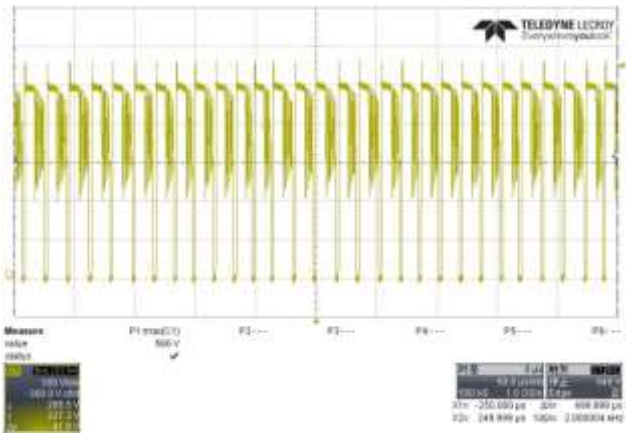


Figure 14: AP3781Vds at FL at 264Vac, Vds=566Vp-p

System Voltage Stress across on D5 A-C

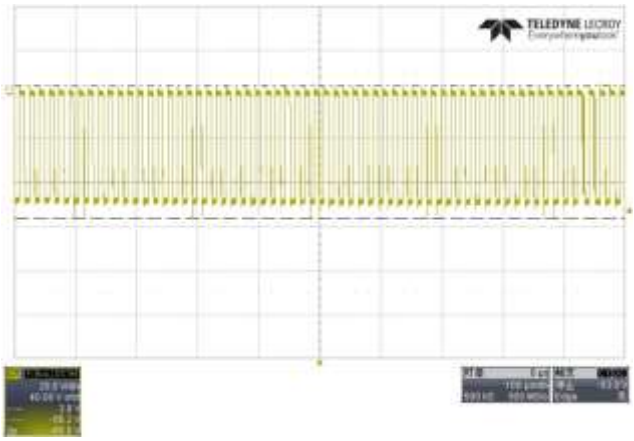


Figure 15: D5 A-C voltage stress at 90Vac FL
Vd = 60Vp-p 20V/div

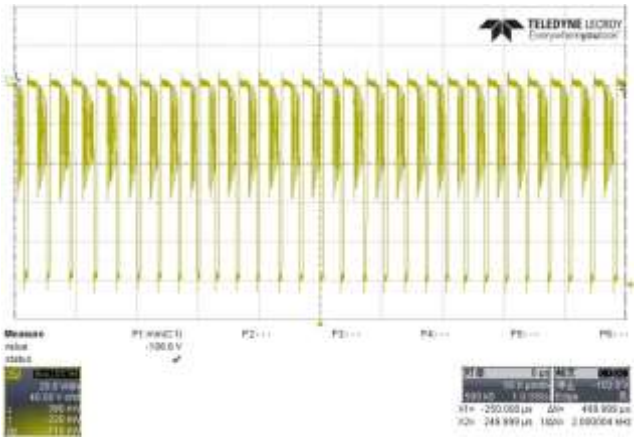
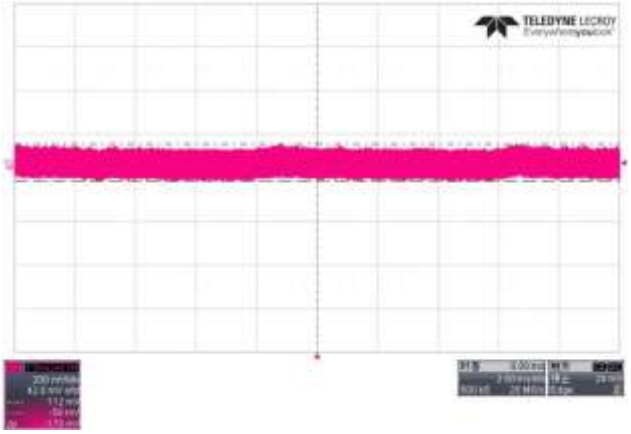


Figure 16: D5 A-C voltage stress at 264Vac at FL
Vd = 106.6Vp-p 20V/div

System output Ripple performance



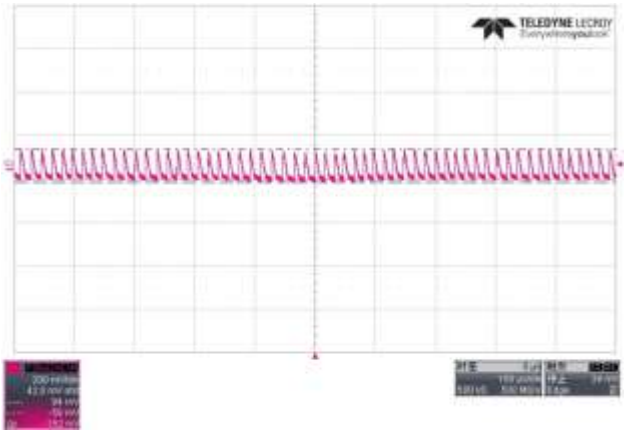
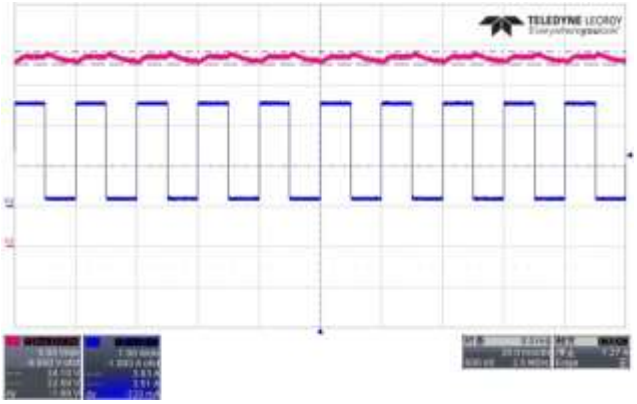


Figure 17: The Ripple at 115Vac_in Vpp=170mv FL **Figure 18:** The Ripple at 230Vac_in Vpp=160mv FL

System Dynamic Response performance



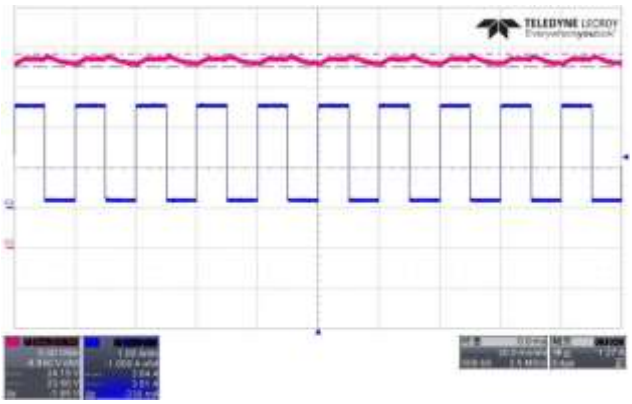


Figure19:115VAC; Load level: 0.27~2.7A; Vout:22.5~24.1V Frequency: 10ms~10mS. Slew rate: 0.25A/us

Figure20: 230VAC; Loadlevel:0.27~2.7A;Vout: 22.5~24.1V Frequency: 10ms~10mS. Slew rate: 0.25A/us

System Dynamic Response performance

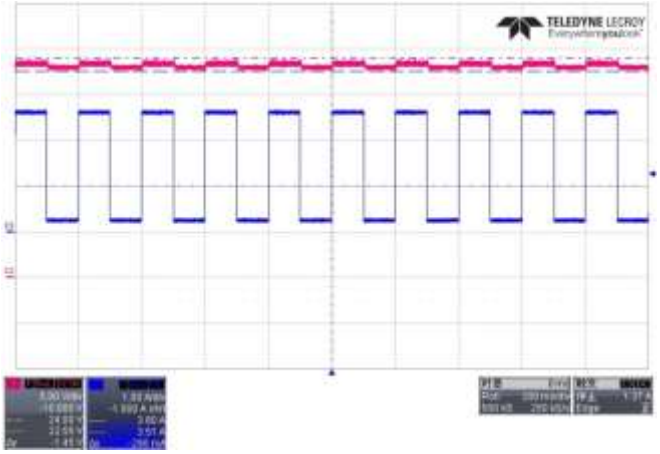


Figure 21: 115VAC; Load level: 0.27~2.7A; Vout:22.5~24.0V
Frequency: 100ms~100mS. Slew rate: 0.25A/us

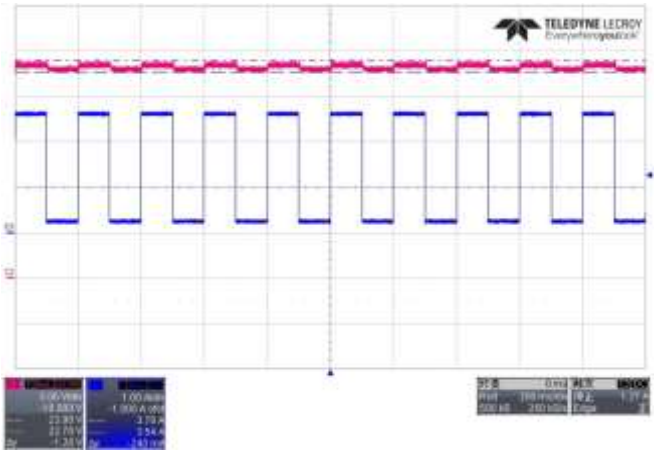
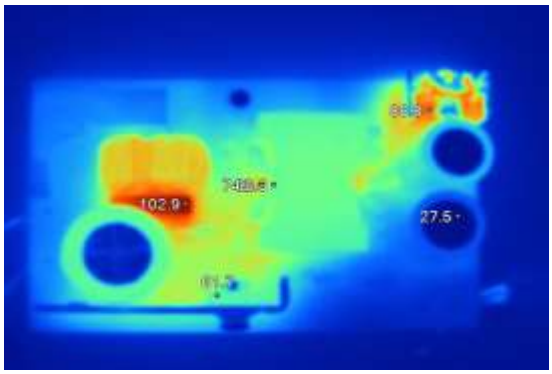


Figure 22: 230VAC; Load level: 0.27~2.7A; Vout:22.7~23.9V
Frequency: 100ms~100mS. Slew rate: 0.25A/u

Thermal Test data at room Temperature after running 1 hr

90Vac full load



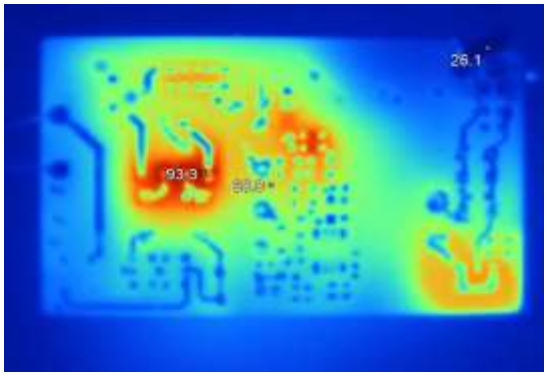
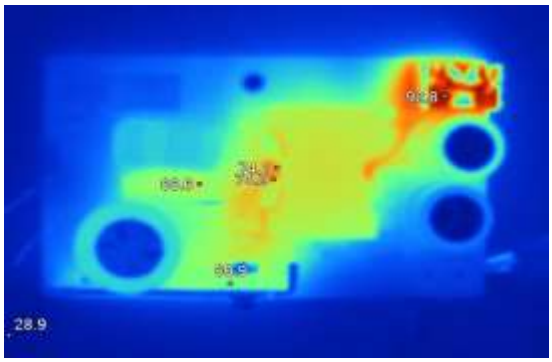


Figure23 Ta 27.5℃ DB1 KBP410 102.9℃ Q1 250N65 61.7℃ T1 74℃ D5 40A120 86.8℃

264Vac full load



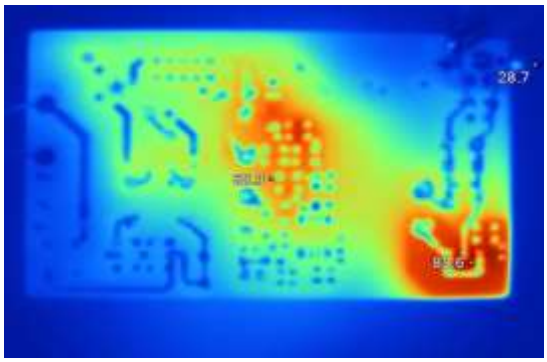
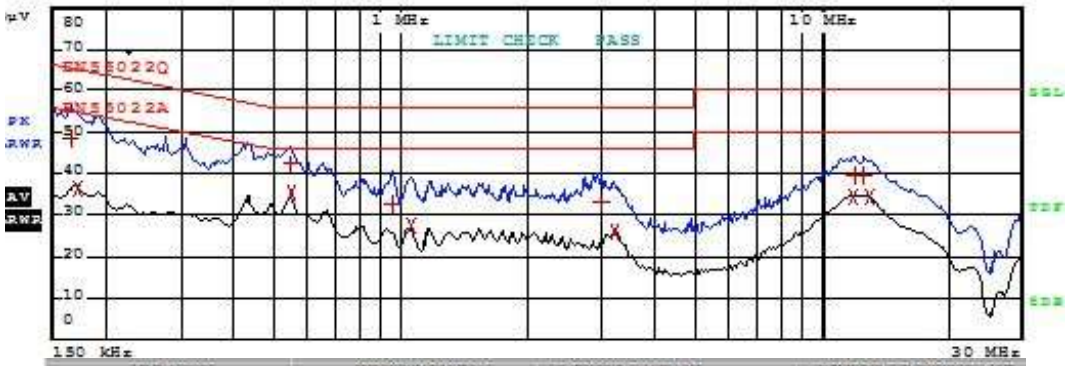


Figure24 Ta 28℃, DB1 KBP410 66.6℃ Q1 250N65 60.9℃ T1 74.2℃ D5 40A120 92.8℃

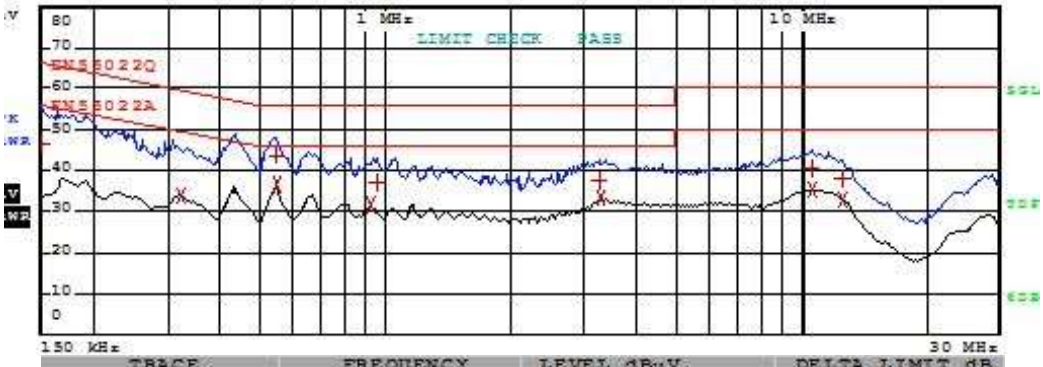
System EMI L-Line Scan Data(at 115Vac)



TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1	Quasi Peak	164.052790903 kHz	48.40	-16.85
2	Average	170.713992065 kHz	36.32	-18.59
1	Quasi Peak	546.852057924 kHz	42.42	-13.57
2	Average	546.852057924 kHz	35.29	-10.70
1	Quasi Peak	945.247220176 kHz	32.70	-23.29
2	Average	1.05458240332 MHz	27.50	-18.49
1	Quasi Peak	2.96826993929 MHz	33.04	-22.95
2	Average	3.21421100787 MHz	26.13	-19.86
2	Average	11.8351658887 MHz	34.31	-15.68
1	Quasi Peak	11.9535175476 MHz	39.57	-20.42
1	Quasi Peak	12.4388782936 MHz	39.65	-20.34
2	Average	12.8157887448 MHz	34.33	-15.66

Figure 25: EMI Scan at 115Vac

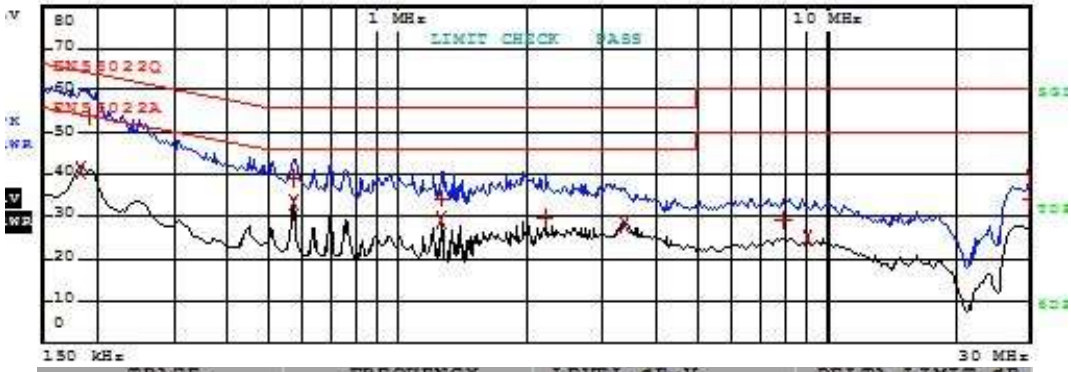
System EMI N-Line Scan Data(at 115Vac)



TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1	Quasi Peak	150 kHz	46.39	-19.60
2	Average	322.728292586 kHz	33.86	-15.77
1	Quasi Peak	546.852057924 kHz	43.81	-12.18
2	Average	546.852057924 kHz	36.75	-9.24
2	Average	917.447639259 kHz	31.71	-14.28
1	Quasi Peak	945.247220176 kHz	37.24	-18.75
1	Quasi Peak	3.24635311795 MHz	37.66	-18.33
2	Average	3.27881664913 MHz	33.32	-12.67
1	Quasi Peak	10.5031087988 MHz	40.55	-19.44
2	Average	10.5031087988 MHz	35.50	-14.50
1	Quasi Peak	12.4388782936 MHz	38.14	-21.85
2	Average	12.4388782936 MHz	32.80	-17.19

Figure 26: EMI Scan at 115Vac

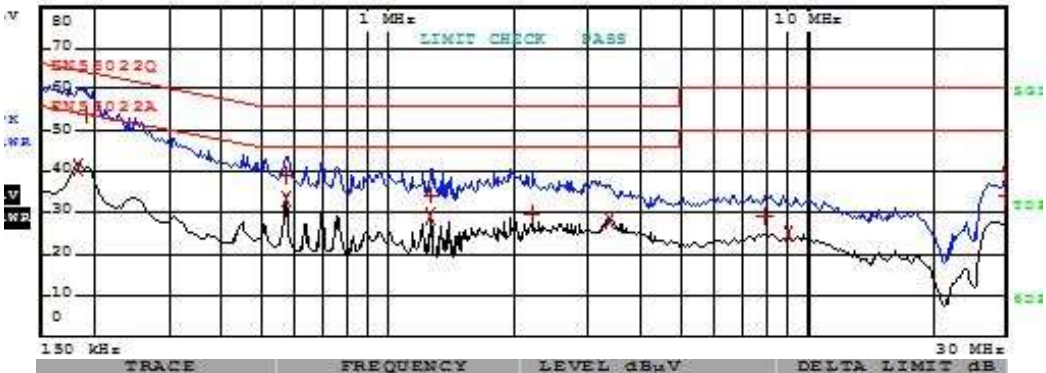
System EMI L-Line Scan Data(at 230Vac)



TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
2	Average	181.216342567 kHz	41.13	-13.29
1	Quasi Peak	190.46019728 kHz	54.02	-9.99
1	Quasi Peak	369.056444353 kHz	39.14	-16.85
2	Average	369.056444353 kHz	33.52	-12.47
1	Quasi Peak	1.26143607964 MHz	34.29	-21.70
2	Average	1.26143607964 MHz	29.15	-16.84
1	Quasi Peak	2.18042326152 MHz	29.73	-26.26
2	Average	3.37816807242 MHz	28.45	-17.54
1	Quasi Peak	7.87042209709 MHz	29.29	-30.70
2	Average	8.95727450287 MHz	24.83	-25.16
1	Quasi Peak	30 MHz	33.95	-26.04
2	Average	30 MHz	39.26	-10.73

Figure 27: EMI Scan at 230Vac

System EMI N-Line Scan Data(at 230Vac)



TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
2	Average	181.216342567 kHz	41.13	-13.29
1	Quasi Peak	190.46019728 kHz	54.02	-9.99
1	Quasi Peak	369.056444353 kHz	39.14	-16.85
2	Average	369.056444353 kHz	33.52	-12.47
1	Quasi Peak	1.26143607964 MHz	34.29	-21.70
2	Average	1.26143607964 MHz	29.15	-16.84
1	Quasi Peak	2.18042326152 MHz	29.73	-26.26
2	Average	3.37816807242 MHz	28.45	-17.54
1	Quasi Peak	7.87042209709 MHz	29.29	-30.70
2	Average	8.95727450287 MHz	24.83	-25.16
1	Quasi Peak	30 MHz	33.95	-26.04
2	Average	30 MHz	39.26	-10.73

Figure 28: EMI Scan at 230Vac

Please see the recommand Application note for reference

(web page - http://www.diodes.com/appnote_dnote.html)

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