

### General Description

This demonstration board utilizes the AP1695 Buck LED driver providing a cost effective triac dimmable solution for offline high brightness LED applications. This user-friendly evaluation board provides users with quick connection to their different types of LEDs string. The demonstration board can be modified easily to adjust the LED output current and the number of series connected LEDs that are driven.

A BOM, schematic and layout are included that describes the parts used on this demonstration board, along with measured performance characteristics. These materials can be used as a reference design.

### Key Features

- Triac Dimmable
- Active PFC with power factor >0.82
- High efficiency >83%
- THD <34%

### Applications

- Retrofit Candle, GU10 lamps

### Specifications

Parameter	Value
AC Input Voltage	198V-264V
Output Power	6.5W
LED Current	175mA
LED Voltage	37V
Power Factor	>0.82
Efficiency	83%
XYZ Dimension	30x16x15mm
ROHS Compliance	Yes

### Evaluation Board



Figure 1: Top View

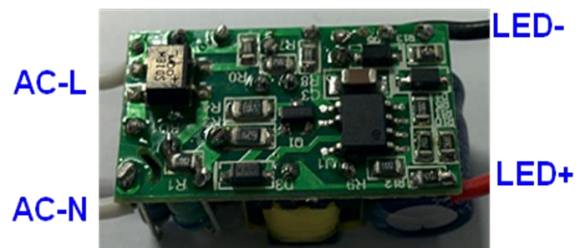
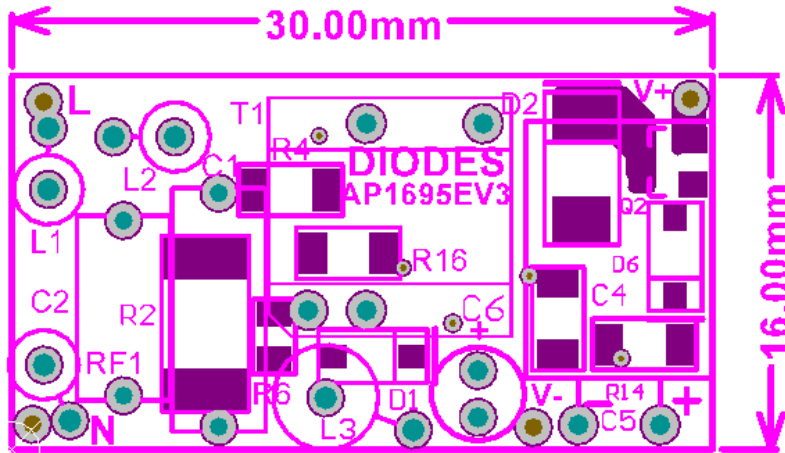


Figure 2: Bottom View

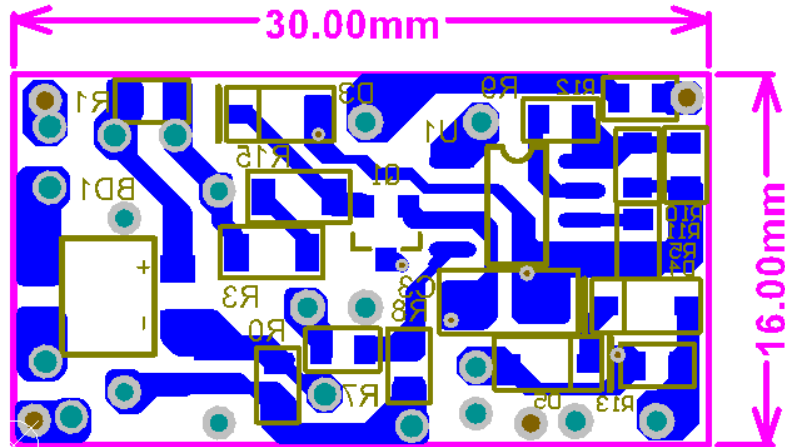
### Connection Instructions:

- AC-L Input: White – Hot
- AC-N Input: White – Neutral
- DC LED+ Output: LED+ (Red)
- DC LED- Output: LED- (Black)

**Board Layout**



**Figure 3: PCB Layout Top View**



**Figure 4: PCB Layout Bottom View**

**Quick Start Guide**

1. Preset the isolated AC source to 230Vac.
2. Ensure that the AC source is switched OFF or disconnected.
3. Connect the anode wire of the LED string to the LED+ terminal of the evaluation board.
4. Connect the cathode wire of the LED string to the LED- terminal of the evaluation board.
5. Connect two AC line wires to the AC-L and AC-N terminals on the evaluation board.
6. Ensure that the area around the board is clear and safe, and preferably that the board and LEDs are enclosed in a transparent safety cover.
7. Turn on the main switch. LED string should light up with LED.  
DO NOT TOUCH THE BOARD, LEDs OR BARE WIRING.

**Caution: All terminals carry high voltage during operation!**

### Schematic

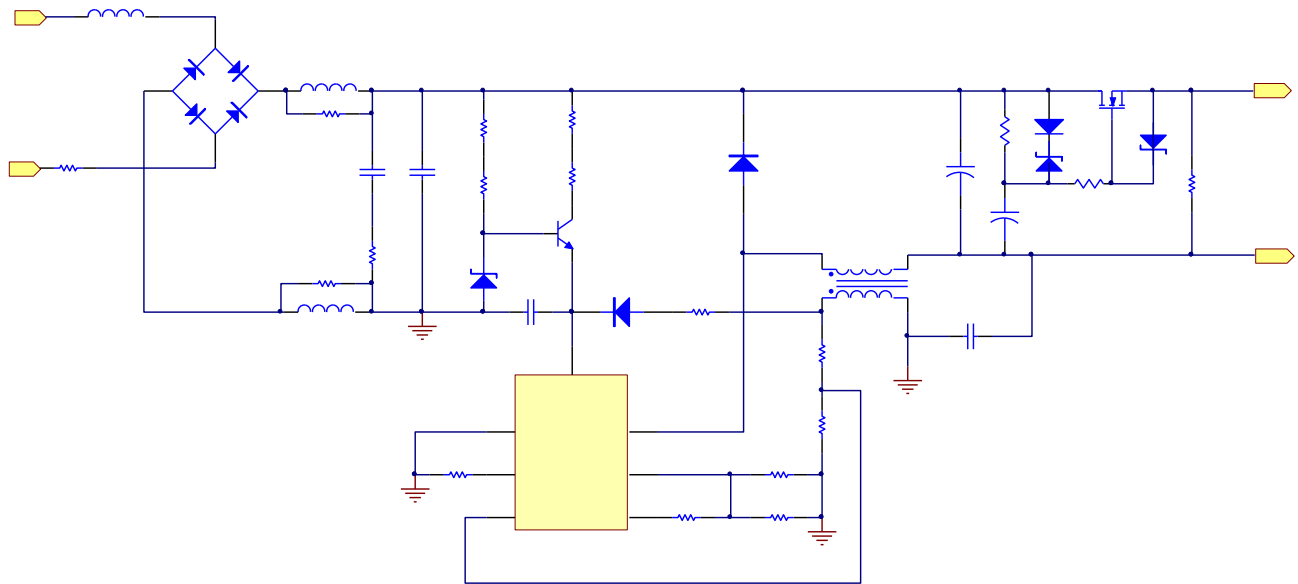


Figure 5: Schematic Circuit

### Transformer Design

#### Bobbin and Core

EE10 Vertical 4+4 pin

#### Transformer Parameters

1. Primary Inductance (Pin 5-Pin 7, all other windings open):  $L_p=0.87\text{mH}$ ,  $\pm 5\%$ @1kHz
2. Primary Winding Turns (Pin 5-Pin 7):  $N_p=152\text{Ts}$
3. Auxiliary Winding Turns (Pin 1-Pin 2):  $N_p=82\text{Ts}$

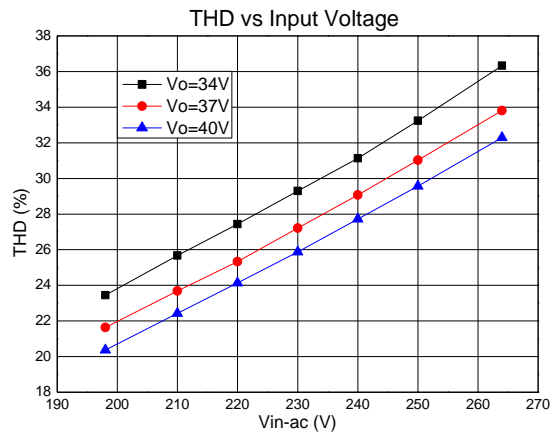
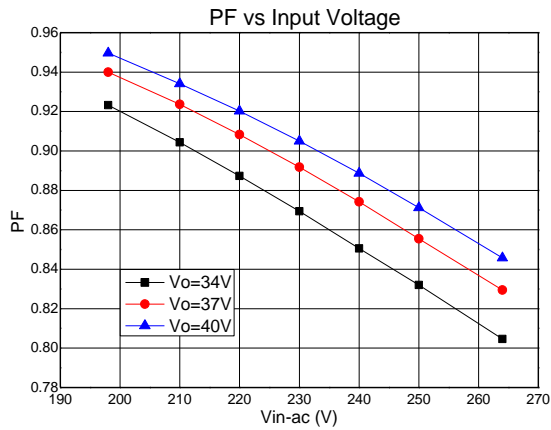
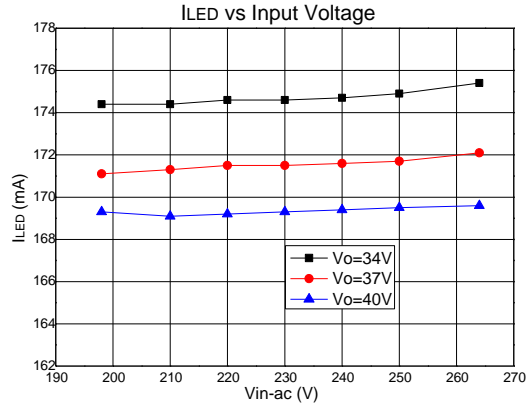
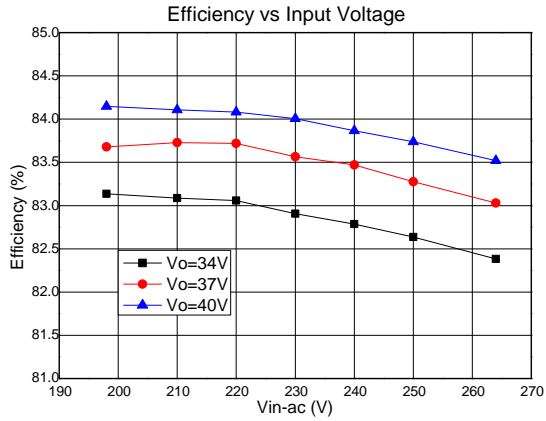
#### Transformer Winding Construction Diagram

Item	Winding name	Description
1	WD1-Primary Winding	Start at Pin5, Wind 152 turns of $\Phi 0.19\text{mm}$ wire and finish on Pin7.
2	Insulation	2 Layers of insulation tape
3	WD2-Auxiliary Winding	Start at Pin 1, Wind 82 turns of $\Phi 0.13\text{mm}$ wire and finish on Pin2.
4	Insulation	3 Layers of insulation tape

### Bill of Material

#	Name	Quantity	Package	Description
1	C1	1	DIP	150nF/400V,CL21,D= 10mm
2	C2	1	DIP	150nF/400V,CL21,D=7.5mm
3	C3	1	1206	Ceramic Cap,10uF/35V,X7R
4	C4	0	1206	NC
5	C5	1	DIP	E-Cap,105°C,220uF/50V,10*13mm
6	C6	1	DIP	E-Cap,105°C,10uF/50V,5*11mm
7	D1	1	SOD-123	1N4007,1A/1000V
8	D2	1	SMA	ES1J,1A/600V
9	D3	1	SOD-123	Zener,DDZ9707,20V/0.5W,Diodes Inc
10	D4	1	SOD-123	1N4148W,150mA/100V,Diodes Inc
11	D5,D6	2	SOD-123	Zener,DDZ9688,4.7V/0.5W,Diodes Inc
12	BD1	1	MiniDIP	Rectifier Bridge,HD06,0.8A/600V
13	RF1	1	DIP	Fuse Resistor,33R,5%,1W
14	R0,R1	2	0805	Resistor,10K, 5%,1/8W
15	R2	1	2512	Resistor,560R,5%,1W
16	R3,R15	2	1206	Resistor,300K, 5%,1/4W
17	R4,R16	2	1206	Resistor,3K, 5%,1/4W
18	R5	1	0805	Resistor,20K, 5%,1/8W
19	R6	1	0805	Resistor,10R, 5%,1/8W
20	R7	1	0805	Resistor,75K, 5%,1/8W
21	R8	1	0805	Resistor,11K, 5%,1/8W
22	R9	1	0805	Resistor,1.5K, 5%,1/8W
23	R10	1	0805	Resistor,3.9R, 1%,1/8W
24	R11	1	0805	Resistor,2.0R, 1%,1/8W
25	R12,R13	2	0805	Resistor,47K, 5%,1/8W
26	R14	1	0805	Resistor,5.1K, 5%,1/8W
27	U1	1	SOIC-7	AP1695, Diodes IC
28	Q1	1	SOT-23	HV BJT,APT17,50mA/700V,Diodes Inc
29	Q2	1	SOT-23	Mosfet,DMG3420U,20V/4A,Diodes Inc
30	L1	1	DIP	Inductor,6.8mH,0510
31	L2,L3	2	DIP	Inductor,8.2mH,0510
32	T1	1	DIP	EE10 Vertical 4+4Pin,0.87mH
33	PCB	1		FR4 double layer,30mm*16mm

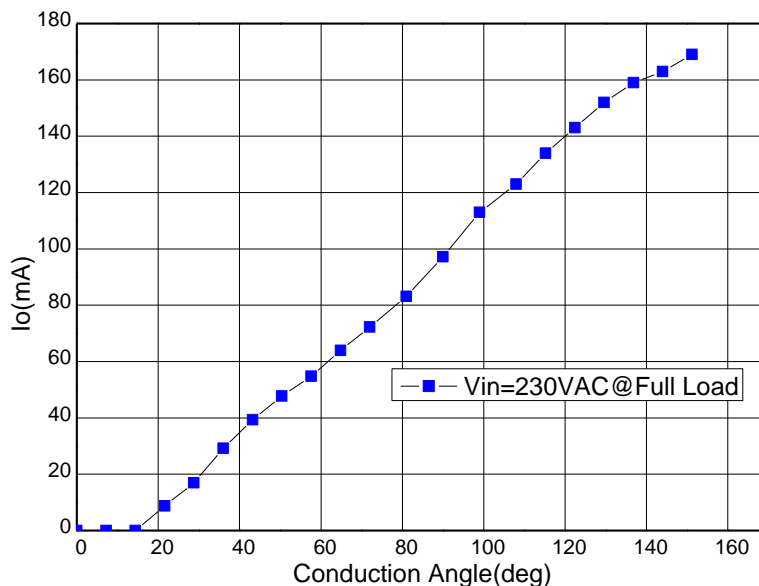
### Functional Performance



### Dimming Test

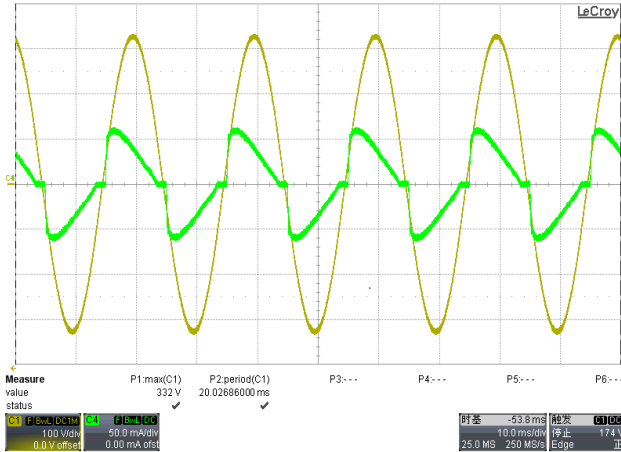
#### Dimmer compatibility and dimming range

Dimmer Type	Io(mA)		Dimming percentage(%)		Flicker or not?
	Min	Max	Min	Max	
EN P500	9.5	164	5.31	91.62	No
Rabtree CPU-2W400	0	174	0.00	97.21	No
HPM Cat 400L	18.4	136	10.28	75.98	No
HPM Cat 250L	31.1	160	17.37	89.39	No
CLIPSAL	0	154	0	86.03	No
LUNED he T46	62.6	173	34.97	96.65	No
JUNG	12.7	166	7.09	92.74	No
Busch 6513U-102	78.5	174	43.85	97.21	No
KIFANSIM(6)	50.2	178	28.04	99.44	No
SIEMENS	3.34	167	1.87	93.30	No
Legrand	78.2	170	43.69	94.97	No
UK 52055SL	24.3	147	13.58	82.12	No
SIEMENS(1)	41.6	161	23.24	89.94	No
WMS549(7)	50.7	165	28.32	92.18	No
Panasonic	0	162	0.00	90.50	No
5TG0200-1CC1	24.9	171	13.91	95.53	No
SIEMENS 5TC8284	57.1	169	31.90	94.41	No

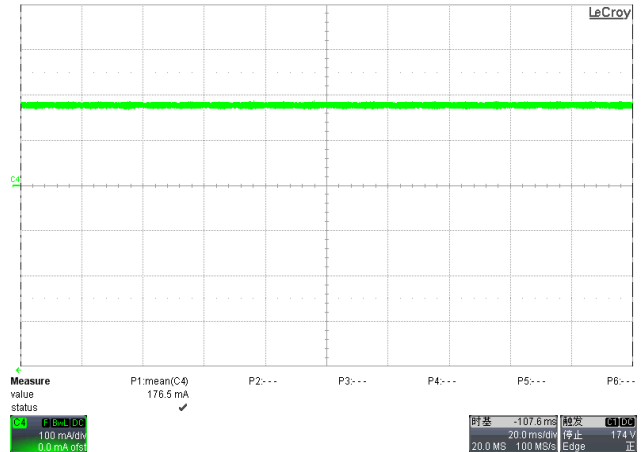


### Functional Waveform

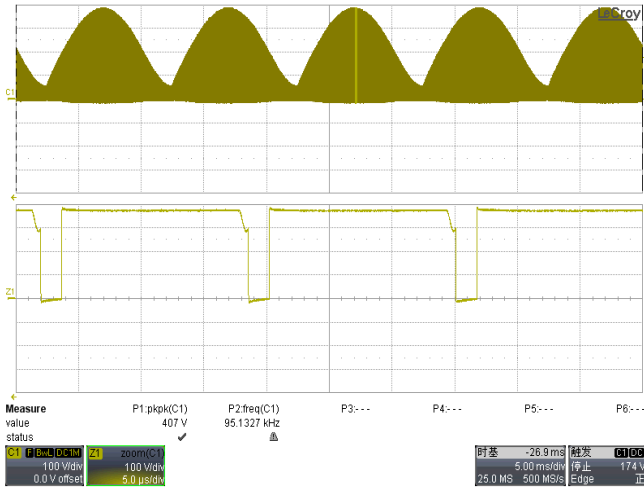
**Input Voltage & Input Current**  
( $V_{in}=230V/50Hz$ )



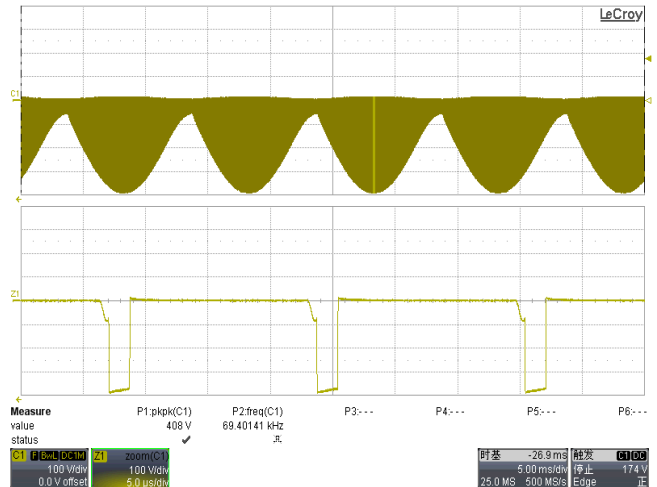
**LED Current Ripple**  
( $V_{in}=230V_{AC}/50Hz$  Ripple=13mA)



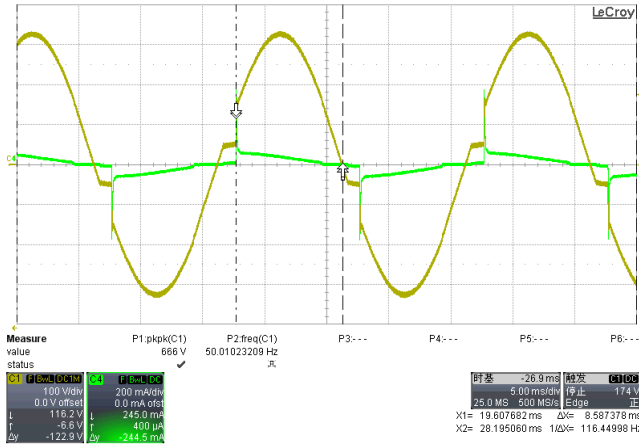
**IC V<sub>DRAIN</sub> Waveform**  
( $V_{in}=264V_{AC}/50Hz$ ,  $V_{DRAIN}=407V$ )



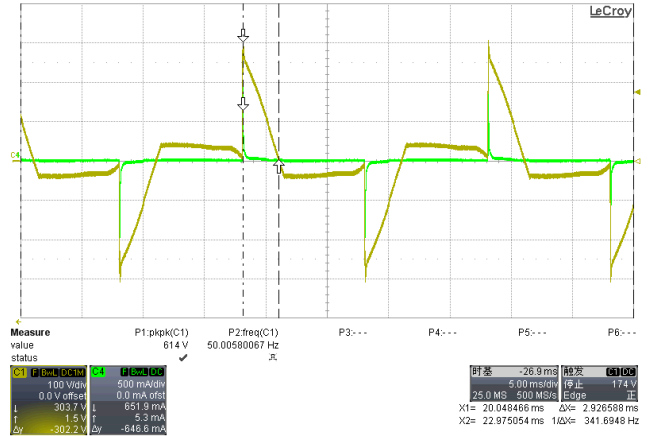
**Output Diode V<sub>R</sub> Waveform**  
( $V_{in}=264V_{AC}/50Hz$ ,  $V_R=408V$ )



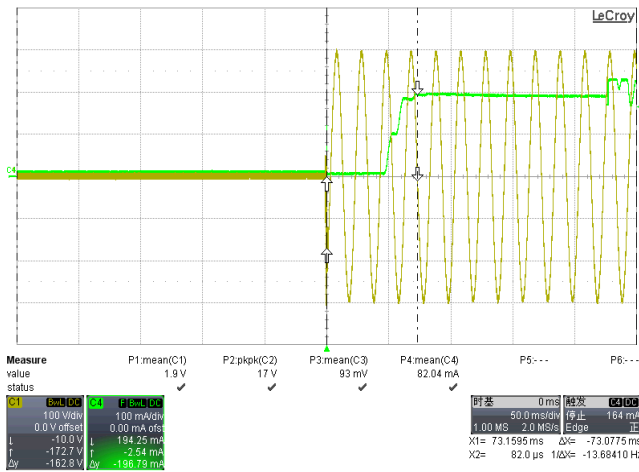
**Input AC Current vs Dimmer Phase**  
(Vin=230VAC/50Hz, Conduction angle 151deg)



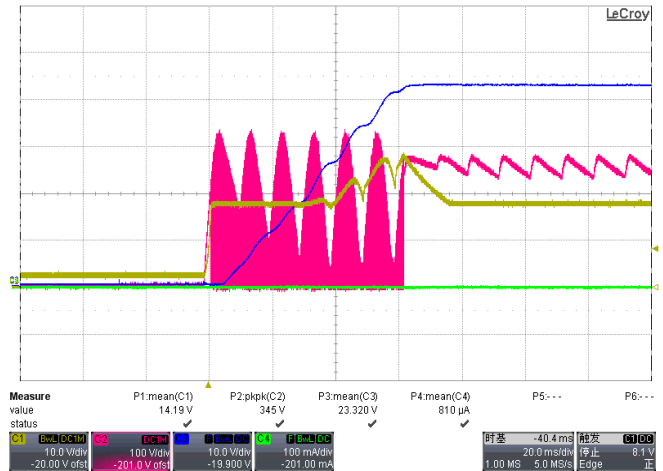
**Input AC Current vs Dimmer Phase**  
(Vin=230VAC/50Hz, Conduction angle 52deg)



**Start-up time**  
(Vin=198VAC/60Hz, Start-up time=73ms)



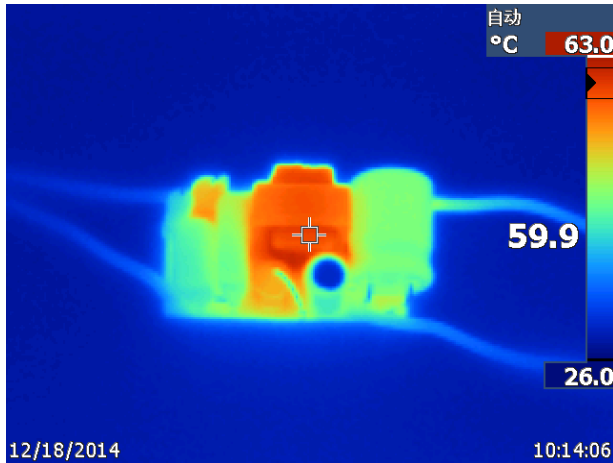
**LED Open Protection (Vin=120VAC/60Hz)**  
Y-VCC, R-VDRAIN, B-Vout, G-ILED



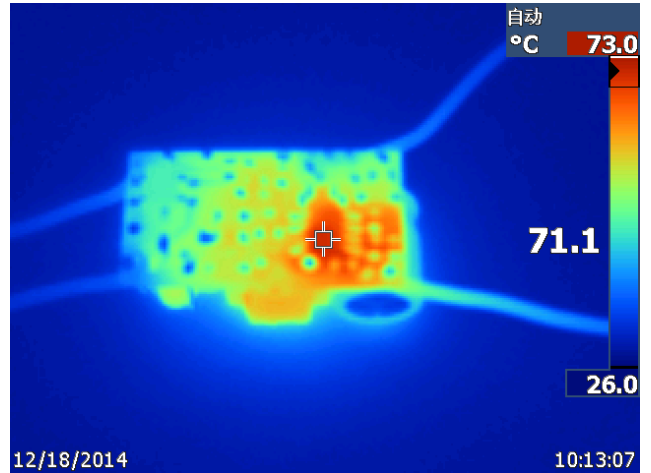


### Thermal Test

**Top**  
(Vin=230VAC, Burn-in time=30min)

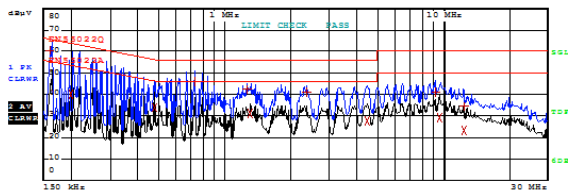
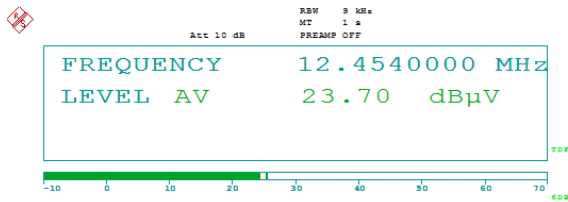


**Bottom**  
(Vin=230VAC, Burn-in time=30min)



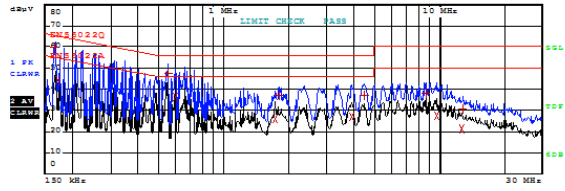
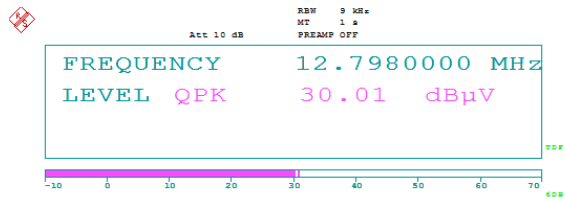
### Conduction Test

**Line Terminal**  
(Vin=230VAC, Margin>5dB)



Date: 23.MAY.2014 16:04:33

**Neutral Terminal**  
(Vin=230VAC, Margin>5dB)



Date: 23.MAY.2014 16:03:21

EDIT PEAK LIST (Final Measurement Results)			
Trace1:	EN55022Q		
Trace2:	EN55022A		
Trace3:	---		
TRACE	FREQUENCY	LEVEL dB $\mu$ V	DELTA LIMIT dB
1 Quasi Peak	1.62 KHz	60.58	-4.77
2 Average	202 KHz	39.94	-13.58
2 Average	478 KHz	33.95	-12.42
1 Quasi Peak	730 KHz	46.03	-9.96
1 Quasi Peak	1.266 MHz	42.24	-13.75
2 Average	1.318 MHz	31.07	-14.92
1 Quasi Peak	2.382 MHz	40.88	-15.11
2 Average	4.486 MHz	28.06	-17.93
1 Quasi Peak	9.238 MHz	41.08	-19.92
2 Average	9.662 MHz	29.40	-20.59
1 Quasi Peak	12.454 MHz	34.48	-25.51
2 Average	12.454 MHz	23.06	-26.93

EDIT PEAK LIST (Final Measurement Results)			
Trace1:	EN55022Q		
Trace2:	EN55022A		
Trace3:	---		
TRACE	FREQUENCY	LEVEL dB $\mu$ V	DELTA LIMIT dB
1 Quasi Peak	1.66 KHz	59.76	-5.39
2 Average	174 KHz	44.04	-10.72
1 Quasi Peak	554 KHz	47.58	-8.41
2 Average	598 KHz	36.47	-9.52
2 Average	1.726 MHz	26.18	-19.81
1 Quasi Peak	1.81 MHz	37.19	-18.80
2 Average	3.914 MHz	27.11	-18.88
1 Quasi Peak	4.49 MHz	37.05	-18.95
1 Quasi Peak	8.646 MHz	38.14	-21.85
2 Average	9.734 MHz	27.21	-22.78
2 Average	12.738 MHz	21.19	-28.80
1 Quasi Peak	12.798 MHz	30.77	-29.22

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