

### 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 >0.85
- High efficiency >83%
- THD<30%

### Applications

- Retrofit Candle, GU10 lamps

### Specifications

Parameter	Value
AC Input Voltage	108V-132V
Output Power	4.05W
LED Current	135mA
LED Voltage	30V
Power Factor	>0.85
Efficiency	83%
XYZ Dimension	30x16x15mm
ROHS Compliance	Yes

### Evaluation Board

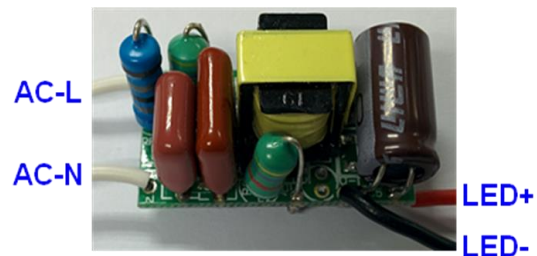


Figure 1: Top View

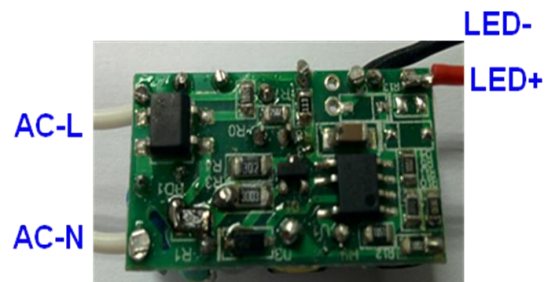


Figure 2: Bottom View

### Connection Instructions:

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

### Board Layouts

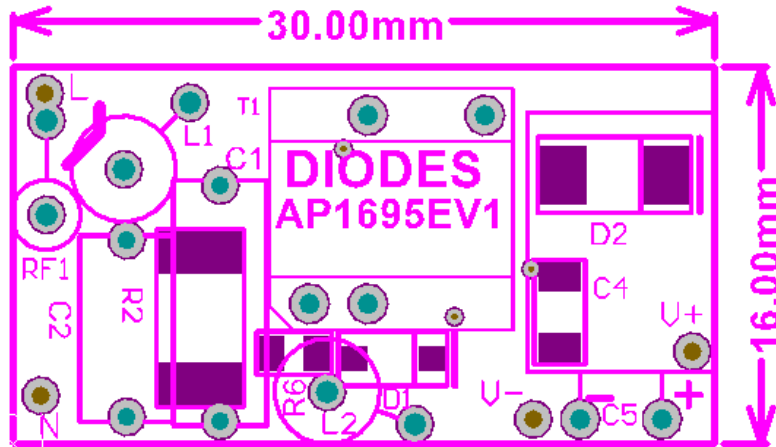


Figure 3: PCB Layout Top View

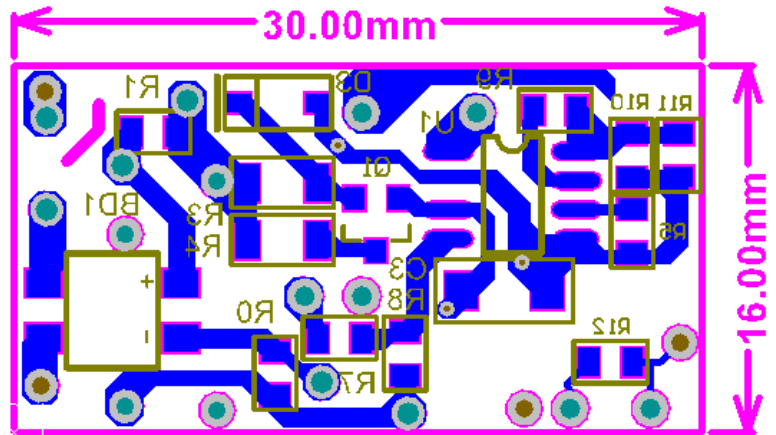


Figure 4: PCB Layout Bottom View

### Quick Start Guide

1. Preset the isolated AC source to 120V<sub>ac</sub>.
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

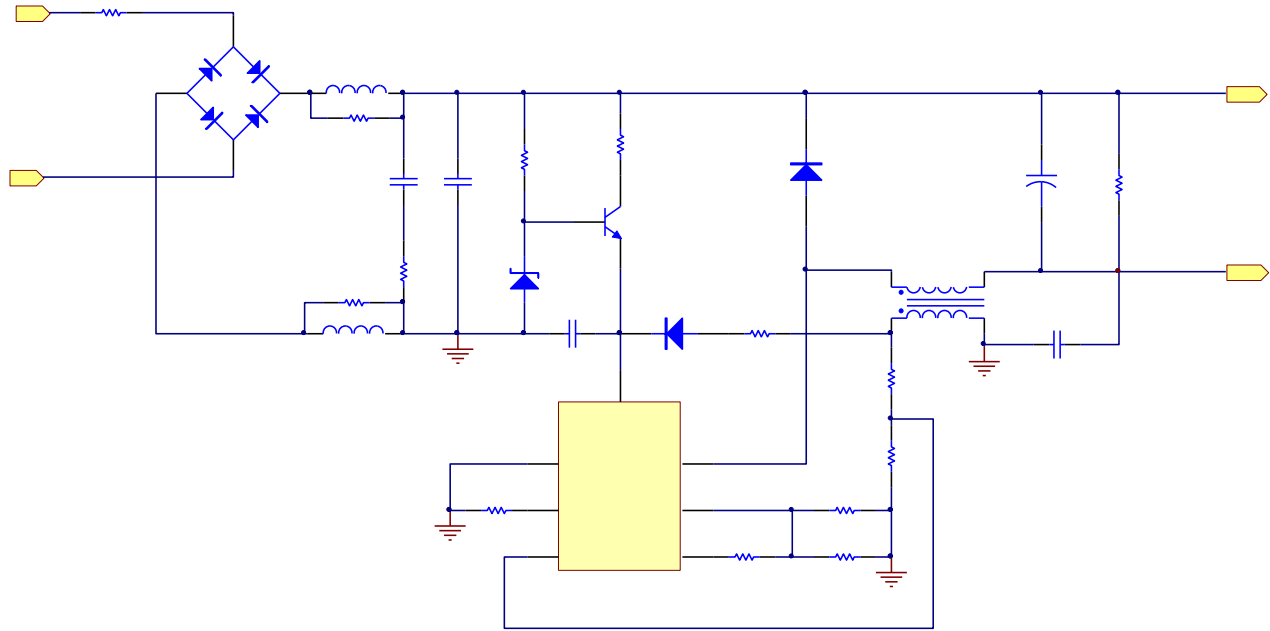


Figure 5: Schematic Circuit

### Transformer Design

#### Bobbin and Core

EE10 Vertical 4+4 pin

#### Transformer Parameters

1. Primary Inductance (Pin 5-Pin 7, all other windings open):  $L_p=1.0\text{mH}$ ,  $\pm 5\% @ 1\text{kHz}$
2. Primary Winding Turns (Pin 5-Pin 7):  $N_p=157\text{Ts}$
3. Auxiliary Winding Turns (Pin 1-Pin 2):  $N_p=105\text{Ts}$

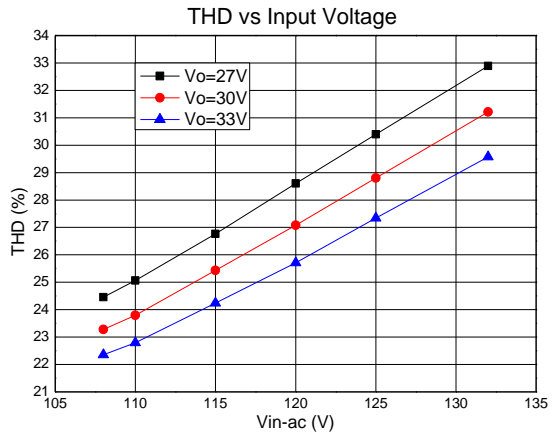
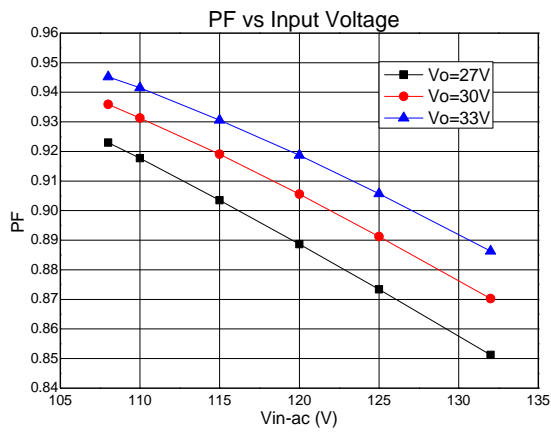
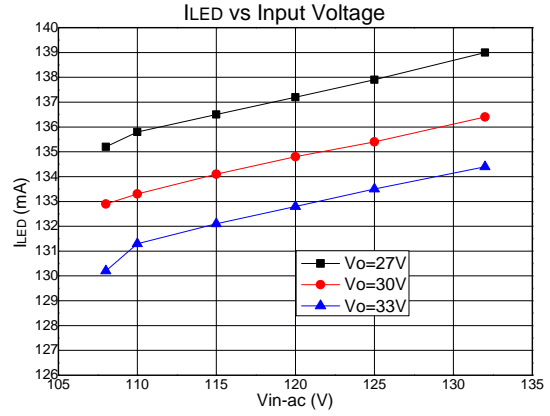
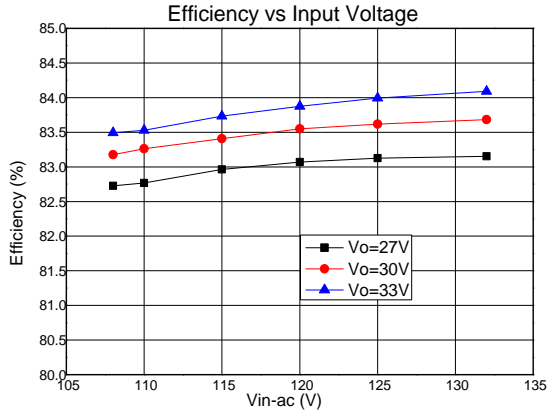
#### Transformer Winding Construction Diagram

Item	Winding name	Description
1	WD1-Primary Winding	Start at Pin5, Wind 157 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 105 turns of $\Phi 0.13\text{mm}$ wire and finish on Pin2.
4	Insulation	3 Layers of insulation tape

### Bill of Material

#	Item	Quantity	Package	Description
1	C1	1	DIP	330nF/250V,CL21,D= 7.5mm
2	C2	1	DIP	220nF/250V,CL21,D=7.5mm
3	C3	1	1206	Ceramic Cap,4.7uF/50V,X7R
4	C4	0	1206	NC
5	C5	1	DIP	E-Cap,105°C,150uF/50V,8*13mm
6	D1	1	SOD-123	BAV21W,200mA/250V,Diodes Inc
7	D2	1	SMA	ES1J,1A/600V
8	D3	1	SOD-123	Zener, DDZ9707, 20V/0.5W,Diodes Inc
9	BD1	1	MiniDIP	Rectifier Bridge,HD06,0.8A/600V,Diodes Inc
10	RF1	1	DIP	Fuse Resistor,68R,5%,1W
11	R0,R1	2	0805	Resistor,5.1K, 5%,1/8W
12	R2	1	2512	Resistor,330R,5%,1W
13	R3	1	1206	Resistor,300K, 5%,1/4W
14	R4	1	1206	Resistor,3K, 5%,1/4W
15	R5	1	0805	Resistor,30K, 5%,1/8W
16	R6	1	0805	Resistor,10R, 5%,1/8W
17	R7	1	0805	Resistor,75K, 5%,1/8W
18	R8	1	0805	Resistor,11K, 5%,1/8W
19	R9	1	0805	Resistor,1.5K, 5%,1/8W
20	R10	1	0805	Resistor,3.9R, 1%,1/8W
21	R11	1	0805	Resistor,3.3R, 1%,1/8W
22	R12	1	0805	Resistor,30K, 5%,1/8W
23	U1	1	SOIC-7	AP1695, Diodes IC
24	Q1	1	SOT-23	HV BJT,APT17,50mA/700V,Diodes Inc
25	L1,L2	2	DIP	Inductor,4.7mH,0510
26	T1	1	DIP	EE10 Vertical 4+4Pin 1.0mH
27	PCB	1		FR4 double layer,30mm*16mm

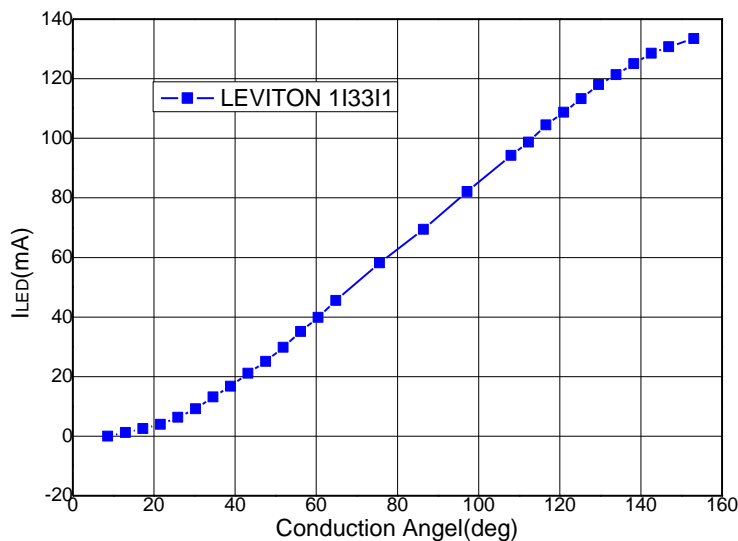
### Functional Performance



### Dimming Test

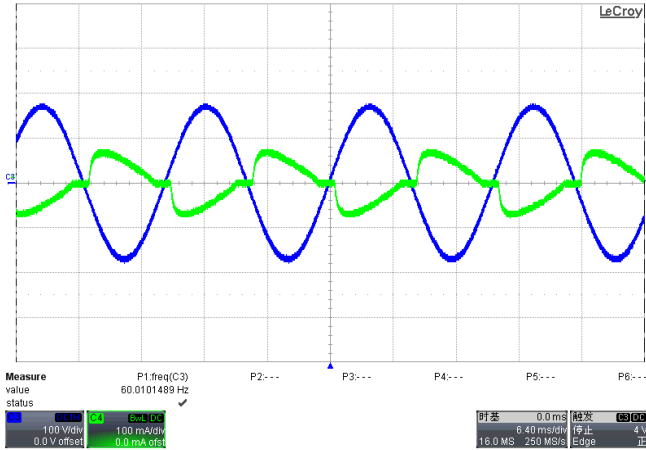
#### Dimmer compatibility and dimming range

Dimmer Type	I <sub>o</sub> (mA)		Dimming percentage(%)		Flicker or not?
	Min	Max	Min	Max	
LUTRON S-600P	2.87	112.67	1.60	62.94	No
LUTRON LISTED6B38	11.75	108.29	6.56	60.50	No
LUTRON TG-103P	11.75	103.53	6.56	57.84	No
LEVITON 1F3011	0.00	133.41	0	74.53	No
LUTRON TGCL-153P	7.01	110.31	3.92	61.63	No
COOPER Cat.No.9539	11.01	99.77	6.15	55.74	No
LUTRON TG-10P	10.00	106.20	5.59	59.33	No
LEVITON Cat NO.6674	8.41	116.11	4.70	64.87	No
LEVITON Cat NO.TGI06	8.49	109.98	4.74	61.44	No
LUTRON D600F	0.34	107.40	0.19	60.00	No
LEVITON 1L1005	0.00	117.92	0	65.88	No
LEVITON 1I3311	0.00	133.19	0	74.41	No
LEVITON Cat NO.6613-P	5.80	127.68	3.24	71.33	No
LUTRON DV-603P	4.64	112.37	2.59	62.78	No
LUTRON CT-603PG	5.06	88.09	2.83	49.21	No

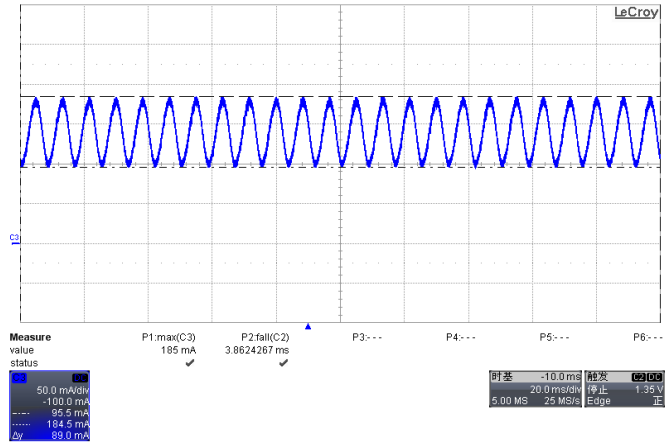


### Functional Waveform

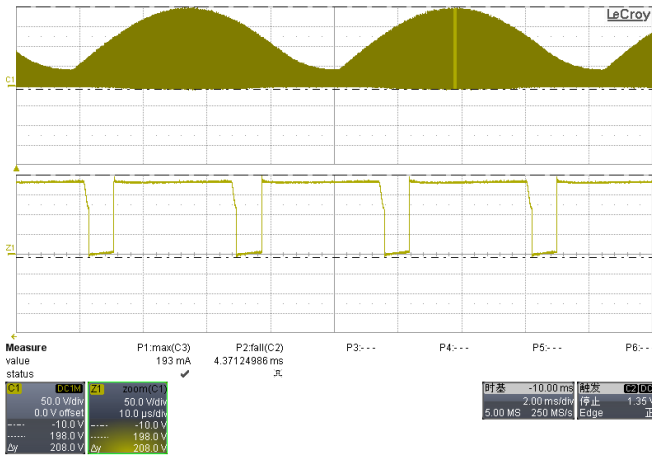
**Input Voltage & Input Current**  
( $V_{in}=120V/60Hz$ )



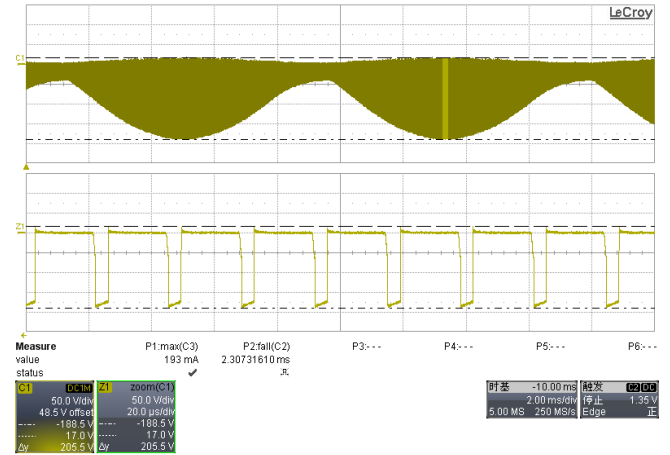
**LED Current Ripple**  
( $V_{in}=120VAC/60Hz$  Ripple=89mA)



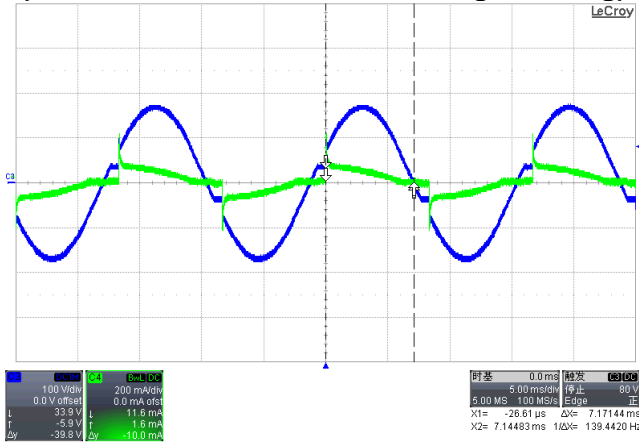
**IC VDRAIN Waveform**  
( $V_{in}=132VAC/60Hz$ ,  $V_{DRAIN}=208V$ )



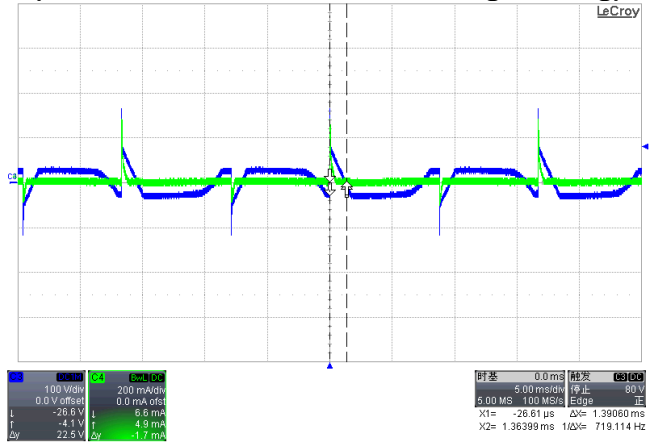
**Output Diode VR Waveform**  
( $V_{in}=132VAC/60Hz$ ,  $V_R=205.5V$ )



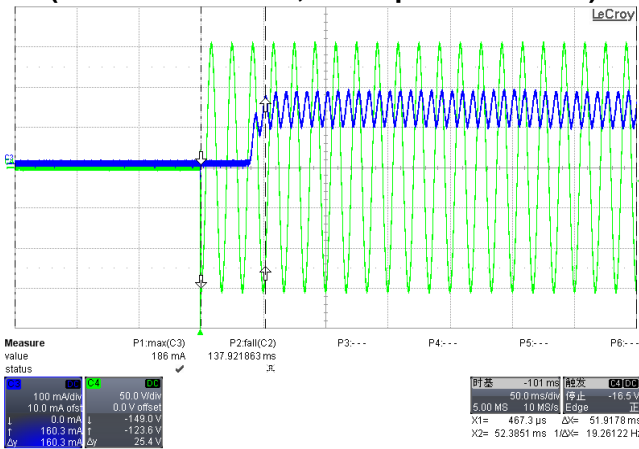
**Input AC Current vs Dimmer Phase**  
( $V_{in}=120VAC/60Hz$ , Conduction angle 155deg)



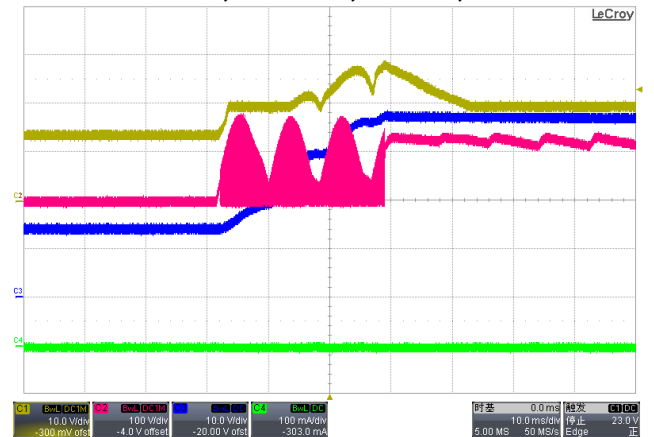
**Input AC Current vs Dimmer Phase**  
( $V_{in}=120VAC/60Hz$ , Conduction angle 30deg)



**Start-up time**  
( $V_{in}=108VAC/60Hz$ , Start-up time=51.9ms)



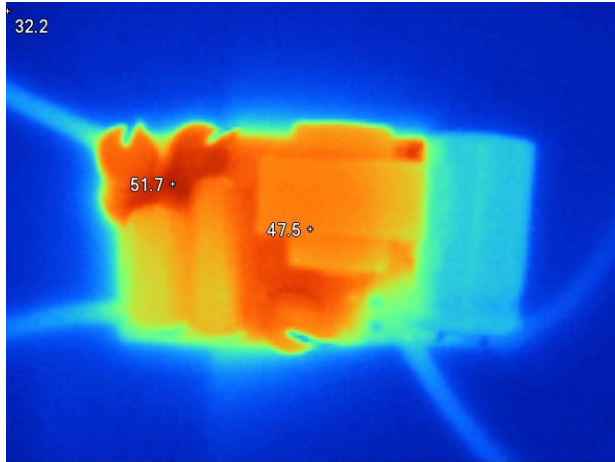
**LED Open Protection**( $V_{in}=120VAC/60Hz$ )  
Y-VCC, R-V<sub>DRAIN</sub>, B-V<sub>out</sub>, G-I<sub>LED</sub>



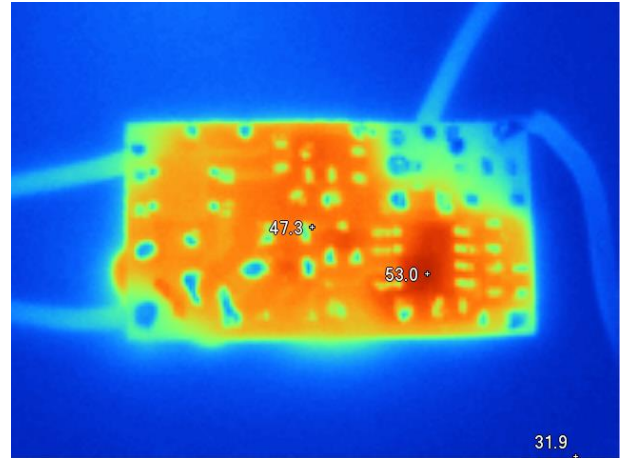


### Thermal Test

**Top**  
(Vin=120VAC, Burn-in time=30min)

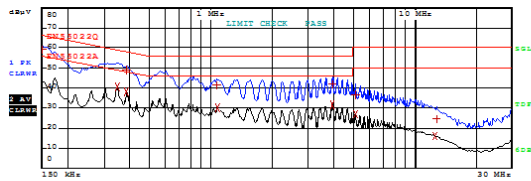


**Bottom**  
(Vin=120VAC, Burn-in time=30min)



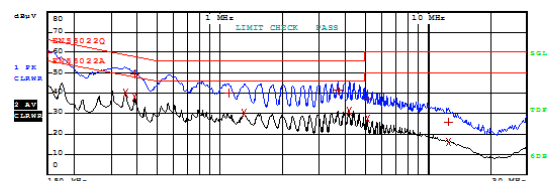
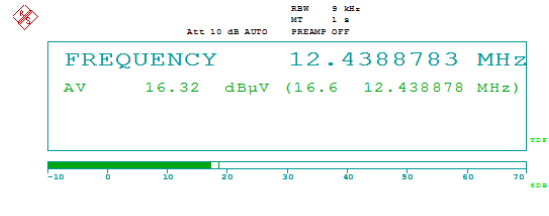
### EMI Conduction Test

**Line Terminal**  
(Vin=120VAC, Margin>6dB)



Date: 1.AUG.2014 15:13:37

**Neutral Terminal**  
(Vin=120VAC, Margin>6dB)



Date: 1.AUG.2014 15:10:19

EDIT PEAK LIST (Final Measurement Results)				
Trace1:	ENS5022Q			
Trace2:	ENS5022A			
Trace3:	---			
TRACE	FREQUENCY	LEVEL dB $\mu$ V	DELTA LIMIT dB	
1 Quasi Peak	150 kHz	59.36 L1 gnd	-6.63	
2 Average	346.008411606 kHz	40.34 L1 gnd	-8.71	
1 Quasi Peak	386.030632509 kHz	49.07 L1 gnd	-9.07	
2 Average	386.030632509 kHz	37.96 L1 gnd	-10.18	
1 Quasi Peak	1.06512622736 MHz	41.27 L1 gnd	-14.73	
2 Average	1.07577950963 MHz	30.05 L1 gnd	-15.94	
1 Quasi Peak	3.9219482581 MHz	41.97 L1 gnd	-14.02	
2 Average	3.9219482581 MHz	31.53 L1 gnd	-14.46	
1 Quasi Peak	5.13072753076 MHz	36.65 L1 gnd	-23.34	
2 Average	5.13072753076 MHz	27.06 L1 gnd	-22.94	
2 Average	12.4388782936 MHz	16.27 L1 gnd	-33.72	
1 Quasi Peak	12.6888997473 MHz	24.50 L1 gnd	-35.49	

EDIT PEAK LIST (Final Measurement Results)				
Trace1:	ENS5022Q			
Trace2:	ENS5022A			
Trace3:	---			
TRACE	FREQUENCY	LEVEL dB $\mu$ V	DELTA LIMIT dB	
1 Quasi Peak	150 kHz	59.53 L1 gnd	-6.46	
2 Average	349.468495722 kHz	39.84 L1 gnd	-9.13	
1 Quasi Peak	389.890938834 kHz	49.14 L1 gnd	-8.92	
2 Average	389.890938834 kHz	37.93 L1 gnd	-10.13	
1 Quasi Peak	1.09740267777 MHz	39.87 L1 gnd	-16.13	
2 Average	1.29965885429 MHz	30.13 L1 gnd	-15.86	
1 Quasi Peak	3.69465266945 MHz	41.29 L1 gnd	-14.70	
2 Average	4.16322710559 MHz	31.09 L1 gnd	-14.90	
1 Quasi Peak	5.13072753076 MHz	37.09 L1 gnd	-22.90	
2 Average	5.13072753076 MHz	27.19 L1 gnd	-22.81	
1 Quasi Peak	12.4388782936 MHz	25.91 L1 gnd	-34.08	
2 Average	12.4388782936 MHz	16.23 L1 gnd	-33.77	

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