Title	***Engineering Prototype Report (EPR-00015)*** ***3W, Universal Input, Single Output, Isolated Converter with TNY254 (EP-15)***
Recipients	
Application	Battery Charger
Author	S. L.
Date	11-November -2000

Abstract

This document presents the specification, schematic & BOM, transformer calculation, test data, wave forms and EMI scan for a low cost, isolated converter for a battery charging application.

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Contents

1.0 Introduction

This document presents the specification, schematic & BOM, transformer design, test data, wave forms and EMI scan for a low cost, isolated converter (EP15) for low current battery charging applications (long charging time, NiCd). A typical application is illustrated in Figure 1.1.
The unit has low input voltage detection circuit, programmable for 110 or 220Vac operation.
When the line voltage drops below the threshold, the battery energizes the inverter and the lamp turns on.
When the line voltage exceeds the threshold, the battery is disconnected from the inverter, the lamp turns off and the battery is recharged.
The EP15 output voltage can be reduced, while maintaining the same charging current (reduced power).
The EP15 is designed to meet the industry's safety and EMI standards.

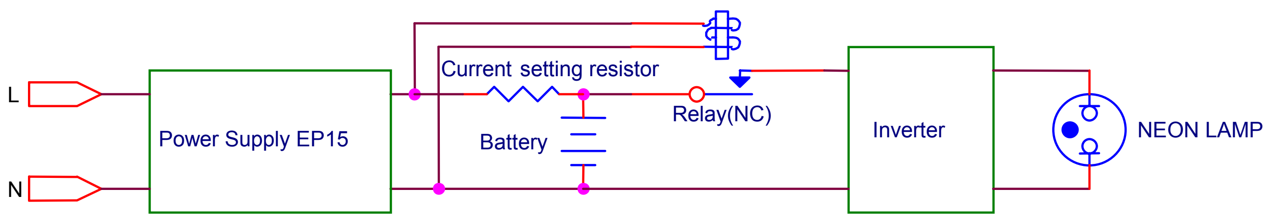


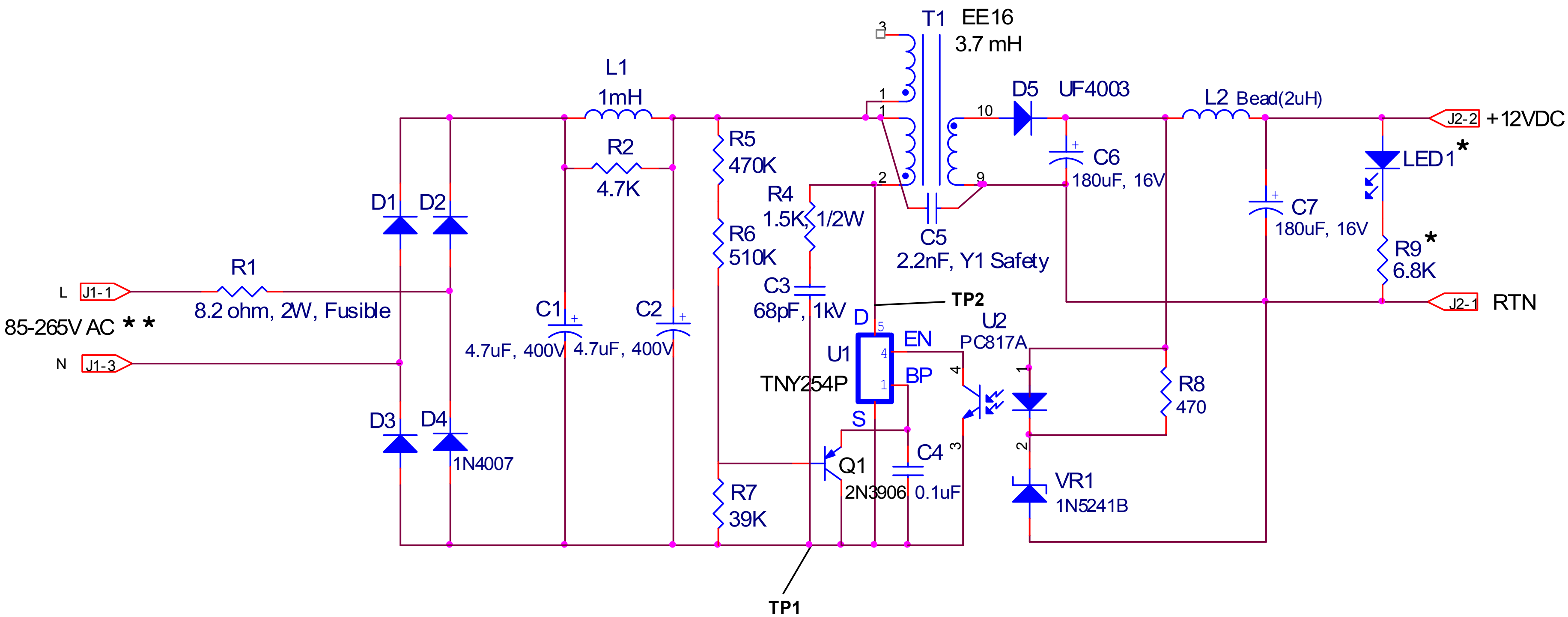
Figure 1.1. Battery charger block diagram.

2.0 Power Supply Requirements Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Operating Input Voltage	Vin	85*		265	Vac	50/60Hz
No load input power				250	mW	@ 230Vac
Output						Green LED indicator
Output Voltage**	Vout		12		Vdc	+/-6% Total
Output Ripple Voltage	Vout ripple			200	mV	Peak to Peak
Output Current ***	Iout		0.25		A	
Power Output						
Continuous Output Power	Pout		3		W	@ Full Load
Power supply efficiency	η		75		%	@ Full Load
Environmental						
Temperature	Tamb	0	25	50	°C	
Safety						IEC950/UL1950
Surge (differential, 2 ohm)	Line-Line		1		kV	IEC/UL 1000-4-5 Class 3
Surge (common mode, 12 ohm)	Line-Earth		2		kV	IEC/UL 1000-4-5 Class 3
EMI-Conducted						CISPR22B

*Under voltage lockout threshold set/programmable with a voltage divider (100Vac for universal input, 175Vac for single voltage input 230Vac).
**Can be adjusted by changing the output Zener diode VR1.
***The maximum short circuit current is 0.94A

3.0 Schematic



Title	12Vdc, 3W Battery Charger	
Size B	Document Number EP15	Rev F
Date: Tuesday, January 16, 2001	Sheet 1 of 1	

*OPTIONAL

* * Minimum voltage determined by the undervoltage lockout circuit(R5, R6 and R7 values).

4.0 Circuit Description

This circuit was designed for emergency lighting battery charging applications.
The unit stops charging when the mains voltage drops below ~175Vac (in a 230Vac system), or ~100Vac (in a 120Vac or universal system). The voltage threshold is set/programmable with the voltage divider R5, R6 and R7. Two ¼ W resistors (R5, R6) are connected in series for voltage rating and board layout flexibility.
For 100Vac threshold R5=470K, R6=510K and R7=39K.
For 175Vac threshold R5=820K, R6=910K and R7=39K.
The threshold accuracy is determined by the resistor value tolerance and is temperature sensitive as the Vbe of Q1.

The EMI standard is met with a low cost transformer (only shield winding, no need for flux band) and low cost input filter (no common mode choke). The R4, C3 snubber reduces the drain dV/dt of U1 (slows the switching speed), reducing the EMI.

In this application, the AC input is rectified and filtered by D1-D4, C1 and C2 to create a high voltage DC bus which is connected to T1. Inductor L1 forms a pi-filter in conjunction with C1 and C2. The resistor R2 damps resonance in inductor L1. The operating mode of TNY254 allows the unit to meet worldwide conducted EMI standards using a simple pi-filter in combination with a small value Y1-capacitor C5 and a proper PCB layout. R4 and C3 form a snubber circuit that limits the turn-off voltage spike to a safe level on the TNY254 DRAIN pin.
The secondary winding is rectified and filtered by D5, C6 with additional filtering provided by L2, C7 to give the 12Vdc output. The output voltage is determined by the sum of the voltage drops across the opto-coupler U2 and the Zener diode VR1 at the bias point. The optocoupler voltage drop is minimum (<1V) at the current required for the TinySwitch control pin and varies with the optocoupler part number. With a 11V 5% zener the output voltage could be as low as 7% off the nominal 12Vdc. For better nominal voltage accuracy a 2% zener should be used.
Resistor R8 sets the bias current for VR1 and improves the optocoupler U2 response time. If LED1 is not used, R8 value can be decreased such that VR1 pre-loading maintains the no-load output regulation.
The primary-to-secondary isolation is assured by using parts/materials (opto/transformer insulation) with the correct level of isolation and creepage distances (opto slot/transformer bobbin).
The 12Vdc monitoring light emitting diode (LED1) and R9 are optional, and have been included in this circuit for troubleshooting convenience. R9 dissipates approximately 20mW and helps the no-load output regulation.

Test points TP1 (U1 SOURCE) and TP2 (U1 DRAIN) are provided for ease of monitoring Vds.

5.0 Layout

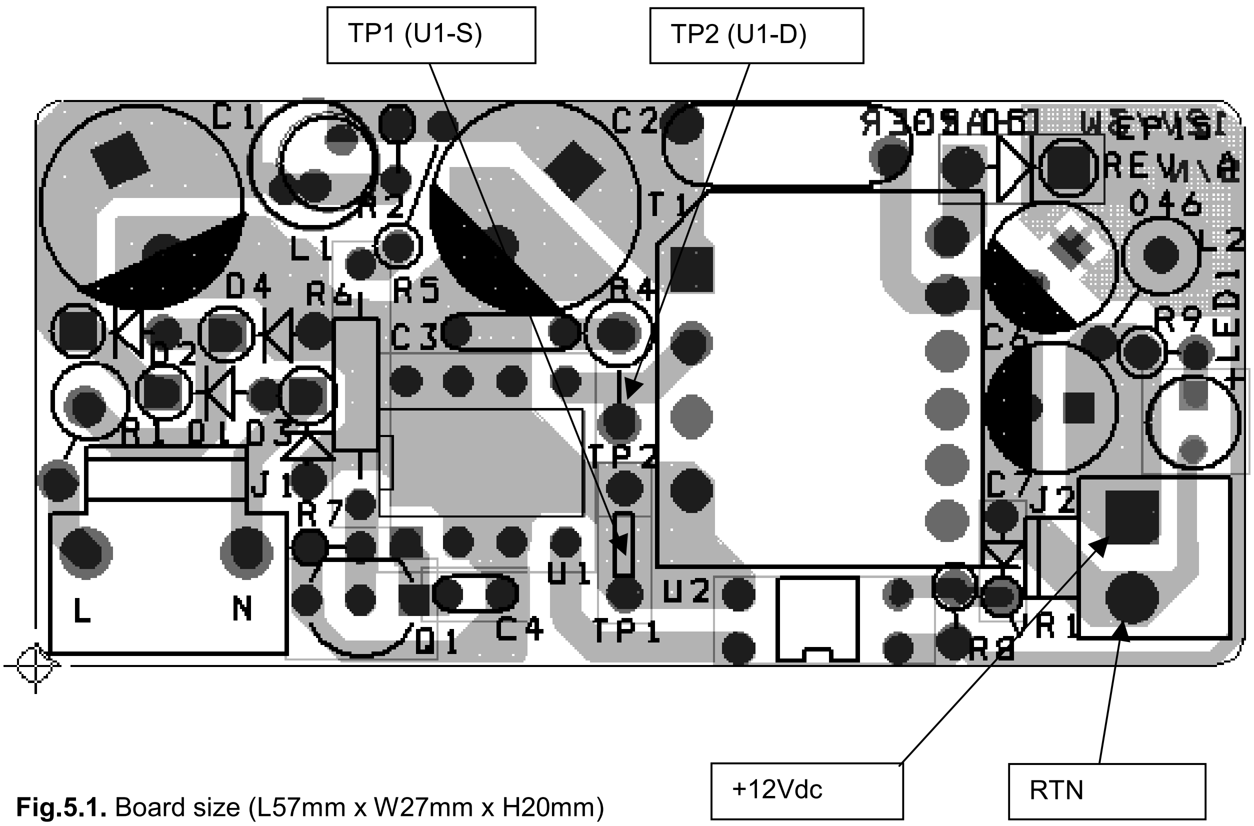


Fig.5.1. Board size (L57mm x W27mm x H20mm)

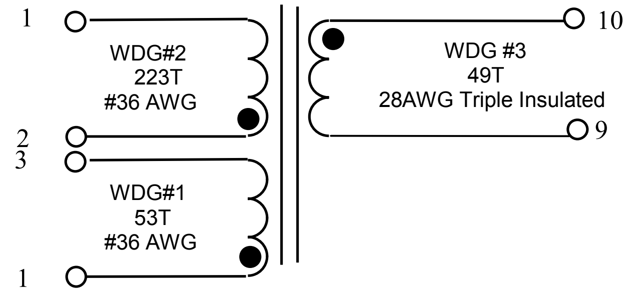
- For the drain-to-source voltage waveforms connect the high voltage probe tip to TP2 and the probe ground to test point TP1.
- For switching current waveforms replace jumper TP2 with a wire loop and use a Tektronix A6302 current probe and AM503 current probe amplifier (with TM501 power module) or equivalent.

6.0 Bill of Materials

Item	Qty.	Ref.	Description	Part number	Manufacturer
1	2	C1	4.7uF, 400V	475 CKH400M	Illinois Cap
		C2	4.7uF, 400V		
2	1	C3	68pF, 1kV	ECC-D3A680JGE	Panasonic
3	1	C4	0.1uF/50V	RPE121Z5U104M50V	Murata
4	1	C5	2.2nF, Y1 Safety, 5.7mm	440LD22	Cera-mite
5	2	C6	180uF, 16V	EEU-FC1C181	Panasonic
		C7	180uF, 16V		
6	4	D1	1A, 600V/1000V	1N4007	Generic
		D2			
		D3			
		D4			
7	1	D5	1A, 200V, 50nsec	UF4003 (UF1003)	GenSemi (Vishay)
8	1	J1	Header (0.156" spacing, 3pos.)	26-48-1035	Molex
9	1	J2	Header (0.156" spacing, 2pos.)		Molex
10	1	LED1	low current, GRN	LG3369	Siemens
11	1	L1	1 mH, 0.15A	47HY102B	Tokin
12	1	L2	2uH, Bead,D3.5xL12,	LBC035138-B	TSC Electronics
13	1	Q1	200MHz (PNP, TO92)	2N3906	Generic
14	1	R1	8.2 ohm, 5%, Fusible	253-4 8R2 (F1W8D2)	Vitrohm (NTE)
15	1	R2	4.7K, 1/8W		Generic
16	1	R4	1.5K, 1/2W		Generic
17	1	R5	470K, 1/4W		Generic
18	1	R6	510K, 1/4W		Generic
19	1	R7	39K, 1/4W		Generic
20	1	R8	470, 1/8W		Generic
21	1	R9	6.8K, 1/4W		Generic
22	1	T1	EE16, 3.7mH	CTX 14-15181-X2 48FLO	Cooper
23	1	U2	Optocoupler	PC817A	Sharp
24	1	U1	TinySwitch	TNY254P	Power Integrations
25	1	VR1	Zener diode,11V, 5%	1N5241B	Generic

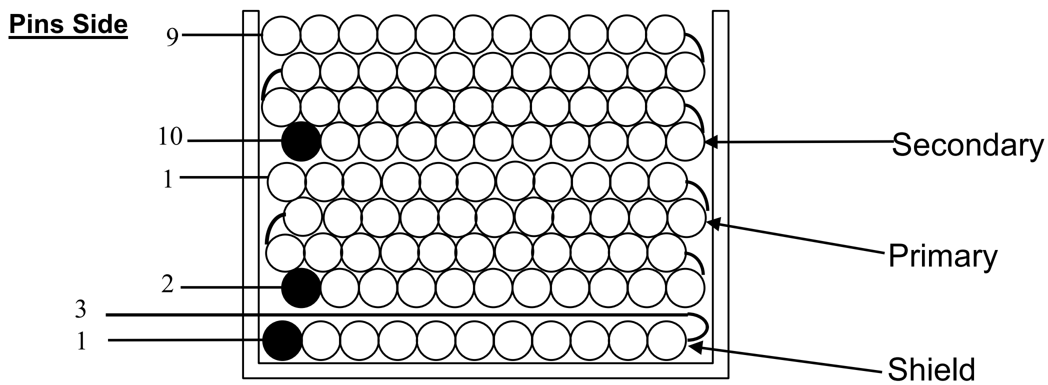
7.0 Transformer – T1

7.1 Transformer drawing



Electrical Specifications:

Electrical Strength	60Hz 1 minute, from Pins 1-4 to Pins 5-10	3000 VAC
Creepage	Between Pins 1-4 and Pins 5-10	6 mm (Min.)
Primary Inductance	Pins 1,2, all other windings open, measured at 44KHz	3676 μH, ±10%
Resonant Frequency	Pins 1,2, all other windings open	500 KHz (Min.)
Primary Leakage Inductance	Pins 1,2, with Pins 5-10 shorted, measured at 44KHz	300 μH (Max.)



Transformer Construction:

Shield	Start at Pin 1. Wind 53 turns of item [3] in 1 layer. Finish on Pin 3.
Primary	Start at Pin 2. Wind 223 turns of item [3] in 4 layers. Finish on Pin 1.
Secondary Winding	Start at Pin 10. Wind 49 turns of item [4]. Finish on Pin 9.
Final Assembly	Cores, Item [1], glued with a mixture of glass beads, item [5], 5% by weight, and JAC133 epoxy, item [6]. (Contact Power Integrations for further details on epoxy-glass bead construction method)

Materials:

Item	Description
[1]	Core: EE16, Nippon Ceramic NC-2H material or equiv. Gapped for A_{LG} of 74 nH/T^2
[2]	Bobbin: 10 pin EE16, Ying Chin YC1607 or equiv.
[3]	Magnet Wire: #36 AWG Heavy Nyleze
[4]	Magnet Wire: #28 AWG Triple insulated
[5]	Glass beads, DIA=0.249mm available from MO-SCI Corp. Telephone: +1 573 364 2338. Fax: +1 573 364 9589
[6]	Epoxy, JAC133 (or equivalent) available from Jungdo Chemical Company, Ltd. South Korea Telephone: +82 2 856 0391 Fax: +82 2 867 1685

7.2 Transformer Spreadsheet

The use of RC snubber across U1 limits the choice of operation to discontinuous only.

ACDC_TNY_Rev2.02_100899 Copyright Power Integrations Inc. 1999	INPUT	INFO	OUTPUT	UNIT	ACDC_TNY_REV2_02_100899.xls: TinySwitch Continuous/Discontinuous Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					Customer
VACMIN	85			Volts	Minimum AC Input Voltage
VACMAX	265			Volts	Maximum AC Input Voltage
fL	50			Hertz	AC Mains Frequency
VO	12			Volts	Output Voltage
PO	3			Watts	Output Power
n	0.75				Efficiency Estimate
Z	0.5				Loss Allocation Factor
tC	3			mSeconds	Bridge Rectifier Conduction Time Estimate
CIN	9.4			uFarads	Input Filter Capacitor
MODE OF OPERATION					
Continuous ('c') or Discontinuous ('d') ?	d				Continuous mode operation or Discontinuous mode operation?
Fully Discontinuous ('y') ?	n	Mostly Disc.			Need Discontinuous mode operation guaranteed in all conditions?
ENTER TinySwitch Parameters		*Universal*		*115/230Vac*	
TinySwitch	tny254	*4W*	*5W*		
ILIMITmin		*0.23*		Amps	Minimum current limit
ILIMITmax		*0.28*		Amps	Maximum current limit
fSmin	40000.00	*40000*		Hertz	Minimum Frequency
VDS	10			Volts	Voltage drop between Drain to Source
ENTER Output Diode Parameters					
Output Diode					
VR	200			Volts	Diode Maximum Peak Repetitive Reverse Voltage
ID	1			Amps	Diode Average Forward Current
VD	1			Volts	Diode Forward Voltage drop
k	0.8				Diode Ipk to Irms factor (k=0.9 for Schottky, k=0.8 for PN diode, k=0.2 TNY256)
ENTER Other Parameters					
BP	2500			Gauss	Target Peak Flux Density at Maximum Current limit
Design Parameters					
VMIN			92	Volts	Minimum DC Input Voltage
VMAX			375	Volts	Maximum DC Input Voltage
IP			0.21	Amps	Peak Primary current
DMAX			0.419		Duty Cycle at minimum DC input Voltage
KDP	1.00		1.00		
VOR			59.34	Volts	Reflected Output Voltage
VDRAIN			513.77	Volts	Maximum Drain Voltage Estimate
PIVS			94	Volts	Output Rectifier Peak Inverse Voltage
LP			3676	uHenries	**Minimum Primary Inductance**
ENTER TRANSFORMER CORE/CONSTRUCTION					
Core Type	ee16	*EE16*			
Glass Bead Construction (y/n)	y				Glass Beads Construction Chosen
AE		*0.192*		cm^2	Core Effective Cross Sectional Area
LE		*3.5*		cm	Core Effective Path Length
AL		*1140*		nH/T^2	Ungapped Core Effective Inductance
BW		*8.5*		mm	Bobbin Physical Winding Width
M	0			mm	Safety Margin Width
NP			223	Turns	Primary Winding Number of Turns
NS			49	Turns	Number of Secondary Turns
Glass_Bead_Diameter			0.249	mm	Glass Bead Diameter (mm)

CURRENT WAVEFORM SHAPE PARAMETERS					
IRMS			0.08	Amps	Primary RMS Current
IR			0.21	Amps	Primary Ripple Current
ISP			0.94	Amps	Maximum Peak Secondary Current
ISRMS			0.42	Amps	Secondary RMS current
IO			0.25	Amps	Power Supply Output Current
IRIPPLE			0.33	Amps	Output Capacitor RMS Ripple Current
IOS			1.02	Amps	Estimated short circuit current
TRANSFORMER PARAMETERS					
L	4				Number of Primary Layers
ALG			74	nH/T^2	Effective Core Inductance - for Standard ALG values see App Note AN-25
BM			2405	Gauss	Operating Flux Density at Max Current Limit
BAC			1006	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
OD			0.15	mm	Maximum Primary Wire Diameter including insulation
INS			0.03	mm	Taping between primary layers can be eliminated using "Class 0" (Asia), "Grade 2"(Europe) or "Heavy Nyleze" (USA) wire
DIA			0.12	mm	Bare conductor diameter
AWG			37	AWG	Primary Wire Gauge (for low capacitance AWG<= 36 recommended)
CMA			260	Cmils/Amp	Primary Winding Current Capacity (CMA > 200)
AWGS			29	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.29	mm	Secondary Minimum Bare Conductor Diameter

8.0 Performance Data

TEST EQUIPMENT

INPUT: VOLTECH (PM100) AC POWER ANALYSER.
Power Line Meter (EPD Inc.)
OUTPUT: KIKUSUI (PLZ153W) ELECTRONIC LOAD.

8.1 Efficiency

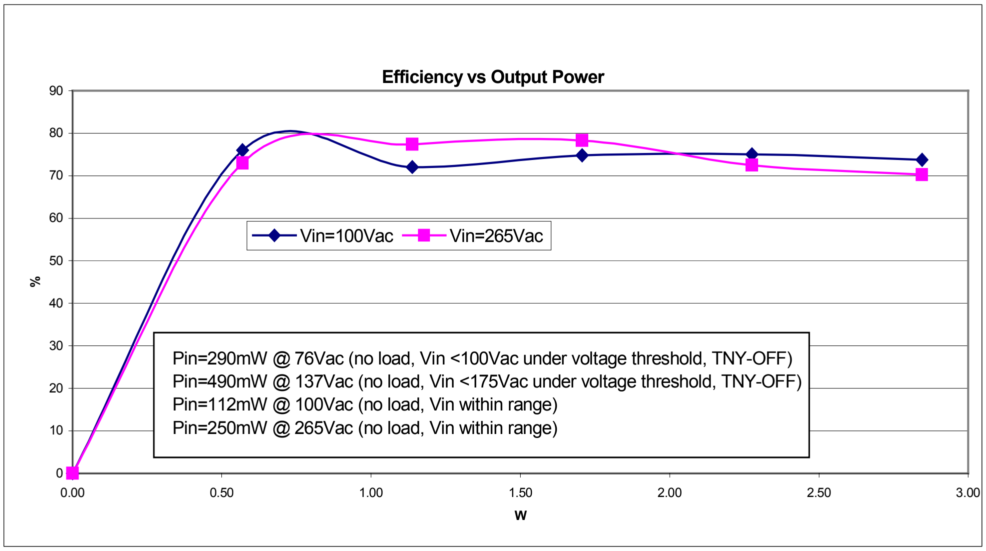


Figure 8.1.1 Efficiency vs output power @ 25C ambient.

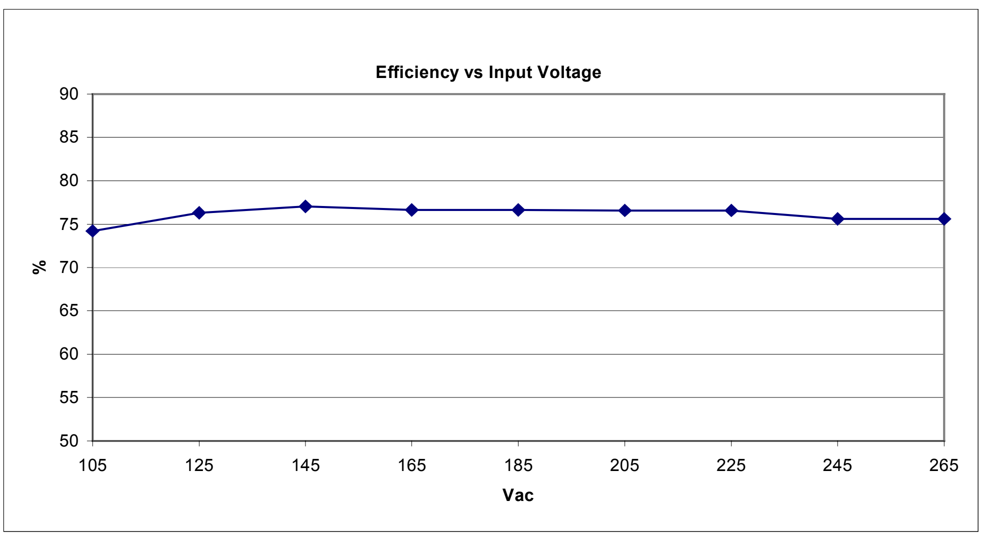


Figure 8.2.1 Efficiency vs input voltage at full load @ 25C ambient.

8.2 Regulation @ 25C ambient

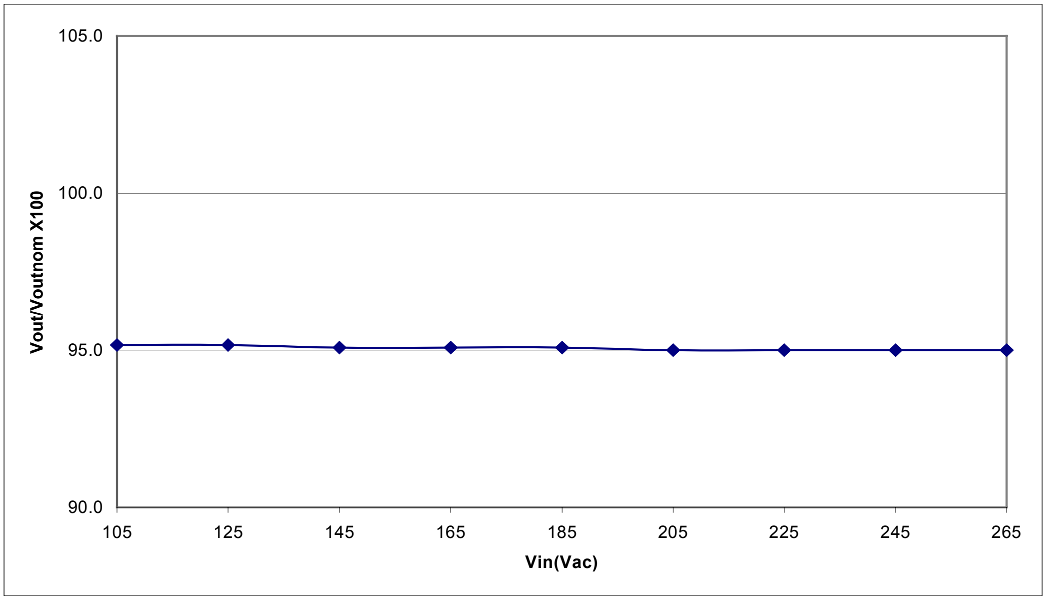


Figure 8.2.1 Line Regulation@full load, 25C ambient

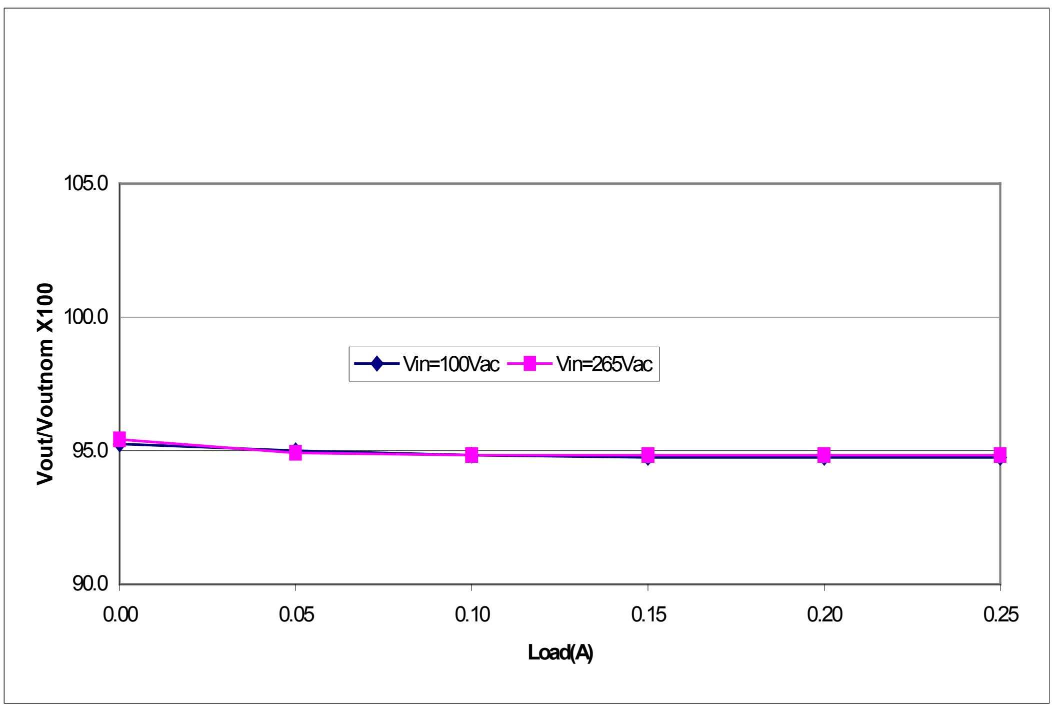


Figure 8.2.2 Load regulation@25C ambient

8.3 Vout vs Iout

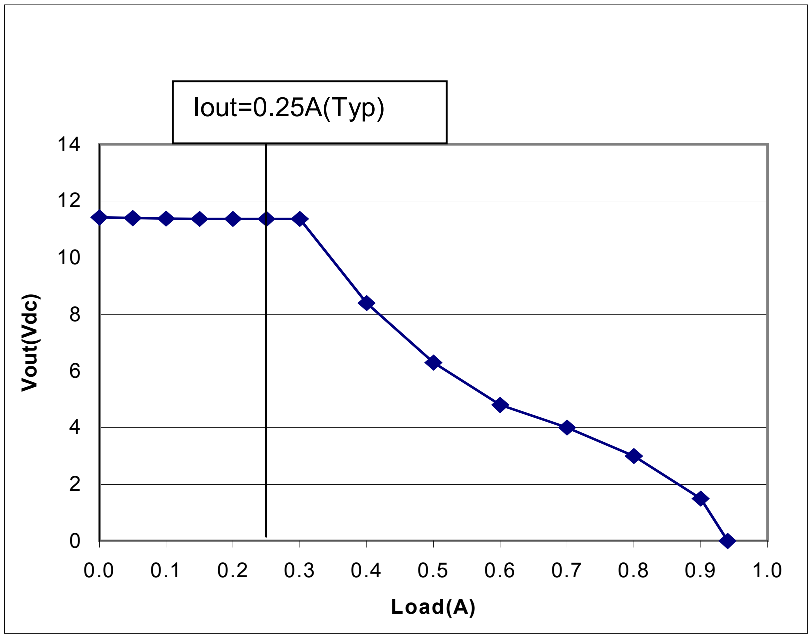


Figure 8.3.1 Vout vs Iout @ Vin=105Vac

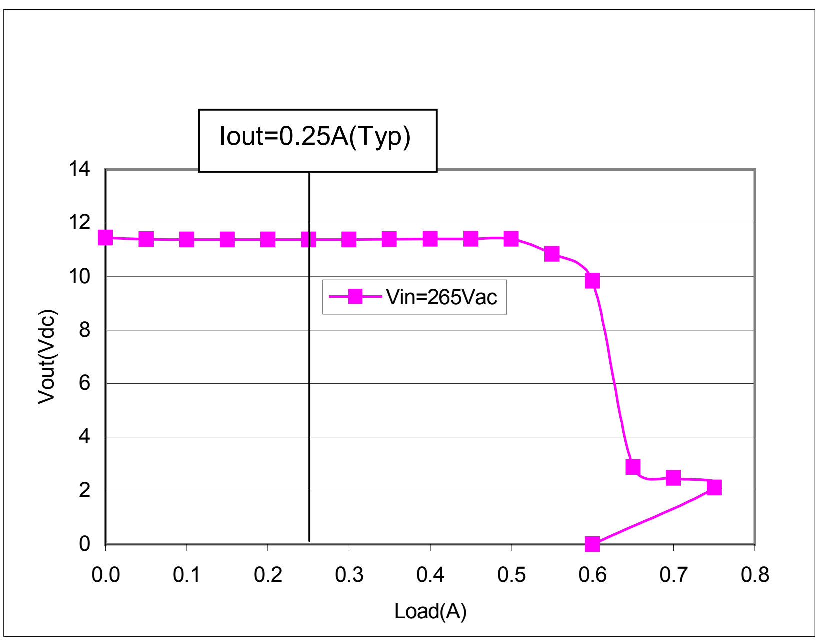


Figure 8.3.2 Vout vs Iout @ Vin=265Vac

8.4. Temperature

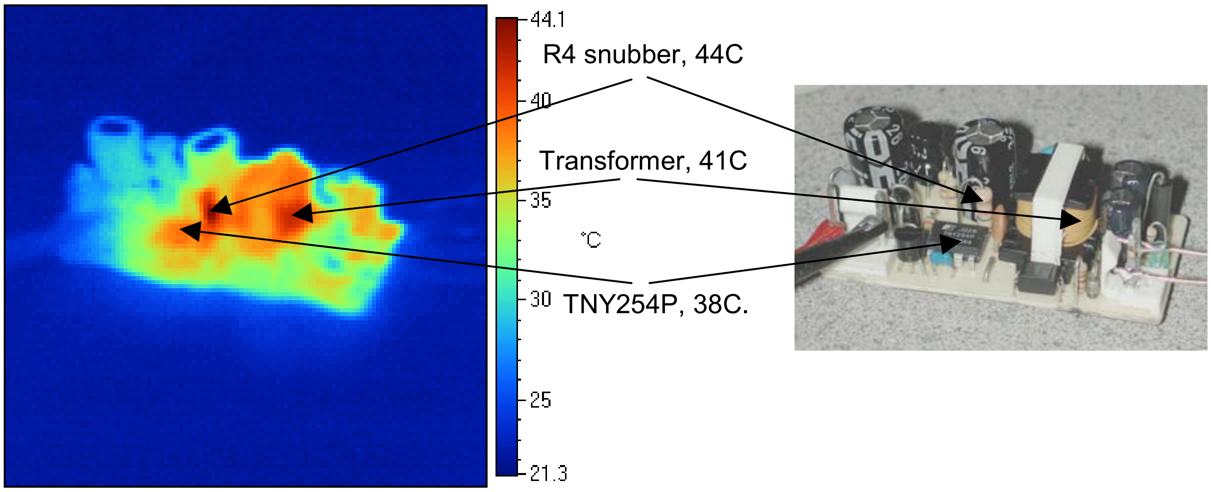


Figure 8.4.1. Infrared scan at Vin=100Vac, full load, 25C ambient, TNY254P side.

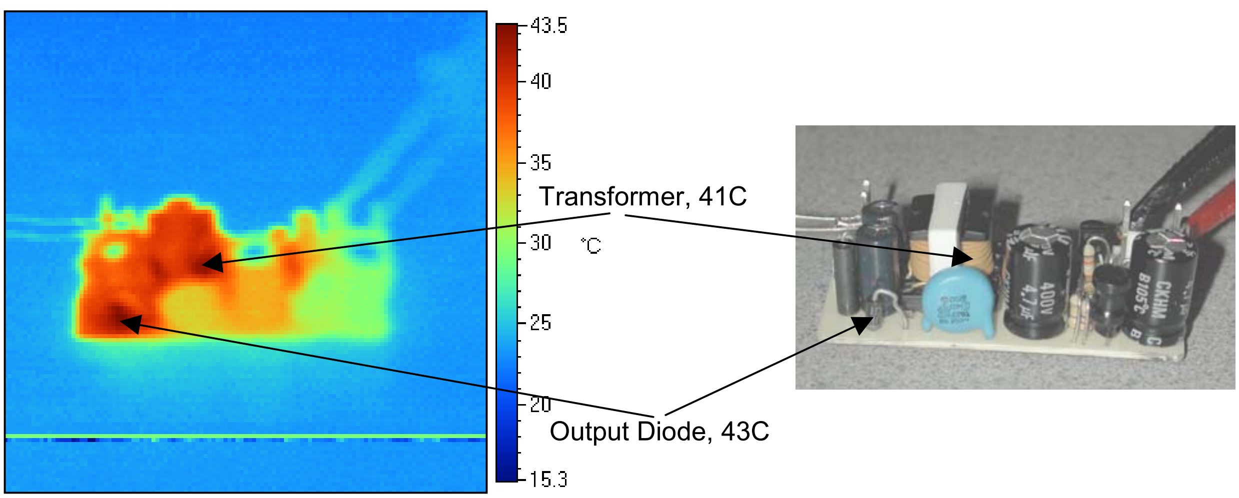


Figure 8.4.2. Infrared scan at Vin=100Vac, full load, 25C ambient, output diode side.

8.5 Waveforms

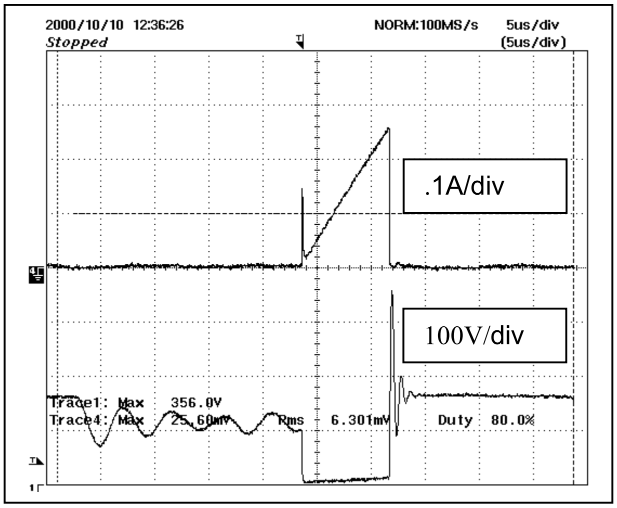


Figure 8.5.1. Drain current and drain-to-source voltage @ full load, Vin=100Vac, 60Hz.

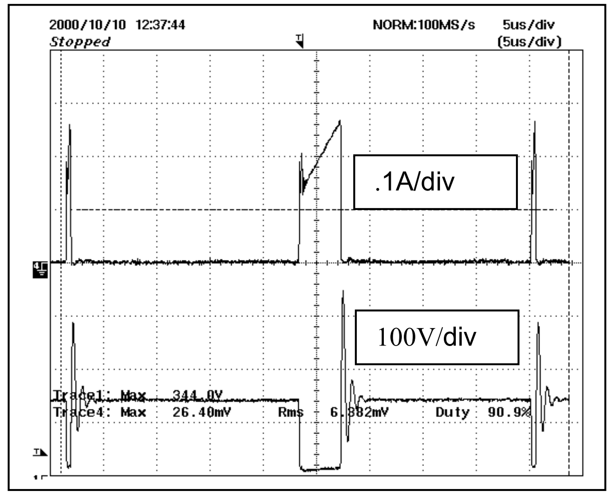


Figure 8.5.2. Drain current and drain-to-source voltage, shorted output, Vin=100Vac, 60Hz.

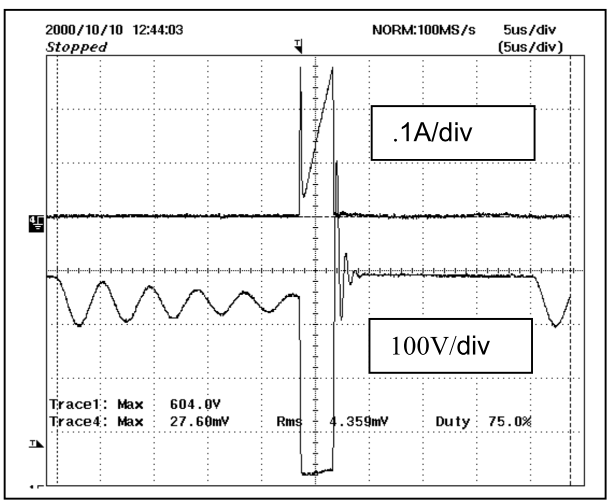


Figure 8.5.3. Drain current and drain-to-source voltage @ full load, Vin=265Vac, 60Hz.

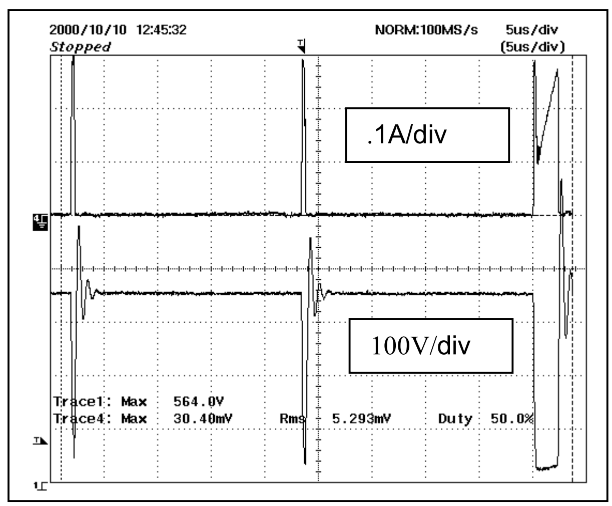


Figure 8.5.4. Drain current and drain-to-source voltage, shorted output, Vin=265Vac, 60Hz.

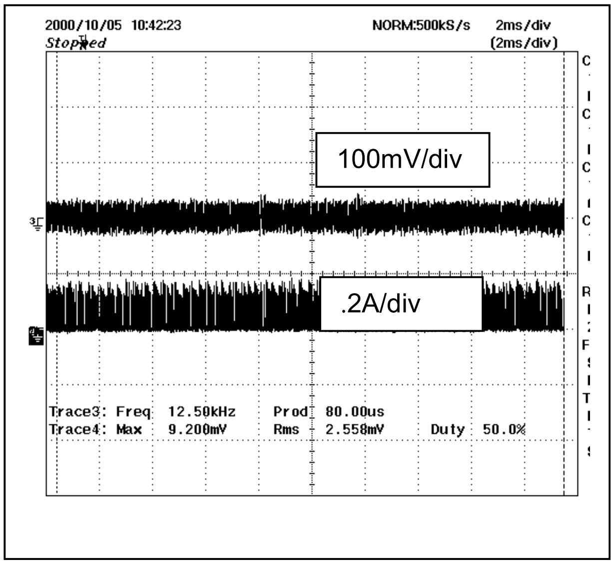


Figure 8.5.5. 120Hz output voltage ripple and drain current @ full load, Vin=100Vac, 60Hz.

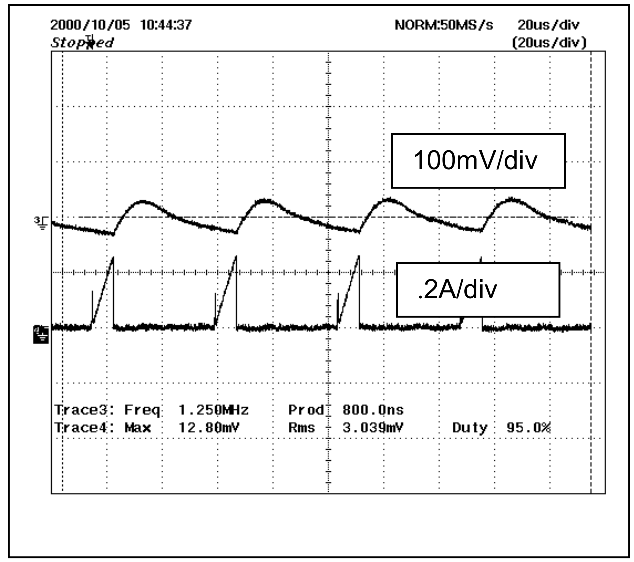


Figure 8.5.6. 44kHz output voltage ripple and drain current @ full load, Vin=100Vac, 60Hz.

8.6 Transient response

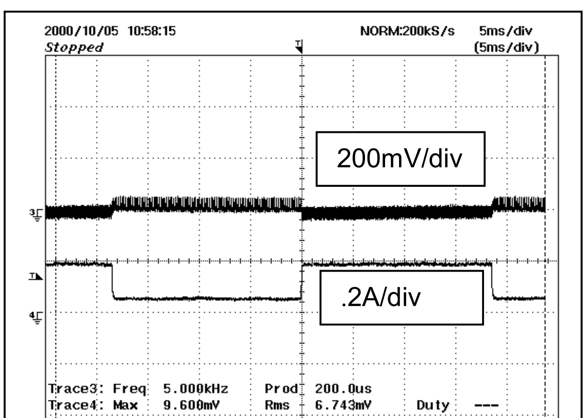


Figure 8.6.1. Vout transient response, for 20%-80% load change, Vin=100Vac, 60Hz.

8.7 Conducted EMI Scans

The attached plots show worst-case EMI performance for EP15 as compared to CISPR22B conducted emissions limits.

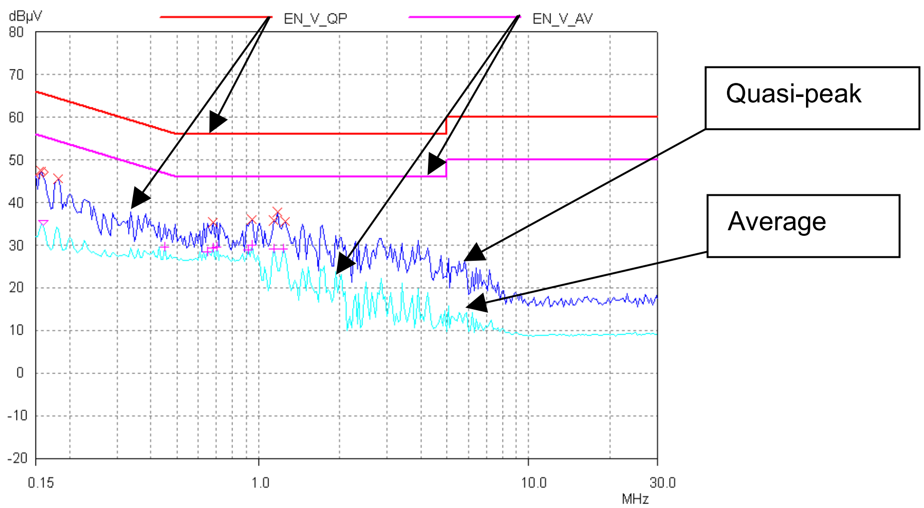


Figure 8.7.1. Vin=230Vac, full load, power supply floating.

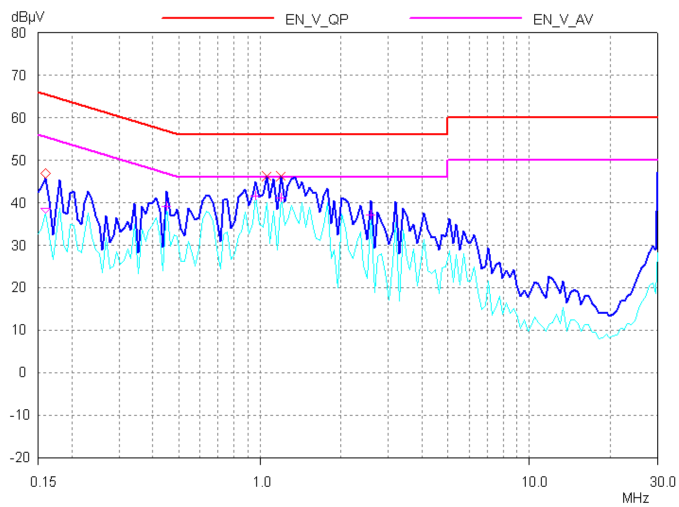


Figure 8.7.2. Vin=230Vac, full load, power supply placed on a plane (1.4mm insulation PCB) grounded via artificial hand.

The test set up, Figure 8.7.3., simulates the application, where the power supply unit (PSU) is placed in a metal enclosure.

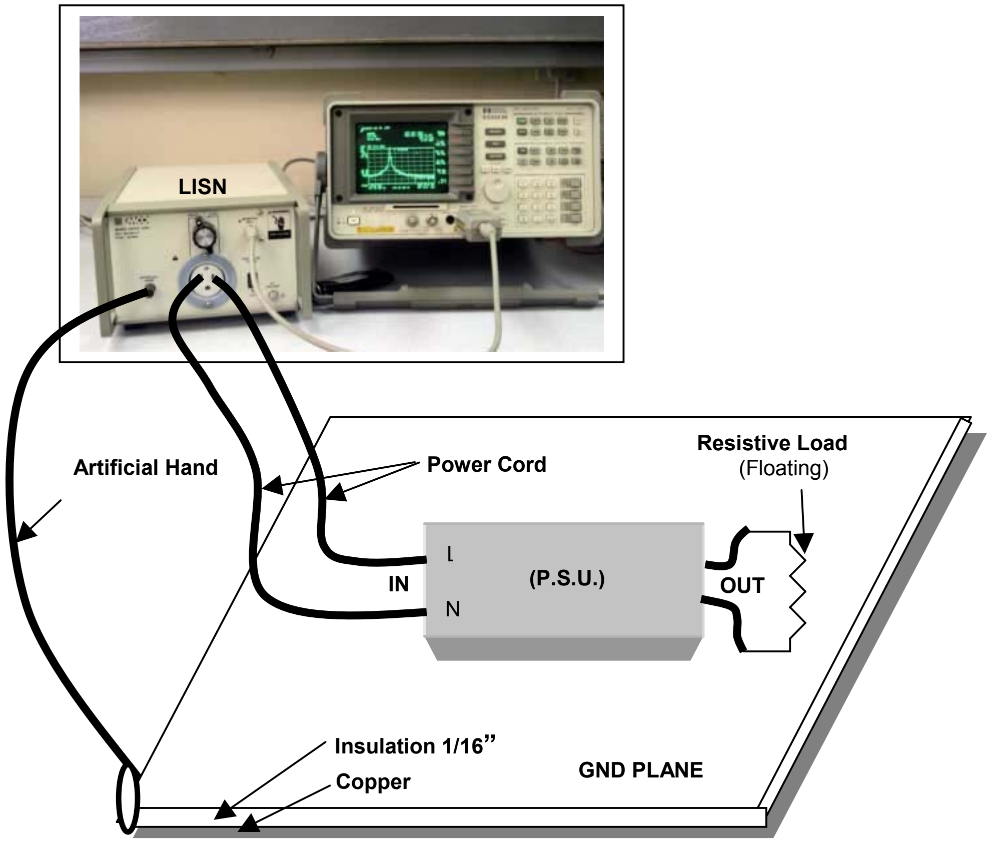


Figure 8.7.3. Test set up.

For EMI and safety techniques refer to PI application note AN15 (Figure 6 shows a typical test set up).

8.8 Surge Voltage

8.8.1 Differential = line-to-line (L- N), 2 ohm source impedance.

The unit exceeded the 1kV IEC/UL 1000-4-5 Class 3 requirement (meets Class 4, 2kV). During the 2.5kV surge the unit continued to operate without damage.

8.8.2 Common mode = line-to-ground (L-GND, N-GND), 12 ohm source impedance

The unit exceeded the IEC/UL 1000-4-5 Class 3, 2kV and Class 4, 4kV requirements.
The maximum test voltage was 4kV. During the 4kV surges the unit continued to operate.
The unit was centered on the insulation side of a 6in x 4 in single sided copper clad board (1.4mm insulation), to avoid surface or insulation breakdown during the voltage surges.
The voltage was applied between the input terminals of the unit (L or N) and the copper clad ground plane (GND), in the following sequence:

L(+4kV) to GND, 5 times
L(-4kV) to GND, 5 times
N(+4kV) to GND, 5 times
N(-4kV) to GND, 5 times

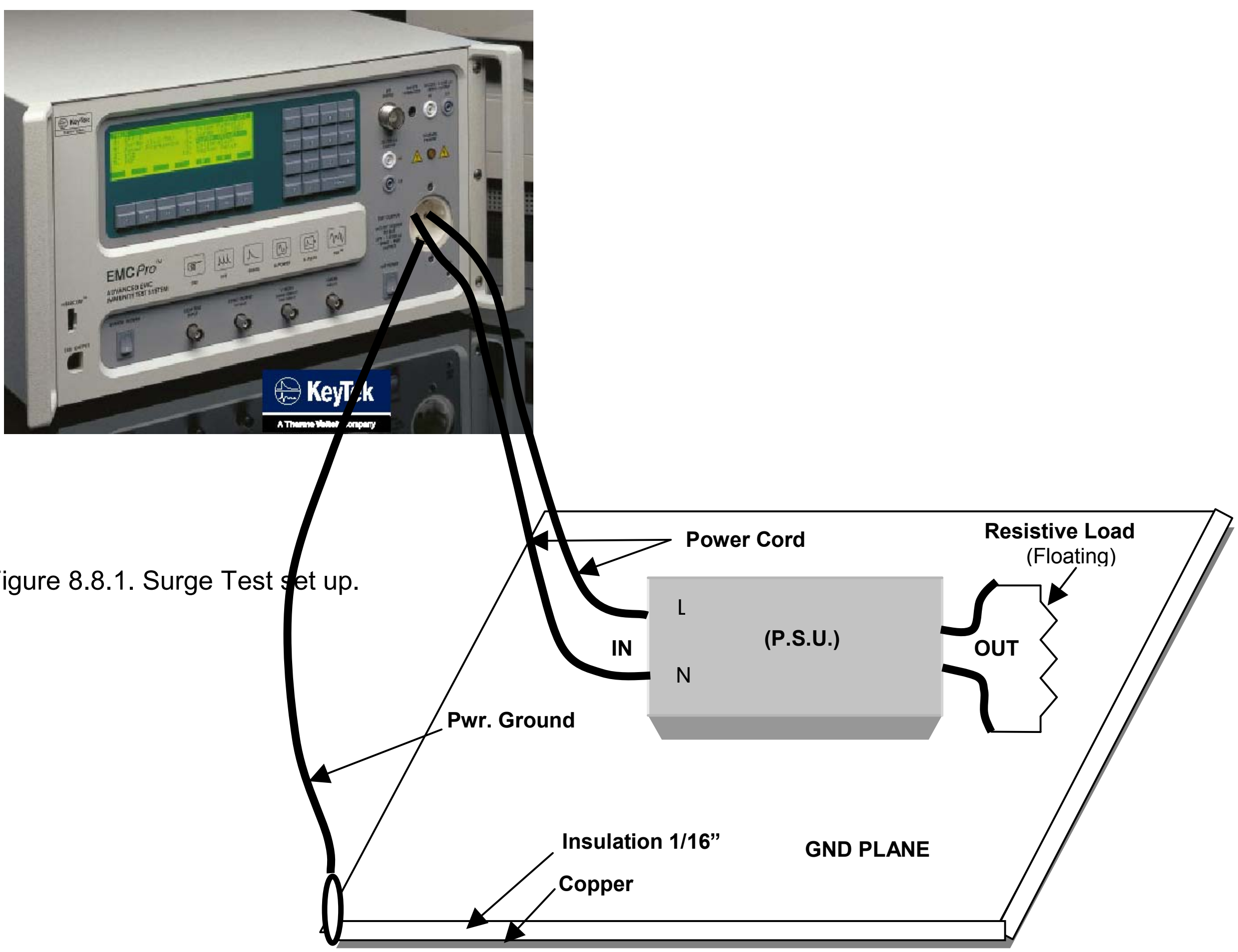


Figure 8.8.1. Surge Test set up.

8.9 Acoustic noise

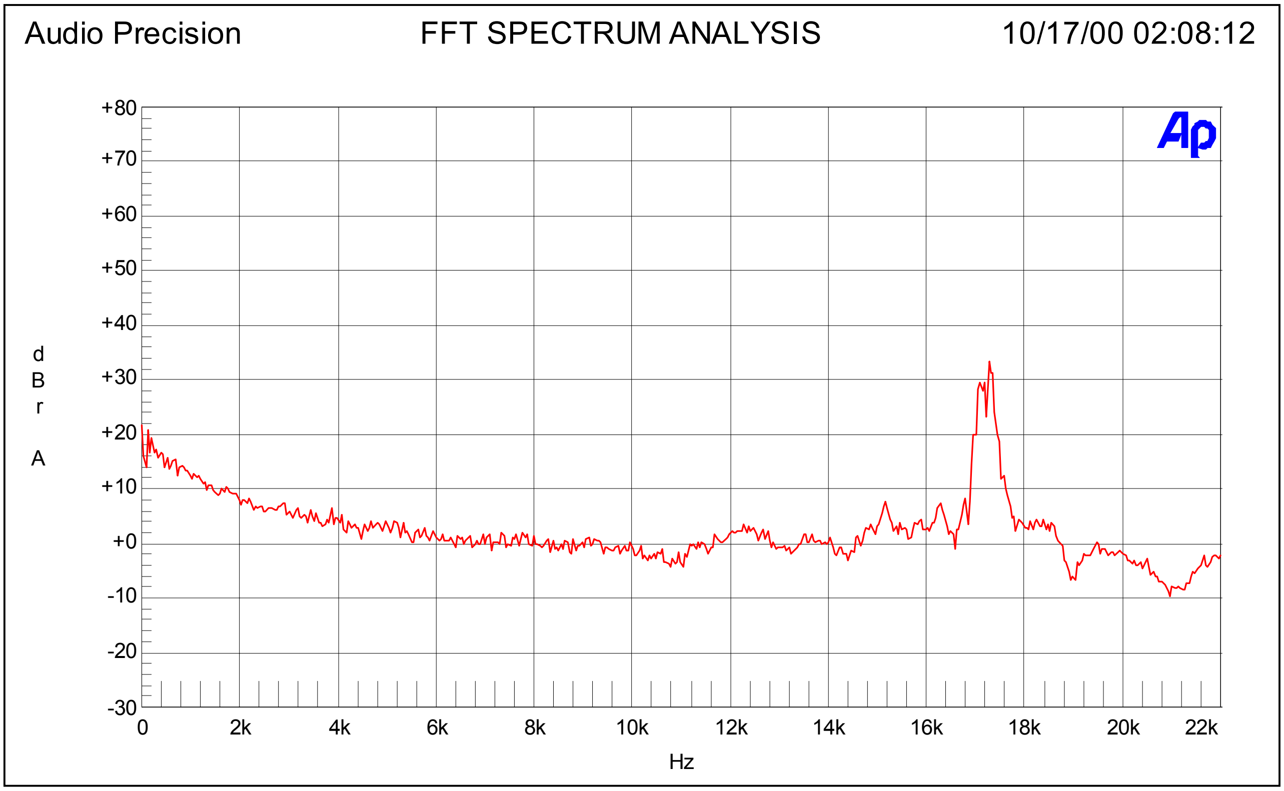


Figure 8.9.1 Worst case acoustic emission (Vin=120Vac, Iout=160mA)

Revisions

Author	Date	Rev	Description
S.L.	5.18.00	1	First Draft
	8.18.00	2	Second Draft
	9.12.00	3	Third Draft
	10.6.00	4	Fourth Draft
	10.9.00	5	Fifth Draft
	10.26.00	6	Release
	11.14.00	7	Changed title from EP10B to EP15
	01.31.01	8	Changed EPR-15 to EPR-00015

Notes

Notes

Notes

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