



Design Example Report

Title	<i>2.25W Power Supply using LNK520P</i>
Specification	Input: 90 – 265 Vac Output: 4.5V / 0.5A
Application	Portable CD player with AM/FM Radio
Author	Power Integrations Applications Department
Document Number	DER-42
Date	November 18, 2004
Revision	1.0

Summary and Features

- Very low No Load Input Power - less than 80 mW @ 100 Vac.
- Low RFI allows good AM radio reception with very little interference
- Meets EMI, EN55022 B with no Y1 capacitor.
- Good voltage regulation with no optocoupler
- Lightweight solution for portable applications
- Ideal replacement for linear adapters
- Average efficiency @ 120 VAC greater than 70%

The products and applications illustrated herein (including circuits external to the products and transformer construction) may be covered by one or more U.S. and foreign patents or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations' patents may be found at www.powerint.com.

Table Of Contents

1	Introduction	3
2	Power Supply Specification	4
3	Schematic	5
4	Circuit Description	6
4.1	Input EMI Filtering	6
4.2	LinkSwitch Primary	6
4.3	Output Rectification	6
5	PCB Layout	7
6	Bill Of Materials	8
7	Transformer Specification	9
7.1	Transformer Winding	9
7.1.1	Electrical Specifications	9
8	Transformer Spreadsheet	10
9	Performance Data	12
9.1	Efficiency	12
9.2	No-load Input Power	13
9.3	Output Voltage Regulation	13
9.4	Output Ripple Measurements	14
9.4.1	Ripple Measurement Technique	14
10	AM Radio Reception Test	15
11	Conducted EMI	16
12	Revision History	18

Important Note:

Although this board is designed to satisfy safety isolation requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

Design Reports contain a power supply design specification, schematic, bill of materials, and transformer documentation. Performance data and typical operation characteristics are included. Typically only a single prototype has been built.



1 Introduction

This document is an engineering report describing a prototype Flyback power supply utilizing LNK520P. The LNK520P is chosen for its superior low noise properties and low system cost.

The document contains the power supply specification, schematic, bill of materials, transformer documentation, printed circuit layout, and performance data.



Figure 1 – LNK520P Power Supply 4.5V 0.5A – Top View

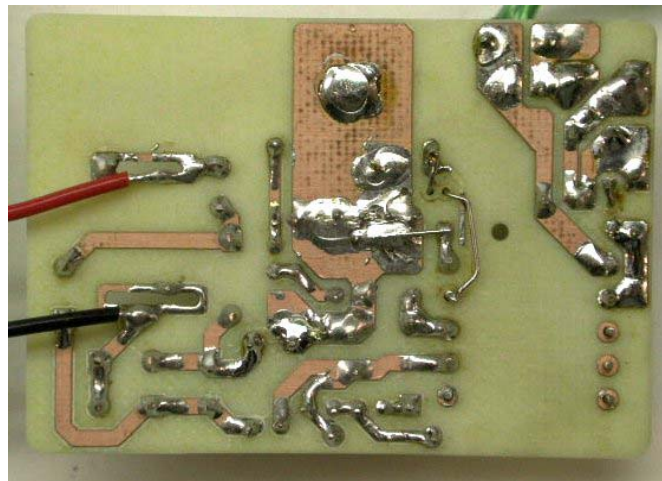


Figure 2 – LNK520P Power Supply 4.5V 0.5A – Bottom View

2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (230 VAC)				0.3	W	
Output						
Output Voltage 1	V_{OUT1}	2.7	4.5	5.4	V	At No Load (RMS), 20 MHz Bandwidth
Output Voltage 1				9.5	V	
Output Ripple Voltage 1	$V_{RIPPLE1}$		200		mV	
Output Current 1	I_{OUT1}		500		mA	
Total Output Power						
Continuous Output Power	P_{OUT}		2.25		W	
No Load Input Power	P_{NoLoad}			100	mW	@ 100 Vac Input
Efficiency	η		50		%	
Environmental						
Conducted EMI			Meets CISPR22B / EN55022B			1.2/50 μ s surge, IEC 1000-4-5, Series Impedance: Differential Mode: 2 Ω Common Mode: 12 Ω
Safety			Designed to meet IEC950, UL1950 Class II			
Surge				1.5	kV	
Ambient Temperature	T_{AMB}	0		50	$^{\circ}$ C	Free convection, sea level



3 Schematic

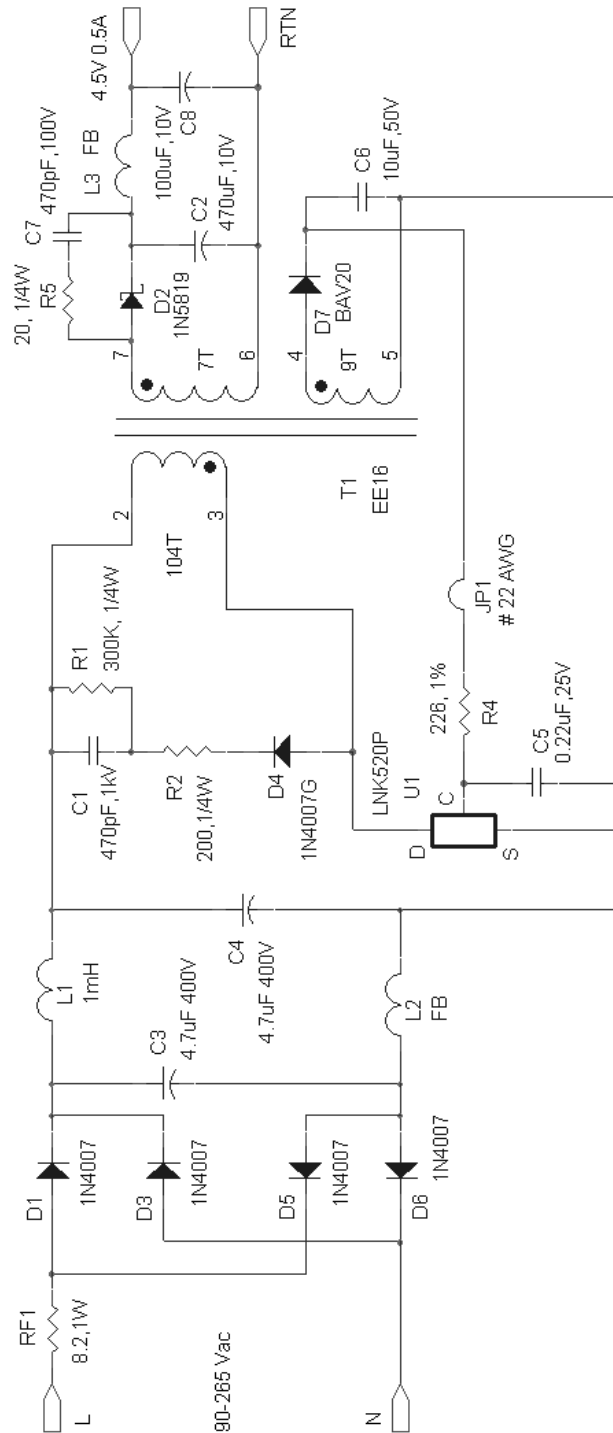


Figure 3 – LNK520P based Flyback Converter Schematic



4 Circuit Description

LinkSwitch LNK520P is used in a Flyback converter shown in Figure 3 to obtain 4.5V, 0.5A output from 90-265 Vac input. The bias winding output voltage is used provide primary side feedback to LinkSwitch. Therefore, the bias winding is wound over the secondary winding to obtain very good regulation. Special construction methods are used for the transformer to obtain low No-Load input power, and at the same time to pass EMI testing and have good AM (530 kHz – 1.6 MHz) reception quality.

4.1 Input EMI Filtering

Fusible resistor RF1 acts as fuse and also limits inrush current during power ON of the power supply. Bridge diodes D1, D3, D5, D6 rectify AC voltage into DC voltage and charges capacitors C3 and C4. Inductor L1, Ferrite bead L2, and capacitors C3 and C4 form a π filter and attenuate EMI noise.

4.2 LinkSwitch Primary

This design uses RCD (C1, D4, R1, and R2) clamping across primary winding to limit the drain voltage below 700V, when the MOSFET inside U1 turns OFF. The capacitor C5 connected to C (control) pin of U1 stores energy and provide power to the internal circuit of U1 and also to turn ON the U1's Mosfet, during power-up and steady state operation. C6, D7, and R4 form bias supply components, which provide feedback current to the Control pin during steady state operation. The bias winding voltage is designed for about 6.4V to keep the No-Load input power to minimum.

4.3 Output Rectification

When U1 Mosfet is turned ON, current flows through transformer primary and stores energy. When U1 is ON, output diode D2 is OFF. When the U1 Mosfet is OFF, D2 is forward biased, and the stored energy is transferred to the secondary and stores in C2. The snubber C7 and R5 across D2 will slow down D2 switching and improve EMI. L3 and C8 form post filter to reduce output ripple voltage and also attenuate EMI noise.



5 PCB Layout

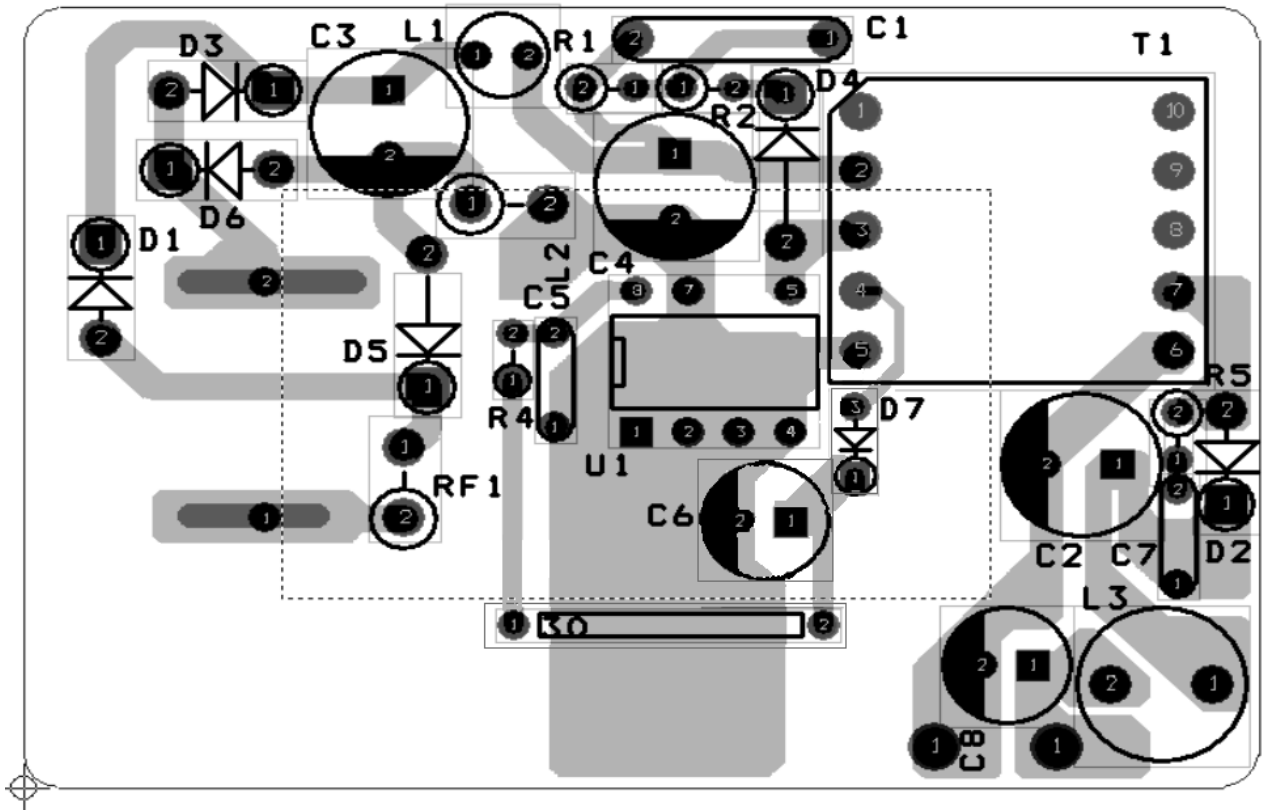


Figure 4 – PCB Layout



6 Bill Of Materials

Item	Qty.	Reference	Part Description	P/N	Mfg.
1	1	C1	470 pF, 1 KV, Ceramic capacitor, Z5U	-	Any
2	1	C2	470 μ F, 10V, AL Electrolytic Low ESR capacitor	-	Any
3	2	C3, C4	4.7 μ F, 400V, AL Electrolytic capacitor	-	Any
4	1	C5	0.22 μ F, 25V, Ceramic capacitor, X7R	-	Any
5	1	C6	10 μ F, 50V, AL Electrolytic capacitor	-	Any
6	1	C7	470 pF, 100V, Ceramic capacitor, NPO	-	Any
7	1	C8	100 μ F, 10V, AL Electrolytic capacitor	-	Any
8	4	D1, D3, D5, D6	General purpose Diode, 1A, 1KV	1N4007	Any
9	1	D2	Schottky diode, 1A, 40V	1N5819	Any
10	1	D4	Glass passivated diode 1A, 1KV	1N4007G	Any
11	1	D7	Switching diode, 200 mA, 200V	BAV20	Any
12		JP1	Jumper wire # 26 AWG	-	Any
13	1	L1	Ferrite core inductor, 1 mH	SBCP-47HY102B	Tokin
14	2	L2, L3	Large Ferrite Bead	2761008112	Fair-rite
15	1	OC1	Output cable 6 foot, # 22 AWG, 2-wire	custom	Any
16	1	PCB1	PCB	custom	Any
17	1	RF1	Fusible resistor, 8.2 Ω , 1W	-	Any
18	1	R1	Resistor, 300 K Ω , 1/4W, 5%	-	Any
19	1	R2	Resistor, 200 Ω , 1/4W, 5%	-	Any
20	1	R4	Resistor, 226 Ω , 1/4 W, 1%	-	Any
21	1	R5	Resistor, 20 Ω , 1/4 W, 5%	-	Any
22	1	T1	EE16 core custom transformer	custom	Any
23	1	U1	LinkSwitch	LNK520P	Power Integrations



7 Transformer Specification

7.1 Transformer Winding

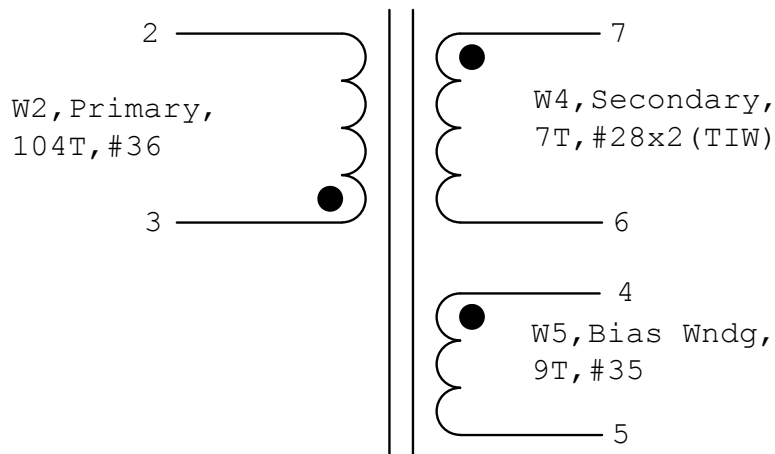


Figure 5 – Transformer Winding

7.1.1 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from Pins 1– 5 to Pins 6–7.	3000 VAC
Primary Inductance	Pins 2-3, all other windings open, measured at 42 kHz, 0.4 VRMS	2.51 mH – 2.64 mH – 2.77 mH
Resonant Frequency	Pins 2-3, all other windings open	300 kHz (Min.)
Primary Leakage Inductance	Pins 2-3, with all other pins shorted, measured at 132 kHz, 0.4 VRMS	83 μ H (Max.)

8 Transformer Spreadsheet

Parameters	INPUT	INFO	OUTPUT	UNIT	Description
ENTER APPLICATION VARIABLES					
VACMIN	90			Volts	Minimum AC Input Voltage
VACMAX	265			Volts	Maximum AC Input Voltage
fL	50			Hertz	AC Mains Frequency
VO	4.5			Volts	Output Voltage
IO	0.633			Amps	Specified Nominal Output current
VBIAS	21				Bias voltage (recommended default 20V, minimum 16V)
tC	3			msec	Bridge Rectifier Conduction Time Estimate
CIN	9.4			uFarads	Input Filter Capacitor

TARGETED / ESTIMATED LOSSES

P_NO_LOAD_GOAL			300	mW	Target No Load losses for Power supply
PCORE			239.4	mW	Estimated Core Losses at peak Flux Density (BP)
RCLAMP	300		300.0	Kohm	Primary clamp resistor (recommended default clamp resistor, RCLAMP)
CTRF	60		60.0	pF	Transformer primary capacitance
ESR	0.15		0.150	Ohms	Output Capacitor ESR at 50C
RSEC	0.02		0.02	Ohms	Estimated Resistance of transformer secondary winding
P_NO_LOAD_LOSS			273	mW	Estimated power losses at no load (includes feedback, switching and primary clamp losses, but not preload resistor or secondary snubber). No Load losses target achieved.

DC INPUT VOLTAGE PARAMETERS

VMIN			104	Volts	Minimum DC Input Voltage
VMAX			375	Volts	Maximum DC Input Voltage

ENTER OUTPUT CABLE PARAMETERS

RCABLE	0.18		0.18	Ohms	Resistance of total length of cable from power supply terminals to load and back.
VCABLE			0.114	Volts	Drop along cable connecting power supply to load

ENTER LinkSWITCH & OUTPUT DIODE VARIABLES

LinkSwitch	LNK520			Universal	115 Doubled/230
				Power	5.5
I ² f			2710	A ² Hz	I ² f (typical) co-efficient for LinkSwitch
VOR	76		76.00	Volts	Reflected Output Voltage (40<VOR<80 recommended)
VLEAK	0		0.00	Volts	Error in Feedback voltage as a result of leakage inductance in primary circuit.
VD	0.5		0.5	Volts	Output Winding Diode Forward Voltage Drop (0.5~0.7V for schottky and 0.7~1.0V for PN diode)
VR			60	Volts	Rated Peak Rep Reverse Voltage of secondary diode



ID	3			Amps	Rated Average Forward current for secondary diode
----	---	--	--	------	---

DISCONTINUOUS MODE CHECK

KDP			1.93		Ensure KDP > 1.15 to for discontinuous mode operation.
TON			6.83	us	Linkswitch conduction time
TDON			8.82	us	Secondary Diode conduction time

VOLTAGE STRESS ON LinkSWITCH AND OUTPUT DIODE

VDRAIN			554	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS			29.7	Volts	Output Rectifier Maximum Reverse Voltage

CURRENT WAVEFORM SHAPE PARAMETERS

DMAX			0.29		Maximum Operating Duty Cycle
I AVG			0.036	Amps	Average Primary Current
IRMS			0.079	Amps	Primary RMS Current

ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES

Core Type	ee16				
Core		PC40EE16-Z			
Bobbin		BE-16-116CP			
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
VE			672	mm ³	Effective Core Volume
BW	7.8		7.8	mm	Bobbin Physical Winding Width
KCORE			602	kW/m ³	Core losses per unit volume
T(n)	0.96		0.9600		Estimated transformer efficiency. T(n)=(PSCU+PCORE/2)/POEFF. Re-iterate with n = 0.9543
M			0	mm	Safety Margin Width
NS	7				Number of Secondary Turns

TRANSFORMER PRIMARY DESIGN PARAMETERS

dLP	1.0000		1.000		Constant to account for reduction of inductance at higher flux densities. (0.999<dLP<1.05)
LP			2638	uHenries	Primary Inductance
L	2		2		Number of Primary Layers
LBIAS	0.6		0.6		
NP			104		Primary Winding Number of Turns
NB			29		
ALG			244	nH/T ²	Gapped Core Effective Inductance
BP			3699	Gauss	Peak Flux Density (BP<3700)
LG			0.08	mm	Consult your transformer vendor for Gaps less than 0.08mm Consider film gapping



OD			0.15	mm	Maximum Primary Wire Diameter including insulation to give specified number of layers.
DIA			0.12	mm	Bare conductor diameter
AWG			37	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CMA			257	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
AWG_BIAS			35	AWG	

TRANSFORMER SECONDARY DESIGN PARAMETERS

ISP			3.77	Amps	Peak Secondary Current
ISRMS			1.33	Amps	Secondary RMS Current
IRIPPLE			1.17	Amps	Output Capacitor RMS Ripple Current
AWGS			29	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.29	mm	Secondary Minimum Bare Conductor Diameter
ODS			1.11	mm	Secondary Maximum Insulated Wire Outside Diameter
INSS			0.41	mm	Maximum Secondary Insulation Wall Thickness
VSEC			0.013	Volts	Voltage Drop across secondary winding

9 Performance Data

All measurements are performed at room temperature, 60 Hz input frequency, unless otherwise specified. The output voltage is measured at the end of a 6-foot # 22 AWG cable with 0.2 Ω total resistance.

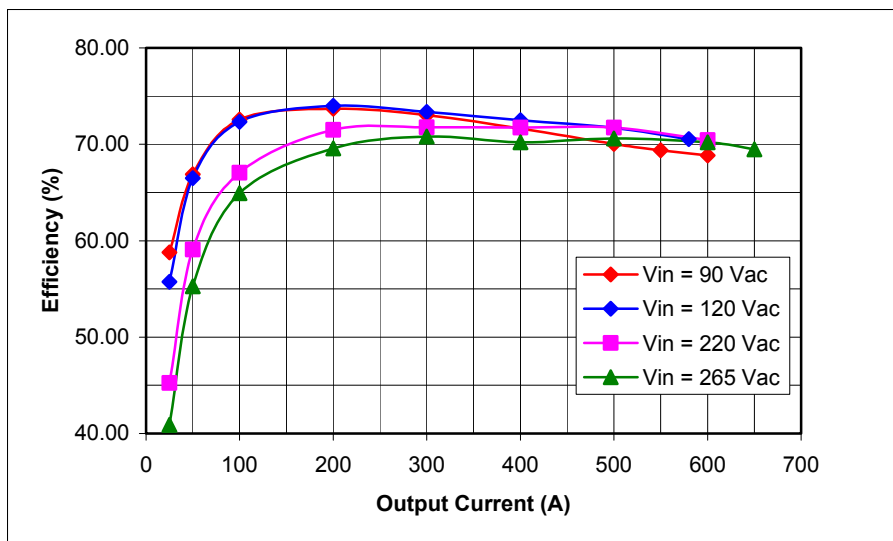
9.1 Efficiency

Figure 6 – Efficiency versus Output Current



9.2 No-load Input Power

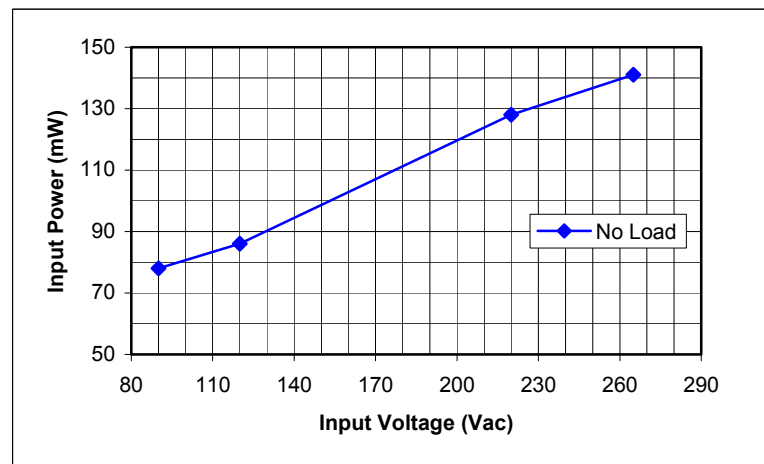


Figure 7 – No-Load Input Power versus Input Voltage

9.3 Output Voltage Regulation

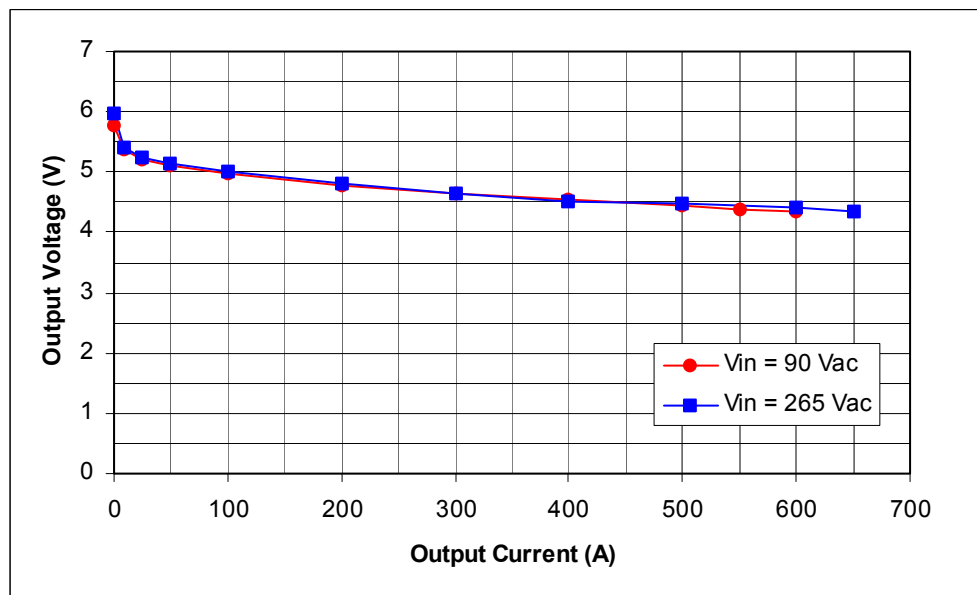


Figure 8 – Output Voltage versus Output Current



9.4 Output Ripple Measurements

9.4.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized in order to reduce spurious signals due to pickup. Details of the probe modification are provided in Figure 9 and Figure 10.

The 5125BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 $\mu\text{F}/50\text{ V}$ ceramic type and one (1) 1.0 $\mu\text{F}/50\text{ V}$ aluminum electrolytic. **The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).**

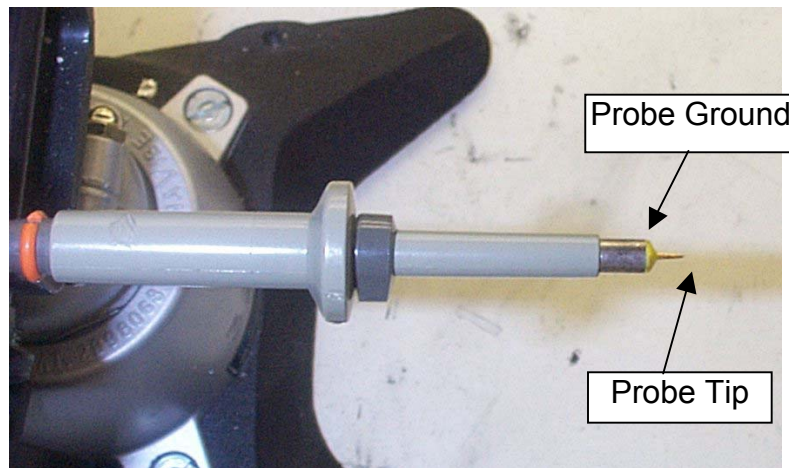


Figure 9 - Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)



Figure 10 - Oscilloscope Probe with Probe Master 5125BA BNC Adapter. (Modified with wires for probe ground for ripple measurement, and two parallel decoupling capacitors added)

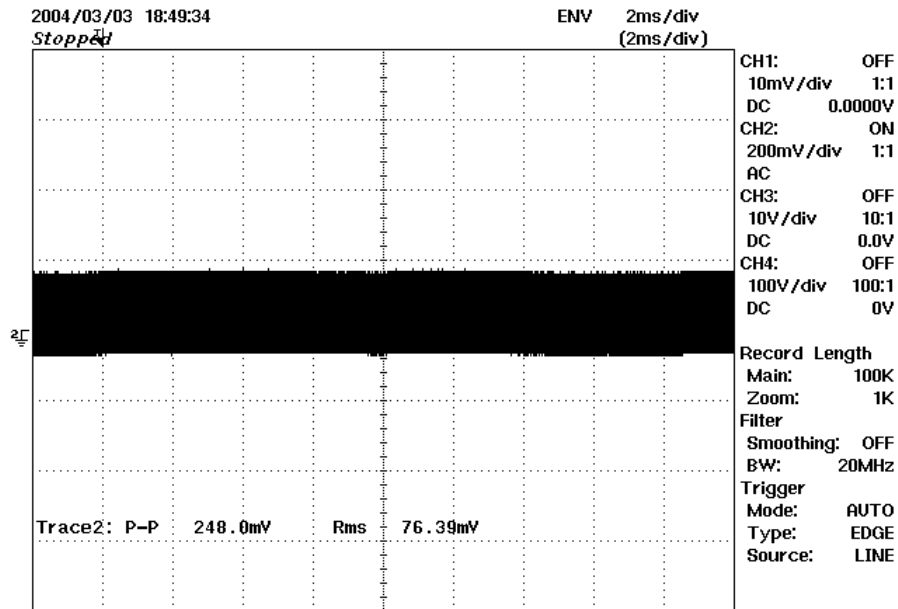


Figure 11 – Output Voltage Ripple (worst case) 120 Vac, 4.47 V, 0.5A

10 AM Radio Reception Test

The adapter is tested with a portable CD player with TV/ Weather/ AM/ FM features, for AM radio reception quality. The tested frequencies are 680 KHz, 810 KHz, and 1170 KHz. The reception is good as compared to operating with batteries. There is either very little or no additional noise at all when tuning to a very weak radio signal and operating in close proximity to the adapter.



11 Conducted EMI

The EMI conducted emission tests (EN55022 B) are done at 120 Vac and 220 Vac, 0.5A load, and Neutral (worst case).

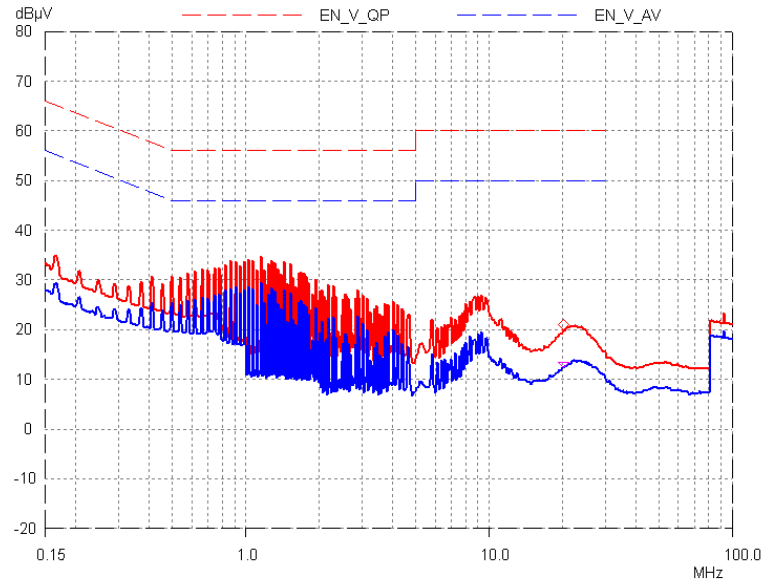


Figure 12 – Conducted EMI, EN55022 B, 120 Vac, output return connected to artificial hand

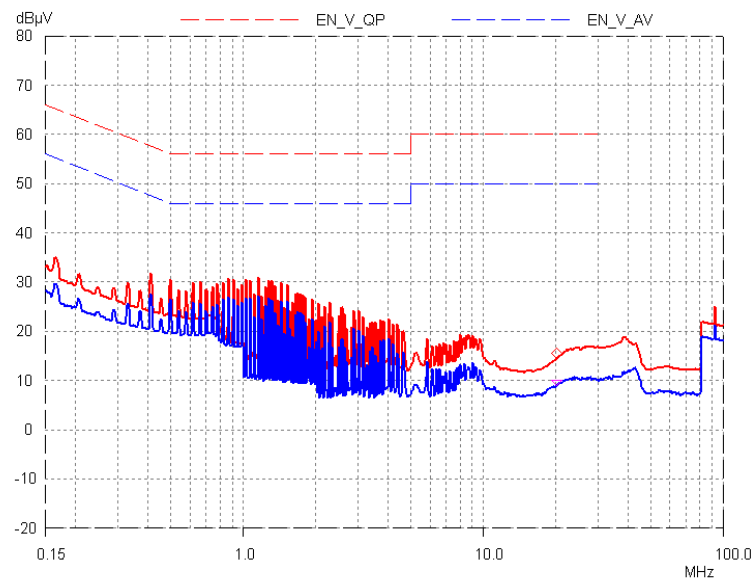


Figure 13 – Conducted EMI, EN55022 B, 120 Vac, output return floating



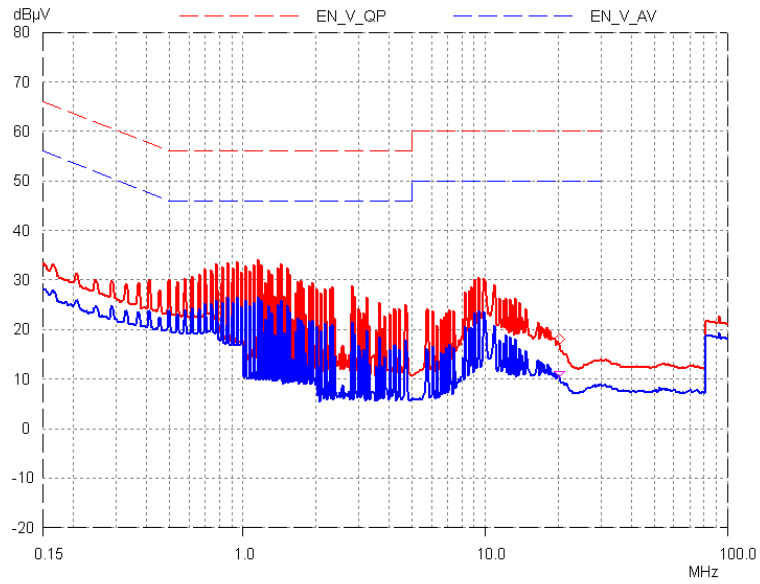


Figure 14 – Conducted EMI, EN55022 B, 220 Vac, output return connected to artificial hand

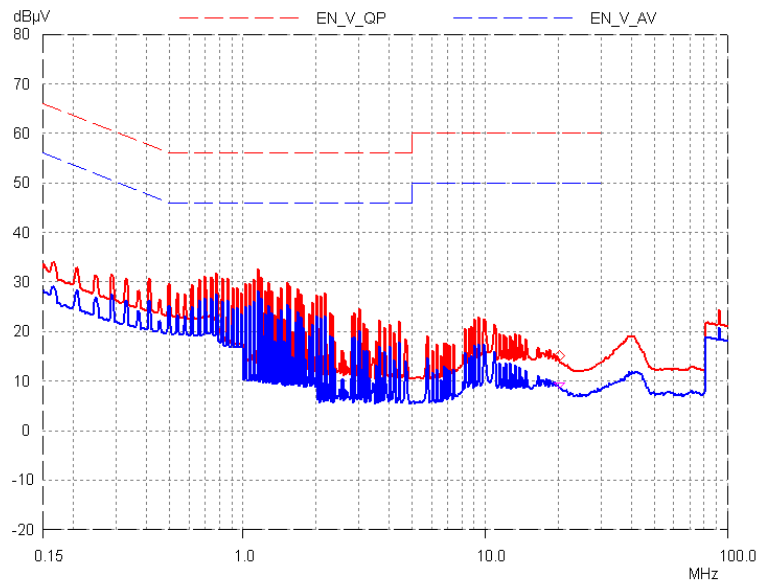


Figure 15 – Conducted EMI, EN55022 B, 220 Vac, output return floating



12 Revision History

Date	Author	Revision	Description & changes	Reviewed
November 18, 2004	MJ	1.0	Initial release	VC / AM



For the latest updates, visit our Web site: www.powerint.com

Power Integrations reserves the right to make changes to its products at any time to improve reliability or manufacturability. Power Integrations does not assume any liability arising from the use of any device or circuit described herein, nor does it convey any license under its patent rights or the rights of others.

PATENT INFORMATION

The products and applications illustrated herein (including circuits external to the products and transformer construction) may be covered by one or more U.S. and foreign patents or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations' patents may be found at www.powerint.com.

The PI Logo, **TOPSwitch**, **TinySwitch**, **LinkSwitch**, and **EcoSmart** are registered trademarks of Power Integrations. **PI Expert** and **DPA-Switch** are trademarks of Power Integrations.

© Copyright 2004, Power Integrations.

WORLD HEADQUARTERS

Power Integrations
5245 Hellyer Avenue,
San Jose, CA 95138, USA
Main: +1-408-414-9200
Customer Service:
Phone: +1-408-414-9665
Fax: +1-408-414-9765
e-mail:
usasales@powerint.com

AMERICAS

Power Integrations, Inc.
4335 South Lee Street,
Suite G,
Buford, GA 30518, USA
Phone: +1-678-714-6033
Fax: +1-678-714-6012
e-mail:
usasales@powerint.com

CHINA (SHANGHAI)

Power Integrations
International Holdings, Inc.
Rm 807, Pacheer,
Commercial Centre,
555 Nanjing West Road,
Shanghai, 200041, China
Phone: +86-21-6215-5548
Fax: +86-21-6215-2468
e-mail:
chinasales@powerint.com

APPLICATIONS HOTLINE

World Wide +1-408-414-9660

CHINA (SHENZHEN)

Power Integrations
International Holdings, Inc.
Rm# 1705, Bao Hua Bldg.
1016 Hua Qiang Bei Lu,
Shenzhen, Guangdong,
518031, China
Phone: +86-755-8367-5143
Fax: +86-755-8377-9610
e-mail: chinasales@powerint.com

GERMANY

Power Integrations, GmbH
Rueckertstrasse 3,
D-80336, Munich, Germany
Phone: +49-895-527-3910
Fax: +49-895-527-3920
e-mail: eurossales@powerint.com

INDIA (TECHNICAL SUPPORT)

Innovatech
261/A, Ground Floor
7th Main, 17th Cross,
Sadashivanagar
Bangalore, India, 560080
Phone: +91-80-5113-8020
Fax: +91-80-5113-8023
e-mail: indiasales@powerint.com

APPLICATIONS FAX

World Wide +1-408-414-9760

ITALY

Power Integrations s.r.l.
Via Vittorio Veneto 12,
Bresso, Milano,
20091, Italy
Phone: +39-028-928-6001
Fax: +39-028-928-6009
e-mail:
eurossales@powerint.com

JAPAN

Power Integrations, K.K.
Keihin-Tatemono 1st Bldg.
12-20 Shin-Yokohama,
2-Chome,
Kohoku-ku, Yokohama-shi,
Kanagawa 222-0033, Japan
Phone: +81-45-471-1021
Fax: +81-45-471-3717
e-mail:
japansales@powerint.com

KOREA

Power Integrations
International Holdings, Inc.
8th Floor, DongSung Bldg.
17-8 Yoido-dong,
Youngdeungpo-gu,
Seoul, 150-874, Korea
Phone: +82-2-782-2840
Fax: +82-2-782-4427
e-mail:
koreasales@powerint.com

SINGAPORE (ASIA PACIFIC HEADQUARTERS)

Power Integrations, Singapore
51 Newton Road,
#15-08/10 Goldhill Plaza,
Singapore, 308900
Phone: +65-6358-2160
Fax: +65-6358-2015
e-mail:
singaporesales@powerint.com

TAIWAN

Power Integrations
International Holdings, Inc.
17F-3, No. 510,
Chung Hsiao E. Rd., Sec. 5,
Taipei, Taiwan 110, R.O.C.
Phone: +886-2-2727-1221
Fax: +886-2-2727-1223
e-mail:
taiwansales@powerint.com

UK (EUROPE & AFRICA HEADQUARTERS)

1st Floor, St. James's House
East Street
Farnham, Surrey GU9 7TJ
United Kingdom
Phone: +44-1252-730-140
Fax: +44-1252-727-689
e-mail: eurossales@powerint.com

