Title	***DPA-Switch – 19.2 W DC-DC Flyback Converter with DPA425***
Specification	36 VDC to 72 VDC Input, +12V @ 0.8A, -12V @ 0.8A Output
Application	Telecom
Author	RSP/RM
Document Number	ASM-140197
Date	2/19/03
Revision	1

Features

- Low parts Count
- Layout allows for tightly regulated +12V output or primary side regulation with no opto-coupler for reduced parts count and lower cost

Power Integrations, Inc.
5245 Hellyer Avenue, San Jose, CA 95138 USA.
Applications Hotline: Tel: +1 408 414 9660 Fax: +1 408 414 9760
www.powerint.com

Table of Contents

1 Introduction

This document is an engineering report describing a dual output Flyback converter employing the DPA425R. The input voltage range is 36 to 72VDC providing a regulated +12V at 0.8A and a cross-regulated -12V @ 0.8A. The design also allow a primary-side regulation of the auxiliary winding that affords further parts count reduction and coarsely regulated +/-12V outputs.

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

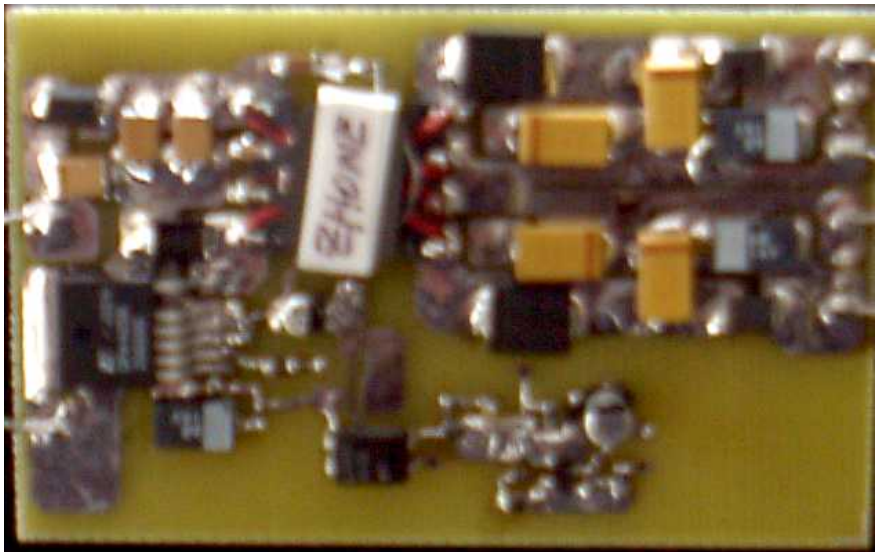


Figure 1 - Populated Circuit Board.

Power Integrations, Inc.
Tel: +1 408 414 9660 Fax: +1 408 414 9760
www.powerint.com

2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	36	48	72	V_{DC}	
No-load Input Power ($60V_{DC}$)				0.75	W	
Output						
Output Voltage 1	V_{OUT1}	11.5	12.1	12.7	V	± 5%
Output Ripple Voltage 1	$V_{RIPPLE1}$			100	mV	20 MHz Bandwidth
Output Current 1	I_{OUT1}			0.8	A	
Output Voltage 2	V_{OUT2}	11.5	12.1	12.7	V	±5%
Output Ripple Voltage 2	$V_{RIPPLE2}$			100	mV	20 MHz Bandwidth
Output Current 2	I_{OUT2}			0.8	A	
Total Output Power						
Continuous Output Power	P_{OUT}			19.6	W	
Peak Output Power	P_{OUT_PEAK}				W	
Efficiency	η	83			%	Measured at Max. P_{OUT}, 25 °C
Ambient Temperature	T_{AMB}	0		40	°C	Free convection, Sea level

3 Schematic

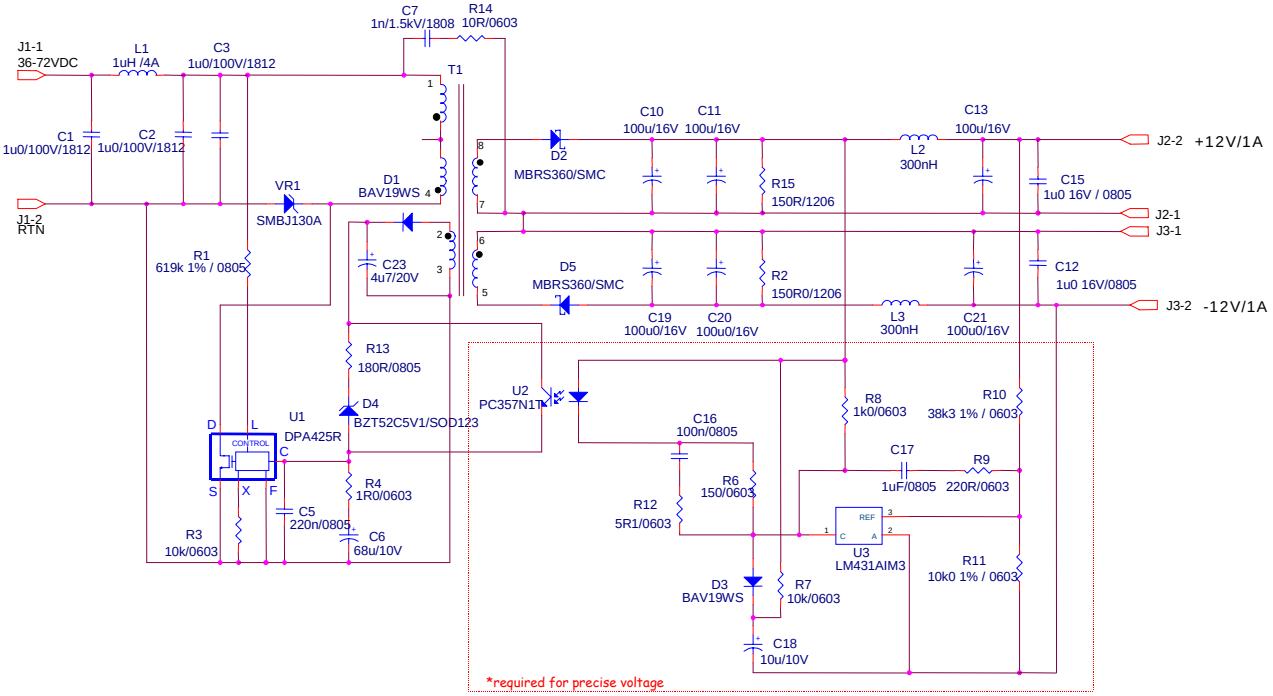


Figure 2 - Schematic.

Power Integrations, Inc.
Tel: +1 408 414 9660 Fax: +1 408 414 9760
www.powerint.com

3.1 Circuit Operation

3.2 Input EMI filtering

Figure 1 shows a single-ended Flyback converter using the DPA425R. The circuit is designed for 36 V to 72 V input range and +/-12 V, 0.8A outputs. C1 and L1 provide input filtering. C2 and C3 bypass the DC rail. The DC rail is applied to the primary winding of T1. The other side of the transformer primary is driven by the integrated MOSFET in U1. VR1 clamps the U1 drain leakage spikes.

R1 is used to set the low line turn-on threshold to approximately 33 V, and also sets the over-voltage shutdown level to approximately 88 V. C5 bypasses the U1 control pin, and provides the peak current necessary for driving the ***DPA-Switch*** internal MOSFET. C6 has three functions. It provides the energy required by U1 during startup, sets the auto-restart frequency during fault conditions, and also reduces the gain of U1 as a function of frequency. R4 adds a zero to stabilize the power supply control loop.

3.3 Output Rectification

The output of T1 is rectified and filtered by D2 (D3) and C10-11 (C19-C20). L2 (L3) and C13 (C21) provides additional high frequency filtering. R2 (R15) damps primary to secondary circulating current, which would otherwise appear imposed on the output ripple voltage.
An auxiliary Flyback winding on T1 powers U1 during normal operation. This winding delivers energy during the off time of U1, with an output voltage proportional to the supply output voltage. The turns-ratio of T1 sets the output voltage of the auxiliary winding to approximately 12 V. D1 and C23 rectify and filter the auxiliary winding output.

3.4 Output Feedback

R10 and R11 divide down the supply output voltage and apply it to the reference pin of error amplifier U3. U3 drives opto-coupler U2 through resistor R6 to provide feedback information to the CONTROL pin of U1. The opto-coupler output also provides power to U1 during normal operating conditions. D3 and C18 apply drive to the opto-coupler during supply startup to eliminate output voltage overshoot. D3 isolates C18 from the supply feedback loop after startup. R7 discharges C18 when the supply is off. R8 provides bias current to U3.

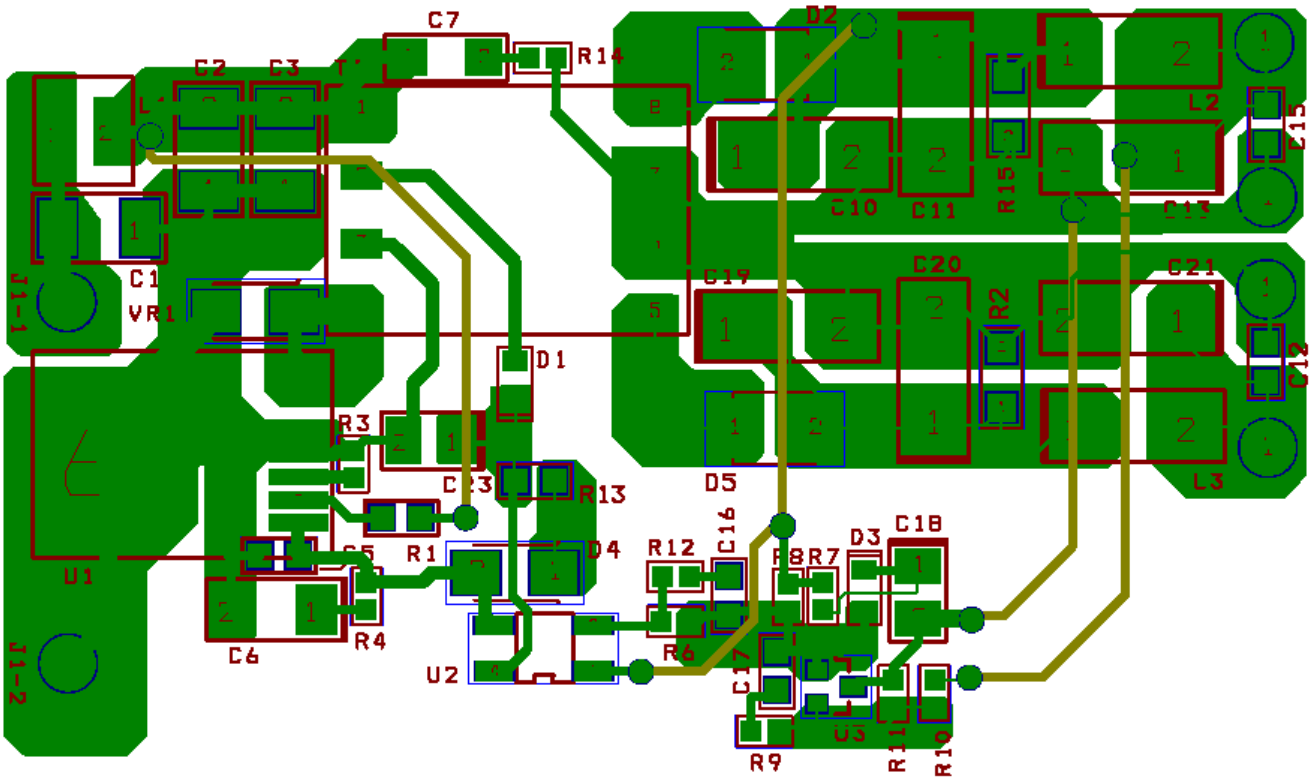
C6, C16, C17, R4, R6, R9, and R12 all play a role in compensating the power supply control loop. C6 rolls off the gain of U1 at a relatively low frequency. R4 provides a zero to cancel the phase shift of C6. R6 sets the gain of the direct signal path from the supply output through U2 and U3. C17 and R9 roll off the gain of U3. R12 and C16 provide phase boost near the resonant frequency of the transformer and output capacitors to improve phase margin and stability.

4 Bill Of Materials

Item	Qty	Reference	Description
1	3	C1, C2, C3	1u0/100V/1812
2	1	C5	220n/0805
3	1	C6	68u/10V
4	1	C7	1n/1.5kV/1808
5	6	C10, C11, C13, C19 C20, C21	100u/16V
6	3	C12, C15, C17	1u0 16V/0805
7	1	C16	100n/0805
8	1	C18	10u/10V
9	1	C23	4u7/20V
10	1	D1	BAV19WS
11	1	D2	MBRS360/SMC
12	1	D3	BAV19WS
13	1	D4	BZT52C5V1/SOD123
14	1	D5	MBRS360/SMC
15	1	L1	1uH /4A
16	2	L2, L3	300nH
17	1	R1	619k 1% / 0805
18	1	R2	150R0/1206
19	2	R3, R7	10k/0603
20	1	R4	1R0/0603
21	1	R6	150/0603
22	1	R8	1k0/0603
23	1	R9	220R/0603
24	1	R10	38k3 1% / 0603
25	1	R11	10k0 1% / 0603
26	1	R12	5R1/0603
27	1	R13	180R/0805
28	1	R14	10R/0603
29	1	R15	150R/1206
30	1	T1	Custom Flyback Transformer
31	1	U1	DPA425R
32	1	U2	PC357N1T
33	1	U3	LM431AIM3
34	1	VR1	SMBJ130A

Power Integrations, Inc.
Tel: +1 408 414 9660 Fax: +1 408 414 9760
www.powerint.com

4.1 Layout


C7
R14
C2
C3
L1
C1
VR1
D1
R3
C23
R13
D5
C16
D3
C18
R12
R8
R7
C5
R1
D4
U1
C6
R4
U2
R6
C17
U3
R9
R11
R10
D2
C10
C11
R15
L2
C15
C20
C21
R2
C12
L3
C14
L1-2

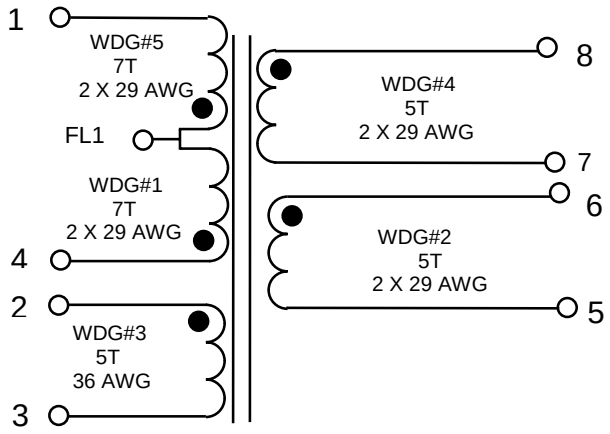
5 Design Spreadsheet

FILE : DPA Flyback Design1 Power Integrations, Inc. Power Supply Design October 09, 2002 16:40:21

A	B	D	F	G	I
DPASwitch_Flyback_Rev_1e_090302; Copyright Power Integrations Inc. 2002	INPUT	INFO	OUTPUT	UNITS	DPASwitch_Flyback_090302 - Continuous/Discontinuous mode Spreadsheet. Copyright 2002 Power Integrations
ENTER APPLICATION VARIABLES					**+/-12V @ 0.8A Dual Output Flyback Converter**
VDCMIN	36			Volts	Minimum DC Input Voltage
VDCMAX	72			Volts	Maximum DC Input Voltage
VO	12			Volts	Output Voltage
PO	19.6			Watts	Output Power
n	0.86				Efficiency Estimate
Z			0.7		Loss Allocation Factor, (0.7 Recommended)
VB	14			Volts	Bias Voltage
UV AND OV PARAMETERS					
		min	max		
VUVOFF		29.3	32.4	Volts	Minimum undervoltage On-Off threshold
VUVON		31.5	33.9	Volts	Maximum undervoltage Off-On threshold (turn-on)
VOVON		73.1	-	Volts	Minimum overvoltage Off-On threshold
VOVOFF			92.4	Volts	Maximum overvoltage On-Off threshold (turn-off)
RL			603.1	k-Ohms	Line Sense Resistor
ENTER DPASWITCH VARIABLES					
DPASWITCH	**dpa425**			*16VDC*	*36VDC*
Chosen Device	*DPA425*		*Power Out*	*31W*	*70W*
ILIMITMAX	*4.65*	*5.35*		Amps	From DPASWITCH Data Sheet
Frequency	*f*				Enter 'F' for fS = 400KHz and 'L' for fS = 300KHz
fS	400000			Hertz	DPASWITCH Switching Frequency
VOR	**35**		**35**	Volts	Reflected Output Voltage
KI	0.60		0.6		Current Limit Reduction Factor
ILIMITEXT			2.790	Amps	Minimum External Current limit
RX			12.7	k-Ohms	Resistor from X pin to source to set external current limit
VDS	2.5			Volts	DPASWITCH on-state Drain to Source Voltage
VD	0.5			Volts	Output Winding Diode Forward Voltage Drop
VDB	0.7			Volts	Bias Winding Diode Forward Voltage Drop
KRP/KDP	**0.90**				Ripple to Peak Current Ratio (0.2 < KRP < 1.0 : 1.0< KDP<6.0)
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**epc19**				
Core Manuf					
Bobbin Manuf					
Core		*EPC19*		*P/N:*	*PC44EPC19-Z*
Bobbin		*#N/A*		*P/N:*	*#N/A*
AE			0.227	cm^2	Core Effective Cross Sectional Area
LE			4.61	cm	Core Effective Path Length
AL			940	nH/T^2	Ungapped Core Effective Inductance
BW			#N/A	mm	Bobbin Physical Winding Width
M	0			mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	**1**				Number of Primary Layers
NS	**6**				Number of Secondary Turns
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.51		Maximum Duty Cycle
IAVG			0.63	Amps	Average Primary Current
IP			2.25	Amps	Peak Primary Current
IR			2.03	Amps	Primary Ripple Current
IRMS			0.98	Amps	Primary RMS Current
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			22	uHenries	Primary Inductance
NP			17		Primary Winding Number of Turns
NB			7		Bias Winding Number of Turns
ALG			77	nH/T^2	Gapped Core Effective Inductance
BP			1590	Gauss	Peak Flux density during transients (Limit to 4000 Gauss)
BM		***Warning***	1284	Gauss	Peak Flux density<2000 Gauss, A smaller core may be used
BAC			578	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1519		Relative Permeability of Ungapped Core
LG			**0.34**	mm	Gap Length (Lg >> 0.051 mm)
BWE			#N/A	mm	Effective Bobbin Width
TRANSFORMER SECONDARY DESIGN PARAMETERS					
ISP			6.31	Amps	Peak Secondary Current
ISRMS			2.68	Amps	Secondary RMS Current
IO			1.63	Amps	Power Supply Output Current
IRIPPLE			2.13	Amps	Output Capacitor RMS Ripple Current
VOLTAGE STRESS PARAMETERS					
VDRAIN			166	Volts	Maximum Drain Voltage (Includes Effect of Leakage Inductance)
PIVS			38	Volts	Output Rectifier Maximum Peak Inverse Voltage
PIVB			44	Volts	Bias Rectifier Maximum Peak Inverse Voltage
ADDITIONAL OUTPUTS					
V_OUT2				Volts	Auxiliary Output Voltage
VD_OUT2				Volts	Auxiliary Diode Forward Voltage Drop
N_OUT2			0.00		Auxiliary Number of Turns

Power Integrations, Inc.
Tel: +1 408 414 9660 Fax: +1 408 414 9760
www.powerint.com

6 Transformer



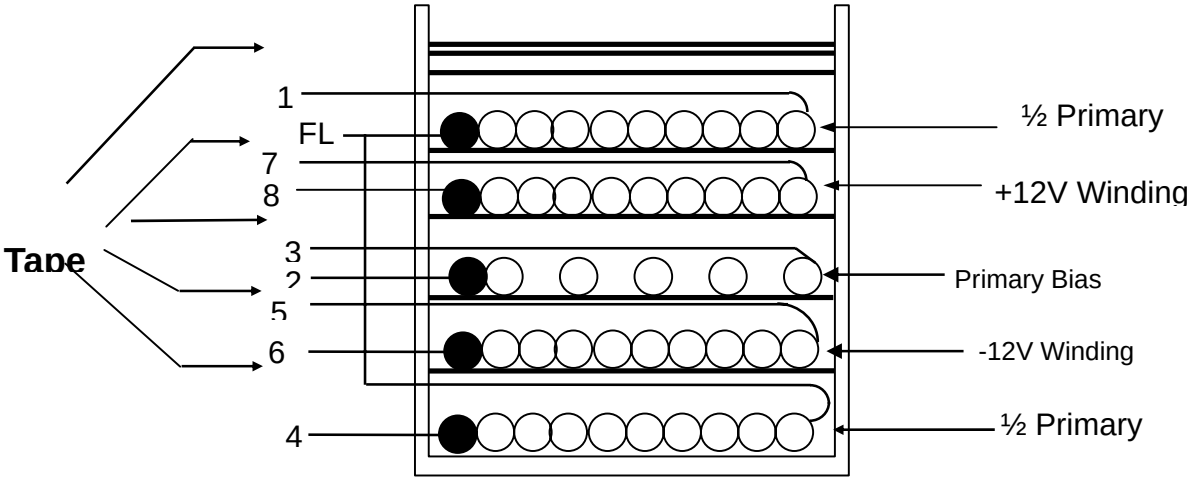
MATERIALS

Item	Description
[1]	Core: PR14X8 or equivalentgap for AL of 112.2 nH/T2
[2]	Bobbin: 8 pin surface mount
[3]	Magnet Wire: #29 AWG Double Coated
[4]	Magnet Wire: #36 AWG Double Coated
[5]	Tape, Polyester
[6]	Varnish

ELECTRICAL SPECIFICATIONS:

Electrical Strength	1 second, from Pins 1-4 to Pins 5-8	1500 VDC
Creepage	Between Pins 1-4 and Pins 5-8	N/A
Primary Inductance	Pins 1,4, all other windings open, measured at 400KHz, 400mVRMS	22 mH, ±10 %
Resonant Frequency	Pins 1,4, all other windings open	5.0 MHz (Min.)
Primary Leakage Inductance	Pins 1,4, with Pins 5-8 shorted, measured at 400KHz, 400mVRMS	0.75 mH (Max.)

TRANSFORMER CONSTRUCTION



WINDING INSTRUCTIONS:

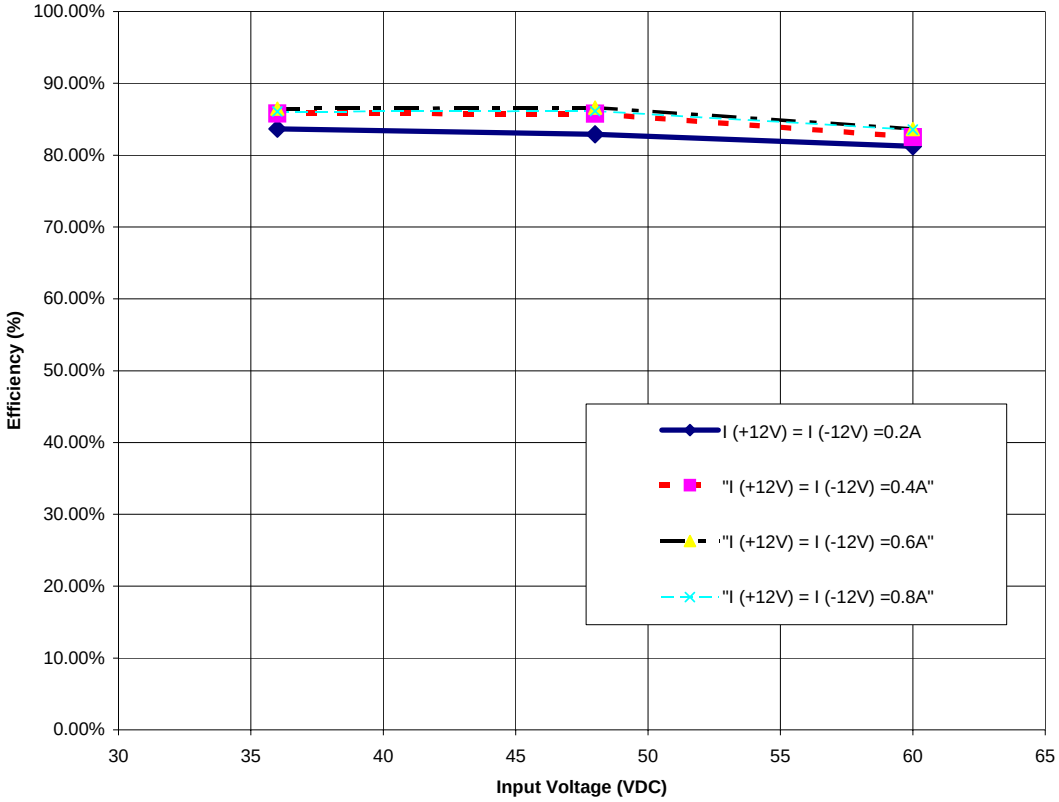
½ Primary	Start at Pin 4. Wind 7 bifiliar turns of item [3]. Finish on Exit-finish lead at bobbin flange slot on primary side of bobbin, leaving 1” lead length.
Basic Insulation	Use one layer of item [5] for basic insulation.
-12V Winding	Start at Pin 6. Wind 5 bifiliar turns of item [3] Finish on Pin 5.
Basic Insulation	Use one layer of item [5] for basic insulation.
Primary Bias	Start at Pin 2. Wind 5 turns of item [4] Finish on Pin 3.
Basic Insulation	Use one layer of item [5] for basic insulation.
+12V Winding	Start at Pin 8. Wind 5 bifiliar turns of item [3] Finish on Pin 7.
½ Primary	Start in bobbin flange slot on primary side of transformer leave 1” lead length at start. Wind 7 bifiliar turns of item [3]. Finish on Pin 1.
Outer Wrap	Wrap windings with 3 layers of tape [item [5].
Flying Lead Finish	Twist start of winding 4 together with finish of winding 2. Tin and trim to 1/8” length (FL1).
Final Assembly	Assemble and secure core halves. Varnish and impregnate (item [6]).

Power Integrations, Inc.
Tel: +1 408 414 9660 Fax: +1 408 414 9760
www.powerint.com

7 Performance Measurements

All measurements performed at room temperature.

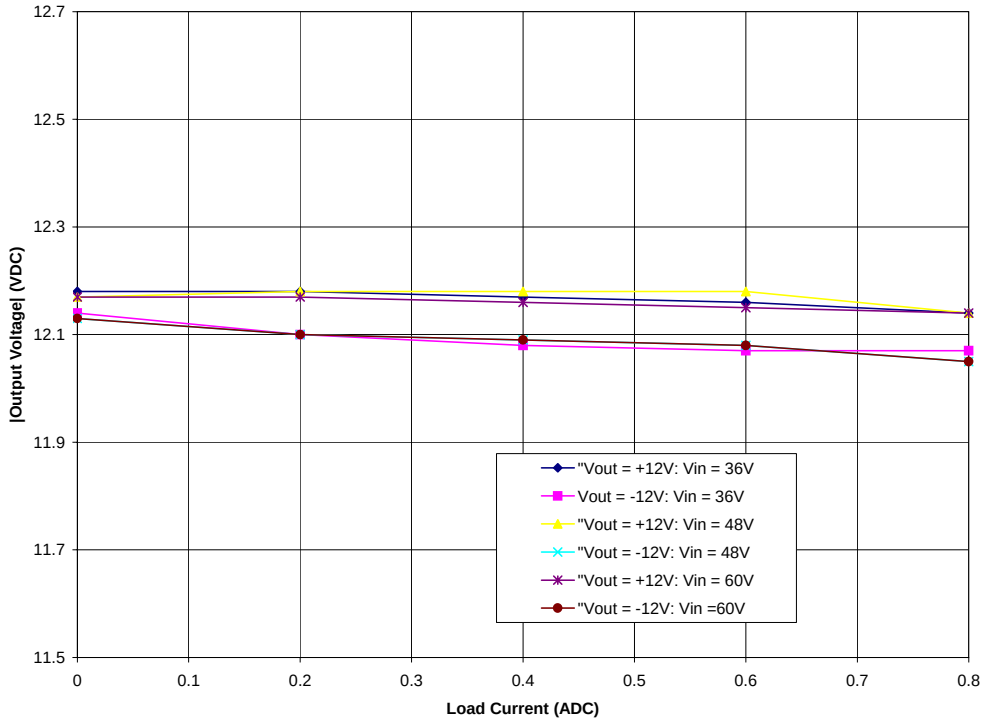
7.1 Efficiency



Efficiency vs. Input Voltage, Full Load, Room Temperature

7.2 Regulation

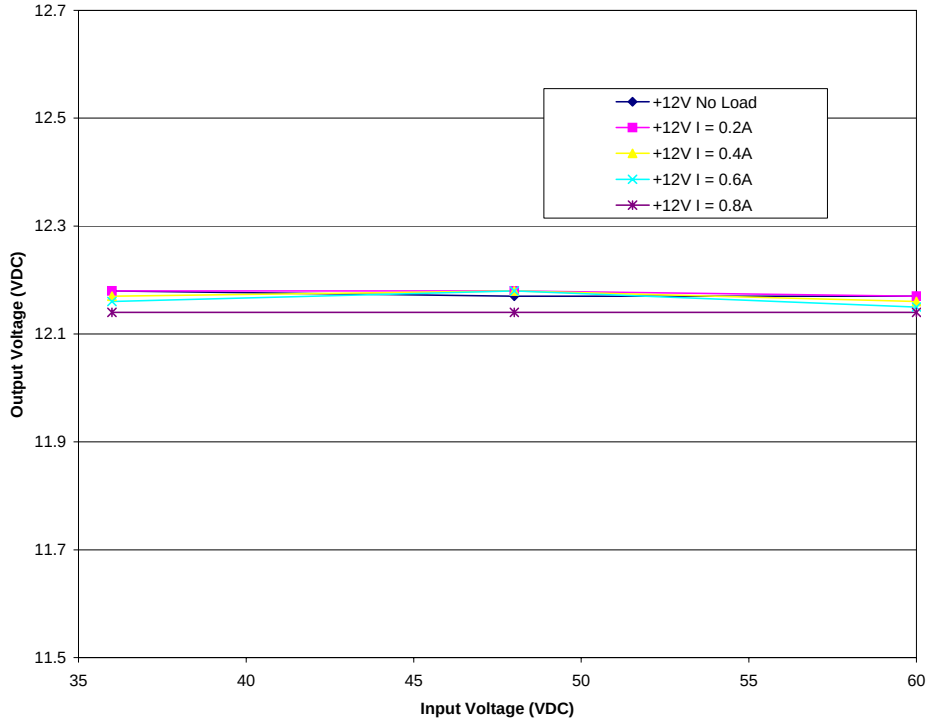
7.2.1 Load



Load Regulation, enter conditions

Power Integrations, Inc.
Tel: +1 408 414 9660 Fax: +1 408 414 9760
www.powerint.com

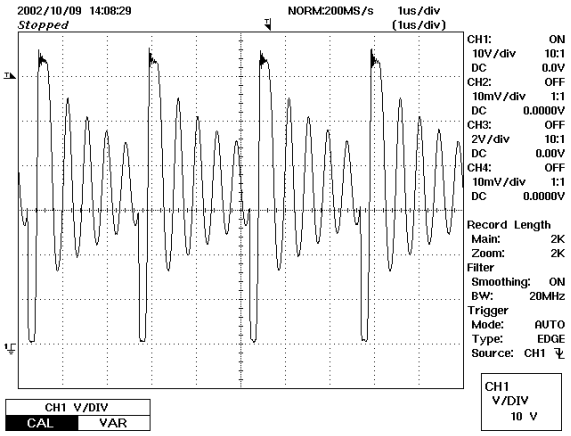
7.2.2 Line



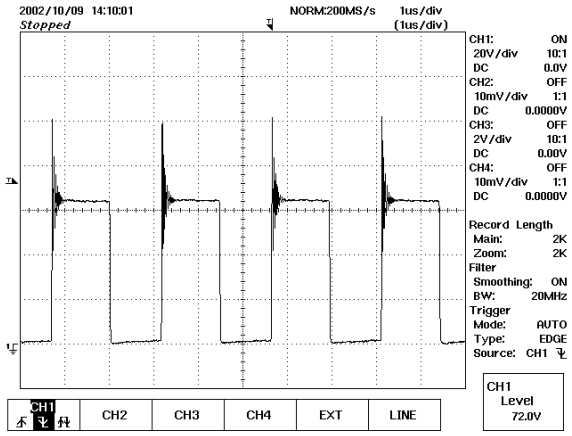
Line Regulation, enter conditions

8 Waveforms

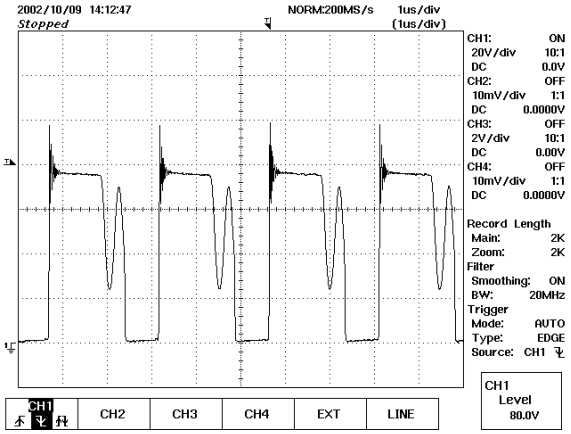
8.1 Drain Voltage, Normal Operation



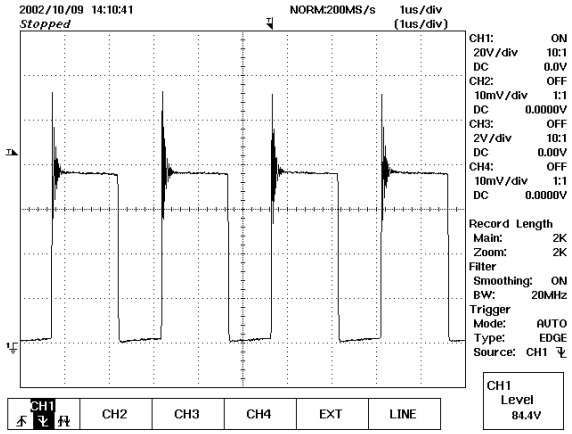
36VDC No Load- VDS, 20V / div



36VDC Full Load- VDS, 20V / div

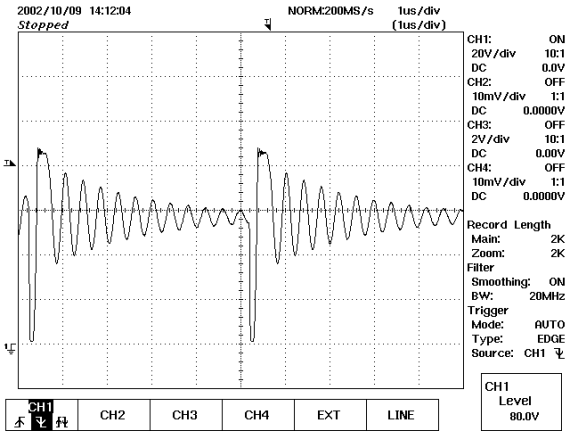


48VDC Half-Load- VDS, 20V / div

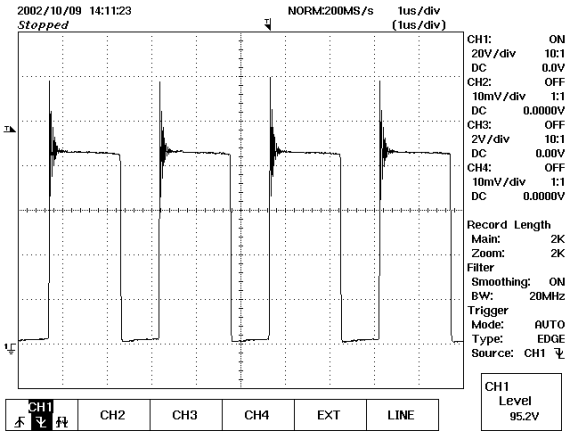


48VDC Full Load- VDS, 20V / div

Power Integrations, Inc.
Tel: +1 408 414 9660 Fax: +1 408 414 9760
www.powerint.com

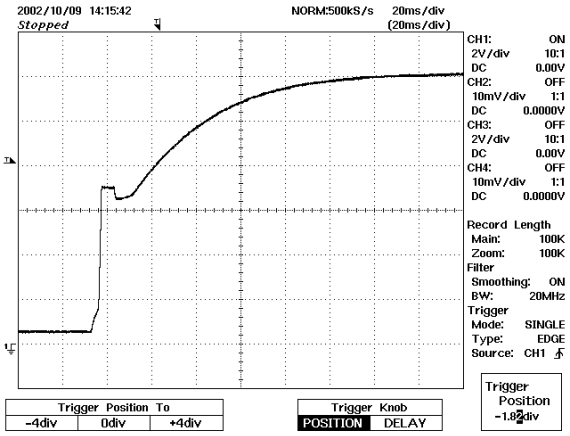


63VDC No Load- VDS, 20V / div

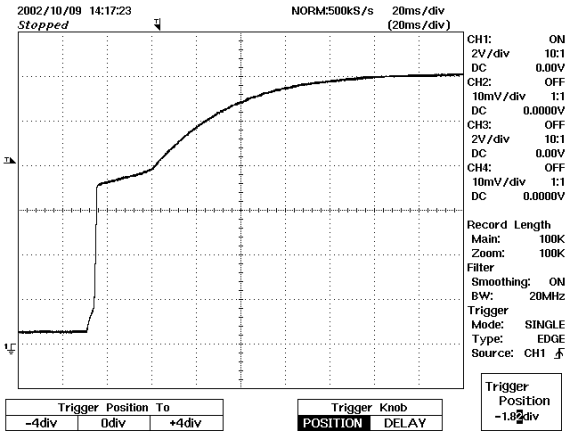


63VDC Full Load- VDS, 20V / div

8.2 Output Voltage Start-up Profile



Start-up Profile, Vin = 48V, No Load (20msec/div) & (2V/div)



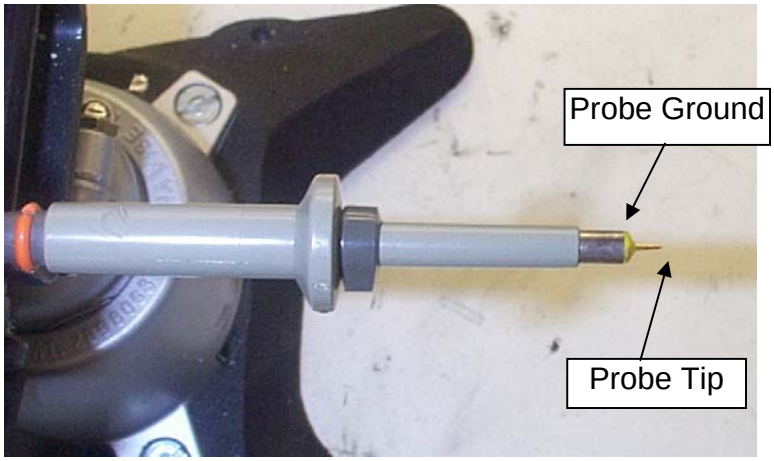
Start-up Profile, Vin = 48V, Full-Load (20msec/div) & (2V/div

8.3 Output Ripple Measurements

8.3.1 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 24 and Figure 25.

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

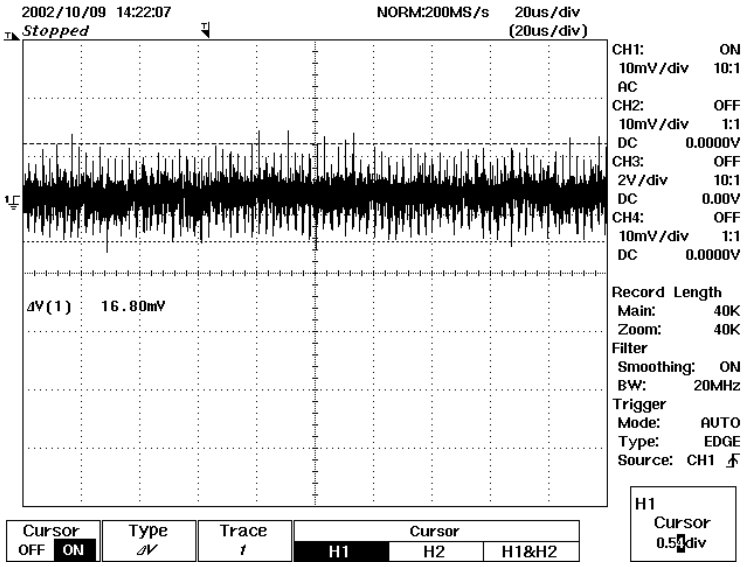


Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

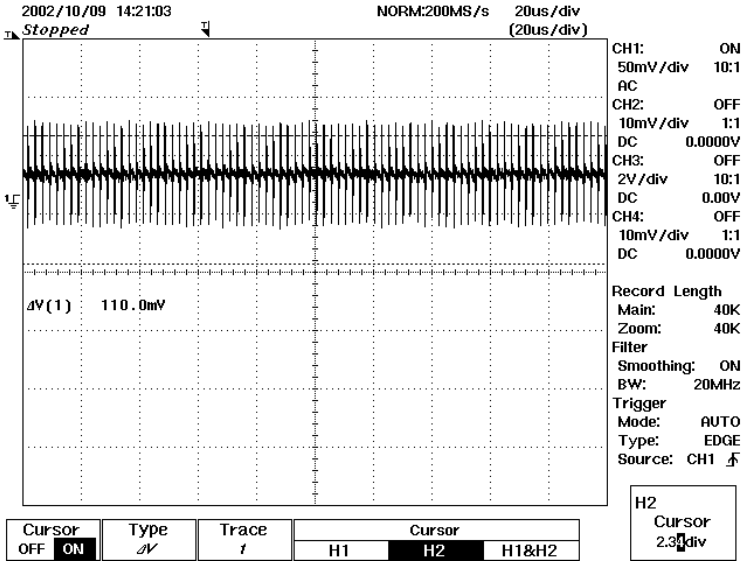
Oscilloscope Probe with Probe Master 5125BA BNC Adapter. (Modified with wires for probe ground for ripple measurement, and two parallel decoupling capacitors added)

Power Integrations, Inc.
Tel: +1 408 414 9660 Fax: +1 408 414 9760
www.powerint.com

8.3.2 Measurement Results at 48 VDC



+12 V Ripple, No Load
2 us, 10 mV / div



+12 V Ripple, Full Load
2 us, 10 mV / div

9 Revision History

Date	Author	Revision	Description & changes
2/19/2003	RM	1	Initial Release

Power Integrations, Inc.
Tel: +1 408 414 9660 Fax: +1 408 414 9760www.powerint.com

Notes

For the latest updates, visit our website: *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.

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.

WORLD HEADQUARTERS AMERICAS
Power Integrations, Inc.
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

EUROPE & AFRICA
Power Integrations (Europe) Ltd.
Centennial Court
Easthampstead Road
Bracknell
Berkshire RG12 1YQ,
United Kingdom
Phone: +44-1344-462-300
Fax: +44-1344-311-732
E-Mail:
eurosales@powerint.com

SINGAPORE
Power Integrations, Singapore
51 Goldhill Plaza #16-05
Republic of 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

CHINA
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

KOREA
Power Integrations
International Holdings, Inc.
8th Floor, DongSung Building
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

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

INDIA (Technical Support)
Innovatech
#1, 8th Main Road
Vasanthnagar
Bangalore, India 560052
Phone: +91-80-226-6023
Fax: +91-80-228-9727
E-Mail:
indiasales@powerint.com

APPLICATIONS HOTLINE
World Wide +1-408-414-9660

APPLICATIONS FAX
World Wide +1-408-414-9760

Power Integrations, Inc.
Tel: +1 408 414 9660 Fax: +1 408 414 9760www.powerint.com