Title	***Engineering Report – 65W Single Output Adapter, iW2210***
Specification	Input: 90 – 265 V_{AC} Output: 19V / 3.5A @65W max.
Customer	Various
Application	Adapter for Various Applications
Author	iWatt Applications Department
Document Number	AE-4003
Date	July 11, 2005
Revision	NR

Summary and Features

- Compact size (100 x 41.5 x 25mm)
- Designed to achieve low cost & part count
- Designed to meet both conducted & radiated EMI requirements
- A Production ready model that meets safety requirements

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Important Note: (Read this before using this document)

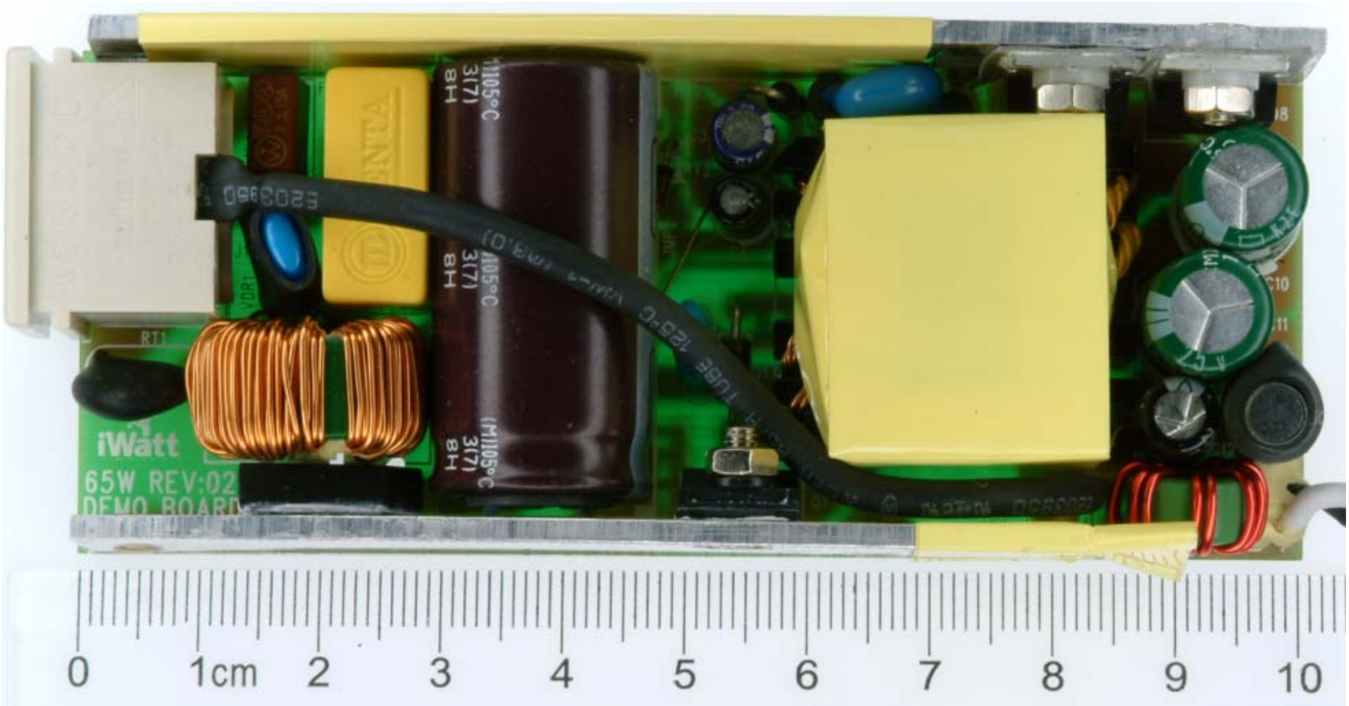
This document and the information provided herein are solely for design and engineering reference (includes safety and related requirements). iWatt is not responsible for any claim of damage resulting from the use of these materials.

This test report describes a 65W converter which utilizes iWatt 2210, an advanced digital PWM controller that delivers 19V, 3.5A (or 65W) of power.

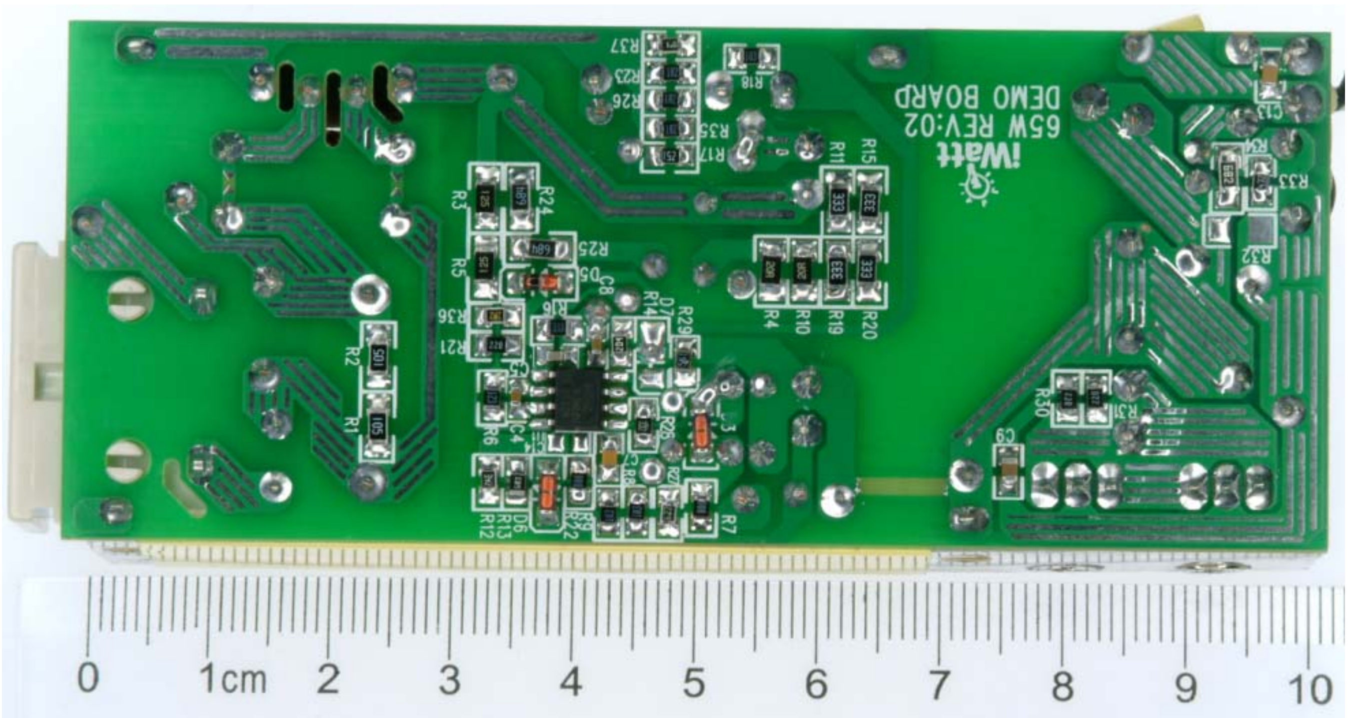
This design aims for low cost and meets EMI and most Immunity requirements.

The following information is included in this test report: schematic, bill of materials, transformer documentation, printed circuit layout and performance data. For additional information please email sales@iwatt.com or visit our website at *http://www.iwatt.com*.

Finished Assembly



Component side (Top)

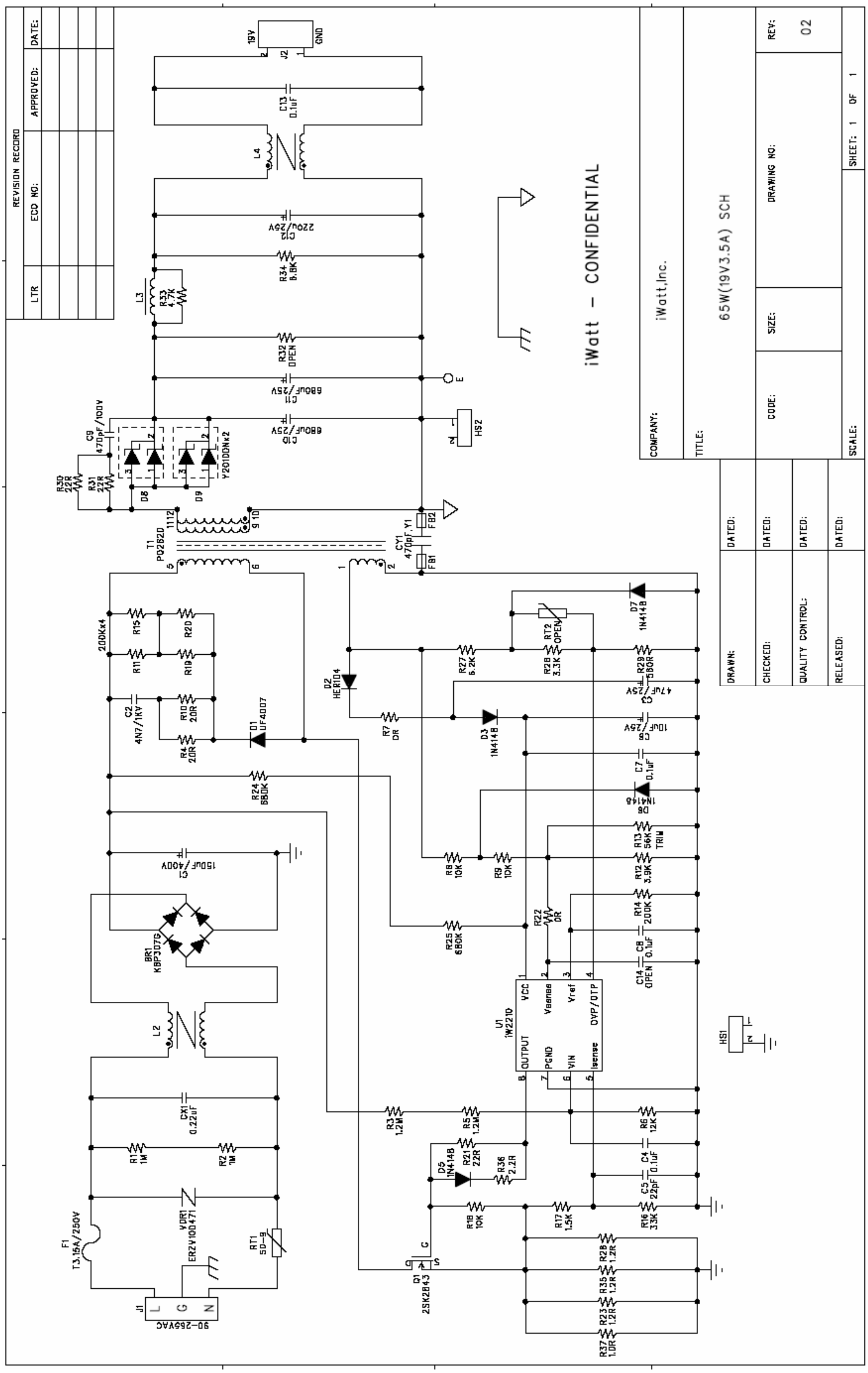


Solder side (Bottom).

1 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		265	V_{AC}	3 Wire
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (265 VAC)				0.6	W	
Output						
Output Voltage 1	V_{OUT1}		19		V	Note 1
Output Ripple Voltage 1	$V_{RIPPLE1}$			150	mV	20 MHz Bandwidth
Output Current 1	I_{OUT1}			3.5	A	
Total Output Power						
Continuous Output Power	P_{OUT}			65	W	
Over Current Protection	I_{OUT_max}			6	A	Latched off, required full AC recycle
Efficiency	η	86			%	Measured conditions : 1) Vin=90Vac @P_{OUT} =65W 2) Ambient temperature is 25 ℃ 3) Reference at PCB/Board end.
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950, UL1950 Class II				
Ambient Temperature	T_{AMB}	0		40	℃	Free convection, sea level

2 Schematic



3 Circuit Description

The iW2210 is a Flyback switch-mode power supply controller that employs intelligent digital processing techniques, green mode efficiency and a low component count. This new digital control technology uses primary side sensing to accurately regulate output voltage and current. The iW2210 eliminates the need for many external circuits, such as feedback loop (opto & reference), OCP, OVP and SCP. iWatt's proprietary digital control scheme improves many key aspects of the power supply design that are not possible with typical conventional approach such as accurate primary side sensing, excellent light load efficiency and ZVS switching. Accurate primary-side constant current mode (CC) operation makes the iW2210 ideal for low cost battery charger applications. In applications where a fixed output voltage is required, the iW2210 can be programmed to operate in constant voltage mode (CV) operation. Ultra-high reliability is achieved by eliminating the low MTBF components like opto-coupler.

The schematic shows an off-line Flyback compact adapter using iWatt's Digital Controller - iW2210. This supply operates from 90 - 265 VAC and provides isolated output of 19V at 3.5A.
DC Filtering - The AC input is first rectified by BR1 and filtered by C1. The startup of the chip is done by drawing a DC bus supply to V_{CC} (pin-1) via R24 & 25. The start function of iW2202 happens as soon as its V_{CC} pin has reach the min. startup voltage of 14V. The operational voltage to this pin needs to be maintained between 8-17V for it to operate properly.
Start up - R3, R5 & R6 is set at a predetermined value to operate within a AC input range (85-264Vac). By selecting the right voltage level at Pin-6 (DC input voltage sense), the supply could be designed to operate at a predetermined AC range.
O/P sensing and chip supply - The Aux winding (Pin 1-2 of the transformer) is used to power the operation of the chip as well as provide regulated output voltage sensing. D2, D3 and C3 provides rectification and filtering. R8, R9, R12 & R13 is used as a voltage divider for output voltage settings. D6 is used to clamp the –ve swing of sensing voltage.
Output Driving – The output is capable of providing up to +/-1.5A of both Sink & Source current for most Power FET available in the market. If the switching speed needs to be adjusted for EMI reasons, external resistors could be used with tread-off of higher switching losses.
OTP and OVP – By setting the values of R27, R28, RT2 & R29, the OTP will be trigger approx at 120° -130°C and OVP would activated ~ 20-21V (also, 22-23Vdc @25'C).
Secondary Output – C10, C11, and C12 are the filtering capacitors and need to be low ESR or low output ripple voltage. C9, R30, and R31 are the secondary snubber to reduce voltage spike across Schottky Diodes D8 & D9. L4 is a common mode choke for radiated EMI and with the unique cable compensation feature in iW2210, it allow a smaller size of output cable to be used.

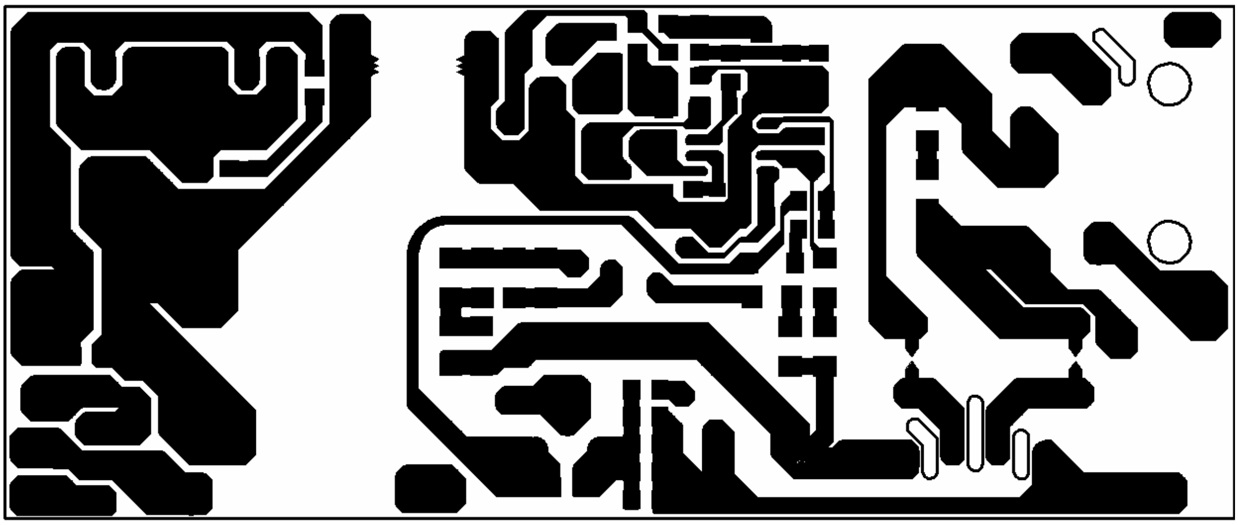
4 Bill of Materials

65W Adapter BOM
Rev.02
Date:2005/04/28

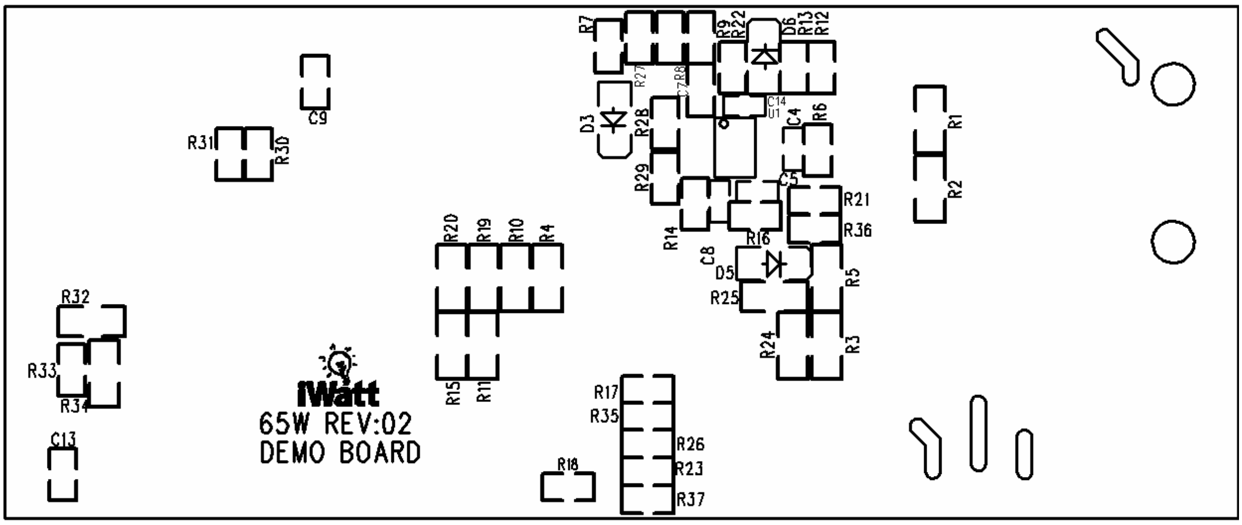
ITEM	Qty	Ref	Description	Value	Manufacturer
BOTTOM SIDE COMPONENTS					
1	1	U1	SO-8	iW2210	iWatt Inc.
2	2	C4,C8	SMD Capacitor,0603	0.1uF/50V	Murata/TDK
3	1	C5	SMD Capacitor,0603	22pF/50V	Murata/TDK
4	1	C14	SMD Capacitor,0603	OPEN	Murata/TDK
5	2	C7,C13	SMD Capacitor,0805	0.1uF/50V	Murata/TDK
6	1	C9	SMD Capacitor,0805	470pF/100V	Murata/TDK
7	1	R6	SMD Resistor,1/8W,0805	12K(±5%)	Various
8	2	R7,R22	SMD Resistor,1/8W,0805	0Ω(±5%)	Various
9	3	R8,R9,R18	SMD Resistor,1/8W,0805	10KΩ(±5%)	Various
10	1	R12	SMD Resistor,1/8W,0805	3.9KΩ(±5%)	Various
11	1	R13	SMD Resistor,1/8W,0805	TRIM	Various
12	1	R14	SMD Resistor,1/8W,0805	200KΩ(±5%)	Various
13	1	R16	SMD Resistor,1/8W,0805	33KΩ(±5%)	Various
14	1	R17	SMD Resistor,1/8W,0805	1.5KΩ(±5%)	Various
15	3	R21,R30,R31	SMD Resistor,1/8W,0805	22Ω(±5%)	Various
16	3	R23,R26,R35	SMD Resistor,1/8W,0805	1.2Ω(±5%)	Various
17	1	R27	SMD Resistor,1/8W,0805	6.2KΩ(±5%)	Various
18	1	R28	SMD Resistor,1/8W,0805	3.3KΩ(±5%)	Various
19	1	R29	SMD Resistor,1/8W,0805	560Ω(±5%)	Various
20	1	R33	SMD Resistor,1/8W,0805	4.7KΩ(±5%)	Various
21	1	R36	SMD Resistor,1/8W,0805	2.2Ω(±5%)	Various
22	1	R37	SMD Resistor,1/8W,0805	1Ω(±5%)	Various
23	2	R1,R2	SMD Resistor,1/4W,1206	1MΩ(±5%)	Various
24	2	R3,R5	SMD Resistor,1/4W,1206	1.2M(±5%)	Various
25	2	R4,R10	SMD Resistor,1/4W,1206	20Ω(±5%)	Various
26	4	R11,R15,R19,R20	SMD Resistor,1/4W,1206	33KΩ(±5%)	Various
27	2	R24,R25	SMD Resistor,1/4W,1206	680KΩ(±5%)	Various
28	1	R32	SMD Resistor,1/4W,1206	OPEN	Various
29	1	R34	SMD Resistor,1/4W,1206	6.8KΩ(±5%)	Various
30	3	D3,D5,D6	Fast rectifier diode,DL-35	1N4148	Various
TOP SIDE COMPONENTS					
31	1	J1	3 Pins AC input connector	ST-03	Various
32	1	J2	Output Cable, AWG#18,1.5M		Custom
33	1	F1	FUSE	T3.15A/250V	Bell/Little Fuse/WAL
34	1	VDR1	Mov,3.5KA(8/20us)/300Vac	ERZV10D471	Panasonic
35	1	BR1	Bridge rectifier,3A/1KV	KBP307G	MOSPEC
36	1	C1	E-Cap,18mmX35mm	150uF/400V	Rubycon/Nichicon
37	1	C3	E-Cap,5mmX12mm	47uF/25V	Rubycon/Nichicon
38	1	C6	E-Cap,4mmX7.5mm	10uF/25V	Rubycon/Nichicon
39	2	C10,C11	E-Cap,10mmX16mm	680uF/25V	Rubycon/Nichicon
40	1	C12	E-Cap,6.3mmX11.5mm	220uF/25V	Rubycon/Nichicon
41	1	C2	Ceramic Capacitor	4.7nF/1KV	Various
42	1	CX1	X-Cap,X2	0.22uF/275V	Siemens/MAT
43	1	CY1	Y-Cap,Y1	470pF/250V	TDK/MAT/Murata

44	1	D1	Ultra fast rectifier diode	UF4007	Various
45	1	D2	Ultra fast rectifier diode	HER104	Various
46	1	D7	Fast rectifier diode,DO-35	1N4148	Various
47	2	D8,D9	SK-Diode,TO-220	Y2010DN	Fairchild
48	1	L2	Please refer to Inductor Specification	Ditto	Custom
49	1	L4	Please refer to Inductor Specification	Ditto	Custom
50	1	L3	Please refer to Inductor Specification	Ditto	Custom
51	1	Q1	Mosfet,TO-220	2SK2843	Infineon
52	1	RT1	NTC Thermistor,5D-9	5Ω	Various
53	1	RT2	NTC Thermistor (For OTP)	OPEN	Various
54	1	T1	Transformer	PQ2620	Custom
OTHERS COMPONENTS					
55	1	JMP1	Jumper Wire	Φ1.0mm	Various
56	2	JMP2-3	Jumper Wire	Φ0.8mm	Various
57	1	HS1	L80mm,H20mm,T2mm		Custom
58	1	HS2	L98.5mm,H20mm,T2mm		Custom
59	2	FB1,FB2	Ferrite Bead,3.5mmx1.5mm		Various
60	3	Counter-Sink Screw	M3x10mm		Various
61	1	PCB	Single Sided thick 1.6mm,FR-4,94V0	100mmX41.5mm	Custom

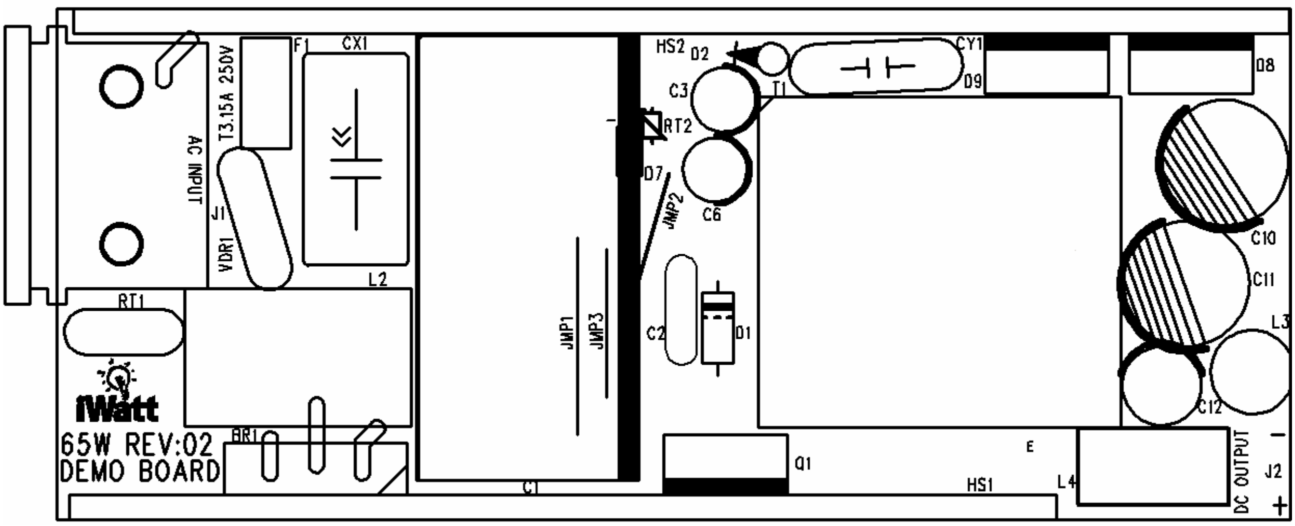
5 PCB Layout



Routing



Bottom Silkscreen

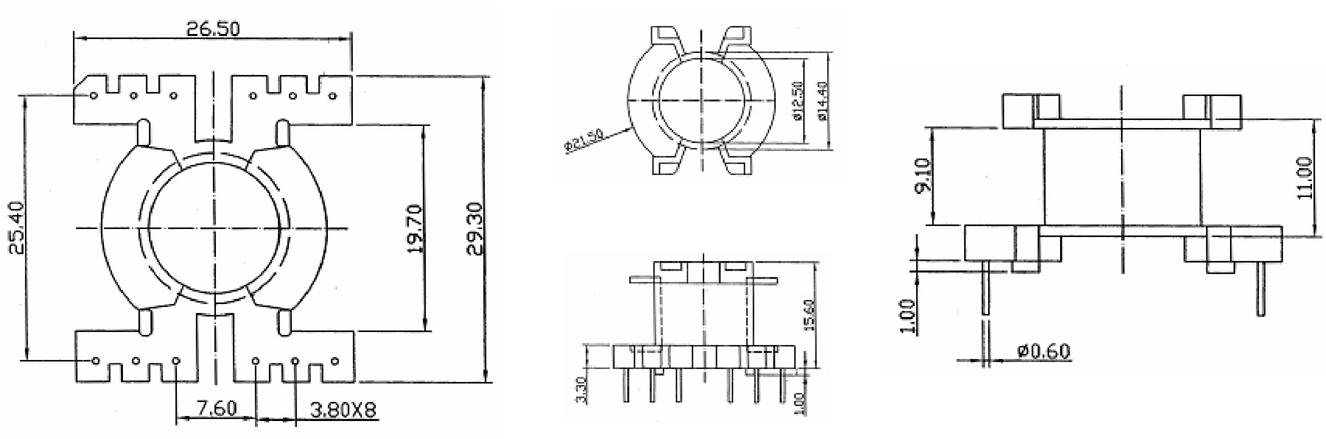


Top Silkscreen

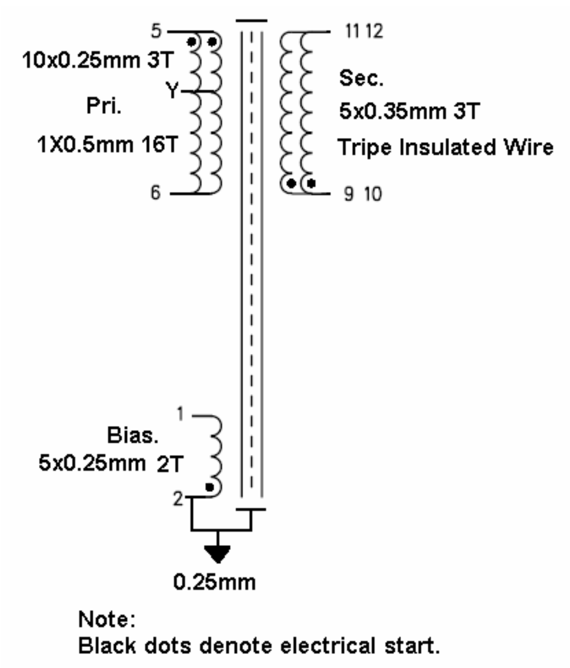
6 Transformer Specification

6.1 Bobbin Outline

Unit: mm



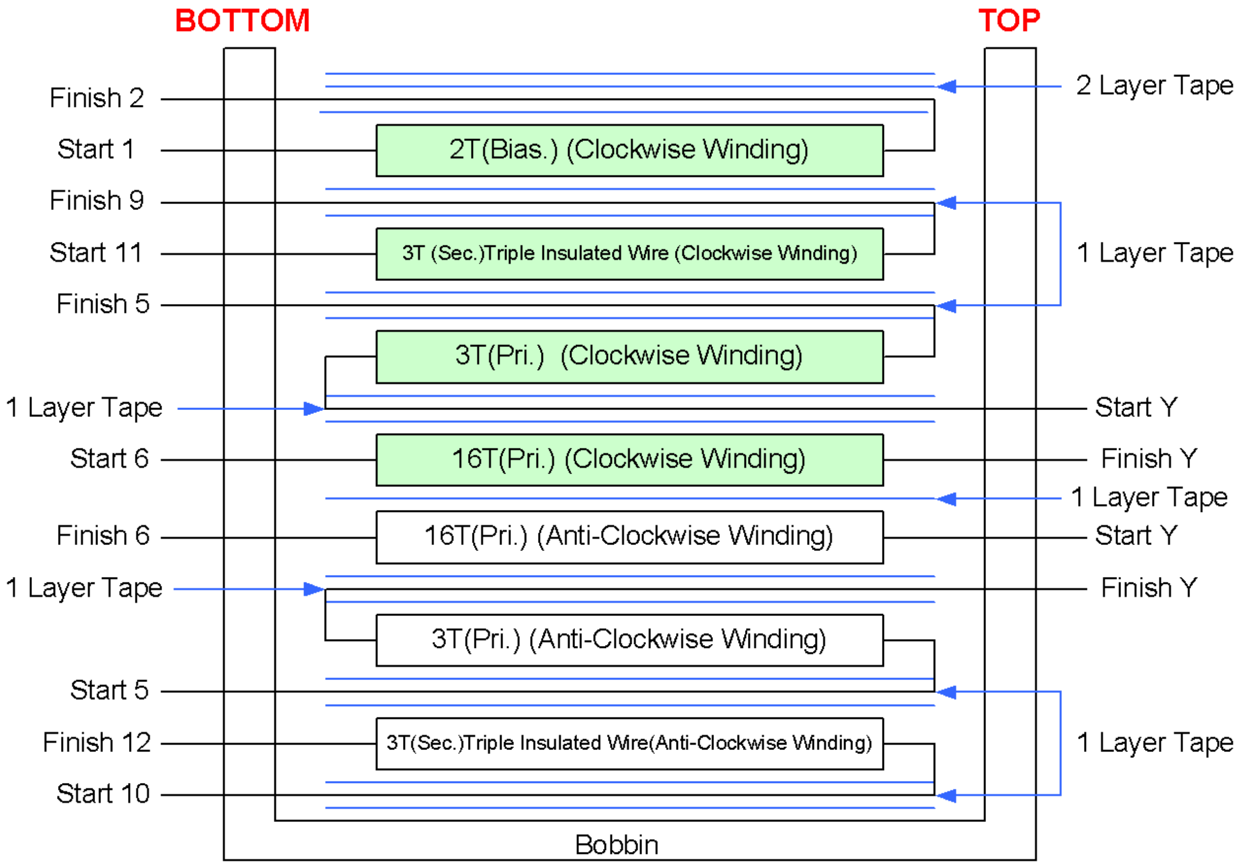
6.2 Electrical Diagram



6.3 Electrical Specifications

Electrical Strength	60Hz, 1minute, from Pins 1, 2, 5, 6 to Pins 9, 10, 11,12	$3000V_{AC}$
Creepage	Between Pins 1, 2, 5, 6 and Pins 9, 10, 11, 12	6mm (Min)
Primary Inductance	Pins 5-6, all other windings open, measured at 10kHz@1V	170µH±5%
Primary Leakage Inductance	Pins 1, 2, 9, 10, 11, 12 shorted, measured at 10kHz@1V	3.5µH (Max.)

6.4 Construction

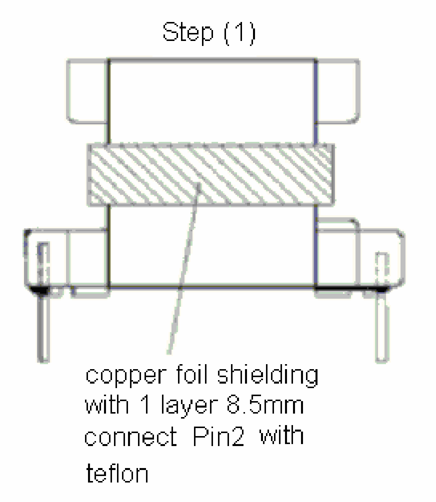


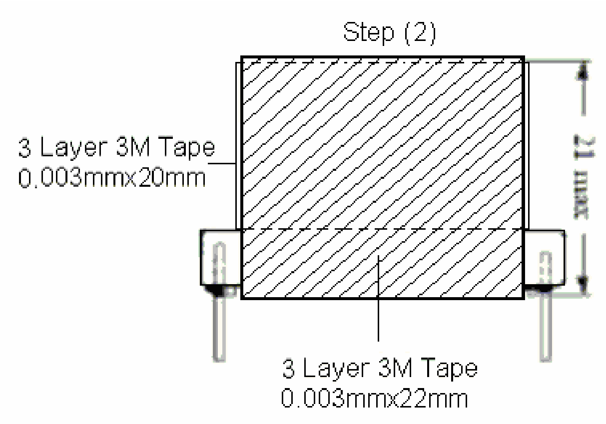
Note:
The winding's direction is viewed from bottom of bobbin.

6.5 Materials

Item	Description
(1)	Core: PQ2620, PC40 material or equivalent. AL of Gapped core ~ 470nH/T^2
(2)	Bobbin: 12 Pin PQ2620
(3)	Triple Insulated Wire: 0.35mm
(4)	Magnet Wire:0.25mm Double Coated
(5)	Magnet Wire:0.5mm Double Coated
(6)	Tape, 3M #1298 or equiv. 9mm wide
(7)	Copper Foil: Thick=0.08mm,Width=8.5mm
(8)	Tape, 3M #1298 or equiv. 20mm wide
(9)	Tape, 3M #1298 or equiv. 22mm wide
(10)	Dolph BC359 varnish (density=0.885) or equivalent

6.6 Others Assembly Details

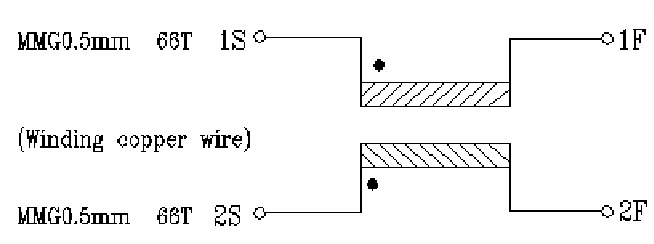


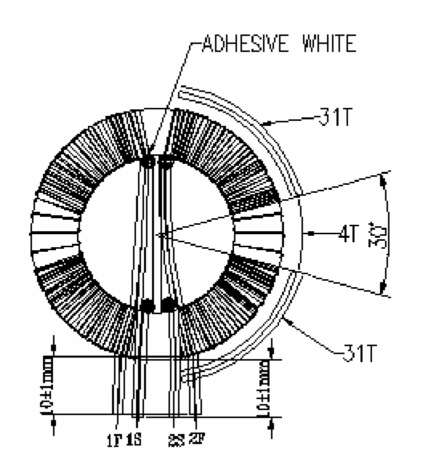


7 Inductor Specification

7.1 CM Inductor (L2)

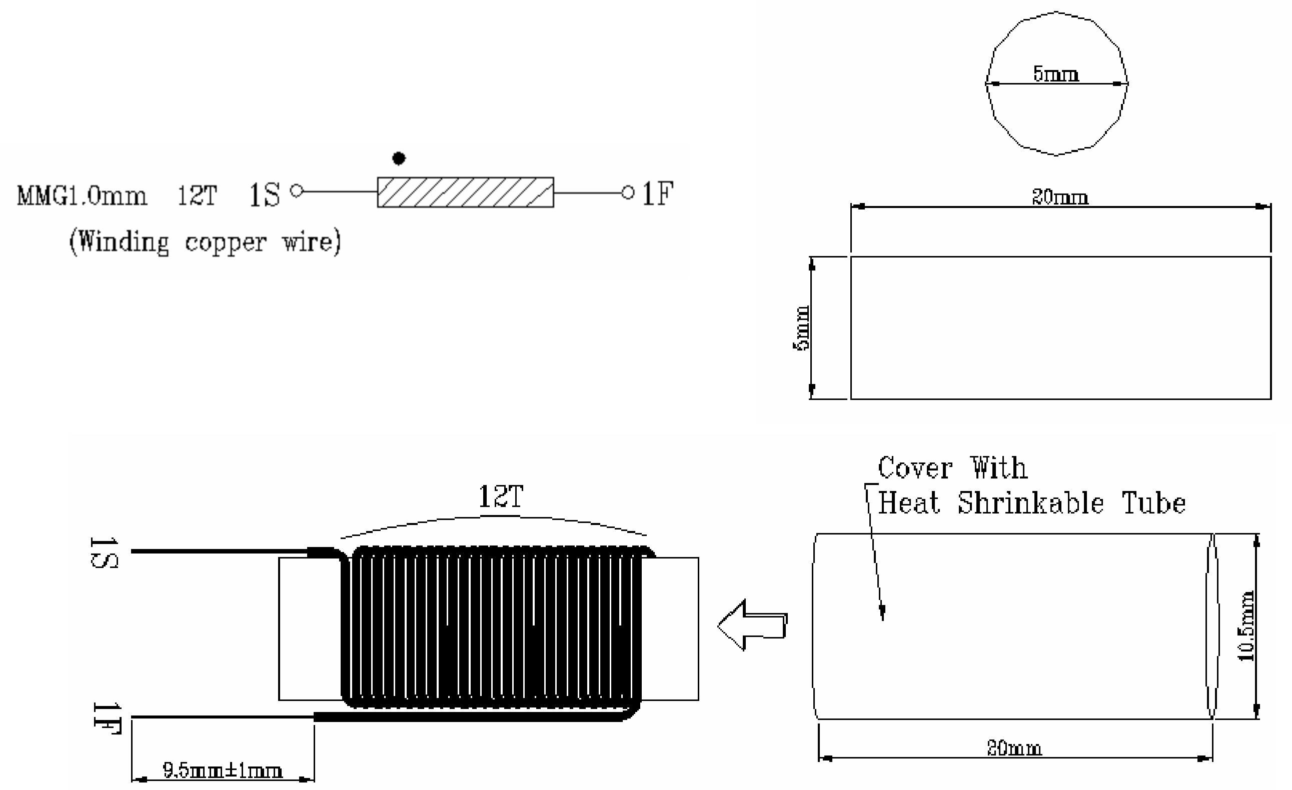
1) Inductance: 9-20mH
2) Material: R5K (μI = 5000±25%, AL= 3286nH/N^2 ±25%) or equivalent
3) Core size (OD x ID x TH): (16 x 10 x 7mm), with polymer coating.





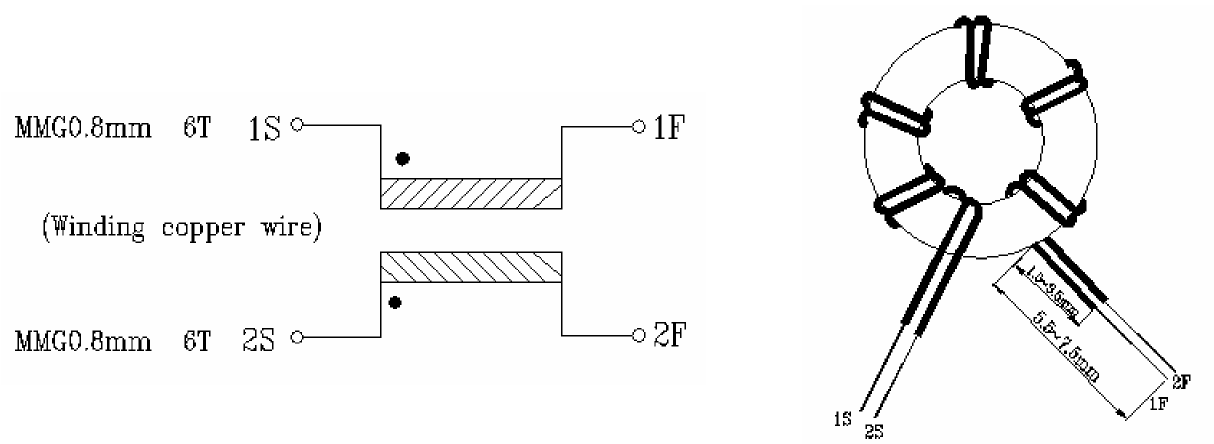
7.2 Output Filter Inductor (L3)

1) Inductance: 3.5 - 4.5 µH
2) Material: DN35H (DMEGC CO.) or equivalent.
3) Core size (DIA x L) : (5 x 20mm)



7.3 CM Inductor (L4)

1) Inductance: 80-130 µH
2) Material: R5K (µI = 5000±25% 2551nH/N² ±25%) or equivalent
3) Core size (OD x ID x TH): (10 x 5 x 5mm), with polymer coating.

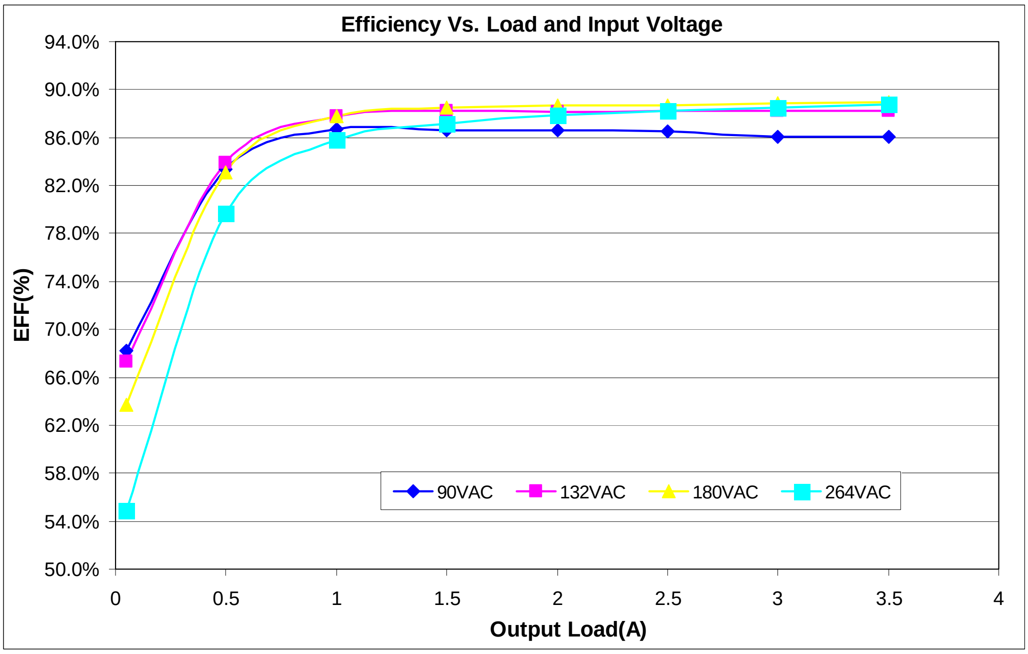


8 Static Electrical Performance

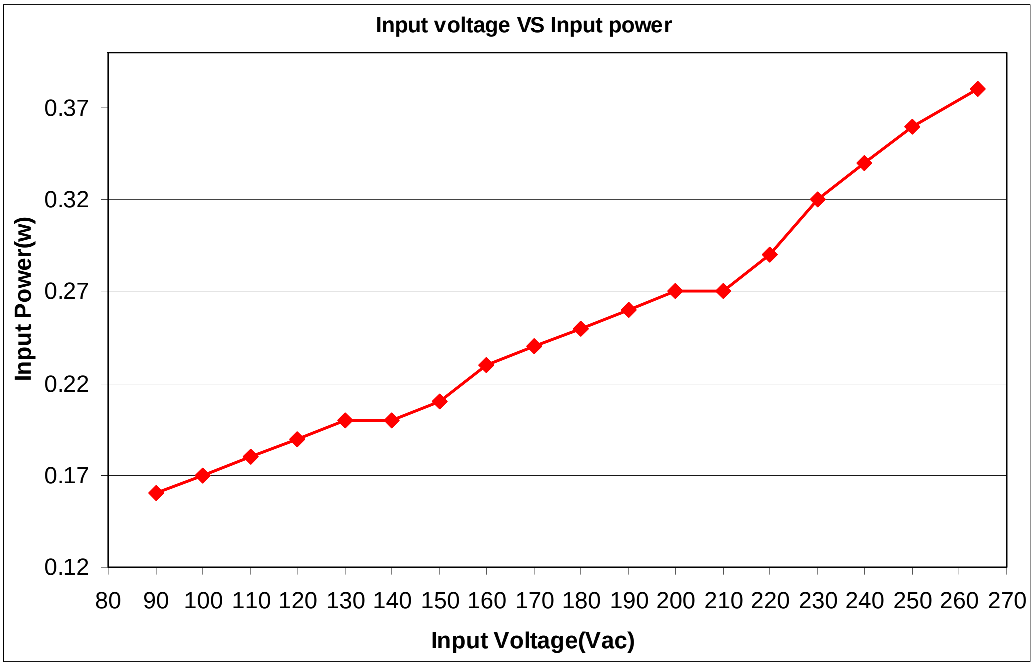
8.1 *Efficiency*

Test Conditions:

1) Output voltage measured at output terminal of the PCB
2) The power supply is tested under different load values and line voltages
3) Ambient temperature: 25 °C

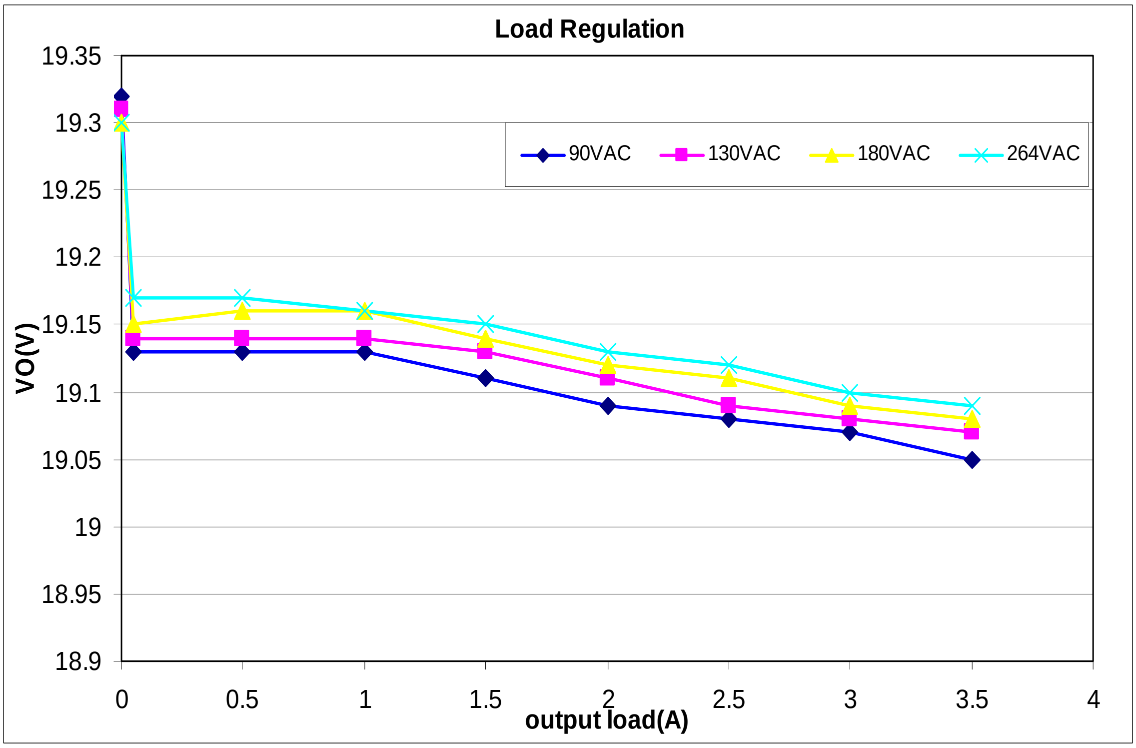


8.2 *No-load Input Power*

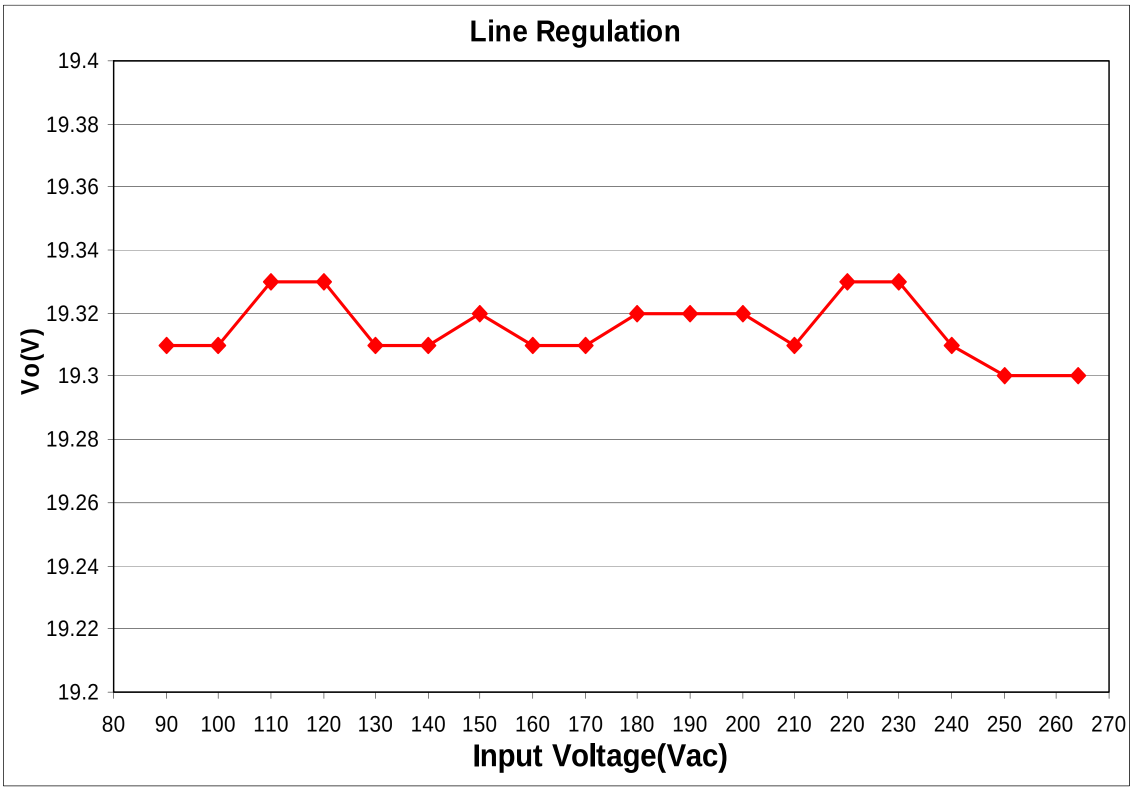


8.3 Regulation

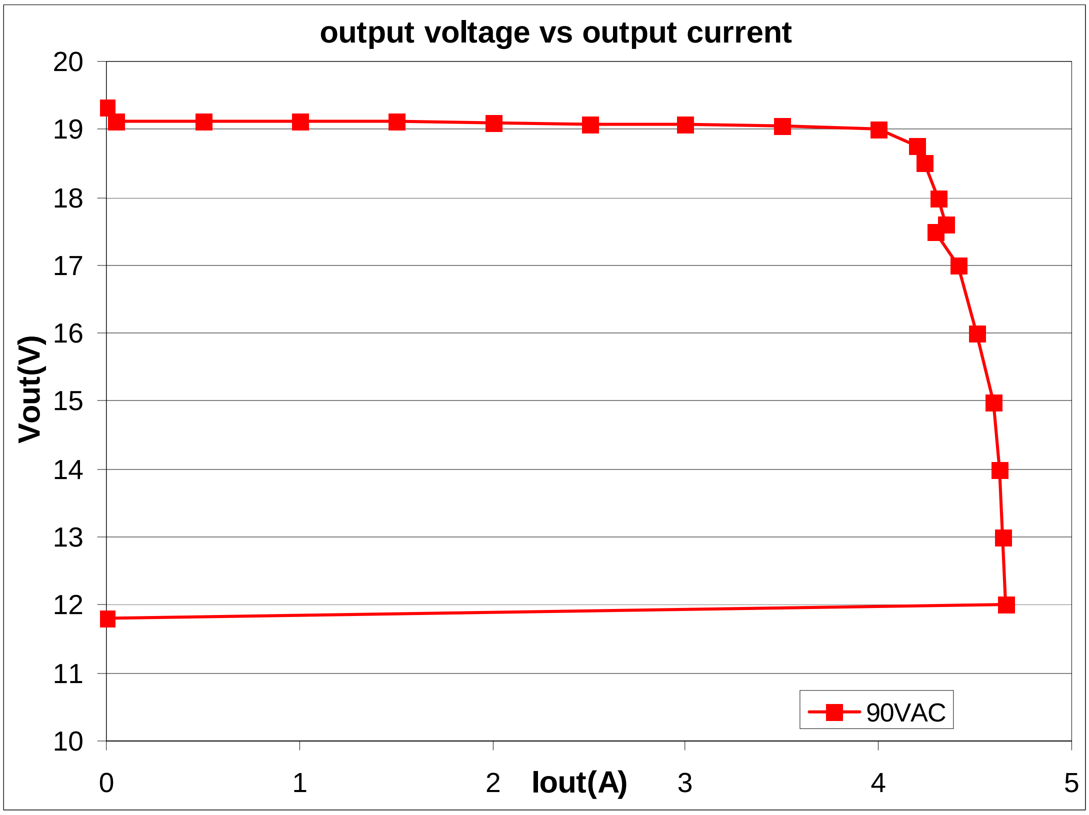
8.3.1 Load

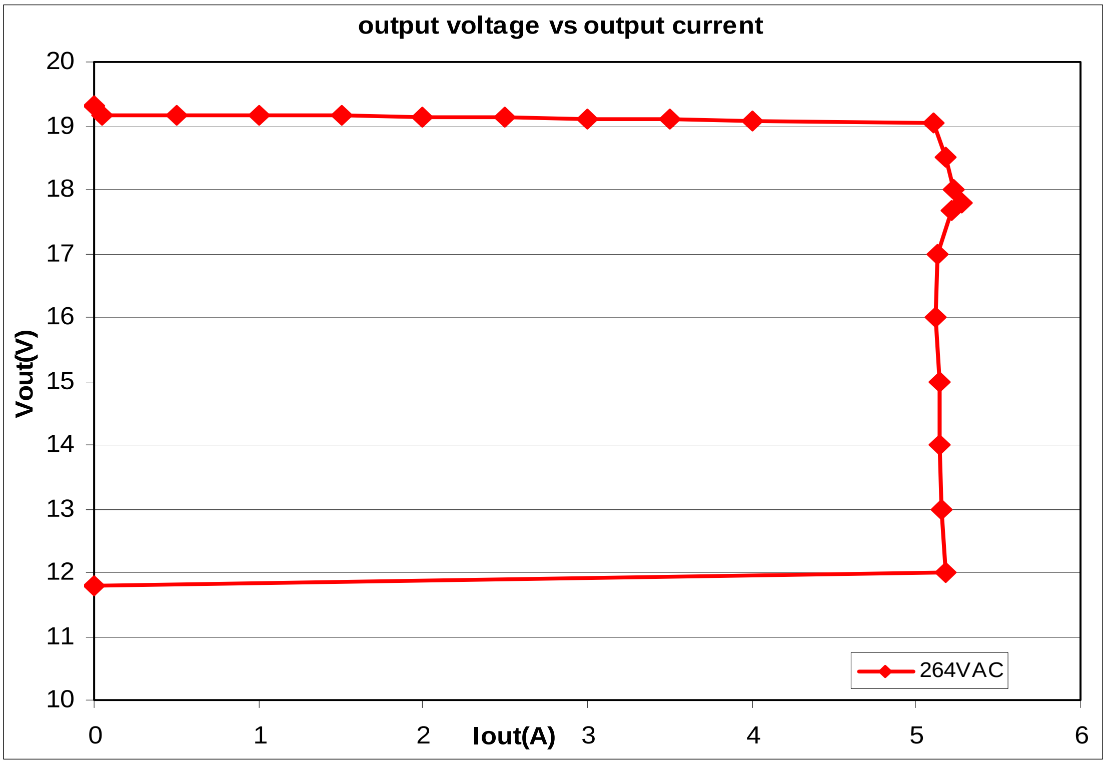


8.3.2 Line



8.4 Output V-I Characteristics Curve

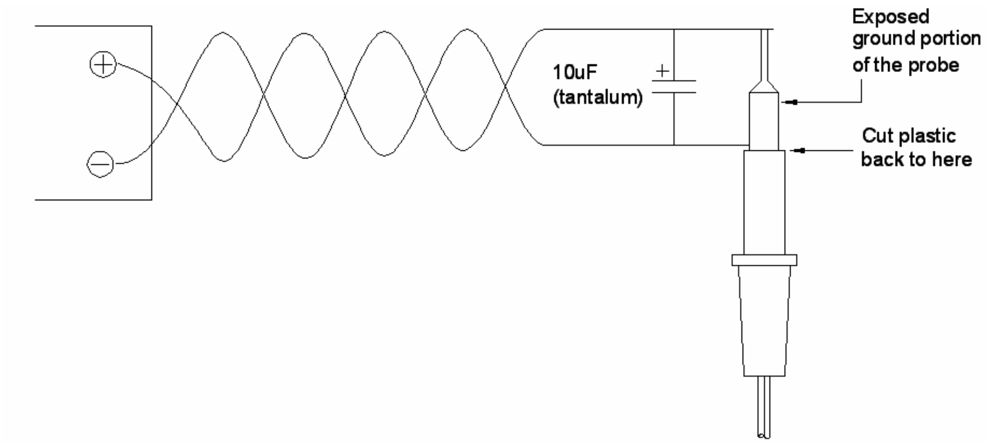




8.5 Ripple and Noise Voltage

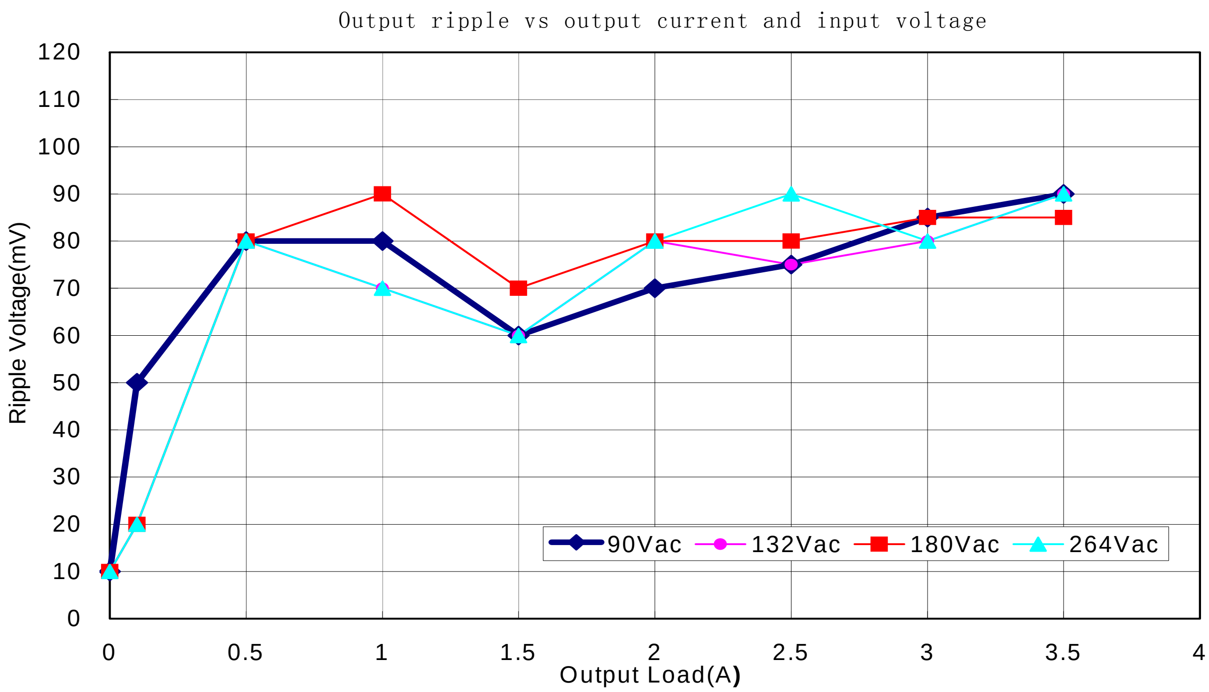
Test Conditions:

The measurement is made using a 20MHz bandwidth oscilloscope. Measure the noise across a 10μF tantalum capacitor connected to the output by a 12" twisted pair of 22 gauge wire. Observe proper polarity and voltage rating of the capacitor. Use the oscilloscope probe as depicted in the following illustration.

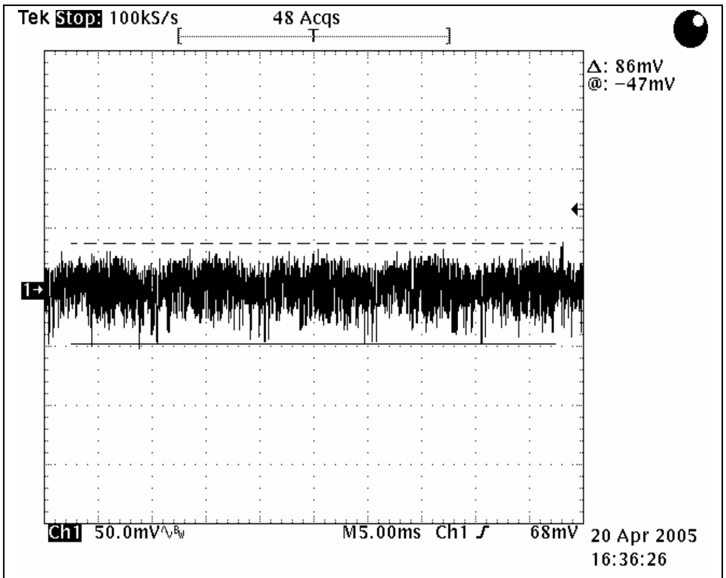


With a sharp knife, remove the plastic sleeve from the probe tip back about 1¼'' from the tip of the probe. Measure the output ripple by placing the exposed ground portion of the probe on the minus (-) terminal and the probe tip on the plus (+) terminal. This will eliminate any spurious pick-up in the normal ground clip.

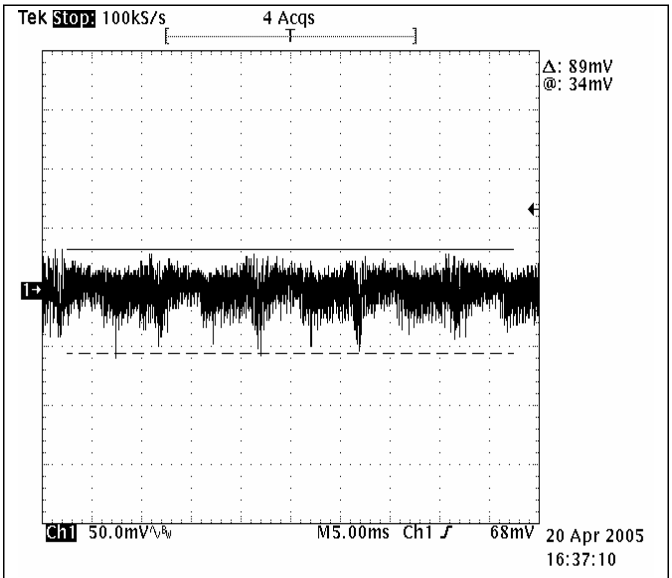
8.5.1 Output ripple voltage



8.5.2 Output ripple waveform



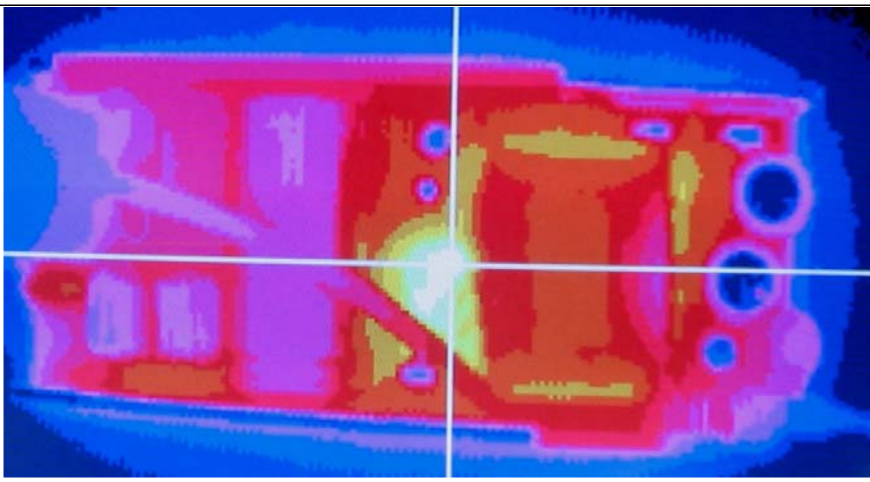
V_{IN} = 90V_{AC}, I_O = 3.5A,
V_{RIPPLE} = 86mV



V_{IN} = 264V_{AC}, I_O = 3.5A,
V_{RIPPLE} = 89mV

9 Thermal Performance

Item	90Vac		115Vac		230Vac		264Vac	
	T(℃)	Tr(℃)	T(℃)	Tr(℃)	T(℃)	Tr(℃)	T(℃)	Tr(℃)
Bridge Rectifier (BR1)	103.4	72.2	86.9	56.9	72.7	42.5	74.5	44.1
CM Inductance (L2)	95.2	64.0	79.2	49.2	63.2	33.0	66.9	36.5
Metallized Polyester Film Capacitor (C1)	76.0	44.8	69.8	39.8	63.7	33.5	66.2	35.8
Mosfet (Q1)	99.3	68.1	85.4	55.4	77.5	47.3	80.6	50.2
SK-Diode (D8)	77.2	46.0	75.0	45.0	75.0	44.8	77.2	46.8
SK-Diode (D9)	84.5	53.3	80.9	50.9	83.1	52.9	85.7	55.3
Transformer (T1)	90.5	59.3	85.3	55.3	88.1	57.9	91.8	61.4
E-Cap (C10)	68.2	37.0	66.4	36.4	67.0	36.8	70.0	39.6
Ambient Temperature	31.2		30.0		30.2		30.4	



Infrared Thermal Graph

10 Transient Performance

10.1 Inrush Current

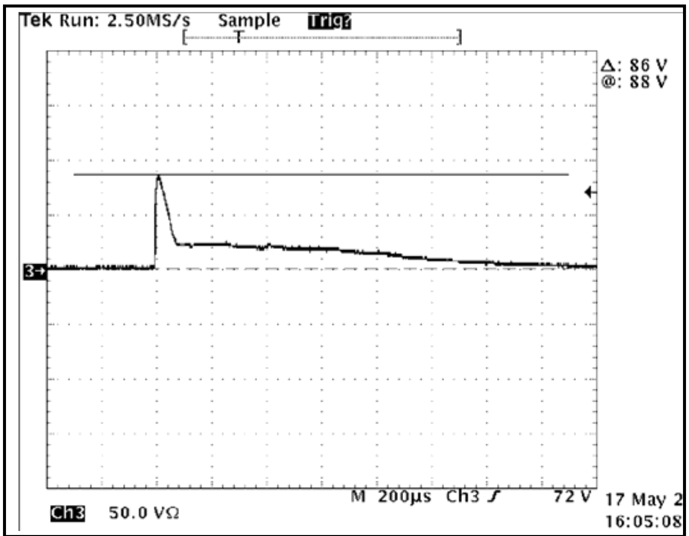
Cold Start at Room Ambient

A. Turn off the unit for at least 30 minutes before the test.

B. Turn on the unit for at least 1 hour before test under AC high line max load.

Quickly switch off power and discharge bulk capacitor to below 10V.

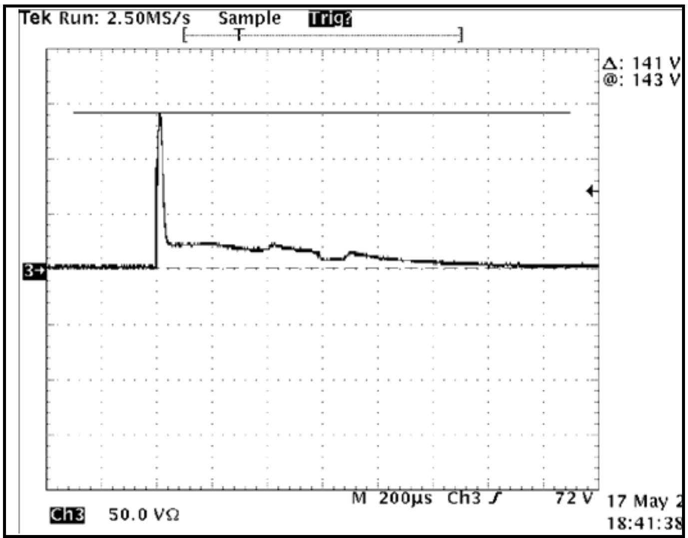
Connect the unit to an inrush current tester. The voltage of the tester shall be set to the peak value of the max AC input voltage. Capacitors in the tester should be at least 20 times the bulk capacitor in the unit. Switch on the power from the tester to the unit with max load. Monitor the current with DC current probe. Use a storage scope to capture the inrush current waveform.



A. Ch1: 50A/Div,

V_{IN} = 264Vac, Cold Start I_P = 86.00A

I^2T = 502.1A^2 mS



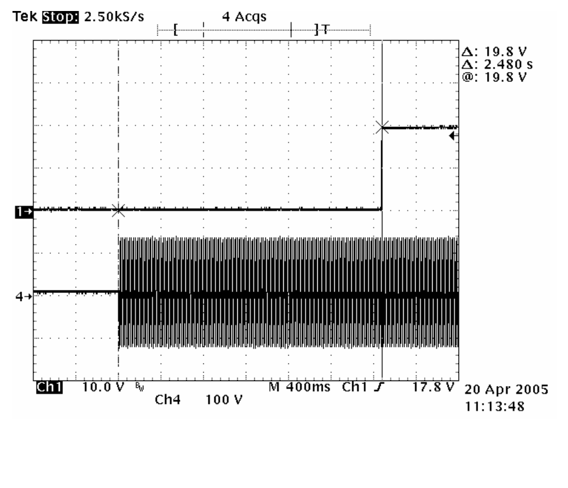
B. Ch1: 50A/Div,

V_{IN} =264Vac, Cold Start I_P = 141.00A

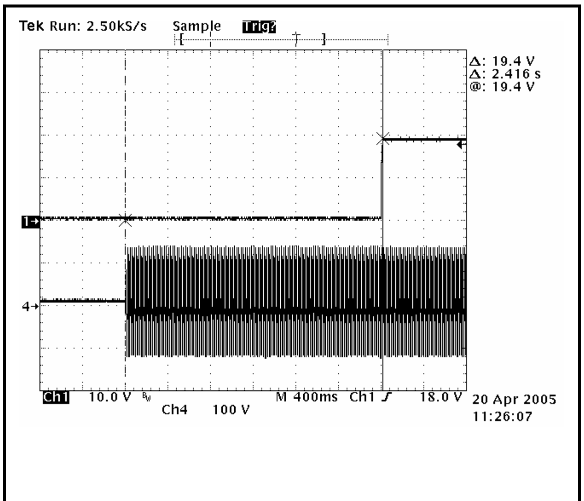
I^2T= 466.8 A^2 mS

10.2 Start Up & Turn on Delay

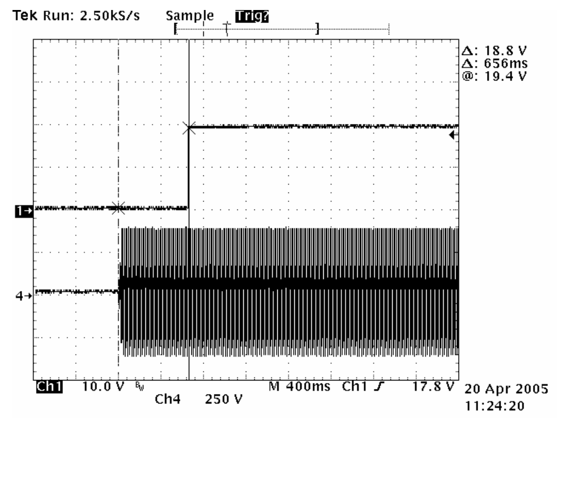
The unit will be able to start up into a resistive load up to the rated current. Use a digital oscilloscope to capture the output voltage waveform against the input voltage waveform. This allows the time from application of AC power to output to reach 90% of the final value. **Criteria**: Overshoot / Undershoot Voltage should not exceed the regulation limit. The elapsed time between the application of input power and the attainment of output voltage to the nominal value should not exceed 1 second.



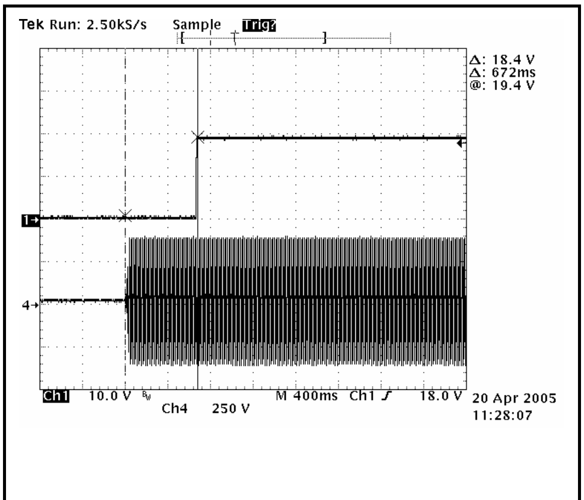
V_{IN} = 90V_{AC}, Open load,
V_{OS} = 0 mV, T_{DELAY} = 2480mS



V_{IN} = 90V_{AC}, I_O = 3.5A,
V_{OS} = 0 mV, T_{DELAY} = 2416mS



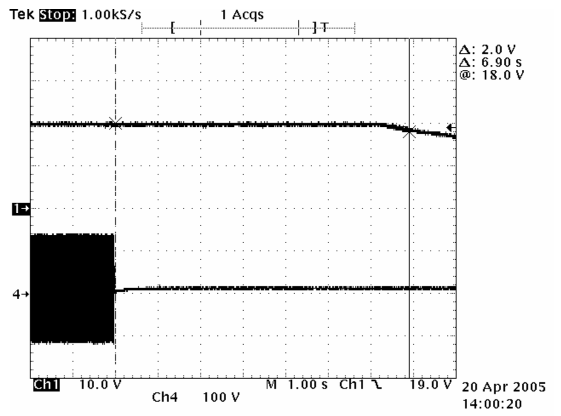
V_{IN} = 264V_{AC}, Open load,
V_{OS} = 0mV, T_{DELAY} = 656mS



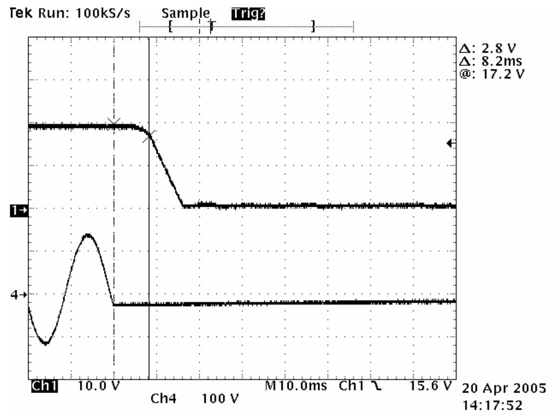
V_{IN} = 264V_{AC}, I_O = 3.5A,
V_{OS} = 0mV, T_{DELAY} = 672mS

10.3 Shut Down & Hold Up Time

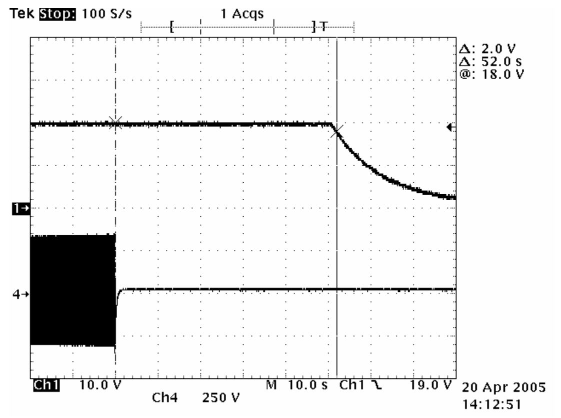
Connect the unit to a missing cycle tester so that the turn off instant can be captured. Set the AC ON-time to maximum and the OFF-time to 1sec or greater. Use a digital oscilloscope to capture the output voltage waveform against the input voltage waveform when the AC power changes from on to off in order to find the time from the zero crossing point of AC power off to output voltage drop out of regulation limit.



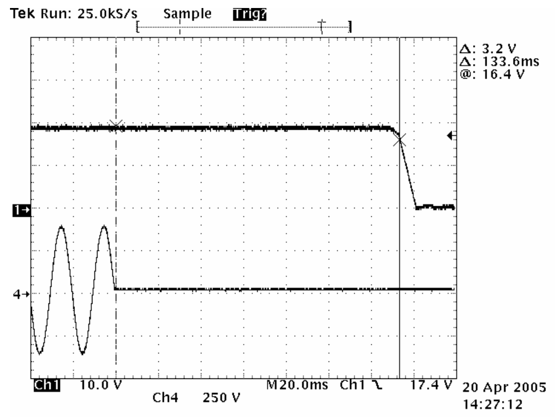
V_{IN} = 90V_{AC}, Open load,
V_{OS} = 0 mV, T_{HOLD}= 6900mS



V_{IN} = 90V_{AC}, I_O = 3.5A,
V_{OS} = 0mV, T_{HOLD} = 8.2mS



V_{IN} = 264V_{AC}, Open load,
V_{OS} = 0mV, T_{HOLD} = 5200mS



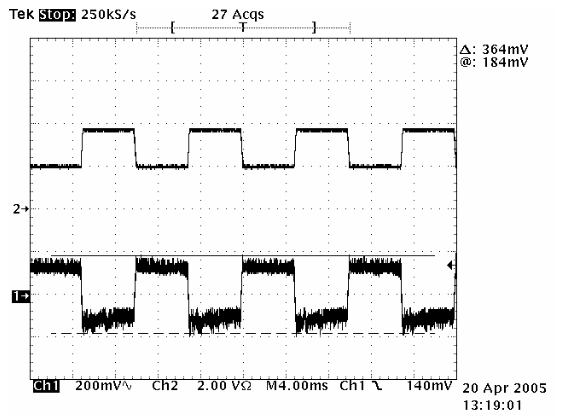
V_{IN} = 264V_{AC}, I_O = 3.5A,
V_{OS} = 0mV, T_{HOLD} = 133.6mS

10.4 Dynamic Load Response

Connect the unit output to an electronic load set to Constant Current mode. Set the electronic load to step between 2 current ranges, 5msec at each current level. Monitor the output voltage waveform with an oscilloscope. The V_{DC} voltage should be measured with DVM meter.

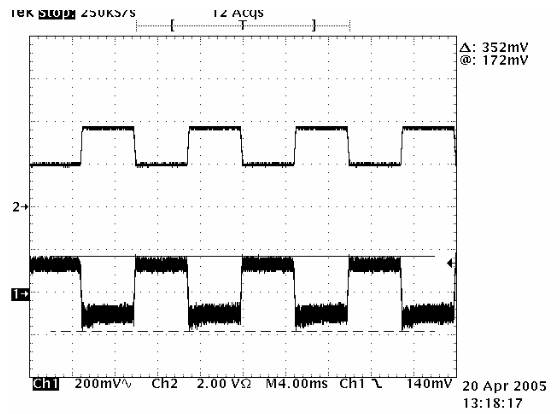
Condition A: V_{IN} = 90V_{AC}, Load = 1.75 (5mS) to 3.5A (5mS)

Condition B: V_{IN} = 264 V_{AC}, Load = 1.75A (5mS) to 3.5A (5mS)



Condition A: V_{DC} = 18.94V, V_{PK} = 0.36V

V_{MAX} = 19.3V, V_{MIN} = 18.58V



Condition B: V_{DC} = 18.98 V, V_{PK} = 0.35V

V_{MAX} = 19.16V, V_{MIN} = 18.80V

11 Protection Circuit

11.1 Over Current Protection

Increase the output current gradually until the unit shuts down, bounces or folds back, then record the maximum output current obtainable.

V_{INAC}	$90V_{AC}$	$132V_{AC}$	$180V_{AC}$	$264V_{AC}$
I_{OMAX}	4.5A	5.5A	5.7A	5.4 A

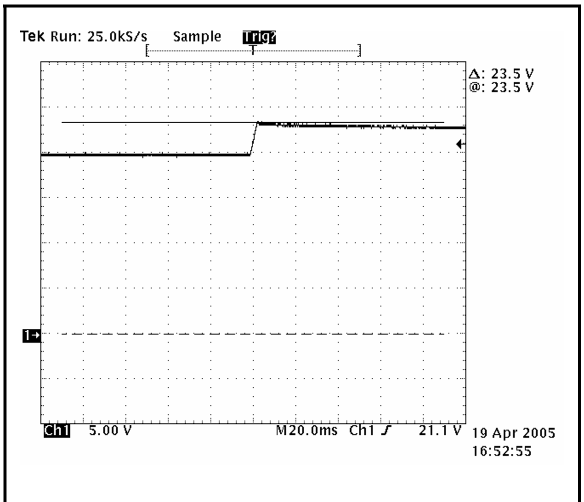
11.2 Short Circuited Protection

The output of the power supply is short-circuited continuously for a few minutes until the unit is under a stable condition. The short shall be applied before or after turning on the power.

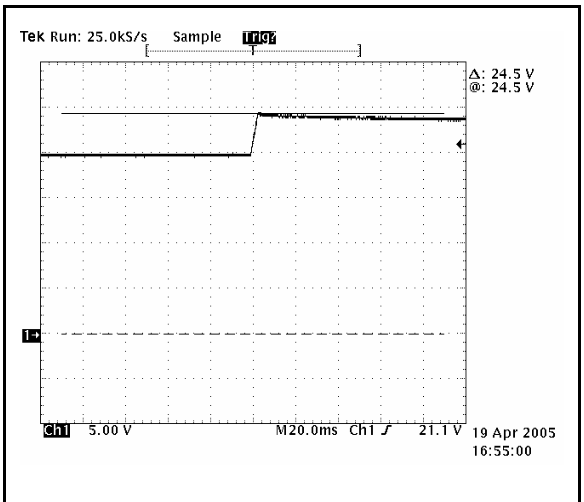
V_{IN}	P_{INMAX}(W)	V_{OUT} (V)	I(A)	State
$90V_{AC}$	0.03	0	0	Shutdown and Latched
$132V_{AC}$	0.06	0	0	Shutdown and Latched
$230V_{AC}$	0.25	0	0	Shutdown and Latched
$264V_{AC}$	0.3	0	0	Shutdown and Latched

11.3 Over Voltage Protection

Vary one component that will break the voltage feedback loop to simulate a single component failure. Check the maximum output voltage rise on storage scope.



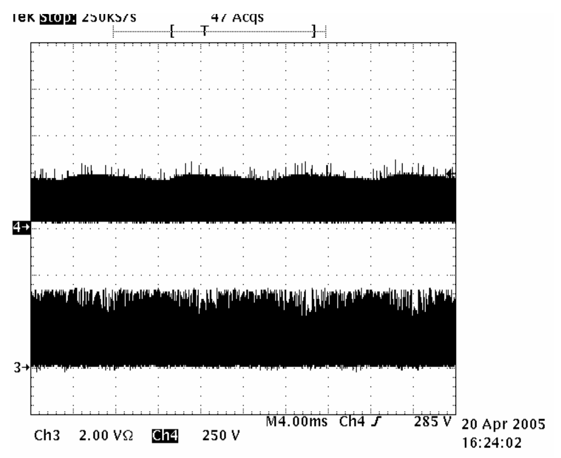
$V_{IN} = 90V_{AC}$, Open load
$V_{OMAX} = 23.5V$ @ 25°C



$V_{IN} = 264V_{AC}$, Open load
$V_{OMAX} = 24.5V$ @ 25°C

12 Major Operational Waveform

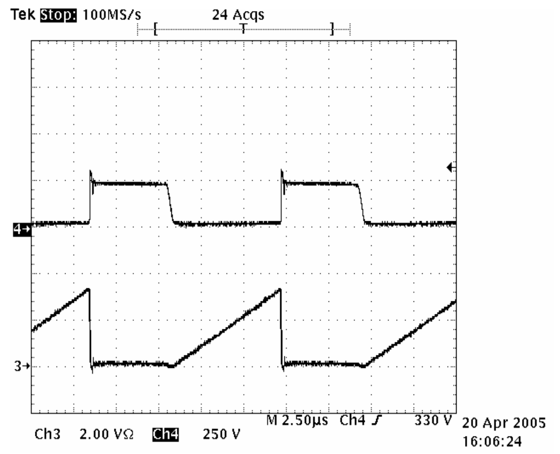
12.1 Drain Voltage and Current, Max Load



$V_{IN} = 90V_{AC}$, $I_O = 3.5A$

Upper: V_{DRAIN}, 250V/div

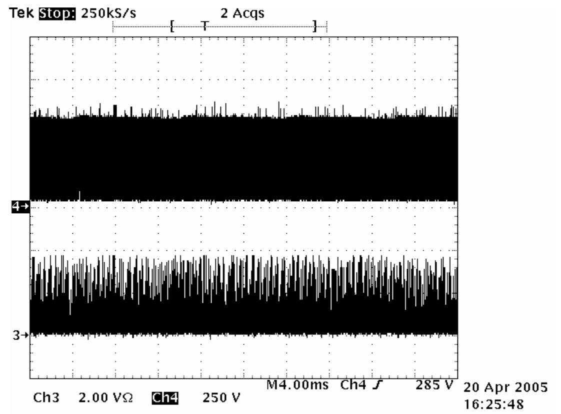
Lower: I_{DRAIN}, 2A/div, 4ms/div



$V_{IN} = 90V_{AC}$, $I_O = 3.5A$

Upper: V_{DRAIN}, 250V/div

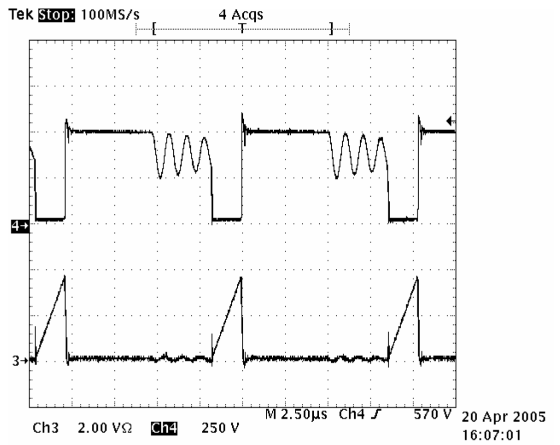
Lower: I_{DRAIN}, 2A/div, 2.5us/div



$V_{IN} = 264V_{AC}$, $I_O = 3.5A$

Upper: V_{DRAIN}, 250V/div

Lower: I_{DRAIN}, 2A/div, 4ms/div

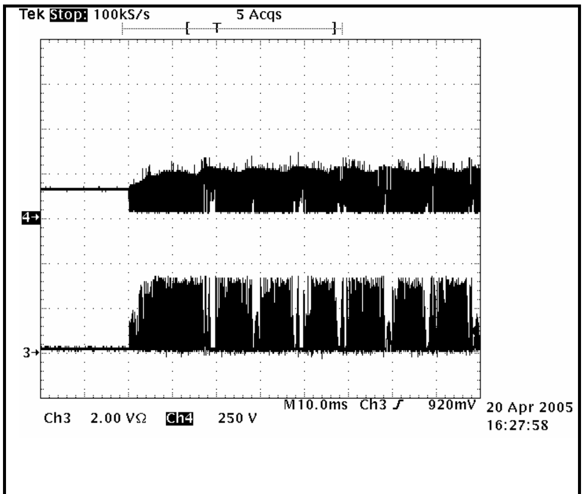


$V_{IN} = 264V_{AC}$, $I_O = 3.5A$

Upper: V_{DRAIN}, 250V/div

Lower: I_{DRAIN}, 2A/div, 2.5us/div

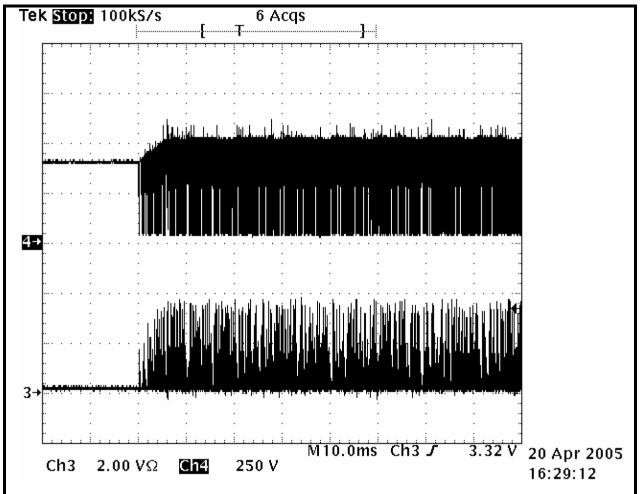
12.2 Drain Voltage and Current during Start-up



V_{IN} = 90V_{AC}, I_O = 3.5A

Upper: V_{DRAIN}, 250V/div

Lower: I_{DRAIN}, 2A/div, 10ms/div



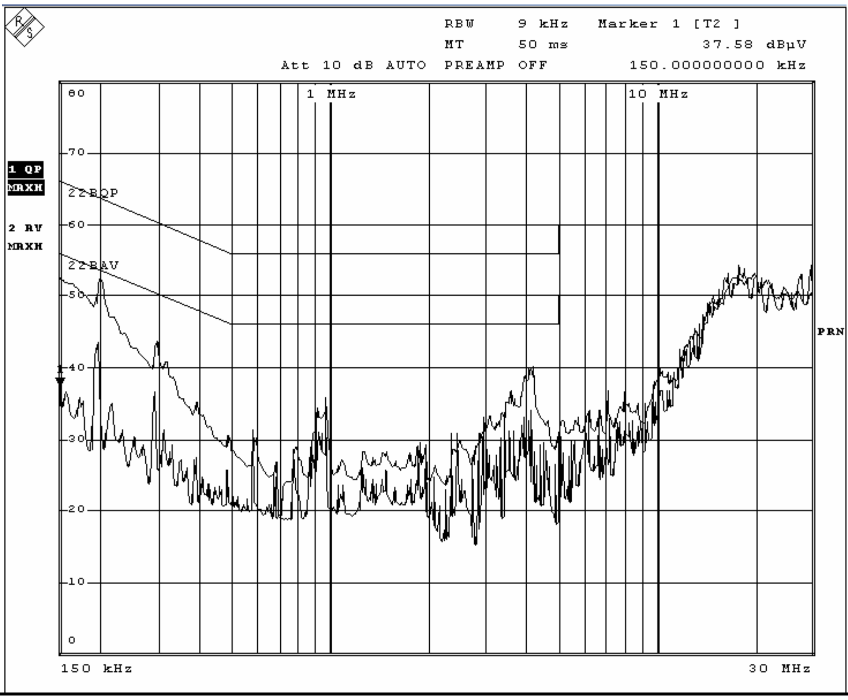
V_{IN} = 264V_{AC}, I_O = 3.5A

Upper: V_{DRAIN}, 250V/div

Lower: I_{DRAIN}, 2A/div, 10ms/div

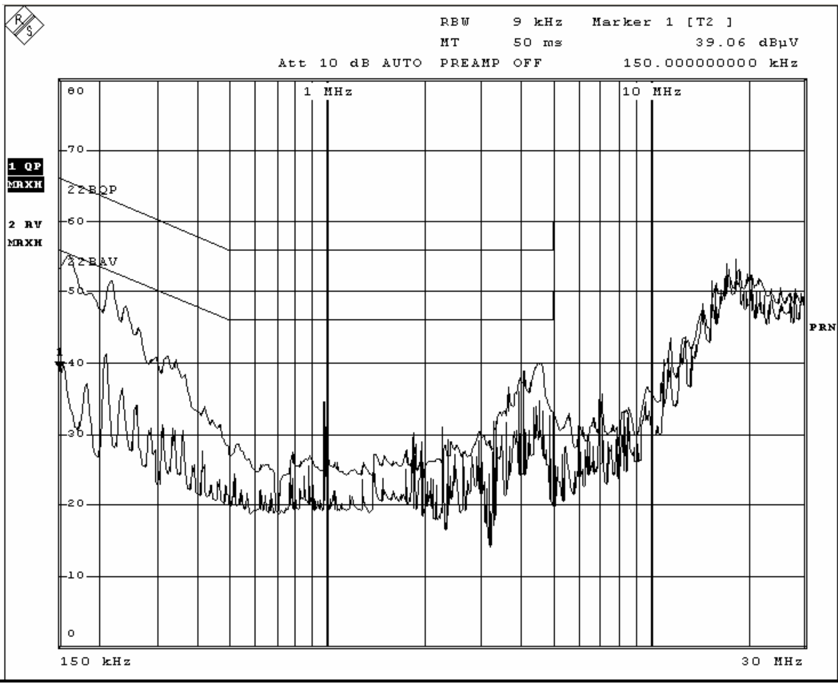
13 EMC Test

13.1 Conducted EMI



V_{IN} = 230 V_{AC}, Line Frequency = 50Hz, I_O = 3.5A, Live wire

Test according to CISPR-22 Class B



V_{IN} = 230V_{AC}, Line Frequency = 50Hz, I_O = 3.5A, Neutral wire

Test according to CISPR-22 Class B

13.2 Power Line Transient

Test conditions:

* 1000-4-12: Low Energy Transient of type A pulses are applied to the power supply. Type A pulses are identified by the **100kHz ring-wave signal** after the initial pulse. The voltage amplitude is 3kV peak (into an open circuit).

* 1000-4-5: High Energy Transients with a 1.2 µs rise time and 50 µs decay to half peak value (1.2 x 50usec) are applied to the power supply once each 10 second period with 12 transients per test. The **1000-4-5 standard** defines four levels of peak voltage.

Pass/Fail criteria:

Operating: The voltage transients will not result in any loss of value to the user.
(Example: Output voltages should not go out of specified limits)

Survival: No component should be damage electrically during the tests. The power supply should continue to operate in a safe manner during abnormal operation.

Voltage Transients	*Mode*	*Repeat Rate*	*Coupling Selector*	*Operation 115Vac*	*Operating 220Vac*
1000-4-5 Level III (801.5)	*Differential (1KV)*	10s	D	PASS	PASS
3KV ringwave (1000-4-12)	*Differential*	30s	D	PASS	PASS

Comments:
Coupling selector D = pulse between Line & Neutral.

14 Revision History

Date	Author	Revision	Description & changes
2005-July-11	ZJ/BLX	NR	First Release

For the latest updates, visit our Web site: *http://www.iWatt.com*

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