Design Example Report

Title	***16W (24W Peak) Multiple Output Supply using TOP244P***
Specification	Input: 98 – 135 V_{AC} Output: 1.8V/0.6A, 3.3V/0.55A, 7V/0.4A, 17V/0.4A (0.8A Peak), 22V/0.4A (0.8A Peak)
Application	Set Top Box
Author	Power Integrations Applications Department
Document Number	DER-22
Date	March 30, 2004
Revision	1.0

Summary and Features

This report describes a design for a multiple output power supply, such as required for a Set Top Box, featuring the following:

- No heatsinks on the complete power supply
- Low Parts Count - Minimal cost power supply
- 16W Continuous / 24W Peak power capability – Allows for hard disk spin up
- >50ms Hold-Up Time – Extended immunity to mains brown out
- Advanced system level surge protection – Increased field reliability
- >75% Operating efficiency

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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 describes a design proposal for a 16W multiple output power supply operating from 110V mains. The supply will deliver 16W continuously with a short duration 23W peak capability. The peak power capability has been specified to allow for a short duration peak current of 800mA on either the 17V or 22V rails when the LNB power circuitry switches between the two voltage levels.

The document includes full schematic, bill of materials and transformer design information. The report also includes a full set of performance measurements on the prototype unit shown in Figure 1 below.

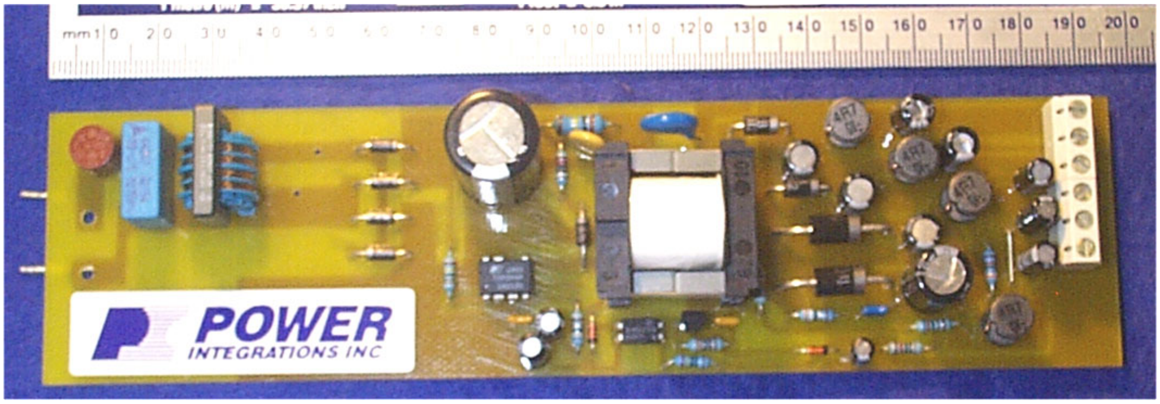


Figure 1 - Prototype Power Supply (Ruler Scale is in mm)

2 Power Supply Specification

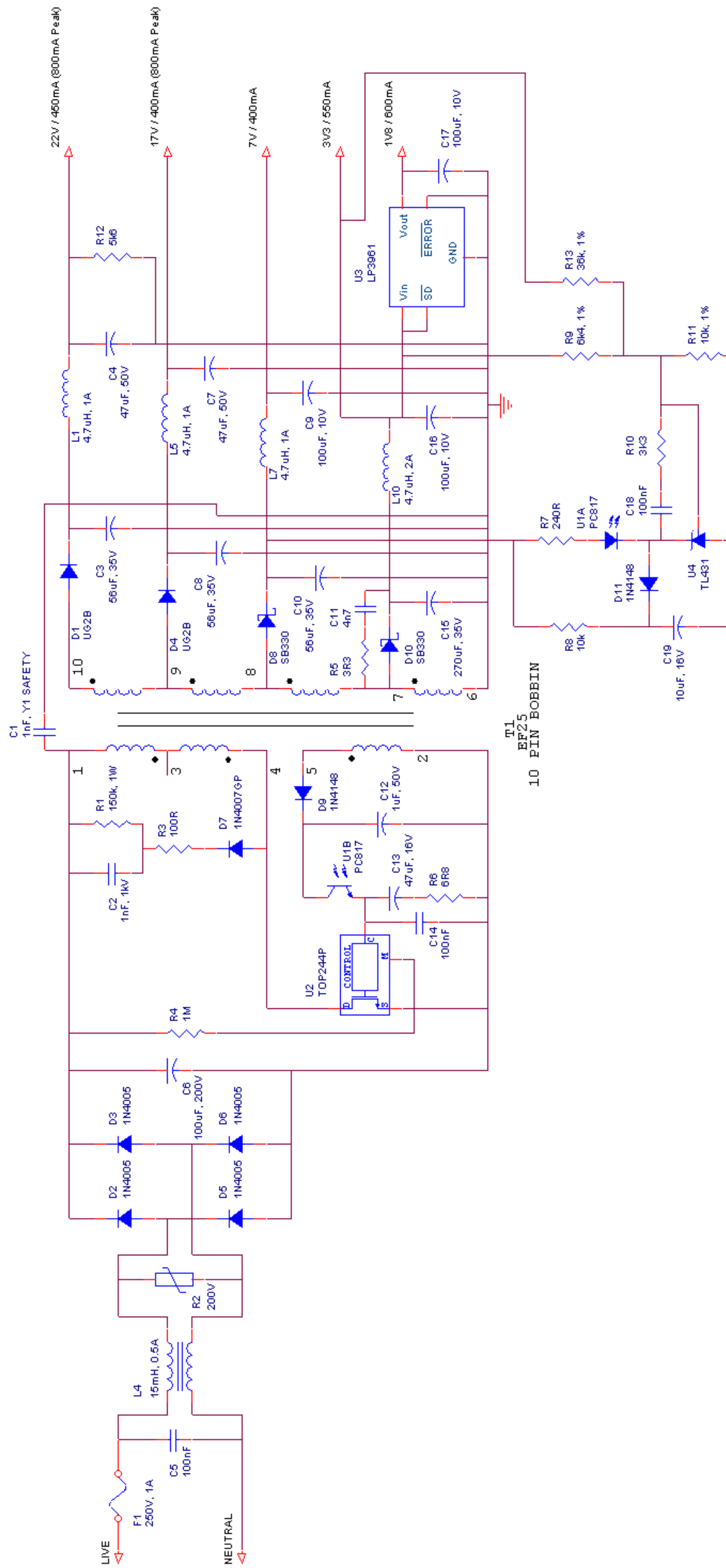
Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	98		135	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	56	60	64	Hz	
Output						
Output Voltage 1	V_{OUT1}	1.7	1.8V	1.95	V	± 5%
Output Ripple Voltage 1	$V_{RIPPLE1}$			50	mV	20 MHz Bandwidth
Output Current 1	I_{OUT1}		0.6	0.6	A	
Output Voltage 2	V_{OUT2}	3.15	3.3V	3.45	V	± 5%
Output Ripple Voltage 2	$V_{RIPPLE2}$			50	mV	20 MHz Bandwidth
Output Current 2	I_{OUT2}		0.55	0.55	A	
Output Voltage 3	V_{OUT3}	6.4	7	7.6	V	± 5%
Output Ripple Voltage 3	$V_{RIPPLE3}$			200	mV	20 MHz Bandwidth
Output Current 3	I_{OUT3}		0.35	0.4	A	
Output Voltage 4	V_{OUT4}	16.25	17	18	V	± 5%
Output Ripple Voltage 4	$V_{RIPPLE4}$			200	mV	20 MHz Bandwidth
Output Current 4	I_{OUT4}	0.03	0.38	0.4	A	(0.8A peak)
Output Voltage 5	V_{OUT5}	21.5	22	23	V	± 5%
Output Ripple Voltage 5	$V_{RIPPLE5}$			200	mV	20 MHz Bandwidth
Output Current 5	I_{OUT5}	0.001	0.45	0.47	A	(0.8A peak)
Total Output Power						
Continuous Output Power	P_{OUT}			16	W	
Peak Output Power	P_{OUT_PEAK}			23	W	Duration 20ms
Efficiency	η	75			%	Measured at full load, 25 °C
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Ambient Temperature	T_{AMB}	0		45	°C	Free convection, sea level

Table 1 - Power Supply Specification

Notes:-

1. Power supply must maintain output voltages within defined tolerances when subject to a mains failure lasting 50ms.
2. The 17V and 22V rails supply LNB circuitry. The load conditions of these two rails are such that when one is at full power, the other is at effectively zero power and vice-versa. Maximum continuous power is calculated with 470mA load on 22V.
3. The 800mA peak occurs when the LNB circuitry switches from 17V to 22V. The peak lasts 20ms.
4. Under low load conditions, the 17V and 22V rail voltages can drift up to an absolute maximum level of 28V. This level should never be exceeded.

3 Schematic



NOTES:-

1) INPUT BULK CAP C6 HAS BEEN CHOSEN TO GIVE 50MS HOLD-UP TIME. IT'S VALUE WILL NEED TO BE EXPERIMENTALLY VERIFIED.
2) THE 17V AND 22V RAILS MAY REQUIRE A ZENER CLAMP TO PREVENT A MAXIMUM VOLTAGE OF 28V BEING EXCEEDED UNDER LIGHT LOADS.
3) THE 1.8V RAIL COULD BE DERIVED FROM A TRANSFORMER WINDING IF A BOBBIN WITH SIX SECONDARY SIDE PINS IS USED.
4) IT MAY BE POSSIBLE TO ELIMINATE R2 SINCE THE SUPPLY OPERATES ONLY FROM 110V AND THE TOP244P INCLUDES OVER-VOLTAGE SHUTDOWN PROTECTION.
5) D7 IS SPECIFIED AS 1N4007GP. PLEASE DO NOT USE A STANDARD 1N4007.
6) ALL ELECTROLYTIC CAPACITORS ARE 105 DEG C / 2000 HOUR LOW ESR TYPES.
7) R12 IS A SMALL PRELOAD TO LIMIT THE MAXIMUM VOLTAGE ON THE 22V RAIL TO UNDER 26V UNDER NO LOAD CONDITIONS

Figure 2- Schematic

4 Circuit Description

This schematic presented above details an isolated flyback power supply using TOP244P from Power Integrations. This IC integrates the following features to minimize PSU cost:

- Frequency jitter which reduces the QP and AV EMI levels by up to 10dB allowing for cheaper EMI filter components
- Soft-Start which prevents transformer saturation during start-up. This increases long term reliability
- Line UV and OV detection to give additional differential surge withstand capability to increase reliability
- Regulation to zero load without pre-load due to very low minimum duty cycle capability
- Line feed forward which improves 100Hz ripple rejection
- Hysteretic thermal and short circuit protection to increase long term reliability
- DIP08 package which requires additional heatsink to minimize BOM and manufacturing cost.

4.1 Design Architecture

The approach used here is standard AC stacking to provide the 3.3V, 7V, 17V and 22V from transformer windings. Due to limited number of secondary side pins on an EF25 core, the 1.8V output was derived by linear drop from the 3.3V rail.

4.2 Input Rectification

AC input power is rectified by a full bridge, consisting of D2, D3, D5 and D6. The rectified DC is then filtered by the bulk storage capacitor C6.

4.3 Primary Side Clamp

D7, R3, C2 and R1 form the primary side leakage spike clamp. Use of a 1N4007GP diode (With specified reverse recovery time) allows some of the clamp energy to be recycled. In addition, this clamp gives smooth clamping action and low resulting EMI

4.4 Output Rectification, Filtering and Feedback

D10 and D8 have been chosen as schottky diodes to give low conduction drop and superior reverse recovery performance. D4 and D1 are normal ultra-fast diodes. C15, C10, C8 and C3 have been chosen to meet the required ripple current rating. The heavily continuous mode of operation used in this design will minimize output capacitor size and cost due to low RMS currents. Each rail uses an LC post filter to meet the specified output noise and ripple requirements. Feedback is provided by a TL431 reference circuit using the 3.3V as the feedback rail.

5 Bill Of Materials

	Reference	Quantity	Description / Value
Capacitors	C1	1	1nF, Y1 SAFETY
	C2	1	1nF, 1kV
	C3,C8,C10	3	56uF, 35V
	C7,C4	2	47uF, 50V
	C5,C14,C18	3	100nF
	C6	1	100uF, 200V
	C16,C9	2	100uF, 10V
	C11	1	4n7
	C12	1	1uF, 50V
	C13	1	47uF, 16V
	C15	1	270uF, 35V
	C17	1	100uF, 10V
	C19	1	10uF, 16V
Diodes	D4,D1	2	UG2B
	D2,D3,D5,D6	4	1N4005
	D7	1	1N4007GP
	D8,D10	2	SB304
	D9,D11	2	1N4148
Protection	R2	1	VDR 200V
	F1	1	250V, 1A
Magnetics	L1,L5,L7	3	4.7uH, 1A
	L4	1	15mH, 0.5A, CM Choke
	L10	1	4.7uH, 2A
	T1	1	CUSTOM EF25
Resistors	R1	1	150k, 1W
	R3	1	100R
	R4	1	1M
	R5	1	3R3
	R6	1	6R8
	R7	1	240R
	R8	1	10k
	R9	1	6k4, 1%
	R10	1	3K3
	R11	1	10k, 1%
	R12	1	5k6
	R13	1	36k
IC's	U1	1	PC817
	U2	1	TOP244P
	U3	1	LP3961
	U4	1	TL431

Total of 54 components

Note: All resistors are 1/8W, 5% unless otherwise specified.

6 Prototype PCB Layout

A prototype based on the schematic shown in Figure 2 has been constructed with outer dimensions of 195mm by 50mm. This PSU could be made smaller due to the high level of integration of TOP244P. All components are through hole devices except the 1.8V linear regulator (U3) which is surface mounted on the underside of the PCB. No heatsinks are required for any part of this design.

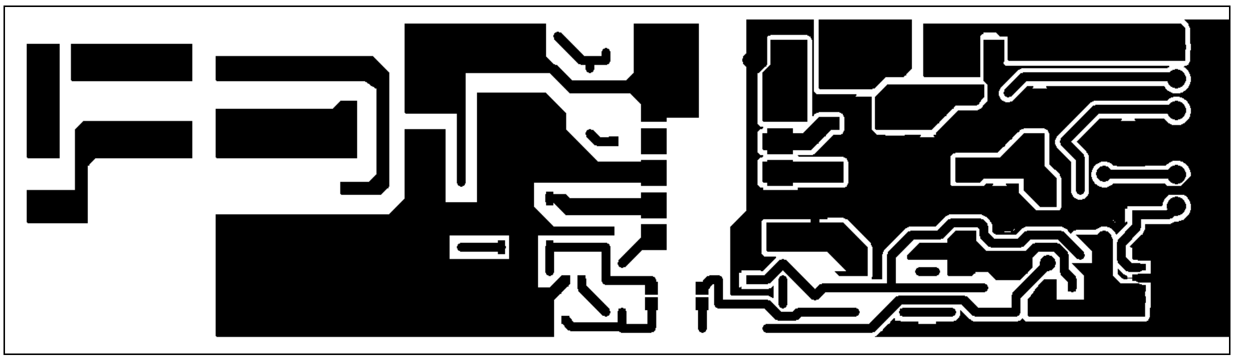


Figure 3 - PCB Copper Layout (viewed from above), approx 195mm by 50mm

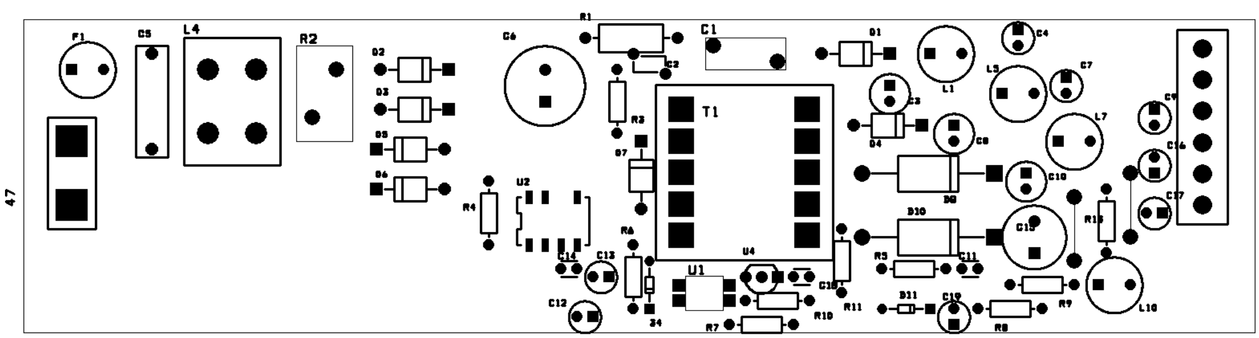


Figure 4 - Component Placement (viewed from above)

7 Transformer Specification

7.1 Electrical Diagram

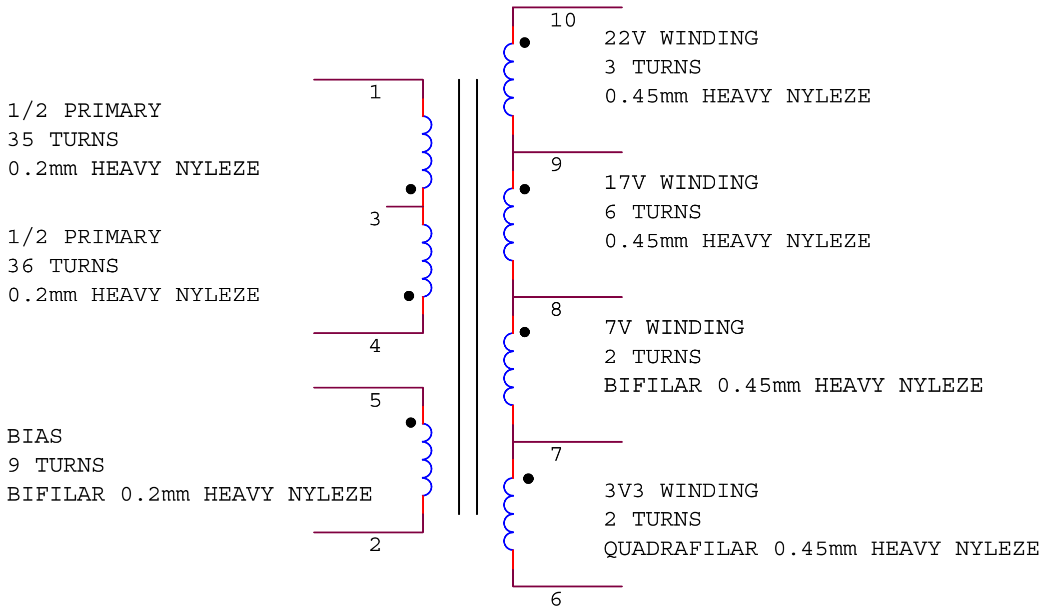


Figure 5 –Transformer Electrical Diagram

7.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from pins 1-5 to pins 6-10	3000 VAC
Primary Inductance	Pins 1-4, all other windings open. Measured at 132 kHz, 1 VRMS	1.31mH +15%
Resonant Frequency	Pin 1-4, all other windings open	600 kHz (Min.)
Primary Leakage Inductance	Pins 1-4, with pins 6-10 shorted. Measured at 132 kHz, 1 VRMS	30 µH (Max.)

7.3 Materials

Item	Description
[1]	Core: EF25/13/7, 3C85 or Equivalent, Gapped for AL of 260 nH/T^2
[2]	Bobbin: EF25, Horizontal 10 pins (P/N Ferroxcube CPH-E25/13/7-1S-10P)
[3]	Magnet Wire: 0.20mm (#32 AWG)
[4]	Magnet Wire: 0.45mm (#25 AWG)
[5]	Tape: 3M 1298 Polyester Film, 15 mm wide
[6]	Margin tape: 3M # 44 Polyester web. 3.0 mm wide
[7]	Varnish

7.4 Transformer Build Diagram

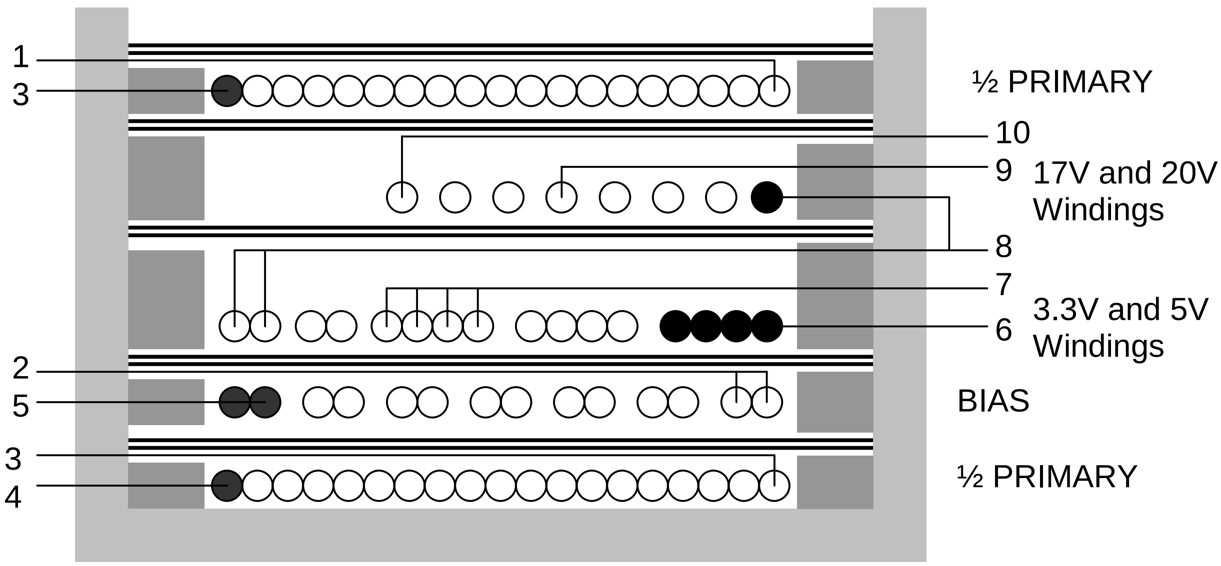


Figure 6 – Transformer Build Diagram

7.5 Winding Instructions

Margin Tape	Apply 3.0 mm margin at each side of bobbin using item [6].
½ PRIMARY	Start at pin 4. Wind 36 turns of item [3] from right to left in a single layer. Wind tightly and uniformly across entire width of bobbin. Terminate on pin 3.
Basic Insulation	Apply 1 layers of tape item [5]
Margin Tape	Apply 3.0 mm margin at each side of bobbin using item [6].
Bias Winding	Start at pin 5. Wind 9 bifilar turns of item [3] from right to left in a single layer. Finish on pin 2.
Safety Insulation	Apply 3 layers of tape item [5]
Margin Tape	Apply 3.0 mm margin at each side of bobbin using item [6].
3.3V and 5V Winding	Start at pin 6. Wind 2 quadrafilar turns of item [4] and terminate on pin 7. Continue with 1 further bifilar turn of item [4]. The wires should be uniformly wound spread across the bobbin width. Finish on pin 8.
Basic Insulation	Apply 1 layers of tape item [5]
Margin Tape	Apply 3.0 mm margin at each side of bobbin using item [6].
17V and 22V Winding	Start at pin 8. Wind 6 turns of item [4]. Terminate on pin 9. Continue winding with 3 further turns of item [4] and terminate on pin 10.
Outer Insulation	3 Layers of tape [8] for insulation.
Core Assembly	Assemble and secure core halves. Item [1]
Final Varnish	Dip varnish uniformly in item [7]

8 Transformer Spreadsheet

The results from the PIExpert design software are given below. **The first results correspond to the continuous maximum loading case of 16W whilst the second results relate to the peak 23W loading case.** In both cases, the power is based on the LNB being powered from the 22V rail which represents the worst case loading condition.

8.1 16W Continuous Loading

Power Supply Input

VACMIN	Volts	98				Min Input AC Voltage
VACMAX	Volts	135				Max Input AC Voltage
FL	Hertz	60				AC Main Frequency
TC	mSeconds	1.8V4				Bridge Rectifier Conduction Time Estimate
Z		0.46				Loss Allocation Factor
N	%	86.0				Efficiency Estimate

Power Supply Outputs

VOx	Volts		3.3V0	7.00	22.00	Output Voltage
IOx	Amps		1.150	0.400	0.470	Output Current
VB	Volts	15.00				Bias Voltage
IB	Amps	0.006				Bias Current

Device Variables

Device		TOP244P/G				Device Name
PO	Watts	17.02				Total Output Power
VDRAIN	Volts	494				Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
VDS	Volts	2.5				Device On-State Drain to Source Voltage
FS	Hertz	132000				Device Switching Frequency
KRPKDP		0.73				Ripple to Peak Current Ratio
KI		1.00				External Current Limit Ratio
ILIMITEXT	Amps	0.93				Device Current Limit External Minimum
ILIMITMIN	Amps	0.93				Device Current Limit Minimum
ILIMITMAX	Amps	1.07				Device Current Limit Maximum
IP	Amps	0.48				Peak Primary Current
IRMS	Amps	0.23				Primary RMS Current
DMAX		0.53				Maximum Duty Cycle

Power Supply Components Selection

CIN	uFarads	68.0				Input Filter Capacitor
VMIN	Volts	124				Minimum DC Input Voltage
VMAX	Volts	191				Maximum DC Input Voltage
VCLO	Volts	200				Clamp Zener Voltage
PZ	Watts	2.4				Estimated Primary Zener Clamp Loss
VDB	Volts	0.7				Bias Winding Diode Forward Voltage Drop
PIVB	Volts	37				Bias Rectifier Maximum Peak Inverse Voltage

Power Supply Output Parameters

VDx	Volts		0.5	0.5	0.7	Output Winding Diode Forward Voltage Drop
PIVSx	Volts		9	18	54	Output Rectifier Maximum Peak Inverse Voltage
ISPx	Amps		3.54	1.23	1.45	Peak Secondary Current
ISRMSx	Amps		1.63	0.57	0.67	Secondary RMS Current
IRIPPLEx	Amps		1.16	0.40	0.47	Output Capacitor RMS Ripple Current

Transformer Construction Parameters

Core/Bobbin		E25/13/7 (EF25) Margi				Core and Bobbin Type
Core Manuf.		Generic				Core Manufacturing
Bobbin Manuf		Generic				Bobbin Manufacturing
LP	uHenries	1313				Primary Inductance
NP		71				Primary Winding Number of Turns
NB		8.26				Bias Winding Number of Turns
OD Actual	mm	0.20				Primary Actual Wire Diameter
Primary Current Density	A/mm^2	7				Primary Winding Current Density
VOR	Volts	135.00				Reflected Output Voltage
BW	mm	15.30				Bobbin Physical Winding Width
M	mm	3.0				Safety Margin Width
L		2.0				Number of Primary Layers
AE	cm^2	0.53				Core Effective Cross Section Area
ALG	nH/T^2	260				Gapped Core Effective Inductance
BM	mTesla	168				Maximum Operating Flux Density
BP	mTesla	377				Peak Flux Density
BAC	mTesla	61				AC Flux Density for Core Curves
LG	mm	0.22				Gap Length

LL	uHenries	26.3				Estimated Transformer Primary Leakage Inductance
LSEC	nHenries	20				Estimated Secondary Trace Inductance

Secondary Parameters

NSx			2.00	3.95	11.95	Secondary Number of Turns
Rounded Down NSx				3	11	Rounded to Integer Secondary Number of Turns
Rounded Down Vox	Volts			5.20	20.20	Auxiliary Output Voltage for Rounded to Integer NSx
Rounded Up NSx				4	12	Rounded to Next Integer Secondary Number of Turns
Rounded Up Vox	Volts			7.10	22.10	Auxiliary Output Voltage for Rounded to Next Integer NSx
ODS Actual Range	mm		0.40 - 0.64	0.23 - 0.36	0.25 - 0.40	Secondary Actual Wire Diameter Range Comment: Wire diameter is greater than recommended maximum (0.40 mm) and may overheat. Tip: Consider a parallel winding technique (bifilar, trifilar), increase size of transformer (larger BW), reduce margin (M).

8.2 23W Peak Loading Case

The 23W peak loading case is limited only by thermal shutdown. A 10 second peak power capability will be achievable with duty cycle long enough to allow the system to thermally recover.
The errors and warnings flagged in the design spreadsheet below indicate that the 24W power level required is not achievable as a continuous power. This is consistent with the 24W being a peak power requirement. The device current limit and system magnetics have been designed to operate safely and reliably with the 24W peak power.

Power Supply Input

VACMIN	Volts	98				Min Input AC Voltage
VACMAX	Volts	135				Max Input AC Voltage
FL	Hertz	60				AC Main Frequency
TC	mSeconds	1.84				Bridge Rectifier Conduction Time Estimate
Z		0.42				Loss Allocation Factor
N	%	83.0				Efficiency Estimate

Power Supply Outputs

VOx	Volts		3.30	7.00	22.00	Output Voltage
IOx	Amps		1.150	0.400	0.800	Output Current
VB	Volts	15.00				Bias Voltage
IB	Amps	0.006				Bias Current

Device Variables

Device		TOP244P/G				Device Name
PO	**Watts**	**24.29**				**Total Output Power** **Warning! Device may be too small or thermally limited for continuous power level (PO).** **Tip: Consider increasing device size. If P/G or R-package select larger device (reduce current limit via X-pin) or choose Y/F-package with appropriat**
VDRAIN	Volts	494				Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
VDS	Volts	4.0				Device On-State Drain to Source Voltage
FS	Hertz	132000				Device Switching Frequency
KRPKDP		0.53				Ripple to Peak Current Ratio
KI		1.00				External Current Limit Ratio
ILIMITEXT	Amps	0.93				Device Current Limit External Minimum
ILIMITMIN	Amps	0.93				Device Current Limit Minimum
ILIMITMAX	Amps	1.07				Device Current Limit Maximum

IP	Amps	0.63				Peak Primary Current
IRMS	Amps	0.35				Primary RMS Current
DMAX		0.54				Maximum Duty Cycle

Power Supply Components Selection

CIN	uFarads	68.0				Input Filter Capacitor
VMIN	Volts	117				Minimum DC Input Voltage
VMAX	Volts	191				Maximum DC Input Voltage
VCLO	Volts	200				Clamp Zener Voltage
PZ	**Watts**	**3.6**				**Estimated Primary Zener Clamp Loss Warning! Zener Clamp loss exceeds 3W and may overheat Tip: Consider alternate clamp circuit; parallel RC or RCD, split primary (L>1) increase efficiency (N), reduce reflected voltage (VOR) and minimize secondary trace in**
VDB	Volts	0.7				Bias Winding Diode Forward Voltage Drop
PIVB	Volts	37				Bias Rectifier Maximum Peak Inverse Voltage

Power Supply Output Parameters

VDx	Volts		0.5	0.5	0.7	Output Winding Diode Forward Voltage Drop
PIVSx	Volts		9	18	54	Output Rectifier Maximum Peak Inverse Voltage
ISPx	Amps		3.28	1.14	2.29	Peak Secondary Current
ISRMSx	Amps		1.66	0.58	1.16	Secondary RMS Current
IRIPPLEx	Amps		1.20	0.42	0.84	Output Capacitor RMS Ripple Current

Transformer Construction Parameters

Core/Bobbin		E25/13/7 (EF25) Margi				Core and Bobbin Type
Core Manuf.		Generic				Core Manufacturing
Bobbin Manuf		Generic				Bobbin Manufacturing
LP	uHenries	1311				Primary Inductance
NP		71				Primary Winding Number of Turns
NB		8.26				Bias Winding Number of Turns
OD Actual	mm	0.20				Primary Actual Wire Diameter

Primary Current Density	**A/mm^2**	**11**				**Primary Winding Current Density** **Error! Primary current density (A/mm 2) is greater than recommended maximum.** **Tip: Increase core size (larger BW), increase layers (L), decrease primary turns (NS), increase minimum input voltage (VACMIN), increase input cap**
VOR	Volts	135.00				Reflected Output Voltage
BW	mm	15.30				Bobbin Physical Winding Width
M	mm	3.0				Safety Margin Width
L		2.0				Number of Primary Layers
AE	cm^2	0.53				Core Effective Cross Section Area
ALG	nH/T^2	260				Gapped Core Effective Inductance
BM	mTesla	220				Maximum Operating Flux Density
BP	mTesla	376				Peak Flux Density
BAC	mTesla	58				AC Flux Density for Core Curves
LG	mm	0.22				Gap Length
LL	uHenries	19.7				Estimated Transformer Primary Leakage Inductance
LSEC	nHenries	20				Estimated Secondary Trace Inductance

Secondary Parameters

NSx			2.00	3.95	11.95	Secondary Number of Turns
Rounded Down NSx				3	11	Rounded to Integer Secondary Number of Turns
Rounded Down Vox	Volts			5.20	20.20	Auxiliary Output Voltage for Rounded to Integer NSx
Rounded Up NSx				4	12	Rounded to Next Integer Secondary Number of Turns
Rounded Up Vox	Volts			7.10	22.10	Auxiliary Output Voltage for Rounded to Next Integer NSx
ODS Actual Range	mm		0.40 - 0.64	0.25 - 0.40	0.36 - 0.57	Secondary Actual Wire Diameter Range Comment: Wire diameter is greater than recommended maximum (0.40 mm) and may overheat. Tip: Consider a parallel winding technique (bifilar, trifilar), increase size of transformer (larger BW), reduce margin (M).

9 Performance Measurements

All measurements were taken using 50Hz mains in a 25˚C lab ambient. Cross regulation measurements were not taken since the loads stated were almost constant. Where loads do vary (i.e. changes on the 17V and 22V rails for the LNB), full measurements have been given.

9.1 Full Power Efficiency

The operating efficiency of the prototype supply was measured as a function of input voltage for the two LNB loading situations. Figure 7 shows that the worst case efficiency is well above 75%.

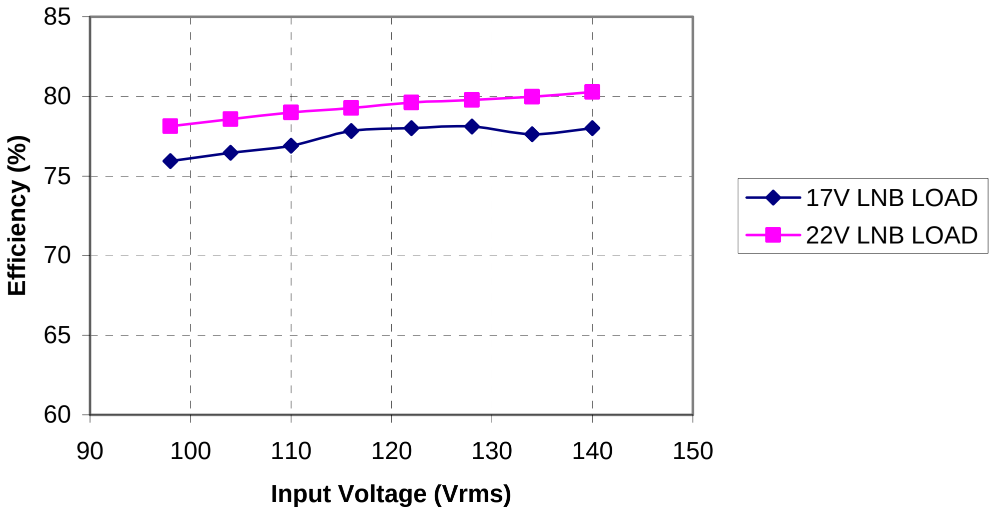


Figure 7 - Full Power Efficiency Variation with Line Voltage

9.2 Efficiency Variation with Load

With 110Vac nominal input and LNB loading on the 22V rail, the efficiency of the supply was measured as a function of output power. The load current on each output rail was varied from 0 to 100% of its rated value in 10% steps and the overall efficiency recorded at each point. Figure 8 shows the resulting efficiency profile.

The graph shows that the target 70% efficiency is maintained down to around 3W output power.

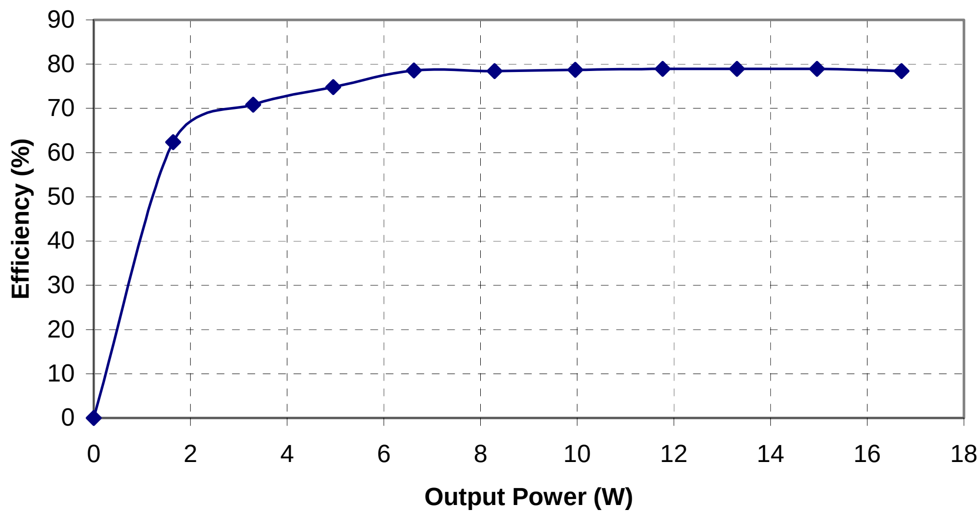


Figure 8 - Efficiency Variation with Output Power at 110Vac Nominal Input

9.3 Line Regulation

Line regulation was measured under the two different loading cases. Figure 9 shows the results of the first case with full load on the 17V LNB supply and zero on the 22V supply. Figure 10 shows the results with zero load on the 17V rail and full load on the 22V rail.

In both cases here, the 17V and the 22V are always well under the 28V maximum allowed.

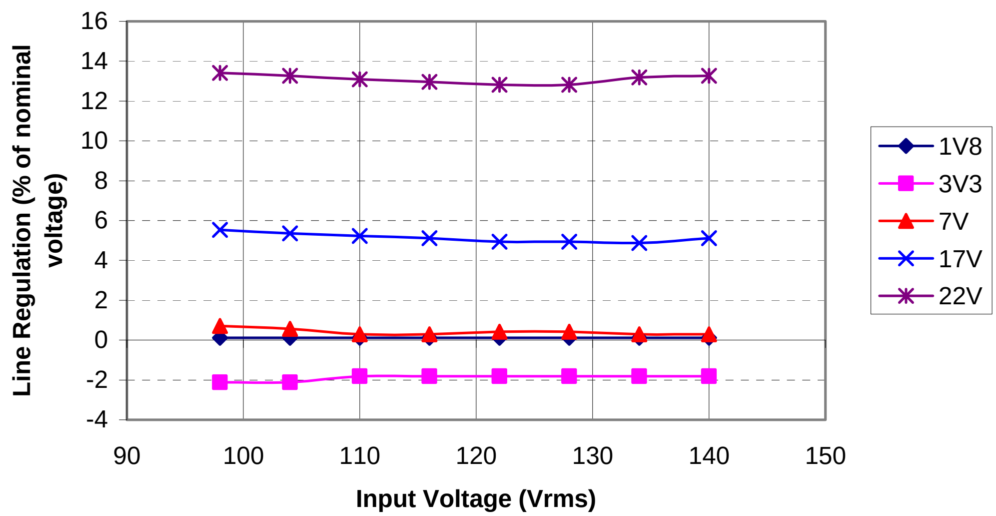


Figure 9 - Line Regulation with LNB Loading on the 17V Rail

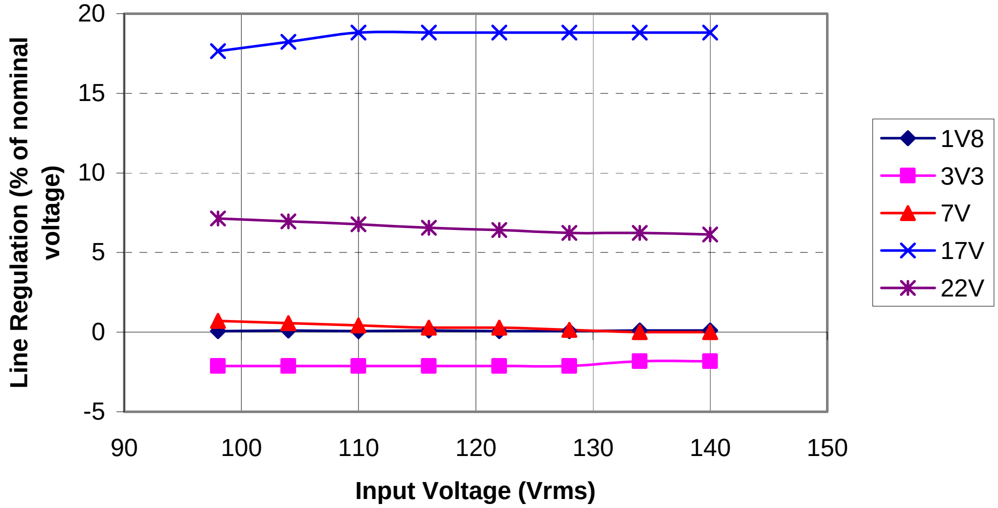


Figure 10 - Line Regulation with LNB Loading on the 22V Rail

9.4 Load Regulation

With LNB loading on the 22V Rail, the rail voltages were measured as a function of output power for 110Vac input. The load on each rail was increased from 0 to 100% power in 10% steps and the rail voltage, specified as a percentage of nominal voltage, were recorded. Figure 11 shows the resulting load regulation profile. The 17V rail does see some peak charging but is still well below the 28V required maximum.

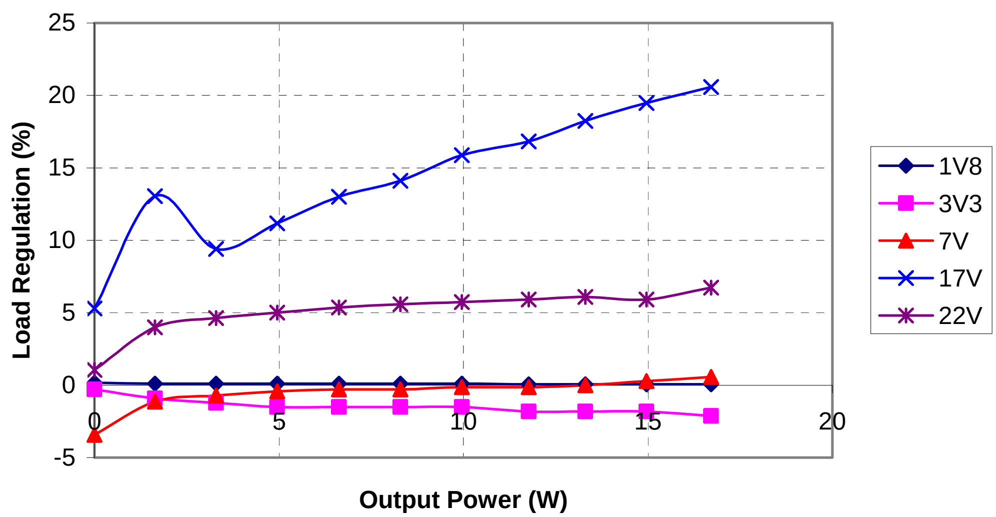


Figure 11 - Load Regulation at 110Vac input with LNB loading on the 22V rail

9.5 Key Component Operating Temperatures

With the PCB mounted horizontally, the key component operating temperatures were measured as a function of input voltage for the two LNB loading cases. Figure 12 shows the temperatures with the loading on the 17V rail (13W total output power) whilst Figure 13 shows the results with loading on the 22V rail (17W total output power).

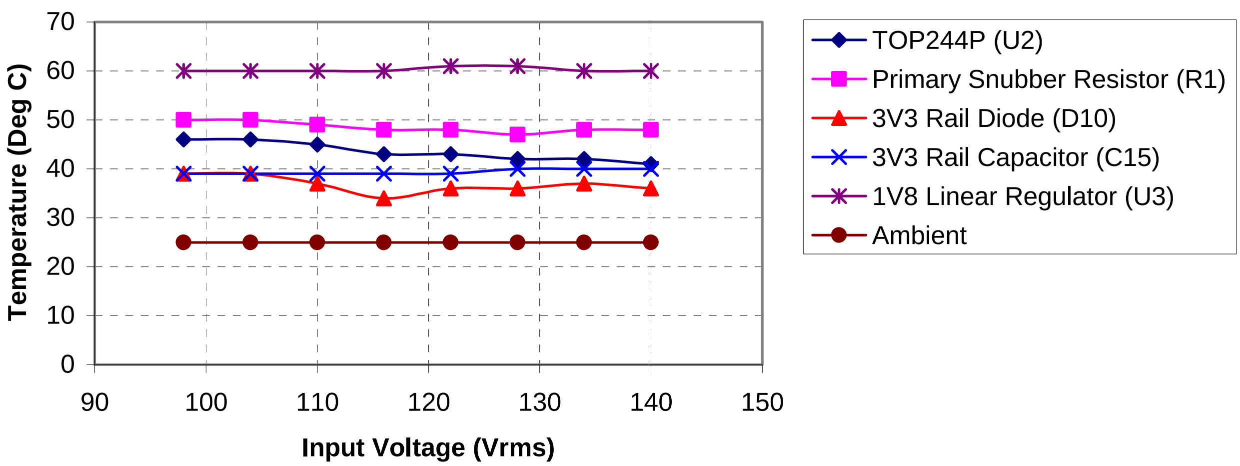


Figure 12 - Key Component Temperatures with 17V LNB loading

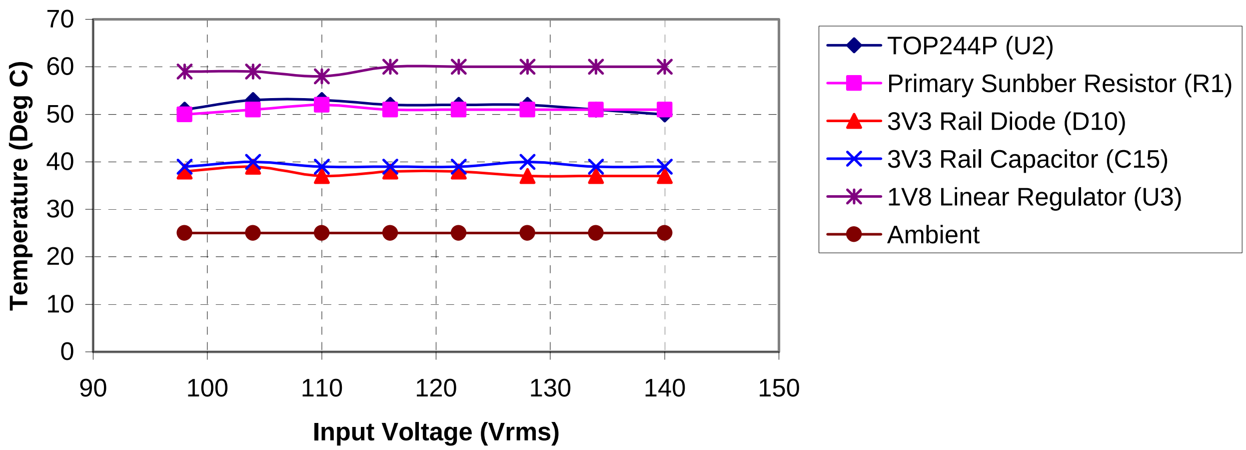


Figure 13 - Key Component Temperatures with 22V LNB loading

10 Operating Waveforms

All waveforms were taken with the highest power case of LNB loading on the 22V rail unless otherwise specified.

10.1 Steady State Drain-Source Voltage and Drain Current Waveforms

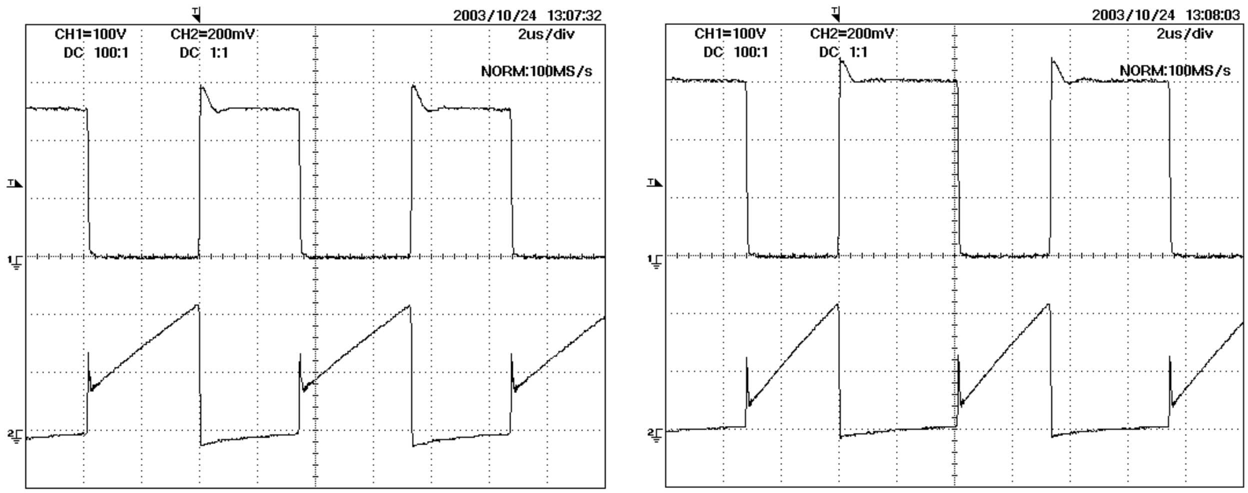


Figure 14 – Drain Current (Lower at 0.2A/div) and Drain-Source Voltage (Upper at 100V/div) for full power operation. Left hand side figure shows operation at 98Vac input whilst the right hand side shows operation at 135Vac input

10.2 Start-up Drain-Source Voltage and Drain Current Waveforms

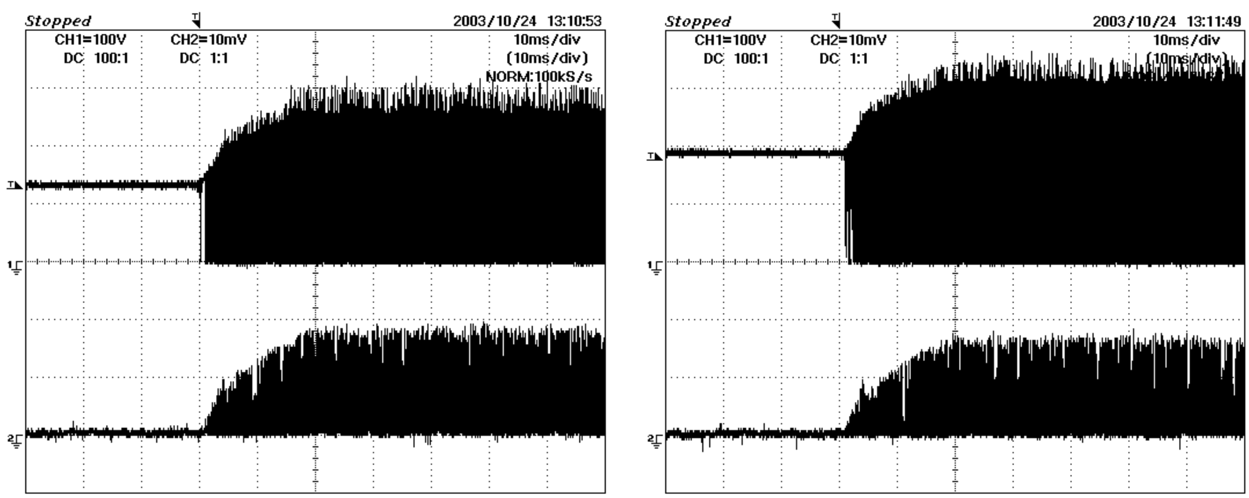


Figure 15 – Drain Current (Lower at 0.2A/div) and Drain-Source Voltage (Upper at 100V/div) under start-up at full power. Left hand side figure shows 98Vac start-up whilst the right hand side shows operation at 135Vac start-up

10.3 Output Voltage Rise Behavior

Output voltage rise behavior was measured using resistive loads on the outputs with 110Vac nominal mains input.

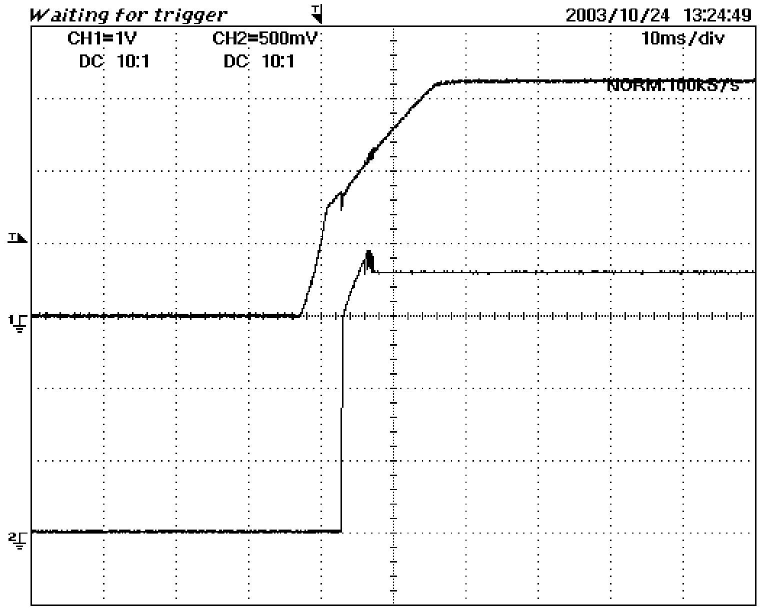


Figure 16 - 3.3V (Upper at 1V/div) and 1.8V (Lower at 0.5V/div) start-up voltage behavior

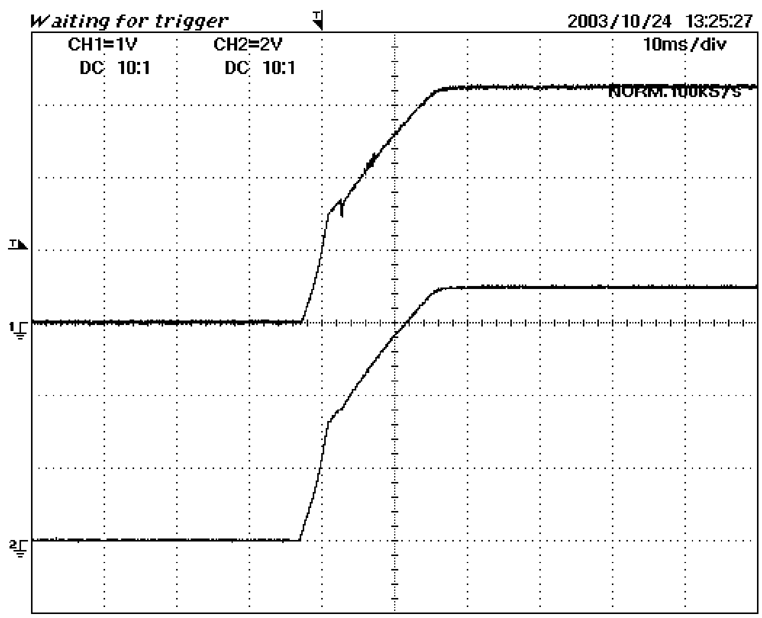


Figure 17 - 3.3V (Upper at 1V/div) and 7V (Lower at 2V/div) start-up voltage behavior

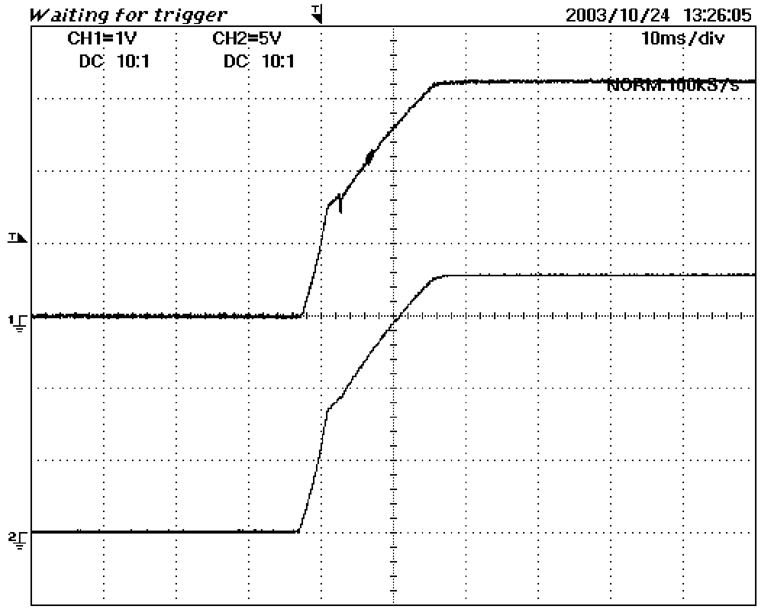


Figure 18 - 3.3V (Upper at 1V/div) and 17V (Lower at 5V/div) start-up voltage behavior

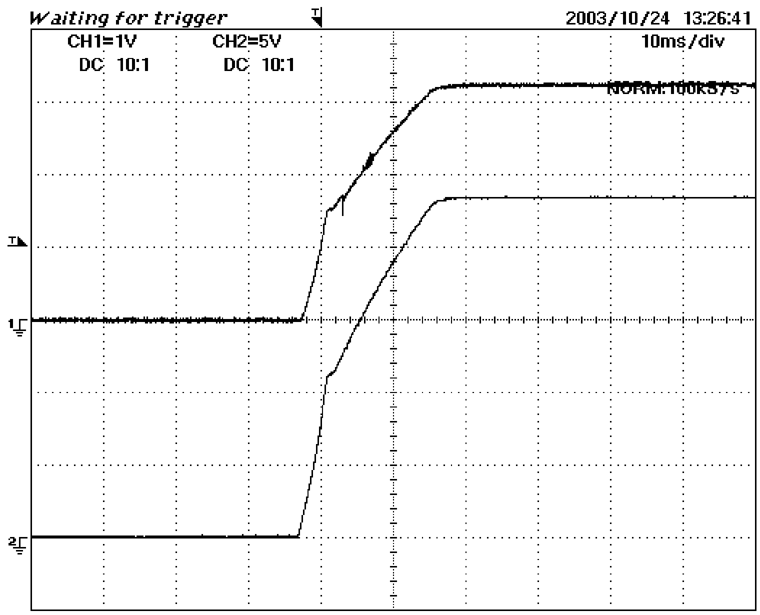


Figure 19 - 3.3V (Upper at 1V/div) and 17V (Lower at 5V/div) start-up voltage behavior

The start-up profiles for the 17V and 22V LNB rails were measured with each rail loaded in turn but not simultaneously.

10.4 Inrush Current

Inrush current was measured with the supply being connected to mains with full power load on the supply outputs. Figure 20 shows the resulting inrush current is around 12A worst case with maximum mains input of 135V.

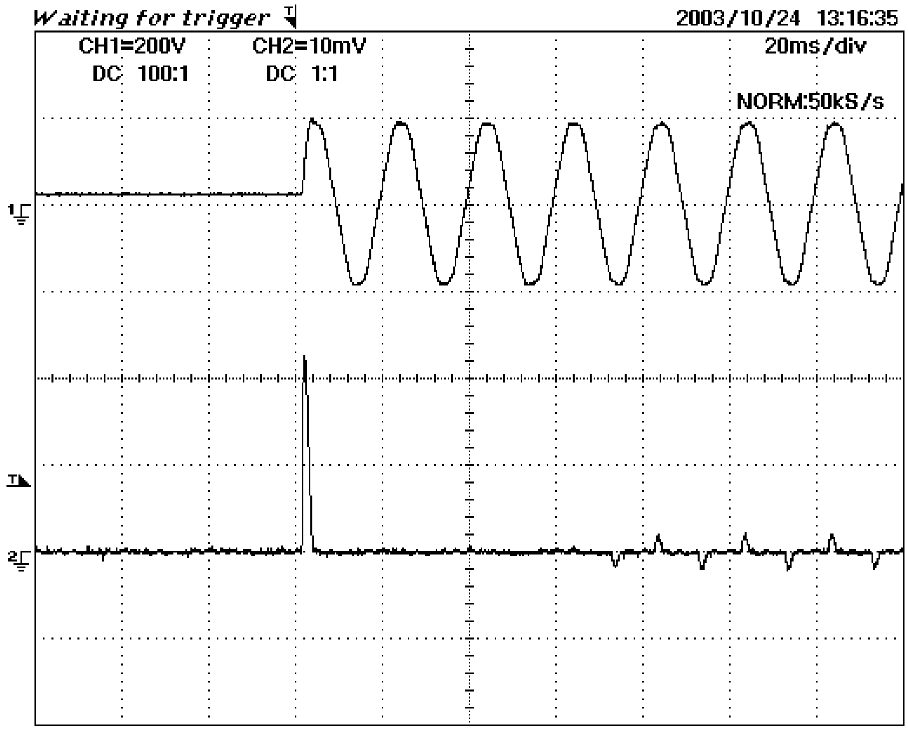


Figure 20 - Worst case inrush current measurement (Upper is mains voltage at 200V/div and lower is current drawn by supply at 5A/div)

10.5 Hold-up

Hold-up was measured with worst case loading on the supply and 110Vax nominal mains. The hold-up was measured under two conditions, the first being mains failure at the zero voltage cross point of the cycle and the second being the peak of the mains cycle.

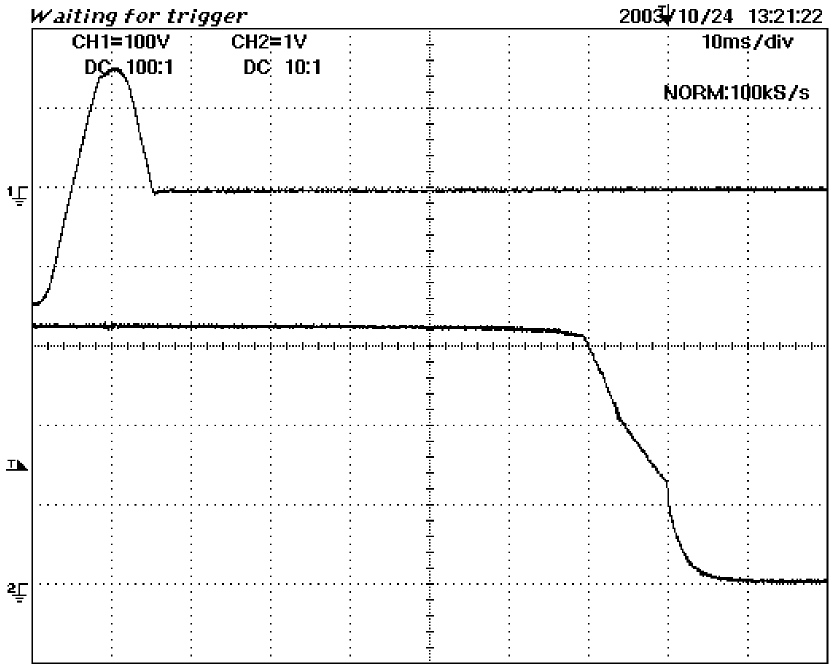


Figure 21 – Hold-up time measurement for removal of mains at zero crossing point. Upper is mains voltage at 100V/div and lower is 3.3V rail voltage. Hold-up is measured at just over 50ms.

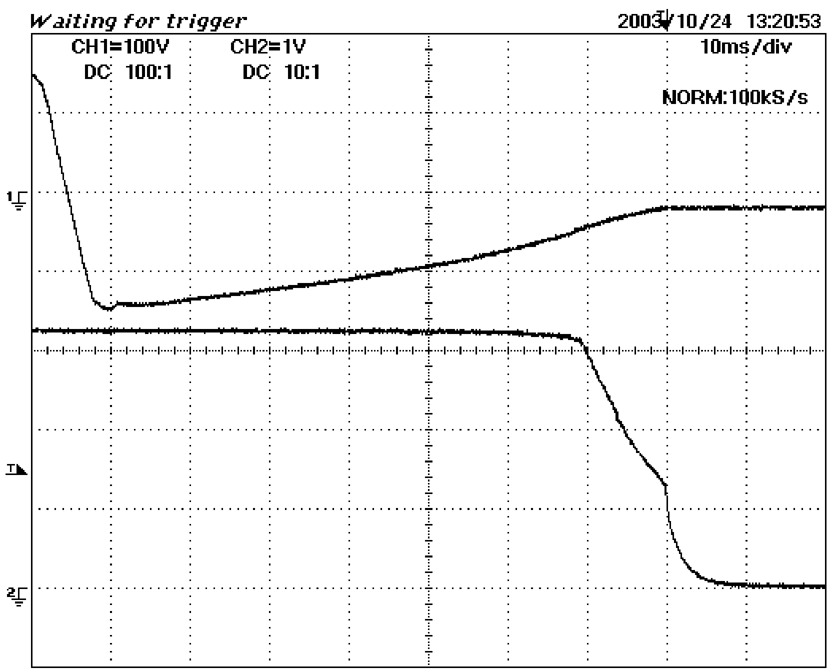


Figure 22 – Hold-up time measurement for removal of mains at peak voltage point. Upper is mains voltage at 100V/div and lower is 3.3V rail voltage. Hold-up is measured at just over 60ms.

10.6 Transient Response

The transient response to load changes at 110Vac input on the 3.3V was measured to give an indication of power supply stability. The power supply was loaded to its full power condition and the load on the 3.3V rail varied from 50% to 100% current. The resulting voltage deviated was measured and is shown in Figure 23 below.

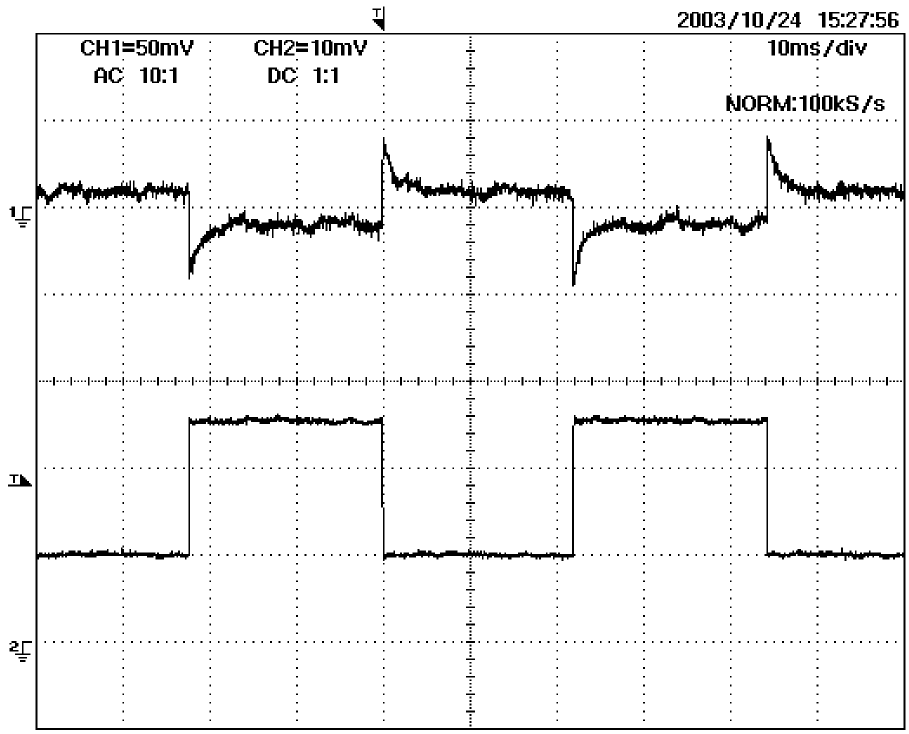


Figure 23 – Load transient response at 110Vac input. Lower is current on 3.3V rail at 0.2A/div and upper is AC coupled 3.3V rail voltage at 50mV/div.

The transient response of the 3.3V rail to load changes indicates a well damped control loop and a stable power supply. For production, PSU stability should be measured under extremes of ambient temperature to ensure full stability.

10.7 Peak Power Loading

When the LNB load transitions from the 17V to the 22V rail, a peak current of up to 800mA may be drawn for a short duration. To check this behavior, the supply was run at full power with the current on the 22V changed from 400mA to 800mA. The 800mA loading was maintained for 100ms bursts at a repletion rate of 3Hz. The power supply can deliver these pulse for a much longer time, dependant on the operating temperature.

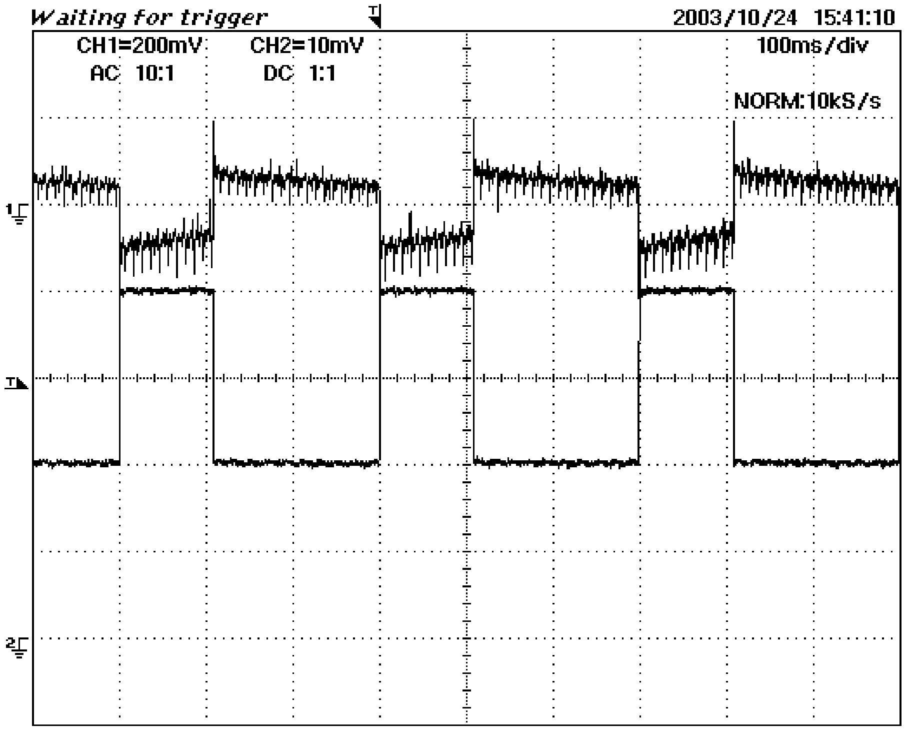


Figure 24 – Peak power loading on the 22V LNB rail. Lower is 22V rail current at 0.2A/div and upper I AC coupled 22V rail voltage at 200mv/div.

During the peak power loading test, all other rails were observed to be operating well within specified voltage levels.

11 Conducted EMI Measurements

The conducted EMI measurements shown in this section are pre-compliance and should be used as an indication of performance.

11.1 Results with output grounded to protective earth

These EMI scans represent the case when the output of the PSU is grounded back to Earth via a functional ground, often found with SCART lead connections.

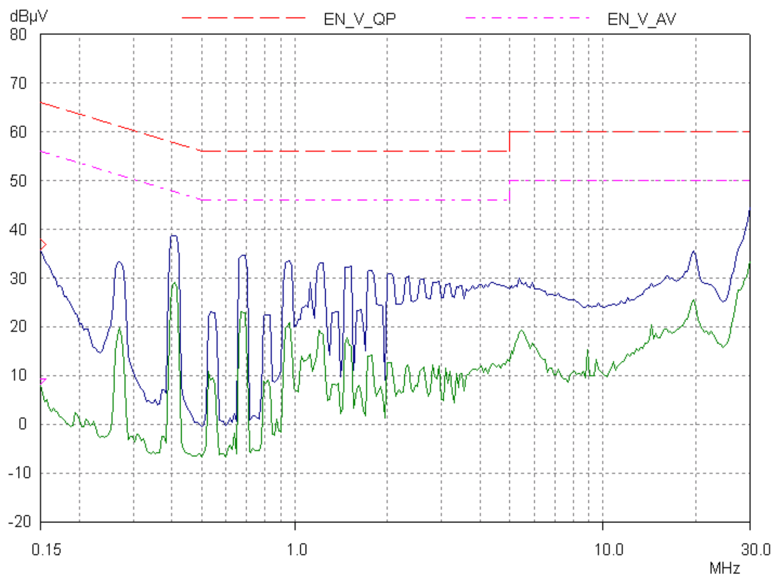


Figure 25 – Conducted EMI measured in Live wire

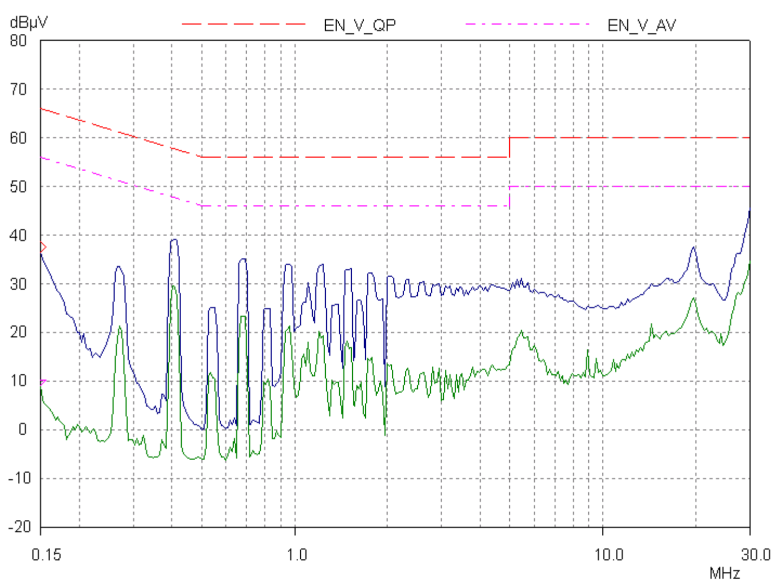


Figure 26 – Conducted EMI measured in Neutral wire

11.2 Results with Output Floating

Here, a simple two wire connection to the LISN was used.

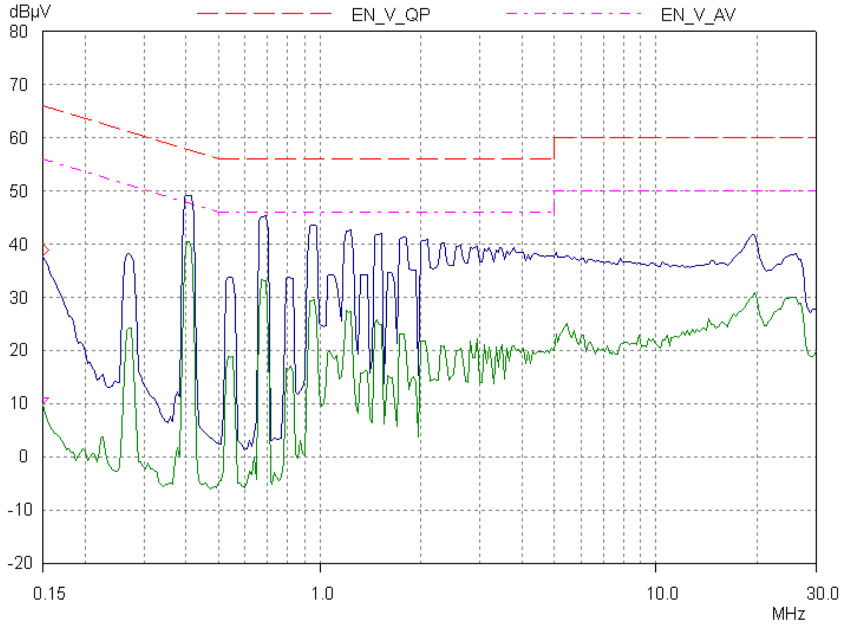


Figure 27 – Conducted EMI measured in Live wire

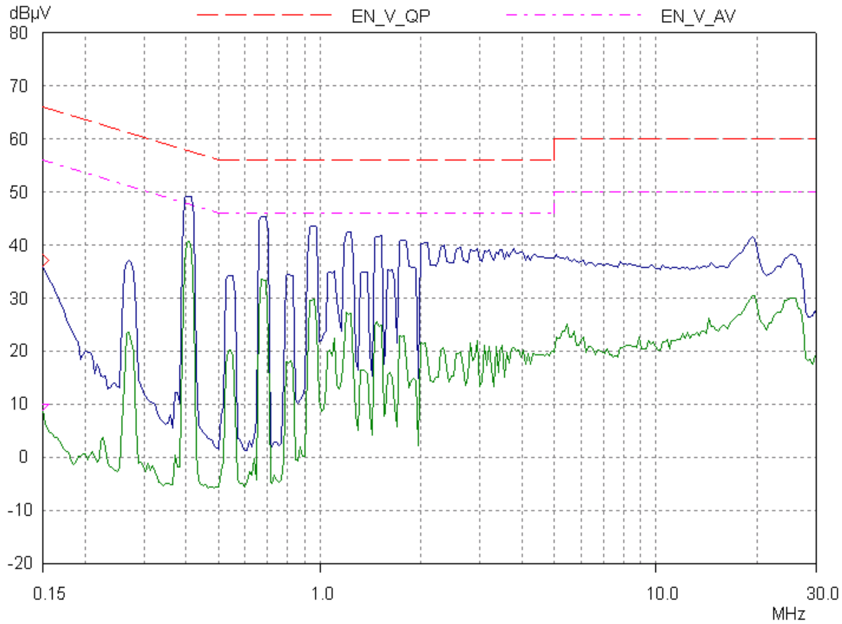


Figure 28 – Conducted EMI measured in Neutral wire

12 Revision History

Date	Author	Revision	Description & changes	Reviewed
March 30, 2004	IM	1.0	Initial Release	VC / AM

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