Design Example Report

Title	***14W PFC Isolated LED Driver circuit using TOP246F***
Specification	Input: 108 – 132 Vac Output: 700mA Constant Current with 16 - 24V LED Load
Application	LED Driver
Author	Power Integrations Applications Department
Document Number	DER-26
Date	March 30, 2004
Revision	1.0

Summary and Features

A TOP245F is used to create an isolated LED driver circuit that features the following:

- Low Cost Single Stage PFC Isolated LED Driver
- No Output Current Overshoot
- 80 ms Startup time
- Low Parts Count
- EMI Compliant (CISPR-22B)

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Important Notes:
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.

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1 Introduction

This document is an engineering report describing a prototype PFC (Power Factor Corrected) 700 mA (average) Constant Current Isolated LED Driver utilizing a TOP246F. This is intended as a general-purpose evaluation platform for *TOPSwitch-GX* controller, using an EF20 transformer in a discontinuous conduction flyback topology.

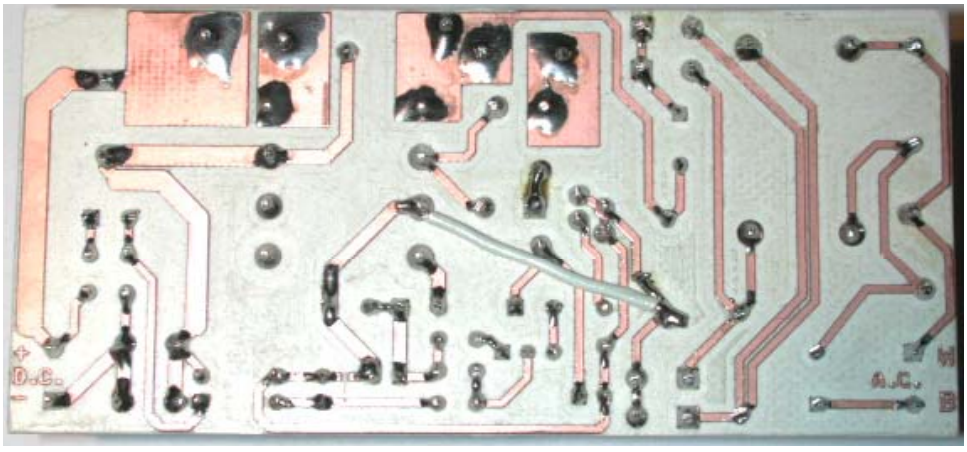
The input and output current waveforms are quasi-sinusoidal, for PFC requirements.

This design was originally intended to drive a Luxeon 12 UP White LED Ring part number LXHL-NW96. It's basic specifications (Technical Data DS22) are as follows: 700 mA average forward current, 1000 mA peak current. The forward drop is 16 V min, 24 V max.

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

1.1 Component side view

1.2 Circuit Side view



Note: The photographs above show the prototype board, which required 1 trace cut, and

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1 jumper wire. This rework is required to improve PFC. The rework wire from T1 pin 3 to C3 (-) reduces the impedance from the bias winding return to C3 ground. The trace cut between C6 (-) and C8 (-) is also required, to prevent a ground loop.

2 LED Driver Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	108		132	VAC	2 Wire – no P.E.
Frequency	f_{LINE}		60		Hz	(60 Hz only)
No-load Input Power (120 VAC)				1.0	W	at 120Vac
Total Harmonic Distortion				25 %		700 mA-24V Diode Load
Power Factor			0.96			700 mA-20V Diode Load
Output						
Output Voltage	V_{OUT1}	16	20	24	V	LED Load Spec
Output Ripple Current	$V_{RIPPLE1}$		600		mA P-P	See 10.3 waveform
Output Average Current	I_{OUT1}	665	700	735	mA Ave.	700 mA ± 5%
Total Output Power						
Continuous Output Power	P_{OUT}	10.6	14	17.6	W	
Peak Output Power	P_{OUT_PEAK}		20		W	See 10.3 waveform
Efficiency	η	75			%	Measured at P_{OUT} (14 W), 25 °C
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Ambient Temperature	T_{AMB}	-40		80	°C	Free convection, sea level

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3 Schematic

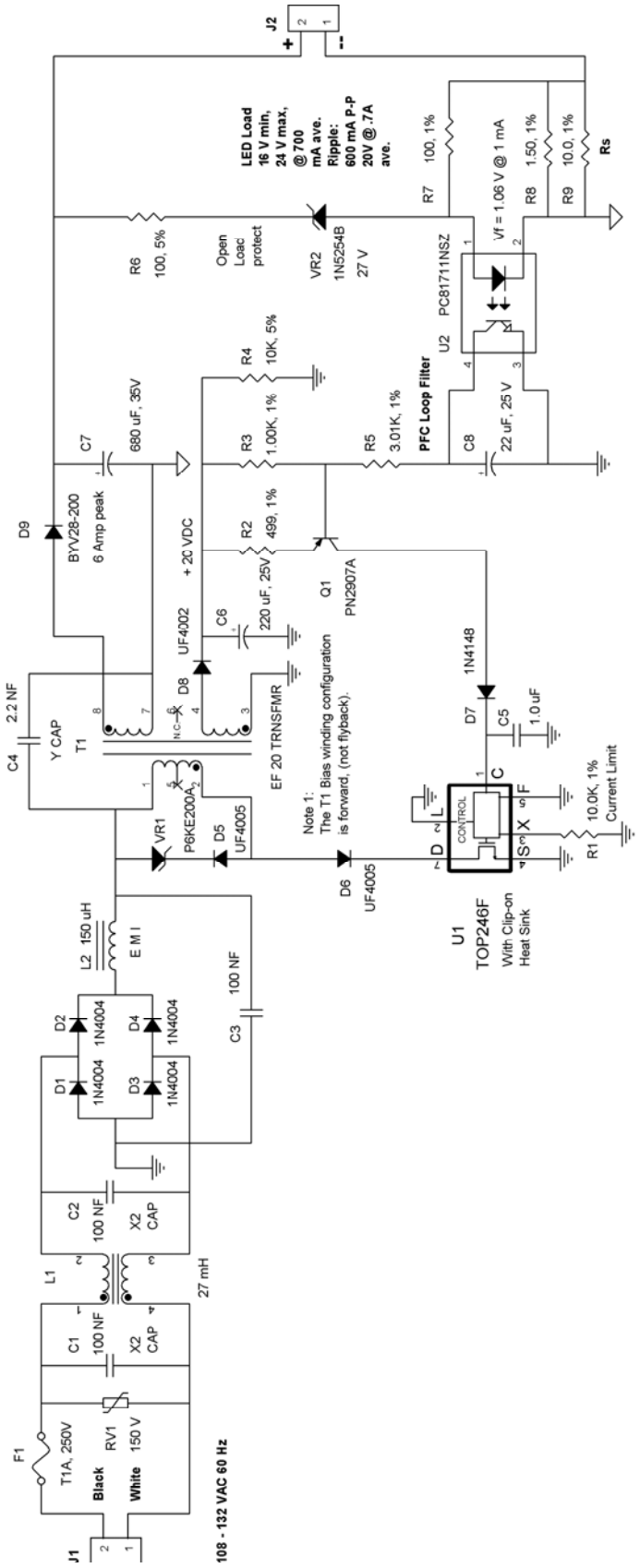

Figure 1 Circuit Schematic

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4 Circuit Description

The following is a functional description of the PFC Isolated 700 mA LED Driver.

4.1 Input EMI Filtering

The AC input is fused, followed by a 150V surge protecting MOV. This input is EMI filtered via C1, L1, and C2. The full wave rectifier's output is also EMI filtered via C3 and L2. C3 is the bulk storage cap. Note that a Discontinuous Flyback design with a small input bulk capacitor, inherently has a high power factor. The voltage across C3 is a full wave rectified waveform, supplied to the EF20 transformer.

4.2 TOPSwitch Primary

The TOP246F PWM controller switches the transformer primary in a discontinuous conduction flyback mode. The VR1 (transorb) and D5 diode, clamps the transformer flyback voltage (due to leakage inductance) to 200 volts above the rail voltage. The 10.0K resistor connected to the X pin, sets the TOP246 peak current limit to approximately 1.4A. The C5 (0.1 uF) cap on the control pin is kept small to allow fast power-up of the bias supply voltage etc.

4.3 Output Rectification and Current Sense

The output voltage for the LED Load is generated via the D9 and C7 cap. The output current is sensed across the R8 & R9 resistors. This sense voltage drives the optocoupler's LED via the R7 current limit resistor, regulating the voltage across R8 and R9 to the forward voltage of the optocoupler LED.

4.4 PFC Loop Feedback

The optocoupler's output transistor drives the C8 PFC Loop filter cap, and the Q1 (PNP) current source transistor circuit, composed of R2, R3, and R5. This circuit is has a current gain of 1.4, and is used to allow the optocoupler to operate near the peak of its CTR curve. R4 is used to discharge C6 and C8, in the absence of AC input voltage. This circuit configuration controls the output current rise time, preventing Output Current Overshoot. The Bias voltage is generated via D8 and C6, and is used to supply the Q1 transistor circuit. Note that the Bias winding configuration is in the Forward (not flyback) Mode, for improved output current regulation to the LED load. This also prevents the bias voltage from collapsing during an output short circuit condition. Note that the Forward Bias Mode only works with a restricted input voltage range.

The Q1 PNP transistor's collector goes to the U1 (TOP246F) Control Pin and C5 bypass cap, via the D7 power-up blocking diode. This closes the loop.

The C6 Bias supply cap is large, to reduce the120 Hz ripple voltage. This will allow a high power factor.

Note: The current design is optimized for a fast Power-up time of approx. 80 ms. As a result, there is some tradeoff in Power Factor and Total Harmonic Distortion. A larger C8 (and/or C5) PFC Loop Filter cap will increase the Power Factor and reduce Total Harmonic Distortion. However, this will significantly increase the Power-up Turn-on delay time.

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4.5 Protection

The VR2 zener diode and its current limit resistor, limits the output voltage to approximately 30 V in the absence of an output load.

A continuous short circuit on the output will not create a failure condition, due to the TOPSwitch-GX Auto-Restart feature which will protect the device and the application circuit.

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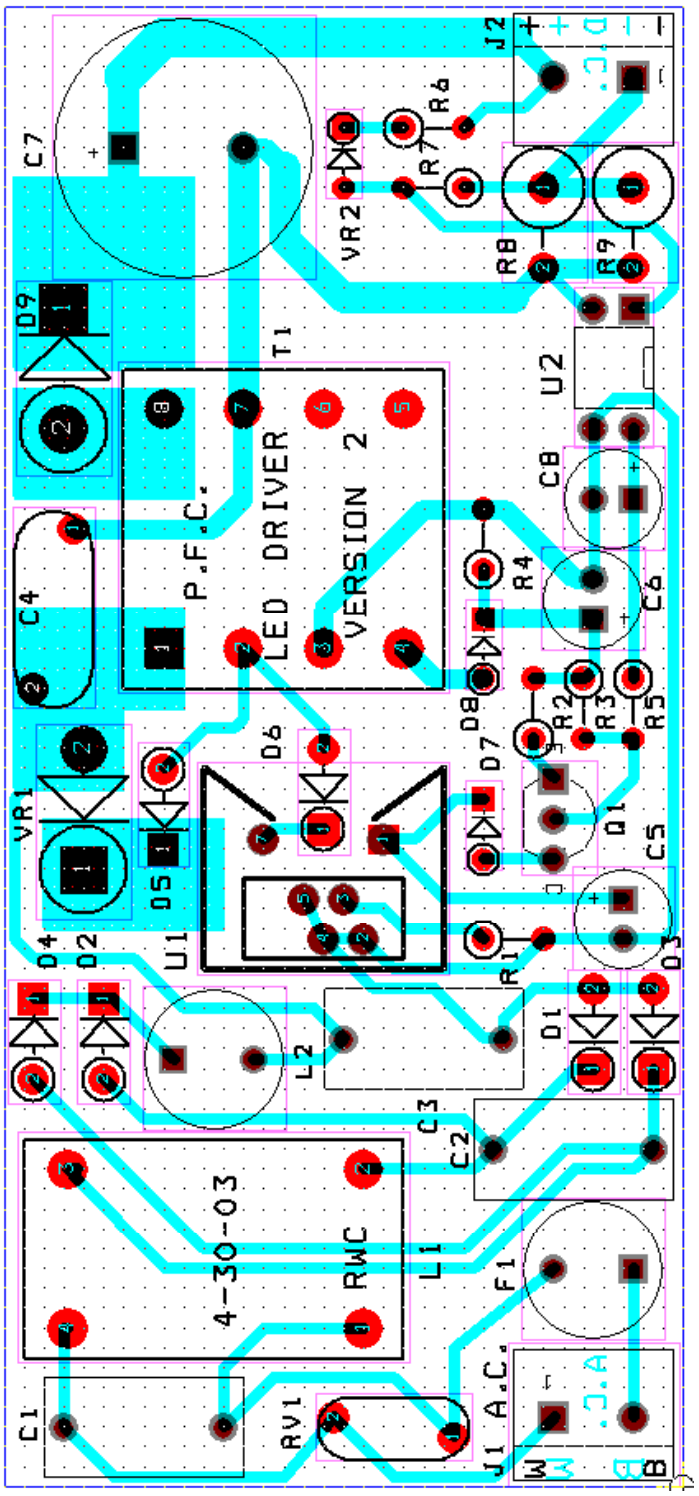
5 PCB Layout



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6 Bill Of Materials

Item	Qty	Ref	Description	Manufacturer	Part Number
1	2	J1, J2	5mm Terminal Block	Phoenix Contact	1729018
2	1	F1	Fuse, 1A 250V TR5 SLO	Wickmann	3721100041
3	1	RV1	MOV, 150V	Panasonic	ERZ-V10D-241
4	1	T1	Transformer,		EF20
5	1	L1	Line Filter, 27 mH	VOGT	RK 17 570 16 270 00
6	1	L2	150 uH, 0.42A	TOKO	R622LY-151K
7	1	U1	IC, offline switcher	Power Integrations	TOP246F
8	1	U1	Heat sink, TO-220 clip-on	Wakefield	233-60AB
9	1	U2	IC, Optocoupler	Sharp	PC81711NSZ
10	1	Q1	Transistor, PNP, GP		PN2907A
11	1	VR1	TransZorb, 200V	Vishay	P6KE200A
12	1	VR2	Zener, 27V	On Semi	1N5254B
13	4	D1-D4	Diode, 400V 1A	General Semi	1N4004
14	1	D8	Diode, 200V, 1A FR	General Semi	UF4002
15	2	D5,D6	Diode, 600V, 1A FR	General Semi	UF4005
16	1	D9	Diode, 200V, 3.5A FR	Phillips Semi	BYV28-200
17	1	D7	Diode, 75V, 150 mA	General Semi	1N4148
18	1	R1	Res, 10.0K, 1/4W, 1%		
19	1	R2	Res, 499, 1/4W, 1%		
20	1	R3	Res, 1.00K, 1/4W, 1%		
21	1	R4	Res, 10K, 1/4W, 5%		
22	1	R5	Res, 3.01K, 1/4W, 1%		
23	1	R6	Res, 100, 1/4W, 5%		
24		R7	Res, 100, 1/4W, 1%		
25	1	R8	Res, 1.5, 1W, 1%	Vishay	RS1A-1.5
26	1	R9	Res, 10.0, 1/4W, 1%		
27	2	C1,C2	Cap, 100 nF,275 VAC, X2,20%	BC Components	2222 388 20104
28	1	C3	Cap, 100 nF, 400VDC	Panasonic	ECQ-E4104KF
29	1	C4	Cap, 2.2 nF, Y1	Cera-Mite	440LD22
30	1	C5	Cap, 1.0 uF		
31	1	C6	Cap, 220 uF, 25V	Panasonic	EEU-FC1E221
32	1	C7	Cap, 680 uF, 35V	Panasonic	EEU-FC1V681S
33	1	C8	Cap, 22 uF, 25V	Panasonic	EEA-FC1E220
34	1	Fab,	LED Driver Version 2		

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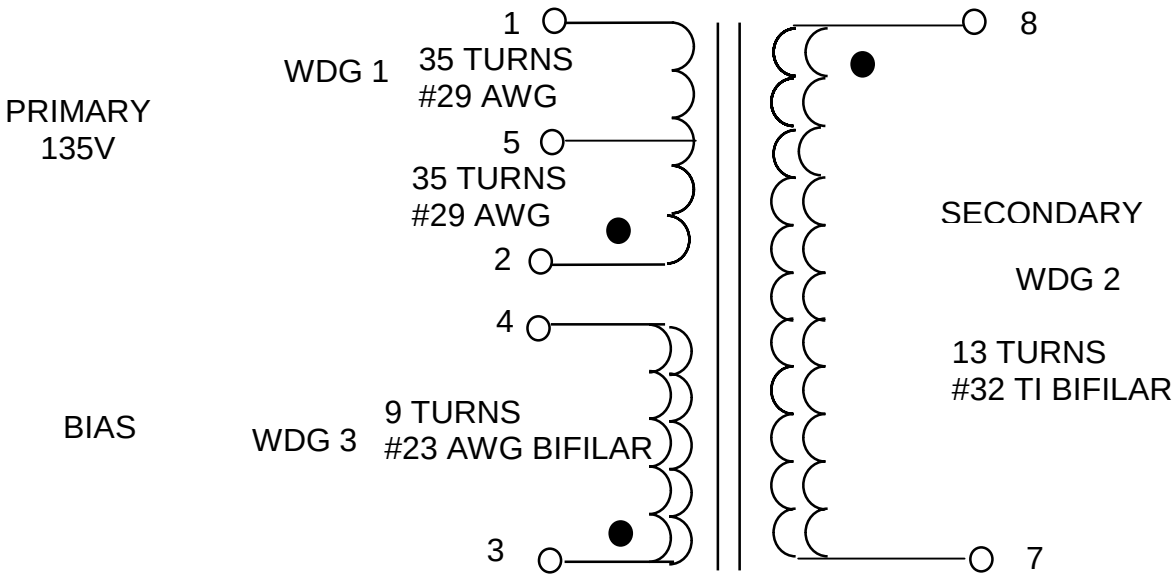
7 Transformer Specification

7.1 Electrical Diagram



7.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from Pin 1 to Pin 8	3000 VAC
Primary Inductance	Pins 1-2, all other windings open, measured at 132 kHz, 0.4 VRMS	350 µH, +0/- 10%
Resonant Frequency	Pins 1-2, all other windings open	2.0 MHz min.
Primary Leakage Inductance	Pins 1-2, with Pins 7-8 shorted, measured at 132 kHz, 0.4 VRMS	10 µH (Max.)

7.3 Materials

Item	Description
[1]	Core: EF20 material or equivalent. Gapped for A_L = 1570nH/T^2
[2]	Bobbin: MILES-PLATTS EF0700, EF20 8-PIN HORIZONTAL.
[3]	Magnet Wire: #29 AWG Heavy Nyleze
[4]	Magnet Wire: #32 AWG Triple Insulated
[5]	Magnet Wire: #23 AWG Heavy Nyleze
[6]	Tape: 3M 1298 Polyester Film (white) 13.41 mils wide by 2.2 mils thick
[7]	Varnish

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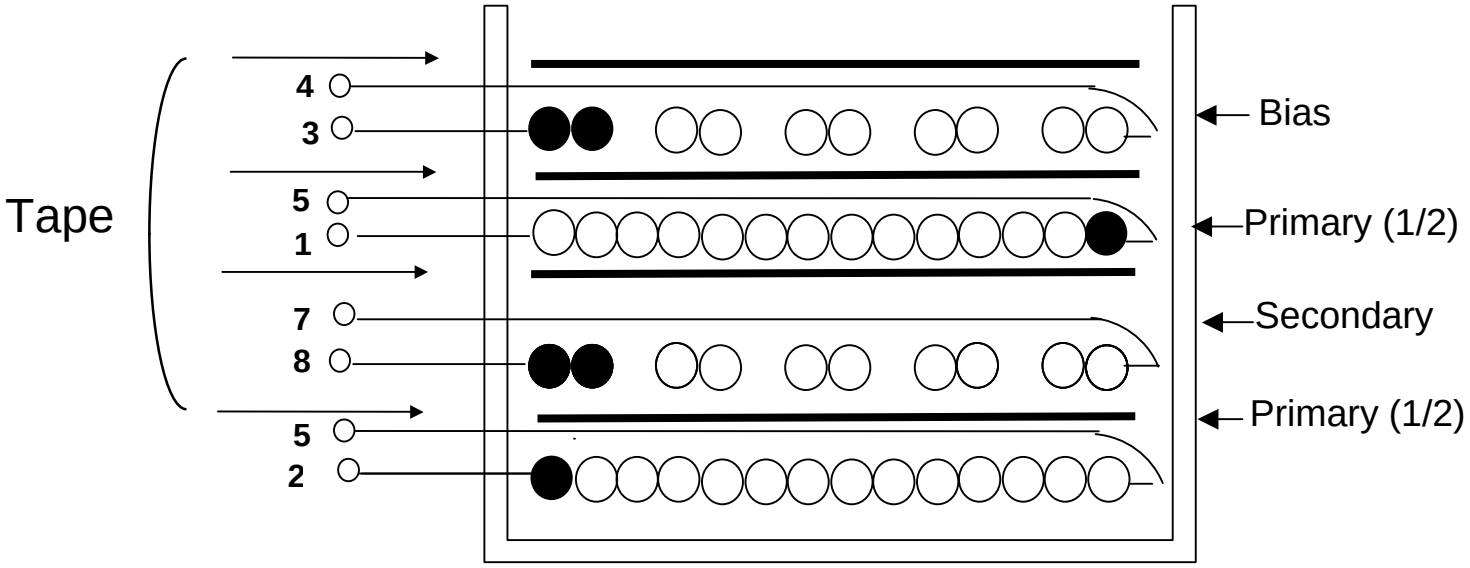
7.4 Transformer Build Diagram

See PCB layout on page 8 for transformer bobbin pin-out information.



Transformer Build Diagram

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7.5 Transformer Construction

Primary Winding (Winding #1)	Start at Pin 2. Wind 35 turns of item [3] uniformly across bobbin. Terminate at Pin 5
Basic Insulation	Use one layer of item [6] for basic insulation.
Secondary Winding (Winding #2)	Start at Pin 8. Wind 13 turns of item [4] bifilar uniformly across bobbin. Terminate at pin 7
Basic Insulation	Use one layer of item [6] for basic insulation.
Primary Winding (Winding #3)	Start at Pin 5. Wind 35 turns of item [3] uniformly across bobbin. Terminate at Pin 1.
Basic Insulation	Use one layer of item [6] for basic insulation.
Bias Winding (Winding #4)	Start at Pin 3. Wind 9 turns of item [5] bifilar uniformly across bobbin. Terminate at pin 4
Outer Insulation	Wrap winding with one layer of item [6]
Final Assembly	Assemble and secure core halves with tape. Impregnate the transformer with item [7]

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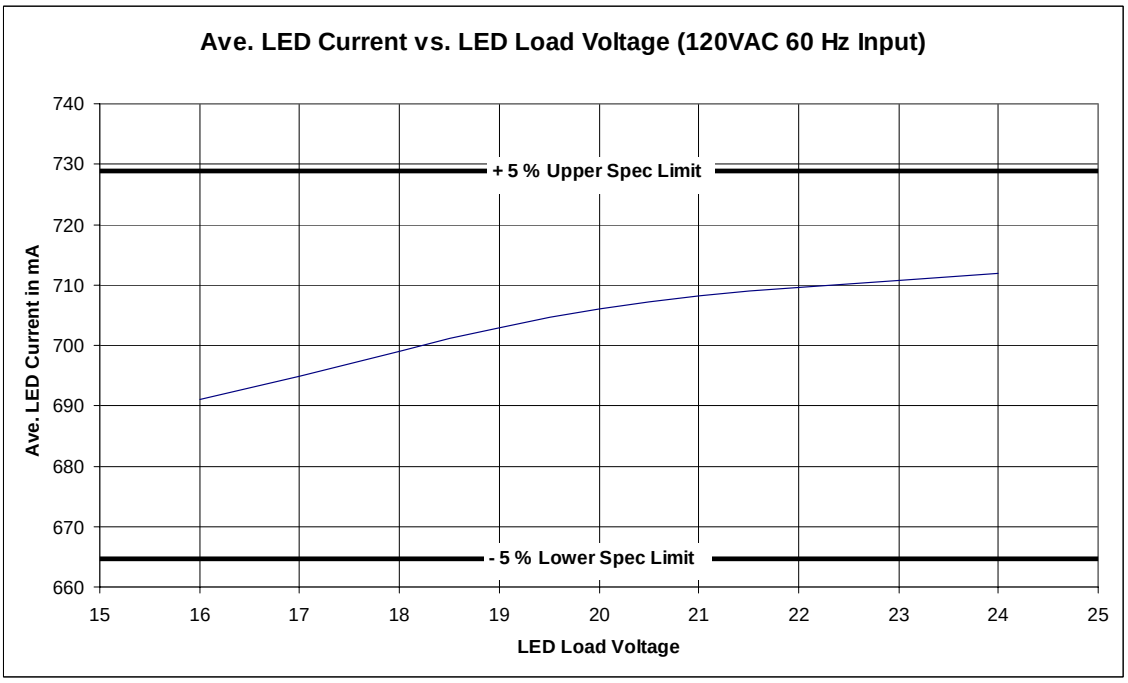
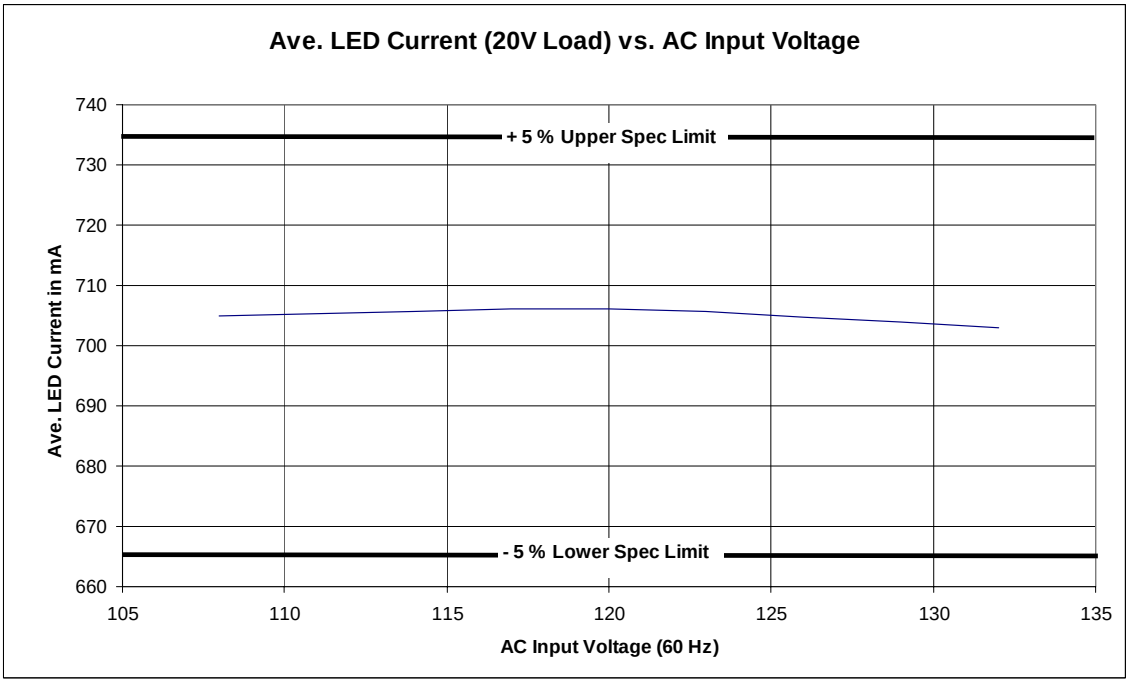
8 Performance Data

All measurements performed at room temperature, 60 Hz input frequency.

8.1 Output LED Current Regulation vs. Output LED Load Voltage



8.2 Output LED Current Regulation vs. AC Input Voltage



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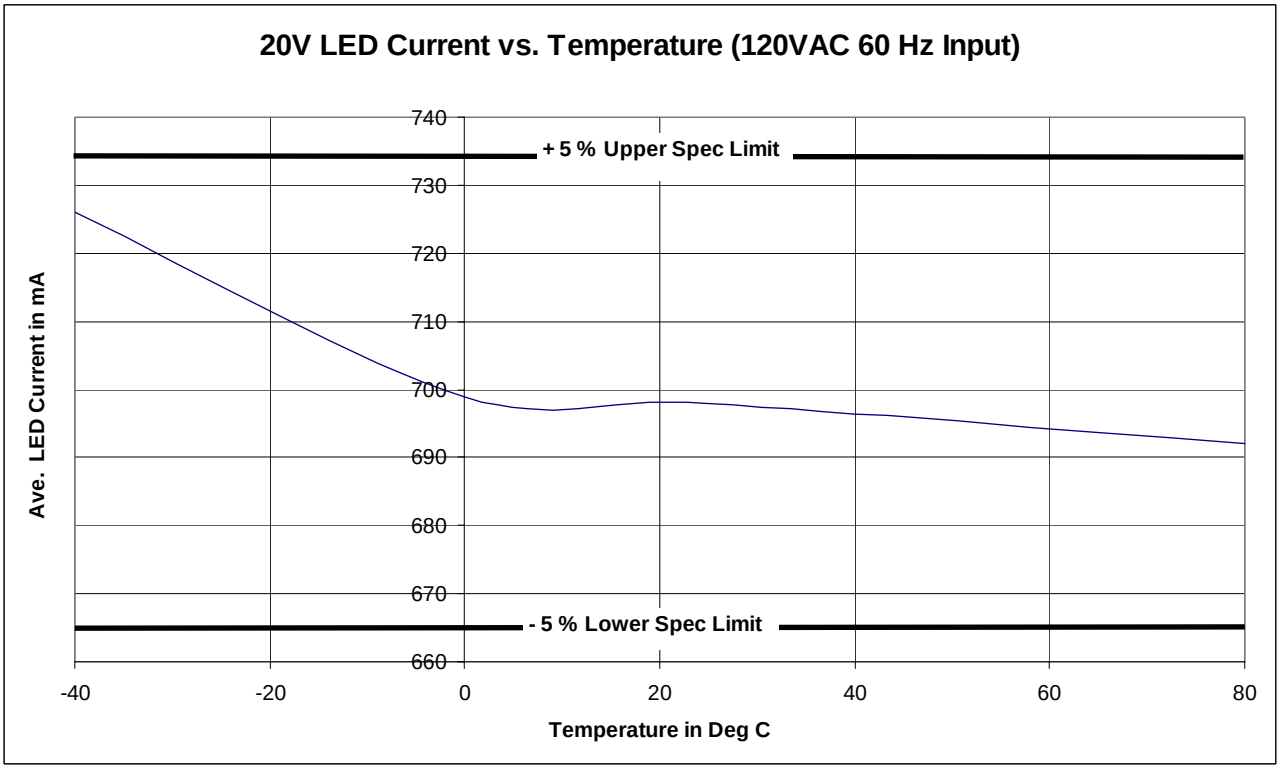
9 Thermal Performance

Un-enclosed Board tested inside the thermo-chamber, 120 VAC 60 Hz.



10 Efficiency

The efficiency is 75 % minimum, with 120 VAC 60 Hz input, and an output of 700 mA ave., using a 16 to 24V LED Load.

11 PFC and THD Performance

The Power Factor (PF) is typically 0.96 and the Total Harmonic Distortion (THD) is 25%, with 120 VAC 60 Hz input, and an output of 700 mA using a 20V LED Load. Note that the Power-up time is 80 ms.

If C8 is changed from 22 uF to 100 uF, the PF is improved to 0.98 and the THD is reduced to 14%. Note that the Power-up time increases from 80 ms to 275 ms.

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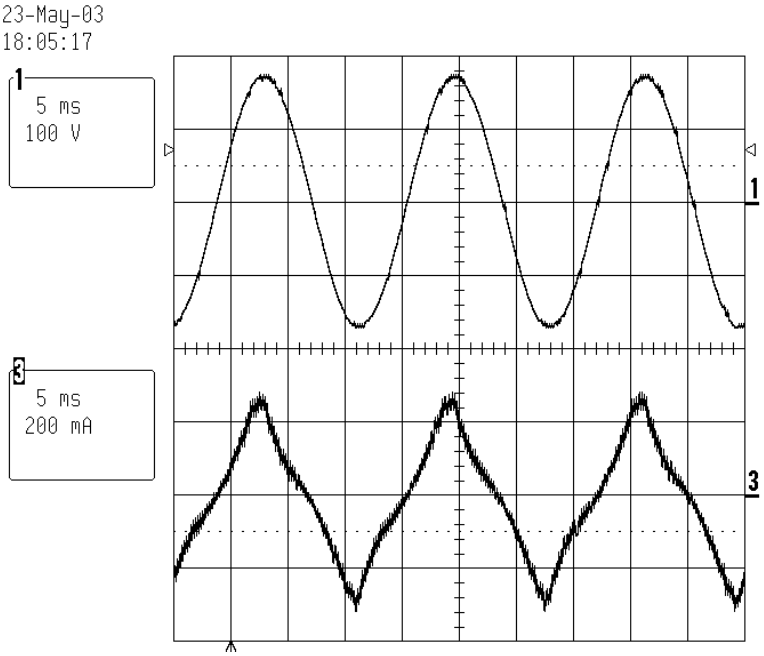
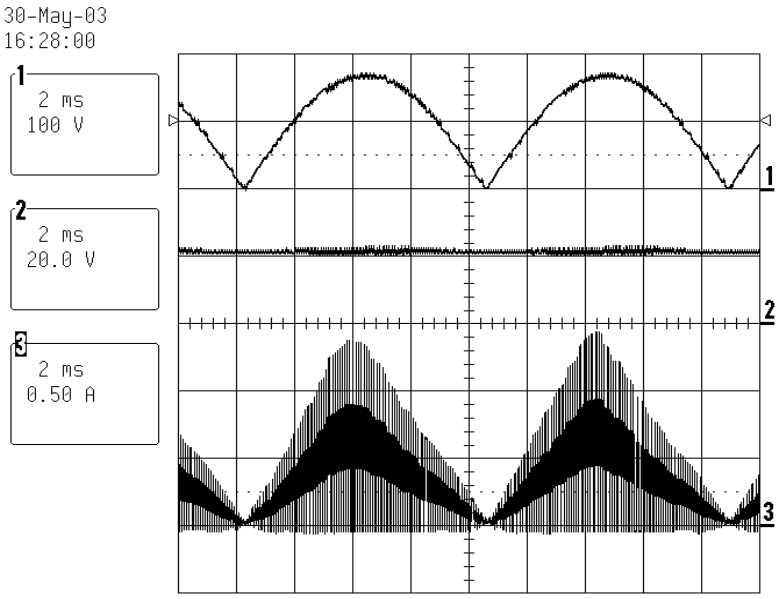
12 Waveforms

12.1 120VAC 60 Hz Input Voltage & Input Current –700 mA 20V LED Output Load



12.2 120VAC 60 Hz input: Full Wave Rectifier, Bias, Drain Current –700 mA 20V LED Output Load



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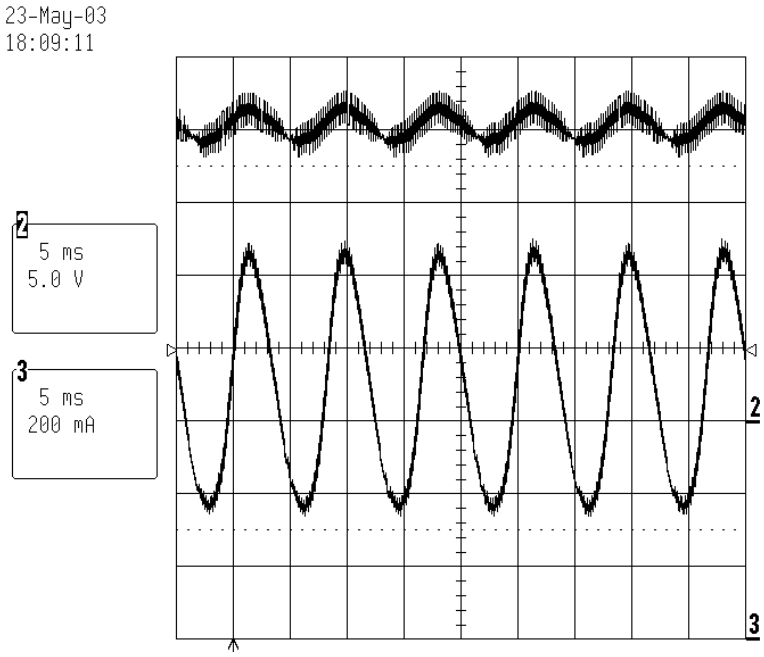
12.3 120VAC 60 Hz Input: Output Voltage & Output Current –700 mA 20V LED Output Load



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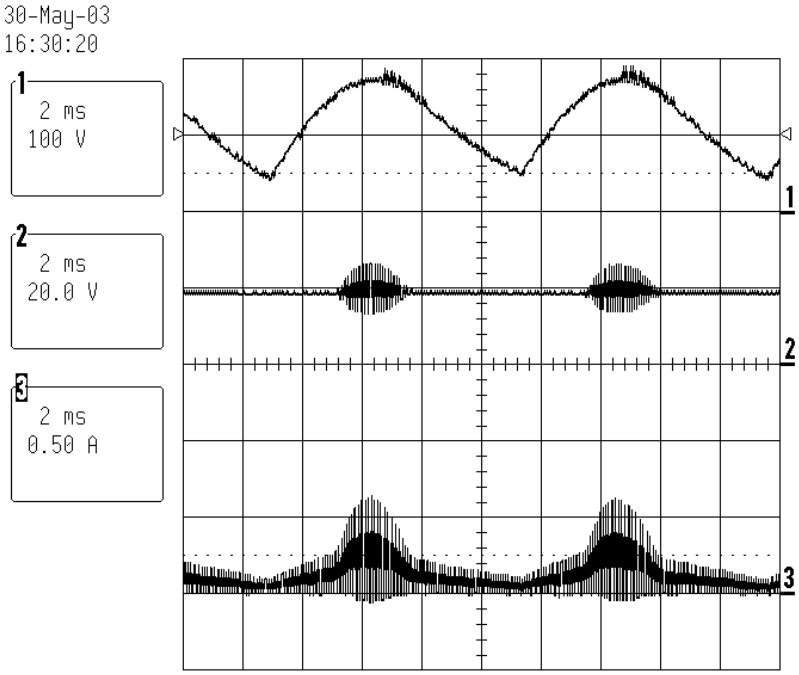
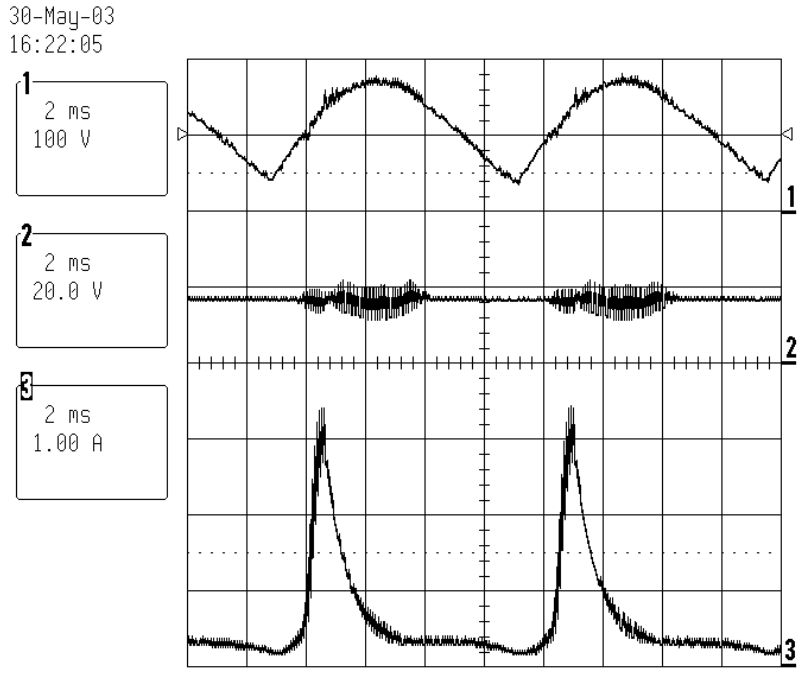
12.4 120VAC 60 Hz Input: Full Wave Rectifier, Bias, Drain Current – Output Open (No Load)



12.5 120VAC 60 Hz Input: Full Wave Rectifier, Bias, Output Current – Output Shorted



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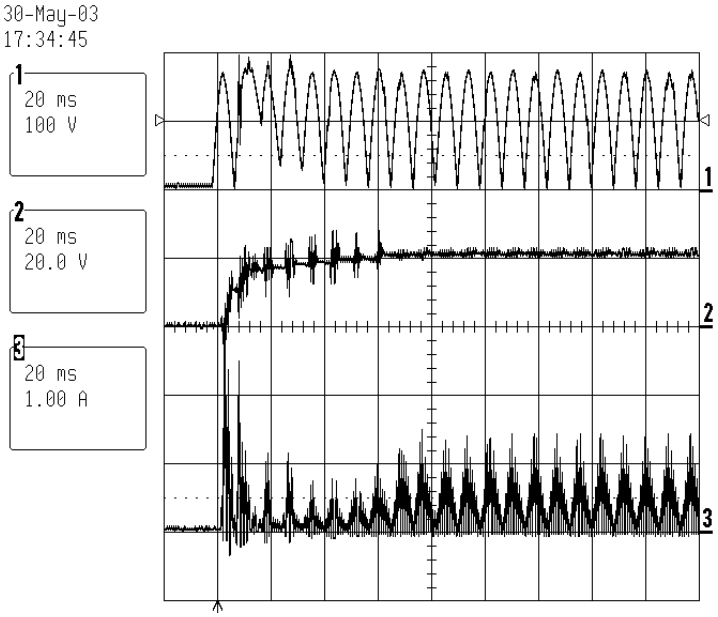
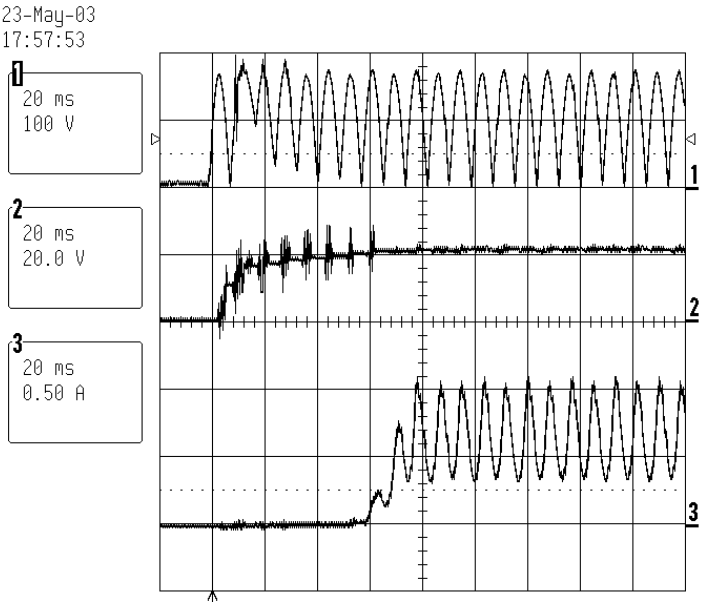
12.6 120VAC 60 Hz Input Power-Up : Full Wave Rectifier Bias, Drain Current – 20V 700 mA Output



12.7 120VAC 60 Hz Input Power-Up : Full Wave Rectifier, Bias, Output Current – 20V 700 mA Output



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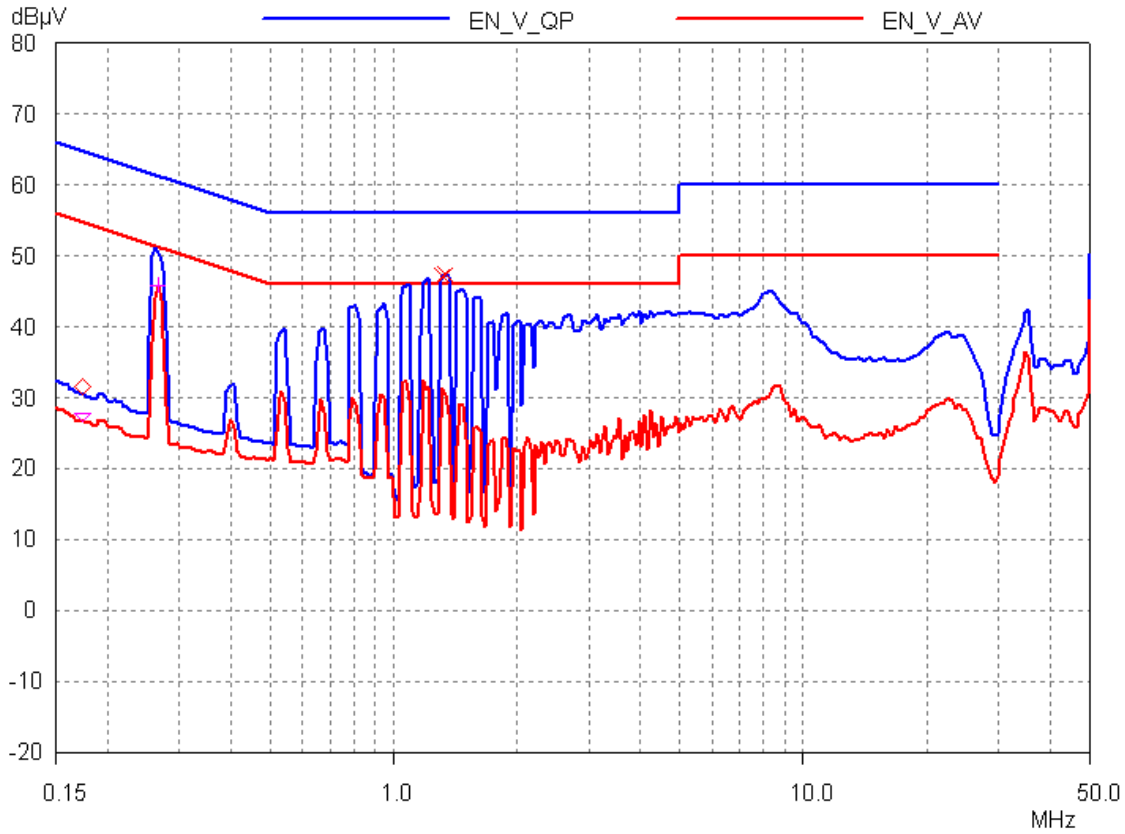
13 Conducted EMI



Conducted EMI, Maximum LED Load (24V@700mA), 120 VAC, 60 Hz, and EN55022 B Limits.

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14 Revision History

Date	Author	Revision	Description & changes	Reviewed
March 30, 2004	R.W.C.	1.0	Initial Release	VC / AM

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