ON Semiconductor

Design Note – DN05072/D

125W Hi-PF Single Stage LED Driver

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCL30001	LED Driver	85 – 265 V ac	125W	CCM Flyback	Yes

	Output 1
Output Current	2.5 A
Ripple	560 mA p-p
Nominal Voltage	48 V
Max Voltage	55 V
Min Voltage	16 V

Typical Power Factor	>0.98
Typical THDi	< 6%
Typical Efficiency	>88 %
Cooling Method / Supply Orientation	Free Air

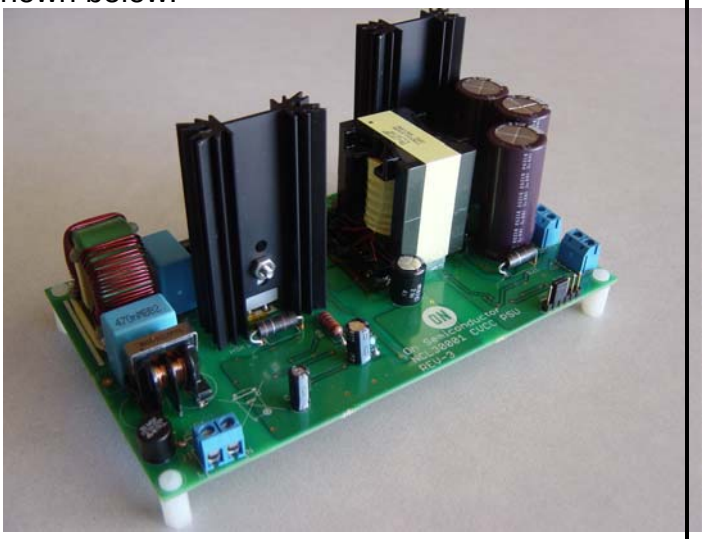
Circuit Description

Single stage power converters offer a cost effective way to provide power for LED applications with high input power factor and low THD. The most common CrM or Critical Conduction Mode solutions are typically limited to about 50 watts due to high peak currents characteristic of this approach. A CCM or Continuous Conduction Mode flyback converter offers higher power with reduced peak current while still providing high power factor and very low THD. This Design Note outlines modifying ON Semiconductor's NCL30001 CCM solution described in Application Note AND8470 extending the output power up to 125 watts. The standard evaluation board is the basis for this design.

The design guidelines for this LED driver are shown below:

- Input range: 85 – 265 V ac
- Output current: 2.5 A
- Output voltage: 48 V typical
- Efficiency: 88%
- Power Factor: >0.98

A photo of the modified evaluation board is shown below:



Design

The design process begins using the NCL30001 design worksheet found at ON Semiconductor's website. Directions for using this worksheet are described in the first tab. The design started by entering design guidelines on tab 'Step1'. Progressing through tabs as directed, the critical changes to the standard evaluation board are noted below and highlighted in the Bill of Materials at the end of this document:

- R19 = 39k
- R12 = 71.5k
- C20,21,22 = 2200 uF

Increasing the power level requires adjustments outlined above. In particular, the output filter capacitance was increased to reduce ripple due to higher output current.

- T1 280 µH

The design worksheet also specified a power transformer with 280 µH inductance and a primary to secondary turns ratio of 2.24. A new transformer is detailed at the end of this design note meeting the requirements with a larger core to process the increased power. The turns ratio was adjusted slightly to optimize fitting the wire in the bobbin. The transformer is available from Wurth Electronik as detailed in the BOM.

- F1 = 3.15 Amp

Current rating of the fuse must be increased to accommodate higher input current. Heatsinks for switching MOSFET Q1 and output rectifier D8 were increased to maintain device temperature with free-air cooling conditions. D7 voltage rating should be increased as well.

The output current is measured by a sense resistor and used by U3B to establish the current regulation feedback point. The formula for output current is shown below:

Iout = (Vref * R31) / (R32 * Rsense)

This can be rearranged to solve for Rsense:

Rsense = (Vref * R31) / (R32 * Iout)

Noting that Vref = 2.5 V as supplied by U3 pin 3 and R31 = 2.7k, R32 = 68k, and the desired output current is 2.5 A:

Rsense = (2.5 * 2.7k) / (68k * 2.5) = 0.0397 ohm

Multiple resistors will be used to create the proper value. Start with the original value of 0.1 ohms for R26, and place a second 0.1 ohm surface mount resistor (R26A) across the appropriate traces on the bottom of the board. Lastly, change C34 from a capacitor to a 0.2 ohm resistor resulting in an equivalent resistance of 0.04 ohms. Note that a filter capacitor like C34 is not always required across low inductance resistors.

- R26A = 0.1 ohm
- ‘C34’ = 0.2 ohm

The PWM dimming function was not required for this solution and therefore removed. In order to maintain functionality, Q5 and Q7 should be bypassed with wire from drain to source. The changes are highlighted below:

- Z5 = Not Fitted
- Q5 = Bypassed
- Q7 = Bypassed
- Q6 = Not Fitted
- C33 = Not Fitted
- R37 = Not Fitted
- R38 = Not Fitted
- R39 = Not Fitted
- R40 = Not Fitted
- R41 = Not Fitted
- R44 = Not Fitted

Additionally, the primary Over Voltage Protection circuit was not used. Changes shown below:

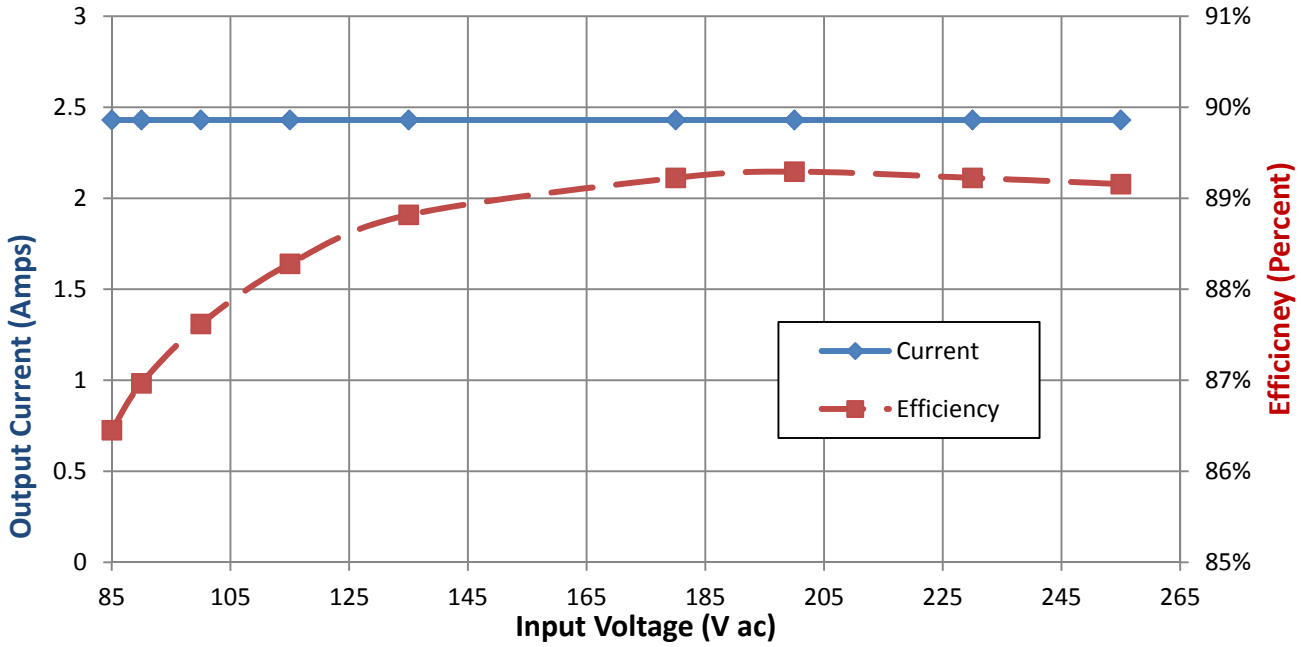
- C8 = Not Fitted
- R5 = Not Fitted
- D9 = Not Fitted
- Z2 = Not Fitted

Summary

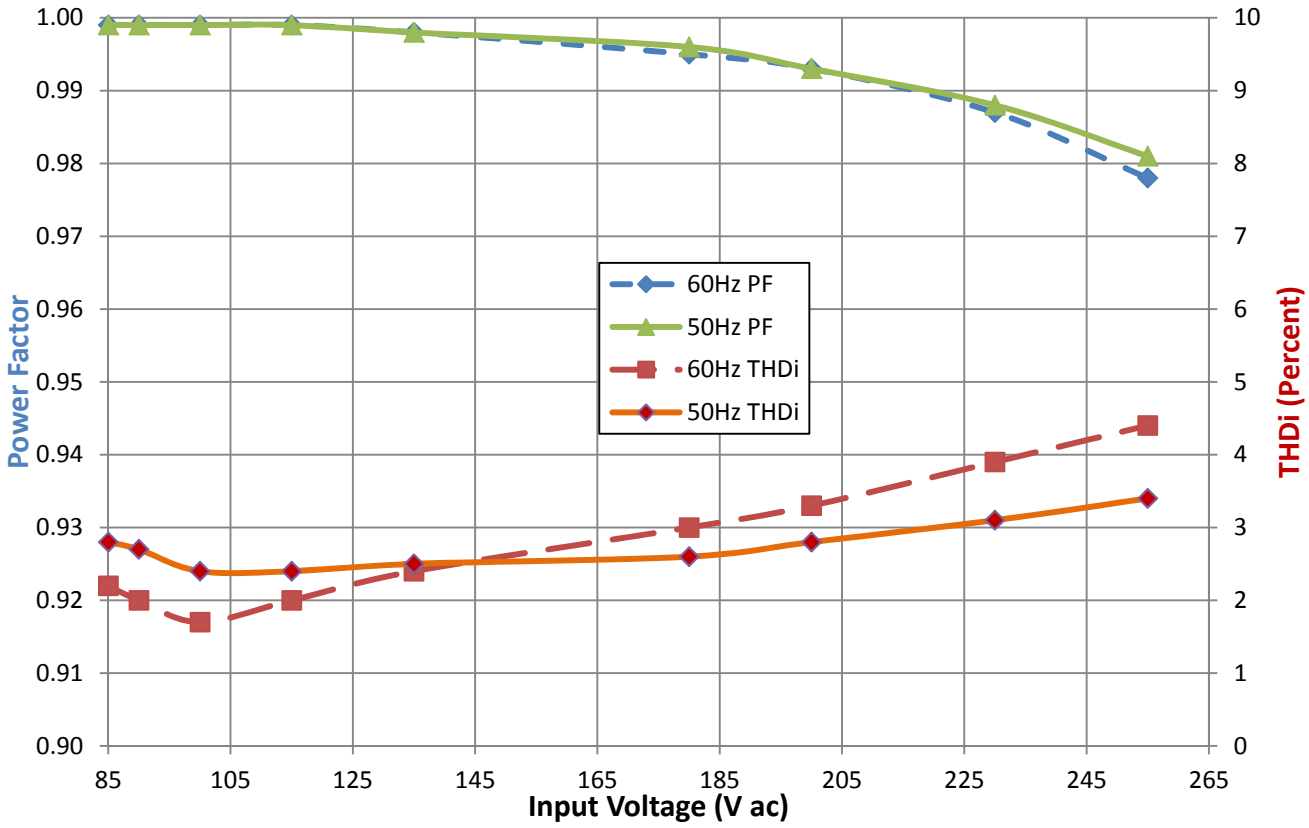
After modifications, the NCL30001 evaluation board met all of the design goals. Detailed performance is outlined on the following pages along with a schematic and Bill of Materials.

Performance

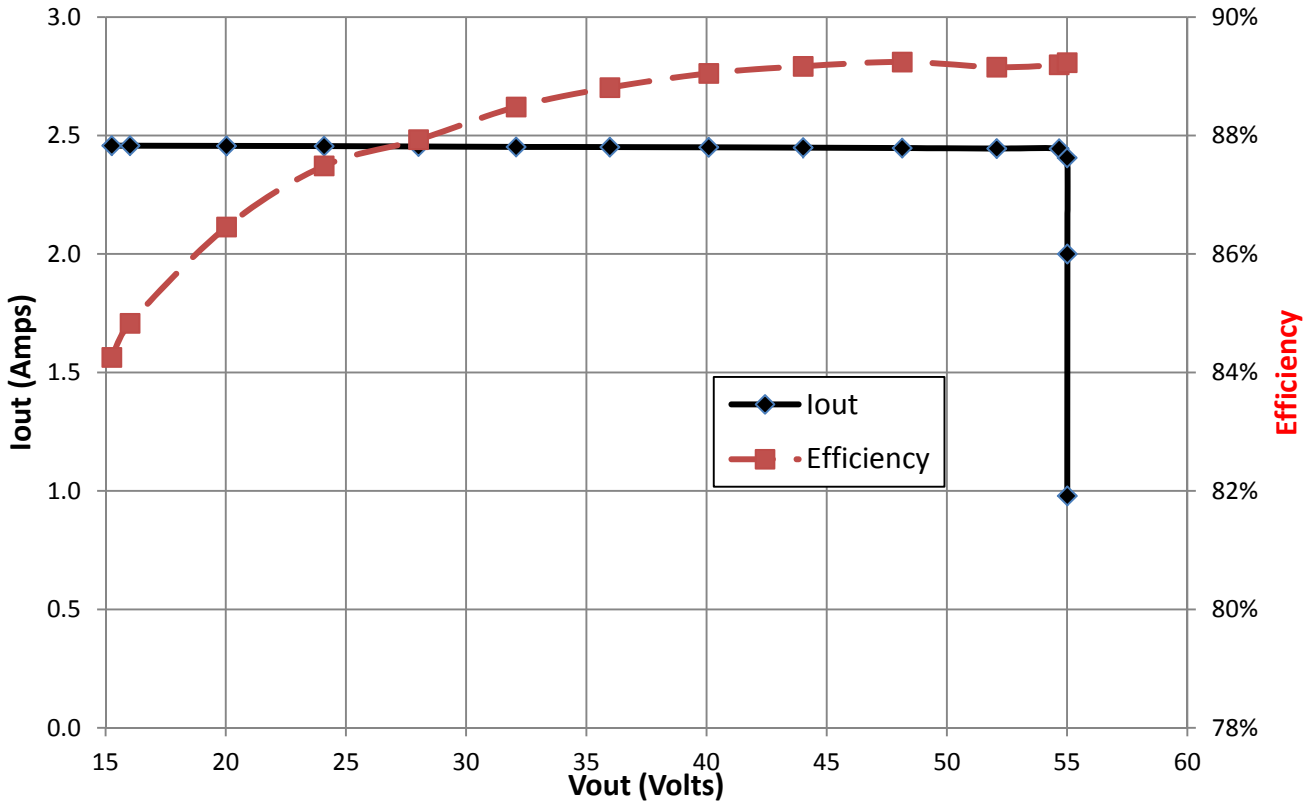
Output current regulation and efficiency across the input voltage range of 85 to 265 V ac is shown below. Typical current was 2.43 amps with a variation of less than 0.1%. Efficiency is above the 88% target.



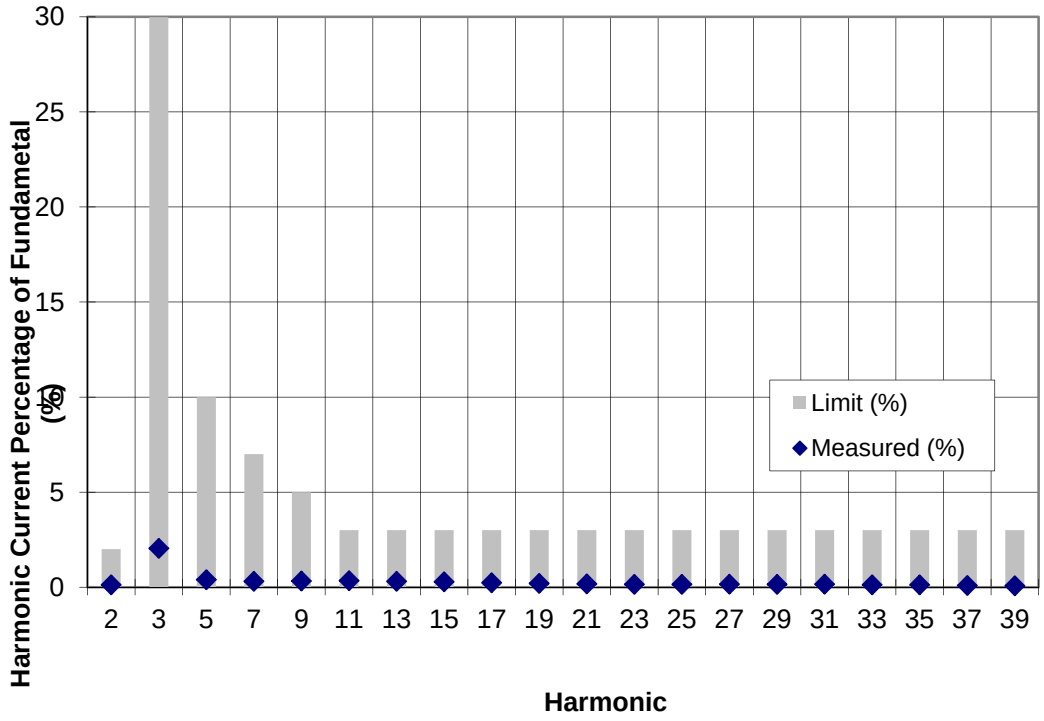
Shown below are Power Factor and input current THD over the input voltage range for 50 and 60 Hz.



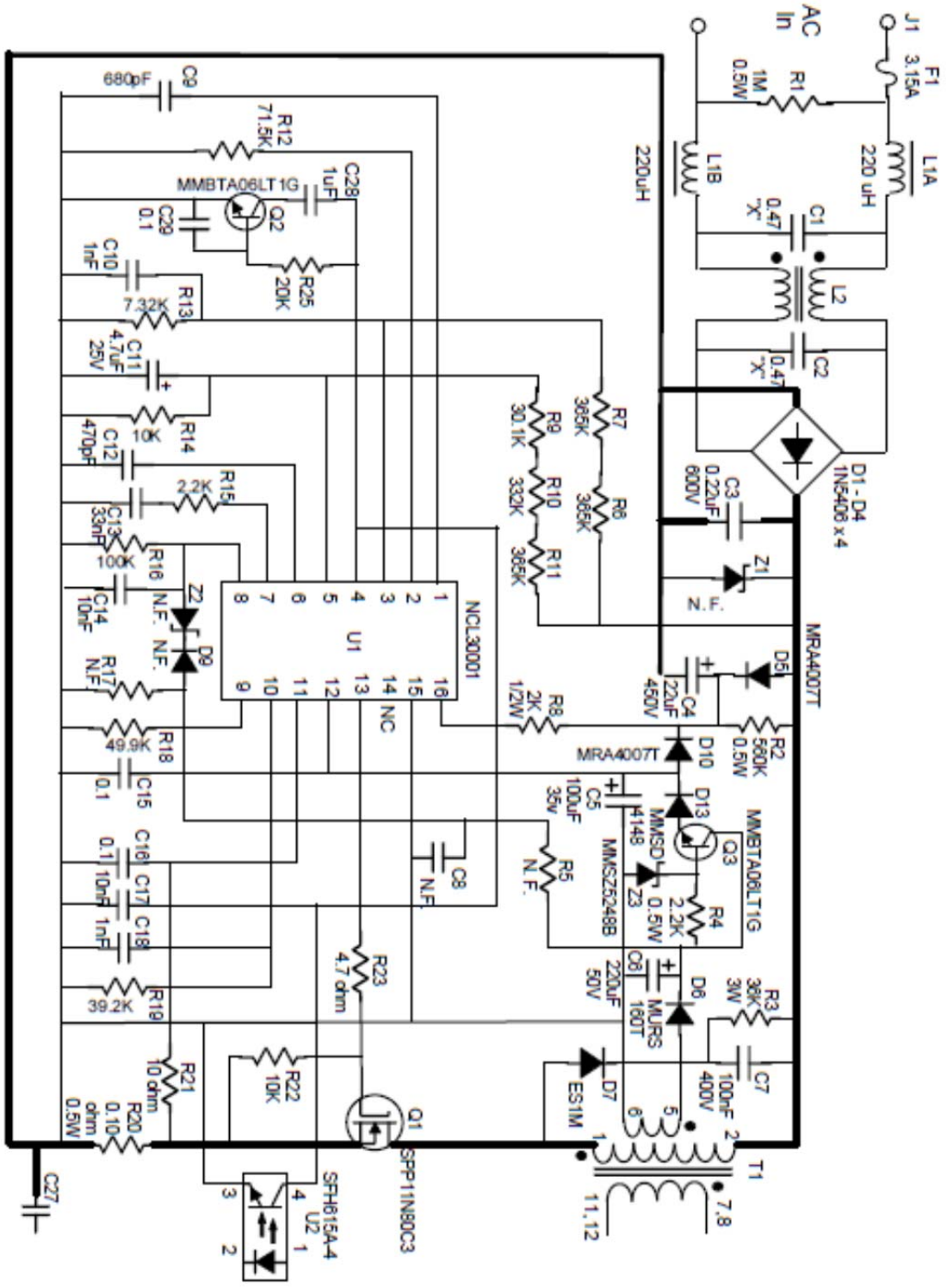
The converter provides constant current output over a wide range of output operating voltage. Efficiency is above 86% for loads greater than 50 watts. Performance is shown below.



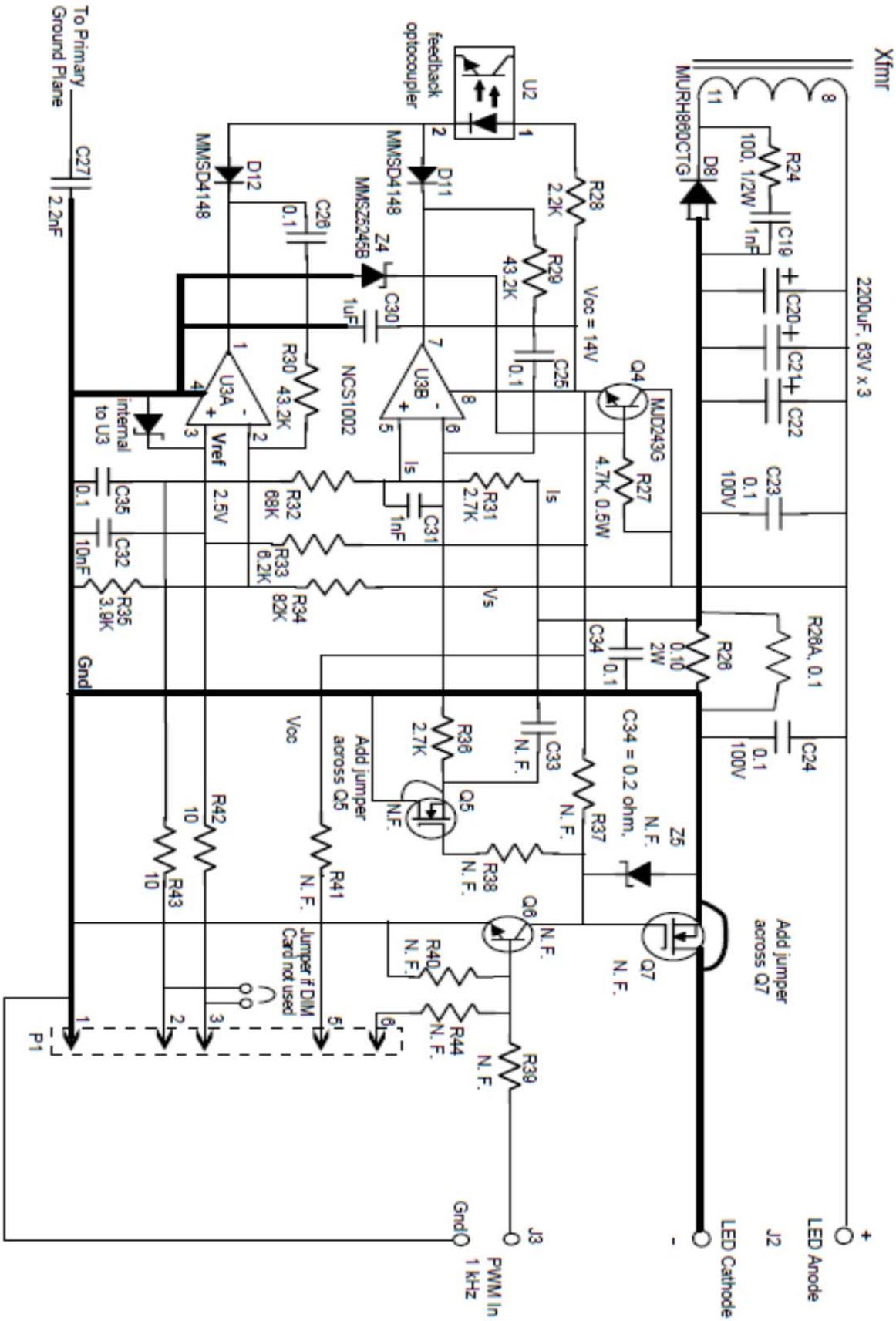
IEC 61000-3-2 Class C data is shown below for 100 V ac 50 Hz input and 2.43 A at 48 V load. The driver is well below the maximum allowed limits:



Primary Schematic



Secondary Schematic



MAGNETICS DESIGN DATA SHEET

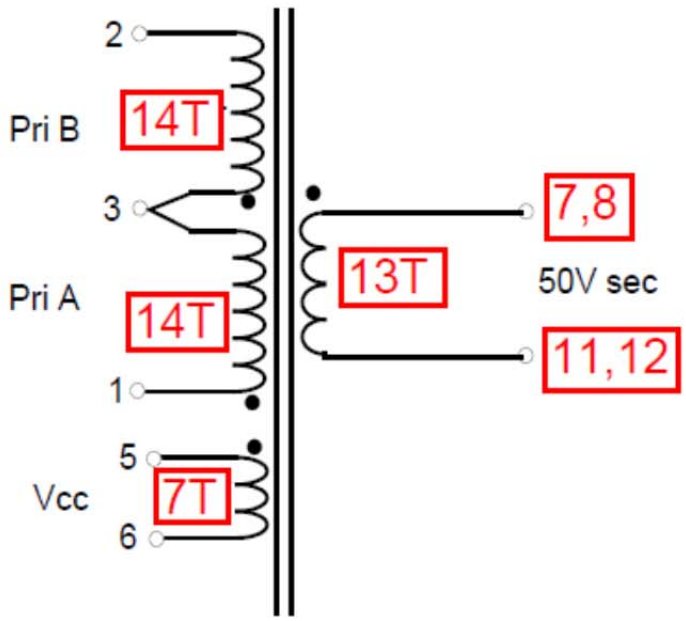
Project / Customer: NCL30001 Demo Part Description: 125 Watt 50V 2.5A LED Driver
Inductance: 280uH Bobbin Type: 12 pin vertical Core Type: PQ3535-
Core Gap: Gap for 280uH, ~0.028 inches

Winding Number / Type Turns / Material / Gauge / Insulation Data

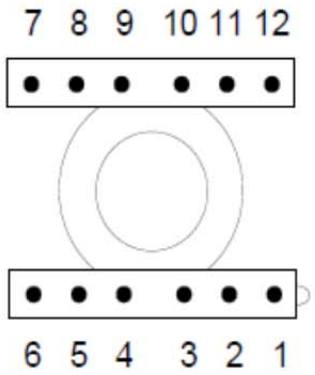
Step	Winding	Start	Finish	Turns	Material	Notes
1	½Primary	1	3	14	•• #26 TEX-E	Wind bifilar in one layer
2	Insulate			2	Mylar Tape	
3	Secondary	7,8	11,12	13	•• #24	Wind bifilar in one layer, terminate one wire per pin
4	Insulate			2	Mylar Tape	
5	½Primary	3	2	14	•• #26 TEX-E	Wind bifilar in one layer
6	Insulate			1	Mylar Tape	
7	Pri Bias	5	6	7	#26 TEX-E	Spread evenly in one layer
8	Insulate			3	Mylar Tape	

Hipot: 3KV from primary to secondary for 1 minute.

Schematic



Lead Breakout / Pinout
(bottom view)



Bill of Materials

Designator	Description	Value	Manufacturer	Manufacturer Part Number
D5, D10	Diode		ON Semiconductor	MRA4007T
D1, D2, D3, D4	Diode		ON Semiconductor	1N5406
D6	Ultrafast diode		ON Semiconductor	MURS160
D7	Ultrafast diode		Micro Commercial	ES1M-TP
D9	Signal diode	Not Fitted	-	-
D11, 12, 13	Signal diode		ON Semiconductor	MMSD4148A
D8	UFR diode		ON Semiconductor	MURH860CTG
Z1	TVS	Input transient option		1.5KE440A
Z4	Zener diode	15V	ON Semiconductor	MMSZ5245B
Z5	Zener diode	Not Fitted	-	-
Z3	Zener diode	18V	ON Semiconductor	MMSZ5248B
Z2	Zener diode	Not Fitted	-	-
Q5	Jumper	#26 bus wire	-	-
Q7	Jumper	#20 bus wire	-	-
Q1	Mosfet	11A, 800V	Infineon	SPP11N80C3
Q2, Q3	BJT	60V, 500 mA	ON Semiconductor	MMBTA06LT1G
Q6	BJT	Not Fitted	-	-
Q4	BJT	100V, 4A	ON Semiconductor	MJD243G
U1	PFC controller		ON Semiconductor	NCL30001
U2	Optocoupler		Vishay	H11A817 or SFH6156A-4
U3	Dual amp + zener		ON Semiconductor	NCS1002
C1, C2	X caps	0.47 uF, 277 Vac	Evox Rifa/Kemet or EPCOS	PHE840MB6470MB16R17 or B32922C3474M
C27	Y2 cap	2.2 nF, 1kV	Evox Rifa/Kemet	PME271Y422M or P271HE222M250A
C3	Polyprop. Film	0.22uF (630V)	Vishay	2222 383 20224
C7	Disc cap	68 to 100 nF, 400V	TDK	FK22X7R2J104K
C15, 16, 25, C26, C29	ceramic cap	0.1 uF, 50V	TDK	C3216X7R2A104K
C8, C33	ceramic cap	Not Fitted	-	-
C23, C24	ceramic cap	0.1 uF, 100V	TDK	C3216X7R2A104K
C28, C30	ceramic cap	1.0 uF, 25V	TDK	C3216X7R1H105K
C19	ceramic disc cap	1 nF, 1 kV	TDK	CK45-B3AD102KYNN
C12	ceramic cap	470 pF, 50V	Vishay	VJ1206A471JXACW1BC
C9	ceramic cap	680 pF, 50V	Kemet	C1206C681K5GACTU
C10, C18, C31	ceramic cap	1 nF, 100V	Kemet	C1206C102K1RACTU
C14, C17, C32	ceramic cap	10 nF, 50V	TDK	C3216COG2A103J
C13	ceramic cap	33 nF, 50V	TDK	C3216COG1H333J
C5	electrolytic cap	100 uF, 35V	UCC	ESMG350ELL101MF11D
C11	electrolytic cap	4.7 uF, 25V	UCC	ESMG250ELL4R7ME11D
C6	electrolytic cap	220 uF, 50V	UCC	ESMG500ELL221MJC5S
C20, 21, 22	electrolytic cap	2200 uF, 63V	Nichicon	UPW1J222MHD
C4	electrolytic cap	22 uF, 450V	Nichicon	647-UVY2W220MHD
C35	ceramic cap	0.1 uF, 50V	TDK	C3216X7R2A104K
C34	0.25W resistor	0.2 ohms	Rohm Semiconductor	MCR18EZHFLR200
R4	0.5W resistor	2.2K	Vishay	NFR25H0002201JR500
R1	0.5W resistor	1M, 0.5W	Vishay	CMF601M0000FHEK

R8	0.5W resistor	2K, 0.5W	Vishay	CMF552K0000FHEB
R2	0.5W resistor	560K	Vishay	HVR3700005603JR500
R27	0.5W resistor	4.7K	Vishay	CRCW12104K70JNEA
R24	0.5W resistor	100 ohms	Vishay	CMF50100R00FHEB
R20, R26	0.5W resistor	0.1 ohms	Ohmite	WNCR10FET
R26A	1W resistor	0.1 ohms	Vishay/Dale	WSL2512R1000FEA
R3	3 or 5W resistor	36K to 39K	Ohmite	PR03000203602JAC00
R23	0.25W resistor	4.7 ohms	Vishay/Dale	CRCW12064R75F
R5	0.25W resistor	Not Fitted	-	-
R38	0.25W resistor	Not Fitted	-	-
R21, 42, 43	0.25W resistor	10 ohms	Vishay/Dale	CRCW120610R0F
R41	0.25W resistor	Not Fitted	-	-
R15, R28	0.25W resistor	2.2K	Vishay/Dale	CRCW12062211F
R31, R36	0.25W resistor	2.7K	Vishay/Dale	CRCW12062741F
R29,R30	0.25W resistor	43.2K	Vishay/Dale	
R25	0.25W resistor	20K	Vishay/Dale	CRCW12062002F
R32	0.25W resistor	68K	Vishay/Dale	CRCW12066812F
R33	0.25W resistor	6.2K	Vishay/Dale	CRCW12066191F
R37	0.25W resistor	Not Fitted	-	-
R34	0.25W resistor	82K	Vishay/Dale	CRCW12068252F
R35	0.25W resistor	3.9K	Vishay/Dale	CRCW12063921F
R14, 22	0.25W resistor	10K	Vishay/Dale	CRCW12061002F
R39, 40, 44	0.25W resistor	Not Fitted	-	-
R13	0.25W resistor	7.32K	Vishay/Dale	CRCW12064322F
R9	0.25W resistor	30.1K	Vishay/Dale	CRCW12063012F
R12	0.25W resistor	71.5K	Vishay/Dale	CRCW12067152F
R17	0.25W resistor	Not Fitted	-	-
R18	0.25W resistor	49.9K	Vishay/Dale	CRCW12064992F
R19	0.25W resistor	39.2K	Vishay/Dale	CRCW12063922F
R16	0.25W resistor	100K	Vishay/Dale	CRCW12061003F
R10	0.25W resistor	332K	Vishay/Dale	CRCW12063323F
R6, 7, 11	0.25W resistor	365K	Vishay/Dale	CRCW12063653F
F1	Fuse	3.15A, 250Vac	Littlefuse	37213150001
L1A/B	EMI inductor	220uH, 2A	Coilcraft	PCV-0-224-03L
L2	EMI inductor		Coilcraft	P3220-AL
T1	Flyback xfmr	50V, 125W CCM	WE-Midcom (Wurth Electronics)	750314494, REV 00
J1, J2, J3	I/O connectors		Weidmuller	1716020000
(for Q1, D8)	Heatsink Q1, D8		Ohmite	EA-T220-64E
HD1	Header	CONN HEADER 2POS 0.1" Two Position	Molex	90120-0122
JMP1	Shorting Jumper	Shorting Jumper	Sullins Connector Solutions	SPC02SYAN

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