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Design Note – DN05031/D

25 watt Offline Hi-Power Factor LED Driver

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCL30000	LED Driver	90 – 305 V ac	25 watts	Flyback	Yes

Output Current	700 mA
Ripple	413 mA pk-pk
Nominal Voltage	36 volts
Max Voltage	44 volts

Typical Power Factor	0.997
Typical THDi	5.6%
Typical Efficiency	88.0%
Inrush Limiting / Fuse	1 Amp fuse
Operating Temp. Range	-40 to 70 ºC

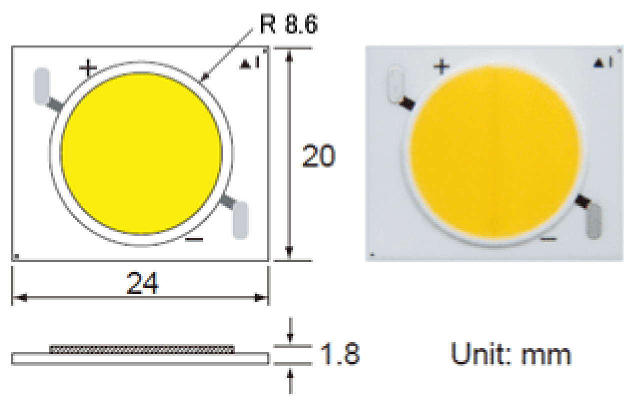
Circuit Description

Recently, new generations of high power chip-on-board LED products have entered the markets that integrate a large number of LED on a single substrate. These devices have high lumen output and can be optimized for either high efficacy or high CRI with a wide range of color temperatures so they can be used in indoor applications like retail downlighting as well as outdoor applications like wall washers for example.

The focus of this design note is the development of an offline, high power factor corrected single stage driver which can support extended wide AC mains from 90-305 V ac. This addresses standard global AC line voltages as well as the 277 V ac commercial input required for the United States.

High power factor and low harmonic content are typically required for commercial lighting. In the US, LED luminaires that meet Energy star requirements need to have a PF ≥ 0.9 and globally EN61000-3-2 Class C lighting requirements define lower thresholds for harmonic currents when the input power is > 25 W.

One example of this class of LEDs is the Sharp Mega ZENIGATA family. For this design, the 25 watt version was selected which consists of an array of 168 LEDs which comprises 14 strings of 12 LEDs in series. Since this appears as a single LED assembly, a single channel constant current driver is required.



The Sharp GW5D series (image above) is rated at typically 2300-2600 lumens at 25 ºC case temperature when driven at 700 mA and the forward voltage range is 34-40 V dc under those conditions.

Shown below are the design guidelines for this driver:

- Input range: 90 – 305 V ac
- Output current: 700 mA
- Output voltage: 36 volts typical
- Efficiency: >87%
- Power Factor: >0.95
- Isolated Output
- Open/Short Circuit protection

The NCL30000LED3GEVB demonstration board was used as the development platform. This demo board was selected as it provides wide input voltage range covering 100 to 277 volt applications with applicable tolerance.

The low profile design provides a compact solution. The high efficiency of this converter minimizes thermal issues. With a few modifications, this demo board will provide the increased power and exceed the performance objectives.

Note that the original transformer for this demo board was designed to accommodate 4-15 series LEDs at up to 18 watts of output power. By targeting a specific number of LEDs, the power available from the same size core can be increased. Transformer construction details are provided at the end of this document.

The open load protection threshold of the original board was reduced due to lower output voltage for this LED module. D12 was changed to 43 V.

Power switch maximum on-time capacitor C9 controls the minimum ac line input voltage. The redesigned transformer requires a shorter maximum on-time at this power level. C9 was changed to 390 pF.

High power factor single stage converters generally have no energy storage in the primary side circuit. As such, storage is required on the secondary side and typically in the form of capacitance in parallel with the LED load. Ripple current is nearly sinusoidal at twice the applied ac input frequency. The ripple amplitude is inversely proportional to the total capacitance, that is, increasing the filter capacitance will reduce ripple current.

Maximum forward current for this LED is 1050 mA. Subtracting the target output current of 700 mA nets a difference of 350 mA. Ripple current must therefore be limited to 350 mA peak or 700 mA peak-to-peak to stay within the manufacturers rating.

Two 470 µF capacitors were used in order to maintain the low profile design. Testing shows this capacitance results in ripple current of up to 480 mA peak-to-peak with 100 V ac 60 Hz input as shown in Figure 1. The zero reference is indicated on the first horizontal gradicule.

The output current sense resistor R29 was reduced from 0.2 ohms to 0.1 ohms to provide the required 700 mA average output current. Two resistors were connected in parallel for thermal spreading.

Converter startup time is controlled by the bias capacitor C8 and the startup resistors. For this application, the startup resistors R12 and R13 were increased in value to reduce dissipation. This increases the converter startup time somewhat.

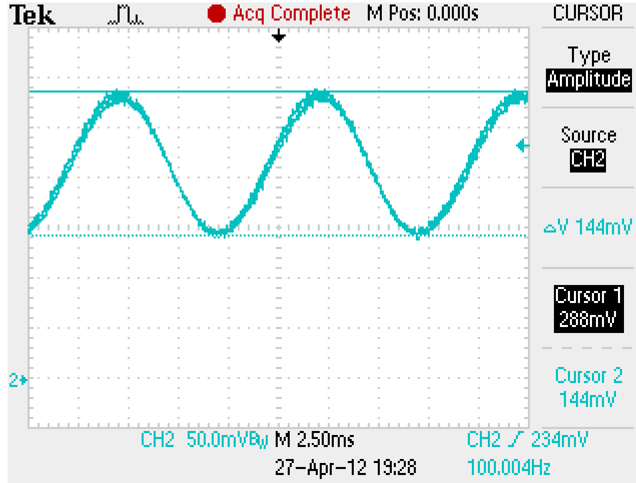


Figure 1: LED ripple current

The power switching FET was changed to a higher current device to support the increased output power level. Current sense resistor R20 was reduced in value due to higher primary current. In addition, the output rectifier was changed to a Schottky type to reduce power loss and increase efficiency.

Increased power level means the input filter must support more switching current. The filter capacitors were increased to minimize ripple voltage and maintain compliance with conducted EMI limits. Capacitors C1 and C2 were increased to 100 nF and C4 was increased to 220 nF.

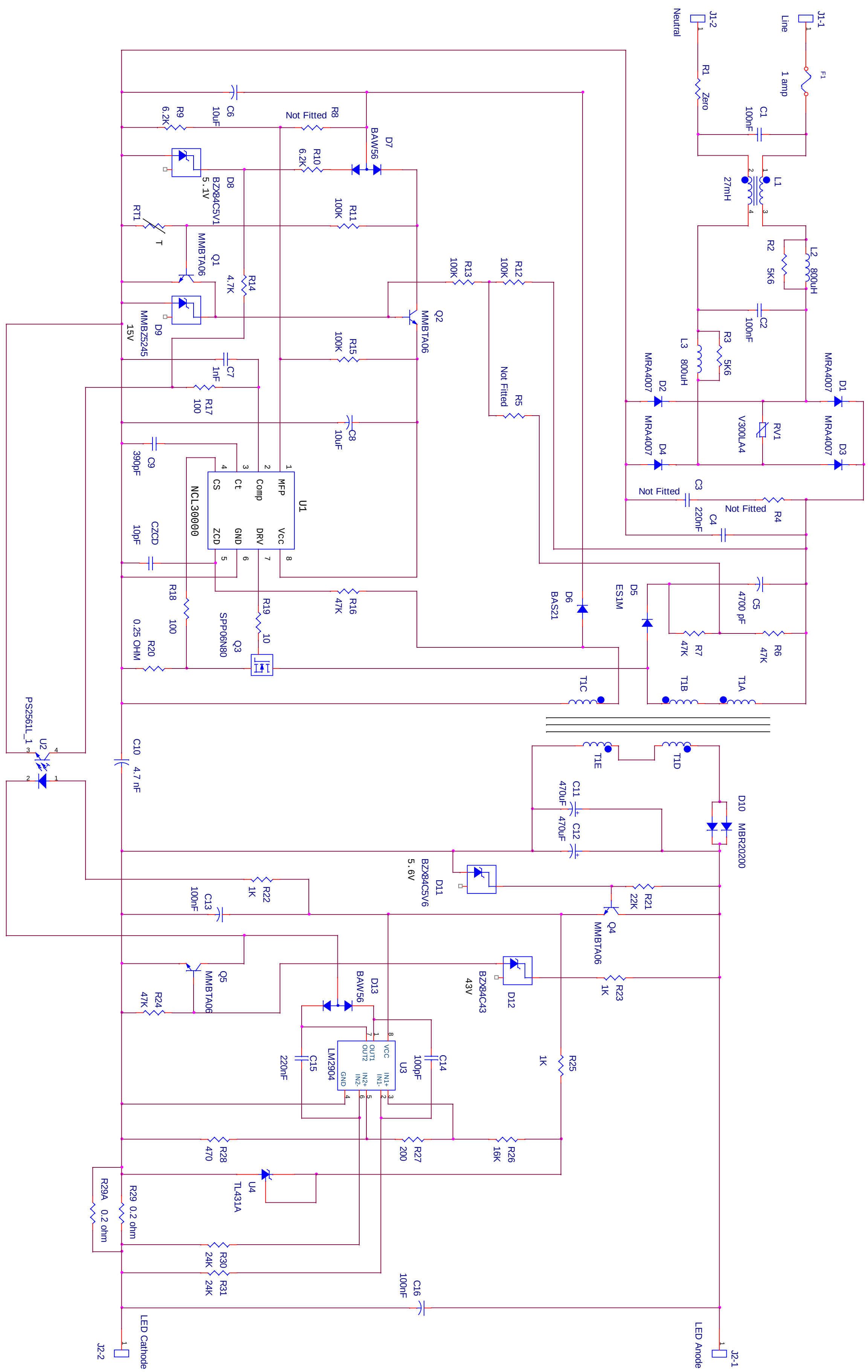
High power factor is maintained by operating in critical conduction mode (CrM). In the case of the NCL30000, this is accomplished with a constant on-time architecture. Details of operation can be found in Application Note AND8451. Moreover, line harmonics in compliance with JIS/EN61000-3-2 Class C are easily met, as shown in Figure 2.

Power factor and Total Harmonic Distortion of input current are shown in Figure 3. PF exceeds the target value and for operation below 140 V ac is above 0.99.

Efficiency over the input line range is shown in Figure 4. For the range of 115 to 230 V ac, efficiency is well above target being greater than 88%. Note that the LED current remains virtually unchanged over the entire input voltage range.

A scan of conducted emissions shows greater than 6 dB of margin for the CISPR 22 Class B limits. See Figure 5.

A bill of materials is provided in Figure 6. The highlighted components have been changed from the standard demo board. Details on power transformer construction are provided at the end of this document.


J1-1
Line
F1
1 amp
J1-2
Neutral
R1
Zero
C1
100nF
L1
27mH
L2
800uH
R2
5K6
C2
100nF
L3
800uH
R3
5K6
D1
MRA4007
D2
MRA4007
D3
MRA4007
D4
MRA4007
RV1
V300LA4
C3
Not Fitted
C4
220nF
R4
Not Fitted
C5
4700 pF
D5
ES1M
R6
47K
R7
47K
T1A
T1B
T1C
T1D
T1E
D6
BAS21
C6
10uF
R8
Not Fitted
R9
6.2K
D7
BAW56
R10
6.2K
D8
BZX84C5V1
5.1V
R11
100K
RT1
T
Q1
MMBTA06
R12
100K
R13
100K
R14
4.7K
Q2
MMBTA06
D9
MMBZ5245
15V
R15
100K
C7
1nF
R17
100
R5
Not Fitted
C8
10uF
C9
390pF
U1
NCL30000
MFP
Comp
Ct
CS
Vcc
DRV
GND
ZCD
CZCD
10pF
R16
47K
R18
100
R19
10
Q3
SPP06N80
R20
0.25 OHM
U2
PS2561L_1
C10
4.7 nF
C11
470uF
C12
470uF
D10
MBR20200
D11
BZX84C5V6
5.6V
R21
22K
R22
1K
C13
100nF
Q4
MMBTA06
Q5
MMBTA06
R24
47K
D12
BZX84C43
43V
R23
1K
D13
BAW56
U3
LM2904
C14
100pF
C15
220nF
R25
1K
R26
16K
R27
200
R28
470
U4
TL431A
R29
0.2 ohm
R29A
0.2 ohm
R30
24K
R31
24K
C16
100nF
J2-2
LED Cathode
J2-1
LED Anode

Schematic

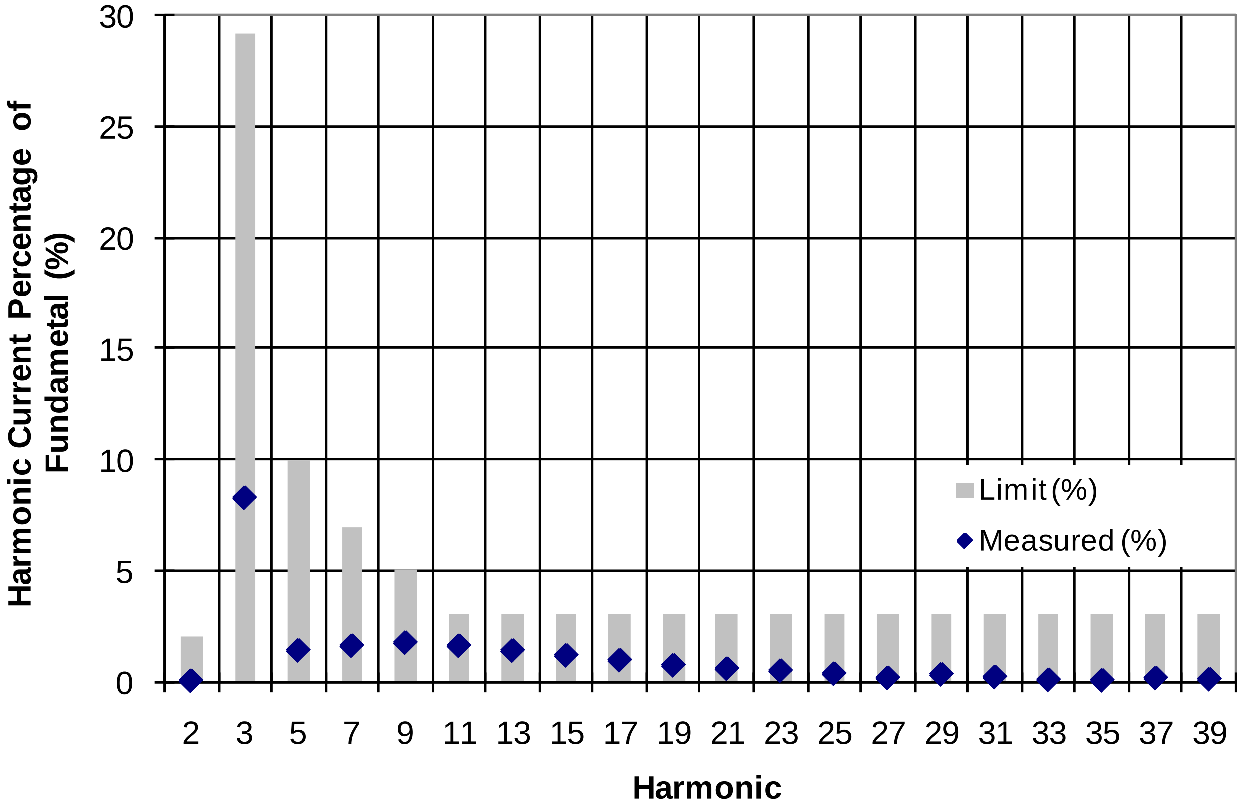


Figure 2: EN61000-3-2 Class C Input Current Harmonic Test
(Vin=230 Vac, 50 Hz, Iout =704 mA @36.1V)

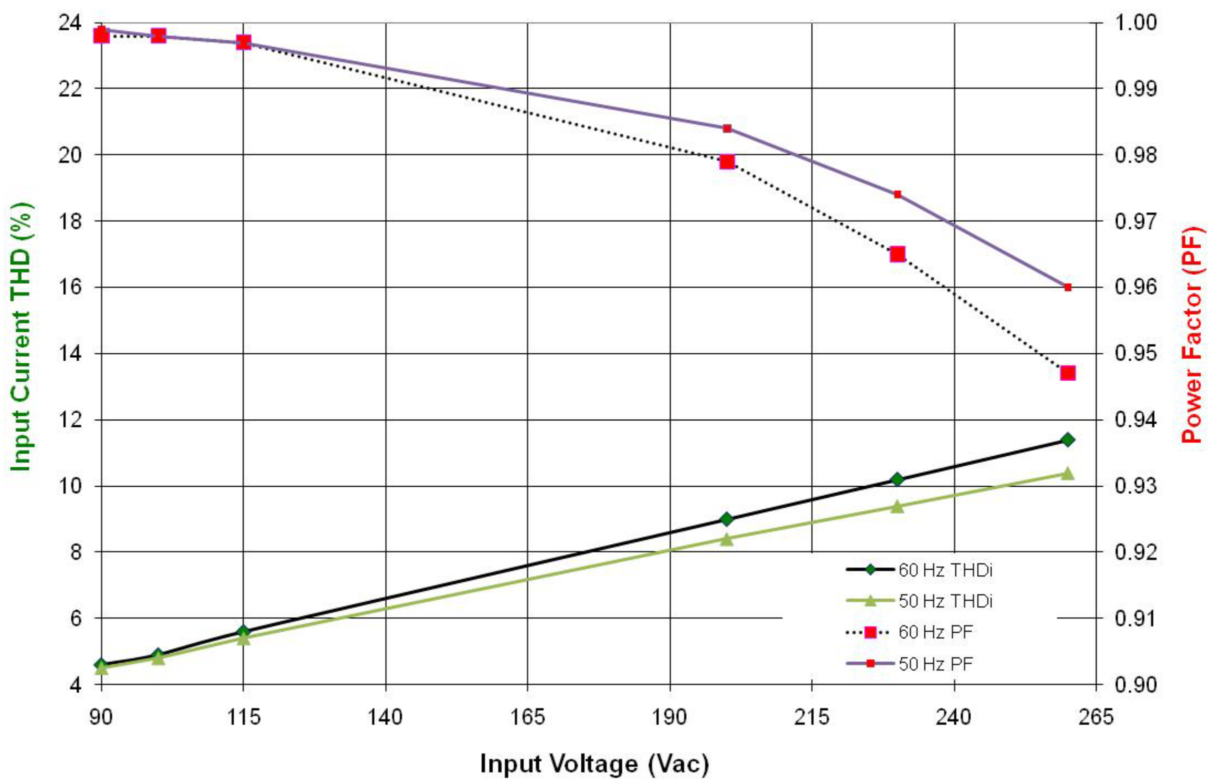


Figure 3: Power Factor and THDi

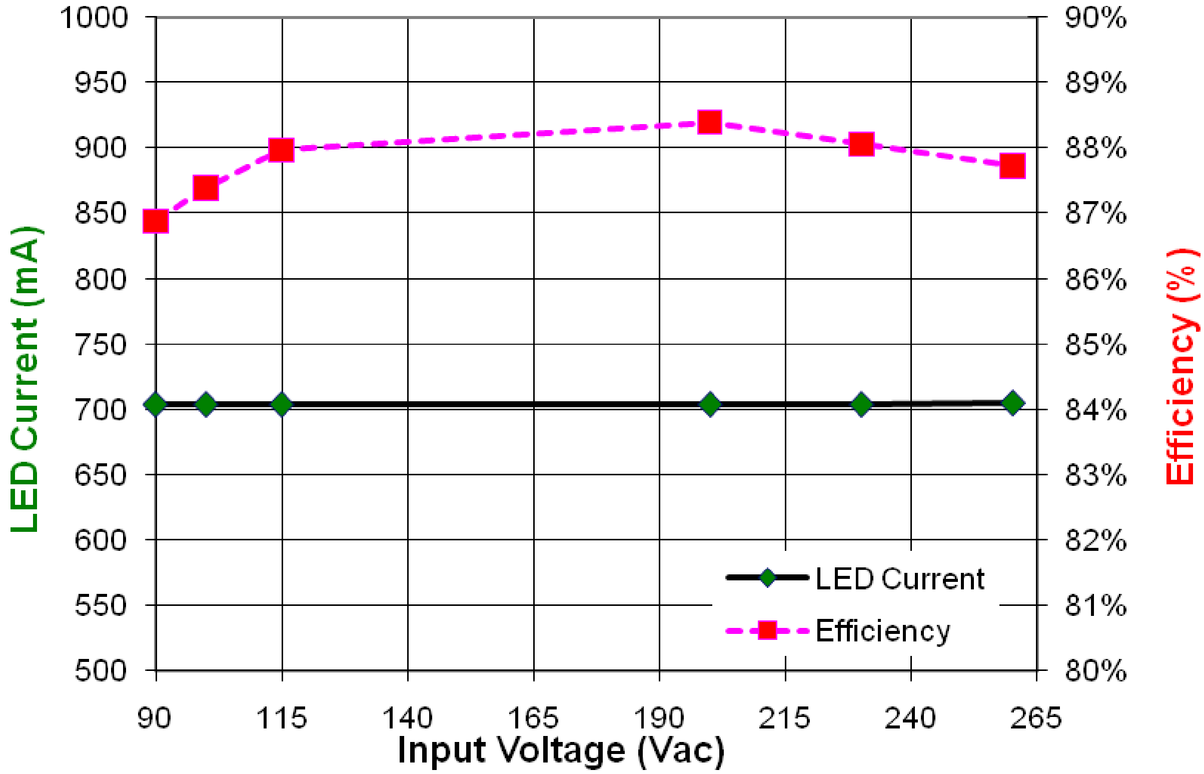


Figure 4: Efficiency and Line Regulation

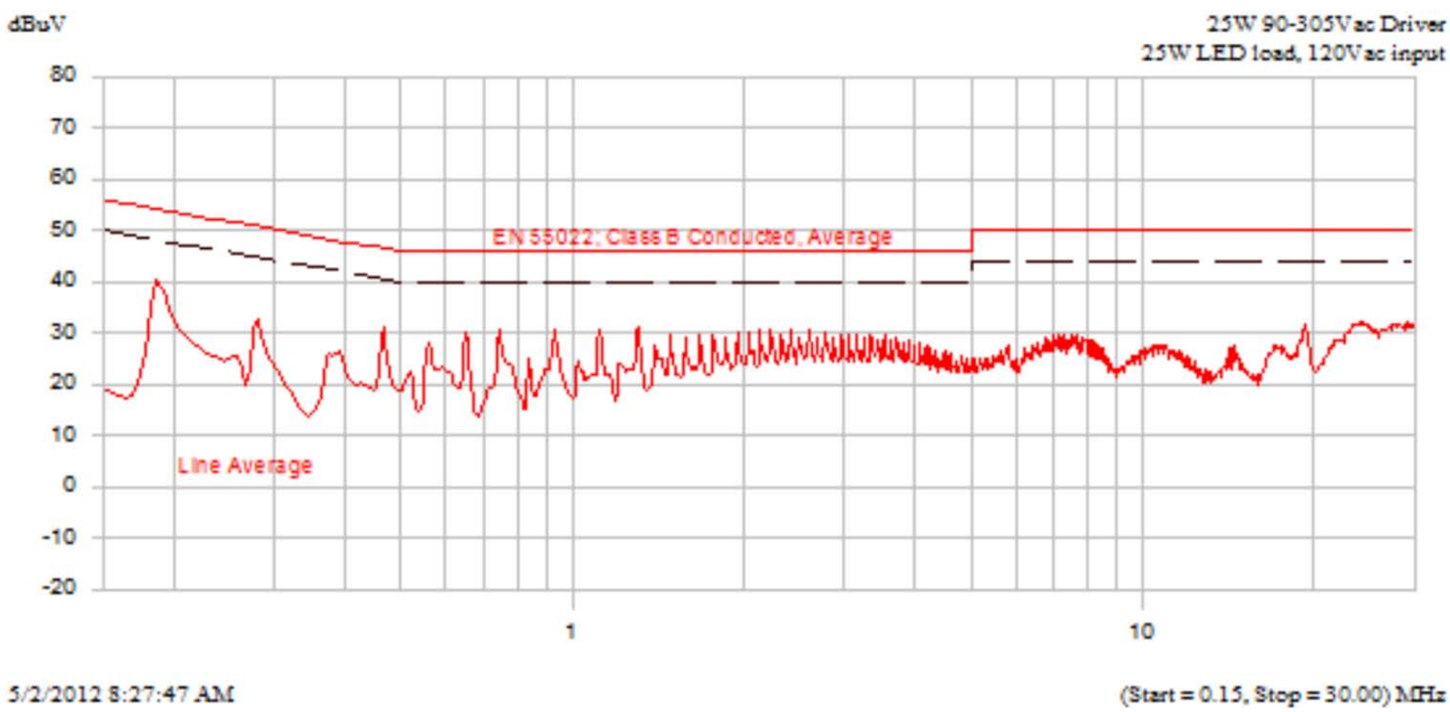


Figure 5: Conducted EMI Signature (Average Scan)

Designator	Value	Description	Footprint	Manufacturer	Part Number
C1, C2	100nF	300 VAC X1 Polyester Film	Box	Panasonic	ECQ-U3A104MG
C3		Not Fitted			
C4	220nF	250/275VAC Polyester Film	Box	Panasonic	ECQ-U2A224ML
C5	4700 pF	Ceramic 2000V Y5U	Radial Disc	AVX	5SS472SBHCA
C6 C8	10uF	50V Electrolytic, 5mm dia	Radial	Panasonic	EEU-EB1H100S
C7	1nF	50V Ceramic X7R	0603 SMD	Panasonic	ECJ-1VB1H102K
C9	390pF	50V Ceramic C0G,NPO	0603 SMD	Murata	GRM1885C1H391JA01D
CZCD	10pF	50V Ceramic C0G,NPO	0603 SMD	Murata	GRM1885C1H1000JA01D
C10	4.7 nF	250VAC Y5U X1Y1 (LS=10mm)	Radial	Panasonic	CD16-E2GA472MYNS
C11 C12	470uF	63V Aluminum Electrolytic Y5U	Radial	Panasonic	ECA-1JHG471
C13	100nF	25V Ceramic X7R	0603 SMD	Panasonic	ECJ-1VB1E104K
C14	100pF	50V Ceramic COG,NPO	0603 SMD	Panasonic	ECJ-1VC1H101J
C15	220nF	25V Ceramic X7R	1206 SMD	Panasonic	ECJ-3VB1E224K
C16	100nF	100V Ceramic X7R	1206 SMD	Panasonic	ECJ-3YB2A104K
D1 D2 D3 D4	MRA4007	Rectifier,1000V,1A	SMA	ON Semiconductor	MRA4007T3
D5	ES1M	Fast Rectifier 1A 1000V	SMA	Micro Commercial	ES1M
D6	BAS21	250V,200mA	SOT23	ON Semiconductor	BAS21LT1G
D7 D13	BAW56	70V,200MA	SOT23	ON Semiconductor	BAW56LT1G
D8	BZX84C5V1	5.1V ZENER	SOT23	ON Semiconductor	BZX84C5V1LT1G
D9	MMBZ5245	15V ZENER	SOT23	ON Semiconductor	MMBZ5245BLT1
D10	MBR20200	Schottky, 200V 20A	TO-220	ON Semiconductor	MBR20200CTG
D11	BZX84C5V6	5.6V ZENER	SOT23	ON Semiconductor	BZX84C5V6LT1G
D12	BZX84C43	43V ZENER	SOT23	ON Semiconductor	BZX84C43LT1G
F1	-	Slow Blow 1A TE5 Series	Axial	Littelfuse	3691100044
J1, J2	-	Screw Connector (0.2" Pitch)	Through Hole	Weidmuller	1716020000
L1	27mH	Common Mode Choke	Through Hole	Wurth Midcom	7446620027
L2,L3	800uH	Shielded radial inductor	Through Hole	Renco	RL-8054-3-821KR38-S
Q1 Q2 Q4 Q5	MMBTA06	NPN, 80V, 500mA	SOT23	ON Semiconductor	MMBTA06LT1G
Q3	SPP06N80	N-Channel 800V,6A, 0.9R	TO-220	Infineon	SPD06N80C3
R1	0 ohm	Wire Jumper	-	-	-
R2,R3	5K6	1/10W	0603 SMD	Panasonic	ERJ-3GEYJ562V
R4 R5		Not Fitted			
R6 R7	47K	1/4W	1206 SMD	Panasonic	ERJ-8GEYJ473V
R11 R15	100K	1/10W	0603 SMD	Panasonic	ERJ-3EKF1003V
R12 R13	100K	1/4W	1206 SMD	Panasonic	ERJ-8GEYJ104V
R9 R10	6K2	1/10W	0603 SMD	Panasonic	ERJ-3EKF6201V
R14	4K7	1/10W	0603 SMD	Panasonic	ERJ-3EKF4701V
R16 R24	47K	1/10W	0603 SMD	Panasonic	ERJ-3EKF4702V
R17 R18	100	1/10W	0603 SMD	Panasonic	ERJ-3EKF1000V
R19	10	1/10W	0603 SMD	Panasonic	ERJ-3EKF10R0V
R20	0.25	1/4W	1206 SMD	Yageo	PT1206FR-070R25L
R21	22K	1/4W	1206 SMD	Panasonic	ERJ-8GEYJ223V
R22 R23 R25	1K	1/10W	0603 SMD	Panasonic	ERJ-3EKF1001V
R26	16K	1/10W	0603 SMD	Panasonic	ERJ-3EKF1602V
R27	200	1/10W	0603 SMD	Panasonic	ERJ-3EKF2000V
R28	470	1/10W	0603 SMD	Panasonic	ERJ-3EKF4700V
R29	0.2	1/4W	1206 SMD	Rohm Semi	MCR18EZHFLR200
R29A	0.2	1/4W	1206 SMD	Rohm Semi	MCR18EZHFLR200
R30 R31	24K	1/10W	0603 SMD	Panasonic	ERJ-3EKF2402V
RT1	PRF21BC	PTC 470 OHM 85C	0603 SMD	Murata	PRF18BE471QB1RB
RV1	V300LA4P	300V 25 Joule (LS= 7mm)	Radial	Littelfuse	V300LA4P
U1	NCL30000	Single Stage PFC LED Driver	SOIC8	ON Semiconductor	NCL30000DR2G
U2	PS2561L_1	80V, 50mA	SMT4	NEC Electronics	PS2561L-1
U3	LM2904	Dual Op Amp	SOIC8	ON Semiconductor	LM2904DR2G
U4	TL431A	Programmable Reference	SOIC8	ON Semiconductor	TL431ACDG
T1	XFMR	Transformer, EFD25, 25 watt	EFD25	Custom	

MAGNETICS DESIGN DATA SHEET

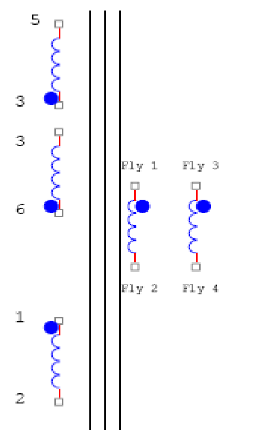
Project / Customer: NCL30000 8May12
Part Description: 25 Watt 37 Volt LED Driver; Full range
Schematic ID: T1
Inductance: 750 uH
Bobbin Type: 10 pin horizontal CSH-EFD25-1S-10P
Core Type: EFD25/13/9-3C90
Core Gap: Gap for 750 uH, ~0.016 inches

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

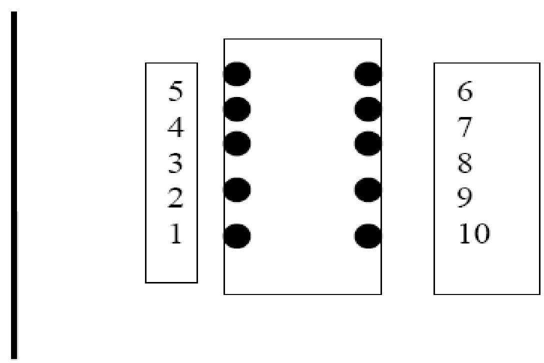
Step	Winding	Start	Finish	Turns	Material	Notes
1	½Primary	6	3	32	#26	Wind in one layer
2	Insulate			2	Mylar Tape	
3	Secondary	Fly1 Fly3	Fly2 Fly4	12	#26 TEX-E Triple insulated	Wind bifilar with two strands of wire. Fly leads exit top of bobbin over pins 6-10
4	Insulate			2	Mylar Tape	
5	½Primary	3	5	32	#26	Wind in one layer
6	Insulate			1	Mylar Tape	
7	Pri Bias	1	2	6	#30	Spread evenly in one layer
8	Insulate			3	Mylar Tape	
9	Assemble				Gap	Final core wrap
10	Shield				Copper	Add shield over core
11	Terminate				Bus wire	Ground shield to Pin 2
12	Insulate				Mylar Tape	Insulate shield

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

Schematic



Bobbin Pinout – Bottom View



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