ON Semiconductor

Design Note – DN05035/D

LED Driver with Synchronous Rectification

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCL30000 NCP4303A NTD5865	LED Driver	90 – 135 V ac	14 Watts	Flyback w/ synchronous rectification	Yes

	Output
Output Current	1.5 amps
Ripple	640 mA pk-pk
Nominal Voltage	9.1 volts
Maximum Voltage	12.5 volts

Typical Power Factor	0.976
Typical THDi	19.7%
Typical Efficiency	85.2%
Inrush Limiting/Fuse	1 amp
Operating Temp. Range	-40 to 70 °C

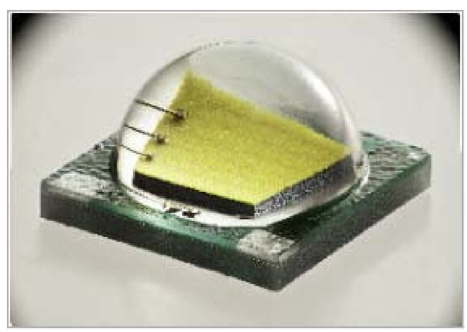
Circuit Description

There are a number of system trends occurring in LED lighting that require improvements to the power architecture to optimize the system efficiency and overall cost. This design note will discuss how the trend to use new generations of LEDs than can be driven at a higher current thus requiring fewer LEDs alters the power architecture of the single stage power factor corrected flyback. As a result a PAR bulb that in the past might have used 9 LEDs (27 V nominal) at 500 mA can now achieve the same lumen output with 3 LEDs driven at 1.5A. As the output current increases and the output voltage decreases, the losses in the output rectifier become more significant.

Drivers with low output voltage historically use Schottky output rectifiers to leverage the low forward drop offered by this type of semiconductor and minimize power loss. Devices with very low forward drop are available, but may not provide the level of performance the designer was anticipating. Some Schottky rectifiers display very high reverse leakage current especially at elevated temperature which can degrade efficiency.

Fortunately there is another rectification option available which displays extremely low effective forward drop in low output voltage applications without reverse leakage issues. The conventional PN junction or even Schottky rectifier can be replaced by a MOSFET device providing a significant reduction in dissipation and consequently an increase in efficiency.

Gate drive for a synchronous rectifier MOSFET is carefully controlled to achieve best performance. The MOSFET must be turned on quickly when secondary current begins to flow and then turned off before reverse current develops. ON Semiconductor's NCP4303A provides the required synchronous rectifier control.



The CREE XLAMP™ XM-L LED shown above is rated for up to 3 amps of drive current and an ANSI Warm White LED driven at 1.5A can provide 330-390 lumens nominal at a junction temperature of 100 ºC.A lighting solution based on these LEDs may require only a few devices to achieve the target lumen output. This example driver is intended to power three XM-L LEDs with a drive current of 1.5 amps.

Shown below are the design guidelines for this driver:

- Input range: 90 – 135 V ac
- Output current: 1.5 amps
- Output voltage: 9.1 volts
- Efficiency: >85%
- Power factor: > 0.95
- TRIAC Dimmer Compatible
- Isolated Output
- Open/Short Circuit protection

Implementation

The NCL30000LED1GEVB demonstration board covers most of the performance requirements listed above. With a few changes it can be modified for this application. The original transformer was designed to accommodate 4 to 15 LEDs at up to 700 mA. A new transformer was designed to optimize performance with three LEDs at 1.5 amps. Transformer design details are included in this Design Note.

The MOSFET used for the synchronous rectifier needs to display a low forward voltage at the circuit operating current. Peak secondary current is 9.6 amps. The NTD5865 MOSFET is rated at 18 milliohms on resistance at 25 ºC. Expected voltage drop will be 9.6 amps times 0.018 ohms or 0.17 volts. Some increase is expected at high ambient but the voltage drop will remain lower than a typical Schottky rectifier and as such will improve efficiency.

The NCP4303A detects current flow by monitoring the voltage drop across the synchronous MOSFET device. When the current reaches appropriate levels the gate is turned on or off as required. The threshold is programmable via an external resistor creating an offset voltage due to an internal 100 µA current source. For this application, a 10 ohm resistor is used to ensure the MOSFET is off before the end of the transformer discharge period to maintain proper CrM timing.

Programmable timing thresholds are used to avoid false triggering due to ringing. Details on use of this synchronous rectifier controller can be found at the ON Semiconductor website in the NCP4303 documentation.

The NCP4303 requires 10.5 volts Vcc worst case. This LED driver has a nominal 9.1 volt output. An additional 3 turn secondary bias winding was added to provide sufficient voltage to power the NCP4303. LED applications operating above 10.5 volts will not require this extra bias winding and accompanying small diode.

The schematic is shown in Figure 3.

Test Results

The waveform in Figure 1 shows the synchronous MOSFET gate turning on after the transformer secondary winding begins to conduct. The gate voltage begins to rise about 26 ns after the MOSFET body diode begins to conduct. This rapid turn on minimizes loss by allowing the MOSFET channel to conduct bypassing the body diode.

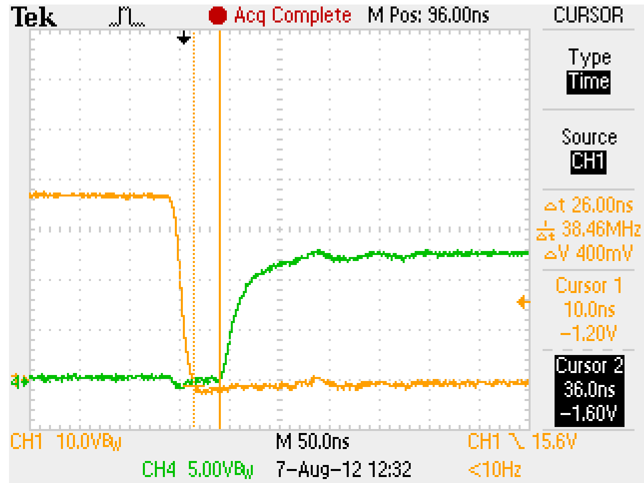


Figure 1: Synchronous MOSFET turn-on

Figure 2 shows the synchronous MOSFET turn-off. The secondary current in a CrM flyback reduces to a very low level near the end of the switching cycle and the MOSFET is off some 800 ns before the next switching cycle. This delay ensures the transformer demagnetization signal is not affected.

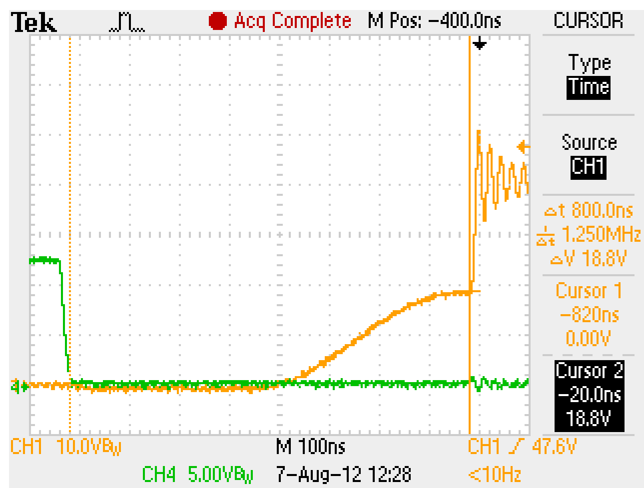


Figure 2: Synchronous MOSFET turn-off

Efficiency of this LED driver operating at 115 V ac input is 85.2%. For comparison purposes, the synchronous rectifier was removed and replaced with an MBRF30H60 Schottky rectifier. This device is rated 30 amps and 60 volts. Efficiency with this rectifier is 82.9%. The sychronous rectification circuit reduced the overall system losses by approximately 440 mW.

The efficiency improved 2.3% using synchronous rectification. The higher efficiency reduces the temperature of the driver which can enhance operational lifetime since the output rectifier is normally placed near the output electrolytic capacitors.

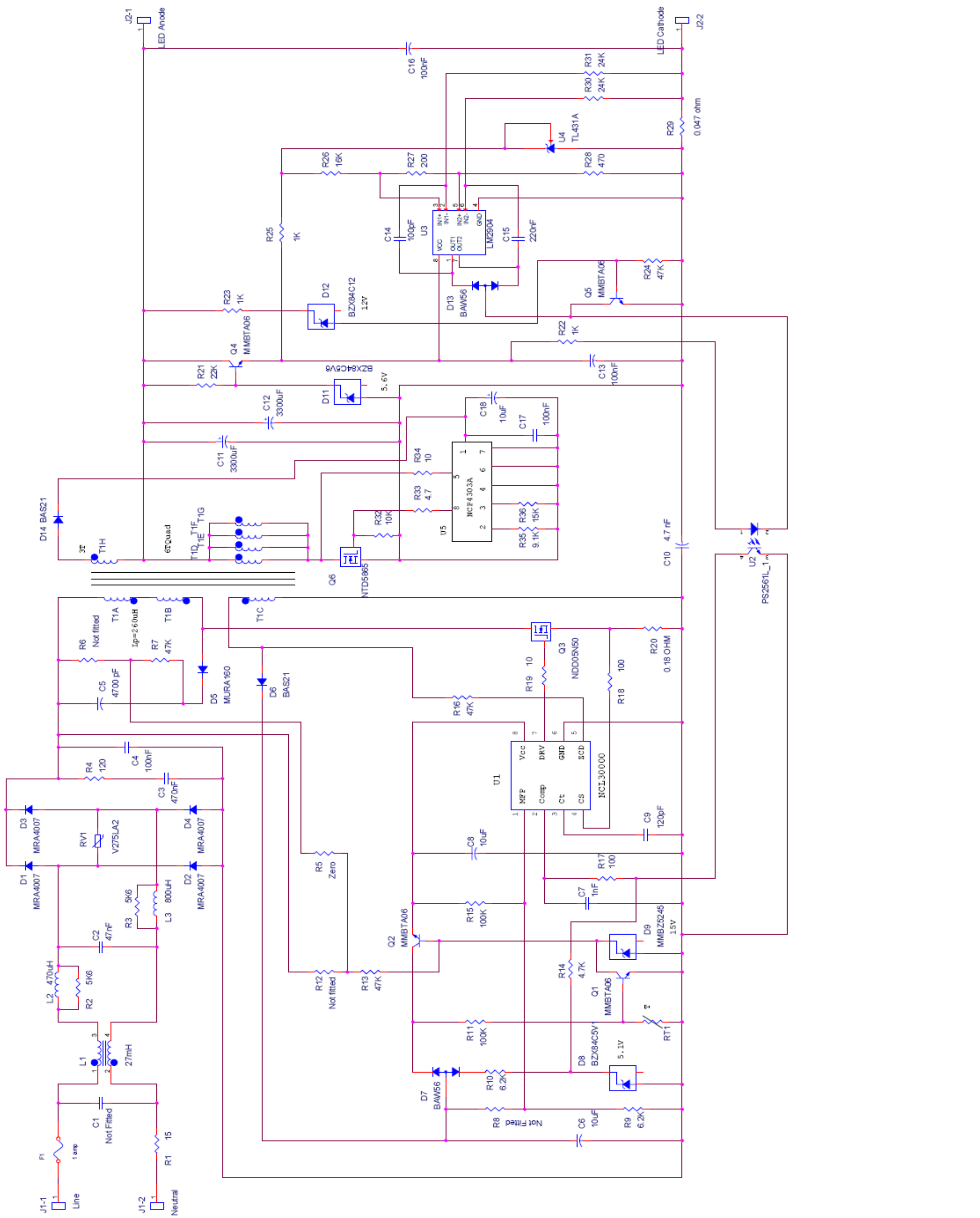


Figure 3 : Schematic

MAGNETICS DESIGN DATA SHEET

Project / Customer: NCL30000 7 Aug2012
Part Description: 14 Watt LED Driver; 115V triac dimmable
Schematic ID: T1
Inductance: 260 µH
Bobbin Type: 10 pin horizontal CSH-EFD25-1S-10P
Core Type: EFD25/13/9-3C90
Core Gap: Gap for 260 µH, ~0.009 inches

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

Step	Winding	Start	Finish	Turns	Material	Notes
1	½Primary	6	3	15	#26	Wind in one layer
2	Insulate			1	Mylar Tape	
3	Secondary	Fly1	Fly2	6	#26 TEX-E Triple insulated	Wind quadfilar in one layer. Fly leads exit top of bobbin over pins 6-10
		Fly3	Fly4			
		Fly5	Fly6			
		Fly7	Fly8			
4	Insulate			1	Mylar Tape	
5	Sec Bias	Fly9	Fly10	3	#26 TEX-E Triple insulated	Spread evenly in one layer
6	Insulate			1	Mylar Tape	
7	½Primary	3	5	15	#26	Wind in one layer
8	Insulate			1	Mylar Tape	
9	Pri Bias	1	2	13	#26	Spread evenly in one layer
10	Insulate			3	Mylar Tape	
11	Assemble				Gap	Final core wrap
12	Shield				Copper	Add shield over core
13	Insulate				Mylar Tape	Insulate shield

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

Note: This transformer is suitable for 230 V ac applications. The switching MOSFET and synchronous rectifier MOSFET ratings should be adjusted for the increased voltage. On-time capacitor C9 may also be changed for optimal dimming performance.

Bill of Materials

The table below highlights the changes made to the NCL30000LED1GEVB demonstration board to implement this 1.5 amp 9.1 volt LED driver with synchronous rectification.

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Part Number
C9	1	Ceramic capacitor	120pF	5%	603	AVX	06033A121JAT4A
R20	1	Resistor	0.18Ω	1%	1206	Rohm	MCR18EZHFLR180
C11, C12	2	Electrolytic capacitor	3300 uF 16V	20%	Radial	UCC	EKZE160ELL332MK35S
T1	1	Transformer		-		-	Custom
Q6	1	MOSFET	60V 18mΩ	-	DPAK	ON Semiconductor	NTD5865N-1G
D12	1	Rectifier	12V	5%	SOT-23	ON Semiconductor	BZX84C12LT1G
U5	1	Sync Rec Controller	-	-	SOIC8	ON Semiconductor	NCP4303ADR2G
R29	1	Resistor	0.047Ω	1%	1206	Rohm	MCR18EZHFLSR047
D14	1	Rectifier	250V 200mA	-	SOT-23	ON Semiconductor	BAS21LT1G
R32	1	Resistor	10k	1%	603	Panasonic	ERJ-3EKF1002V
R33	1	Resistor	4.7Ω	1%	603	Panasonic	ERJ-3RQF4R7V
R34	1	Resistor	10Ω	1%	603	Panasonic	ERJ-3EKF10R0V
R35	1	Resistor	9.1k	1%	603	Panasonic	ERJ-3EKF9101V
R36	1	Resistor	15k	1%	603	Panasonic	ERJ-3EKF1502V
C17	1	Ceramic capacitor	100nF 25V	10%	603	Panasonic	ECJ-1VB1E104K
C18	1	Electrolytic capacitor	10uF 50V	20%	Radial	Panasonic	EEU-EB1H100S

Design note created by Jim Young, e-mail: james.young@onsemi.com