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AND9132/D

Performances of a LED Driver Driven by the NCL30080/81/82/83

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APPLICATION NOTE

Introduction

As LED lighting finds its way into low wattage applications, lamp designers are challenged for a variety of conflicting requirements. Size is often dictated by the incumbent lamp and fixture size whether it's A19, GU10, etc. Thermal performance, reliability, safety, and EMC requirements also present design challenges. The NCL3008X family of controllers incorporates all the features and protection needed to design compact low wattage LED drivers with a minimum of external components.

Overview

The NCL3008X is a family of 4 controllers in 2 different packages (Micro 8 and TSOP6). The 8 pin packaged parts have 2 extra pins for Dimming and thermal / over voltage protection. The 6 pin package parts have all the basic control and protection feature required to make a low parts count LED driver.

Table 1. PRODUCT MATRIX

Product	Package	Thermal Foldback	Analog/Digital Dimming	5 Step LOG Dimming
NCL30080A/B	TSOP6	No	No	No
NCL30081A/B	TSOP6	No	No	Yes
NCL30082A/B	Micro-8	Yes	Yes	No
NCL30083A/B	Micro-8	Yes	Soft-start	Yes

In the A versions of the NCL3008X, some protections are latched. In the B versions, all faults are auto-recoverable.

The controllers have a built in control algorithm that allows to precisely regulate the output current of a Flyback converter from the primary side. This eliminates the need for an optocoupler and associated circuitry. The control scheme also support Buck-boost and SEPIC topology. The output current regulation is within ± 2% over a line range of 85-265 V rms.

The power control uses a Critical Conduction Mode (CrM) approach with valley switching to optimize efficiency and EMI filtering. The controller selects the appropriate valley for operation which keeps the frequency within a tighter range than would normally be possible with simple CrM operation.

This application note focuses on the experimental results of a LED driver controlled by the NCL30080-81-82-83.

LED Driver Specification

The LED driver is designed to meet the specifications of Table 2.

Table 2. 12 W LED DRIVER SPECIFICATION

Description	Symbol	Value	Units
LED driver specification			
Minimum input voltage	$V_{in,min}$	85	V rms
Maximum input voltage	$V_{in,max}$	265	V rms
Power factor (valley fill version only)	PF	> 0.7	
Minimum output voltage	$V_{out,min}$	12	V
Maximum output voltage	$V_{out,max}$	24	V
Output voltage at which the OVP is activated	$V_{out(OVP)}$	28	V
Output current (nominal)	I_{out}	0.5	A

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AND9132/D

Table 2. 12 W LED DRIVER SPECIFICATION

Description	Symbol	Value	Units
Output rectifier voltage drop (estimated)	V_f	0.6	V
Input voltage for brown-in	$V_{in(start)}$	72	Vrms
Startup time	$t_{startup}$	≤ 1.5	s
Other parameters			
Estimated efficiency	η	85	%
Estimated lump capacitor	C_{lump}	50	pF
Switching frequency at $P_{out,max}$, $V_{in,min}$	F_{sw}	45	kHz
Estimated bulk voltage ripple	V_{ripple}	30	V

Description of the Board

The 12 W LED driver has been designed using the method described in the application note AND9131/D [1]. Figure 1 shows the schematic of the default board version and Figure 2 shows the schematic with the valley fill circuit to provide passive power correction.

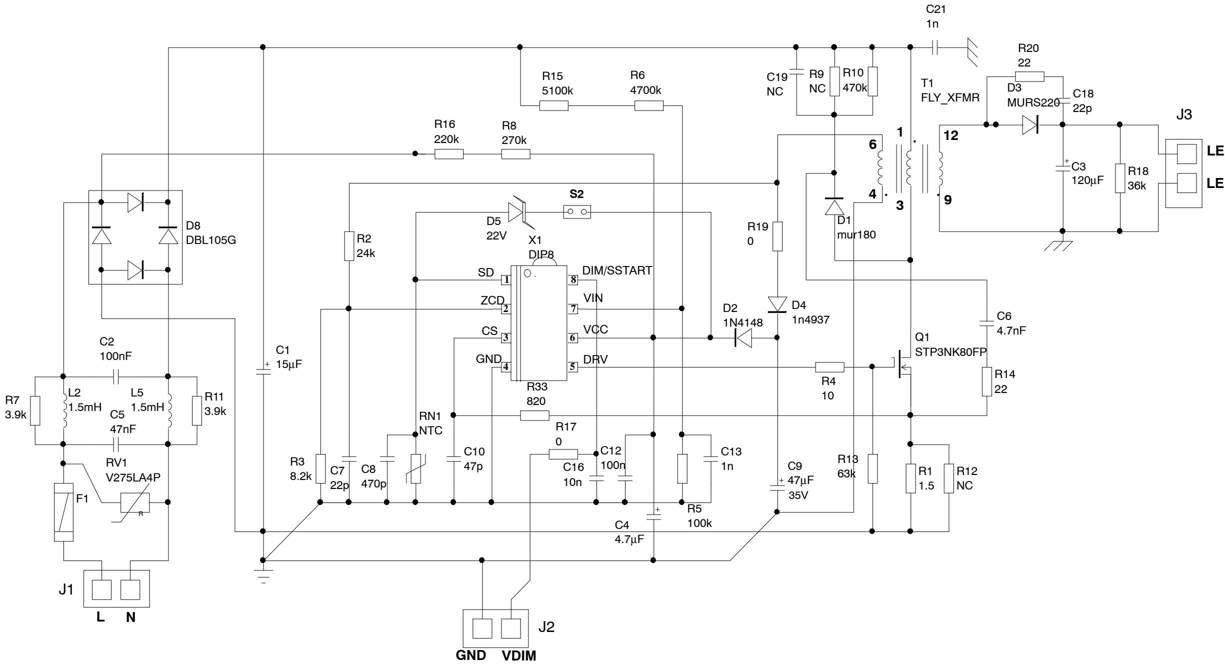

Figure 1. Default Evaluation Board Schematic

The evaluation board (EVB) supports all 4 controllers the NCL30080, NCL30081, NCL30082 and NCL30083 thanks to a small daughter board.

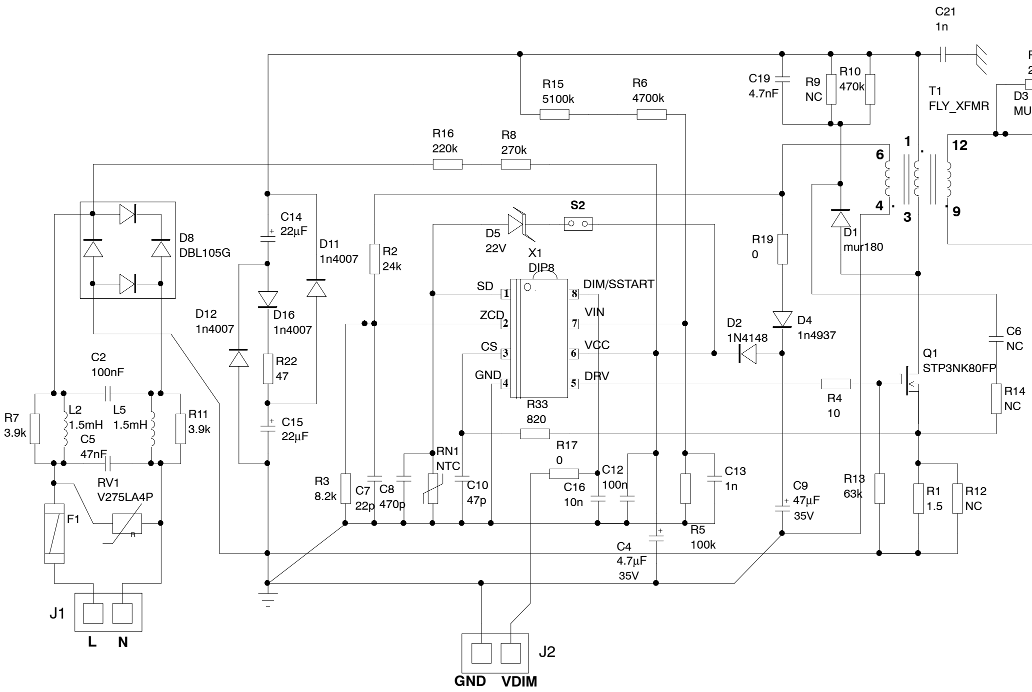

Figure 2. Evaluation Board with Valley Fill

The varistor RV1 protects the power supply in case of line surge.

The resistors R7 and R11 damp the oscillation caused by the self resonant frequency of the coils L2 and L5. This is only for EMI filtering purpose.

R16 and R8 are the startup resistors connected to the half-wave in order to decrease the power losses in the startup network. They were sized to provide a startup time of 1.5 s at 85 V rms.

R2 and R3 limit the current flowing in the ZCD pin. Also, these resistors together with C7 capacitor delay the zero voltage crossing event and helps to tune the turn-on instant when the drain voltage is in the valley.

RN1 is a NTC chosen to provide a thermal foldback starting point at 75°C and an over temperature trip point at 95°C. We selected a NTC with $B_{25/85}$ = 4220 and a resistance at 25°C R_{25} = 100 kΩ.

R33 is the line feedforward resistor that compensates the output current variation caused by the propagation delay.

R15, R6 and R5 are the brown-out resistors which have been calculated to start operating at V_{in} = 71 V rms.

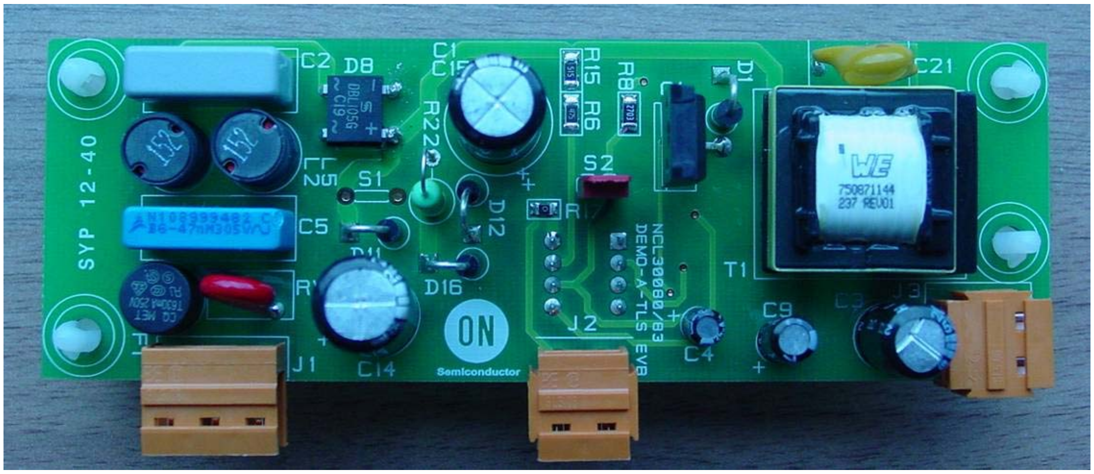

Figure 3. Photograph of the Top Side of the Valley Fill EVB

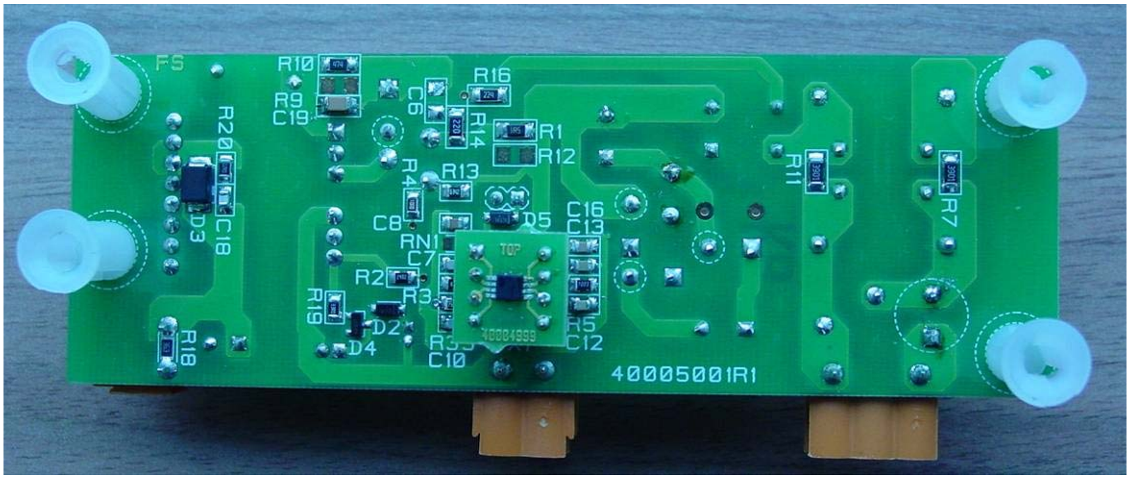

Figure 4. Photograph of the Bottom Side of the Valley Fill EVB

Output current regulation

The output current is measured as the input voltage and the output load vary. The output load varied by changing the number of LEDs connected to the board output. The LEDs used are Xlamp MX-6 LEDs from Cree with have a forward voltage drop around 3.6 V at 480 mA. The number of LEDs is varied from 3 to 6, fixing an output voltage from 10.9 V to 21.7 V. The input voltage is varied from 85 to 265 V rms for the default EVB or from 90 V rms to 265 V rms for the Valley Fill EVB.

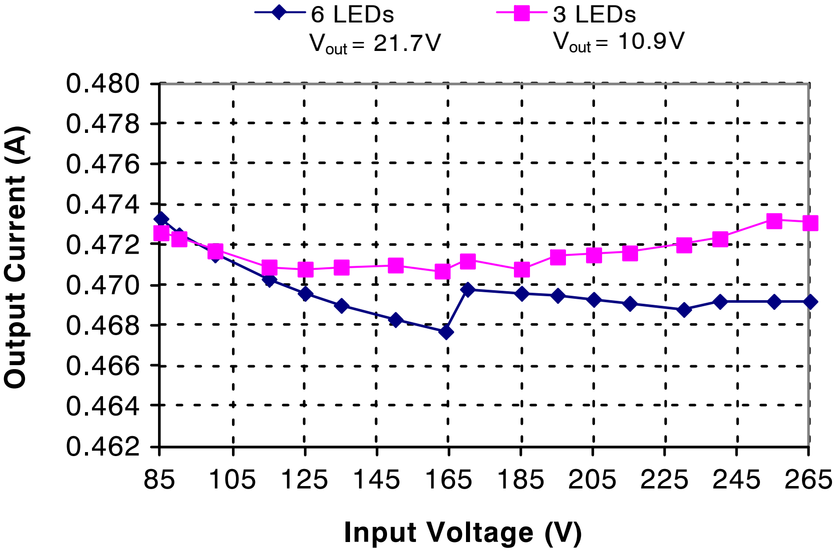

Figure 5. Line and Load Regulation with the NCL30080B (Normal EVB)

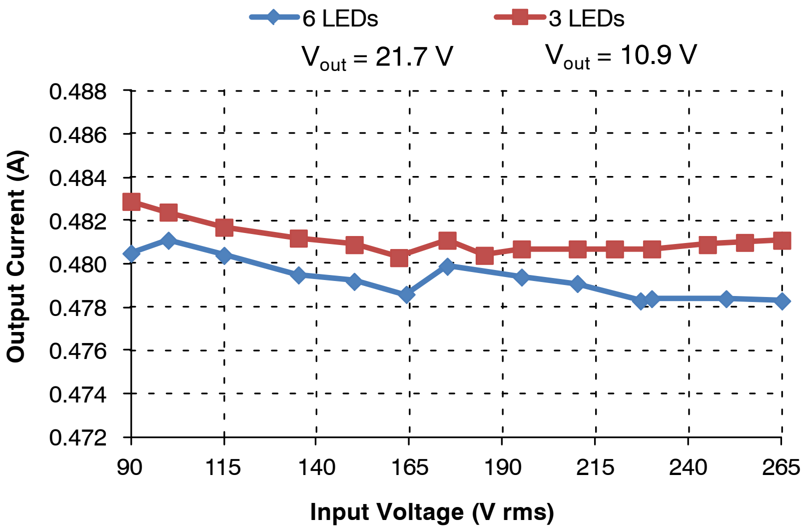

Figure 6. Line and Load Regulation with Valley Fill EVB (NCL30083B)

The output current regulation is estimated by calculating the median value of the output current $I_{out(mean)}$ considering the maximum and the minimum value measured:

$$I_{out(mean)} = \frac{I_{out(max)} + I_{out(mean)}}{2} \qquad \text{(eq. 1)}$$

Then, we calculate the gap from the maximum value to the median value to deduce the current regulation expressed as a percentage of $I_{out(mean)}$:

$$\delta\, I_{out} = 100\, \frac{\Delta I_{out}}{I_{out(mean)}} = 100\, \frac{I_{out(max)} - I_{out(mean)}}{I_{out(mean)}} \qquad \text{(eq. 2)}$$

For the measurements shown in Figure 5, we have the following results:

$I_{out(mean)}$ = 470.5 mA
$I_{out(max)}$ = 473.2 mA
$I_{out(min)}$ = 467.7 mA
δI_{out} = ± 0.6%

The output current regulation is ± 0.6 %.

For the Valley Fill EVB (Figure 6), we have the following results:

$I_{out(mean)}$ = 480.6 mA
$I_{out(max)}$ = 482.9 mA
$I_{out(min)}$ = 478.3 mA
δI_{out} = ± 0.5%

The output current regulation is ± 0.5% with valley fill circuit for power factor correction. The valley fill circuit does not decrease the precision of the current regulation.

We can also measure the output current regulation when the ambient temperature varies. The board is placed in a stove and the temperature is varied from 80°C to -20°C. The LEDs are placed outside the stove. The current circulating in the LEDs is measured with an electronic multimeter. The measurements are plotted in Figure 7.

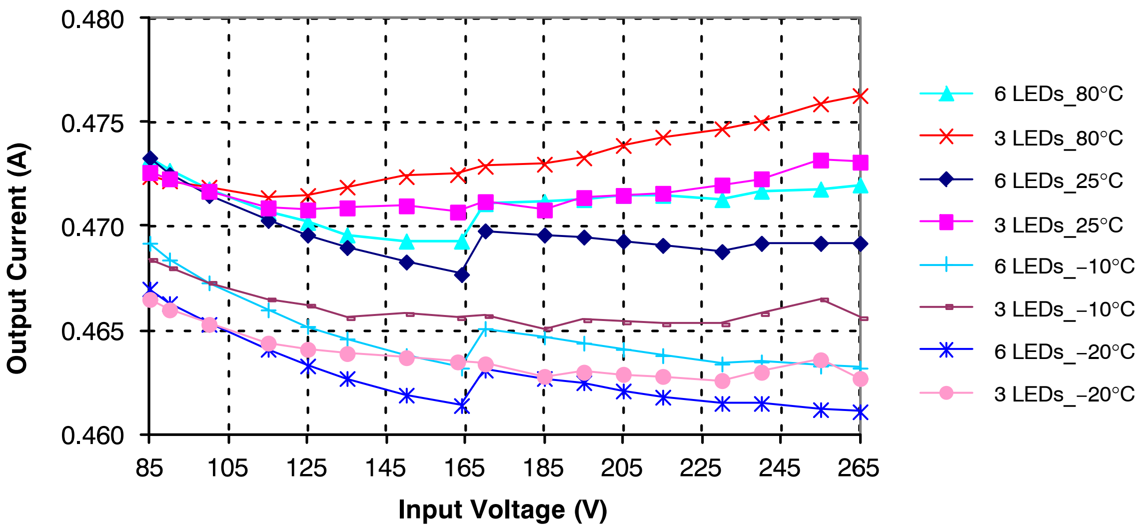

Figure 7. Output Current Regulation with Temperature (NCL30080B, Normal EVB)

The output current variations with temperature are not caused by the controller alone. The output rectifier plays a significant role in the output current variation. From the measurements on Figure 6, we have the following results:

$I_{out(mean)}$ = 468.7 mA
$I_{out(max)}$ = 476.3 mA
$I_{out(min)}$ = 461.1 mA
δI_{out} = ± 1.6%

The output current regulation is ± 1.6% from 80°C to -20°C.

Step Dimming Results

The NCL30081 and NCL30083 can dim the LED current to 5 discrete levels sequentially. Interrupting the mains briefly will step the LED current down one level until returning back to full light. Figure 8 shows the output current evolution for each dimming step. Table 3 summarizes the output current regulation for each dimming step when the input voltage is varied from 85 to 265 V rms and the output load from 6 LEDs to 4 LEDs.

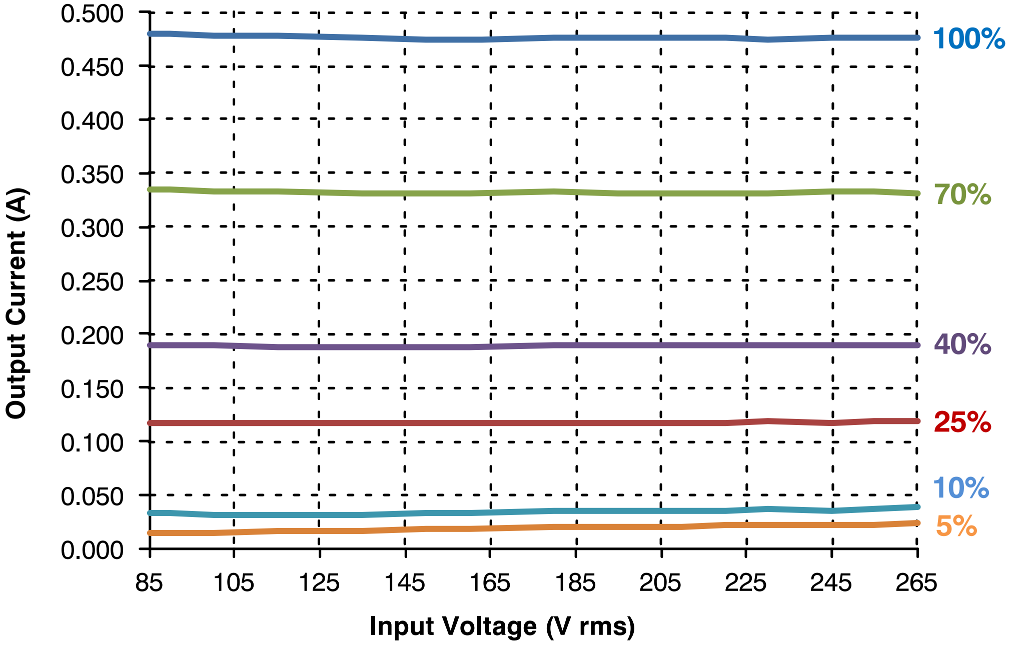

Figure 8. Dimming with the NCL30081 (Normal EVB)

Table 3. LINE AND LOAD REGULATION FOR EACH DIMMING STEP WITH THE NCL30081 (NORMAL EVB)

Dimming Step		$I_{out(mean)}$ (mA)	$I_{out(min)}$ (mA)	$I_{out(max)}$ (mA)	δI_{out} (%)	δI_{out} (mA)
ON	100%	478.5	480.6	474.5	0.64%	6.1
1	70%	333.2	330.9	335.5	0.7%	4.6
2	40%	191.2	187.9	194.5	1.7%	6.6
3	25%	115.5	110.5	120.6	4.4%	10.1
4	10%	37.7	32.3	43.1	14%	10.8
5	5%	24.6	15.0	34.2	39%	19.2

The current regulation decrease for the last dimming step (5%) because the line-feedforward offset is removed for the NCL30081.

For the NCL30083, the line-feedforward offset is removed for the 10% and the 5% step.

Efficiency and Power Factor

The measurements were made after the board was operated during 10 mn at full load (6 LEDs), low line, with an open frame and at ambient temperature.

The input power and the PF were measured with the power meter WT210A from Yokogawa.

The output current and the output voltage were measured using the digital multimeter 34401A from HP.

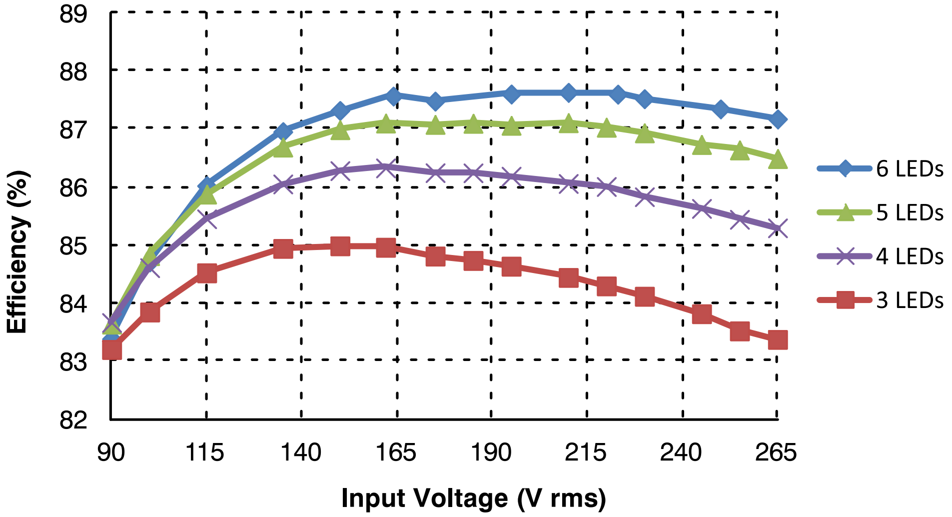

Figure 9. Valley Fill EVB Efficiency for 6, 5, 4 and 3 LEDs Connected at the Output

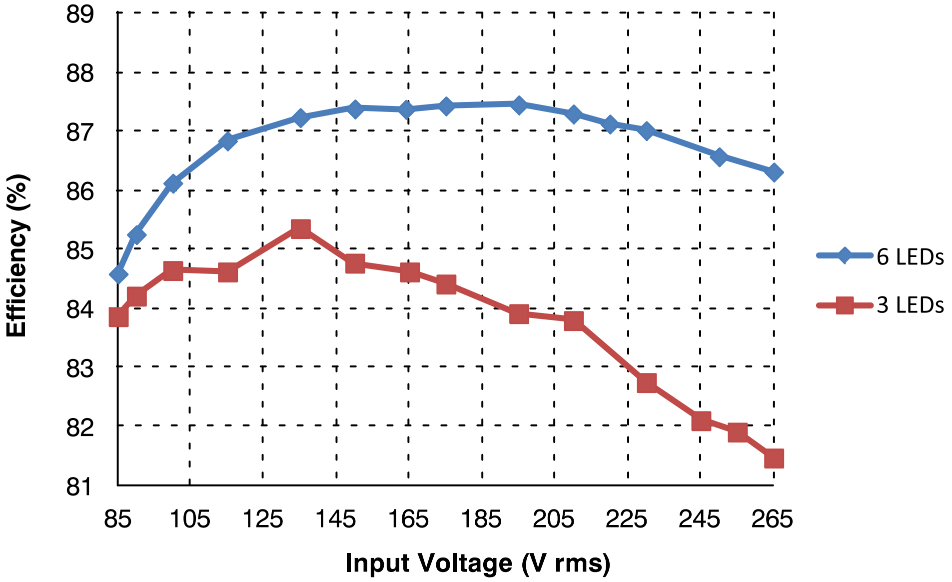

Figure 10. Efficiency for Default EVB with 6 LEDs and 3 LEDs

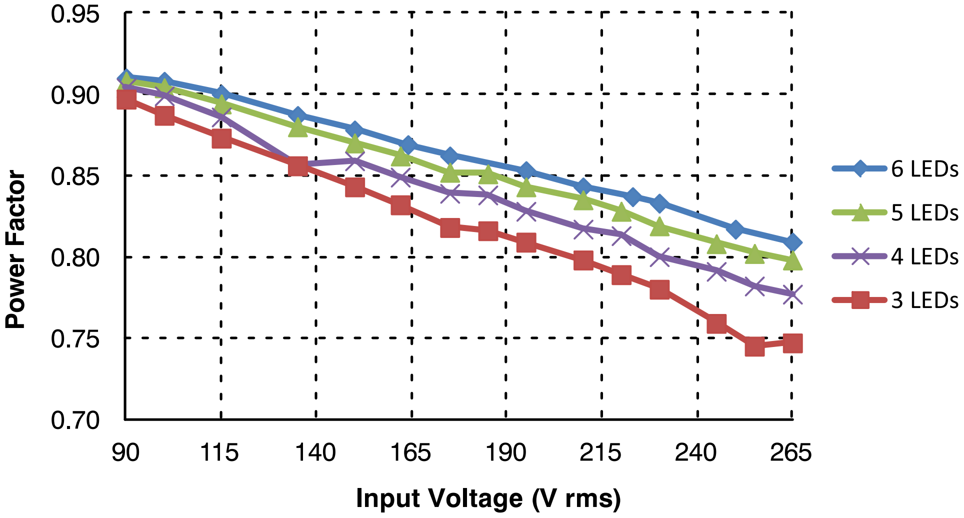

Figure 11. Power Factor with Valley Fill EVB

Startup Waveforms

The startup resistors have been calculated to provide a maximum startup time of 1.5 s at 85 V rms. Figure 12 and Figure 13 shows the startup waveforms at 115 V rms and 230 Vrms. No overshoot is observed on the output current.

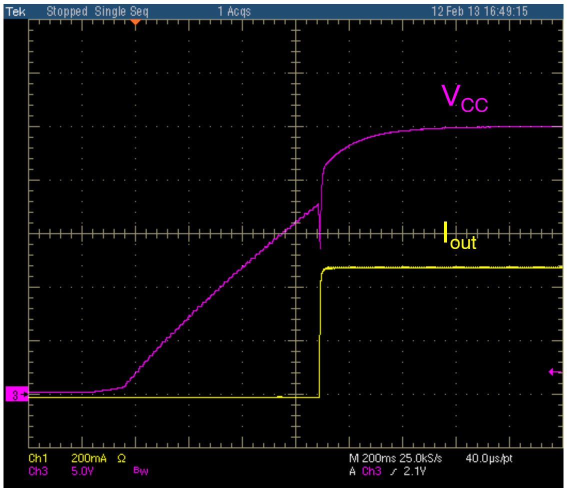

Figure 12. Startup Waveforms 115 V rms

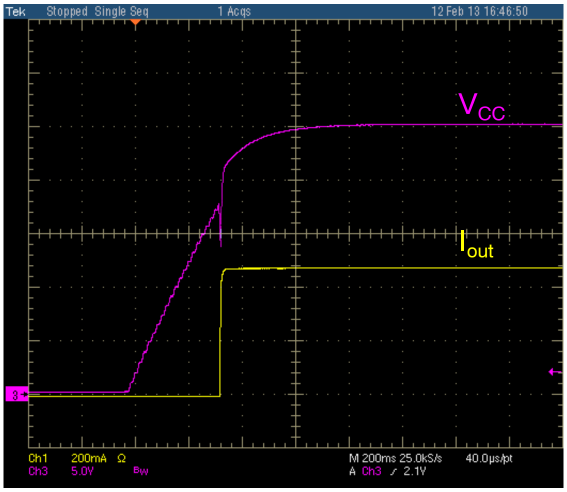

Figure 13. Startup Waveforms 230 V rms

Open LED protection

When V_{CC} increases above 28 V, the controller detects an open LED condition and shuts down during 4 s. When the 4-s timer has elapsed, the controller tries to restart. This forces a low duty cycle burst operation which allows decreasing the power consumed by the LED driver if no load is connected to its output. Table 4 shows the no load power consumption of the Evaluation board. Figure 11 shows the output voltage variation when no output load is connected to board. The maximum output voltage reached is 37 V.

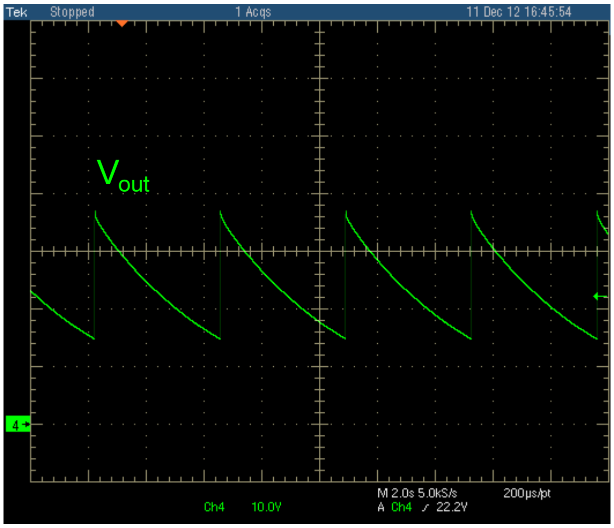

Figure 14. Output Voltage Variation with No Output Load

Table 4. NO LOAD POWER CONSUMPTION

	115 Vrms	230 Vrms
P_{out} (W)	P_{in} (mW)	P_{in} (mW)
0	**24**	**66**

EMI Tests

After operating the board during 15 mn at full load in order to warm it up, conducted electromagnetic emission measurements were made in quasi-peak mode using a Rohde & Schwarz EMI Test Receiver following the CISPR22 standard. The EMI signature is shown in Figure 15.

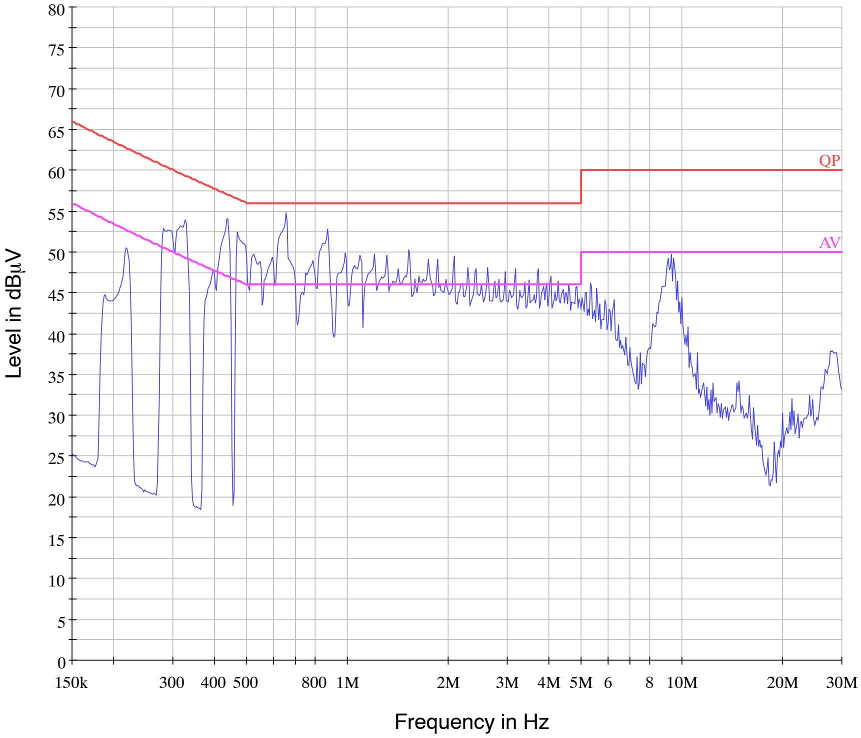

Figure 15. EMI Signature in Quasi−peak, 6 LEDs, Low Line

Conclusion

This application note has shows the experimental results of a LED driver controlled by the NCL30080-81-82-83.

This new family of controllers provides a very good regulation of the output current from the primary side of a flyback controller: ± 0.6 % achieved with the evaluation boards. The controllers support Valley Fill operation without degrading the output current precision and offer a wide range of features to implement reliable LED drivers.

References

[1] Stéphanie Cannenterre, “Designing a LED driver with the NCL30080-81-82-83”, AND9131/D

Bill of Material

Table 5. BILL OF MATERIAL

Ref	Qty	Description	Value	Tolerance/ Constraint	Package/ Footprint	Manufacturer	Part Number	S	VF
T1	1	QR transformer				WURTH	750871144	X	X
X1	1	Controller	NCL30080, NCL30081, NCL30082, NCL30083		TSOP6 Micro8	ON Semiconductor	NCL30080, NCL30081, NCL30082, NCL30083	X	X
X1b	1	DIP8 support			DIP8	Standard	Standard	X	X
R1	1	Ceramic resistor, SMD	1.5 Ω	1%	SMD 1206	Standard	Standard	X	X
R12	1	Ceramic resistor, SMD	NC						
R4	1	Ceramic resistor, SMD	10	5%	SMD 0805	Standard	Standard	X	X
R22	1	Axial resistor, 1W	47 Ω	1 W, 500 V	through-hole	TE Connectivity	EP1WS47RJ		X
R6	1	Ceramic resistor, SMD	4.7 MegΩ	200 V,1%	SMD 1206	Standard	Standard	X	X
R15	1	Ceramic resistor, SMD	5.1 MegΩ	200 V, 1%	SMD 1206	Standard	Standard	X	X
R3	1	Ceramic resistor, SMD	8.2 kΩ	5%	SMD 0805	Standard	Standard	X	X
R2	1	Ceramic resistor, SMD	24 kΩ	5%	SMD 0806	Standard	Standard	X	X
R16	1	Ceramic resistor, SMD	220 kΩ	200 V, 5%	SMD 1206	Standard	Standard	X	X
R5	1	Ceramic resistor, SMD	100 kΩ	1%	SMD 0805	Standard	Standard	X	X
R7, R11	2	Ceramic resistor, SMD	5.6 kΩ	5%	SMD 1206	Standard	Standard	X	X
R8	1	Ceramic resistor, SMD	270 kΩ	200 V, 5%	SMD 1206	Standard	Standard	X	X
R33	1	Ceramic resistor, SMD	820 Ω	1%	SMD 0805	Standard	Standard	X	X
R13	1	Ceramic resistor, SMD	63 kΩ	5%	SMD 0805	Standard	Standard	X	X
R14	1	Ceramic resistor, SMD	22 Ω	5%	SMD 1206	Standard	Standard	X	
R18	1	Ceramic resistor, SMD	36 kΩ	5%	SMD 1206	Standard	Standard	X	X
R20	1	Ceramic resistor, SMD	22 Ω	5%	SMD 0805	Standard	Standard	X	X
R9	1	Ceramic resistor, SMD	NC						
R10	1	Ceramic resistor, SMD	470 kΩ	5%, 200 V	SMD 1206	PANASONIC	ERJP08F4703V	X	X
R17	1	Ceramic resistor, SMD	0 Ω		SMD 0805	Standard	Standard	X	X
R19	1	Ceramic resistor, SMD	33 Ω	5%	SMD 0805	Standard	Standard	X	X
C7	1	Ceramic resistor, SMD	22 pF	25 V	SMD 0805	Standard	Standard	X	X
C10	1	Ceramic capacitor, SMD	47 pF	25 V	SMD 0805	Standard	Standard	X	X
C8	1	Ceramic capacitor, SMD	470 pF	25 V	SMD 0805	Standard	Standard	X	X
C13	1	Ceramic capacitor, SMD	1 nF	25 V	SMD 0805	Standard	Standard	X	X
C16	1	Ceramic capacitor, SMD	10 nF	25 V	SMD 0805	Standard	Standard	X	X
C6	1	Ceramic capacitor, SMD	4.7 nF	1000 V	SMD 1206	Standard	Standard	X	
C12	1	Ceramic capacitor, SMD	100 nF	50 V	SMD 0805	Standard	Standard	X	X
C19	1	Ceramic capacitor, SMD	4.7 nF	1000 V	SMD 1206	Standard	Standard		X
C18	1	Ceramic capacitor, SMD	22 pF	100 V	SMD 0805	Standard	Standard	X	X
C5	1	X2 capacitor	47 nF	300 Vac	through-hole	Standard	Standard	X	X
C2	1	X2 capacitor	100 nF	300 Vac	through-hole	Standard	Standard	X	X
C4	1	Electrolytic capacitor	4.7 μF	35 V	through-hole	Standard	Standard	X	X
C14, C15	2	Electrolytic capacitor	22 μF	250 V	through-hole	PANASONIC	EEUEE2E220		X
C1	1	Electrolytic capacitor	15 μF	400V	through-hole	PANASONIC	EEUEE2G150	X	

Table 5. BILL OF MATERIAL

Ref	Qty	Description	Value	Tolerance/ Constraint	Package/ Footprint	Manufacturer	Part Number	S	VF
C9	1	Electrolytic capacitor	47 μF	35 V	through-hole	Standard	Standard	X	X
C3	1	Electrolytic capacitor	120 μF	50 V	through-hole	PANASONIC	EEUFR1H121L	X	X
C21	1	Y2 capacitor	1 nF	500 V ac	through-hole	Standard	Standard	X	X
D1	1	Diode, axial, ultra fast recovery		1 A, 800 V	through-hole	ON Semiconductor	MUR180EG	X	X
D3	1	Diode, SMD, ultra fast recovery		2 A, 200 V	SMB	ON Semiconductor	MURS220T3G	X	X
D11, D12, D16	3	Diode, axial, 1 A, 1000 V		1A, 1000 V	through-hole	ON Semiconductor	1N4007G		X
D2	1	Diode, SMD, 100 V		100 V	SOD-123	ON Semiconductor	MMSD4148T1G	X	X
D4	1	Diode, SMD, 250 V		250 V	SOT-723	ON Semiconductor	BAS21LT3G	X	X
D5	1	Zener 22V		22 V	SOD-123	ON Semiconductor	MMSZ5251BT1G	X	X
Q1	1	MOSFET, 3A, 800 V		3 A, 800 V	TO220FP	ST Micro	STP3NK80FP	X	X
RN1	1	NTC thermistor		100 kΩ, 5%	SMD 0805	AVX	NB12P00104JBB	X	X
RVI	1	Varistor		275 V		Littelfuse	V275LA4P	X	X
J1	1	Male connector			through-hole	WEIDMULLER	SL5.08/3/90 4.5	X	X
J1a	1	Female connector			through-hole	WEIDMULLER	BL5.08/3	X	X
L2, L5	2	Radial coil 1.5 mH	1.5 mH		through-hole	COILCRAFT	RFB0810	X	X
D8	1	Diode bridge, 1 A, 600 V		1A, 600 V	through-hole	Taiwan Semi	DBL105G	X	X
F1	1	Fuse, 360 mA, 250 V	630 mA	250 V ac	through-hole	SCHURTER	34.6012	X	X
J2,J3	2	Male Connector			through-hole	WEIDMULLER	SL5.08/2/90B4.5	X	X
J2a, J3a	2	Female connector			through-hole	WEIDMULLER	BL5.08/2	X	X

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