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Design Note – DN05075/D

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Buck-Boost Converter for 15 W LEDs

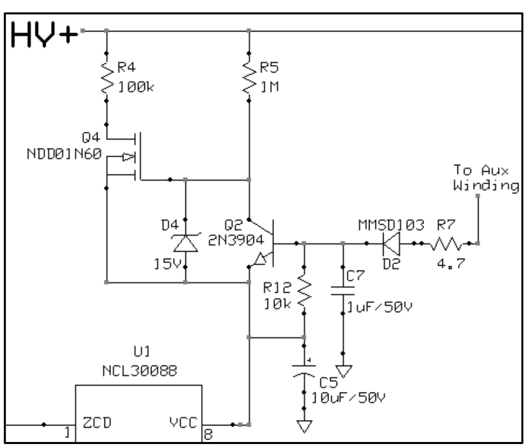
Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCL30088D	Wall powered LED driver	90-300 Vac	**15 Watts**	**Buck-Boost**	**None**

Output Voltage	140 V
Nominal Current	100 mA
Current Ripple	< 3mA
Nominal Efficiency	89 – 92%
PFC	Yes

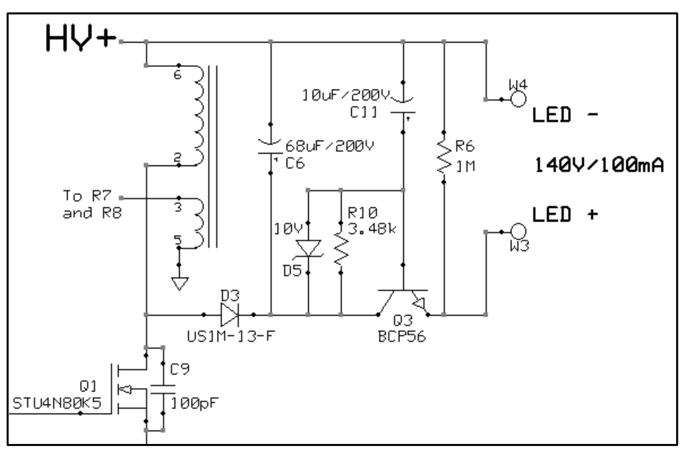
Introduction

As the LED lighting industry continues to grow, many LED manufacturers ask for designs that maintain high efficiency over a universal input, but also require low start up times. Using traditional start up resistors from the HV+ rail to Vcc forces the design to balance start up time at low line and efficiency at high line. Finding a design that circumvents this trade off will allow LED solutions to meet the demands of universal input LED applications. Low current ripple is also required by some manufacturers to mitigate shimmer or stroboscopic effects, but often the space inside the bulbs is not ample for fitting large capacitors.

This Design Note is based off of the NCL30088LED EVB (with slight modifications – see schematic) and describes two circuits that increase performance for LED applications. The first (a) maintains short start up times at low line while also minimizing power loss at high line. The second (b) reduces LED current ripple without the need for large amounts of capacitance. The following sections will describe the circuitry and performance for these solutions.



(a)



(b)

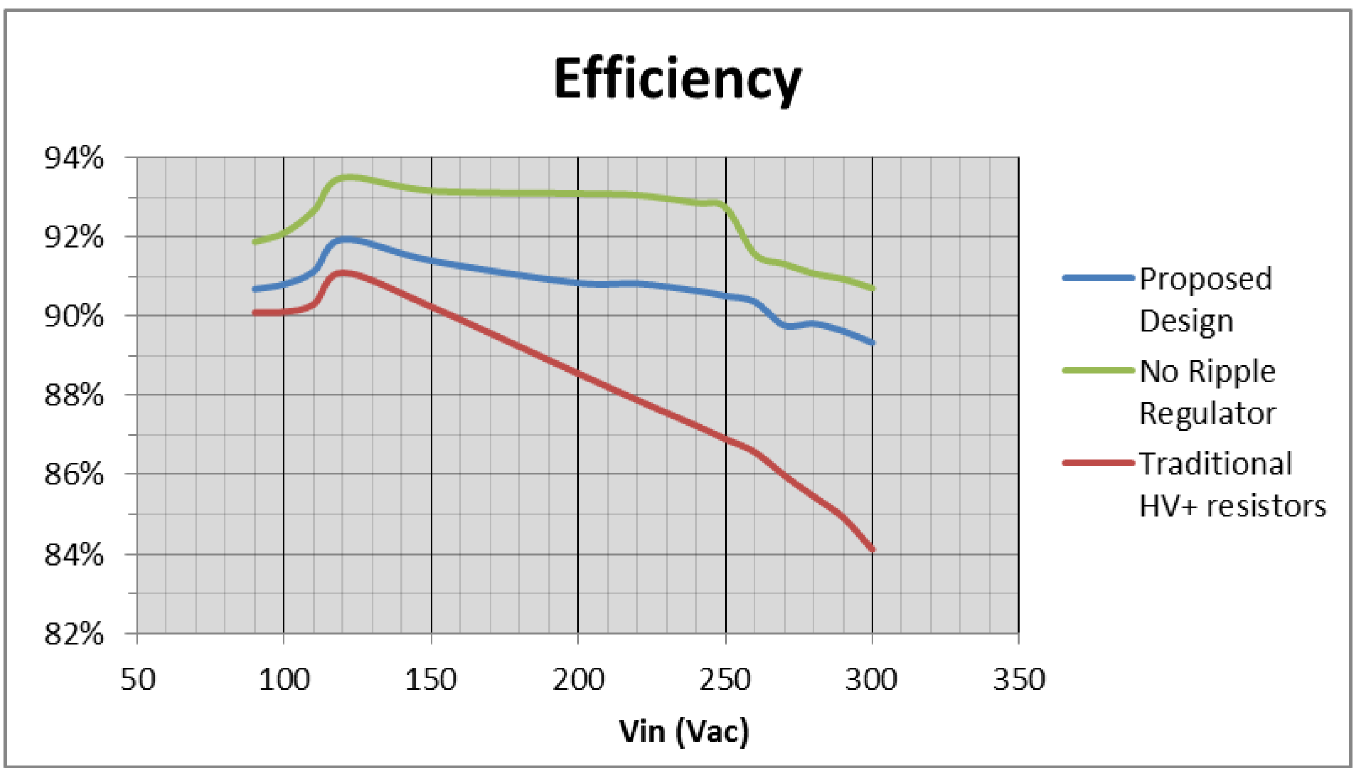
Circuit Description

This design utilizes a buck-boost topology where the output floats above the rectified AC line. Values for the parallel combination of Rsens1 and Rsens2 set the device output current. The controller's CS pin monitors peak currents and compares them to the rectified line so that power factor above 0.9 is maintained up through 300 Vac. Further information regarding detailed operation of the controller and topology may be found using the links at the bottom of this document.

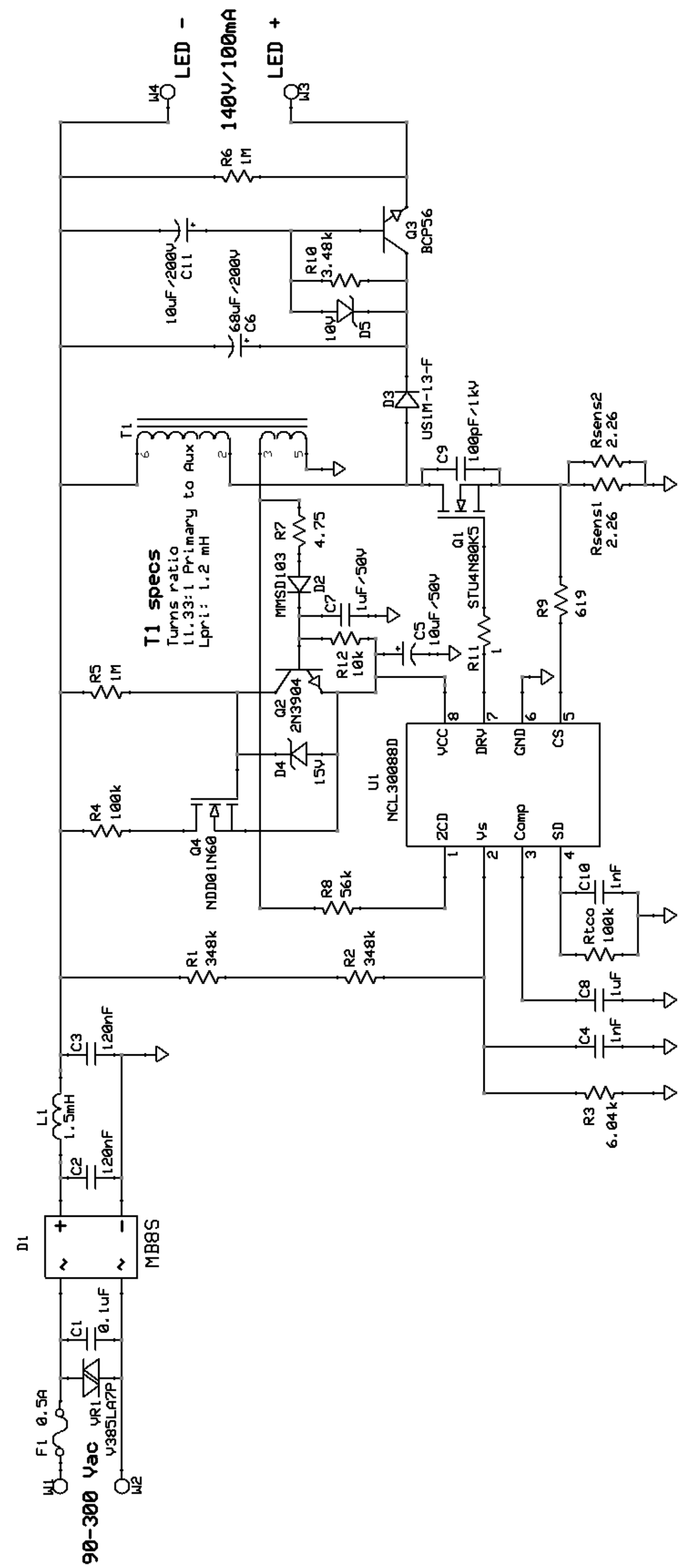
Startup circuit: When the AC voltage is applied to the device, the voltage rises at the gate of Q4 turning on the FET and allowing C5 to be charged to the turn on threshold of the part (around 18 V). Once the part's driver starts switching, power to the controller is supplied by the auxiliary winding. This turns on Q2 and pulls the gate of Q4 low disconnecting the 100k start-up resistor.

Output circuit: Initial filtering for the LEDs is performed by C6. The reduced ripple waveform is fed through the RC filter comprised of R10 and C11 so that the ripple at the collector mimics the base albeit 0.7 V lower. The Zener diode D5 placed from collector to base allows for Q3 to turn on faster during start-up providing a significant reduction to the initial spike in output current.

In the chart below, the efficiency curves for three different configurations are shown. The design proposed in the schematic is shown in blue, having both the ripple reduction circuit and the start-up circuit. The most efficient design is that in green, with the ripple reduction circuit removed and start-up circuit in place. The impact this has on current ripple will be shown later. The least efficient design is in red, and shows the design with the start-up circuit replaced by three 33 kΩ resistors (totaling about 100kΩ) in series to model similar low line start up and with the low ripple reduction circuit in place.

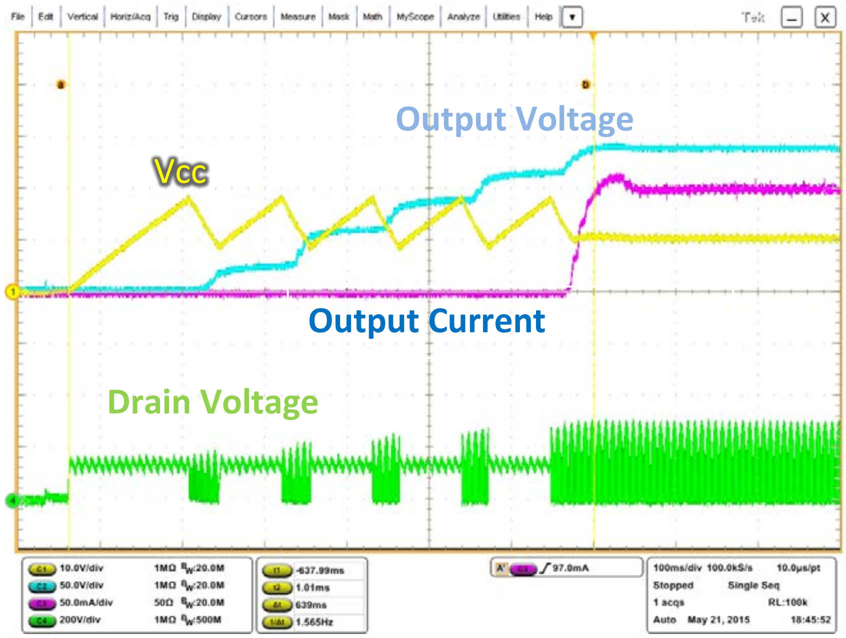


Schematic



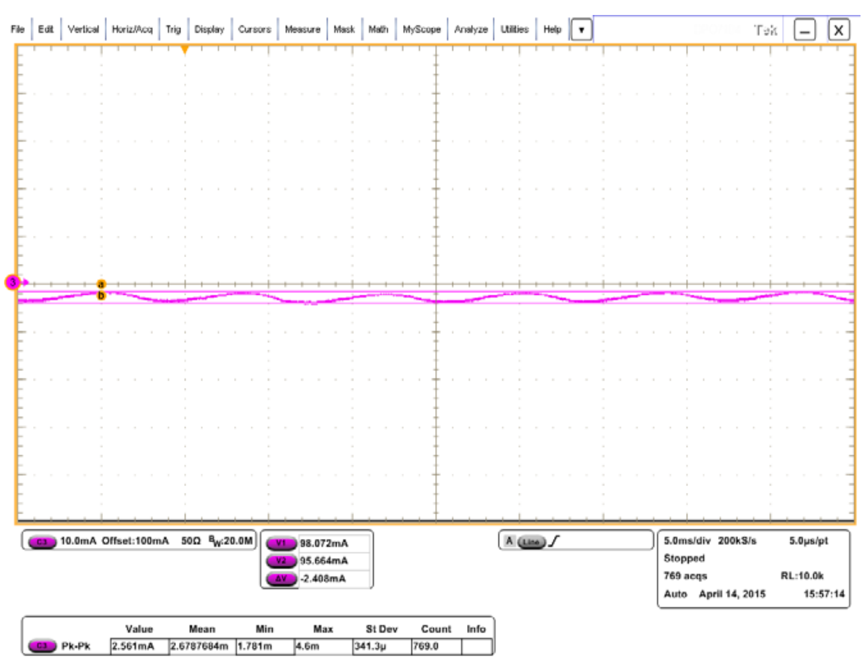
Start-up

The image below shows the device starting up at 110 Vac. The steps in the output voltage are a result of Vcc hitting its start-up (turn on) voltage threshold at which point the controller begins driving the gate of Q1 until Vcc reaches the shut-down (turn off) threshold, and then pausing while C7 is again charged to the start-up threshold of the part. Decreasing the output capacitance (C6 and C11) and/or the resistance of R10 will reduce start up time but increase current ripple.

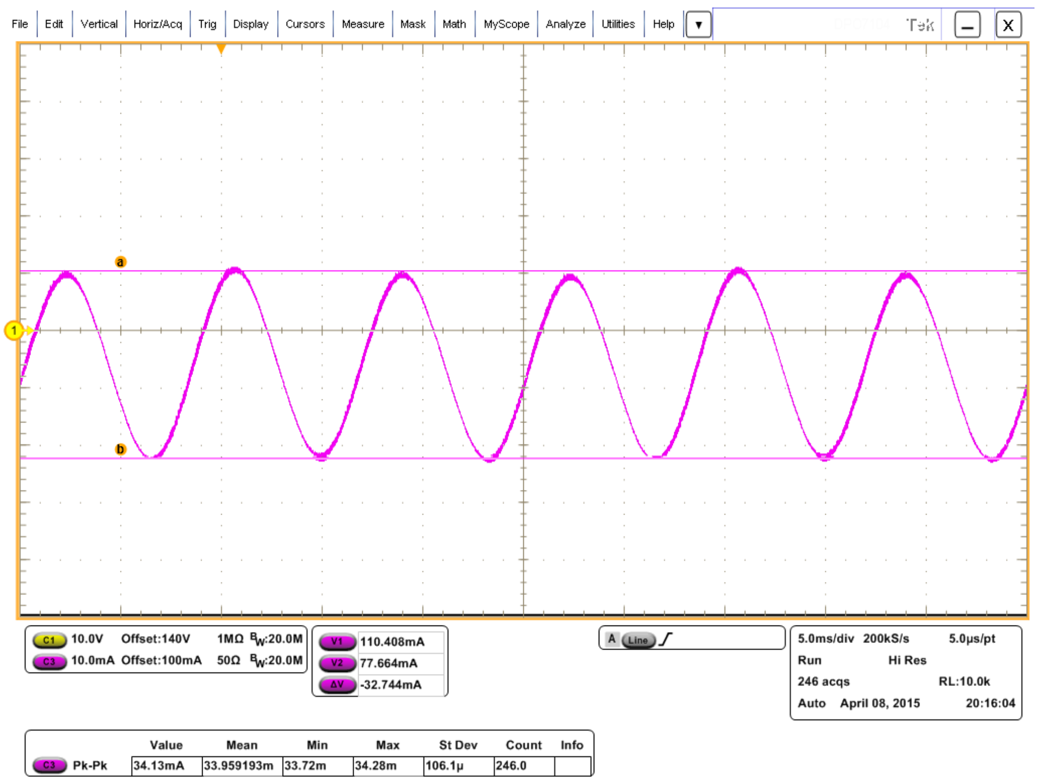


Current Ripple

This image shows current ripple using the linear regulator comprised of R10, C11, and Q3. The current ripple is extremely low and can meet the needs of high performance LED applications.



Removing components after C6 (except R6) and connecting the LEDs there results in current ripple shown in the following image. While the current ripple has increased to a little over 30 mA, the efficiency also increases by about 2% across input range. If low current ripple is not necessary, the removal of these parts can decrease cost, size, and provide a significant increase in efficiency.

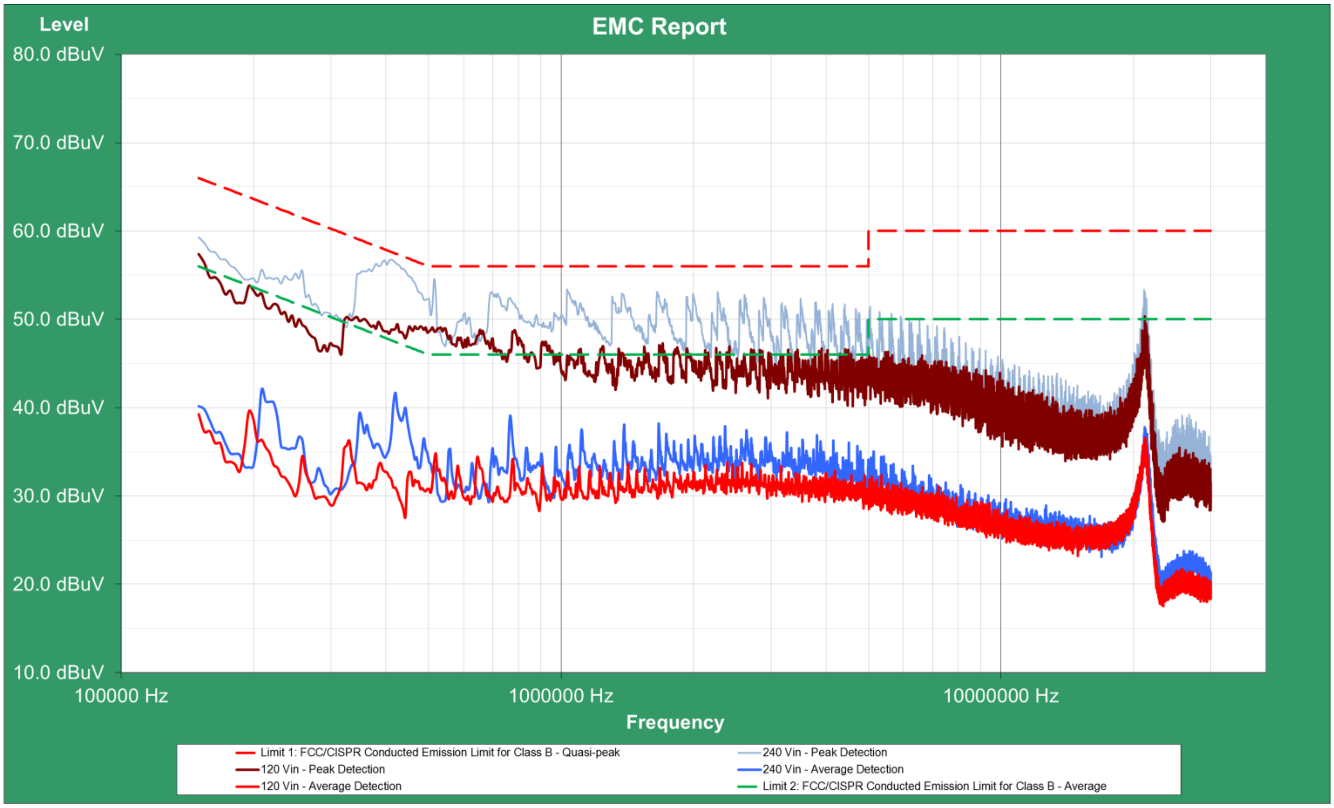


Output Current Ripple Adjustment

Output current ripple can be adjusted with minor tweaking to a few select components. Adjusting any of these components will require careful consideration of accompanying effects. Increasing R10 will provide lower current ripple at the cost of efficiency (due to Vce increasing). If done in conjunction with lowering C6 and C11, a more compact design with similar current ripple can be achieved at the cost of efficiency (heat).

EMC Conducted Emissions

Below is a chart showing both quasi-peak and average class B conducted emissions limits with corresponding scans at 120 and 240 Vac. Note that two scans use peak detection (as opposed to quasi-peak) producing results that show less margin than when measuring emissions with quasi-peak detection. Since the scans shown here are below the limit, it can be assured that the design will pass if using quasi-peak detection for the scan.



Key Features

- Low current ripple
- High efficiency for universal output
- Constant output current

Further information on the NCL30088 and evaluation board (**NOT** modified for additional circuitry proposed in this design note) can be found at:

- NCL30088 datasheet - http://www.onsemi.com/pub_link/Collateral/NCL30088-D.PDF
- Eval Board - http://onsemi.com/PowerSolutions/evalBoard.do?id=NCL30088LED1GEVB

Design note created by Thomas Ashe, e-mail: thomasashe@onsemi.com