NCL30082SMRTGEVB

NCL30082 8 W Smart LED Driver Evaluation Board User's Manual

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EVAL BOARD USER'S MANUAL

Overview

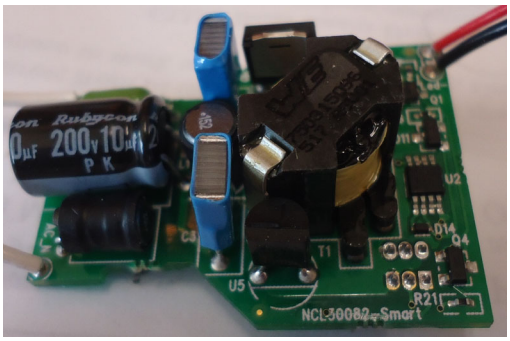
This manual covers the specification, theory of operation, testing and construction of the NCL30082DIMGEVB demonstration board. The NCL30082 board demonstrates an 8 W SEPIC LED driver with a 3.3 V aux voltage for power control accessories.

Table 1. SPECIFICATIONS

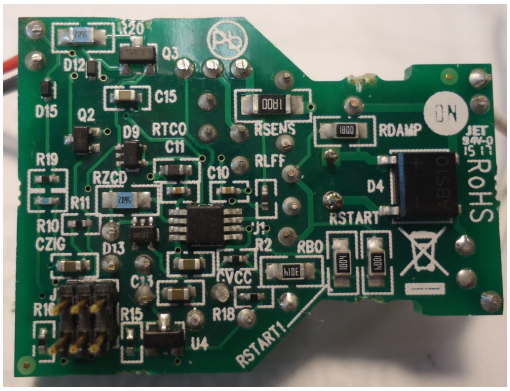
Parameter	Value	Notes
Input Voltage (Class 2 Input, No Ground)	100–120 V ac	
Line Frequency	50 Hz/60 Hz	
Power Factor (100% Load)	0.6	Typ.
LED Output Voltage Range	40–80 V dc	
LED Output Current	100 mA dc	±5%
Aux. Voltage (Available in All Modes)	3.3–3.5 V	
Aux. Current	20 mA	Max.
Efficiency	83.5%	Typ.
Standby Power		
120 V 60 Hz	90 mW	Typ.
Analog Dimming Voltage		
100% Output	V_{DIM} > 2.5 V	
0% Output	V_{DIM} < 0.1 V	
PWM Dimming Voltage	0–3.3 V	
PWM Range (Freq > 200 Hz)	0–100%	
Start Up Time (from AC On)	< 600 ms	Typ.
Start Up Time (from Enable On)	< 1 ms	
EMI (Conducted)	Class B	FCC/CISPR

Key Features

- Single Mains
- Integrated Auto-Recovery Fault Protection (Can be Latched by Choice of Options)
  - Over Temperature on Board (a PCB Mounted NTC)
  - Over Current
  - Output and V_{CC} Over Voltage
- 3.3 V Aux Voltage
  - Available in All Modes
- "Dim to Zero Output"
- On/Off Control



(Top View)



(Bottom View)

Figure 1. NCL30082SMRTGEVB Evaluation Board

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THEORY OF OPERATION

Power Stage

The power stage for the demo board is a non-isolated coupled SEPIC converter. The controller has a built in control algorithm that is specific to the flyback transfer function. Specifically:

$$\frac{V_{OUT}}{V_{IN}} = \frac{Duty}{(1 - Duty)} \quad \text{(eq. 1)}$$

This is applicable to flyback, buck-boost, and SEPIC converters. The controller has a built in hardware algorithm that relates the output current to a reference on the primary side.

$$I_{OUT} = \frac{V_{REF} \cdot N_{PS}}{2 \cdot R_{SENSE}} \quad \text{(eq. 2)}$$

$$N_{PS} = \frac{N_{PRI}}{N_{SEC}} \quad \text{(eq. 3)}$$

Where N_{PRI} = Primary Turns and N_{SEC} = Secondary Turns.

We can now find R_{SENSE} for a given output current.

$$R_{SENSE} = \frac{V_{REF} \cdot N_{PS}}{2 \cdot I_{OUT}} \quad \text{(eq. 4)}$$

Line Feedforward

The controller is designed to precisely regulate output current but variation input line voltage do have an impact. RLFF sets the line feedforward and compensates for power stage delay times by reducing the current threshold as the line voltage increases. RLFF is also used by the shorted pin detection. At start up the controller puts out a current to check for a shorted pin. If RLFF is zero, the current sense resistor is too low a value and the controller will not start because it will detect a shorted pin. So RLFF is required to make the controller operate properly. In practice, RLFF should be greater than 250 Ω.

Voltage Sense

The voltage sense pin has several functions sets the brown level and line range selection.

The amplitude of V_{IN} is important for the range detection. Generally, the voltage on V_{IN} should be 3.5 V peak at the highest input voltage of interest. Voltage on V_{IN} must **not** be greater than 4 V under any operating condition. The voltage on V_{IN} determines which valley the power stage will operate in. At low line and maximum load, the power stage operates in the first valley (standard CrM operation). At the higher line range, the power stage moves to the second valley to lower the switching frequency while retaining the advantage of CrM soft switching.

Auxiliary Winding

The auxiliary winding has 3 functions:

1. CrM Timing
2. V_{CC} Power
3. Output Voltage Sense

CrM Timing

In the off time, the voltage on the transformer/inductor forward biases D_{OUT} and D9. When the current in the magnetic has reached zero, the voltage collapses to zero. This voltage collapse triggers a comparator on the ZCD pin to start a new switching cycle. The ZCD pin also counts rings on the auxiliary winding for higher order valley operation. A failure of the ZCD pin to reach a certain threshold also indicates a shorted output condition.

V_{CC} Power

The auxiliary winding forward biases D9 to provide power for the controller. This arrangement is called a “bootstrap”. Initially the C_{VCC}, is charged through RSTART and RSTART1. When the voltage on C_{VCC} reaches the startup threshold, the controller starts switching and providing power to the output circuit and the C_{VCC}. C_{VCC} discharges as the controller draws current. As the output voltage rises, the auxiliary winding starts to provide all the power to the controller. Ideally, this happens before C_{VCC} discharges to the under voltage threshold where the controller stops operating to allow C_{VCC} to recharge once again. The size of the output capacitor will have a large effect on the rise of the output voltage. Since the LED driver is a current source, the rise of output voltage is directly dependent on the size of the output capacitor.

There are tradeoffs in the selection of C_{OUT} and C_{VCC}. A low output ripple will require a large C_{OUT} value. This requires that C_{VCC} be large enough to support V_{CC} power to the controller while C_{OUT} is charging up. A large value of C_{VCC} requires that RSTART and RSTART1 be lower in value to allow a fast enough startup time. Smaller values of RSTART and RSTART1 have higher static power dissipation which lowers efficiency of the driver.

Output Voltage Sense

The auxiliary winding voltage is proportional to the output voltage by the turns ratio of the output winding and the auxiliary winding. The controller has an overvoltage limit on the V_{CC} pin at about 26 V minimum. Above that threshold, the controller will stop operation and enter overvoltage fault mode such as when an open LED string occurs.

In cases where the output has a lot of ripple current and the LED has high dynamic resistance, the peak output voltage can be much higher than the average output voltage. The auxiliary winding will charge the C_{VCC} to the peak of the output voltage which may trigger the OVP sooner than expected so in this case the peak voltage of the LED string is critical.

SD Pin

The SD pin is a multi-function protection input.

1. Thermal Foldback Protection
2. Programmable OVP

Thermal Protection

There is an internal current source from the SD pin. Placing an NTC from the SD pin to ground will allow the designer to choose the level of current foldback protection from over temperature. Below 0.5 V on SD, the controller stops. Series or parallel resistors on the NTC and shape the foldback curve. In the event that the pin is left open, there is a soft voltage clamp at 1.35 V (nominal). Output current is reduced when the voltage on the SD pin drops below 1 V.

Programmable OVP

While the SD pin has a current source for the OTP, it can be overcome raising the voltage on the SD pin. At about 2.5 V, the SD pin detects an OVP and shuts down the controller. Typically, a zener to V_{CC} is used for this. In this way, the designer can set the OVP to a lower value that the OVP threshold built into the V_{CC} pin. The zener programmable OVP is not implemented on this demo board.

Aux Power Management

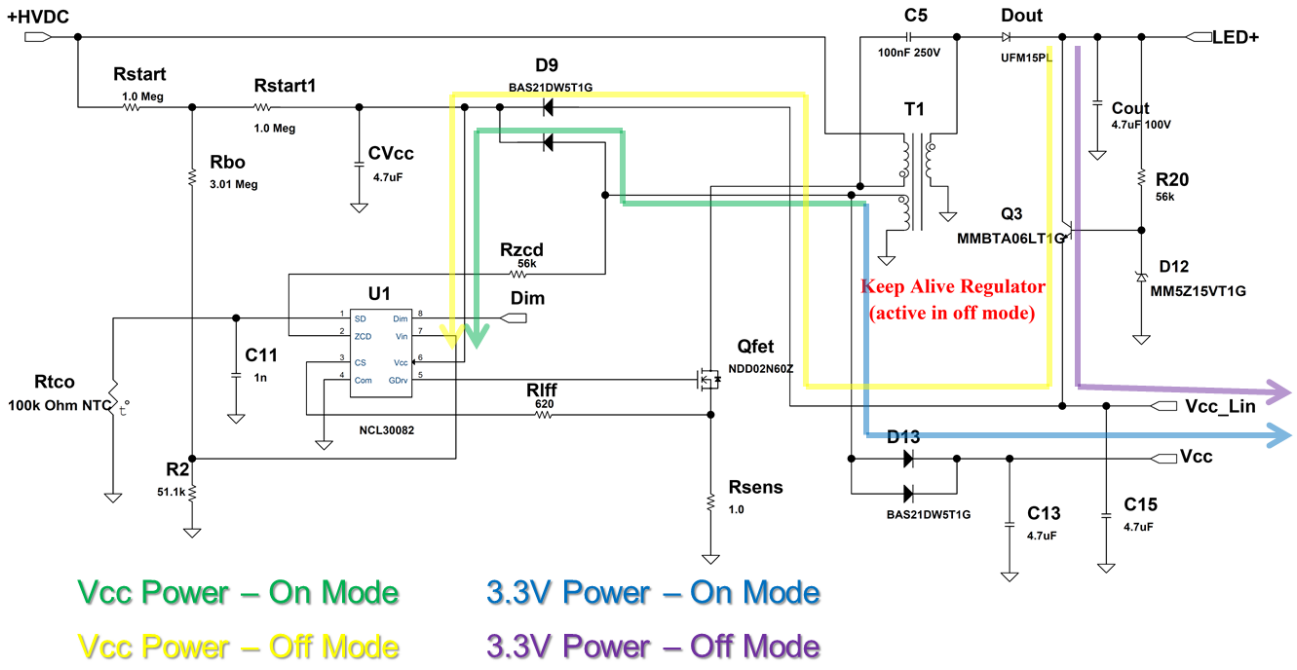


Figure 2. Aux Power Management

Circuit Modifications

Output Current

The output current is set by the value of R_{SENSE} as shown above. It's possible to adjust the output current by changing R_{SENSE}. Since the magnetic is designed for 8 W, it is possible to increase the current while reducing the maximum LED forward voltage within limits. Changes of current of ±10% are within the existing EMI filter design and magnetic, changes of more than 10% may require further adjustments to the transformer or EMI filter.

Connections

AC Input

1. Wire 1 (White) – AC Line
2. Wire 2 (White) – AC Neutral

Output

1. Wire 3 (Red) – LED+
2. Wire 4 (Black) – LED–

I/O (J7)

1. 3.3 V
2. On/Off
3. Dim
4. NC
5. Common
6. NC

Interface Control Signals

On/Off Control

The on/off control defaults to “on” if left open. Grounding this pin to signal ground turns the output “off”. In “off” mode, the output voltage will regulate to ~16 V. This is well below the level that will cause the LEDs to pass current resulting in a true off mode. “Off” mode is also the standby mode. The standby power consumption is greatly affected by the values of R_{START} and R_{START1}. The designer may choose to trade off start up time for standby power consumption. In a “Smart Bulb” application, the mains power is left on so the bulb can be controlled remotely. This designer can choose to optimize standby power by allowing the power on startup time to be longer than 0.5 s since power on timing is now a one-time event. In this case, R_{START} and R_{START1} are optimized for low power consumption rather than an optimized startup time. Once the converter is operating, startup through on/off control is less than 1 ms.

Dim Control

The dim control input will accept either an analog or PWM signal. The output has full range from 0% to 100% output. A 0 V input to the dim connection causes Q4 to operate in linear mode which maintains the voltage on the dim pin of the controller at its minimum level. At 0 V on the dim connection, the output voltage will be ~25 V which is below the V_f of the LEDs.

SCHEMATIC

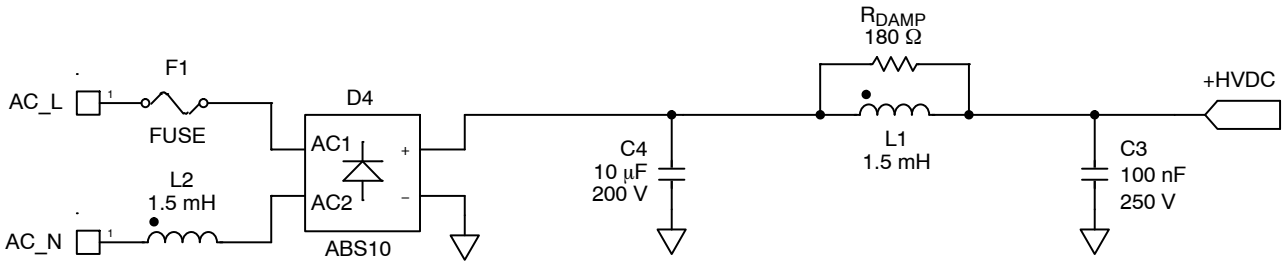


Figure 3. Input Circuit

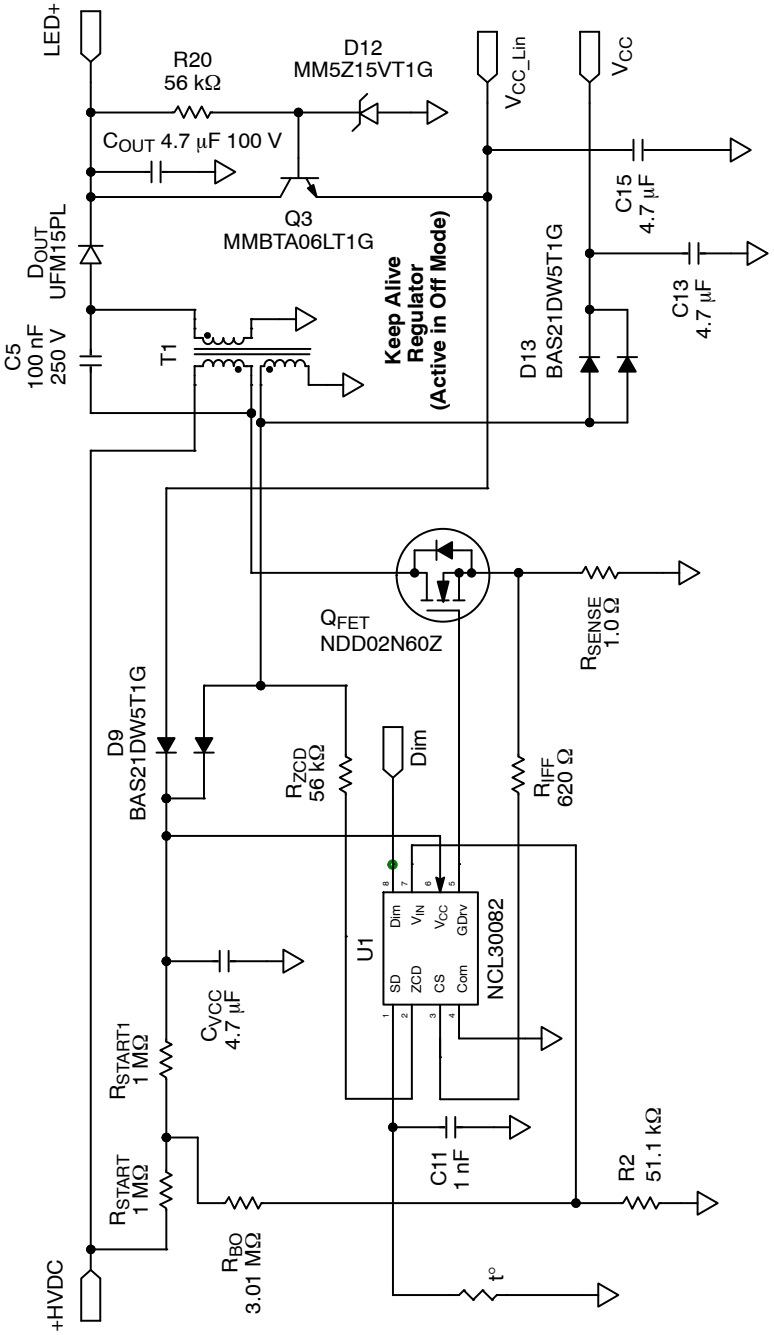


Figure 4. Main Schematic

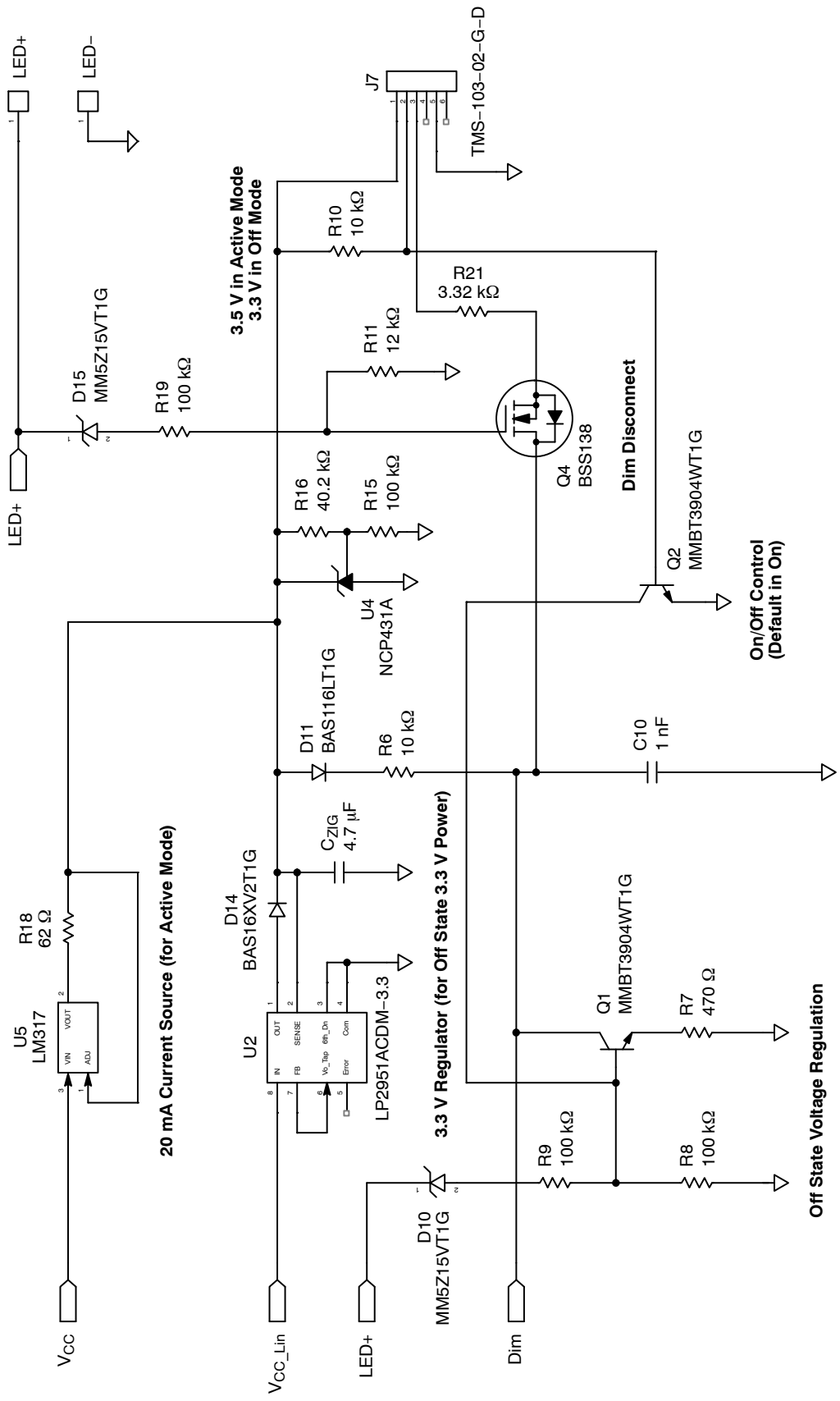


Figure 5. Interface Schematic

GERBER VIEWS

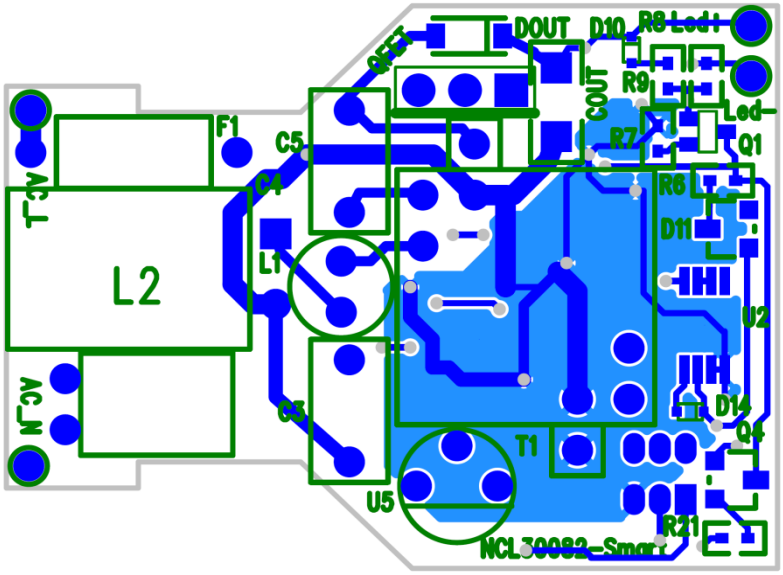


Figure 6. Top Side PCB

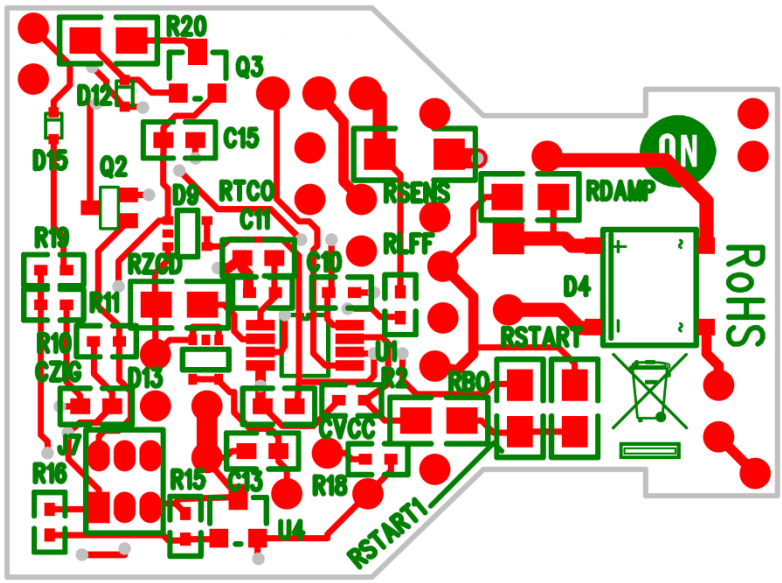


Figure 7. Bottom Side PCB

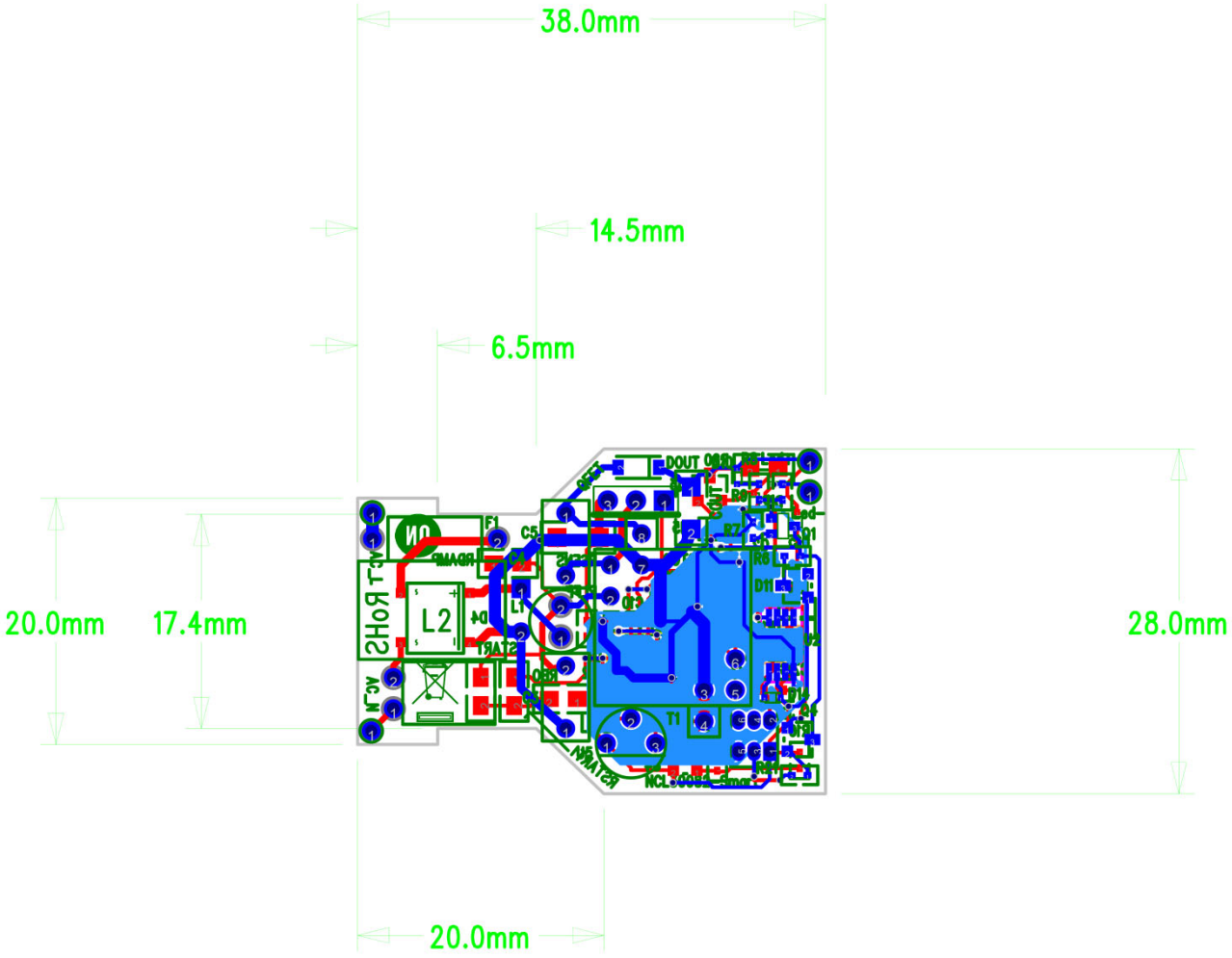


Figure 8. PCB Outline

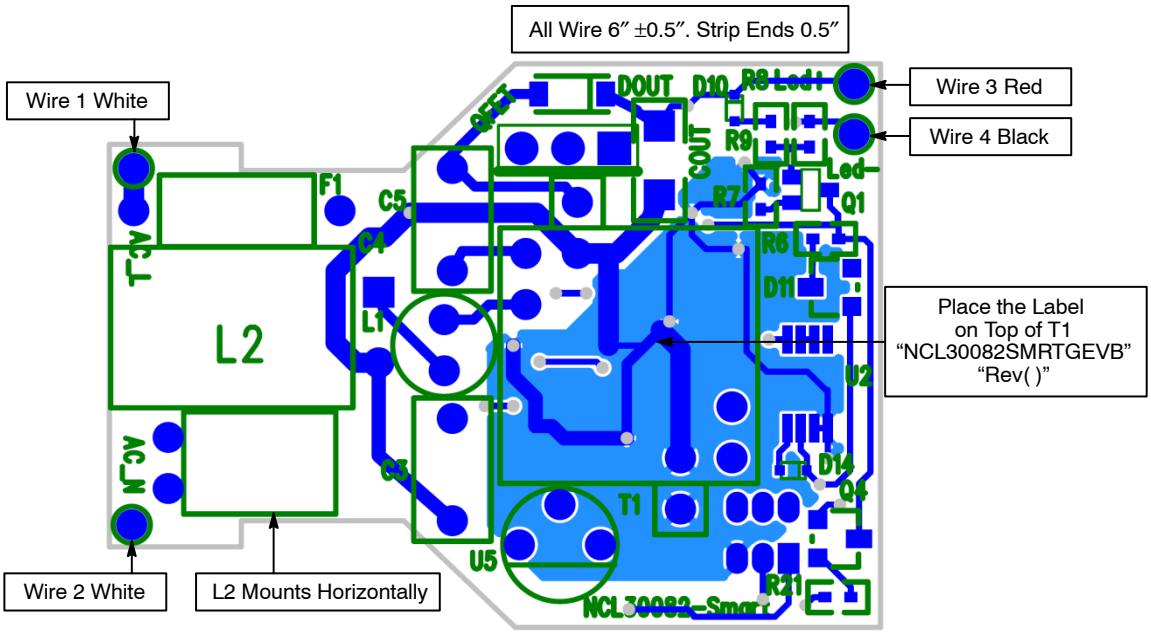


Figure 9. Assembly Notes Top

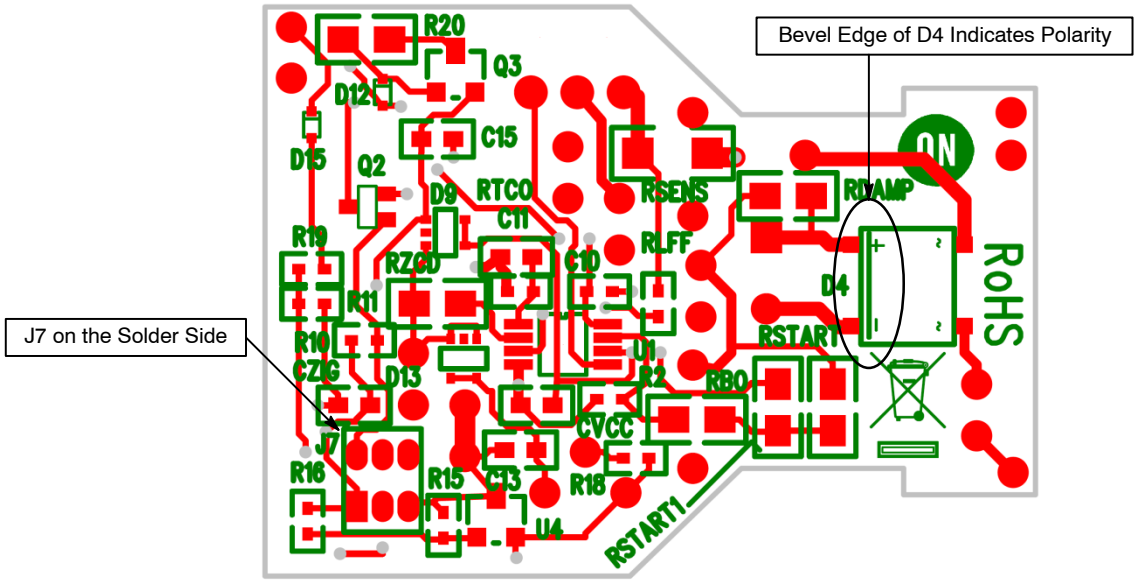


Figure 10. Assembly Notes Bottom

CIRCUIT BARD FABRICATION NOTES

1. Fabricate per IPC−6011 and IPC6012. Inspect to IPA−A−600 Class 2 or updated standard.
2. Printed Circuit Board is defined by files listed in fileset.
3. Modification to copper within the PCB outline is not allowed without permission, except where noted otherwise. The manufacturer may make adjustments to compensate for manufacturing process, but the final PCB is required to reflect the associated gerber file design ±0.001″ for etched features within the PCB outline.
4. Material in accordance with IPC−4101/21, FR4, Tg 125°C min.
5. Layer to layer registration shall not exceed ±0.004″.
6. External finished copper conductor thickness shall be 0.0026″ min. (i.e. 2 oz).
7. Copper plating thickness for through holes shall be 0.0013″ min. (i.e. 1 oz).
8. All holes sizes are finished hole size.
9. Finished PCB thickness 0.031″.
10. All un-dimensioned holes to be drilled using the NC drill data.
11. Size tolerance of plated holes: ±0.003″: non-plated holes ±0.002″.
12. All holes shall be ±0.003″ of their true position U.D.S.
13. Construction to be SMOBC, using liquid photo image (LPI) solder mask in accordance with IPC−SM−B40C, Type B, Class 2, and be green in color.
14. Solder mask mis-registration ±0.004 in. max.
15. Silkscreen shall be permanent non-conductive white ink.
16. The fabrication process shall be UL approved and the PCB shall have a flammability rating of UL94V0 to be marked on the solder side in silkscreen with date, manufactures approved logo, and type designation.
17. Warp and twist of the PCB shall not exceed 0.0075″ per in.
18. 100% electrical verification required.
19. Surface finish: electroless nickel immersion gold (ENIG).
20. RoHS 2002/95/EC compliance required.

SEPIC INDUCTOR SPECIFICATION

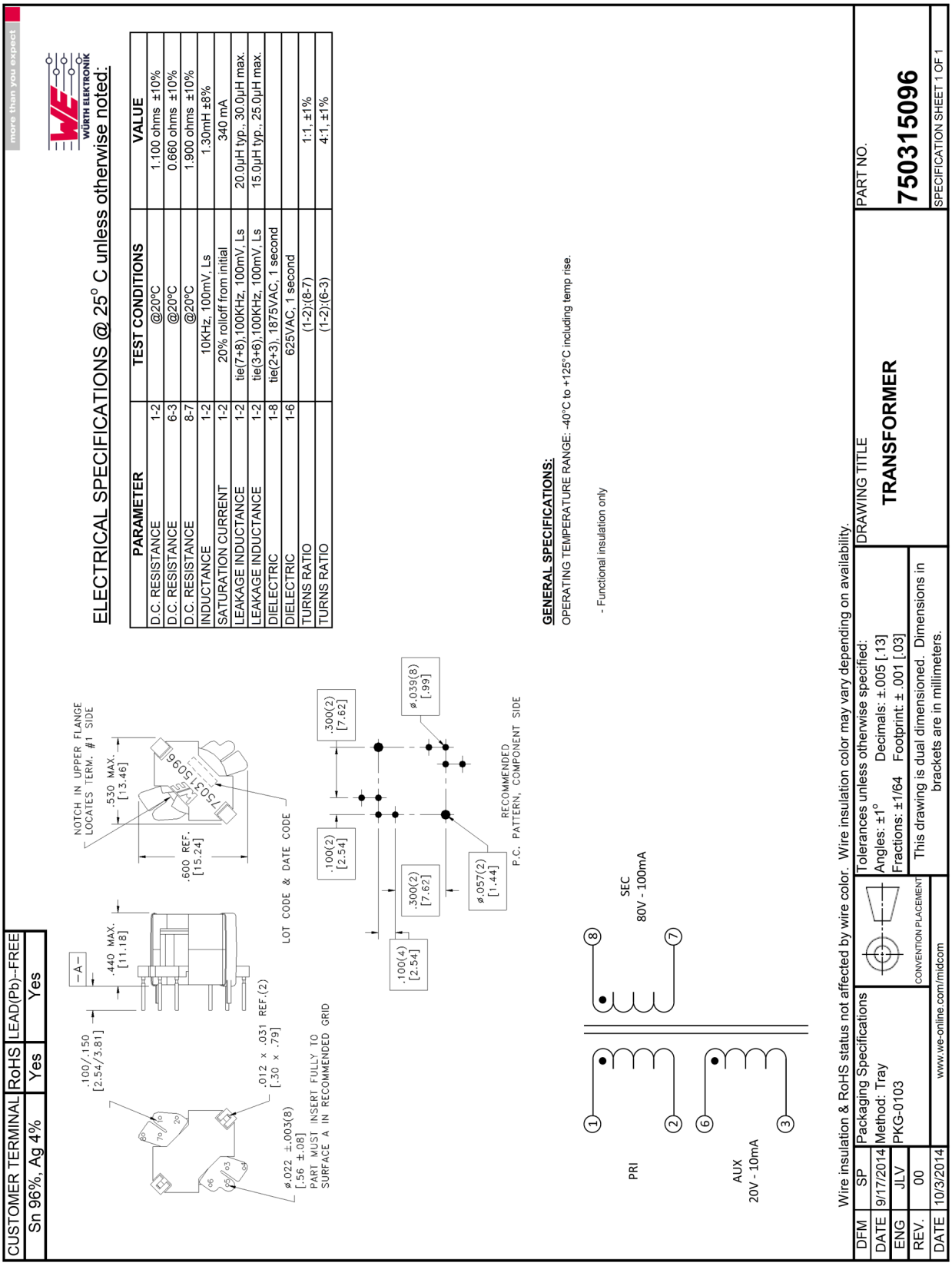


Figure 11. SEPIC Inductor Specification

ECA PICTURES

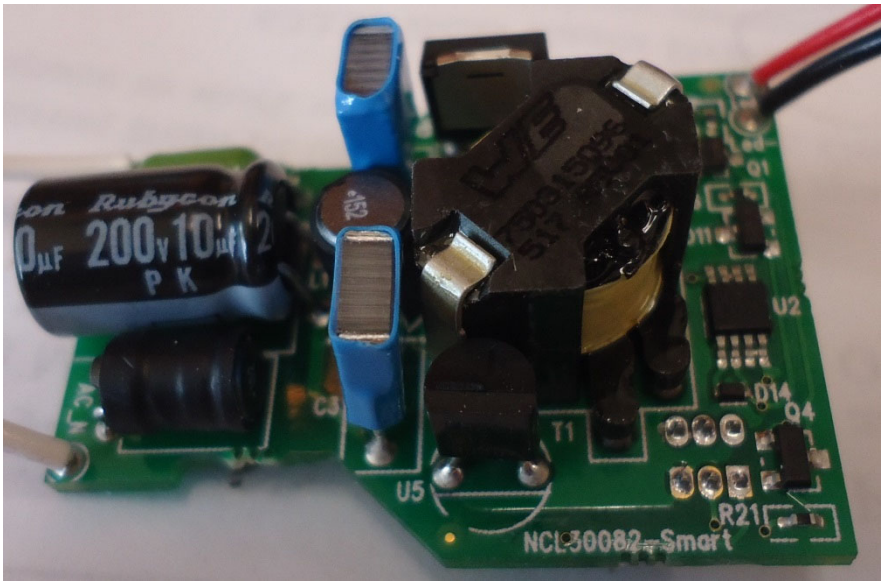


Figure 12. Top View

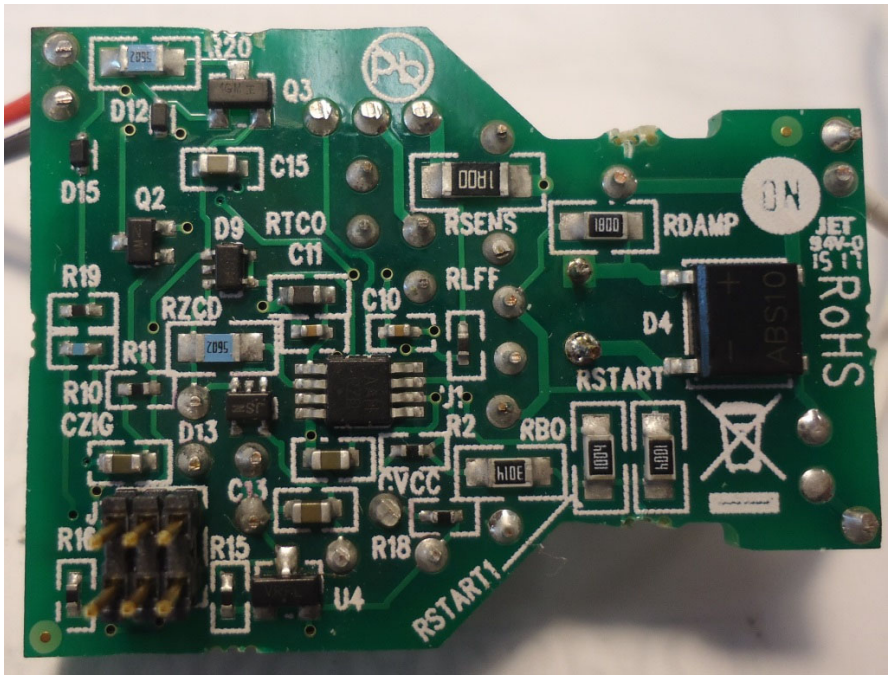


Figure 13. Bottom View

TEST PROCEDURE

Equipment Needed

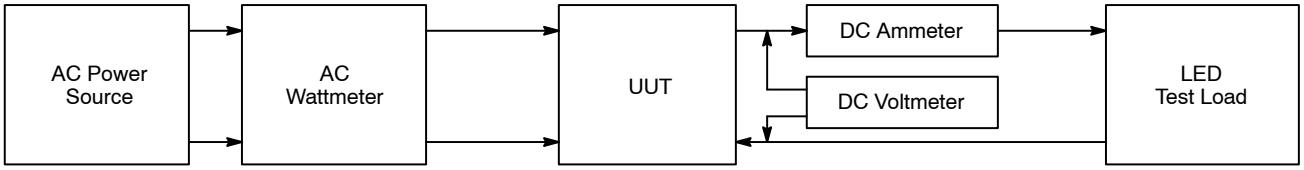
- AC Source – 90 to 135 V ac 50/60 Hz minimum 500 W capability
- AC Wattmeter – 300 W minimum, true RMS input voltage, current, power factor, and THD 0.2% accuracy or better
- DC Voltmeter – 300 V dc minimum 0.1% accuracy or better
- DC Ammeter – 1 A dc minimum 0.1% accuracy or better
- LED Load – 75 V @ 0.1 A. A constant voltage electronic load is an acceptable substitute for the LEDs as long as it is stable

Test Connections

1. Connect the LED load to the red(+) and black(−) leads through the ammeter shown in Figure 14. **Caution:** Observe the correct polarity or the load may be damaged.
2. Connect the AC power to the input of the AC wattmeter shown in Figure 14. Connect the white leads to the output of the AC wattmeter.
3. Connect the DC voltmeter as shown in Figure 14.

Functional Test Procedure

1. Set the LED Load for 75 V output.
2. Set the input power to 120 V 60 Hz. **Caution:** Do not touch the ECA once it is energized because there are hazardous voltages present.



NOTE: Unless otherwise specified, all voltage measurements are taken at the terminals of the UUT.

Figure 14. Test Set Up

Line and Load Regulation

Table 2. 120 V/MAX LOAD

LED Output	Output Current 100 mA ± 3 mA	Output Power	Power Factor	
75 V				3.3 V Load = 0
75 V				3.3 V Load = 20 mA

	Output Voltage			
Aux Voltage	Min	Measured	Max	
3.3 V	3.0 V		3.6 V	LED Current = Max
3.3 V	3.0 V		3.6 V	LED Current = 0 (Dim = 0 V)
3.3 V	3.0 V		3.6 V	On/Off = Off

$$\text{Efficiency} = \frac{V_{OUT} \cdot I_{OUT}}{P_{IN}} \cdot 100\%$$

TEST DATA

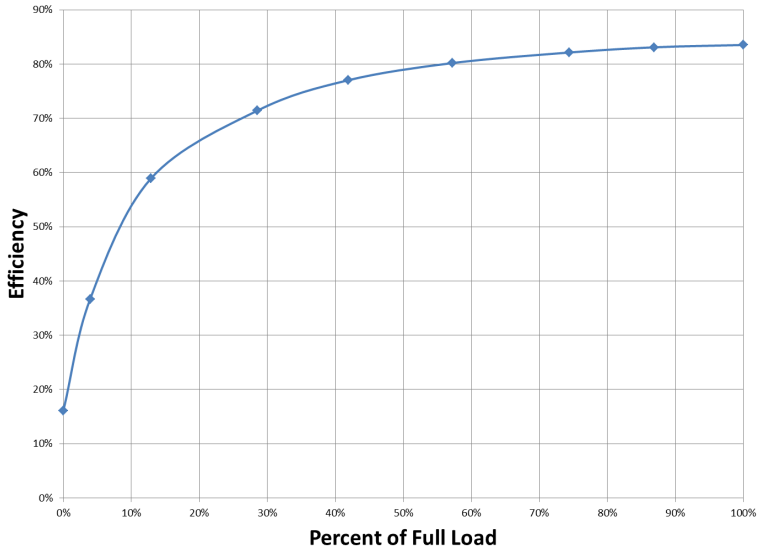


Figure 15. Efficiency over Load

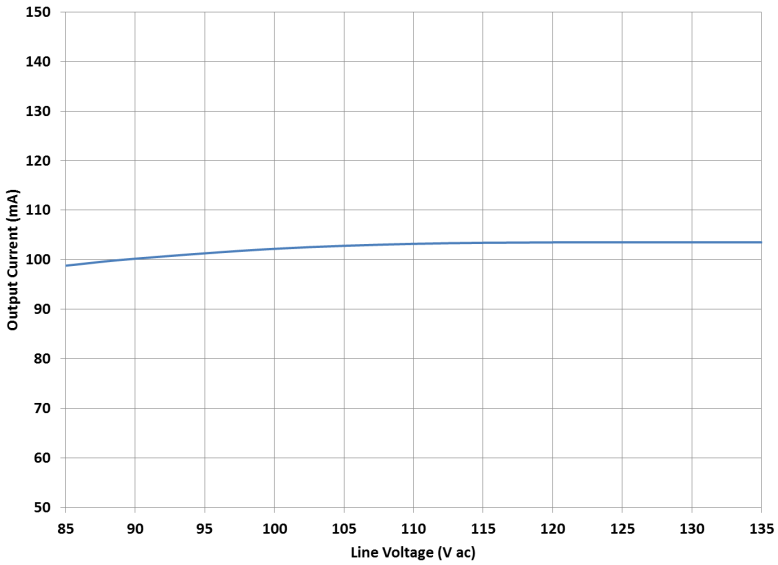


Figure 16. Regulation over Line

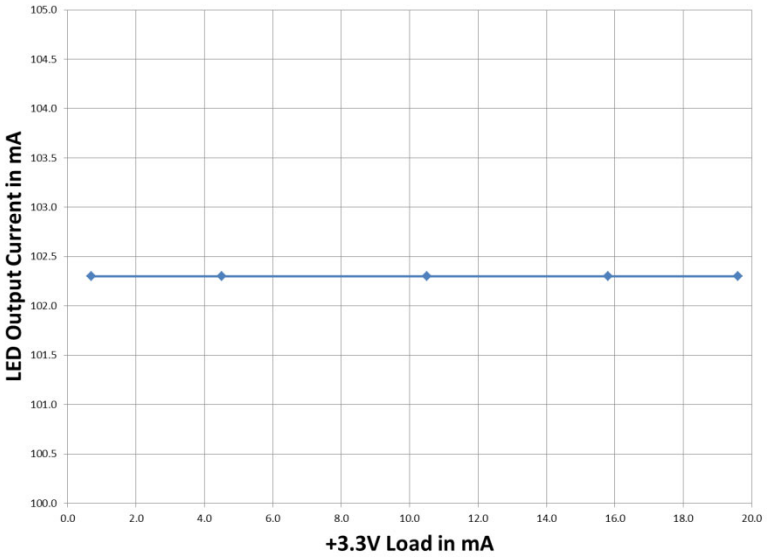


Figure 17. Cross Regulation Effect of +3.3 Load on Output Current

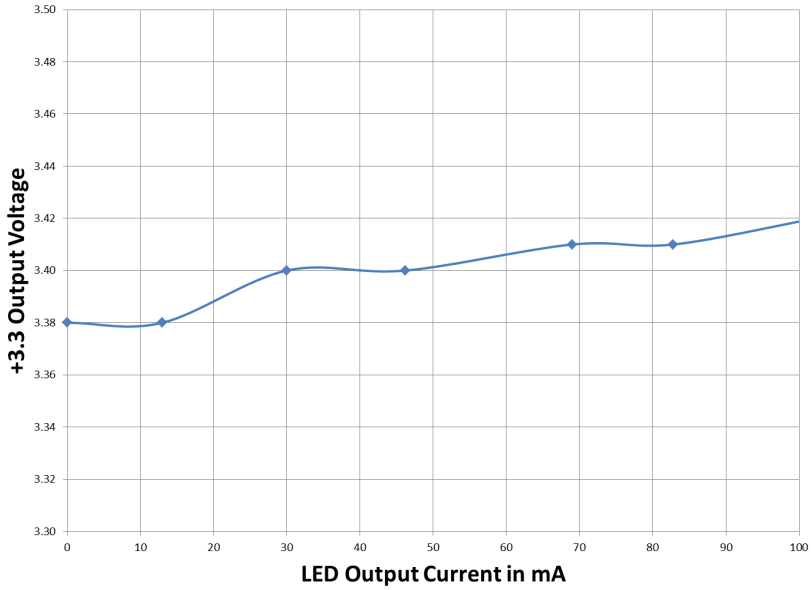


Figure 18. Cross Regulation Effect of Output Current on +3.3 V Output

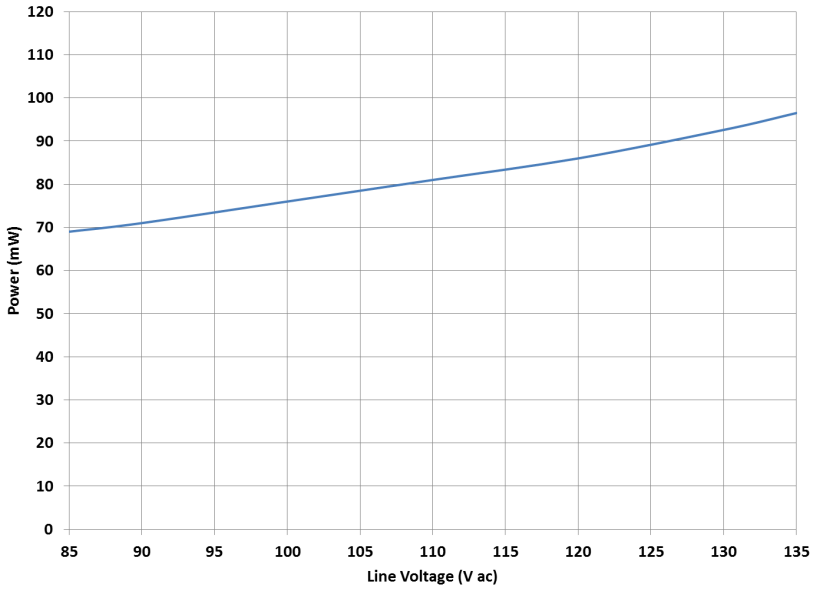


Figure 19. Standby Power Consumption over Line

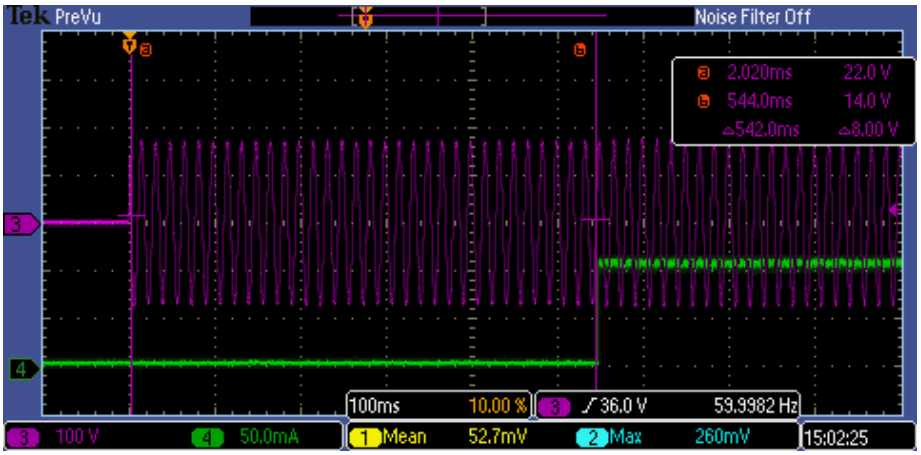


Figure 20. Start Up with AC Applied 120 V Maximum Load

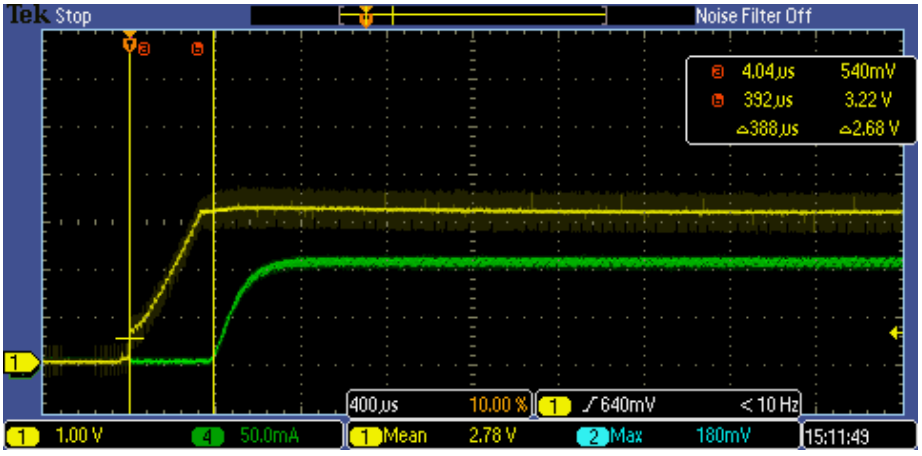


Figure 21. Start Up with Enable

BILL OF MATERIALS

Table 3. NCL30082SMRTGEVB BILL OF MATERIALS

Qty.	Reference	Part	Manufacturer	Manufacturer Part Number	PCB Footprint	Substitution Allowed
4	C13, C15, C_{ZIG}, C_{VCC}	4.7 μF	Taiyo Yuden	EMK107ABJ475KA-T	603	Yes
1	C_{OUT}	4.7 μF, 100 V	AVX	12061Z475KAT2A	1206	Yes
2	C3, C5	100 nF, 250 V	Epcos	B32559-C3104-+***	CAP-BOX-LS5-3M5X7M2	Yes
1	C4	10 μF, 200 V	Rubycon	200LLE10MEFC8X11.5	CAP-ALEL-8X12-HOR	Yes
2	C10, C11	1 nF	Kemet	C0402C102K3GACTU	402	Yes
1	D_{OUT}	UFM15PL	MCC	UFM15PL	SOD123FL	Yes
1	D4	ABS10	Comchip	ABS10	ABS10	Yes
2	D9, D13	BAS21DW5T1G	ON Semiconductor	BAS21DW5T1G	SC-88A	No
3	D10, D12, D15	MM5Z15VT1G	ON Semiconductor	MM5Z15VT1G	SOD523	No
1	D11	BAS116LT1G	ON Semiconductor	BAS116LT1G	SOT23	No
1	D14	BAS16XV2T1G	ON Semiconductor	BAS16XV2T1G	SOD523	No
1	F1	FUSE	Littelfuse	0263.500WRT1L	FUSE-AXIAL-LS450	Yes
1	J7	TMS−103−02−G−D	Samtec	TMS-103-02-G-D	Conn_Samtec_2X3	Yes
1	L1	1.5 mH	Wurth	7447462152	IND-UPRIGHT-LS25	Yes
1	L2	1.5 mH	Wurth	7447462152	IND-HOR-LS25	Yes
1	Q_{FET}	NDD02N60Z	ON Semiconductor	NDD02N60Z	IPAK	No
2	Q1, Q2	MMBT3904WT1G	ON Semiconductor	MMBT2904WT1G	SOT323	No
1	Q3	MMBTA06LT1G	ON Semiconductor	MMBTA06LT1G	SOT23	No
1	Q4	BSS138	ON Semiconductor	BSS138	SOT23	No
1	R_{BO}	3.01 MΩ	Yaego	RC0805FR-073M01L	805	Yes
1	R_{DAMP}	180 Ω	Yaego	RC0805JR-07180RL	805	Yes
1	R_{IFF}	620 Ω	Yaego	RC0402FR-07620RL	402	Yes
1	R_{SENSE}	1 Ω	Yaego	RC1206FR-071RL	1206	Yes
2	R_{START1}, R_{START}	1.0 MΩ	Yaego	RC0805FR-071ML	805	Yes
1	R_{TCO}	100 kΩ NTC	Epcos	B57331V2104J60	603	Yes
2	R20, R_{ZCD}	56 kΩ	Yaego	RC0805FR-0756KL	805	Yes
1	R2	51.1 kΩ	Yaego	RC0402FR-0751K1L	402	Yes
2	R6, R10	10 kΩ	Yaego	RC0402FR-0710KL	402	Yes
1	R7	470 Ω	Yaego	RC0402FR-07470RL	402	Yes
4	R8, R9, R15, R19	100 kΩ	Yaego	RC0402FR-07100KL	402	Yes
1	R11	12 kΩ	Yaego	RC0402FR-0712KL	402	Yes
1	R16	40.2 kΩ	Yaego	RC0402FR-0740K2L	402	Yes
1	R18	62 Ω	Yaego	RC0402FR-0762RL	402	Yes
1	R21	3.32 kΩ	Yaego	RC0402FR-073K32L	402	Yes
1	T1	XFRM_LINEAR	Wurth	750315096	RM5_8P_TH	Yes
1	U1	NCL30082B	ON Semiconductor	NCL30082B	MICRO8	No
1	U2	LP2951ACDM−3.3	ON Semiconductor	LP2951ACDM-3.3	MICRO8	No
1	U4	NCP431A	ON Semiconductor	NCP431A	SOT23	No
1	U5	LM317	ON Semiconductor	LM317LBDR2G	TO92	No
6″	W1	Wire, Red, 24AWG	McMaster Carr	7587K922	UL1569	Yes
6″	W2	Wire, Blk, 24AWG	McMaster Carr	7587K921	UL1569	Yes
12″	W3, W4	Wire, Wht, 24AWG	McMaster Carr	7587K924	UL1569	Yes

NOTE: All components to comply with RoHS 2002/95/EC.

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