

AN-2061 LM3445 A19 Edison Retrofit Evaluation Board

1 Introduction

The evaluation board included in this shipment converts 85V_{AC} to 135V_{AC} input and drives five to thirteen series connected LED's at the currents listed in the *Evaluation Board Operating Conditions* section. This is a two-layer board using the bottom and top layer for component placement. The board is surrounded by a larger area allowing for extra test points and connectors for ease of evaluation. The actual board size is contained inside the larger outer area and can be cut out for the smallest size possible. The evaluation board can be modified to adjust the LED forward current and the number of series connected LEDs. The topology used for this evaluation board eliminates the need for passive power factor correction and results in high efficiency and power factor with minimal component count which results in a size that can fit in a standard A19 Edison socket. This board also operates correctly and dims smoothly using most standard triac dimmers. Output current is regulated within $\pm 15\%$ of nominal from circuit to circuit and over line voltage variation. For details on the LM3445 IC, see the *LM3445 Triac Dimmable Offline LED Driver Data Sheet* ([SNVS570](#)).

A bill of materials shown in [Table 2](#) describes the parts used on this demonstration board. A schematic and layout have also been included along with measured performance characteristics including EMI/EMC data. The above restrictions for the input voltage are valid only for the demonstration board as shipped with the schematic below. for detailed information regarding the LM3445 device, see the *LM3445 Triac Dimmable Offline LED Driver Data Sheet* ([SNVS570](#)). The board is currently set up to drive five to thirteen series connected LEDs, but the evaluation board may be modified to accept more series LEDs. Refer to the tables in this document to modify the board to accept more LEDs and/or adjust for different current levels.

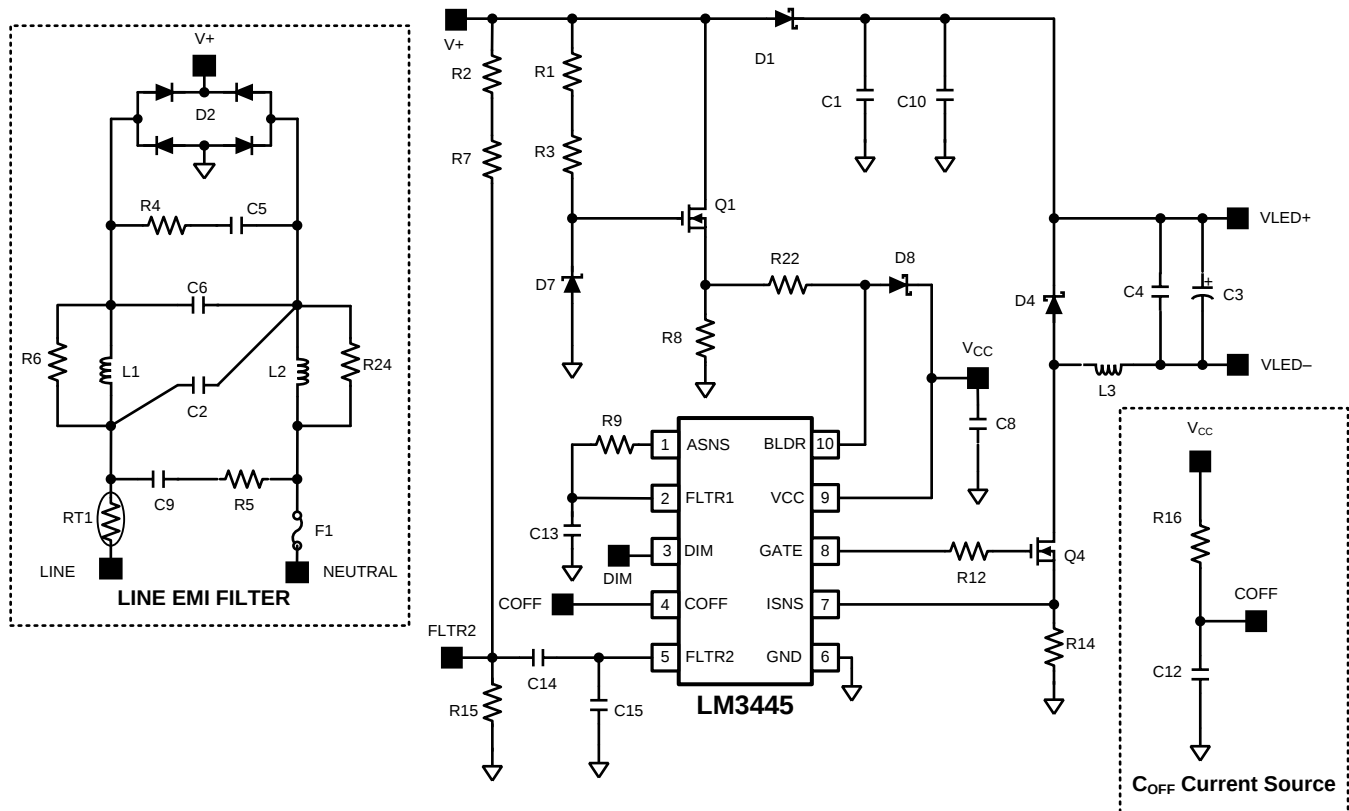
2 Evaluation Board Operating Conditions

$V_{IN} = 85V_{AC}$ to $135V_{AC}$

5 to 13 series connected LEDs as configured with the currents listed below:

- Can drive up to 18 series LEDs (see table)
- $I_{LED} = 340$ mA (5 LEDs)
- $I_{LED} = 300$ mA (7 LEDs)
- $I_{LED} = 260$ mA (9 LEDs)
- $I_{LED} = 230$ mA (11 LEDs)
- $I_{LED} = 205$ mA (13 LEDs)

3 Simplified LM3445 Schematic



WARNING

The LM3445 evaluation boards have no isolation or any type of protection from shock. Caution must be taken when handling evaluation board. Avoid touching evaluation board, and removing any cables while evaluation board is operating. Isolating the evaluation board rather than the oscilloscope is highly recommended.

WARNING

This LM3445 evaluation PCB is a non-isolated design. The ground connection on the evaluation board is NOT referenced to earth ground. If an oscilloscope ground lead is connected to the evaluation board ground test point for analysis, and AC power is applied, the fuse (F1) will fail open. The oscilloscope should be powered via an isolation transformer before an oscilloscope ground lead is connected to the evaluation board.

4 Pin-Out

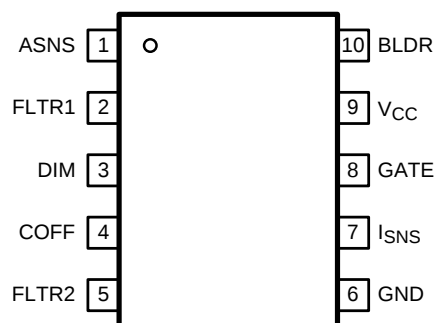
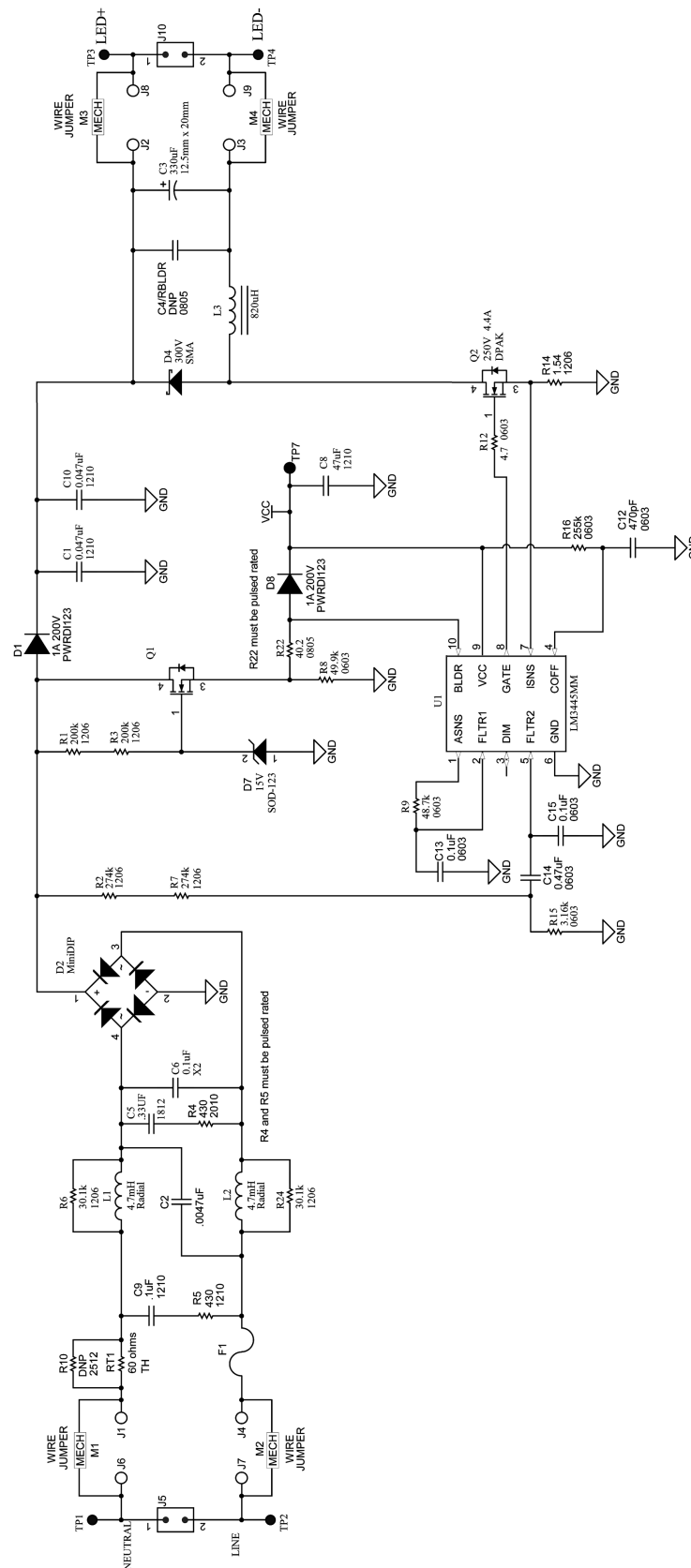


Figure 1. 10-Pin VSSOP

Table 1. Pin Description 10 Pin VSSOP

Pin No	Name	Description
1	ASNS	PWM output of the triac dim decoder circuit. Outputs a 0 to 4V PWM signal with a duty cycle proportional to the triac dimmer on-time.
2	FLTR1	First filter input. The 120Hz PWM signal from ASNS is filtered to a DC signal and compared to a 1 to 3V, 5.85 kHz ramp to generate a higher frequency PWM signal with a duty cycle proportional to the triac dimmer firing angle. Pull above 4.9V (typical) to tri-state DIM.
3	DIM	Input/output dual function dim pin. This pin can be driven with an external PWM signal to dim the LEDs. It may also be used as an output signal and connected to the DIM pin of other LM3445 or LED drivers to dim multiple LED circuits simultaneously.
4	COFF	OFF time setting pin. A user set current and capacitor connected from the output to this pin sets the constant OFF time of the switching controller.
5	FLTR2	Second filter input. A capacitor tied to this pin filters the PWM dimming signal to supply a DC voltage to control the LED current. Could also be used as an analog dimming input.
6	GND	Circuit ground connection.
7	ISNS	LED current sense pin. Connect a resistor from main switching MOSFET source, ISNS to GND to set the maximum LED current.
8	GATE	Power MOSFET driver pin. This output provides the gate drive for the power switching MOSFET of the buck controller.
9	V _{CC}	Input voltage pin. This pin provides the power for the internal control circuitry and gate driver.
10	BLDR	Bleeder pin. Provides the input signal to the angle detect circuitry as well as a current path through a switched 230Ω resistor to ensure proper firing of the triac dimmer.

5 LM3445 Evaluation Board Schematic



6 Bill of Materials (BOM) LM3445 Evaluation Board

Table 2. Bill of Materials (BOM)

REF DES	Description	MFG	MFG Part Number
U1	IC DRIVER LED W/TRIAC DIM 10VSSOP	Texas Instruments	LM3445
C1, C10	Ceramic, 47000pF, 500V, X7R, 1210	Johanson Dielectrics	501S41W473KV4E
C2	CAP FILM MKP .0047μF 310VAC X2	Vishay/BC Components	BFC233820472
C3	CAP 470μF 50V ELECT PW RADIAL	Nichicon	UPW1H471MHD
C4/RBLDR ⁽¹⁾	DNP		
C5	Ceramic, .33μF, 250V, X7R, 1812	TDK Corporation	C4532X7R2E334K
C6	CAP .10μF 305VAC EMI SUPPRESSION	EPCOS	B32921C3104M
C8	Ceramic, 47μF, X5R, 16V, 1210	MuRata	GRM32ER61C476ME15L
C9	Ceramic, .1μF, 250V, X7R, 1210	Taiyo Yuden	QMK325B7104KN-T
C12	Ceramic, 470pF, 50V, X7R, 0603	MuRata	GRM188R71H471KA01D
C13, C15	Ceramic, 0.1μF, 16V, X7R, 0603	MuRata	GRM188R71C104KA01D
C14	Ceramic, 0.47μF, 16V, X7R, 0603	MuRata	GRM188R71C474KA88D
D1	DIODE SCHOTTKY 1A 200V PWRDI 123	Diodes Inc.	DFLS1200-7
D2	Bridge Rectifier, Vr = 400V, Io = 0.8A, Vf = 1V	Diodes Inc.	HD04-T
D4	DIODE FAST 1A 300V SMA	Fairchild Semi conductor	ES1F
D7	DIODE ZENER 15V 500MW SOD-123	Fairchild Semi conductor	MMSZ5245B
D8	DIODE SCHOTTKY 1A 200V PWRDI 123	Diodes Inc.	DFLS1200-7
F1	FUSE 1A 125V FAST	Cooper/Bussman	6125FA1A
J5, J10	CONN HEADER .312 VERT 2POS TIN	Tyco Electronics	1-1318301-2
L1, L2	INDUCTOR 3900μH .12A RADIAL	J.W. Miller/Bourns	RL875S-392K-RC
L3	820μH, Shielded Drum Core	Coilcraft Inc.	MSS1038-824KL
M1	JUMPER WIRE 0.3" J6 TO J1	3M	923345-03-C
M2	JUMPER WIRE 0.3" J7 TO J4	3M	923345-03-C
M3	JUMPER WIRE 0.3" J2 TO J8	3M	923345-03-C
M4	JUMPER WIRE 0.3" J3 TO J9	3M	923345-03-C
Q1	MOSFET N-CH 240V 260MA SOT-89	Infineon Technologies	BSS87 L6327
Q2	MOSFET N-CH 250V 4.4A DPAK	Fairchild Semi conductor	FDD6N25TM
R1, R3	RES 200kΩ, 0.25W, 1%, 1206	Vishay-Dale	CRCW1206200kFKEA
R2, R7	RES 274kΩ, 0.25W, 1%, 1206	Vishay-Dale	CRCW1206274kFKEA
R4	RES 430Ω, 1/2W, 5%, 2010	Vishay-Dale	CRCW2010430RJNEF
R5	RES 430Ω, 1/3W, 5%, 1210	Vishay-Dale	CRCW1210430RJNEA
R6, R24	RES 30.1kΩ, 0.25W, 1%, 1206	Vishay-Dale	CRCW120630k1FKEA
R8	RES 49.9kΩ, 0.1W, 1%, 0603	Vishay-Dale	CRCW060349K9FKEA
R9	RES 48.7kΩ, 0.1W, 1%, 0603	Vishay-Dale	CRCW060348K7FKEA
R10	DNP		
R12	RES 4.7Ω, 0.1W, 5%, 0603	Vishay-Dale	CRCW06034R70JNEA
R14	RES 1.54Ω, 1/4W, 1%, 1206	Vishay-Dale	CRCW12061R54FNEA
R15	RES 3.16kΩ, 0.1W, 1%, 0603	Vishay-Dale	CRCW06033K16FKEA
R16	RES 255kΩ, 0.1W, 1%, 0603	Vishay-Dale	CRCW0603255KFKEA
R22	RES 40.2Ω, 0.125W, 1%, 0805	Vishay-Dale	CRCW080540R2FKEA
RT1	CURRENT LIMITOR INRUSH 60Ω 20%	Cantherm	MF72-060D5
TP1, TP2, TP3, TP4	Terminal, Turret, TH, Double	Keystone Electronics	1502-2

⁽¹⁾ C4/RBLDR is a dual purpose pad which is unpopulated by default. A ceramic capacitor (C4) may be used here if extra high frequency bypassing is desired across the LED load. Alternatively a bleeder resistor (RBLDR) in the range of 10kΩ to 100kΩ may be placed here to quickly discharge C3 and prevent prolonged LED glow due to the energy stored in C3.

7 Output Current versus Number of LEDs for Various Modifications

# of LEDs	Output Current (mA) Original Circuit	Output Current (mA) Modification A ⁽¹⁾	Output Current (mA) Modification B ⁽²⁾	Output Current (mA) Modification C ⁽³⁾
2				520
3				500
4				475
5	340	248	265	455
6	315	235	250	432
7	300	222	237	412
8	275	210	224	
9	260	200	212	
10	245	190	200	
11	230	180	190	
12	215	170	180	
13	205	164	170	
14 ⁽⁴⁾	196	156	162	
15 ⁽⁴⁾	190	150	155	
16 ⁽⁴⁾	183	142	148	
17 ⁽⁴⁾	175	135	142	
18 ⁽⁴⁾	170	130	137	

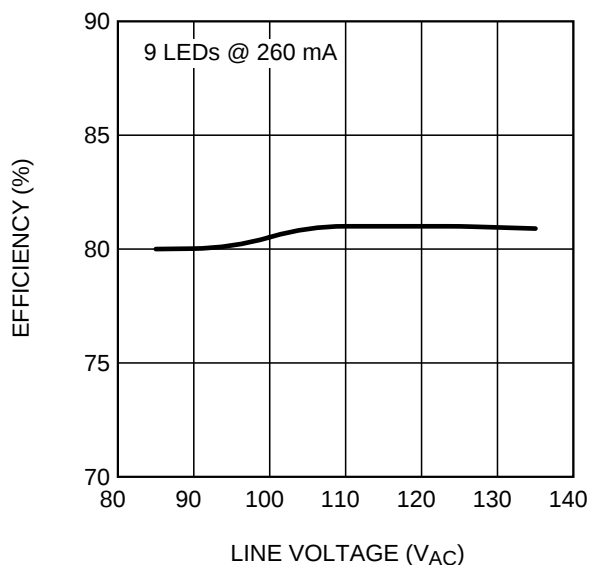
⁽¹⁾ Modification A: R14 = 2.37 Ω , R16 = 150k Ω , C3 = 330 μ F, 63V.

⁽²⁾ Modification B: R14 = 2.2 Ω , R16 = 165k Ω .

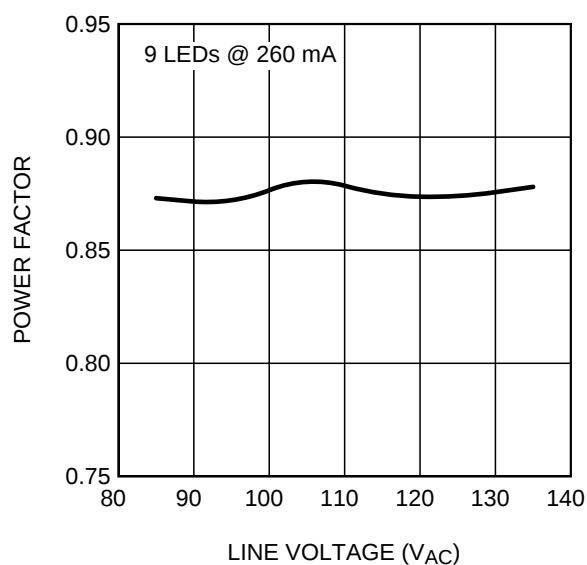
⁽³⁾ Modification C: R14 = 1.2 Ω , R16 = 137k Ω , L3 = 470 μ H, C3 = 1000 μ F, 25V.

⁽⁴⁾ For all applications using greater than 13 LEDs a 330 μ F, 63V output capacitor (C3) was used.

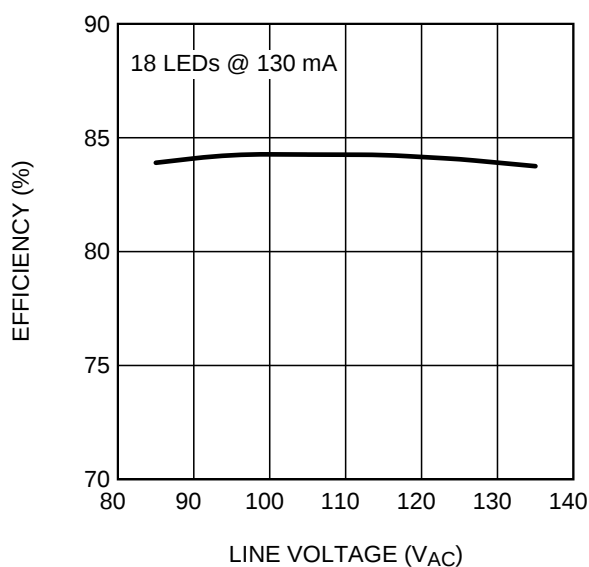
8 Typical Performance Characteristics



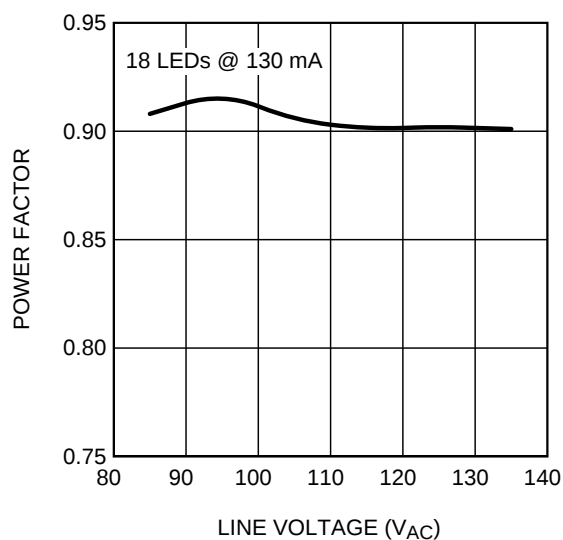
**Figure 2. Efficiency vs. Line Voltage
Original Circuit**



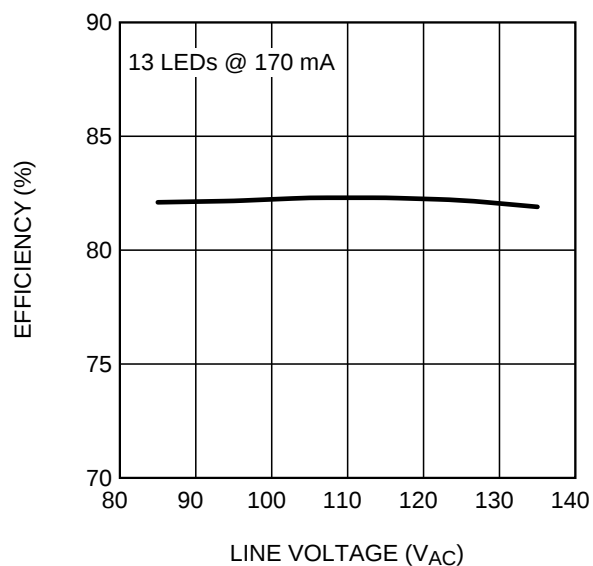
**Figure 3. Power Factor vs. Line Voltage
Original Circuit**



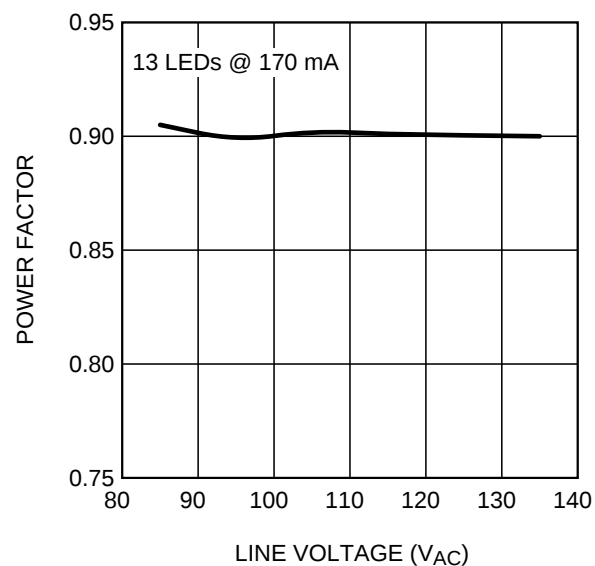
**Figure 4. Efficiency vs. Line Voltage
Modification A**



**Figure 5. Power Factor vs. Line Voltage
Modification A**



**Figure 6. Efficiency vs. Line Voltage
Modification B**



**Figure 7. Power Factor vs. Line Voltage
Modification B**

9 PCB Layout

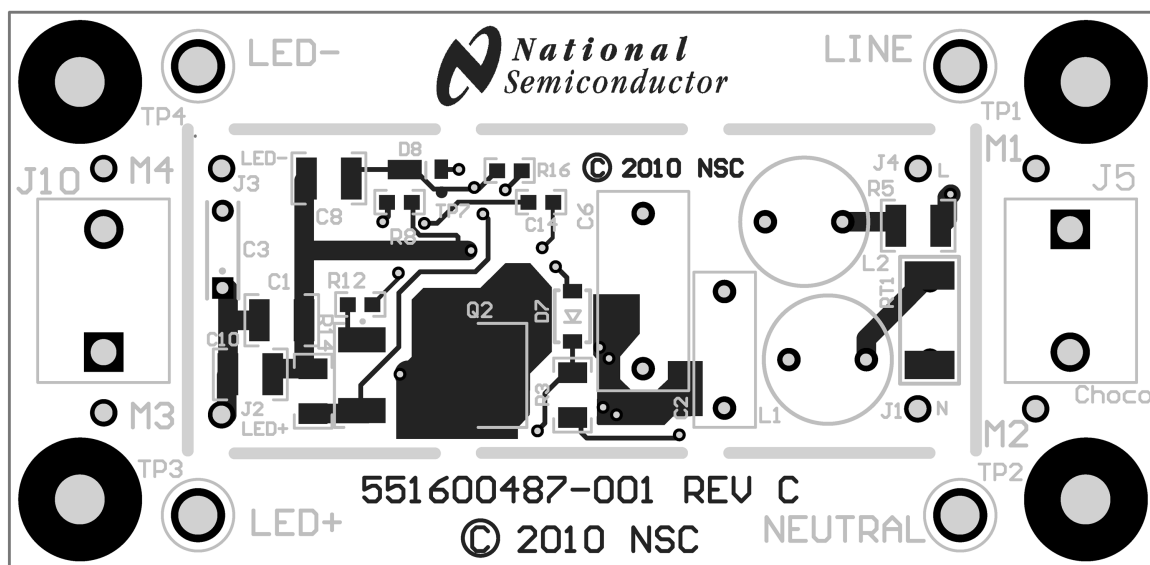


Figure 8. Top Layer

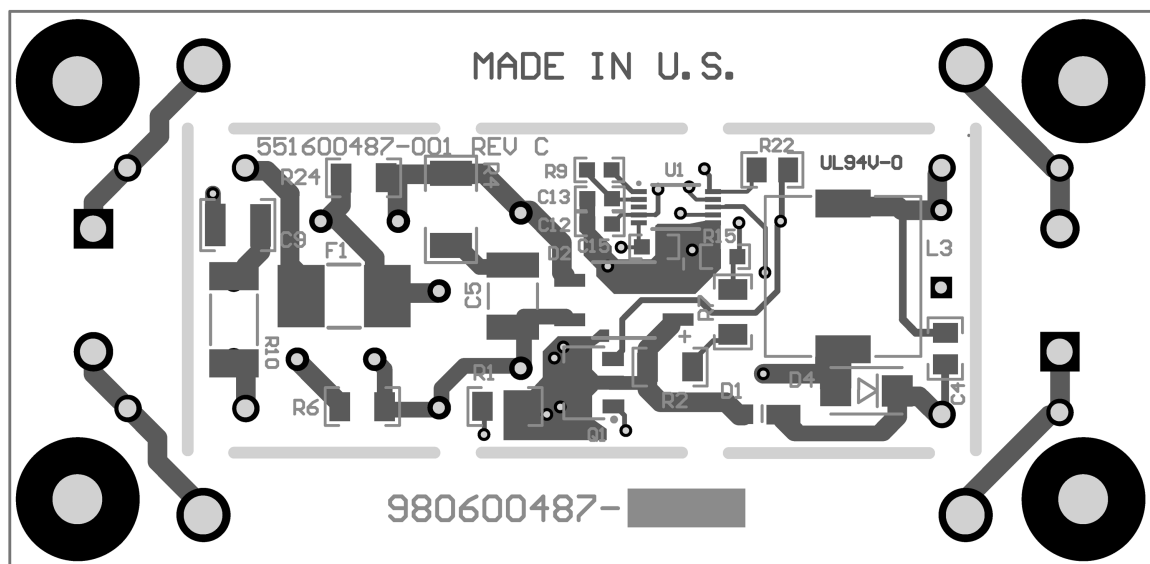


Figure 9. Bottom Layer

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10 EMI/EMC Information

LM3445-EDSNEV Radiated

30 - 1,000 MHz, Peak data - Tested by EMI Test Lab, emitestlab.com, CISPR B @ 10 M

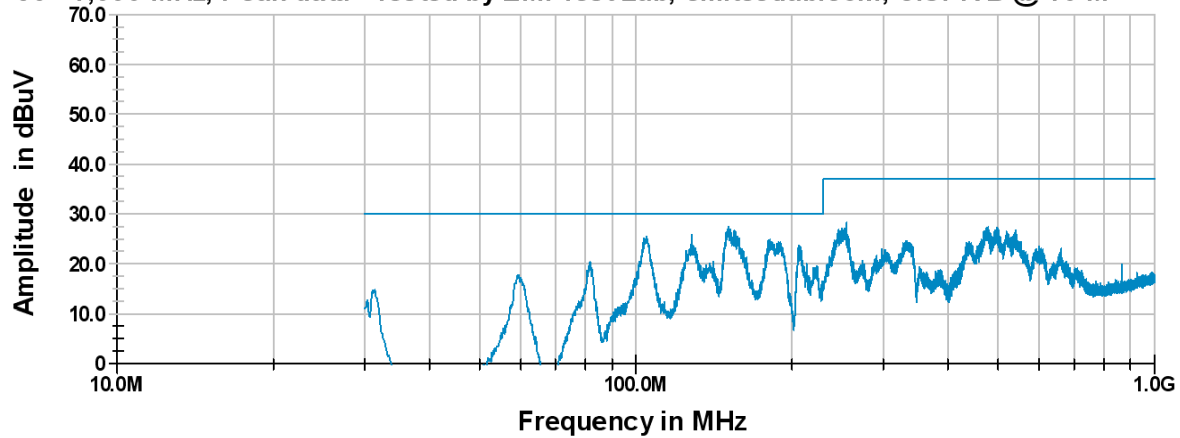


Figure 10. Radiated EMI

LM3445-EDSNEV Conducted

120V 60Hz, Line and Neutral - CISPR/FCC Class B - quasi peak and average limits
Peak Scan - Tested by EMI Test Lab, emitestlab.com

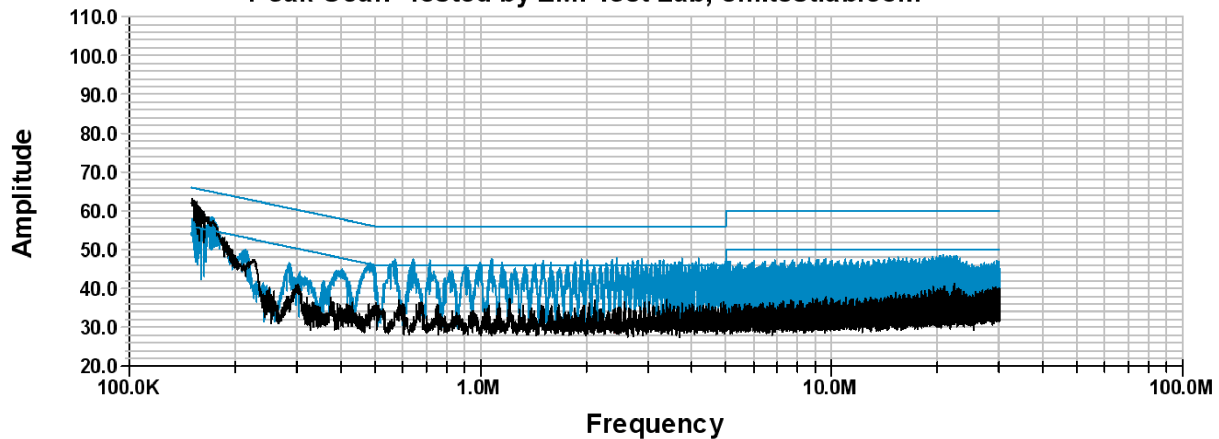


Figure 11. Conducted EMC. Line = Blue, Neutral = Black

	Frequency	Quasi-Peak Amplitude	Quasi-Peak Limit	Quasi-Peak Delta	Average Amplitude	Average Limit	Average Delta
Neutral	154 kHz	57	66	-9	47	56	-9
Line	1.1 MHz				31	46	-15

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