UM10589

SSL2129AT 12 W 230 V flyback mains dimmable LED driver

Rev. 1 — 11 December 2012 **User manual**

Document information

Info	Content
Keywords	SSL2129AT, SSL2129ADB1101, mains dimmable, AC/DC conversion, flyback, LED driver
Abstract	This user manual describes the operation of an SSL2129AT 12 W 230 V flyback mains dimmable LED driver demo board.

Revision history

Rev	Date	Description
v.1	20121211	first issue

Contact information

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1. Introduction

WARNING

Lethal voltage and fire ignition hazard

The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire.

This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

This manual describes the performance, technical data and connections of the SSL2129AT 12 W 230 V (AC) flyback mains dimmable demo board. The SSL2129AT driver is a solution for a professional application with multiple high-power LEDs that require galvanic isolation and a safe output voltage.

The driver is mains dimmable for both leading edge triac dimmers, and trailing edge transistor dimmers. Examples include shelf lighting, down lighting and LED lighting for bathrooms. The design demonstrates how to produce a driver that is suitable for small form factor applications such as retrofit lamps.

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Fig 1. Demo board (front view)

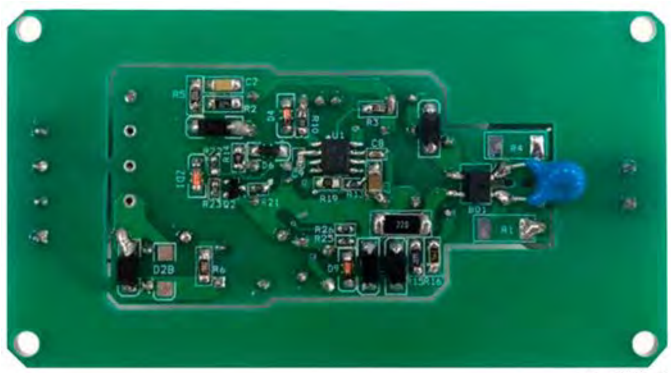

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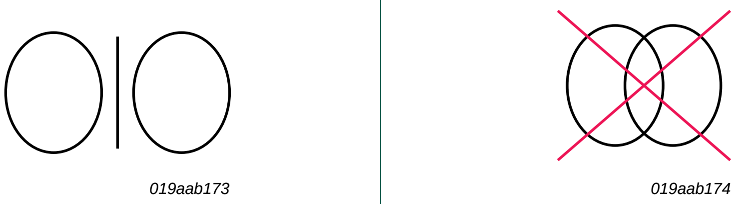
Fig 2. Demo board (back view)

2. Safety Warning

This board is connected to the mains voltage. Avoid touching the board while it is connected to the mains voltage. An isolated housing is mandatory when used in uncontrolled, non-laboratory environments. Galvanic isolation of the mains phase using a variable transformer is always recommended.



a. isolated

b. non-isolated

Fig 3. Variable transformer isolation symbols

3. Specifications

Table 1. Specifications for the SSL2129AT 12 W 230 V demo board

Symbol	Parameter	Condition	Value
V_{mains}	mains input voltage		196 V (AC) to 264 V (AC); 50 Hz
$V_{o(LED)}$	LED output voltage		40 V (DC)
$V_{O(ovp)}$	output voltage protection	IC latched	56 V (DC)
$I_{o(LED)}$	LED output current		240 mA
$\Delta I_{O(LED)}/\Delta V_{mains}$	line regulation	load current dependency	0.89 mA/V (±0.19 % at nominal V_{in} = 230 V (AC))
$\Delta I_{O(LED)}/\Delta V_{O(LED)}$	load regulation	load current dependency	2.65 mA/V (±0.5 % at nominal I_{LED} = 240 mA)
η	efficiency		82 % at V_{mains} = 230 V (AC) and $V_{o(LED)}$ = 40 V (DC)
PF	Power Factor		>0.9 at V_{mains} = 230 V (AC) and $V_{o(LED)}$ = 40 V (DC)
V_{isol}	isolation voltage		4 kV between primary and secondary circuit
THD	Total Harmonic Distortion		<30 %
PCB size	Length × Width × Height	Internal dimensions	63 mm × 34 mm × 25 mm
		External dimensions	94 mm × 54 mm × 25 mm

Remark: EMC Compliance: FCC15 and EN55015.

4. Functional description

4.1 Overview

The converter in the SSL2129AT is a Boundary Conduction Mode (BCM), peak current controlled system. The convertor can control and drive a buck, tapped buck or flyback component, and ensures proper dimmer operation.

Figure 12 shows the schematic of the board.

4.2 Start-up and VCC supply

The charging current flows from R3 and the high-voltage HV pin via an internal start-up current source to the VCC pin. The IC starts switching when the voltage on pin VCC exceeds the $V_{CC(start)}$ level 13 V (max). After start-up, an auxiliary winding connection provides the required external supply. Design the voltage of the auxiliary winding to a minimum of 20 V to ensure that the VCC supply voltage is larger than 8 V at nominal mains.

4.3 Mains dimmer compatibility

The SSL2129AT achieves mains dimmer compatibility using dynamic TON control. This control is used to shape an input current waveform. Thus providing the most effective current to load the dimmer over most of the mains cycle. At dimmed position, output current is controlled both by the conductive phase of the dimmer and the slope current control of the TONMOD function. An additional advantage of this method is a high-power factor.

4.4 Holding current

Q3, R18 and R20 create a bleeder circuit, providing the holding current for mains dimmer, parallel with flyback input current. Resistor R24 sets the minimum holding current. At high level dimming, the flyback input current provides most of the holding current. At low level dimming, the bleeder circuit provides most of it. Sufficient holding current keeps dimming stable and the system effective.

4.5 Deep dimming

At low level dimming, the voltage of R17 drops and extra current from R13 and Q1 boosts charging of C9. The t_{on} time is reduced and the power transferred to the secondary side is reduced. The output current can then be smaller. There is no need for deep dimming circuits for some dimmers, especially in 100 V (AC) or 120 V (AC) applications. Several components are then no longer required (R8, R9, R17, C11, Q1, R13, D11,R27) when there is no need for good line regulation.

4.6 OverVoltage Protection

If no control is implemented when output starts, the output voltage boosts to a high value. An auxiliary winding coupled with a secondary winding can be used to sense the output voltage. When the output voltage is too high, Q2 and ZD1 form a circuit to pull down the voltage on the NTC pin. The IC then stops working and runs in safe restart mode.

5. System Optimization

The following modifications can be made to meet customer application specifications.

5.1 Set the minimum holding current

The forward voltage of D8 and the sensing resistor R24 determines the minimum holding current.

The minimum holding current can be estimated from the following equation:

$$I_{hold} = \frac{V_F}{R24} \tag{1}$$

For example, at least 30 mA is needed for dimmers in 230 V (AC) applications. The forward voltage of D10 is 0.7 V, so the sensing resistor is 0.7 V / 30 mA = 23.3 Ω. 22 Ω is chosen.

5.2 Change the output ripple current

The LED voltage, the LED dynamic resistance and the output capacitor mostly determine the output current ripple. The current value of C4 and C5 has been chosen to optimize capacitor size with light output. A ripple of ±25 % results in an expected deterioration of light output <1 %.

The size for the buffer capacitor can be estimated from the following equation:

$$C_{out} = \frac{I_{o(LED)}}{\Delta I} \times \frac{1}{6 \times f_{mains} \times R_{dyn}} \tag{2}$$

Using a series of LEDs, the dynamic resistance of each LED can be added to the total dynamic resistance. With 50 Hz or 60 Hz, f_{mains} is the AC mains frequency.

5.3 Improve line regulation

To optimize line regulation for output current, add Zener diode D11 and resistor R27 to reduce the peak current of MOSFET M1 during mains voltage raise (see Figure 4).

Table 2 shows the line regulation test results. The line regulation of the LED current improves by 0.12mA/V.

Table 2. Improved line regulation test results

V_{mains} (V)	P_{in} (W)	PF	$V_{o(LED)}$ (V)	$I_{O(LED)}$ (mA)
200	11.16	0.93	40.426	225
230	11.42	0.912	40.445	229
265	12.12	0.897	40.46	233

Table 3. Component changes

Part ref	Description	Manufacturer	Remarks
C9	capacitor; ceramic; 39 pF; 50 V; 2 %; 0603; COG	Murata	value change
C11	capacitor; ceramic; 0.15 μF; 35 V; 0805; X7R	Murata	remove
C13	capacitor; ceramic; 0.082 μF; 200 V; 1206; X7R	Murata	add
D11	Zener; 56 V; 0.5 W; SOD323; BZX384C56	NXP semiconductors	add
R11	resistor; chip; 1.2 Ω; 1 %; 0805	TA-I	value change
R12	resistor; chip; 4.3 Ω; 1 %; 0805	TA-I	value change
R13	resistor; chip; 22 kΩ; 5 %; 0603	TA-I	value change
R27	resistor; chip; 300 kΩ; 5 %; 0603	TA-I	add

5.4 High accuracy design recommendations

- Use 1 % (or better) devices for peak current sensing resistors R11, R12
- Use 5 % (or better) inductance tolerance for transformer
- Use 2 % (or better) tolerance for COG ceramic capacitor C9

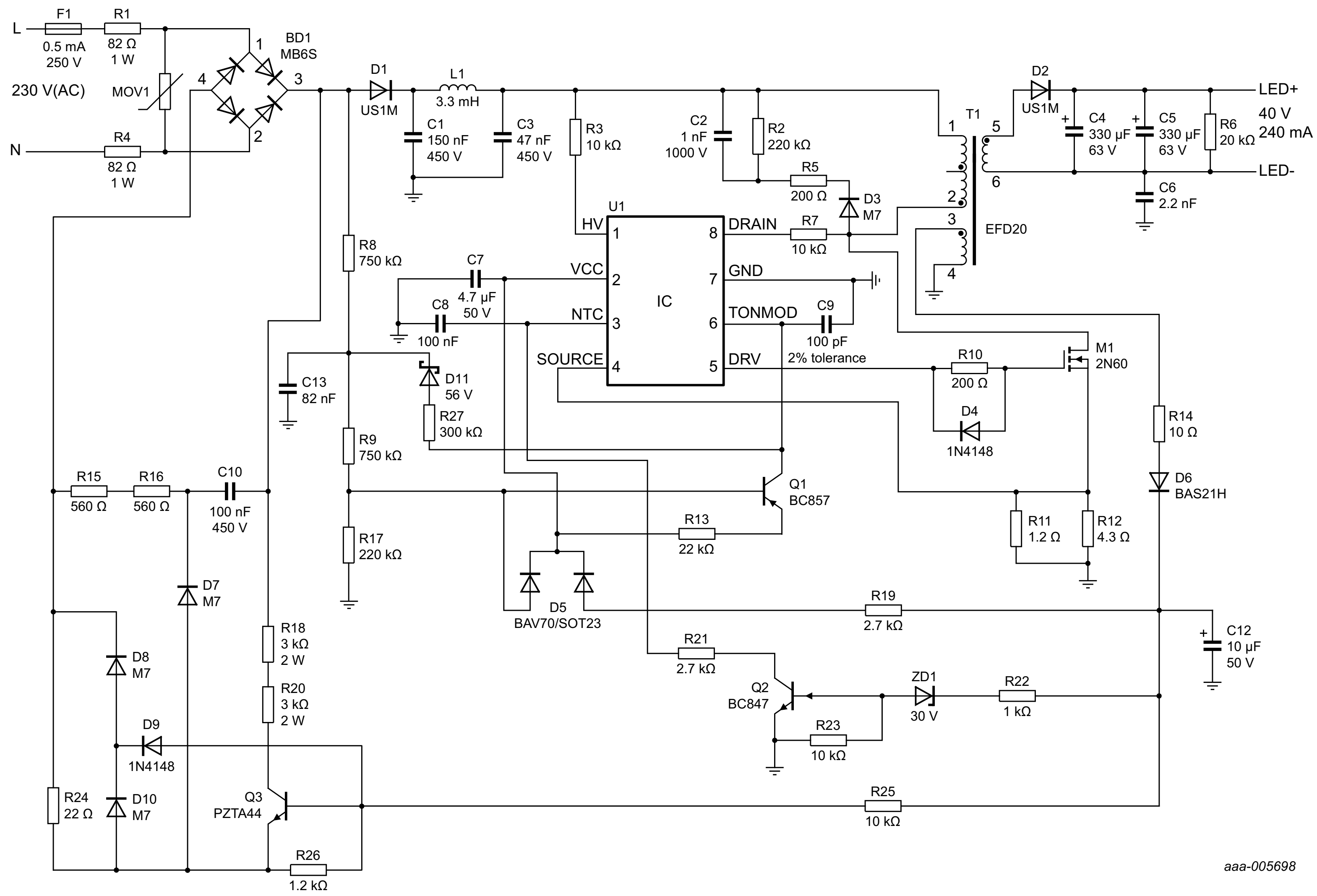


Fig 4. Schematic with improved line regulation

6. SSL2129AT demo board connections

The SSL2129AT 12 W board is optimized for a 230 V (AC) at 50 Hz mains supply. In addition, the board has been designed to work with multiple high-power LEDs with a total working voltage between 32 V (DC) and 48 V (DC). When attaching an LED load to an operational board (hot plugging), an inrush peak current occurs due to the discharge of capacitors C4 and C5. After frequent discharges, the LEDs can deteriorate or become damaged.

It is recommended for demonstration purposes, that the board is mounted in a shielded or isolated box.

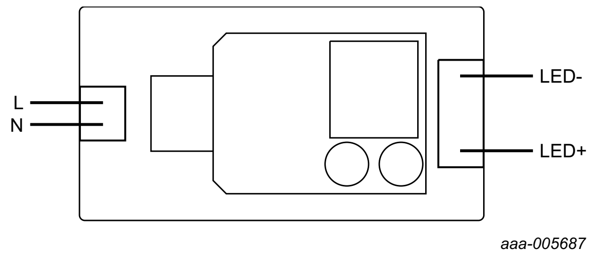


Fig 5. Connection to the SSL2129AT 12 W 230 V demo board (front)

If a galvanic isolated transformer is used, place it between the AC source and the demo board.

7. Dimmers

NXP Semiconductors have tested several triac and transistor-based dimmers. Table 4 shows a list of dimmers that have currently been tested with the board.

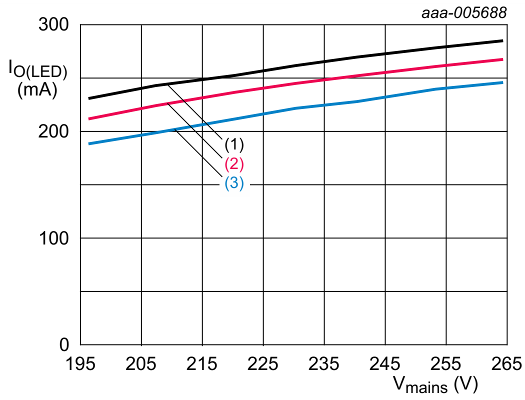
Table 4. Selection of dimmers tested

Manufacturer	$I_{o(LED)}$ no dimming (mA)	$I_{o(LED)}$ minimum dimming (mA)	$I_{o(LED)}$ maximum dimming (mA)	range (%)
Leading-edge				
Berker 2819	235	29	224	12.3[1] to 95.3
Berker 2873	235.47	11.72	220.66	4.98[1] to 93.71
GIRA 0300 00/I01	235	26	218	11.1[1] to 92.8
GIRA 1184 00/I00	235.47	4.84	234.67	2.06[1] to 99.6
Lichtregler T10	235.47	0.05	229.41	0.02[1] to 97.43
Busch 2200	235.47	12.27	223.37	5.21[1] to 94.86
Busch 2250U	235.47	5.07	226.04	2.15[1] to 96
Meierte	235.47	42.66	234.51	18.12[1] to 99.59
Shoniador	235.47	0.05	232.88	0.02[1] to 98.9
Peking Shitong	235.47	19.63	232.25	8.34[1] to 98.63
HPM Cat 250L	238	0.8	180.8	0.34 to 75.97
Legrand Cat 400L	238	11.5	182.7	4.83 to 76.76
HPM Cat 400L	238	7.8	185.6	3.28 to 77.98
NVC	238	21.7	236.4	9.12[1] to 99.93
Mank	238	24	236.2	10.08[1] to 99.24
LG Electric	238	47	232	19.75[1] to 97.48
Berker 2819	235	29	224	12.3[1] to 95.3
Berker 2873	235.47	11.72	220.66	4.98[1] to 93.71
Trailing-edge				
ABB-Busch 6513 U102	235.47	40.74	292.22	17.3[1] to 97.35
Berker 286170	235.47	23.86	170.35	10.13[1] to 72.34
Berker 2874	235.47	24.86	224.4	10.56[1] to 95.3
Jung 225TDE	235.47	25.85	224.09	10.98[1] to 95.17
Jung 243EX	235.47	20.35	227.02	8.64[1] to 96.41
Gira 030700/102	235.47	29.82	224.94	12.66[1] to 95.53
PEH433HAB	235.47	29.95	221.51	12.66[1] to 95.53
Niko	235.47	52.98	210.5	22.5[1] to 84.90
CLIPSAL 32E450UDM	238	11.6	205.6	4.87 to 86.39

[1] Dimmer can be switched off.

8. Performance data

8.1 Line Regulation



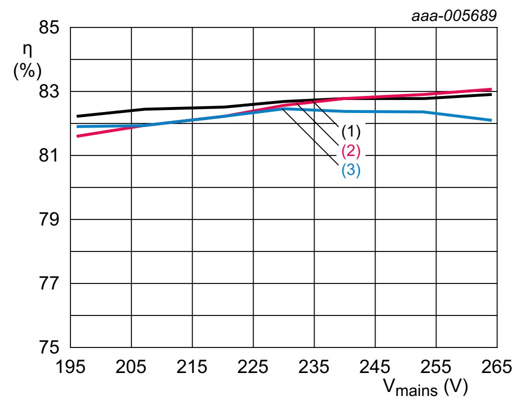
(1) $V_{o(LED)}$ = 40 V (DC)

(2) $V_{o(LED)}$ = 32 V (DC)

(3) $V_{o(LED)}$ = 48 V (DC)

Fig 6. Line Regulation

8.2 Efficiency



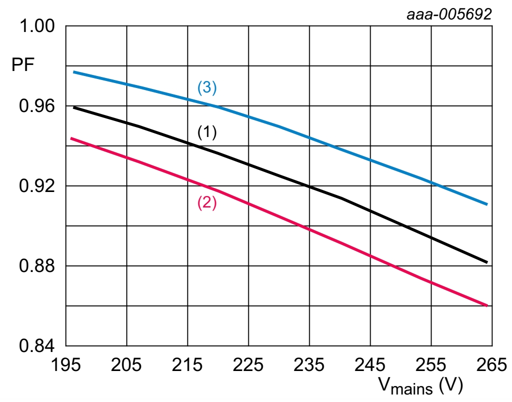
(1) $V_{o(LED)}$ = 40 V (DC)

(2) $V_{o(LED)}$ = 48 V (DC)

(3) $V_{o(LED)}$ = 32 V (DC)

Fig 7. Efficiency

8.3 Power factor



(1) $V_{o(LED)}$ = 40 V (DC)

(2) $V_{o(LED)}$ = 48 V (DC)

(3) $V_{o(LED)}$ = 32 V (DC)

Fig 8. Power Factor

8.4 Electromagnetic Conductance (EMC)

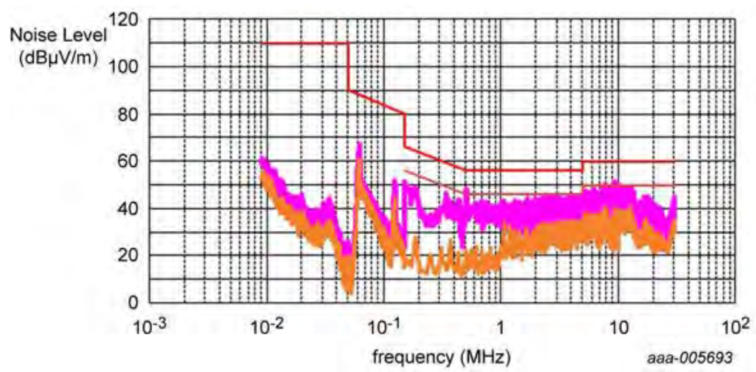


Fig 9. Conducted Emission: Line

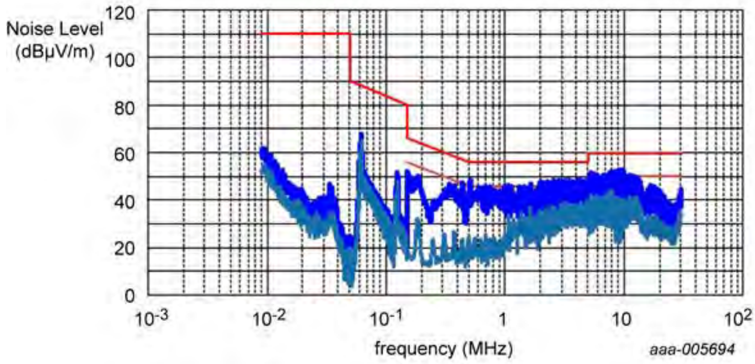


Fig 10. Conducted Emission: Neutral

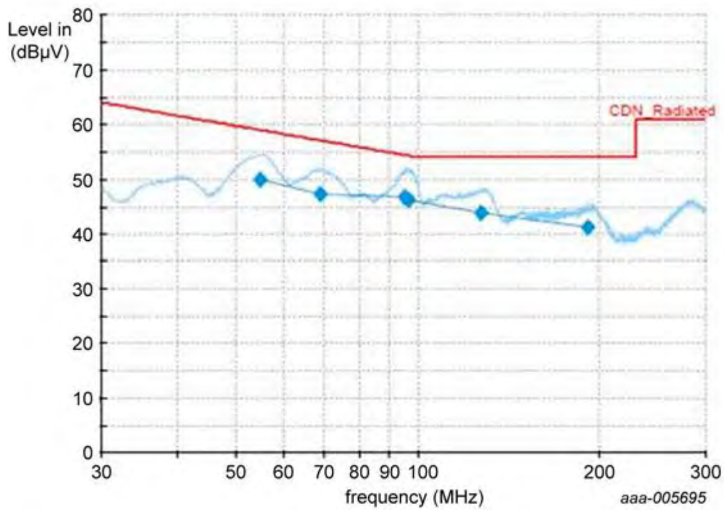


Fig 11. Radiated Emission

Table 5. Radiated emissions results

Frequency (MHz)	Quasi-peak (dBμV)	Measured time (ms)	Bandwidth (kHz)	Correction (dB)	Margin (dB)	Limit (dBμV)
54.88	49.8	1000	120.000	10	9.2	59
68.8	47.2	1000	120.000	10.1	9.9	57.1
95.16	46.8	1000	120.000	10.2	7.6	54.4
96.72	46.1	1000	120.000	10.2	8.2	54.3
127.4	43.9	1000	120.000	10.4	10.1	54
191.4	41.2	1000	120.000	10.5	12.8	54

9. SSL2129AT 12 W 230 V demo board schematic

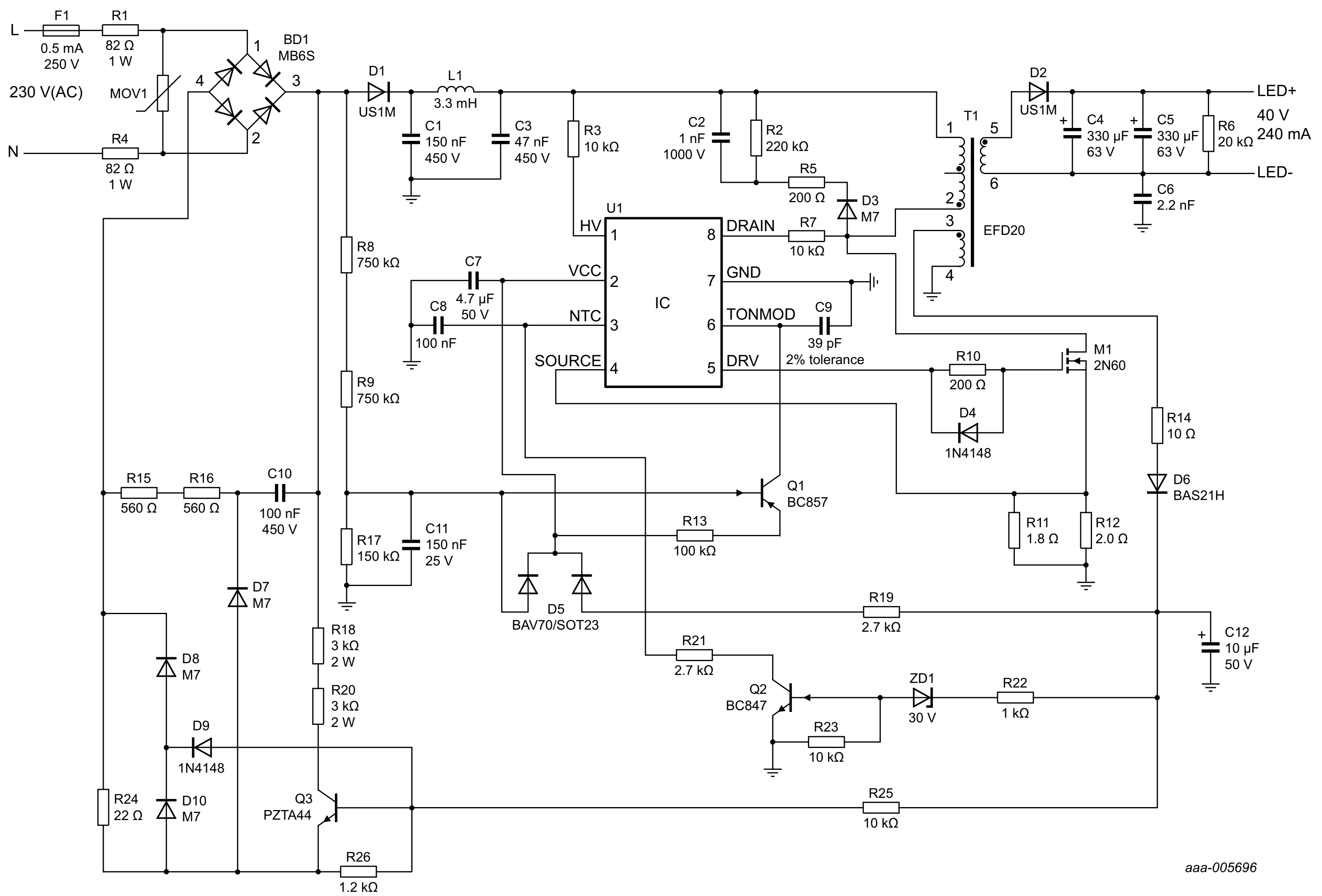


Fig 12. SSL2129AT 12 W 230 V demo board schematic

10. Bill of Materials (BOM)

Table 6. Bill of Materials

Reference	Description and Value	Part number	Manufacturer
BD1	bridge diode; 0.5 A; 600 V	MB6S	General-Semi
C1	capacitor; film; 0.15 μF; 450 V; P10	-	Fara
C2	capacitor; ceramic; 1000 pF; 1 kV; 1206; X7R	-	Murata
C3	capacitor; film; 0.047 μF; 450 V; P10	-	Fara
C4	capacitor; E-CAP; 330 μF; 63 V; LKF; 12 × 20 mm	-	Yonming
C5	capacitor; E-CAP; 330 μF; 63 V; LKF; 12 × 20 mm	-	Yonming
C6	capacitor; YCAP; 2200 pF; 275 V	-	Vishay
C7	capacitor; ceramic; 4.7 mF; 25 V; 1206; X7R	-	Murata
C8	capacitor; ceramic; 0.1 mF; 25 V; 0603; X7R	-	Murata
C9	capacitor; ceramic; 39 pF; 50 V; 2 %; 0603; COG	-	Murata
C10	capacitor; film; 0.1 mF; 450 V; P10	-	Fara
C11	capacitor; ceramic; 0.15 mF; 35 V; 0805; X7R	-	Murata
C12	capacitor; E-CAP; 10 μF; 50 V; LKF; 5 × 11 mm	-	Yonming
D1	diode; general; M7; 1 A; 1 kV; SMA-SIYU	US1M	Diodes
D2	diode; fast; 1 A; 700 V; SMA	US1M	Diodes
D3	diode; general; M7; 1 A; 1 kV; SMA	-	SIYU
D4	diode; fast; 100 mA; 75 V; SOD523	1N4148WT	NXP Semiconductors
D5	diode; dual; 100 mA; 75 V; SOT23-3	BAV70	NXP Semiconductors
D6	diode; fast; 200 mA; 200 V; SOD123	BAS21H	
D7	diode; general; M7; 1 A; 1 kV; SMA	-	SIYU
D8	diode; general; M7; 1 A; 1 kV; SMA	-	SIYU
D9	diode; fast; 100 mA; 75 V; SOD523	1N4148WT	NXP Semiconductors
D10	diode; general; M7; 1 A; 1 kV; SMA	-	SIYU
F1	fuse; lead type; 0.5 A; 250 V; can be removed when R1/R4 are fusible resistors	-	Littelfuse
L1	inductor; power; 3.3 mH; 6 × 8 mm	-	Yageo
M1	N-MOSFET; 2N60; TO251	-	UTC
MOV1	varistor	TVR05431	Thinking
Q1	PNP; SOT23-3	BC857	NXP Semiconductors
Q2	NPN; SOT23-3	BC847	NXP Semiconductors
Q3	NPN; SOT223	PZTA44	NXP Semiconductors
R1	resistor; fusible; lead type; 82 Ω; 1 W; 5 %	-	Token
R2	resistor; chip; 220 kΩ; 5 %; 1206	-	TA-I
R3	resistor; chip; 10 kΩ; 5 %; 1206	-	TA-I
R4	resistor; fusible; lead type; 82 Ω; 1 W; 5 %	-	Token
R5	resistor; chip; 200 Ω; 5 %; 1206	-	TA-I
R6	resistor; chip; 20 kΩ; 5 %; 1206	-	TA-I
R7	resistor; chip; 10 kΩ; 5 %; 0805	-	TA-I
R8	resistor; chip; 750 kΩ; 5 %; 1206	-	TA-I

Table 6. Bill of Materials *…continued*

Reference	Description and Value	Part number	Manufacturer
R9	resistor; chip; 750 kΩ; 5 %; 1206	-	TA-I
R10	resistor; chip; 200 Ω; 5 %; 0805	-	TA-I
R11	resistor; chip; 1.8 Ω; 1 %; 0805	-	TA-I
R12	resistor; chip; 2 Ω; 5 %; 0805	-	TA-I
R13	resistor; chip; 100 kΩ; 5 %; 0603	-	TA-I
R14	resistor; chip; 10 Ω; 1 %; 0805	-	TA-I
R15	resistor; chip; 560 Ω; 5 %; 1206	-	TA-I
R16	resistor; chip; 560 Ω; 5 %; 1206	-	TA-I
R17	resistor; chip; 150 kΩ; 1 %; 0805	-	TA-I
R18	resistor; carbon film, flame retardant; 3 kΩ; 2 W; 5 %	-	Yageo
R19	resistor; chip; 2.7 kΩ; 5 %; 0805	-	TA-I
R20	resistor; carbon film, flame retardant; 3 kΩ; 2 W; 5 %	-	Yageo
R21	resistor; chip; 2.7 kΩ; 5 %; 0603	-	TA-I
R22	resistor; chip; 1 kΩ; 5 %; 0603	-	TA-I
R23	resistor; chip; 10 kΩ; 5 %; 0603	-	TA-I
R24	resistor; chip; 22 Ω; 1 W; 5 %; 2512	-	TA-I
R25	resistor; chip; 10 kΩ; 5 %; 0603	-	TA-I
R26	resistor; chip; 1.2 kΩ; 5 %; 0603	-	TA-I
T1	transformer; 4 pin + 4 pin	EFD20	Kangshun
U1	IC; SSL2129AT; SO-8	-	NXP Semiconductors
ZD1	Zener; 30 V; 0.5 W; SOD323	BZX384C30	NXP Semiconductors

11. Transformer specification

11.1 Transformer pin allocation

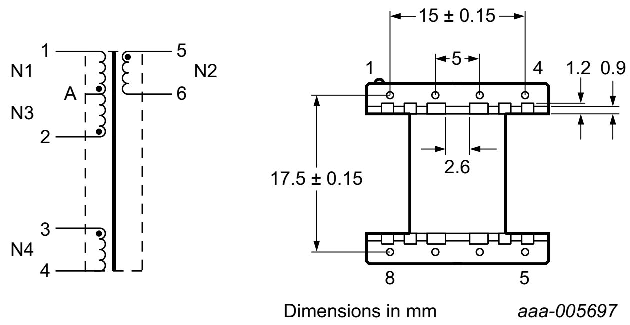


Fig 13. Transformer pin allocation

11.2 Test Specifications

Table 7. Test Specifications

Bobbin	Core/Material	Ae (mm^2)	L_p (N1:6 to 8)	Solution mark
Pitch = 5 mm; 4 + 4	EFD2020 (PC40)	31	2.0 mH at 50 kHz	±10 % tolerance

11.3 Winding information

Table 8. Test Specifications

Winding	Start pin	Finish pin	Wire size	Turns	Tape	Winding tape
N1	1	A	∅ 0.20× 1UEW	60	0	Center
N2	6[1]	5[1]	∅ 0.4 × 1TIW	60	0	Center
N3	A	2	∅ 0.20 × 1UEW	60	2	Center
N2	4	3	∅ 0.15 × 1UEW	30	2	Center

[1] Pins 6 and 5 need fly out for a 4 kV hi-pot test.

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13. Contents

Date of release: 11 December 2012
Document identifier: UM10589