UM10507

SSL2103 based 14 W LED driver demo board for mains dimmable aplications

Rev. 1 — 5 March 2012 **User manual**

Document information

Info	Content
Keywords	SSL2103, AC mains supply, dimmable LED driver, AC/DC conversion
Abstract	This user manual describes a demonstration (demo) board for evaluating an AC mains LED driver with a dimmer for 14 W, A55 LEDs using the SSL2103. It also describes key features and connections to aid the design of LED drivers for typical applications.

Revision history

Rev	Date	Description
v.1	20120305	first issue

Contact information

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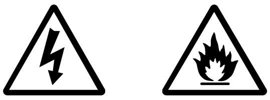
1. Introduction

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 user manual describes a demonstration (demo) board for evaluating an AC mains LED driver with a dimmer for 14 W, A55 LEDs using the SSL2103. It describes key features and connections to aid the design of LED drivers for typical applications.

The demo board operates from an AC mains voltage of 230 V (AC) at 50 Hz. The resulting design is a trade-off between high-power factor, efficiency and dimmer compatibility.

2. Safety Warning

The demo board is powered by AC mains voltage. Avoid touching the board when power is applied. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments. The secondary circuit with LED connection has galvanic isolation, however this isolation is not in accordance with any standard and has not been thoroughly tested. Always provide galvanic isolation of the mains phase using a variable transformer. The following symbols identify isolated and non-isolated devices.

a. Isolated

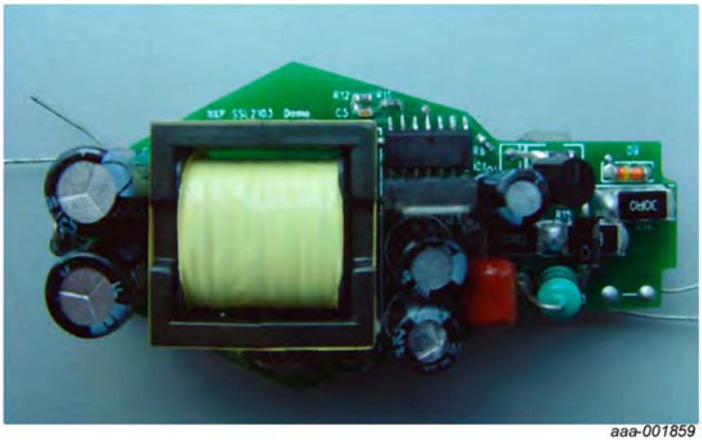
b. Non-isolated

Fig 1. Isolated and non-isolated symbols

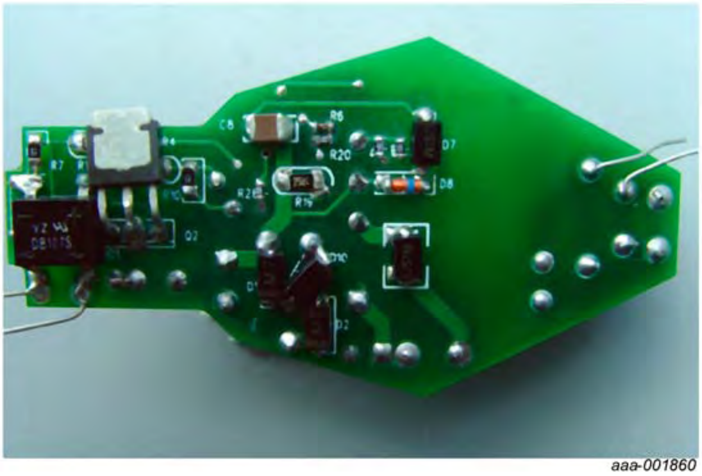
3. Specification

Table 1. Demo board specification

Parameter	Value	Comment
AC line input voltage	230 V (AC), ±10 %, 60 Hz	230 V (AC) model
Output voltage (LED voltage)	55.5 V (DC)	for 18 LEDs
Output current (LED current)	230 mA typical	for 18 LEDs
Input voltage and load current dependency	230 mA ±10 %, input voltage between 210 V (AC) and 250 V (AC) for 18 LEDs	see Figure 7 on page 17
Output voltage and load current dependency	230 mA ±5 %, output voltage between 47 V (DC) to 55.7 V (DC) at V_{IN} = 230 V (AC)	see Figure 8 on page 17
Current ripple	±16 % at 230 mA	typical value
Maximum output power (LED power)	14 W	depends on load
Efficiency	77 % to 80 %	at T_{amb} = 25 °C, depends on output load and input voltage
Power factor	>0.9 at 230 V (AC)	see Figure 9 on page 18
Switching frequency	64 kHz to 77 kHz	at 230 V (AC) input voltage
Dimming range	100 % to 1 %	for triac dimmers
Board dimensions	60 mm × 34 mm × 20 mm	L × B × H
Operating temperature	−20 °C to +85 °C	-



a. Top view.



b. Bottom view

Fig 2. 14 W, A55 LED demo board

4. Demo board connections

The demo board is optimized for an AC mains source of 230 V (50 Hz). It is designed to work with multiple high-power LEDs having a total working voltage of between 54 V and 56 V. The output current is set to 230 mA at typical load.

When attaching an LED load to an operational board (hot plugging) an inrush peak current occurs due to the discharge of output capacitors C9 and C10. Frequent discharges can damage or deteriorate the LEDs.

Remark: Mount the board in a shielded or isolated box for demonstration purposes.

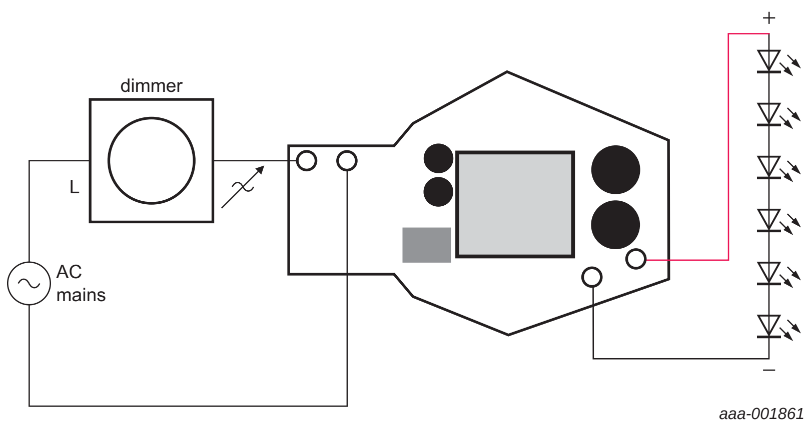


Fig 3. Demo board connections

Place a galvanic isolated transformer between the AC source and the demo board, if used. Connect a series of between 15 and 18 LEDs to the output as shown in Figure 3.

5. Dimmers

NXP Semiconductors has tested the performance of several triac-based dimmers with different specifications. The range of dimmers which have been tested with the demo board are given in Table 2.

Table 2. Tested dimmers

Manufacturer	Type	AC Voltage (V)	Power range (W)	Load type	Low dim level (%)
Mank	-	230	200	[1]	0
Berker	2819	230	60 to 400	[1]	0
Berker	2873	230	20 to 500	[1]	0
Le	T10	230	60 to 300	[1]	0
GIRA	03000/I01	230	60 to 400	[1]	0
GIRA	118400/I00	230	60 to 400	[1]	0
Hawaiian Electric Industries	T46	230	20 to 315	[1]	0
Busch-Jaeger Elektro	2200	230	60 to 400	[1]	0
Busch-Jaeger Elektro	2250U	230	600	[1]	0
Berker	286710	230	20 to 360	[1][2]	0
Berker	2874	230	20 to 525	[1][2]	0
Busch-Jaeger Elektro	6591U-101-500	230	420	[1][2]	0
Busch-Jaeger Elektro	6513U-102	230	420	[1][2]	0
Busch-Jaeger Elektro	6565U	230	40 to 315	[1][2]	0
Niko	09-017	230	20 to 250	[1][2]	0
GIRA	030700/I02	230	20 to 525	[1][2]	0
JUNG	243EX	230/240	20 to 360	[1][2]	0
JUNG	225TDE	230	20 to 525	[1][2]	0

[1] Incandescent.

[2] Halogen.

6. Functional description

Refer to Figure 6 “SSL2103 230 V (AC) 14 W flyback schematic” on page 14 for more information.

The board is equipped with the SSL2103 driver IC. Based on the SSL2101/SSL2102 core controller, the SSL2103 allows engineers to cover the full range of applications.

The device includes a circuit that allows start-up directly from the rectified mains voltage.

The IC dimming circuitry drives two external current sinks (called bleeders), allowing design for optimized dimmer interoperability. A strong bleeder is used for zero-cross dimmer resets and triac latching. A weak bleeder maintains the hold current through the dimmer.

The device provides external power switch drive for output power flexibility or high-efficiency external bleeder transistor drive for extended dimmer interchangeability.

The device contains a bleeding circuit which drives two switched for the external bleeders. The WB_DRV pin drives the weak bleeder and the SB_DRV pin drives the strong bleeder.

When the voltage on the HVDET pin is below a certain value ($V_{th(SBLEED)}$) which is typically 52 V, the strong-bleeder switches on. On activation, of the SB_DRV signal, a path for load current to the dimmer during zero voltage crossing which resets the dimmer timer.

The WB_DRV output is activated as soon as the voltage on pin ISENSE exceeds the $V_{th(high)(ISENSE)}$ level (–100 mV typically). The WB_DRV output is deactivated when the ISENSE voltage drops below the $V_{th(low)(ISENSE)}$ level (–250 mV typically). The WB_DRV output is also deactivated when the strong bleeder switch is switched on. In this application, the WB_DRV signal is floating.

When dimmers are used, the circuit detects the rectified voltage change and lowers the duty cycle and oscillator frequency to reduce the output current.

The SSL2103 uses on-time mode control and frequency control to control the LED brightness. The BRIGHTNESS and PWMLIMIT input of the IC can be used to control the LED light output in combination with an external dimmer. The PWMLIMIT input can also be used for Thermal Lumen Management (TLM) and for precision LED current control.

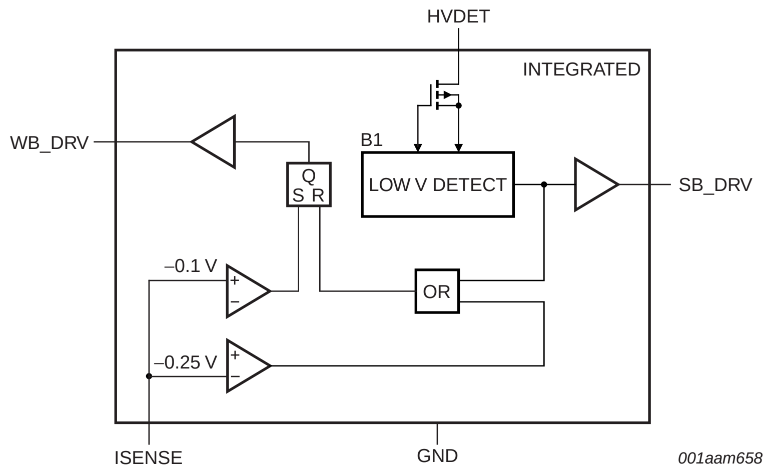
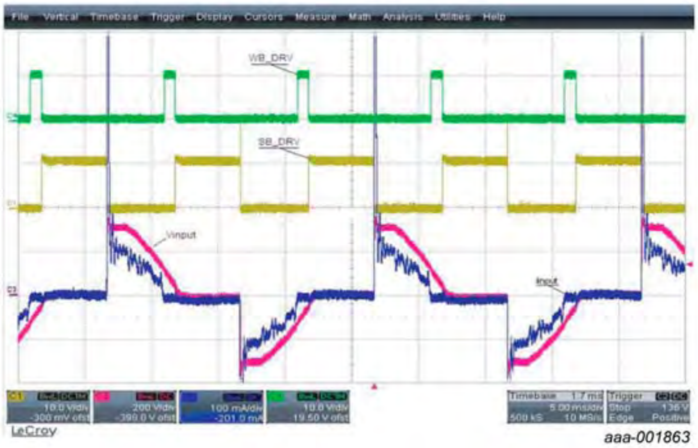


Fig 4. Bleeder circuit

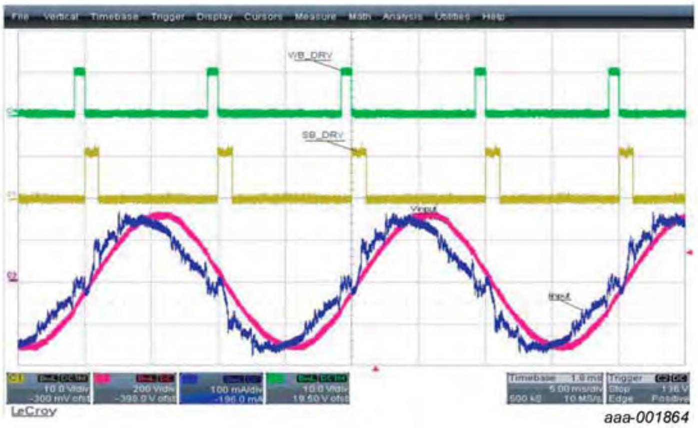
When the voltage on pin SOURCE exceeds 0.5 V, the current is interrupted. In the next cycle, the energy stored in the transformer is discharged through D6, output capacitors C9/C10 and finally, absorbed by the load.

The converter frequency is set using the internal oscillator. The external RC components on pins RC and RC2 control the frequency of the internal oscillator. The ratio between resistors R11 and R12 sets the frequency variation. The frequency can also be modulated to the upper and lower value using the BRIGHTNESS pin. The dim range is detected by sensing the average rectified voltage. Resistors R2 and R10 form a voltage divider and capacitor C4 filters the resulting signal.

See Figure 5 shows bleeder drive outputs compared as a function of time for both dimmed and undimmed operation.



a. Dimmed mode



b. Undimmed mode

(1) WB_DRV action.

(2) SB_DRV action.

(3) V_I.

(4) I_I.

Fig 5. Bleeder operation

The demo board is optimized to work at a power factor above 0.9. The flyback converter operates at a constant t_{on} to ensure that the power factor is obtained.

Capacitors C9 and C10 buffer the output power of the flyback converter. This configuration gives the circuit a resistive input current behavior in undimmed mode. See input curve shown on Figure 5.

In dimmed mode, the dimmer latch and hold current must be maintained. In addition, a damper must be added to dampen the inrush current and dissipate the electric power stored in the dimmer LC filter.

Mount a partially capacitive filter in the converter input circuit. The combination of C2, C3, C14 and L2 makes a filter that blocks most of the disturbance generated by the converter input current. Drawback of this filter is a power factor reduction due to the capacitive load. Lower converter power in relation to the capacitive value of the filter causes a reduction in power factor.

An active damper is required to limit inrush current. Inrush current occurs when the input capacitors encounter fast voltage changes for example in the following situations:

- when the board is hot-plugged into an AC input source
- when the board is fed from a leading-edge phase-cut dimmer

There are many ways to perform damping. A single resistor is the cheapest solution but can lead to thermal issues and low efficiency. The damper resistor is a major factor in the power losses of the system.

A serial resistor can be used as a damper at low-power ranges (<10 W). However, this solution is inefficient at higher power ranges. An active circuit is the preferred solution for higher power ranges to achieve high-efficiency.

The solution described in this user manual is an active damper using the MOSFET Q2. Q2 is used to bypass the damping resistor R15 following inrush current. The MOSFET is on as long as the voltage across resistor R7 is high enough to trigger the gate of MOSFET Q2.

7. System optimization

The modifications described in this section can be applied to achieve customer application specifications.

7.1 Changing output voltage and LED current

One of the major advantages of a flyback converter over other topologies is its suitability for driving different output voltages. In essence, changing the winding ratio while maintaining the value of the primary inductance shifts the output working voltage accordingly. Part of the efficiency of the driver is linked to the output voltage. A lower output voltage increases the transformation ratio and cause higher secondary losses. In practice, the efficiency of mains dimmable flyback converters is as follows:

- 80 % for higher output power and voltage such as 60 V
- 50 % for lower output power and voltage such as 3 W and 3 V

At lower voltages, synchronous rectification is advisable to reduce losses after high current is rectified. NXP Semiconductors TEA1761 and TEA1791 synchronous rectification controllers are ideal for this purpose. Calculations for transformer properties and peak current are described in detail in application note *AN10754, SSL2101 and SSL2103 dimmable mains LED driver*.

7.2 Changing the output ripple current

The LED voltage, The LED dynamic resistance and the output capacitor determine the output ripple current. while the values of C9 and C10 are chosen to optimize capacitor size with light output. A ripple of ±17 % results in an expected deterioration of LED brightness of less than 1 %[1].

The size of the buffer capacitor is determined using Equation 1.

$$C10 + C9 = \frac{I_{led}}{\Delta I} \times \frac{1}{6 \times f_{net} \times R_{dynamic}} \quad (1)$$

Example:

A ±5 % ripple current, a 50 Hz AC mains frequency and a 0.6 Ω dynamic resistance, results in a combined C9 + C10 value of $\frac{20}{300 \times 0.6} = 111\ \mu F$.

A ripple current of 15 % and a dynamic resistance of 11 Ω for 18 LEDs, results in a value for C9 + C10 of $\frac{100}{15 \times (300 \times 11)} = 2000\ \mu F$.

Using a series of LEDs, the dynamic resistance of each LED can be added to the total dynamic resistance.

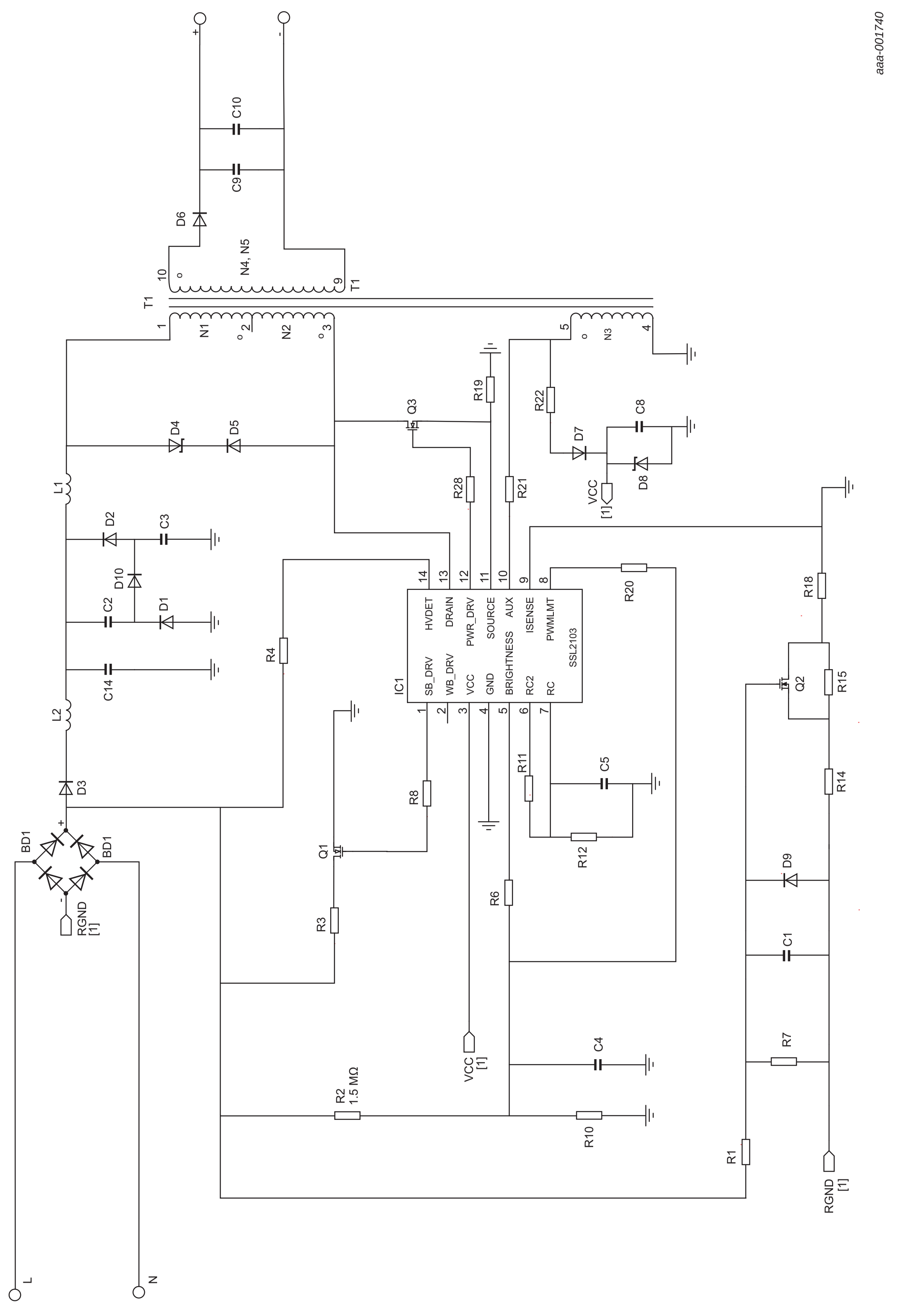
1. M. Weiland 28-07-2006

7.3 Adapting to high-power reverse phase transistor dimmers

Reverse phase (transistor) dimmers differ in two ways that can be beneficial:

- Because of the negative phase, there is no inrush current when the dimmer triggers. Using triac dimmers, there is a sudden voltage difference over the input, resulting in a steep charge of the input capacitors. The resulting peak current results in higher damper dissipation. Using transistor dimmers, the steep charge is missing. The input capacitors are less stressed and the input circuit is less prone to audible noise.
- Transistor dimmers contain active circuitry that requires a load charge while the dimmer is open. To avoid internal dimmer losses, the dimensioning of the internal supply voltage generation circuit is critical. This means that the remaining voltage drop across the lamp must be low enough to allow this charge to be reached. The minimum load to achieve such a low voltage drop results in very inefficient operation at low output power levels. The cause of which is that most of the energy is wasted driving the dimmer instead of used to producing light.

8. Demo board schematic



(1) Optional.

Fig 6. SSL2103 230 V (AC) 14 W flyback schematic

9. PCB components

Table 3. A55 14 W 230 V (AC) demo board components

Ref	Description and value	Part number	Manufacturer
BD1	rectifier bridge; 700 V; DB-1S; SMD	DB107S	-
C1	ceramic capacitor; 100 nF; 10 %; 50 V; pitch = 5 mm; axial	-	-
C2	electrolytic capacitor; 2.2 μF; 20 %; 250 V; ∅6.5 mm × 11 mm; axial	-	-
C3	electrolytic capacitor; 2.2 μF; 20 %; 250 V; ∅6.5 mm × 11 mm; axial	-	-
C4	electrolytic capacitor; 10 μF; 20 %; 50 V; ∅5 mm × 10 mm; axial	-	-
C5	capacitor; 330 pF; 10 %; 50 V; 00603/0805; SMD	-	Murata
C8	capacitor; 10 μF; 10 %; 50 V; 1210; SMD	-	Murata
C9	electrolytic capacitor; 330 μF; 20 %; 63 V; ∅8 mm × 12 mm; axial	-	-
C10	electrolytic capacitor; 330 μF; 20 %; 63 V; ∅8 mm × 12 mm; axial	-	-
C14	MPP capacitor; 100 nF; 10 %; 400 V; pitch = 5 mm; axial	-	-
D1	diode; 700 V; SMD	M7	SIYU
D2	diode; 700 V; SMD	M7	SIYU
D3	diode; 700 V; axial	HER107	-
D4	TVS diode; 3 W; 180 V; axial	P6KE180A	-
D5	diode; 700 V; SMD	US1M	DIODES
D6	diode; 700 V; axial	HER107	-
D7	diode; 700 V; SMD	US1M	DIODES
D8	Zener diode; 0.5 W; 5 %; 33 V; SOD80 V; SMD	BZV55-C33	NXP Semiconductors
D9	Zener diode; 0.5 W; 5 %; 12 V; SOD80; SMD	BZV55-C12	NXP Semiconductors
D10	diode; 700 V; SMD	M7	SIYU
IC1	controller IC; SO14; SMD	SSL2103	NXP Semiconductors
L1	jumper; pitch = 3 mm; axial	-	-
L2	color ring inductor; 1 mH; axial	-	-
Q1	transistor; NPN; 400 V; TO92	BUJ100	NXP Semiconductors
Q2	transistor; NMOS; 600 V; TO251	SPU02N60C3	Infineon
Q3	transistor; NMOS; 600 V; TO251	SPU02N60C3	Infineon
R1	resistor; 390 kΩ; 0.25 W; 5 %; 200 V; 1206; SMD	-	-
R2	resistor; 1.5 MΩ; 0.25 W; 5 %; 200 V; 1206; SMD	-	-
R3	resistor; 10 kΩ/10 kΩ; 0.5 W; 1 %; 200 V; 1210; SMD	-	-
R4	resistor; 10 kΩ; 0.125 W; 1 %; 150 V; 0603; SMD	-	-
R6	resistor; 7.5 kΩ; 0.125 W; 1 %; 150 V; 0603; SMD	-	-
R7	resistor; 12 kΩ; 0.125 W; 1 %; 150 V; 0805; SMD	-	-
R8	resistor; 1 kΩ; 0.125 W; 1 %; 150 V; 0603; SMD	-	-
R10	resistor; 13 kΩ; 0.125 W; 1 %; 150 V; 0805; SMD	-	-
R11	resistor; 8.2 kΩ; 0.125 W; 1 %; 150 V; 0603; SMD	-	-
R12	resistor; 100 kΩ; 0.125 W; 5 %; 150 V; 0603; SMD	-	-
R14	resistor; 30 Ω/30 Ω/30 Ω; 1 W; 1 %; 200 V; 2512; SMD	-	-
R15	resistor; 680 Ω/680 Ω/680 Ω; 1 W; 1 %; 200 V; 2512; SMD	-	-
R18	resistor; 30 Ω/30 Ω/30 Ω; 1 W; 1 %; 200 V; 2512; SMD	-	-

Table 3. A55 14 W 230 V (AC) demo board components *…continued*

Ref	Description and value	Part number	Manufacturer
R19	resistor; 1.6 Ω; 0.25 W; 1 %; 200 V; 1206; SMD	-	-
R20	resistor; 1 kΩ; 0.125 W; 1 %; 150 V; 0603; SMD	-	-
R21	resistor; 100 kΩ; 0.125 W; 5 %; 150 V; 0603; SMD	-	-
R22	resistor; 10 Ω; 0.125 W; 1 %; 150 V; 0603; SMD	-	-
R28	resistor; 1 kΩ; 0.125 W; 1 %; 150 V; 0603; SMD	-	-
T1	transformer; 3 mH; axial; EFD20-THT10	750340751	Würth Elektronik

10. Transformer specifications

Table 4. General specification

Parameter	Comment
Bobbin	EFD20; 10-pin; THT
Core material	EFD20 (PC44/PC40
Ae	32 mm^2
Lp (1-3)	3 mH ±7 % at 100 kHz
Lm	~10 µH at 100 kHz
Solution mark	3mh LSLASA

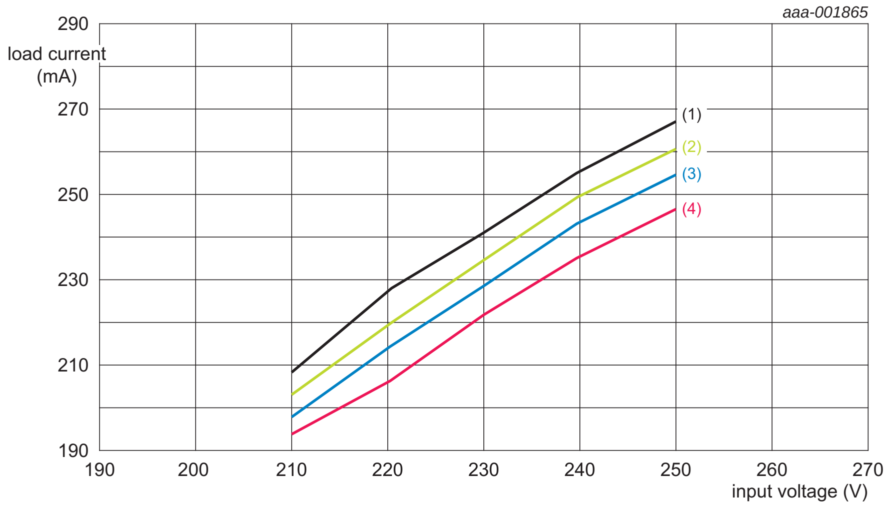
Table 5. Winding specification

Number	Pin		Wire	Turns	Turns per layer	Winding method
	start	finish				
N2	3	2	∅0.2 × 1	60	60	center
S1	-	-	-	1	1	tape
N4	10	9	∅0.25 (3L)	50	50	center
S2	-	-	-	1	1	tape
N1	2	1	∅0.2 × 1	60	60	center
S3	-	-	-	1	1	tape
N5	10	9	∅0.25 (3L)	50	50	center
S4	-	-	-	1	1	tape
N3	5	4	∅0.2 × 1	18	18	center
S5	-	-	-	3	1	tape

[1] See Figure 6 for the winding diagram.

11. Test results

11.1 Input/output stability



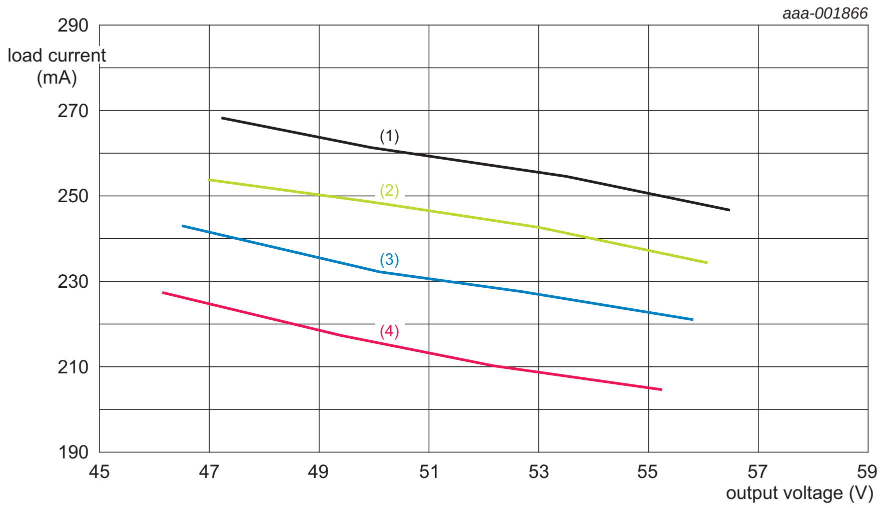
(1) 15 LEDs.

(2) 16 LEDs.

(3) 17 LEDs.

(4) 18 LEDs.

Fig 7. Input voltage stability



(1) 250 V (AC).

(2) 240 V (AC).

(3) 230 V (AC).

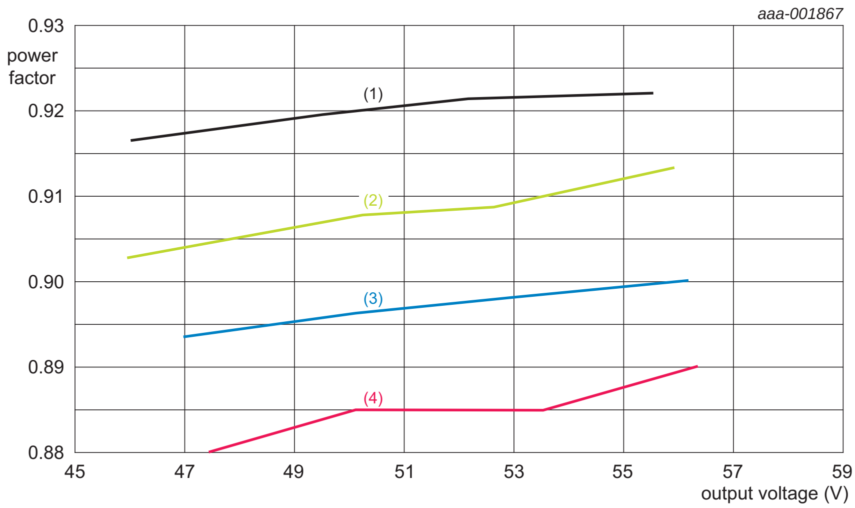
(4) 220 V (AC).

Fig 8. Output voltage stability

11.2 Temperature stability

The temperature stability depends on the LED heatsink and the lamp form factor.

11.3 Power factor



(1) 220 V (AC).

(2) 230 V (AC).

(3) 240 V (AC).

(4) 250 V (AC).

Fig 9. Power factor as a function of output voltage

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