UM10735

SSL2101DB1169 230 V 5 W buck boost dimmable candle LED driver

Rev. 1 — 11 November 2013 **User manual**

Document information

Info	Content
Keywords	SSL2101DB1169, SSL2101T, mains dimmable, AC to DC conversion, buck boost, candle LE driver
Abstract	This user manual describes the SSL2101 mains 230 V 5 W candle buck boost dimmable demo board.

Revision history

Rev	Date	Description
v.1	20131111	first issue

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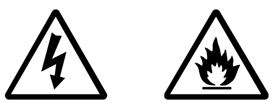
1. Introduction

WARNING

Lethal voltage and fire ignition hazard



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The SSL2101T is a highly integrated switching mode LED driver. It enables constant current driving from the mains input. The SSL2101T supports buck converter topology. It is suitable for non-isolated LED retrofit lamps.

The application in this document is a compact 230 V mains dimmable LED driver for candle size 5 W input power. It improves dimmer compatibility by drawing strong bleeding current and weak bleeding current from the input. To reach the strict form factor, all the bleeding circuits are integrated. The application is energy saving because it uses the SSL2101 quasi-resonant switching technology.

All values listed in this user manual are typical values unless otherwise specified.

2. Safety warning

The board must be connected to the mains voltage. Touching the board during operation must be avoided at all times. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments. Even though the secondary circuit with LED connection includes galvanic isolation, this isolation is not according to any norm. Thus, galvanic isolation of the mains phase using a variable transformer is always recommended. Figure 1 shows the symbols by which these devices can be recognized.

a. Isolated b. Not isolated

Fig 1. Variable transformer (Variac) isolation symbols

3. Specification

Table 1. SSL2101DB1169 specifications

Symbol	Parameter	Condition	Value
$V_{i(mains)}$	mains input voltage		207 V to 253 V; 50 Hz
$V_{O(LED)}$	LED output voltage		30 V (DC)
$V_{O(ovp)}$	overvoltage protection output voltage		60 V (DC)
$I_{o(LED)}$	LED output current		128 mA
$I_{o(LED)ripple}$ / $I_{o(LED)}$	LED output current ripple to LED output current ratio		±13 %; nominal I_{LED} = 128 mA
$\Delta I_{O(LED)}$ / ΔV_{mains}	line regulation	load current dependent	±7.5 %; V_{mains} = 230 V ± 10 %
$\Delta I_{O(LED)}$ / $\Delta V_{O(LED)}$	load regulation	load current dependent	±7 % at V_{LED} ± 10 %
η	efficiency		77 %; V_{mains} = 230 V (AC); $V_{O(LED)}$ = 30 V (DC)
PF	power factor		0.56; V_{mains} = 230 V (AC)
THD	total harmonic distortion		< 66 %
	PCB size		diameter = 28 mm
	EMC compliance		meets EN55015

4. Board photographs

Fig 2. SSL2101DB1169 demo board (top)

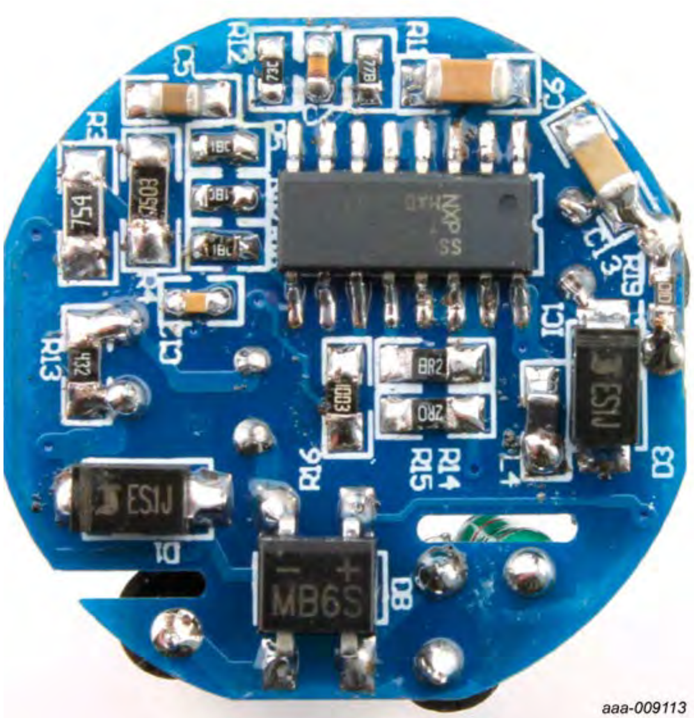


Fig 3. SSL2101DB1169 demo board (back)

5. Connecting the board

The board can be optimized for a 230 V/50 Hz mains supply. In addition to the mains voltage optimization, the board is designed to work with multiple high-power LEDs with a total working voltage of between 28 V and 33 V.

When attaching an LED load to an operational board (hot plugging) an inrush peak current occurs due to the discharge of the output capacitor. After a number of discharges, the LEDs can be damaged.

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

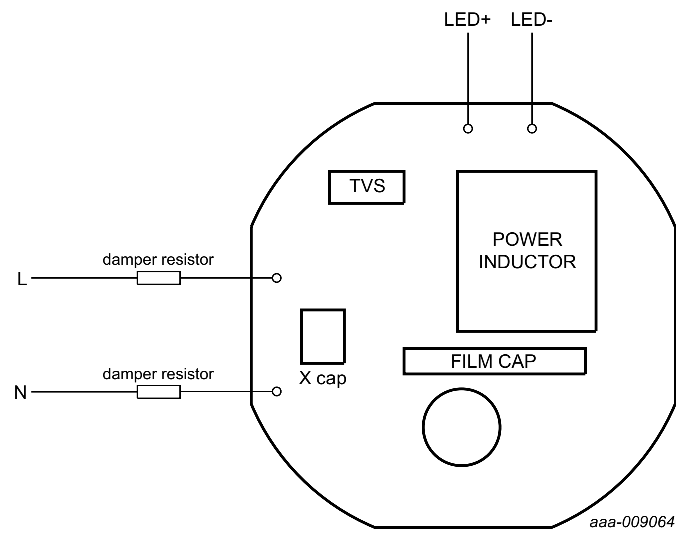


Fig 4. SSL2101DB1169 board connections(top view)

6. Dimmers

NXP Semiconductors have tested several TRIAC and transistor-based dimmers. Table 2 shows a list of dimmers that have been tested with the board.

Table 2. List of tested dimmers

Manufacturer	$I_{O(LED)}$ no dimming (mA)	$I_{O(LED)}$ minimum dimming (mA)	$I_{O(LED)}$ maximum dimming (mA)	Stability
Clipsal 32E450LM	129	10	111	smooth
HPM legrand	129	25	100	smooth
Berker2819	129	45	115	smooth; increase damper resistor (R1) to 150 Ω
Berker2873	129	16	108	smooth
GIRA030000/I01	129	46	114	smooth; increase damper resistor (R1) to 150 Ω
GIRA118400/I00	129	22	110	smooth; increase damper resistor (R1) to 150 Ω
LICHTERGLER	129	3	115	smooth
BUSH2200	129	29	109	smooth
BUSH2250U	129	5	112	smooth
Chinese dimmer 01	129	40	126	smooth
NVC	129	49	126	smooth
Chinese dimmer 02	129	54	128	smooth
Clipsal 32V500 series	129	5	116	smooth

7. Functional description

The SSL2101T is an LED driver IC that operates directly from the rectified mains. It uses on-time mode control and frequency control to control the LED brightness. The BRIGHTNESS and PWMLIMIT pins can be used to control the LED output current when an external dimmer is connected.

7.1 Start-up and V_{CC} supply

The charging current flows from high-voltage DRAIN pin via an internal start-up current source to the V_{CC} pin. The IC starts switching when the voltage on the V_{CC} pin passes the $V_{CC(startup)}$ level. The auxiliary winding of the transformer can take over the supply when V_{CC} is high enough and the supply from the line is stopped for high-efficiency operation.

7.2 Frequency setting

External RC components on pins RC and RC2 control the timing of an internal oscillator. The internal oscillator sets the converter frequency. The frequency can be modulated to an upper and lower value using the BRIGHTNESS pin.

7.3 Bleeding

The IC has two bleeding circuits that ensure proper dimmer operation The two circuits are called weak bleeder (pin WBLEED) and strong bleeder (pin SBLEED). When the voltage on both pins is lower than 52 V, the SBLEED switches on providing a current path that loads the dimmer.

7.4 Output Short Protection (OSP)

When the LEDs are short-circuited, the demagnetization time is much longer than during normal operation because the voltage (V_f) of diode D3 determines the demagnetized slope. The valley switch circuit keeps the MOSFET switched off until the demagnetization time has passed. The work frequency is very low during a short circuit event, which limits the input power.

7.5 Output OverVoltage Protection (OVP)

Zener diode D5 and the V_{CC} pin are positioned in parallel to detect output overvoltage. Because of the ratio between the auxiliary wind and the primary winding, the V_{CC} voltage increases with the output voltage until it reaches the threshold of diode D5. Diode D5 acts as a voltage fuse when an overvoltage event occurs. It breaks down and shorts V_{CC} to GND.

8. System optimization

Several modifications can be made to meet customer application specifications.

8.1 Changing the output ripple current

The LED voltage, the LED dynamic resistance, and the output capacitor determine the output current ripple. The value of capacitor C3 is chosen to optimize the capacitor size and the light output. A ripple of ±25 % results in an expected light output deterioration of < 1 %.

The size for the buffer capacitor can be estimated from Equation 1:

$$C_{out} = \frac{I_{LED}}{\Delta I} \cdot \frac{1}{6 \cdot f_{mains} \cdot R_{dynamic}} \quad (1)$$

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

8.2 High-accuracy design recommendations

- Use 1 % (or better) devices for peak current sensing resistors R14 and R15
- Use 10 % (or better) inductance tolerance for transformer T1
- Use 5 % (or better) tolerance for COG ceramic capacitor C7

8.3 Multistring dimming

For multistring LED dimming (several LED candles in parallel), decrease the X capacitor C1 to 4.7 nF. It changes the conductive EMI margin from 150 kHz to 500 kHz. However, the final scan result of the peak value still meets the EN55015 standard.

9. Schematic

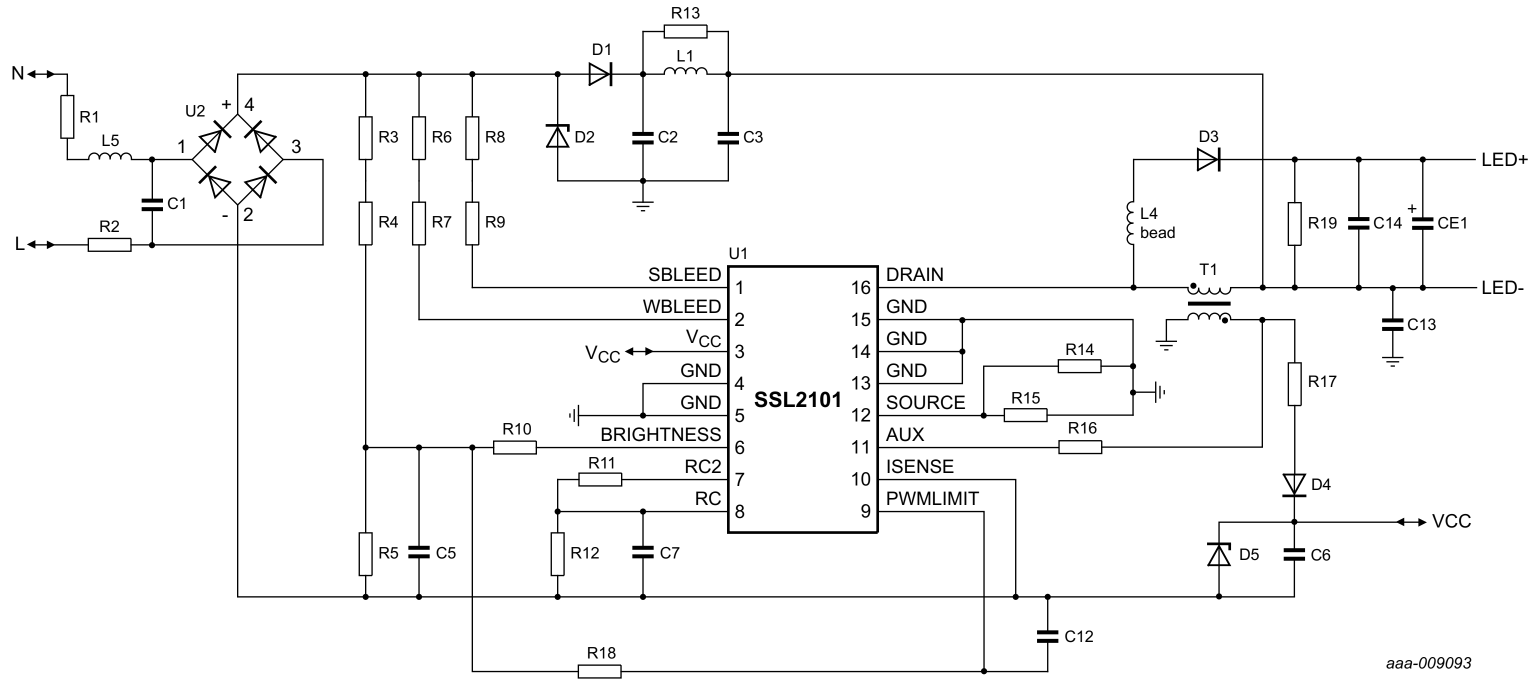


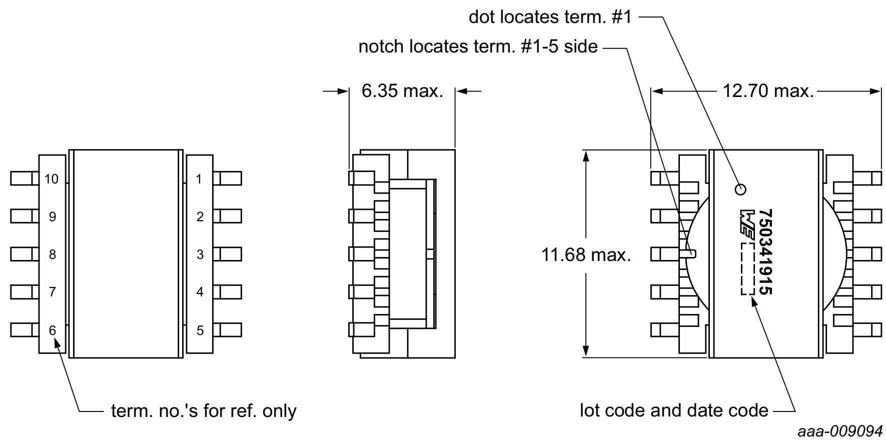
Fig 5. SSL2101DB1169 schematic

10. Bill Of Material (BOM)

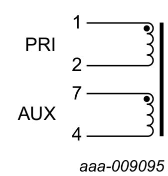
Table 3. SSL2101DB1169 bill of material

Reference	Description and value	Part number	Manufacturer
C1	X capacitor; ceramic; 10 nF; 250 V (AC)	GRM55D7U3A103JW31L	Murata
C2	capacitor; ceramic; 22 nF; 630 V; 1210	GHM1335X7T223K630D500	Murata
C3	capacitor; film; 330 nF; 400 V; P = 10 mm	-	Fara
C5	capacitor; ceramic; 4.7 μF; 25 V; X7R; 0805	-	Murata
C6	capacitor; ceramic; 10 μF; 50 V; X5R; 1206	GRM31CR61H106KA	Murata
C7	capacitor; ceramic; 330 pF; 50 V; 0603; X7R; 5 %	-	Murata
C12	capacitor; ceramic; 1 nF; 25 V; 0603; X7R	-	Murata
C13	capacitor; ceramic; 2.2 nF; 630 V; X7T; 1206	GHM1530X7R222K630D500	Murata
C14	capacitor; ceramic; 47 nF; 250 V; X7R; 1206	GR331BD72E473KW01L	Murata
CE1	capacitor; electrical; 100 μF; 63 V; 105; 8 × 15 mm	-	-
D1; D3	fast recovery diode; 600 V; 1 A; SMA	ES1J	Diotec
D2	TVS diode; 500 W; SMA	SMAJ440A	Micro Commercial Components
D4	switching diode; 200 V; 0.2 A; SOD123F	BAS21H	NXP Semiconductors
D5	Zener diode; 27 V; SOD323F	BZX84J-B27	NXP Semiconductors
L1	drum inductor; power; 3.3 mH; 6 × 8 mm	-	-
L4	EMI suppression ferrite bead; 0805	WE-CBF 742792097	WE Electronic
L5	Inductor; axial; 1.3 mH; 0408	-	-
R1	resistor; axial; 120 Ω; 2 W	-	Yageo
R2	resistor; axial; 100 Ω; 1 W	-	Yageo
R3; R4	resistor; chip; 750 kΩ; 5 %; 1206	-	Yageo
R5; R10; R18	resistor; chip; 15 kΩ; 1 %; 0603	-	Yageo
R6; R7	resistor; chip; 180 kΩ; 5 %; 1206	-	Yageo
R8; R9	resistor; chip; 1.1 kΩ; 5 %; 1206	-	Yageo
R11	resistor; chip; 6.2 kΩ; 1 %; 0603	-	Yageo
R12	resistor; chip; 56 kΩ; 1 %; 0603	-	Yageo
R13	resistor; chip; 4.3 kΩ; 5 %; 0805	-	Yageo
R14	resistor; chip; 2 Ω; 1 %; 0805	-	Yageo
R15	resistor; chip; 8.2 Ω; 1 %; 0805	-	Yageo
R16	resistor; chip; 100 kΩ; 5 %; 0805	-	Yageo
R17	resistor; chip; 1 Ω; 5 %; 0805	-	Yageo
R19	resistor; chip; 100 kΩ; 5 %; 0603	-	Yageo
T1	transformer; 1.1 mH; ER11.5	750341915	Wurth Electronics Midcom
U1	IC; SSL2101; SO-16	-	NXP Semiconductors
U2	bridge rectifier; 0.5 A; 600 V; MB6S	-	Vishay

11. Transformer



a. Bobbin



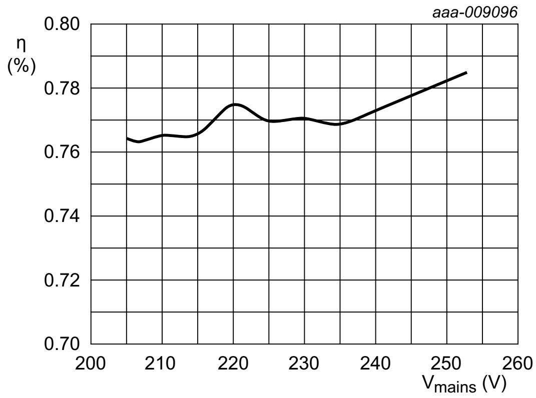
b. Schematic

Fig 6. SSL2101DB1169 transformer specification

Table 4. Winding information

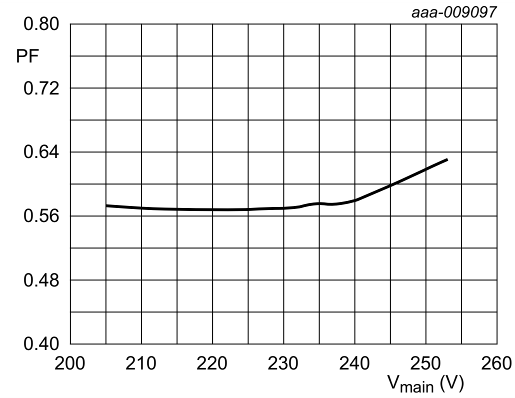
Number	Section	Wire	Turns	Begin pin	End pin	Description
N1	pins 1 to 2	∅0.12 mm * 1UEW	108	1	2	1.1 mH ± 10 %
N2	pins 7 to 4	∅0.12 mm * 1UEW	56	7	4	

12. Performance data



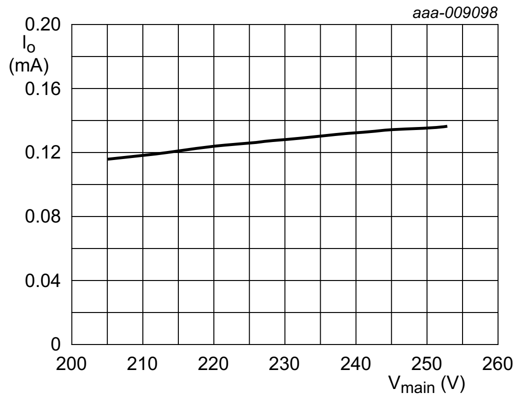
Efficiency at V_{mains} = 230 V ± 10 %

Fig 7. Efficiency as a function of mains voltage



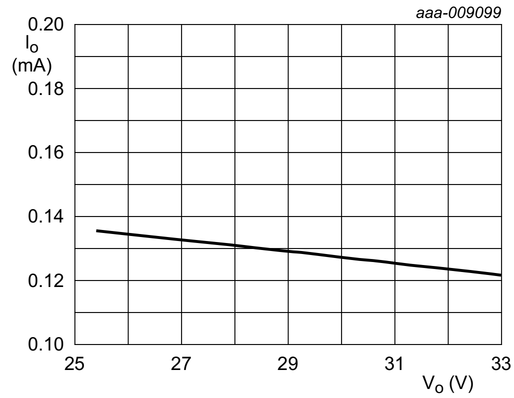
Power factor at V_{mains} = 230 V

Fig 8. Power factor as a function of mains voltage



Line regulation at V_{mains} = 230 V ± 10 %

Fig 9. Line regulation



Load regulation at V_{mains} = 230 V ± 10 %

Fig 10. Load regulation

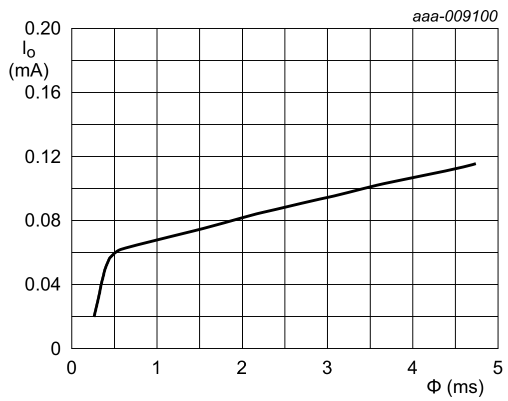


Fig 11. LED current loss as a function of dimmer conduction angle (ϕ)

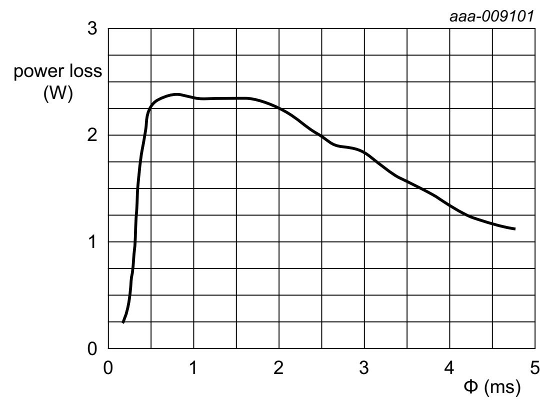


Fig 12. Power loss as a function of dimmer conduction angle (ϕ)

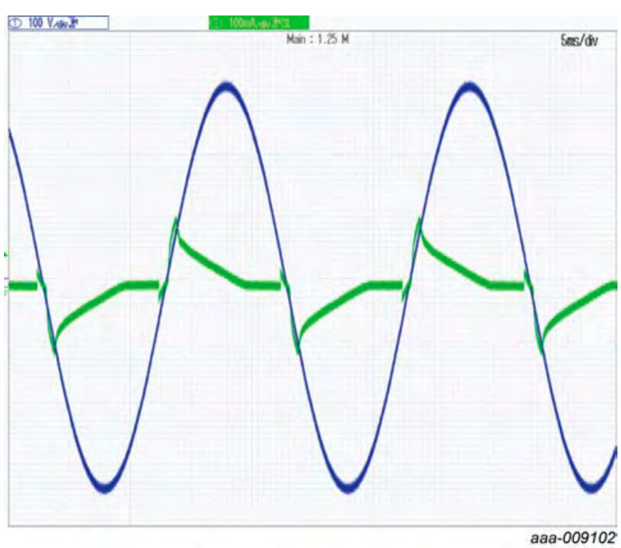
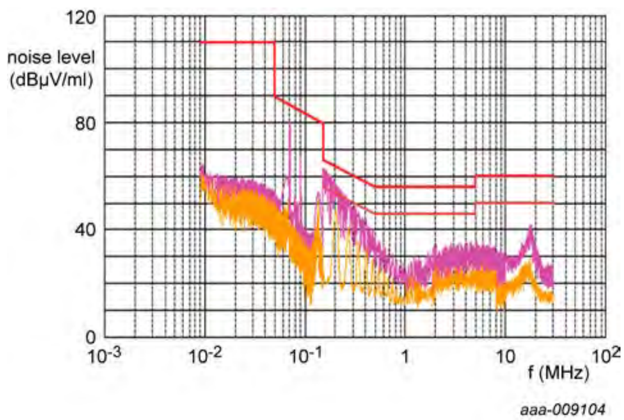


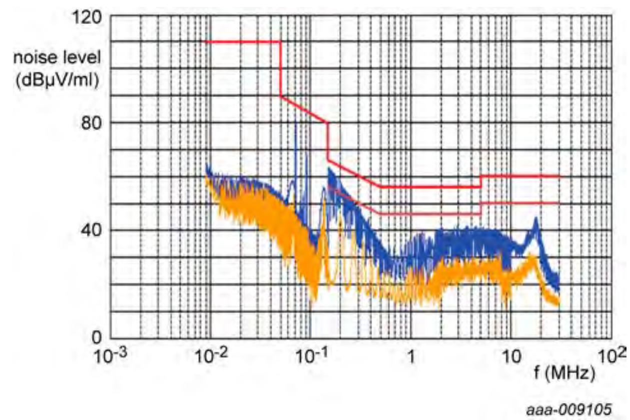
Fig 13. Input voltage waveform

Fig 14. Output voltage waveform

13. EMC performance

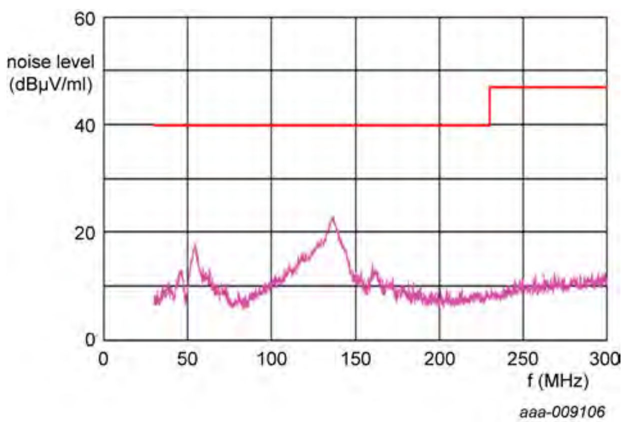


a. L-line

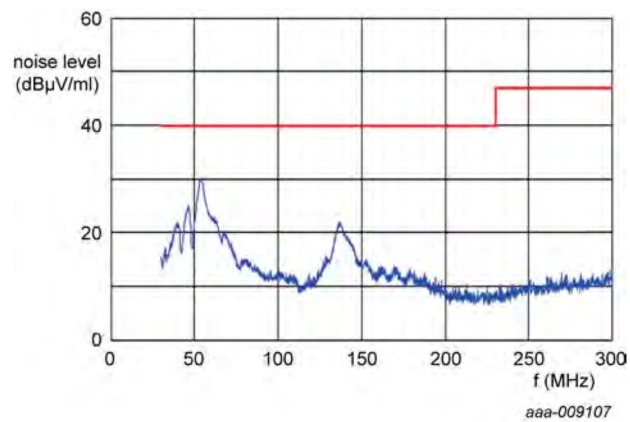


b. N-line

Fig 15. EMC conducted emission line



a. Horizontal



b. Vertical

Fig 16. EMC radiated emission

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Date of release: 11 November 2013
Document identifier: UM10735