UM10423

SSL2101 120 V PAR30 buck reference board

Rev. 1 — 6 July 2011 **User manual**

Document information

Info	Content
Keywords	SSL2101, LED driver, Buck SMPS topology, Mains dimmable
Abstract	This is a user manual for the SSL2101 mains dimmable 10 W LED driver application board

Revision history

Rev	Date	Description
v.1	20110706	first issue

Contact information

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1. Introduction

The intention of this user manual is to provide basic information on the operation and performance of the SSL2101 120 V buck reference board. This reference board is designed to highlight an efficient solution for the driver circuit used in mains dimmable, PAR30 LED recessed-light applications. It does not provide galvanic isolation from the AC line to the DC output, therefore mechanical isolation is required in the luminaire design. The design is highly efficient, cost effective and compatible for a wide range of dimmers. For more information on the operation of the controller IC, the SSL2101 and the Buck converters, please consult the SSL2101 data sheet (Ref. 1) and application note (Ref. 2). Data sheets and application notes are available on www.nxp.com.

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.

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Fig 1. Photo of SSL2101 120 V buck reference board; top side

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Fig 2. Photo of SSL2101 120 V buck reference board; bottom side

1.1 Design specifications

Table 1. Performance and specifications

T_{amb} = 25 °C

Parameter	Conditions	Min	Typ	Max	Unit
Input voltage range	f = 60 Hz	100	120	132	V
Output voltage		18	20	30	V
Output current	V_I = 120 V; V_O = 20 V	-	450	-	mA
Switching frequency		-	70	90	kHz

Table 1. Performance and specifications *...continued*
T_{amb} = 25 °C

Parameter	Conditions	Min	Typ	Max	Unit
Output current ripple	V_I = 120 V; V_O = 20 V; I_O = 445 mA	-	5.4	-	%
Input power factor	V_I = 108 V to 132 V; V_O = 20 V; I_O = 445 mA	0.84	0.85	-	
Efficiency	V_I = 108 V to 132 V; V_O = 20 V; I_O = 445 mA	84.1	84.5	-	%
Output current regulation	V_I = 108 V to 132 V	-	±0.45	-	%

2. SSL2101

The SSL2101 is a Switched Mode Power Supply (SMPS) controller IC that can be used in both buck (non-isolated) and flyback (isolated) topologies. The SSL2101 controller has the benefit of valley switching which improves the power supply efficiency. It incorporates an integrated bleeder circuit for triac dimming and an integrated power MOSFET to save board space and reduce costs. The SSL2101 is a very effective solution for applications with an output power up to 14 W. For higher wattage applications refer to the SSL2102 data sheet (Ref. 3).

3. Basic description

The reference board is designed to operate from a nominal input voltage of 120 V (AC) at 60 Hz with a tolerance of ± 10 % on the AC input voltage. It is designed to provide a nominal DC output current of 450 mA when the triac is fully ON. The maximum output voltage, V_LED+, for the reference board is 35 V (DC). The nominal switching frequency when the triac is fully ON or when the board is connected directly to the 120 V (AC) line is 90 kHz. The driver is connected to six LEDs in the test condition. Six LEDs were used in this test application to achieve the desired forward voltage for optimal performance of this reference design. The user can adapt the design to match any LED solution up to 14 W.

This board has been designed with special focus on improving dimmer compatibility. High performances can be reached with SSL2101 fully integrated bleeder switches. This board further improves these performances with dedicated external circuitry.

4. Basic operation

The driver circuit can be divided into four parts:

- Input circuitry
- Damper and bleeder circuit
- Power circuit
- Dimming circuit

4.1 Input circuitry (F1, C1, R1, D1, D2, D5 to D8, C3, L2, C4, C5, C6)

The input circuitry provides rectification of the AC line, some dampening, surge protection, EMI conditioning, and valley filling of the rectified AC input. The valley fill capacitors (C4 and C5) charge and discharge during every 120 Hz cycle which allows the demo unit to have a high Power Factor (PF).

4.2 Damper and bleeder circuit (Q3 to Q6, Q8, Q10)

Since C9 and C6 charge and discharge every cycle, an active damper (R24, R25, R26, Q8) is needed to limit the inrush current every 120 Hz. The damper also assists in preventing oscillations that could cause interference with the triac in the dimmer. The bleeder circuit (Q3 to Q6) ensures that there is enough current flowing in the circuit to keep the triac inside the dimmer in conduction. The circuit can be modified via resistors R22 and R27 to adjust the minimum amount of current flowing through the circuit.

4.3 Power circuit

The power stage converts the high voltage input from the input circuitry into a low voltage DC output to drive the LEDs. It also provides power to the IC with the auxiliary winding on the coupled inductor. During dimming the switching frequency and duty cycle of the switching MOSFET is adjusted. Note that the number of LEDs connected must not be less than 5 so that V_{CC} voltage is always above UnderVoltage LockOut (UVLO) during dimming of the LEDs.

4.4 Dimming circuit (R8, R9, R12, D4 and C2)

The dimming circuit detects input voltage changes when dimming and appropriately adjusts the oscillator frequency and duty cycle to ensure good logarithmic dimming. More information on dimming adjustment can be found in the SSL2101 data sheet (Ref. 1).

5. Results

5.1 Electrical performance results

- All performance results described here are for an LED load of 6 LEDs with a combined forward voltage drop of 18.6 V.

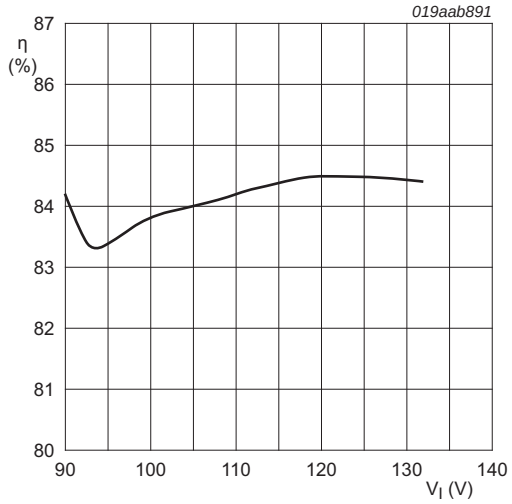


Fig 3. Efficiency as a function of input voltage

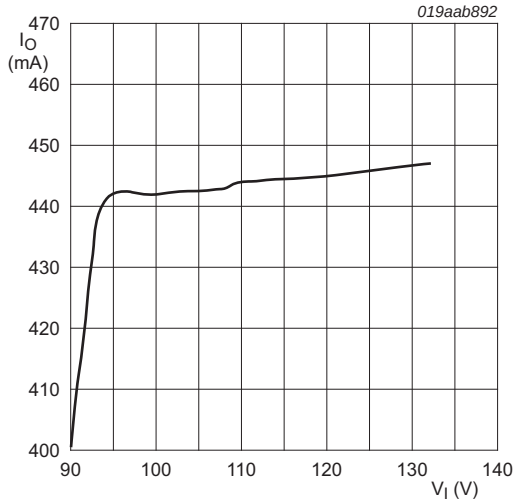


Fig 4. Output current as a function of input voltage

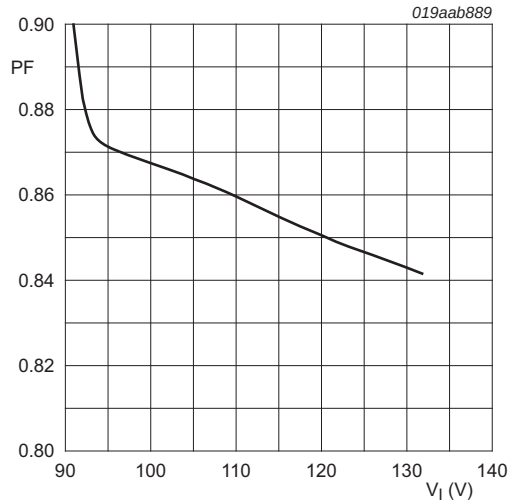


Fig 5. Power factor as a function of input voltage

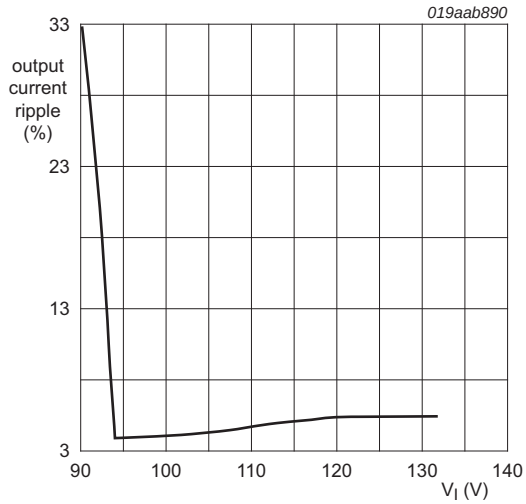


Fig 6. Output current ripple as a function of input voltage

5.2 Driver board thermal tests

5.2.1 Thermal run1 vertical

As the main application for this driver design was a recess down-light application, thermal performance was a critical consideration. A test setup was developed to measure the increase in driver heat and component thermal stress.

The LED board and metal plate are separated from the driver board. Two driver assemblies are tested for comparison reasons. Driver boards are viewed on front (pin-through component) and back (surface mount) sides with a thermal imaging camera. Data is collected for drivers both with and without triac dimmer as part of the circuit.

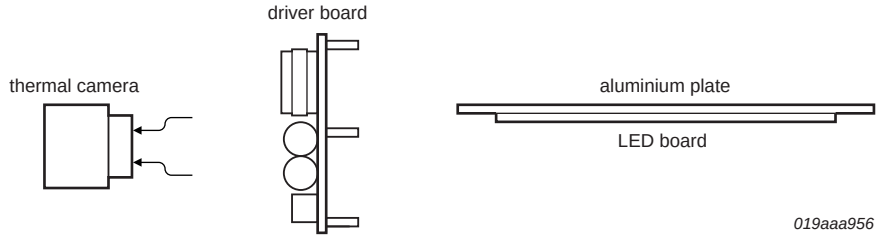
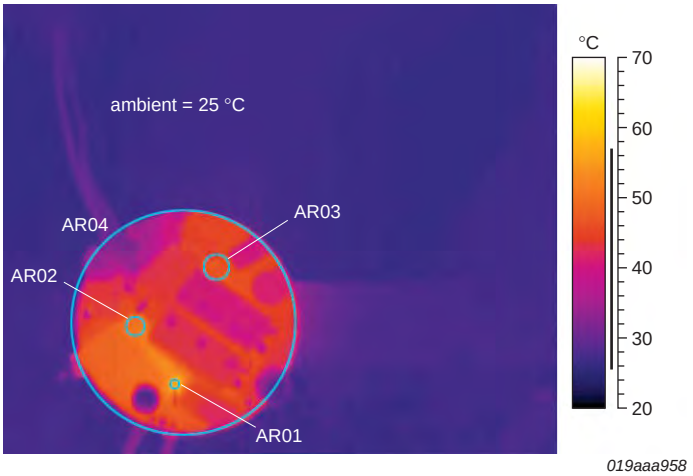


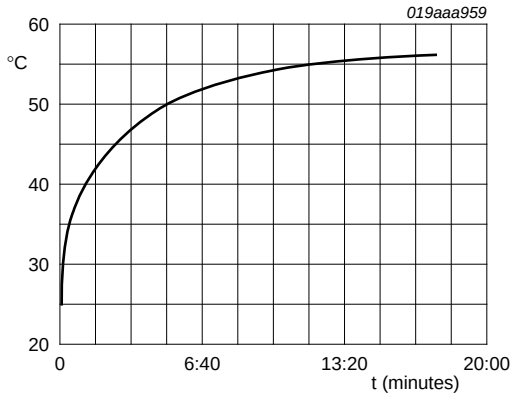
Fig 7. LED board, driver board and thermal camera

5.3 Driver board thermals (top side); Full-on



AR01 = diode D10; AR02 = R28, R29; AR03 = R27; AR04 = entire board.

Fig 8. 120 V (AC), no dimmer, Bd 100506026



Hottest component, D10, experiences a Δt = 34 °C.

Hottest board area experiences a Δt = 27 °C.

Fig 9. Plot AR01 (D10); maximum temperature as a function of time

Table 2. Analysis

Max and Min are respectively the highest and lowest pixel temperatures in a thermal image area. Average is the average of all the pixels in an area and is ***not*** *½ x max − min*

Label	Value (°C)		
	Min	Max	Average
5 minutes			
image	25.2	52	-
AR01[1]	45	52	49.4
AR02[2]	39.3	44.4	42.1
AR03[3]	34.1	43.3	40.2
AR04[4]	26.4	52	36.6
10 minutes			
image	25.5	56.3	-
AR01[1]	49.1	56.3	53.7
AR02[2]	46	49.7	47.6
AR03[3]	38.2	46	43
AR04[4]	26.6	56.3	40
20 minutes			
image	25.7	58.8	-
AR01[1]	51.4	58.8	56.1
AR02[2]	47.7	52	50
AR03[3]	40.6	46.9	44.6
AR04[4]	26.8	58.8	41.9

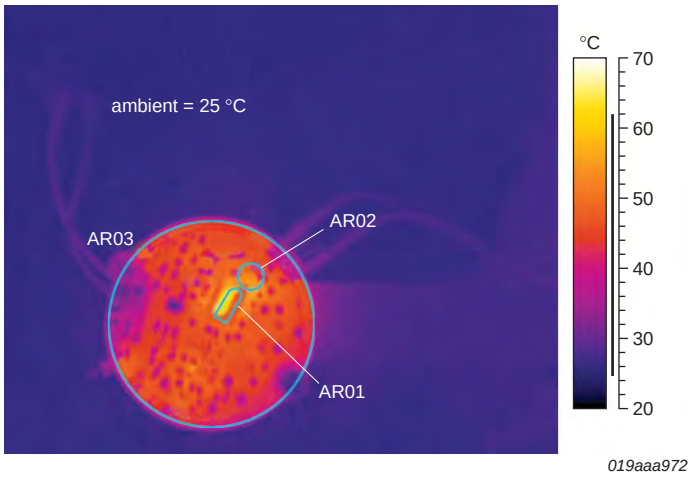
[1] AR01: diode D10.

[2] AR02: R28, R29.

[3] AR03: R27.

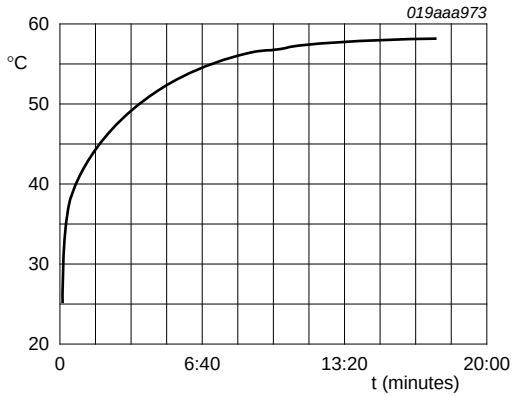
[4] AR04: entire board.

5.4 Driver board thermals (bottom side); Full-on



AR01 = SSL2101; AR02 = board area next to SSL2101; AR03 = entire board.

Fig 10. 120 V (AC), no dimmer, Bd 100506026



Hottest component, SSL2101, experiences a Δt = 38 °C.

Hottest board area experiences a Δt = 31 °C.

Fig 11. Plot AR01 (SSL2101); maximum temperature as a function of time

Table 3. Analysis

Max and Min are respectively the highest and lowest pixel temperatures in a thermal image area. Average is the average of all the pixels in an area and is ***not*** $\frac{1}{2}$ *x max − min*

Label	Value (°C)		
	Min	Max	Average
5 minutes			
image	25	57.3	-
AR01[1]	44.4	57.3	52.4
AR02[2]	36.2	50.4	45.8
AR03[3]	27.6	57.3	39.6

Table 3. Analysis *…continued*

Max and Min are respectively the highest and lowest pixel temperatures in a thermal image area. Average is the average of all the pixels in an area and is ***not*** *½ x max − min*

Label	Value (°C)		
	Min	Max	Average
10 minutes			
image	25.5	61.9	-
AR01[1]	47.8	61.9	56.6
AR02[2]	39	54.7	50
AR03[3]	28.2	61.9	43.2
20 minutes			
image	24.7	63.2	-
AR01[1]	48.5	63.2	58
AR02[2]	39.6	56	51.1
AR03[3]	27.9	63.2	44.4

[1] AR01: SSL2101.

[2] AR02: board area next to SSL2101.

[3] AR03: entire board.

5.5 Conducted emission testing

ElectroMagnetic Compatibility (EMC) testing was administered to a driver with LED load. In Figure 12, the blue line represents peak detection, while the black line represents average detection results. Both sets of results show that the driver board passes the limits set for LED luminaire products.

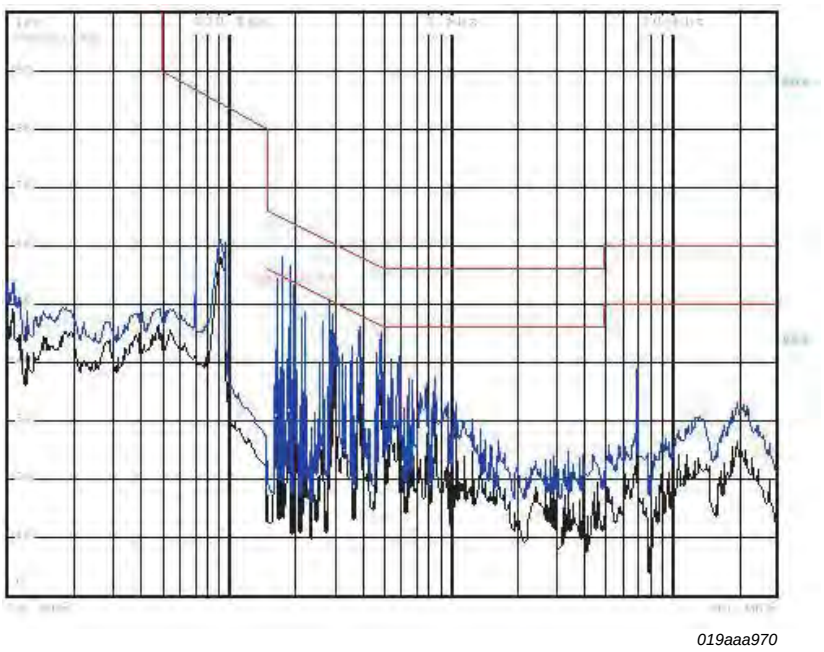


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Fig 12. SSL2101 120 V buck reference design EMC image

5.6 SSL2101 120 V, 10 W, 2 inch, round buck application schematic

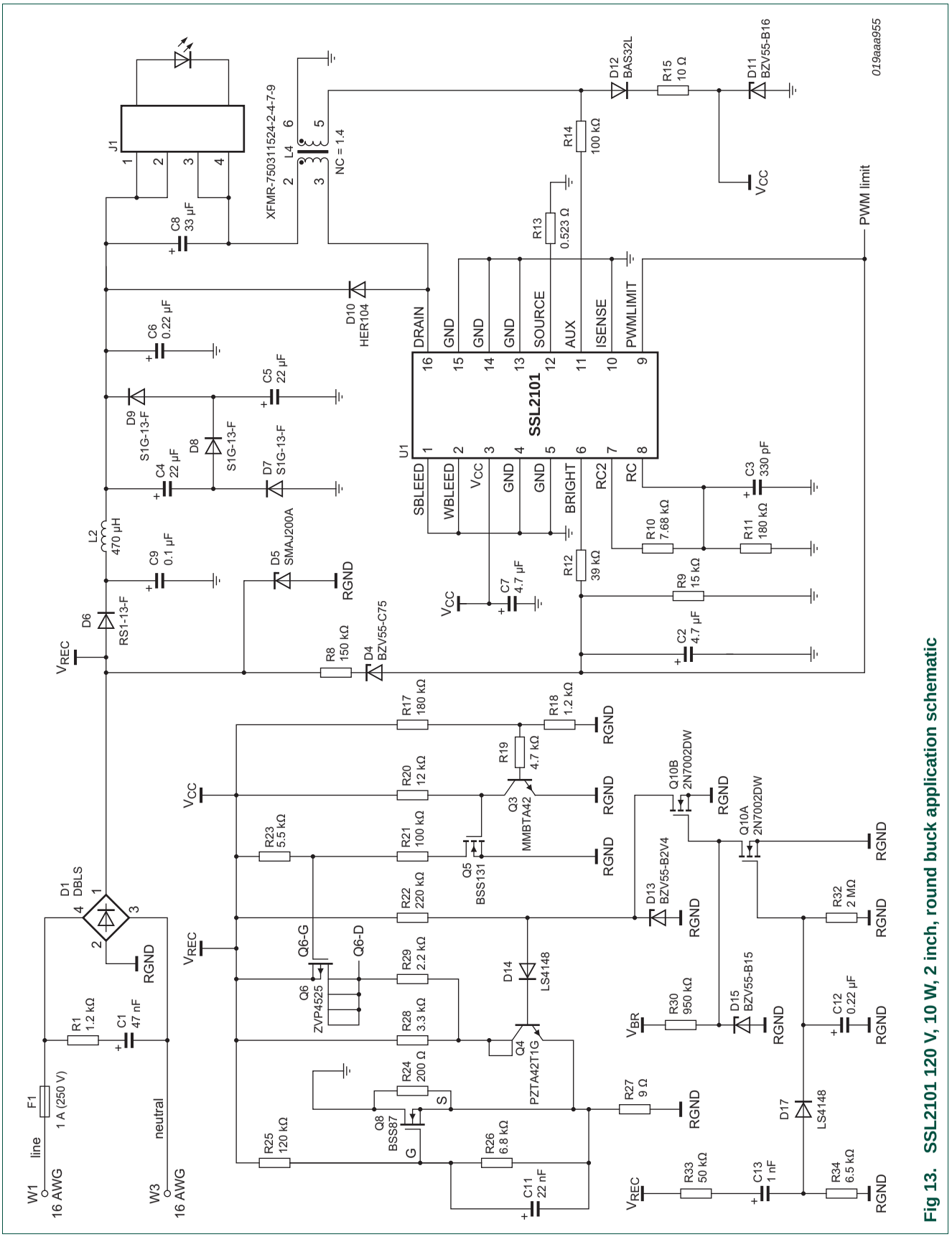

Fig 13. SSL2101 120 V, 10 W, 2 inch, round buck application schematic

6. Bill Of Materials (BOM)

Table 4. NXP Semiconductors reference design SSL2101 buck board 20 V, 450 mA

RefDes	Quantity	Value, type	PKG	Tolerance	Rating	Manufacturer	Part number
R1	1	1.2 kΩ	1206	5 %	1/4 W	Yageo	RC1206JR-071K2L
R8	1	150 kΩ	1206	1 %	1/4 W	Yageo	RC1206FR-07150KL
R9	1	15 kΩ	0603	1 %	1/10 W	Panasonic	ERJ-3EKF1502V
R10	1	7.68 kΩ	0603	1 %	1/10 W	Panasonic	ERJ-3EKF7681V
R11	1	180 kΩ	0603	1 %	1/10 W	Panasonic	ERJ-3GEYJ184V
R12	1	39 kΩ	0603	1 %	1/10 W	Panasonic	ERJ-3EKF3922V
R13	1	0.56 Ω	1206	1 %	1/4 W	Rohm	MCR18EZHFLR560
R14	1	100 kΩ	0805	1 %	1/8 W	Panasonic	ERJ-6ENF1003V
R15	1	10 Ω	0603	1 %	1/10 W	Panasonic	ERJ-3GEYJ100V
R17	1	200 kΩ	1206	1 %	1/4 W	Yageo	RC1206FR-07200KL
R18	1	1.2 kΩ	0603	1 %	1/10 W	Yageo	RC0603JR-071K2L
R19	1	4.7 kΩ	0603	1 %	1/10 W	Yageo	RC0603JR-074K7L
R20	1	12 kΩ	0603	1 %	1/10 W	Yageo	RC0603JR-0712KL
R21	1	100 kΩ	1206	1 %	1/4 W	Stackpole	RMCF 1/8 100K 1% R
R22	1	37.4 kΩ	1206	1 %	1/4 W	Yageo	RC1206FR-0737K4L
R23	1	5.49 kΩ	0603	1 %	1/10 W	Yageo	RC0603FR-075K49L
R24	1	200 Ω	1210	5 %	1/3 W	Stackpole	RMCF 1/4 200 5% R
		200 Ω	axial	5 %	1/2 W	Yageo	CFR-50JB-200R
R25	1	120 kΩ	1206	-	1/4 W	Yageo	RC1206JR-07120KL
R26	2	6.8 Ω	1206	-	1/10 W	Yageo	RC0603JR-076K8L
R27	1	9.1 Ω	1206	1 %	1/4 W	Yageo	CFR-25JR-9R1
R28	1	3.3 kΩ	1206	5 %	1 W	Yageo	FMP100JR-52-3K3
R29	1	2.2 kΩ	1206	5 %	1 W	Yageo	FMP100JR-52-2K2
R30	1	953 kΩ	1206	1 %	1/4 W	Yageo	RC1206JR-07953KL
R32	1	2 MΩ	0603	5 %	1/10 W	Stackpole	RMCF 1/16 2M 5% R
R33	1	49.9 kΩ	1206	1 %	1/4 W	Stackpole	RMCF 1/8 49.9K 1% R
R34	1	6.5 kΩ	0603	1 %	1/10 W	Stackpole	RMCF 1/16 6.49K 1% R
C1	1	0.047 µF	radial	10 %	250 V	AVX	BF024G0473K
						EPCOS	B32529C3473K189
C2, C7	2	4.7 µF	0805	20 %	25 V (DC) (X5R)	Murata	GRM21BR61E475MA12L
			1206	20 %	25 V (DC) (X7R)	Murata	GRM31CR71E475KA88L
C3	1	330 pF	0603	10 %	50 V (DC) (X7R)	Murata	GRM188R71H331MA01D
			0805	20 %	50 V (DC) (X7R)	Kemet	C0805C331K5RACTU
C4, C5	2	22 µF	radial	20 %	200 V (DC)	Panasonic	EEU-EB2D220
					160 V (DC)	Nichicon	UPW2C220MPD

Table 4. NXP Semiconductors reference design SSL2101 buck board 20 V, 450 mA *…continued*

RefDes	Quantity	Value, type	PKG	Tolerance	Rating	Manufacturer	Part number
C6	1	0.22 μF	radial	5 %	250 V	WIMA	MKP4.22/250/5
		0.15 μF	radial	5 %	250 V	WIMA	MKP4-.15/250/10 P10
C8	1	100 μF	radial	20 %	50 V (DC)	Panasonic	EKY-500ELL101MHB5D
					50 V (DC)	Nichicon	UPW1H330MED
C9	1	0.1 μF	radial	5 %	250 V	WIMA	MKP2.1/250/5
C11	1	22 nF	0603	-	22 nF; 16 V	TDK	C1608X7R1C223K
C12	1	0.22 μF	0603	10 %	0.22 μF; 16 V	TDK	C1608X7R1C224K
C13	1	1 nF	0805	5 %	1 nF; 250 V	TDK	C2012C0G2E102J
D1	1	bridge rectifier	MBS-1	-		ComChip Tech	B6S-G
D4[1]	1	75 V Zener diode	SOD80C	5 %	75 V	NXP Semiconductors	BZV55-C75
D5	1	200 V TVS	SMA	-	200 V	Littlefuse Inc.	SMAJ200A
D6	1	fast recovery diode	SMA	-	400 V; 1 A	Fairchild	RS1G_Q
					600 V; 1 A	Vishay Zetex	RS1J-13-F
D7, D8, D9	3	fast recovery diode	SMA	-	400 V; 1 A	Diodes Inc.	S1G-13-F
D10	1	fast recovery diode	axial	-	400 V; 1 A	Taiwan Semiconductor	HER104
D11[1]	1	16 V Zener diode	SOD80C	2 %	16 V	NXP Semiconductors	BZV55-B16
D12[1]	1	switching diode	SOD80C	-	75 V; 100 mA	NXP Semiconductors	BAV103; BAV115
D13[1]	1	2.4 V Zener diode	SOD80C	-	2.4 V	NXP Semiconductors	BZV55-B2V4
D14	1	diode	LL-34 /SOD80	-	150 mA; 100 V	Vishay Zetex	LS4148-GS08
D15[1]	1	15 V Zener diode		-	15 V	NXP Semiconductors	BZV55-B15
D17	1	switching diode	LL-34 /SOD80	-	150 mA; 100 V	Vishay Zetex	LS4148-GS08
F1	1	fast acting fuse	axial	-	1 A; 250 V	Littlefuse Inc.	0224001.HXP
		fast pico fuse	axial	-	1 A; 250 V	Littlefuse Inc.	0263001.MXL
L2	1	470 μh coil	pin-through	-	460 mA	Bourns	RLB1314-471K
							RL622-471K-RC
					450 mA	Murata Power	13R474C
L4	1	transformer /inductor; 270 μh	EP13	-	-	Wurth Midcom	-
MOV1	1	MOV	-	-	240 V; 1.25 kA; 15 J	Panasonic	ERZ-V07D241
Q3[1]	1	NPN _MMBTA42	SOT23	-	100 mA; 300 V	NXP Semiconductors	MMBTA42; 215
						Fairchild Semiconductors	MMBTA42_Q

Table 4. NXP Semiconductors reference design SSL2101 buck board 20 V, 450 mA *…continued*

RefDes	Quantity	Value, type	PKG	Tolerance	Rating	Manufacturer	Part number
Q4[1]	1	NPN _PZTA42	SOT223	-	100 mA; 300 V	NXP Semiconductors	PZTA42; 215
Q5	1	NFET _BSS131	SOT23	-	110 mA; 240 V	Infineon	BSS131 L6327
Q6	1	PFET _ZVP4525	SOT23-6	-	200 mA; 250 V	Diodes	ZVP4525E6
		PFET _ZVP2120A	TO-92	-	120 mA; 200 V	Diodes	ZVP2120A
Q8[1]	1	NFET_BSP87	SOT89	-	100 mA; 300 V	NXP Semiconductors	BSP87; BSP115
		NFET_BSP89	SOT223	-	-	NXP Semiconductors	BSP89; BSP115
Q10		NFET _2N7002	SOT363		-	Fairchild Semiconductors	2N7002DW
U1[1]	1	control IC	SO16	-	-	NXP Semiconductors	SSL2101

[1] Components supplied by NXP Semiconductors

7. References

[1] **Data sheet SSL2101 —** SMPS IC for dimmable LED lighting

[2] **Application note AN10876 —** Buck converter for SSL applications

[3] **Data sheet SSL2102 —** SMPS IC for dimmable LED lighting

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9. Contents

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