UM10689

SSL2109ADB1121 4-channel DC-to-DC LED driver demo board

Rev. 1.1 — 13 May 2013 **User manual**

Document information

Info	Content
Keywords	SSL2109T, SSL2109AT, SSL2109ADB1121, buck, controller, reference board, LED driver, PWM
Abstract	This document explains the operation and application of the SSL2109AT 4-channel, small form factor demo board. The demo board incorporates four independent DC-to-DC switch mode current drivers with a common input power stage. By default, the board is optimized to drive 1 A (typical) per channel. The board is particularly suitable for use in street and high-bay lighting applications. Multiple user configuration options are available for the demo board; some options require components changes.

Revision history

Rev	Date	Description
v.1.1	20130513	Section 3.1.6 and Section 4.3 added; Table 3 reformatted
v.1	20130326	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.

The SSL2109AT 4-channel demo board demonstrates the LED driving capabilities of the SSL2109AT device. The SSL2109T (with Short-Winding Protection (SWP)) could replace the SSL2109AT on the demo board if SWP is required. Typical target applications for the demo board include LED street lighting, high and low bay lighting, and refrigeration lighting. Each channel is individually dimmable using Pulse Width Modulation (PWM). The circuit contains four Boundary Conduction Mode (BCM) buck converters and a common input power stage. The BCM buck converter is a true switch-mode current source.

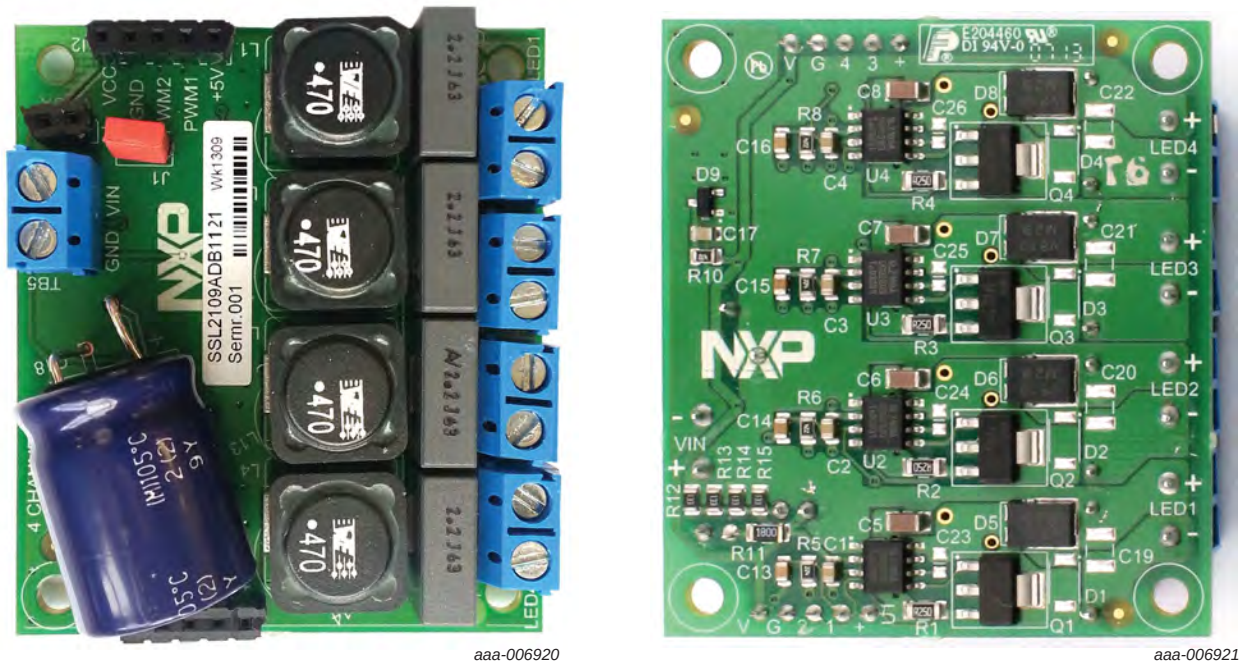
Key features of the board include:

- Up to 98 % efficiency
- User-configurable output current (no custom-made magnetic components needed)
- Intrinsically protected against short-circuit, open load and overtemperature conditions
- BCM buck converters operate as true switch-mode current sources
- Operates with input voltages ranging from 33 V (DC) to 600 V (DC) with some component changes
- Low-cost LED driver solution
- Small form factor
- PWM dimming
- Independent or combined channel control
- No LED binning required

Applications:

- Street lighting
- High and low bay lighting
- Refrigeration lighting

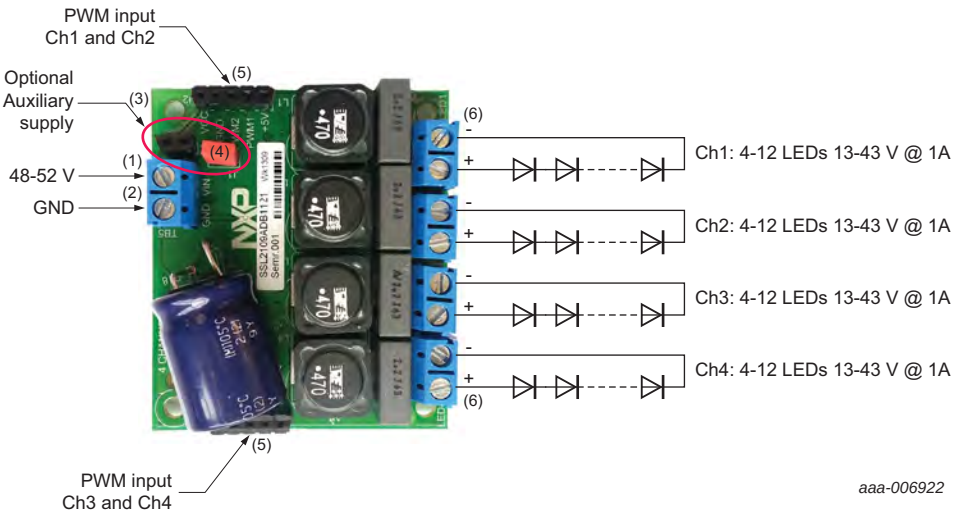
Figure 1 is a populated view of the demo board; Figure 2 shows the connections.



a. top view

b. bottom view

Fig 1. SSL2109ADB1121 demo board



(1) Main DC supply input (48 V to 52 V)
(2) Main supply ground (GND)
(3) Optional auxiliary supply (15 V to 20 V)
(4) Jumper for internal/external V_{CC} supply
(5) PWM inputs (Ch1 to Ch4)
(6) LED string connections (Ch1 to Ch4)

Fig 2. SSL2109ADB1121 demo board showing connections

2. Specifications

Table 1. Demo board specifications

Parameter	Value	Comment
Output current	1 A	the channels can be configured individually
Supply voltage	48 V (DC) to 52 V (DC)	the board can be used with other combinations of input/output voltages; it is recommended to keep the switching frequency between 20 kHz and 200 kHz
Output voltage	13 V to 43 V	at 52 V (DC) input voltage
Efficiency	> 90 %	see Figure 5
Auxiliary supply voltage	15 V (DC) to 20 V (DC)	optional
Switching frequency	65 kHz to 120 kHz	at 52 V (DC) input voltage
PWM frequency	0.1 kHz to 1 kHz	dimming resolution < 1 %
Board dimensions	51 mm × 58.5 mm	length × width

3. Functional description

3.1 Introduction

The SSL2109AT multi-channel demo board circuit consists of a general power input section and four SSL2109AT current source sections. Each of the current source sections contains the following blocks: common power input, dimming input, switching circuit, current measurement/feedback and output. Figure 9 is a circuit diagram of the demo board default configuration. The BOM component list is detailed in Table 3.

3.1.1 General power input section

The common power input section of the default demo board consists of a buffer capacitor (C18) and terminal TB5. TB5 has two ports and must be connected to the mains input DC voltage (48 V to 52 V) and to ground, as marked on the board. J4 can be connected to an auxiliary power supply (15 V (DC) to 20 V (DC)). By default, jumper J1 (a 2-way female jumper) connects the V_{CC} supply voltage to the SSL2109ATs via resistors R12, R13, R14 and R15. So the auxiliary supply is not needed in the default configuration.

3.1.2 PWM dimming sections

The PWM dimming input signals are connected to the IC input ports via J2 and J3, as indicated on the PCB (see Figure 2). 10 nF capacitors are used for low-pass filtering. Voltage reference D9 is provided for fast booting of the SSL2109AT ICs. Alternatively, C13, C14, C15 and C16 can be tied to ground. The dimming input signals are connected to the SSL2109AT control pins (NTC). When a low voltage signal ($-0.4\ V < V_{low} < 0.3\ V$) is supplied to this pin, the SSL2109AT converter is effectively disabled. A high voltage ($0.53\ V < V_{high} < 5.2\ V$) on the same pin causes the SSL2109AT to be fully enabled. The light output can be varied by toggling between low and high voltages on pin NTC. Typically, the light output is exactly proportional to the duty ratio of the PWM dimming signal. In principle, any PWM frequency is acceptable for PWM dimming. In practice, a very low PWM frequency can give the impression that the LED string is flickering. A very high frequency can result in inaccurate dimming, since PWM dimming resolution is proportional to the ratio between the switching frequency and PWM frequency. The

slew-rate of the PWM signal must be steep enough (> 2200V/sec between 0.2 V and 0.3 V) to prevent the SSL2109AT activating overtemperature protection. See the SSL2109 data sheet for more information. A PWM frequency in the range 100 Hz to 1 kHz is recommended for most applications. SMD coils are mounted on the default demo board. SMD coils generate the least amount of audible noise when PWM dimming is used. Cheaper through-hole coils can be substituted if PWM dimming is not used (as specified in the BOM, see Table 3). Typical PWM input (yellow) and output current (pink) waveforms are shown in Figure 3.

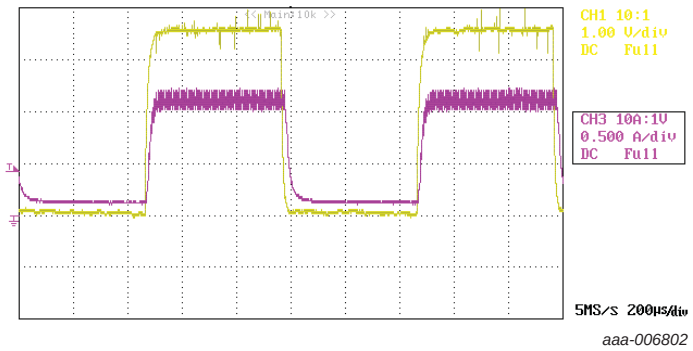


Fig 3. Typical PWM input and output current waveforms

3.1.3 SSL2109 demagnetization detection

A new cycle starts when the primary switch is turned on and the current starts to ramp up via the current sense resistors (R1, R2, R3, R4). The switch is turned off when the current reaches I_{peak}, and it starts to ramp down again. When the current reaches zero, the drain voltage starts to oscillate. The peak-to-peak amplitude equals $2 \times V_O$.

A special feature called valley detection is integrated into the SSL2109. Dedicated built-in circuitry senses the voltage on the DRAIN pin. A valley is detected when the differential voltage between V_{HV} and V_{DRAIN} falls to 25 V. Therefore, the minimum output voltage is 12.5 V. If a valid valley is not detected, the secondary stroke continues until the maximum off-time of the SSL2109 ($t_{off(high)}$) has been exceeded. A new cycle then begins.

3.1.4 Output selection

The switching section generates a sawtooth-shaped current waveform in the inductor. The current ramps up linearly from 0 A to I_{peak} and then ramps down again linearly from I_{peak} to 0 A. This waveform is not applied directly to the LED load. Capacitors C9, C10, C11 and C12 in the output sections reduce the ripple on the LED current. The output current ripple is relatively high by default (<30%, see Figure 3) and is dependent on the LED load. Ripple can be reduced by adding extra output capacitance, although higher output capacitance will affect the transient response speed at the output. The transient response time must be fast for PWM dimming.

3.1.5 Different voltage and current versions

Some components would need to be changed to allow the demo board to be used to drive longer LED strings (higher output voltage) and operate at a higher supply voltage. The input voltage rating of the circuit can be increased by substituting components with a higher input voltage rating for C18, C9, C10, C11, C12, C5, C6, C7, C8, Q1, Q2, Q3, Q4, D5, D6, D7 and D8.

For maximum efficiency, it is recommended to use either the auxiliary supply or the DVDT supply (C23, C24, C25, C26) for higher input voltages. The output current can be controlled by changing the values of R1, R2, R3 and R4. Inductance value may also need to be changed in order to maintain a suitable switching frequency. D1, D2, D3 and D4 can be used instead of D5, D6, D7 and D8 if lower output currents are required.

3.1.6 Extra low output voltage

A voltage swing of at least 25 V is required in order for the valley detection circuitry of the SSL2109A to detect a valley. Therefore, the minimum output voltage is limited to 12.5 V. The output voltage range can be extended below 12.5 V by replacing the buck coil with a transformer. The secondary side of the transformer can be connected to the DRAIN pin on the SSL2109A. The secondary side of the transformer should have more windings than the primary side; this will increase the magnitude of the ringing voltage (see the schematic diagram, Figure 4). R16 is required to filter the ringing caused by the transformer leakage inductance. The converter still operates as a true boundary conduction mode buck SMPS. Table 2 provides an overview of the output voltage versus efficiency for this configuration.

Table 2. Extra low output voltage measurements

P_I (W)	V_I (V)	I_O (mA)	V_O (V)	efficiency (%)
4.668	48.505	986.7	3.833	81.0
7.689	48.480	970.9	6.839	86.4
10.554	48.457	952.7	9.835	88.8
13.373	48.435	938.1	12.834	90.0

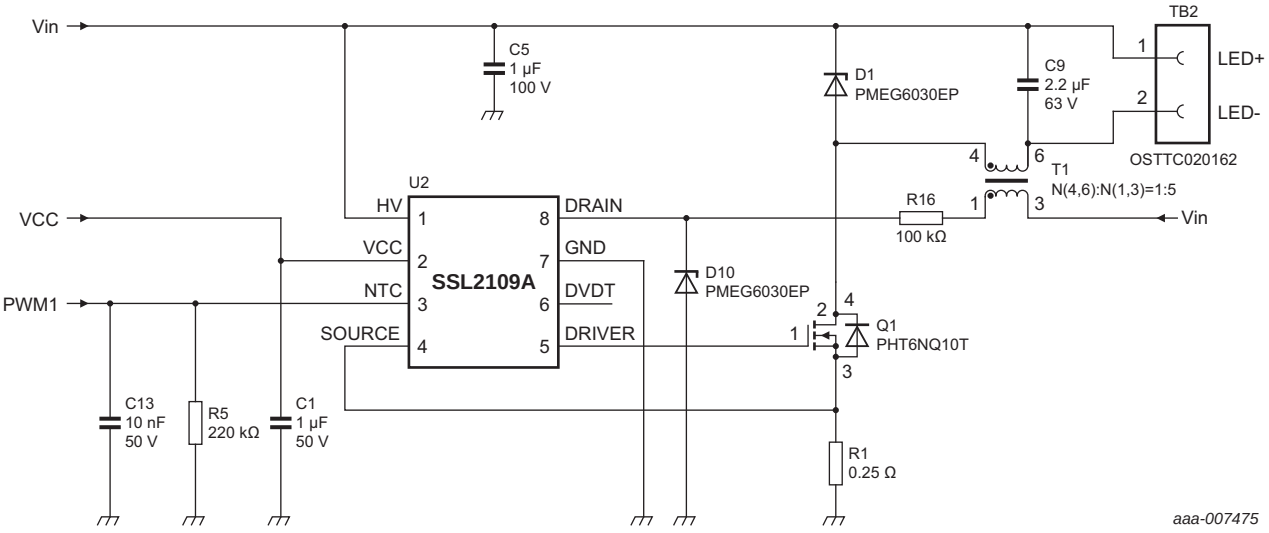


Fig 4. SSL2109A extra low output power schematic

4. Performance data

4.1 Efficiency

The SSL2109AT 4-channel demo board is suitable for driving long or short LED strings. High efficiency figures (98 %) are normally only obtained with relatively long LED strings. Figure 5 gives an indication of the level of efficiency that can be expected from the demo board. Efficiency levels are consistent over a wide range of output voltages.

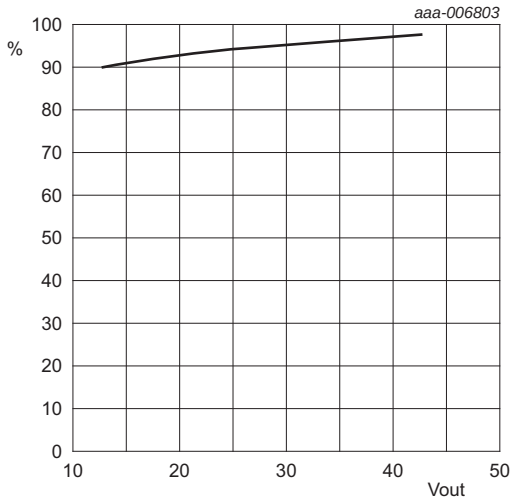


Fig 5. Efficiency curve

4.2 Load and Line regulation

The output current of the SSL2109AT 4-channel demo board varies slightly with the load and the supply voltage. The curves in Figure 5 and Figure 6 demonstrate that the demo board has excellent load and line regulation properties, which is ideal for general lighting purposes (line regulation was measured by changing the critical default capacitors to similar types with higher voltage ratings). The slight variations in light output intensity are barely visible to the human eye.

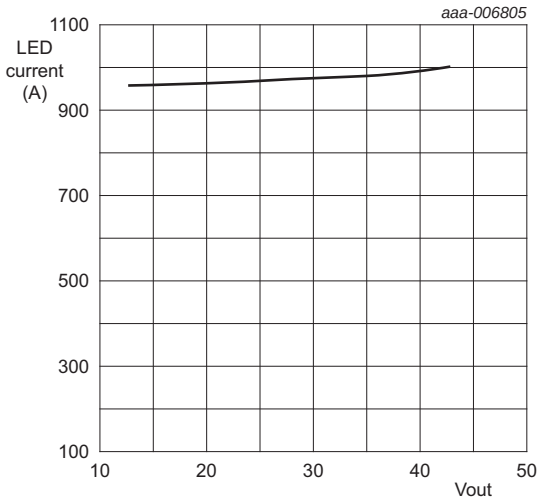


Fig 6. Load regulation

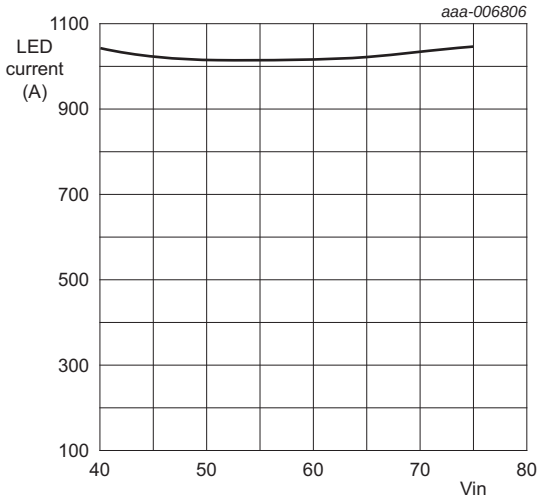


Fig 7. Line regulation

4.3 Output current accuracy

One hundred SSL2109ADB1121 demo boards were constructed, each containing four SSL2109AT current source sections. The current at the output of all four hundred LED string drivers was measured under typical conditions. Figure 8 shows how the measurement results were distributed.

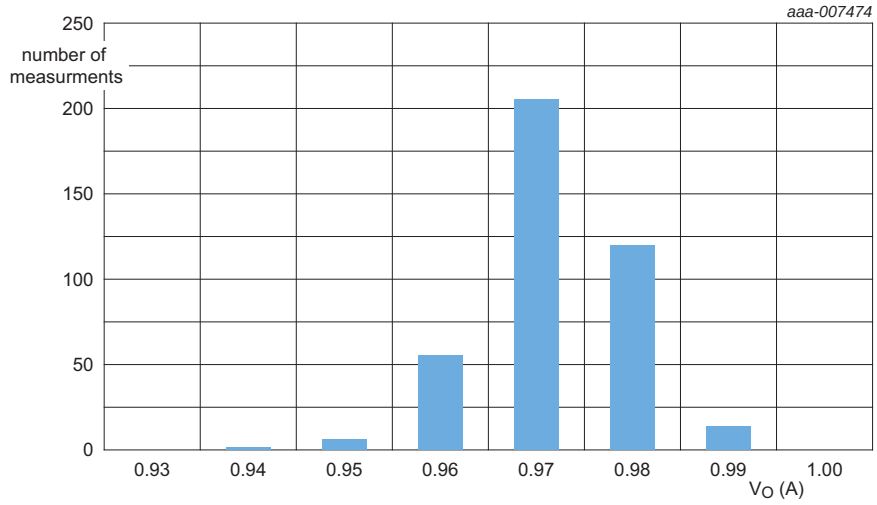


Fig 8. Distribution chart of V_O measurements for all 400 LED drivers

5. ElectroMagnetic Interference (EMI)

The SSL2109AT 4-channel demo board is pre-compliant with EMC regulations.

6. Schematic

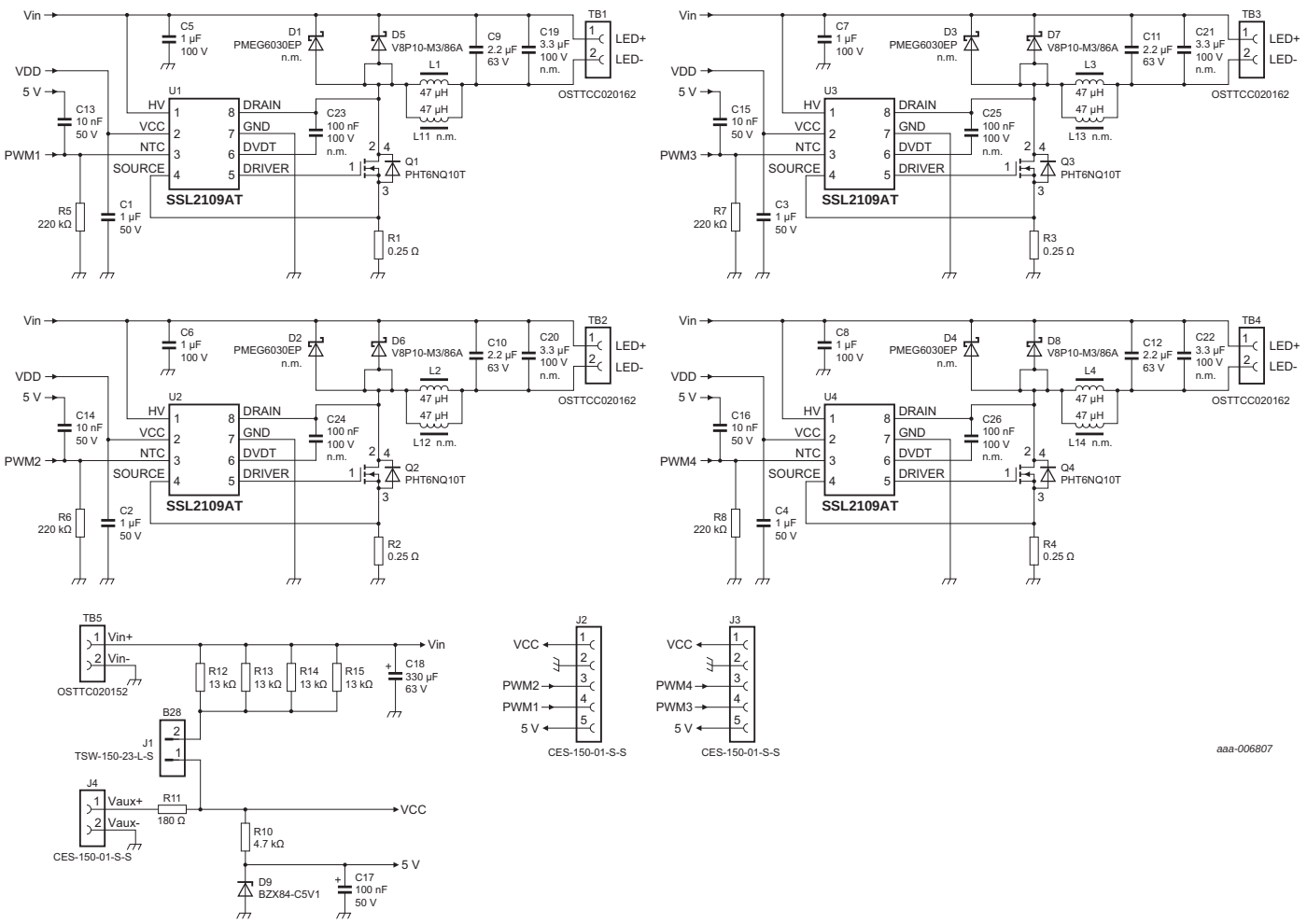


Fig 9. Schematic diagram of demo board default configuration

7. Bill of materials (BOM)

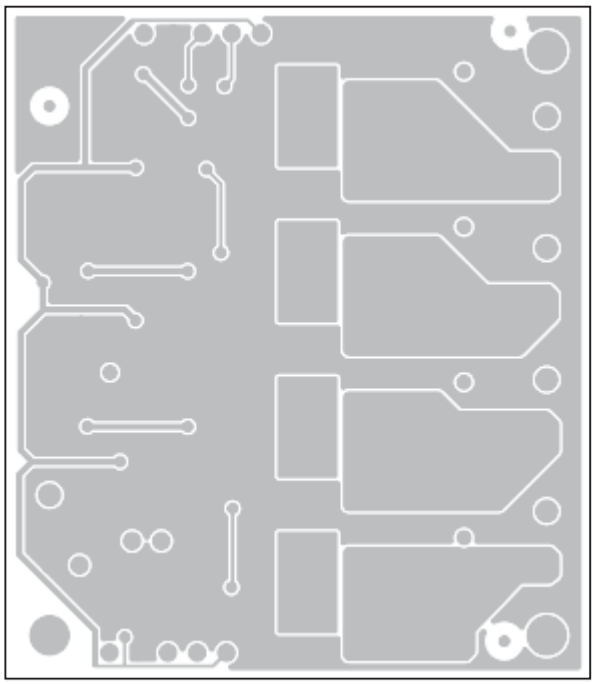
Table 3. BOM for 4-channel SSL2109AT demo board

Reference	Description and values	Part number	Manufacturer
C1	capacitor; 1 μF; 50 V; 0805; X7R; 10 % tolerance	CC0805KKX7R8BB105	Yageo
C2	capacitor; 1 μF; 50 V; 0805; X7R; 10 % tolerance	CC0805KKX7R8BB105	Yageo
C2	capacitor; 1 μF; 50 V; 0805; X7R; 10 % tolerance	CC0805KKX7R8BB105	Yageo
C4	capacitor; 1 μF; 50 V; 0805; X7R; 10 %tolerance	CC0805KKX7R8BB105	Yageo
C5	capacitor; 1 μF; 100 V; 1206; X7R; 20 % tolerance	C3216X7R2A105M	TDK
C6	capacitor; 1 μF; 100 V; 1206; X7R; 20 % tolerance	C3216X7R2A105M	TDK
C7	capacitor; 1 μF; 100 V; 1206; X7R; 20 % tolerance	C3216X7R2A105M	TDK
C8	capacitor; 1 μF; 100 V; 1206; X7R; 20 % tolerance	C3216X7R2A105M	TDK
C9	capacitor; 2.2 μF; 63 V; MKT; 5 % tolerance	R60DF4220506AJ	Kemet
C10	capacitor; 2.2 μF; 63 V; MKT; 5 % tolerance	R60DF4220506AJ	Kemet
C11	capacitor; 2.2 μF; 63 V; MKT; 5 % tolerance	R60DF4220506AJ	Kemet
C12	capacitor; 2.2 μF; 63 V; MKT; 5 % tolerance	R60DF4220506AJ	Kemet
C13	capacitor; 10 nF; 50 V; 0805; X7R; 10 % tolerance		
C14	capacitor; 10 nF; 50 V; 0805; X7R; 10 % tolerance		
C15	capacitor; 10 nF; 50 V; 0805; X7R; 10 % tolerance		
C16	capacitor; 10 nF; 50 V; 0805; X7R; 10 % tolerance		
C17	capacitor; 100 nF; 50 V; 0805; X7R; 10 % tolerance	08055C104KAT2A	AVX
C18	capacitor; 330 μF; 63 V; ALU; 20 % tolerance	ELXY630ELL331ML20S	United Chemi-Con
C19	capacitor; 3.3 μF; 100 V; 1210; X7S; 10 % tolerance; not mounted	C3225X7S2A335K	TDK
C20	capacitor; 3.3 μF; 100 V; 1210; X7S; 10 % tolerance; not mounted	C3225X7S2A335K	TDK
C21	capacitor; 3.3 μF; 100 V; 1210; X7S; 10 % tolerance; not mounted	C3225X7S2A335K	TDK
C22	capacitor; 3.3 μF; 100 V; 1210; X7S; 10 % tolerance; not mounted	C3225X7S2A335K	TDK
C23	capacitor; 100 nF; 100 V; 0805; X7R; 10 % tolerance; not mounted	08055C104KAT2A	AVX
C24	capacitor; 100 nF; 100 V; 0805; X7R; 10 % tolerance; not mounted	08055C104KAT2A	AVX
C25	capacitor; 100 nF; 100 V; 0805; X7R; 10 % tolerance; not mounted	08055C104KAT2A	AVX
C26	capacitor; 100 nF; 100 V; 0805; X7R; 10 % tolerance; not mounted	08055C104KAT2A	AVX
D1	diode; Schottky; 3 A; 60 V; SOD128; not mounted	PMEG6030EP	NXP Semiconductors
D2	diode; Schottky; 3 A; 60 V; SOD128; not mounted	PMEG6030EP	NXP Semiconductors
D3	diode; Schottky; 3 A; 60 V; SOD128; not mounted	PMEG6030EP	NXP Semiconductors
D4	diode; Schottky; 3 A; 60 V; SOD128; not mounted	PMEG6030EP	NXP Semiconductors
D5	diode; Schottky; 8 A; 100 V; TO-277A	V8P10-M3/86A	Vishay
D6	diode; Schottky; 8 A; 100 V; TO-277A	V8P10-M3/86A	Vishay
D7	diode; Schottky; 8 A; 100 V; TO-277A	V8P10-M3/86A	Vishay

Table 3. BOM for 4-channel SSL2109AT demo board

Reference	Description and values	Part number	Manufacturer
D8	diode; Schottky; 8 A; 100 V; TO-277A	V8P10-M3/86A	Vishay
D9	diode; Zener; 5.1 V; 250 mW; SO-23	BZX84-C5V1	Fairchild
J1	2-way male header connector with 2-way female jumper		
J2	5-way female receptacle connector		
J3	5-way female receptacle connector		
J4	2-way female header connector		
L1	choke; 47 μH; 3.8 A; 20 % tolerance	7447709470	Würth Elektronik
L2	choke; 47 μH; 3.8 A; 20 % tolerance	7447709470	Würth Elektronik
L3	choke; 47 μH; 3.8 A; 20 % tolerance	7447709470	Würth Elektronik
L4	choke; 47 μH; 3.8 A; 20 % tolerance	7447709470	Würth Elektronik
L11	choke; 47 μH; 3 A; 20 % tolerance; not mounted	7447471470	Würth Elektronik
L12	choke; 47 μH; 3 A; 20 % tolerance; not mounted	7447471470	Würth Elektronik
L13	choke; 47 μH; 3 A; 20 % tolerance; not mounted	7447471470	Würth Elektronik
L14	choke; 47 μH; 3 A; 20 % tolerance; not mounted	7447471470	Würth Elektronik
Q1	MOSFET-N; 100 V; 6.5 A; SOT223	PHT6NQ10T	NXP Semiconductors
Q2	MOSFET-N; 100 V; 6.5 A; SOT223	PHT6NQ10T	NXP Semiconductors
Q3	MOSFET-N; 100 V; 6.5 A; SOT223	PHT6NQ10T	NXP Semiconductors
Q4	MOSFET-N; 100 V; 6.5 A; SOT223	PHT6NQ10T	NXP Semiconductors
R1	resistor; 0.25 Ω; 5 W; 1 %; 1206		
R2	resistor; 0.25 Ω; 5 W; 1 %; 1206		
R3	resistor; 0.25 Ω; 5 W; 1 %; 1206		
R4	resistor; 0.25 Ω; 5 W; 1 %; 1206		
R5	resistor; 220 kΩ; 0.125 W; 5 %; 0805		
R6	resistor; 220 kΩ; 0.125 W; 5 %; 0805		
R7	resistor; 220 kΩ; 0.125 W; 5 %; 0805		
R8	resistor; 220 kΩ; 0.125 W; 5 %; 0805		
R10	resistor; 4.7 kΩ; 0.125 W; 5 %; 0805		
R11	resistor; 180 Ω; 0.5 W; 5 %; 1206		
R12	resistor; 13 kΩ; 0.25 W; 5 %; 0805		
R13	resistor; 13 kΩ; 0.25 W; 5 %; 0805		
R14	resistor; 13 kΩ; 0.25 W; 5 %; 0805		
R15	resistor; 13 kΩ; 0.25 W; 5 %; 0805		
TB1	2-way terminal block		
TB2	2-way terminal block		
TB3	2-way terminal block		
TB4	2-way terminal block		
TB5	2-way terminal block		
U1	IC; LED driver	SSL2109AT	NXP Semiconductors
U2	IC; LED driver	SSL2109AT	NXP Semiconductors
U3	IC; LED driver	SSL2109AT	NXP Semiconductors
U4	IC; LED driver	SSL2109AT	NXP Semiconductors

8. Board layout



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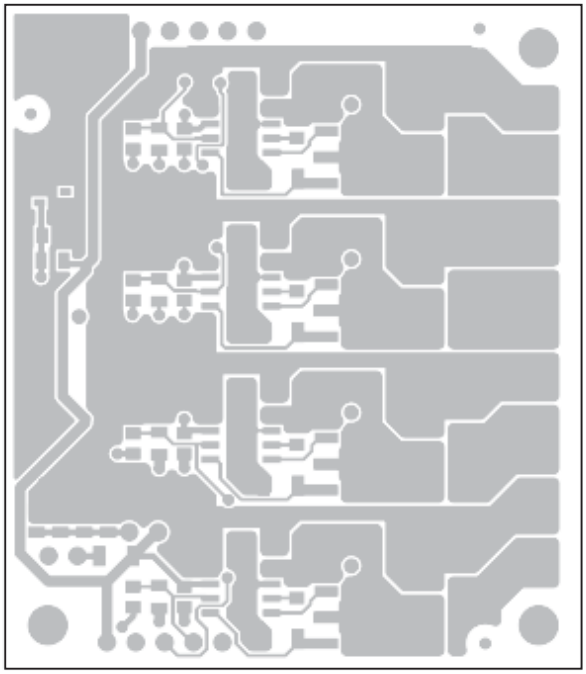

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b. bottom

Fig 10. Board layout

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10. Contents

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