UM10575

SSL4120T 90 W LED driver demo board

Rev. 1 — 20 September 2012 **User manual**

Document information

Info	Content
Keywords	SSL4120T, SSL4120DB1091, 90 W, LED driver, SSL, LLC, resonant, half-bridge, PFC, controller, converter, demo board, burst mode, user manual
Abstract	The SSL4120T 90 W LED driver demo board provides a single channel LED driver with an adjustable current controlled output. The maximum output current is 1.5 A. The minimum current is 50 mA which is reached using LLC bust mode. The forward voltage drop of LED string that is driven is between 35 V to 60 V. The SSL4120T includes both a PFC controller and a half-bridge resonant converter controller. The total efficiency at high power is up to 93 %. This user manual describes the SSL4120T 90 W LED driver demo board. Refer to the SSL4120T data sheet for details on the SSL4120T IC. In addition, refer to application note AN11227 for general application information.

Revision history

Rev	Date	Description
v.1	20120920	first issue

Contact information

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1. Introduction

WARNING

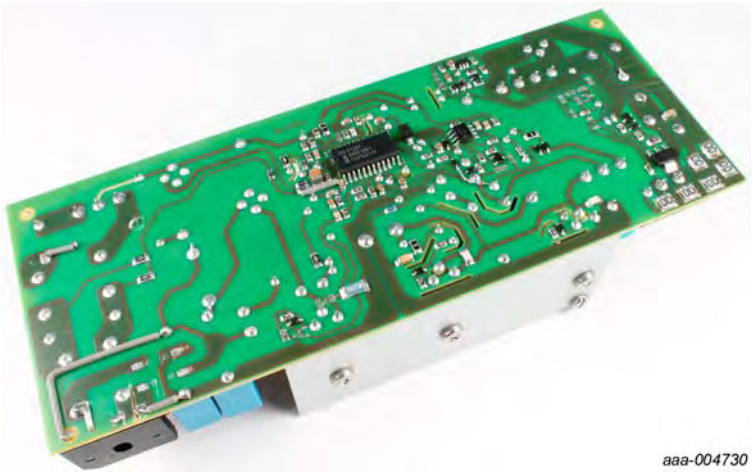
Lethal voltage and fire ignition hazard

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 SSL4120T 90 W demo board (SSL4120DB1091) is a dimmable LED driver example which provides LLC stage burst mode to reach low LED currents. This user manual describes the specification and use of the SSL4120T 90 W LED driver demo board.

a. Top view.



b. Bottom view.

Fig 1. Photographs of the SSL4120T demo board

2. Safety warning

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

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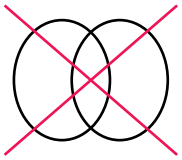

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a. Isolated

b. Not isolated

Fig 2. Variable transformer isolation symbols

3. Specifications

Table 1. Electrical specification

Description	Value	Condition
Line voltage	90 V (AC) to 300 V (AC)	-
Line frequency	50 Hz or 60 Hz	-
P_O	90 W	V_O = 60 V; I_O = 1.5 A
Efficiency	93 %	V_O = 60 V; I_O = 1.5 A; V_{mains} = 230 V
	91 %	V_O = 60 V; I_O = 1.5 A; V_{mains} = 120 V
$I_{O(nom)}$	1.5 A	-
$V_{O(min)}$	35 V	-
$V_{O(max)}$	60 V	-
PF	> 0.95	-
THD	< 15 %	-
DIM interface	1 V to 10 V	-
$I_{O(min)}$	50 mA	-
$I_{O(max)}$	1.5 A	-
Mains harmonics	complies with IEC 61000-3-2, Class-C	-

4. Wiring diagram

The mains line voltage input is connected to connector J1. The LED output and the DIM input are connected to connector J2.

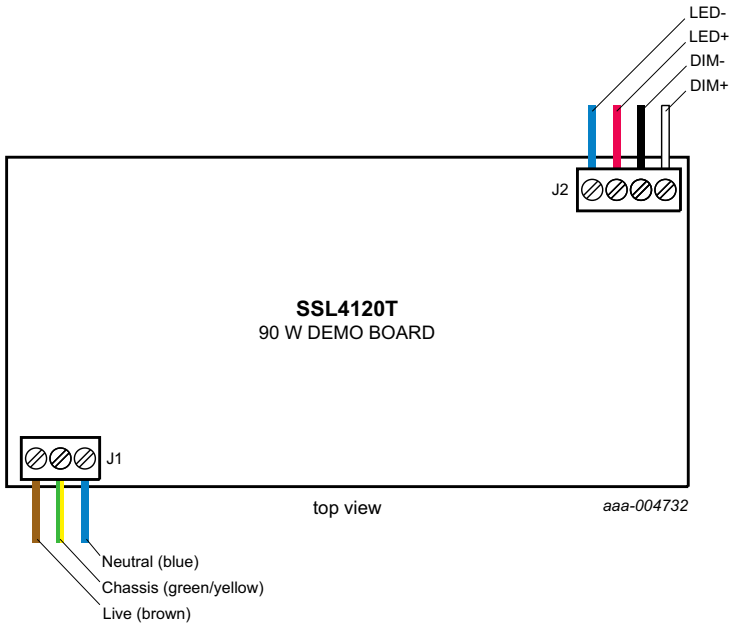


Fig 3. Wiring diagram

5. Board information

5.1 Description of the SSL4120T integrated controller

The SSL4120T integrates controllers for the PFC and an HBC. The board provides the drive function for the:

- discrete MOSFET of the up-converter
- two discrete power MOSFETs in a resonant half-bridge configuration

The internal high-voltage resonant controller provides Zero-Voltage Switching (ZVS) of the LLC resonant converter. The SSL4120T includes a high-voltage level-shift circuit and several protection features such as:

- OverCurrent Protection (OCP)
- Open-Loop Protection (OLP)
- Capacitive Mode Protection (CMP)
- general-purpose latched protection input

In addition to the resonant controller, the SSL4120T contains a PFC controller. Efficient PFC operation is achieved using:

- quasi-resonant operation at high-power levels
- quasi-resonant operation with valley skipping at lower power levels

Safe operation under all conditions is guaranteed using:

- OverCurrent Protection (OCP)
- OverVoltage Protection (OVP)
- demagnetization sensing

Compared to the TEA1713T, the SSL4120T has a higher PFC frequency limit to support IEC 61000-3-2 Class-C requirements for lighting applications.

Table 2. Comparison TEA1713T and SSL4120T

Symbol	Parameter	TEA1713T	SSL4120T	Unit
$f_{max(PFC)}$	PFC maximum frequency	125	380	kHz
$t_{off(PFC)min}$	minimum PFC off-time	1.4	1.1	µs

The proprietary high-voltage BCD power logic process makes efficient direct start-up from the rectified universal mains voltage possible. A second low-voltage Silicon-On-Insulator (SOI) IC is used for accurate, high speed protection functions and control.

The combination of PFC and a resonant controller in one IC makes the SSL4120T an interesting component for very efficient and small LED driver applications.

5.2 SSL4120T LED demo board block diagram

The board can operate at a mains input voltage of between 90 V and 300 V (universal mains).

The demo board contains two converter circuits:

- a BCM PFC
- a resonant LLC HBC

The SSL4120T controls both converters.

The demo board is to illustrate SSL4120T operation in a single channel current controlled LED driver with burst mode operation during dimming. A limitation is that the output voltage must be between 35 V and 60 V.

The performance is according to today's general standards and can be used as a starting point for further development.

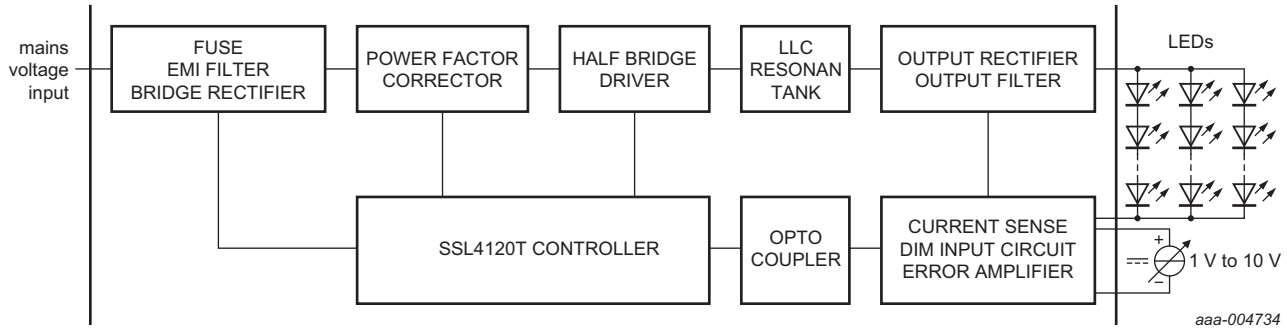


Fig 4. SSL4120T LED demo board block diagram

A typical feature of the demo board is burst mode operation which is used to reach the low LED currents during dimming. An external comparator U2A (shown in the Figure 17) triggers the bursts.

To reach the low THD values, the PFC on-time is modulated using the SSL4120T COMPPFC pin. The modulation signal is derived from the mains voltage and it is injected by capacitor C8a in Figure 17.

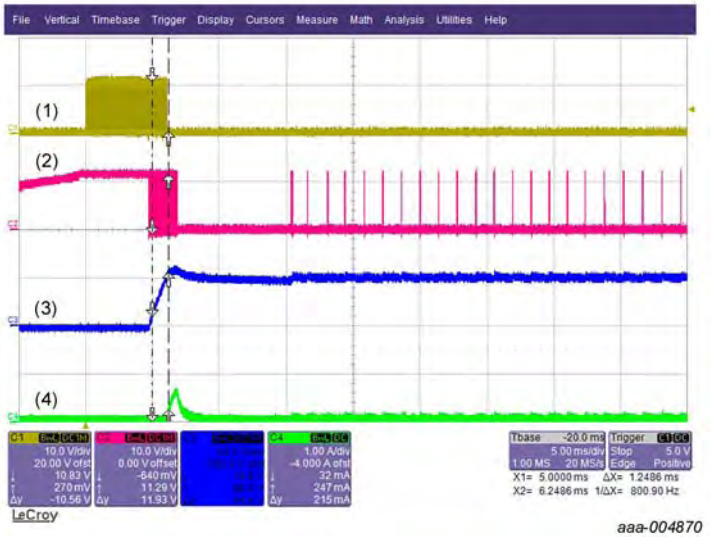
6. Measurements

6.1 Test facilities

- Oscilloscope: LeCroy waveRunner 104Xi
- AC power source: Agilent 6811B
- Electronic load: BK Precision 8500
- Digital power meter: Yokogawa WT210
- Multimeter: Fluke 87V
- EMI analyzer: Rohde & Schwarz 1164.6407.03
- EMI two line V network: Rohde & Schwarz ENV216, 3560.6550.02

6.2 Start-up behavior

The output current rise time is approximately 25 ms depending on the output load.



a. V_{mains} = 230 V and minimum load.

b. V_{mains} = 120 V and full load.

(1) $V_{GATEPFC}$.

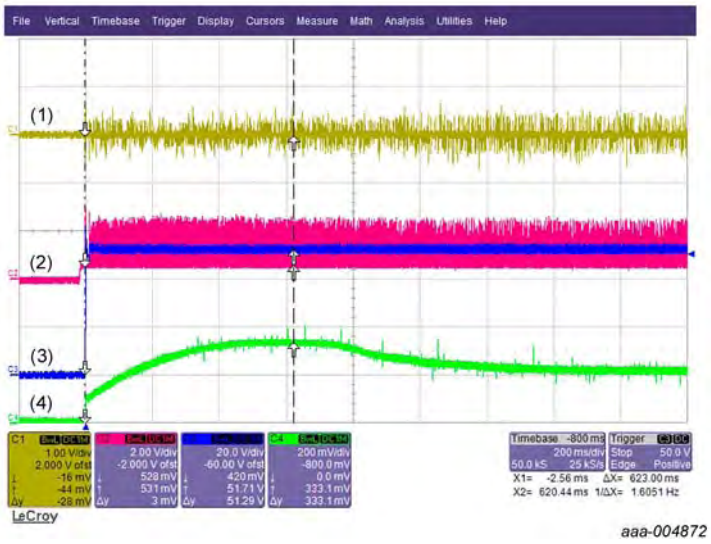
(2) V_{GATELS}.

(3) V_O.

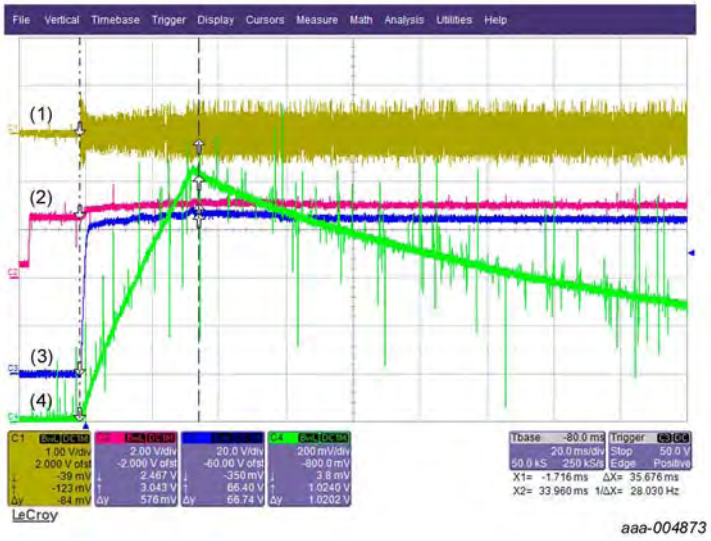
(4) I_O.

Fig 5. Start-up behavior

6.3 Protection levels on pins SNSCURHBC and SNSOUT during start-up



a. V_{mains} = 230 V and minimum load.



b. V_{mains} = 120 V and full load.

(1) $V_{SNSCURHBC}$.

(2) V_{SNSOUT}.

(3) V_O.

(4) V_{RCPROT}.

Fig 6. Protection function behavior during start-up

During start-up, the RCPROT (protection timer) pin voltage always rises. The SNSCURHBC pin detects the initial high primary current and the SNSOUT pin starts at a low voltage.

After the first switching cycles, the levels become normal for operation and charging of V_{RCPROT} stops.

The V_{RCPROT} level decreases to zero again using the external discharge resistor that is part of the RCPROT system.

During normal start-up, the initial charging of V_{RCPROT} must not trigger a protection function (4 V level).

6.4 Efficiency

Efficiency measurements are made measuring the output voltage on the board and the current through the LED string. The losses in the output connection cable are not taken into account.

Table 3. Efficiency results

V_O = 60 V.

Conditions	Efficiency (%)		
V_{mains}	$P_{O(min)}$	50 % $P_{O(nom)}$	100 % $P_{O(nom)}$
120 V; 60 Hz	51.5	90.3	90.9
230 V; 50 Hz	60	90.7	93.1
277 V; 50 Hz	61.5	90.4	93.2

6.5 Power factor

Table 4. Power factor results

V_O = 60 V.

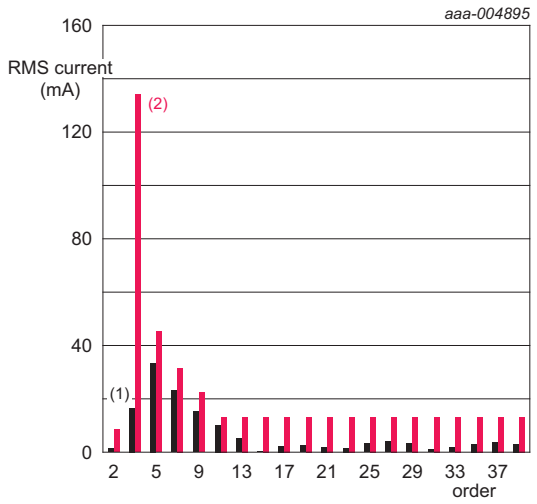
Conditions	Power factor		
V_{mains}	$P_{O(min)}$	50 % $P_{O(nom)}$	100 % $P_{O(nom)}$
120 V; 60 Hz	0.3451	0.9643	0.9896
230 V; 50 Hz	0.1989	0.8993	0.9649
277 V; 50 Hz	0.1543	0.8027	0.9177

6.6 Total harmonic distortion

Table 5. THD results

Measured according IEC method; V_O = 60 V.

Conditions	ATHD (%)		
V_{mains}	$P_{O(min)}$	50 % $P_{O(nom)}$	100 % $P_{O(nom)}$
120 V; 60 Hz	52.95	9.95	5.76
230 V; 50 Hz	45.50	16.31	11.25
277 V; 50 Hz	37.21	24.35	17.72



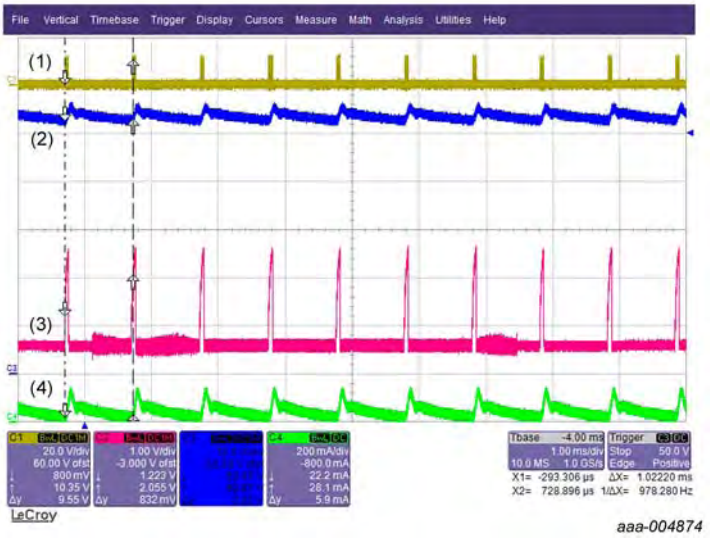
(1) Full load.

(2) IEC limit.

Fig 7. Mains harmonics; V_{mains} = 230 V

6.7 Burst mode operation

To reach the low output currents, burst mode operation is implemented in the IC. In the demo board, burst mode is active under approximately 65 W output power.



(1) V_{GATELS}.

(2) V_O.

(3) V_{SNSFB}.

(4) I_O.

Fig 8. Burst mode operation; V_{mains} = 230 V and I_O = 50 mA

The interruptive character of burst mode can generate unwanted audible noise. Audible noise levels are low because the burst mode supply only operates at low-power levels. The burst frequency can be controlled using the:

- hysteresis of comparator circuit U2A (resistor R27);
- output capacitor value (C32, C37);
- speed of the control loop (C36, R43).

Improvements for the LLC transformer can be considered, such as:

- Potting of the transformer windings
- Adding of air gap filler to damp acoustic resonance

(1) C1 = Z1 = V_{GATELS}.

(2) C3 = Z3 = V_O.

(3) C2 = Z2 = V_{SNSOUT}.

(4) C4 = Z4 = I_O.

Fig 9. HBC switch on/switch off using V_{SNSOUT} in burst mode operation

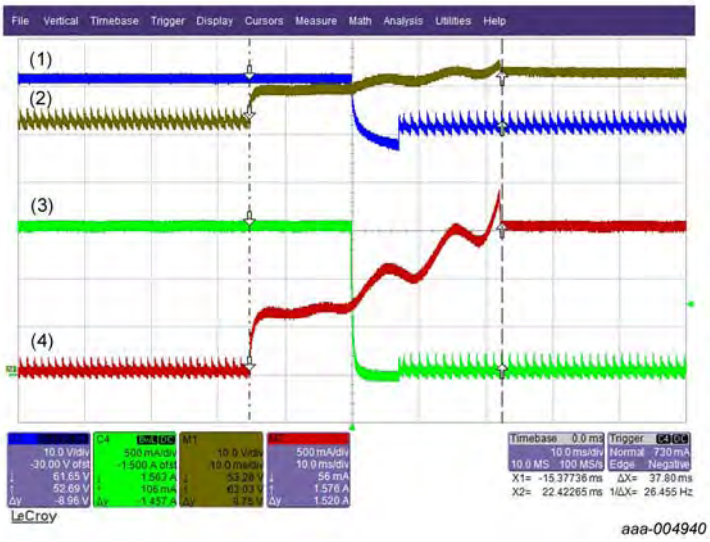
The GATEPFC is not switched off using the SNSOUT pin. However, when checking the GATEPFC signal it is sometimes switched off at light loads. The GATEPFC signal is switched off because the SNSBOOST reaches its OverVoltage Protection (OVP) trigger level.

6.8 Transient response

The load step response is shown in Figure 10.

Channels M1 and M2 show the load step from $I_{O(nom)}$ to $I_{O(min)}$.

Channels C3 and C4 show the load step from $I_{O(min)}$ to $I_{O(nom)}$.



(1) V_O.
(2) V_O.
(3) I_O.
(4) I_O.

Fig 10. Load step during operation; V_{mains} = 230 V

6.9 Output ripple current and noise

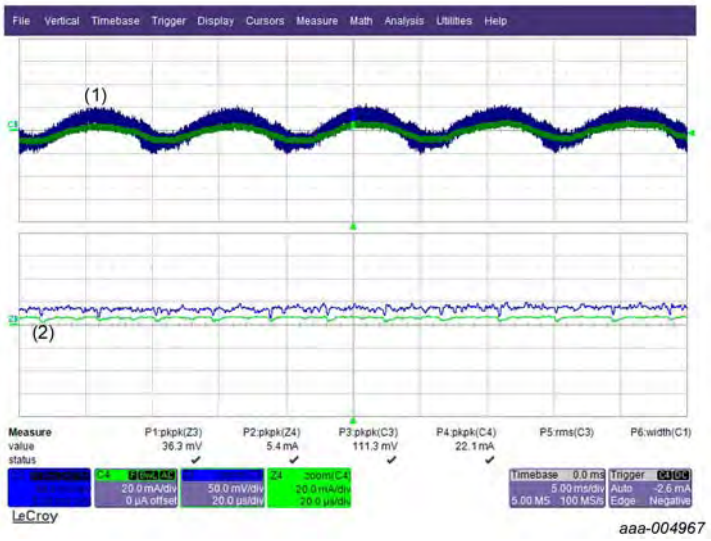
Ripple and noise are measured at full output load.

The resonant converter input voltage causes a frequency component in the output current ripple. The ripple is related to the mains voltage frequency (50 Hz or 60 Hz). The resonant converter switching frequency causes the other component in the output current ripple.

Table 6. Output ripple and noise current results

LF = 50 Hz/60 Hz; HF = HBC switching frequency is approximately 75 kHz

Conditions		Ripple (peak-to-peak)			
V_{mains}	V_O (V)	LF (mA)	HF (mA)	LF (mV)	LF (mV)
120 V; 60 Hz	60	22.6	5.6	117.6	38.9
230 V; 50 Hz	60	22.1	5.4	111.3	36.3
277 V; 50 Hz	60	20.4	5.4	113.9	41.9



(1) C3 = Z3 = low pass filter (V_O, −3 db, 800 kHz).

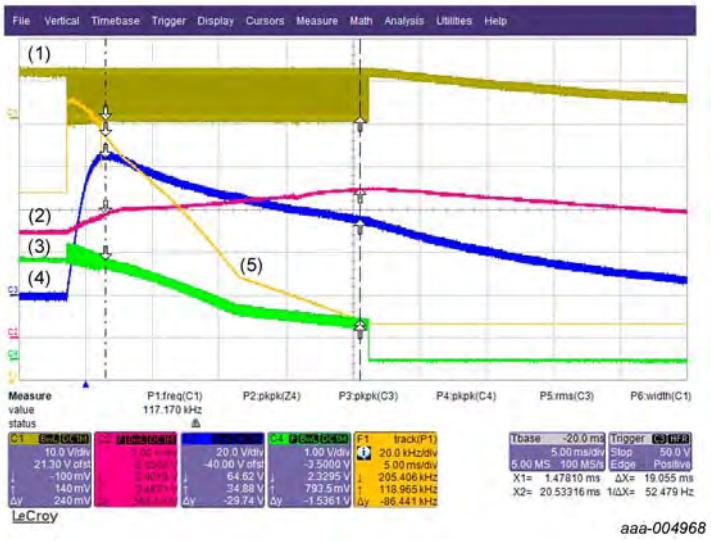
(2) C4 = Z4 = low pass filter (I_O, −3 db, 800 kHz).

Fig 11. Output current ripple; V_{mains} = 230 V and I_O = 1.5 A

6.10 No-load behavior

When an LED string or other load is not attached to the current driver, the output voltage V_O rises to a maximum value of approximately 65 V.

The controller then enters the latched protection shut-down state due to OVP using the SNSOUT pin.



(1) V_{GATELS}.

(2) I_{SNSOUT}.

(3) V_O.

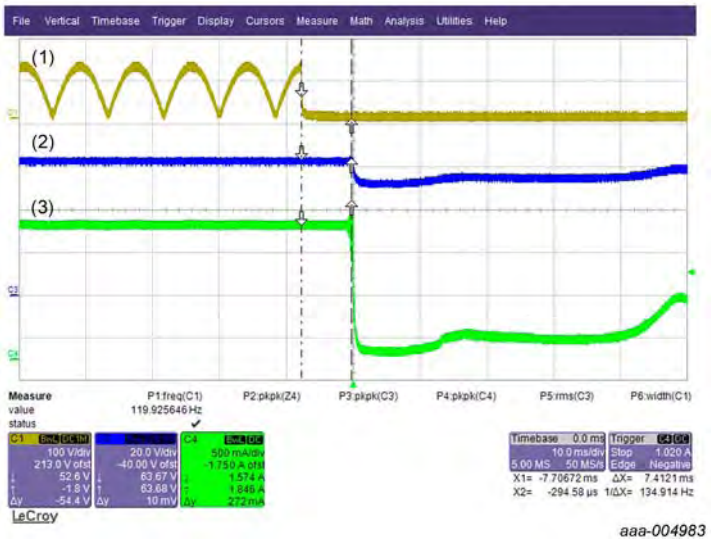
(4) V_{RFMAX}.

(5) Frequency C1.

Fig 12. No-load behavior; SNSOUT overvoltage protection

6.11 Hold-up time

The output is set to full-load and the 90 V mains supply voltage is disconnected. The hold-up time is the time that passes before the output current drops significantly. The hold-up time in this case is 7.4 ms.



(1) V_{mains}.

(2) V_O.

(3) I_O.

Fig 13. No-load behavior; SNSOUT overvoltage protection

6.12 Short-circuit behavior

A short-circuit on the output of the resonant converter causes the primary current to increase. The SNSCURHBC function detects the increase causing the IC to run at the maximum frequency until the protection timer RCPROT reaches the 4 V protection level.

The RCPROT function performs a restart timer function and restarts when the voltage drops to 0.5 V. After the short-circuit is removed, the converter starts up and operates as normal.

The RCPROT function is the main protection mechanism. Under certain conditions other protections are activated during the output short-circuit test. In the demoboard, the SUPIC voltage is cycles between the UVP level and start level.

Remark: An additional capacitor of 220 μF was added to SUPIC for the test in Figure 14(a) to prevent SUPIC reaching the UVP level.

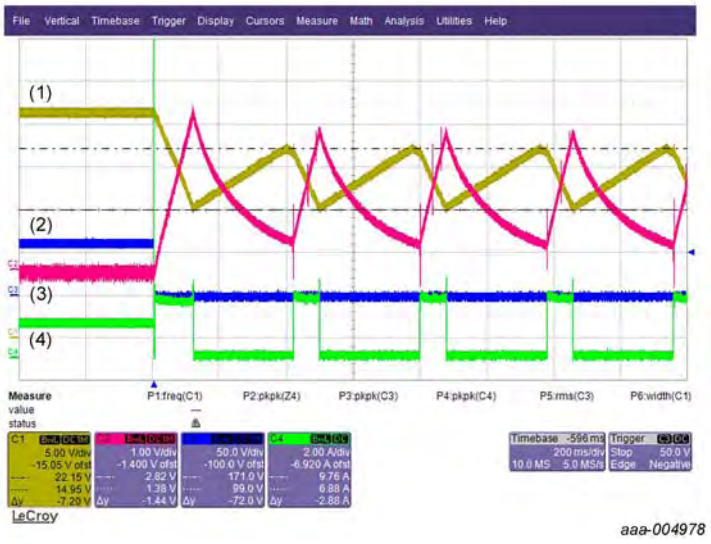
(1) $V_{SNSCURHBC}$.

(2) V_O.

(3) I_{RCPROT}.

(4) I_O.

a. **RCPROT cycle**.



b. **SUPIC cycle**.

(1) V_{SUPIC}.

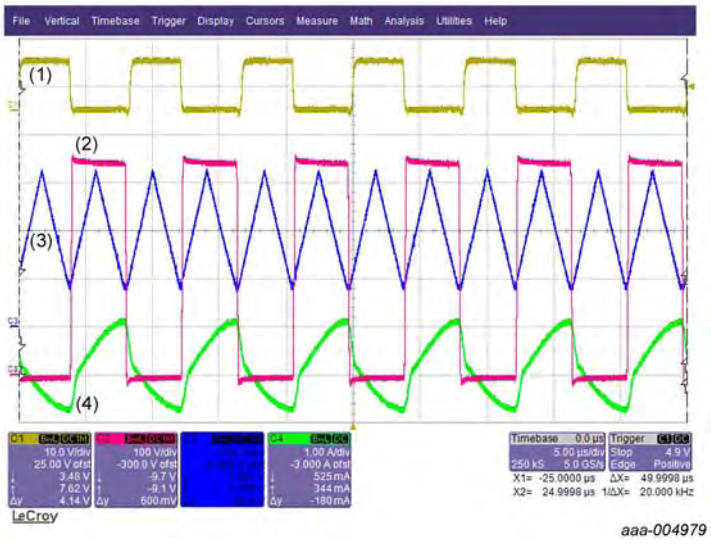
(2) V_O.

(3) V_{RCPROT}.

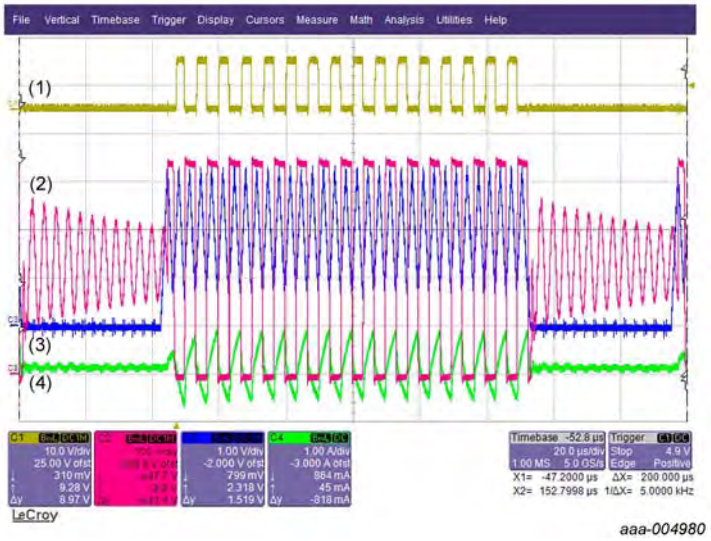
(4) I_O.

Fig 14. Protection functions and restart at output short-circuit

6.13 LLC voltage and current measurements



a. I_O = 1.5 A.



b. I_O = 75 mA.

(1) V_{GATELS}.

(2) V_{HB}.

(3) V_{CFMIN}.

(4) I_{res}.

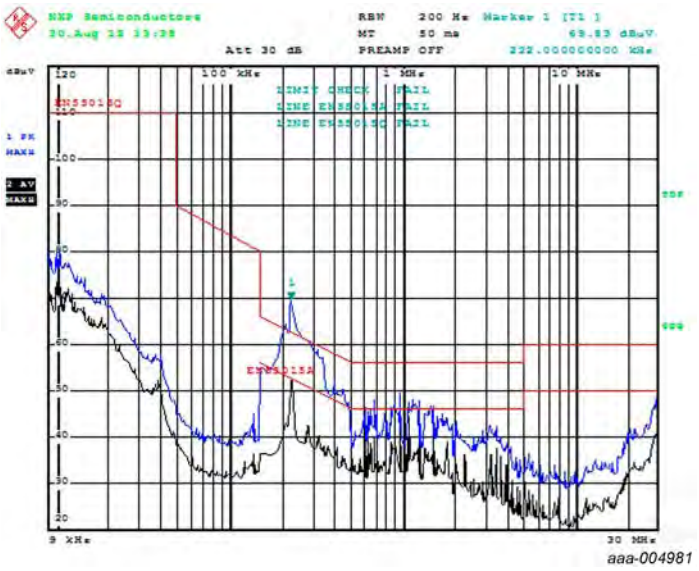
Fig 15. Resonant voltage and current waveforms

6.14 ElectroMagnetic Compatibility (EMC) results

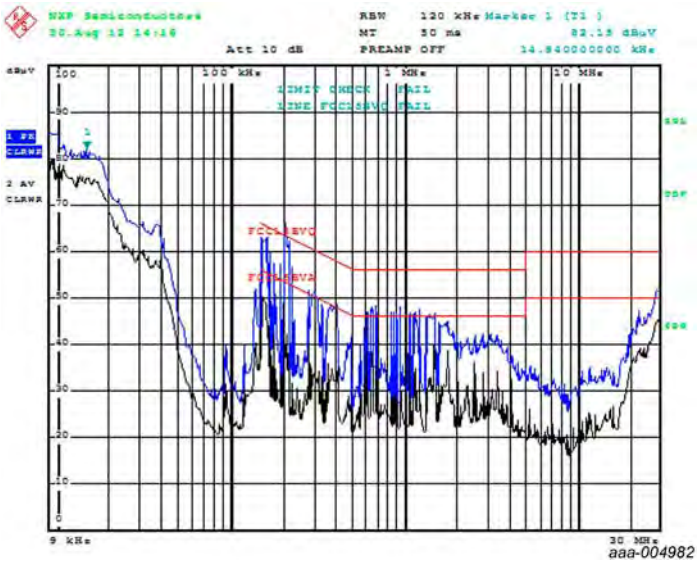
Measurement conditions:

- Type: conducted EMC measurement
- Frequency range: 150 kHz to 30 MHz
- Output power: full-load condition
- Supply voltage: 120 V and 230 V
- Measuring time: 50 ms

The EMC limits are exceeded at around 200 kHz, which is caused by the PFC stage. Check Section 7 “Known limitations” for improvement suggestions.



a. Line N; V_{mains} = 230 V (AC) and I_O = 1.5 A.



b. Line N; V_{mains} = 120 V (AC) and I_O = 1.5 A

Fig 16. Conducted emission tests

7. Known limitations

The SSL4120T demo board is not a reference design. It is a demo board to highlight the features of the SSL4120T IC. There are some known issues with this board.

7.1 No CVCC regulation

This demo board only has a current controlled output. When a load is not connected, the output rises to 65 V and the board shuts down. Cycling the power restarts the board.

When the load impedance is too high, constant voltage and constant current control (CVCC) can be use to limit the output voltage to 58 V.

7.2 $I_{O(min)}$ high tolerance

The minimum output current has a high tolerance in this design. It varies between 35 mA and 50 mA. When designing an LED driver, reduce the minimum current tolerance. A slightly negative voltage can be applied to the DIM input to reduce the LED current below $I_{O(min)}$ for testing.

7.3 Limited V_O range

The output voltage range is from 35 V to 60 V. Larger voltage ranges are possible when special circuits are added to supply the IC and feedback amplifier.

7.4 EMI conducted emission

At some frequencies, the EMI test limits are exceeded. The design can be improved with the following items:

- PFC inductor start of winding: start the winding closest to the core
- PFC inductor: shield
- PFC large signal current loop: reduce area
- EMI input section and the PFC stage: mount a metal shield between them

8. Schematic

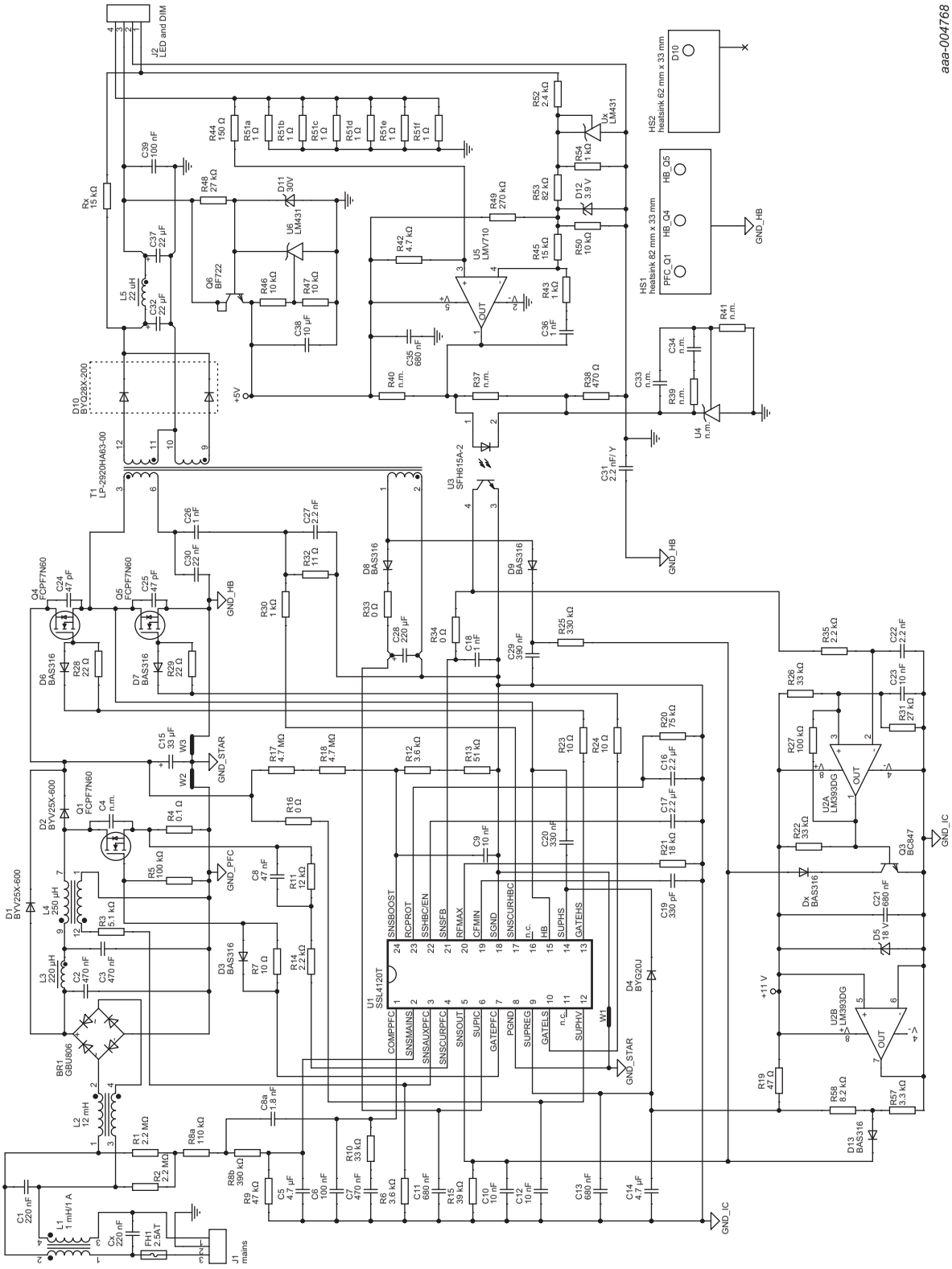
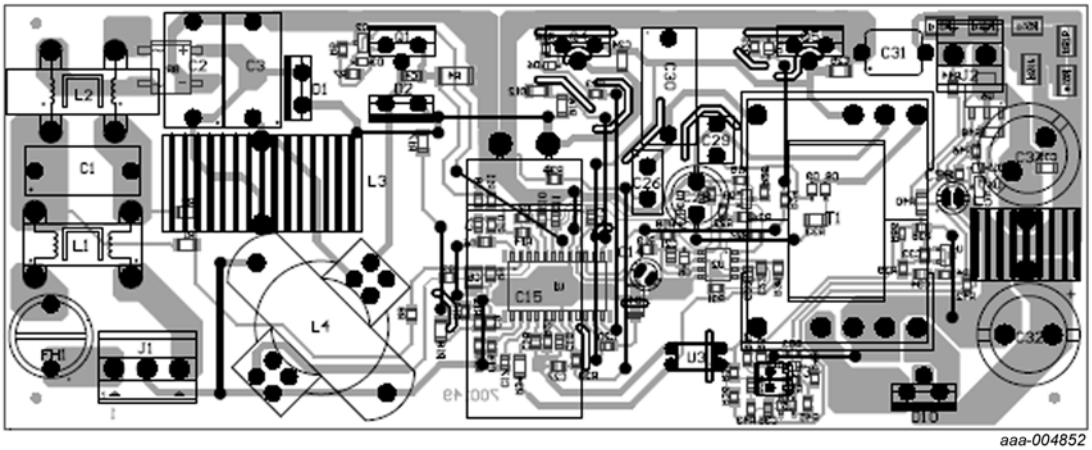
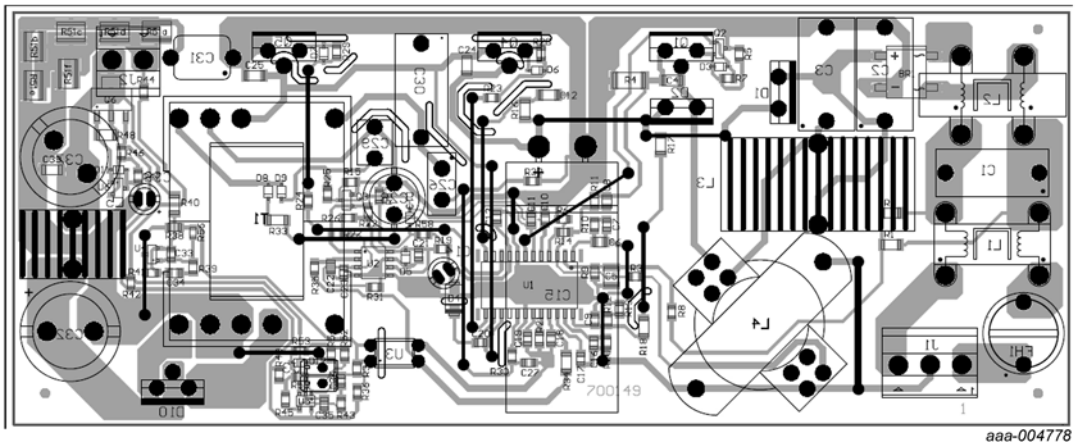


Fig 17. Schematic diagram

9. PCB layout



a. Top view.



b. Bottom view.

Fig 18. PCB layout

10. Bill of materials

Table 7. Bill of materials

Reference	Description and value	Part number	Manufacturer
BR1	diode bridge; 8 A; 800 V; SMA	GBU806	Taiwan Semiconductor
C1	capacitor; polypropylene; 220 nF; 310 V; 20 %; X2; RDL	R46KI322050M2K	ARCOTRONICS
C2	capacitor; MKP; 470 nF; 450 V; 10 %; RDL	B32652A4474J000	EPCOS
C3	capacitor; MKP; 470 nF; 450 V; 10 %; RDL	B32652A4474J000	EPCOS
C4	capacitor; NP0; not mounted; 500 V; 5 %; 1206	12067A221JAT2A	AVX
C5	capacitor; X7R; 4.7 μF; 50 V; 10 %; 1210	C1210C475K5- RAC7800	KEMET
C6	capacitor; X7R; 100 nF; 50 V; 10 %; 0805	MCCA000386	Multicomp
C7	capacitor; X7R; 470 nF; 25 V; 10 %; 0805	C0805C474K3RAC	KEMET
C8	capacitor; X7R; 47 nF; 25 V; 10 %; 0805	08053C473KAT2A	AVX
C8a	capacitor; X7R; 1.8 nF; 100 V; 10 %; 0805	C0805C182K1RAC	KEMET
C9	capacitor; X7R; 10 nF; 50 V; 10 %; 0805	CC0805KRX7R9BB103	Yageo
C10	capacitor; X7R; 10 nF; 50 V; 10 %; 0805	CC0805KRX7R9BB103	Yageo
C11	capacitor; X7R; 680 nF; 50 V; 10 %; 0805	C0805C684K5RACTU	KEMET
C12	capacitor; X7R; 10 nF; 500 V; 10 %; 1206	12067C103KAT2A	AVX
C13	capacitor; X7R; 680 nF; 50 V; 10 %; 0805	C0805C684K5RACTU	KEMET
C14	capacitor; aluminum; 4.7 μF; 100 V; 10 %; RDL	RD2A475M05011PC	SAMWHA
C15	capacitor; aluminum; 33 μF; 450 V; 20 %; RDL	450BXC33MEFC16X25	RUBYCON
C16	capacitor; Y5V; 2.2 μF; 25 V; +80 % to −20 %; 0805	GRM21BF51E225ZA01L	Murata
C17	capacitor; Y5V; 2.2 μF; 25 V; +80 % to −20 %; 0805	GRM21BF51E225ZA01L	Murata
C18	capacitor; X7R; 1 nF; 50 V; 10 %; 0805	CC0805KRX7R9BB102	Yageo
C19	capacitor; C0G/NP0; 330 pF; 50 V; 5 %; 0805	CC0805JRNPO9BN331	Yageo
C20	capacitor; X7R; 330 nF; 25 V; 10 %; 0805	C0805C334K3RACTU	KEMET
C21	capacitor; X7R; 680 nF; 50 V; 10 %; 0805	C0805C684K5RACTU	KEMET
C22	capacitor; X7R; 2.2 nF; 50 V; 10 %; 0805	CC0805KRX7R9BB222	Yageo
C23	capacitor; X7R; 10 nF; 25 V; 10 %; 0805	CC0805KRX7R8BB103	Yageo
C24	capacitor; C0G/NP0; 47 pF; 500 V; 5 %; 0805	12067A470JAT2A	AVX
C25	capacitor; C0G/NP0; 47 pF; 500 V; 5 %; 1206	12067A470JAT2A	AVX
C26	capacitor; Class 2; disc; 1 nF; 1 kV; 10 %	F102K39Y5RN6UJ5R	Vishay BC Components
C27	capacitor; X7R; 2.2 nF; 50 V; 10 %; 0805	CC0805KRX7R9BB222	Yageo
C28	capacitor; aluminum; 220 μF; 50 V; 20 %; RDL	50YXF220MEFC10X16	RUBYCON
C29	capacitor; polyester film; 390 nF; 50 V; 5 %; RDL	ECQV1H394JL	Panasonic
C30	capacitor; polypropylene; 22 nF; 1.25 kV; 5 %; RDL	B32652A7223J000	EPCOS
C31	Y-capacitor X1/Y1; disc; 2.2 nF; 250 V; 20 %	DE1E3KX222MA5BA01	Murata
C32	capacitor; aluminum; 22 μF; 100 V; 20 %; RDL	EEUFC2A220	Panasonic
C33	capacitor; X7R; not mounted; 50 V; 10 %; 0805	CC0805KRX7R9BB222	Yageo
C34	capacitor; X7R; not mounted; 25 V; 10 %; 0805	08053C473KAT2A	AVX
C35	capacitor; X7R; 680 nF; 50 V; 10 %; 0805	C0805C684K5RACTU	KEMET
C36	capacitor; X7R; 1 nF; 50 V; 10 %; 0805	CC0805KRX7R9BB102	Yageo

Table 7. Bill of materials *...continued*

Reference	Description and value	Part number	Manufacturer
C37	capacitor; aluminum; 22 μF; 100 V; 20 %; RDL	EEUFC2A220	Panasonic
C38	capacitor; aluminum; 10 μF; 50 V; 20 %; RDL	50ML10MEFC5X7	RUBYCON
C39	capacitor; X7R; 100 nF; 100 V; 10 %; 1206	C1206C104K1RACTU	KEMET
Cx	capacitor; polypropylene; 220 nF; 310 V; 20 %; X2; RDL	BFC233922224	Vishay BC Components
D1	diode; ultra-fast; 600 V; 5 A; 1.3 VF; TH	BYV25X-600,127	NXP Semiconductors
D2	diode; ultra-fast; 600 V; 5 A; 1.3 VF; TH	BYV25X-600,127	NXP Semiconductors
D3	diode; ultra-fast; 100 V; 0.215 A; 1.25 VF; SMA	BAS316,135	NXP Semiconductors
D4	diode; ultra-fast; 600 V; 1.5 A; 1.4 VF; SMA	BYG20J-E3/TR	Vishay Semiconductor
D5	diode; Zener; 18 V; 0.3 W; 5 %; SMA	BZX384-C18,115	NXP Semiconductors
D6	diode; ultra-fast; 100 V; 0.215 A; 1.25 VF; SMA	BAS316,135	NXP Semiconductors
D7	diode; ultra-fast; 100 V; 0.215 A; 1.25 VF; SMA	BAS316,135	NXP Semiconductors
D8	diode; ultra-fast; 100 V; 0.215 A; 1.25 VF; SMA	BAS316,135	NXP Semiconductors
D9	diode; ultra-fast; 100 V; 0.215 A; 1.25 VF; SMA	BAS316,135	NXP Semiconductors
D10	diode; ultra-fast; dual; 200 V; 10 A; 1.1 VF; TH	BYQ28X-200,127	NXP Semiconductors
D11	diode Zener; 30 V; 0.3 W; 5 %; SMA	BZX384-C30,115	NXP Semiconductors
D12	diode Zener; 3.9 V; 0.3 W; 5 %; SMA	BZX384-C3V9,115	NXP Semiconductors
D13	diode; ultra-fast; 100 V; 0.215 A; 1.25 VF; SMA	BAS316,135	NXP Semiconductors
Dx	diode; ultra-fast; 100 V; 0.215 A; 1.25 VF; SMA	BAS316,135	NXP Semiconductors
FH1	fuse; 2.5 AT; 250 V; TH	031302.5HXP	Littelfuse
HS1	heatsink; 82 mm × 33 mm	not applicable	not applicable
HS2	heatsink; 62 mm × 33 mm	not applicable	not applicable
J1	mains connector term block; 250 V; 28 A; 5.08 mm; 3P; TH	1711738	Phoenix Contact
J2	LED and DIM connector terminal block; 250 V 28 A; 5.08 mm; 4P; TH	1712805	Phoenix Contact
L1	inductor common mode; 1 mH; 2 A; 30 %; TH	7446122001	WURTH ELEKTRONIK
L2	inductor common mode; 12 mH; 1.2 A; 30 %; TH	7446221012	WURTH ELEKTRONIK
L3	inductor; 220 μH; 3 A; 10 %; TH	744136	WURTH ELEKTRONIK
L4	inductor PFC; 250 μH; 5.7 A; 10 %; TH	760806110	WURTH ELEKTRONIK
L5	inductor; 22 μH; 3 A; 10 %; TH	744131	WURTH ELEKTRONIK
Q1	transistor; NMOST; 600 V; 7 A; 0.53 Ω; TH	FCPF7N60	Fairchild
Q3	transistor; NPN; 45 V; 0.2 A; SMA	BC847.215	NXP Semiconductors
Q4	transistor; NMOST; 600 V; 7 A; 0.53 Ω; TH	FCPF7N60	Fairchild
Q5	transistor; NMOST; 600 V; 7 A; 0.53 Ω; TH	FCPF7N60	Fairchild
Q6	transistor; NPN; 250 V; 0.1 A SMA	771-BF722-T/R	NXP Semiconductors
R1	resistor; thick film; 2.2 MΩ; 200 V; 1 %; 1206	RC1206 Series	Yageo
R2	resistor; thick film; 2.2 MΩ; 200 V; 1 %; 1206	RC1206 Series	Yageo
R3	resistor; thick film; 5.1 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R4	resistor; thick film; 0.1 Ω; 200 V; 1 W; 1 %; 2010	LR2010-R10FW	Welwyn Components
R5	resistor; thick film; 100 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R6	resistor; thick film; 3.6 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo

Table 7. Bill of materials *...continued*

Reference	Description and value	Part number	Manufacturer
R7	resistor; thick film; 10 Ω; 150 V; 1 %; 0805	RC0805 Series	Yageo
R8a	resistor; thick film; 110 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R8b	resistor; thick film; 390 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R9	resistor; thick film; 47 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R10	resistor; thick film; 33 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R11	resistor; thick film; 12 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R12	resistor; thick film; 3.6 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R13	resistor; thick film; 51 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R14	resistor; thick film; 2.2 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R15	resistor; thick film; 39 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R16	resistor; thick film; 0 Ω; 200 V; 1 %; 1206	RC1206 Series	Yageo
R17	resistor; thick film; 4.7 MΩ; 200 V; 1 %; 1206	RC1206 Series	Yageo
R18	resistor; thick film; 4.7 MΩ; 200 V; 1 %; 1206	RC1206 Series	Yageo
R19	resistor; thick film; 47 Ω; 150 V; 1 %; 0805	RC0805 Series	Yageo
R20	resistor; thick film; 75 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R21	resistor; thick film; 18 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R22	resistor; thick film; 33 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R23	resistor; thick film; 10 Ω; 150 V; 1 %; 0805	RC0805 Series	Yageo
R24	resistor; thick film; 10 Ω; 150 V; 1 %; 0805	RC0805 Series	Yageo
R25	resistor; thick film; 330 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R26	resistor; thick film; 33 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R27	resistor; thick film; 100 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R28	resistor; thick film; 22 Ω; 150 V; 1 %; 0805	RC0805 Series	Yageo
R29	resistor; thick film; 22 Ω; 150 V; 1 %; 0805	RC0805 Series	Yageo
R30	resistor; thick film; 1 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R31	resistor; thick film; 27 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R32	resistor; thick film; 11 Ω; 150 V; 1 %; 0805	RC0805 Series	Yageo
R33	resistor; thick film; 0 Ω; 200 V; 1 %; 1206	RC1206 Series	Yageo
R34	resistor; thick film; 0 Ω; 200 V; 1 %; 1206	RC1206 Series	Yageo
R35	resistor; thick film; 2.2 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R36	resistor; thick film; not mounted; 150 V; 1 %; 0805	RC0805 Series	Yageo
R37	resistor; thick film; not mounted; 150 V; 1 %; 0805	RC0805 Series	Yageo
R38	resistor; thick film; 470 Ω; 150 V; 1 %; 0805	RC0805 Series	Yageo
R39	resistor; thick film; not mounted; 150 V; 1 %; 0805	RC0805 Series	Yageo
R41	resistor; thick film; not mounted; 150 V; 1 %; 0805	RC0805 Series	Yageo
R42	resistor; thick film; 4.7 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R43	resistor; thick film; 1 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R44	resistor; thick film; 150 Ω; 150 V; 1 %; 0805	RC0805 Series	Yageo
R45	resistor; thick film; 15 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R46	resistor; thick film; 10 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R47	resistor; thick film; 10 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo

Table 7. Bill of materials *...continued*

Reference	Description and value	Part number	Manufacturer
R48	resistor; thick film; 27 kΩ; 200 V; 1 %; 1206	RC1206 Series	Yageo
R49	resistor; thick film; 270 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R50	resistor; thick film; 10 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R51a	resistor; thick film; 1 Ω; 200 V; 1 W; 1 %; 1218	RC1218FK-071RL	Yageo
R51b	resistor; thick film; 1 Ω; 200 V; 1 W; 1 %; 1218	RC1218FK-071RL	Yageo
R51c	resistor; thick film; 1 Ω; 200 V; 1 W; 1 %; 1218	RC1218FK-071RL	Yageo
R51d	resistor; thick film; 1 Ω; 200 V; 1 W; 1 %; 1218	RC1218FK-071RL	Yageo
R51e	resistor; thick film; 1 Ω; 200 V; 1 W; 1 %; 1218	RC1218FK-071RL	Yageo
R51f	resistor; thick film; 1 Ω; 200 V; 1 W; 1 %; 1218	RC1218FK-071RL	Yageo
R52	resistor; thick film; 2.4 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R53	resistor; thick film; 82 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R54	resistor; thick film; 1 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R56	resistor; thick film; not mounted; 150 V; 1 %; 0805	RC0805 Series	Yageo
R57	resistor; thick film; 3.3 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
R58	resistor; thick film; 8.2 kΩ; 150 V; 1 %; 0805	RC0805 Series	Yageo
Rx	resistor; metal film; 15 kΩ; 350 V; 1 %; TH	MRS25000C1502FCT00	Vishay BC Components
T1	transformer LLC; 1.4 mH; Lp 225 μH; LI 10 %	LP-2920HA63-00	Yu-Jing
U1	SSL4120T; IC combi-controller; LLC and PFC; SMA	9352 983 46518	NXP Semiconductors
U2	LM393DG; IC comparator; dual; SMA	LM393DG	ON Semiconductors
U3	SFH615A-2; IC opto-transistor O/P TH	SFH615A-2	Vishay Semiconductor
U4	IC shunt REG 2.5 V; not mounted; SMA	LM431AIM3	National
U5	LMV710; IC operational amplifier; 5 V; 5 MHz; SMA	LMV710M5	National
U6	LM431; IC shunt regulator; 2.5 V; SMA	LM431AIM3	National
Ux	LM431; IC shunt regulator; 2.5 V; SMA	LM431AIM3	National
W1	GND; PCB layout pattern interconnect	-	-
W2	GND; PCB layout pattern interconnect	-	-
W3	GND; PCB layout pattern interconnect	-	-

11. Inductor appearance and dimensions

11.1 Power factor corrector inductor L4

- Core: RM10 (EPCOS or equivalent)
- Core material: NC-2H
- Bobbin: RM10; 8-pin version (EPCOS or equivalent)
- Primary inductance: 250 μH, ± 10 %

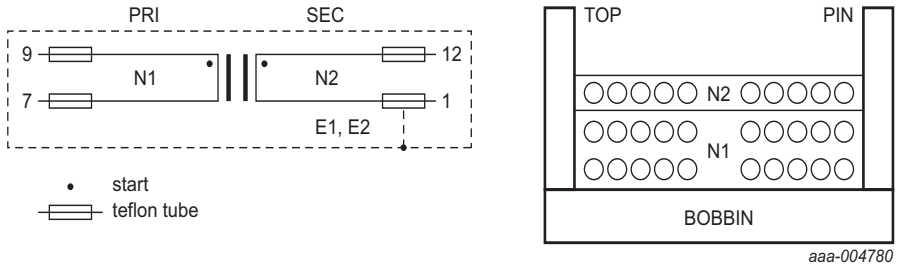
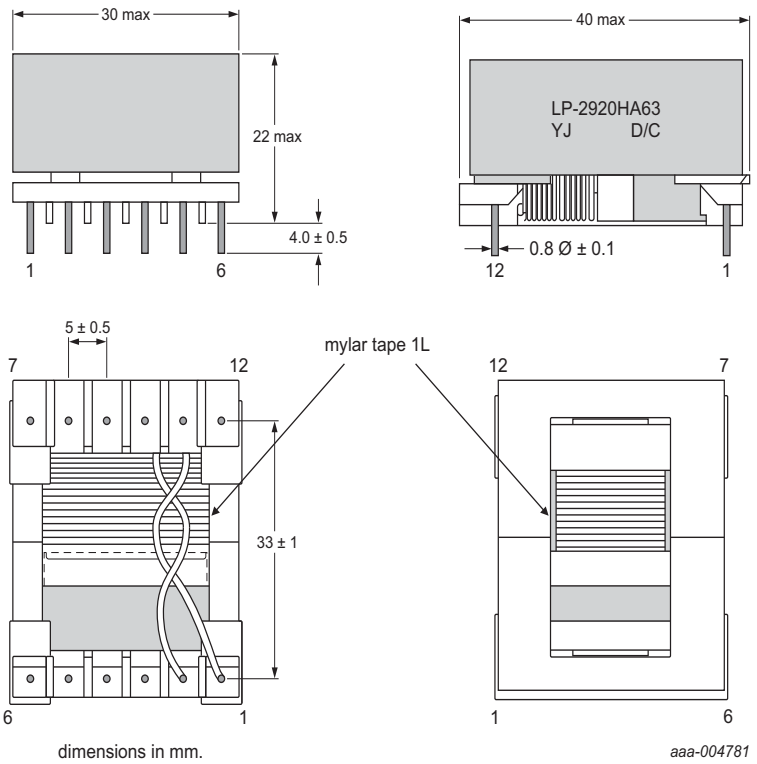


Fig 19. Power factor corrector inductor L4

Table 8. Power factor corrector inductor winding specification

Winding		Terminal number		Winding specifications	Mylar tape
Order	number	Start	Finish		
1	N1	9	7	USTC 0.1 and * 30 * 1 * 40 Ts	1 Ts
2	N1	12	1	2UEW 0.22 and * 2 * 2.5 Ts	3 Ts

11.2 Half-bridge transformer T1



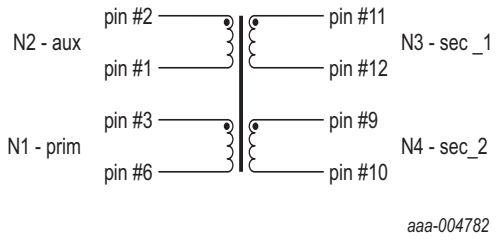
All dimensions in mm

Fig 20. Half-bridge transformer T1 mechanical specification

Table 9. Half-bridge transformer T1 winding specification

Winding	Terminal number		Wire	Turns	Inductance	DCR
number	Start	Finish				
L1	3	6	∅0.10 * 25 s * 1c (litz)	50	1.4 mH	340 mΩ
L2	2	1	∅0.20 *1c (TEX-E)	6	20 μH	250 mΩ
L3	11	12	∅0.10 *30 s*1c (litz)	16	140 μH	95 mΩ
L4	9	10	∅0.10 * 30 s*1c (litz)	16	140 μH	95 mΩ
Llk[1]	3	6	-	-	225 μH	-

[1] Llk measured with L2, L3 and L4 short-circuited.



All dimensions in mm

Fig 21. Half-bridge transformer T1 electrical specification

Table 10. Half-bridge transformer electrical specifications

Parameter	Value	Remark
Primary inductance	1.4 mH	±10 %
Leakage inductance (4 to 1)	225 μH	±10 %
Operating frequency)	60 Hz to 100 Hz	-
Total power	~ 90 W	-
Turns ratio N1 : N2 : N3 : N4	50 : 6 : 16 : 16	see Table 9
I_{pri} (N1)	0.5 A RMS	maximum
I_{sec} (N3 : N4)	2 A RMS	maximum
I_{aux} (N2)	100 mA	maximum

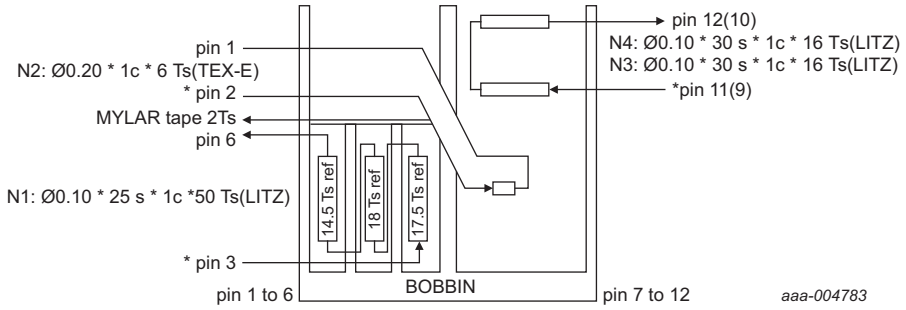


Fig 22. Half-bridge transformer construction and winding order

12. References

[1] **SSL4120 —** Resonant power supply control IC with PFC data sheet

[2] **AN11227 —** SSL4120 resonant power supply control IC with PFC application note

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Date of release: 20 September 2012
Document identifier: UM10575