UM10879

SSL8516BDB1317 75 W 48 V/1.6 A CVCC LED driver

Rev. 1 — 26 May 2015 **User manual**

Document information

Info	Content
Keywords	SSL8516BDB1317, LED driver, constant voltage, constant current, isolated, demo board, Power Factor Corrector (PFC), flyback, synchronous rectification, TEA1892ATS
Abstract	The SSL8516BDB1317 is a global mains 75 W CVCC LED driver demo board featuring the NXP Semiconductors GreenChip SSL8516BT PFC + flyback controller IC with burst mode. The board has a two-stage (PFC + flyback) topology. This topology ensures good Total Harmonic Distortion (THD) performance (mains current class C compliance) over a wide mains input voltage range and output power range. The SSL8516BDB1317 can drive a large LED current control mode range.

Revision history

Rev	Date	Description
v.1	20150526	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 SSL8516BDB1317 demo board is a constant voltage and constant current CVCC LED driver example using a PFC and a flyback stage. This manual describes the specification and use of the SSL8516BDB1317 board.

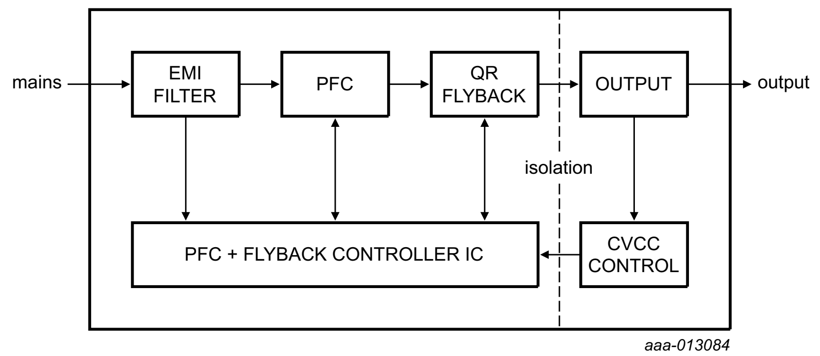


Fig 1. SSL8516BDB1317 demo board block diagram

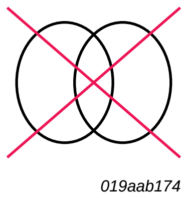
1.1 Features and benefits

- Efficient and low-cost PFC and Quasi-Resonant (QR) flyback topology
- Large input voltage range
- Short start-up time
- Low mains current harmonics
- Low no-load input power
- Flyback stage with large output voltage range
- Single layer Printed-Circuit Board (PCB) 146 × 61 mm

2. Safety warning

The SSL8516BDB1317 demo board must be connected to mains voltage. Avoid touching the demo 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. Figure 2 shows the symbols that identify the isolated and non-isolated devices.

a. Isolated



b. Not isolated

Fig 2. Isolation symbols

3. Specifications

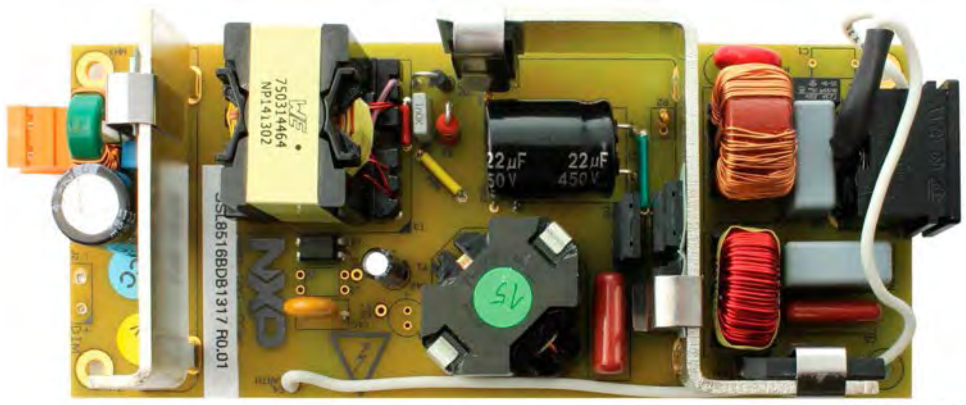
Table 1. SSL8516BDB1317 demo board specifications

Symbol	Description	Value	Condition
V_{mains}	mains voltage (AC)	90 V to 300 V (AC)	
$t_{startup}$	start-up time	< 350 ms	
$P_{o(max)}$	maximum output power	75 W	R_{load} = 32 Ω; at $t_{startup}$; precondition: V_{CC} < 2.0 V
$V_{o(max)}$	maximum output voltage	48.5 V	Constant Voltage (CV) mode
V_o	output voltage range	24 V to 48 V	Current Controlled (CC) mode
$V_{o(noload)}$	no-load output voltage	48.5 V	no-load
$I_{o(max)}$	maximum output current	1.6 A	CC mode
$\Delta I_o/\Delta V_{mains}$	line regulation	< 3 %	
$\Delta I_o/\Delta V_o$	load regulation	< 3 %	
η	efficiency	> 90 %	full load
PF	power factor	> 0.95	full load
		< 20 %	quarter load
THD	total harmonic distortion	< 10 %	full load
$P_{i(noload)}$	no-load input power	< 0.5 W	no-load; PFC auto-off
		< 1.0 W[1]	no-load; PFC forced on
$P_{i(pd)}$	power-down input power	< 100 mW[2]	forced standby

[1] Not default, PFCTIMER is shorted to GND to force PFC always on.

[2] Not default, VINSENSE is shorted to GND for this measurement.

4. Board photographs



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a. Top

aaa-016711

b. Bottom

Fig 3. SSL8516BDB1317 demo board photographs

5. Connecting the board

Connect the mains voltage to the input connector X1, type IEC C6.

Connect the load to the output connector J1.

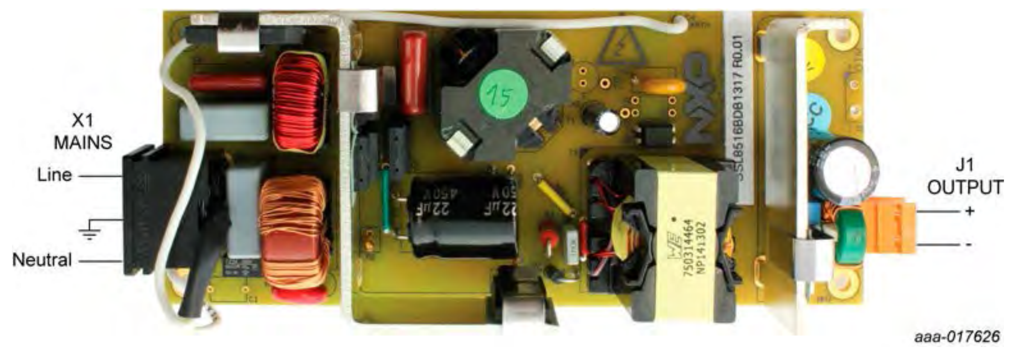


Fig 4. SSL8516BDB1317 demo board connections

6. Functional description

The SSL8516BDB1317 LED driver demo board is a constant voltage and constant current LED driver. This board was especially designed to drive a wide LED voltage at a fixed output current. At low load, a low input power is achieved by the burst mode feature of the IC.

For more information about the SSL8516BT IC, see the *SSL8516BT data sheet* and the *AN11486 application note*.

6.1 SSL8516BT controller IC

The SSL8516BT is a very robust and reliable PFC + flyback controller IC from the NXP Semiconductors GreenChip family. The SSL8516BT is almost identical to the SSL8516T. However, the SSL8516BT includes a burst mode for improved no-load power. The SSL8516T has a VCO mode down to 0 Hz for low flicker at deep dimming in current controlled mode.

Various internal protections ensure fail-safe operation of the LED driver under all conditions.

- Safe restart (non-latched) protections:
  - Flyback overvoltage protection
  - Flyback time-out
  - Flyback maximum on-time
  - IC supply under voltage lockout
  - IC internal temperature protection
- Latched protection:
  - External LATCH pin

- Other protections:
  - PFC overvoltage protection
  - PFC overcurrent protection
  - Flyback overpower protection (triggering flyback time-out timer)

6.1.1 Pinning

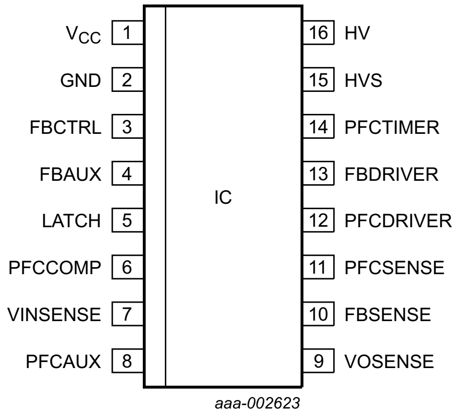


Fig 5. SSL8516BT pinning diagram

6.2 Dual stage LED driver

The board consists of a PFC boost stage to meet the class C lighting requirements and a flyback stage to drive the output.

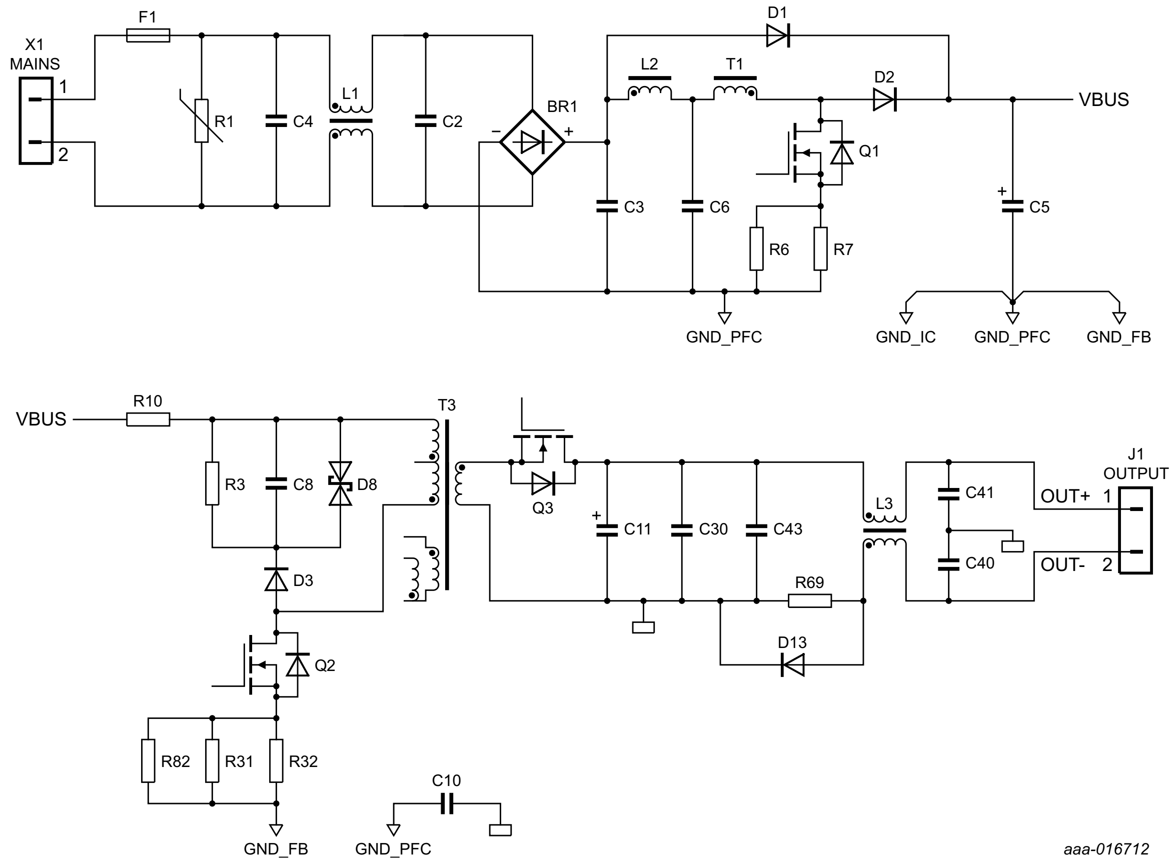


Fig 6. Large signal path of the board

6.3 ElectroMagnetic Interference (EMI) filter

The EMI filter consists of the following magnetic components:

- Common-mode inductor L1
- Differential mode inductor L2

The EMI filter includes the following capacitors:

- The differential filter: C4, C2, C3 and C6
- The common-mode filter: C10

6.4 Power Factor Correction (PFC)

The PFC is a boost stage consisting of components T1, Q1, D2, and C5. In normal operation, the PFC stage operates in Boundary Conduction Mode (BCM) with valley switching and fixed on-time. Valley switching is described in the *SSL8516BT data sheet*.

The design choices for the PFC stage are based on the following targets:

- A wide mains input voltage range from 90 V (AC) to 305 V (AC)
- A large output power range must comply with the mains current harmonics class C requirements for lighting equipment of IEC 61000-3-2

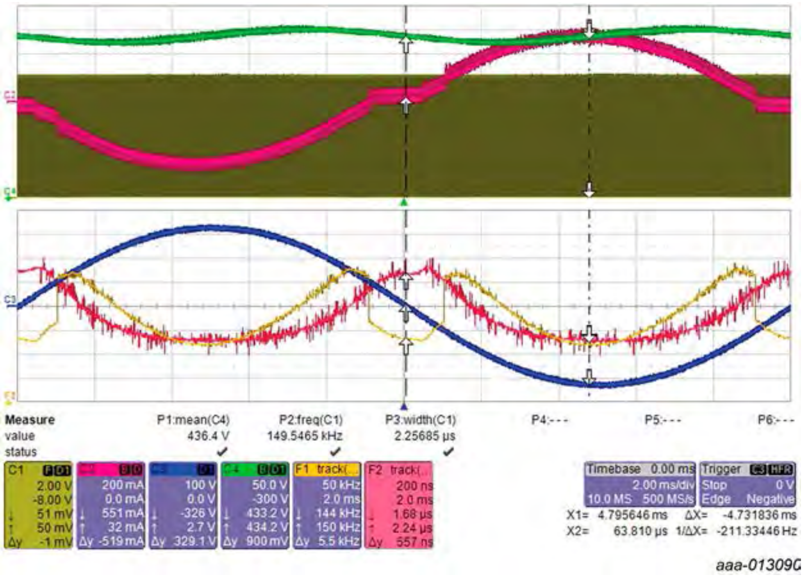
The PFC inductance T1 is maximized (lowest PFC switching frequency) for a large frequency range. The maximum PFC frequency of the SSL8516BT is limited to 400 kHz.

The controller keeps the PFC frequency under 400 kHz through valley skipping. The operating mode of the PFC changes from BCM to Discontinuous Conduction Mode (DCM) in case of valley skipping.

The PFC frequency range of up to 400 kHz prevents discrete steps in the mains current which can be the result of valley skipping.

The PFC inductance on this board is 500 μH. A larger value can cause audible noise at a 300 V high mains voltage and full load. $f_{sw(PFC)}$ drops significantly when the peak of the mains voltage is close to the bus voltage. In this condition, $t_{off(PFC)}$ increases.

The PFC output voltage V_{bus} is dimensioned for the use of a 450 V rated bus capacitor (C5). $V_{bus(nom)}$ = 431 V, the ripple is ±10 V. For 75 W, a 22 μF capacitor is sufficient when there are no hold-up time (mains voltage cycle skipping) requirements.



C1 = $V_{PFCDRIVER}$

C2 = I_{mains}

C3 = V_{mains}

C4 = V_{bus}

F1 = $f_{sw(C1)} = f_{sw(PFC)}$

F2 = $t_{on(C1)} = t_{on(PFC)}$

Fig 7. PFC signals 230 V; V_o = 48 V; I_o = 1.6 A

Channel F1 shows the frequency of the PFC gate drive signal $V_{PFCDRIVER}$. During the zero crossing of V_{mains}, the valley skipping of the PFC controller is visible. Channel F2 shows the on-time ($t_{on(PFC)}$) of the PFC gate drive signal $V_{PFCDRIVER}$. The THD in Figure 7 is 9.9 %.

The PFC on-time, $t_{on(PFC)}$, is modulated to increase near the zero crossings of V_{mains}. The on-time increase improves the THD and class C performance significantly.

The modulation signal is added to the PFC compensation network on pin PFCCOMP using capacitor C15. The voltage ($V_{PFCCOMP}$) on the PFCCOMP pin represents the on-time. Low voltage is high $t_{on(PFC)}$, high voltage is low $t_{on(PFC)}$.

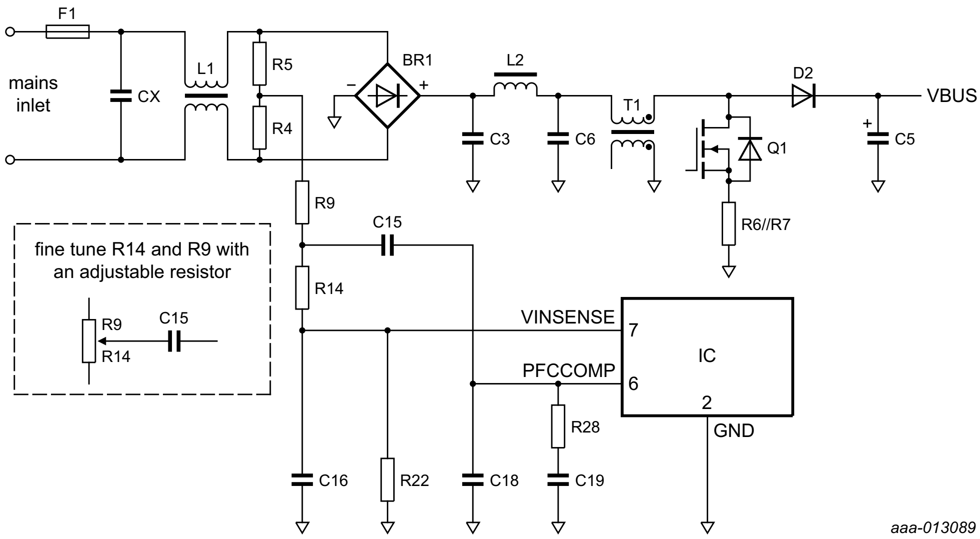
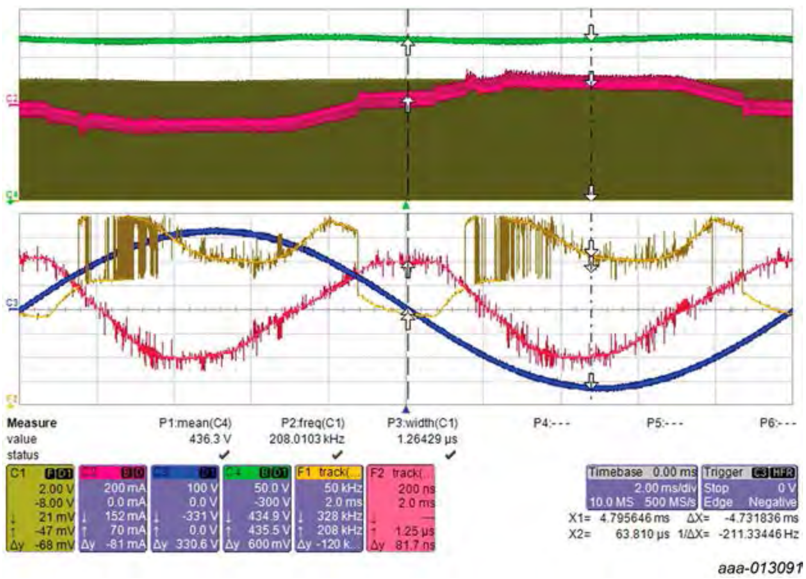


Fig 8. $t_{on(PFC)}$ modulation with capacitor C15

At low load, $f_{sw(PFC)}$ increases and the frequency limit of the PFC controller is reached. At the mains angle where $f_{sw(PFC)max}$ is reached, the valley skipping is active. A discrete step in the mains current is present. The valley hopping and the flat line during the V_{mains} zero crossings determine the THD and class C performance.



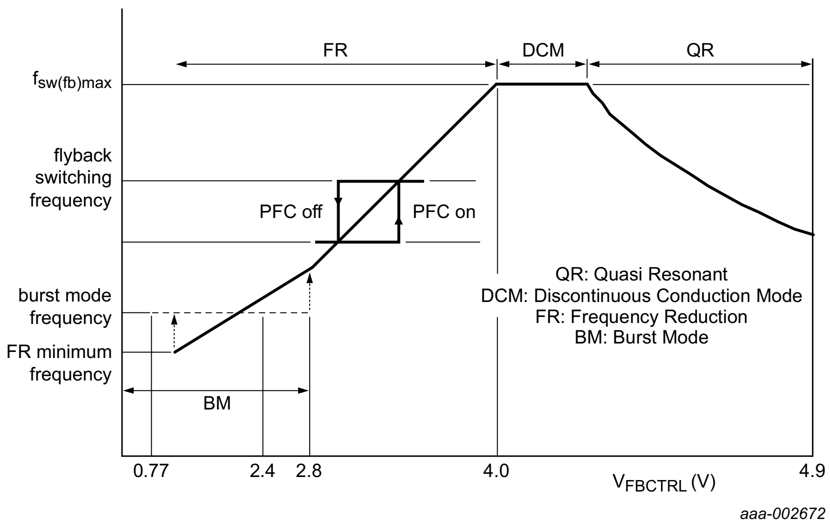
Upper grid: C1 = $V_{PFCDRIVER}$; C2 = I_{mains}; C4 = V_{bus}

Fig 9. PFC signals 230 V; V_o = 16 V; I_o = 1.6 A

6.5 Flyback converter

Depending on the output power/FBCTRL pin voltage, the flyback converter operates in multiple modes:

- Quasi-Resonant (QR)
- Discontinuous Conduction Mode (DCM)
- Frequency Reduction (FR)
- Burst Mode (BM)



(1) QR: The flyback is operated in Quasi-Resonant (QR) mode at $P_{o(max)}$.

(2) DCM: The IC clamps the flyback switching frequency to $f_{sw(fb)max}$ = 130 kHz.

(3) FRM: the FBCTRL pin controls the VCO, allowing $f_{sw(fb)}$ to drop to 25 kHz.

(4) BM: at $f_{sw(fb)}$ = 25 kHz, BM is activated to allow higher efficiency, especially for no-load and low load conditions.

Fig 10. Multimode flyback operation

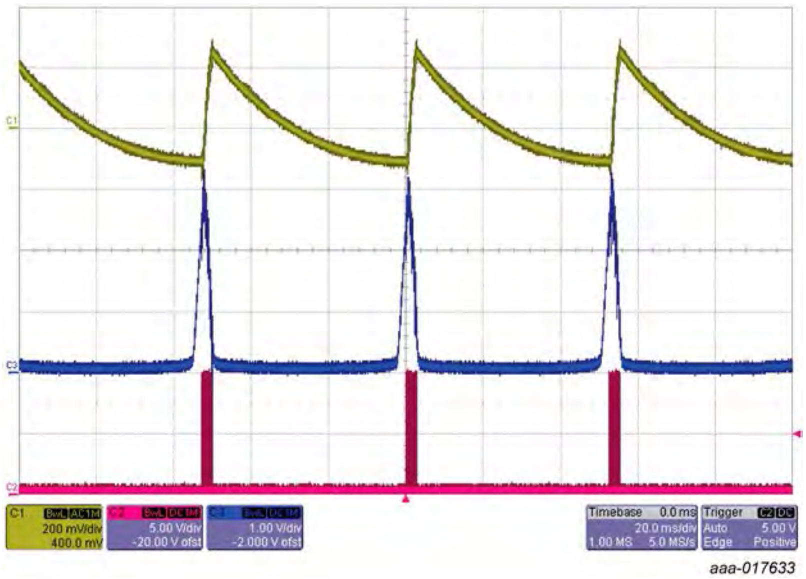
At low load, the PFC is switched off. V_{bus} is then charged until the peak of the mains voltage is reached. The switch-off delay of the flyback power switch variation must be considered to benefit from the accurate PFC switch-on and switch-off levels.

Because of the delay compensation circuit at the FBSENSE pin, the $f_{sw(fb)}$ is almost independent of V_{bus} for this board. Resistors R12, R17, and R20 set the compensation current.

Resistor R33 sets the amount of correction. See the *AN11486 application note* for more information on the delay compensation on the FBSENSE pin and flyback adjustment $I_{pk(fb)min}$ and $I_{pk(fb)max}$.

6.6 Burst mode

When the flyback switching frequency drops to below 25 kHz (in FR mode not in QR mode), the IC enters BM. To reduce the IC current consumption, most internal IC circuits are switched off in BM. In BM, $f_{sw(fb)}$ = 35 kHz with a 225 mV FBSENSE level.

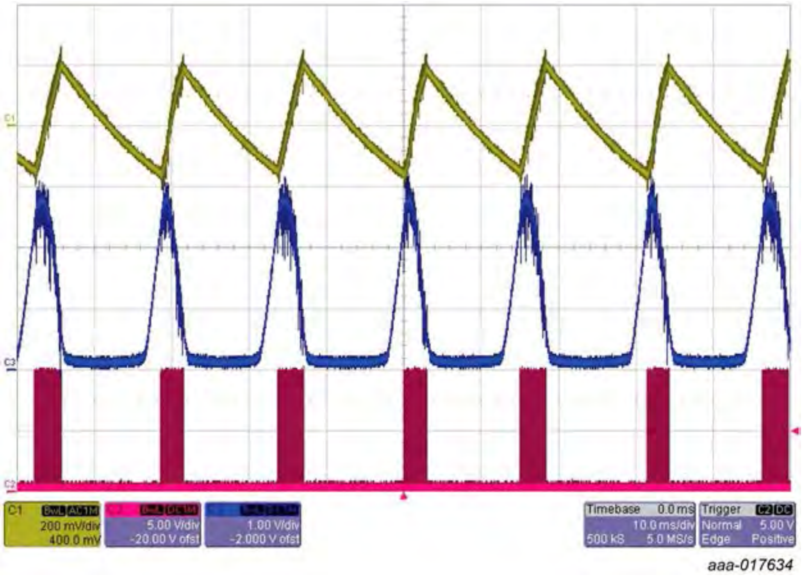


(1) C1 = V_o (AC coupled)

(2) C2 = $V_{FBDRIVER}$

(3) C3 = V_{FBCTRL}

Fig 11. Burst mode signals V_o = 48.5 V; I_o = 0 mA

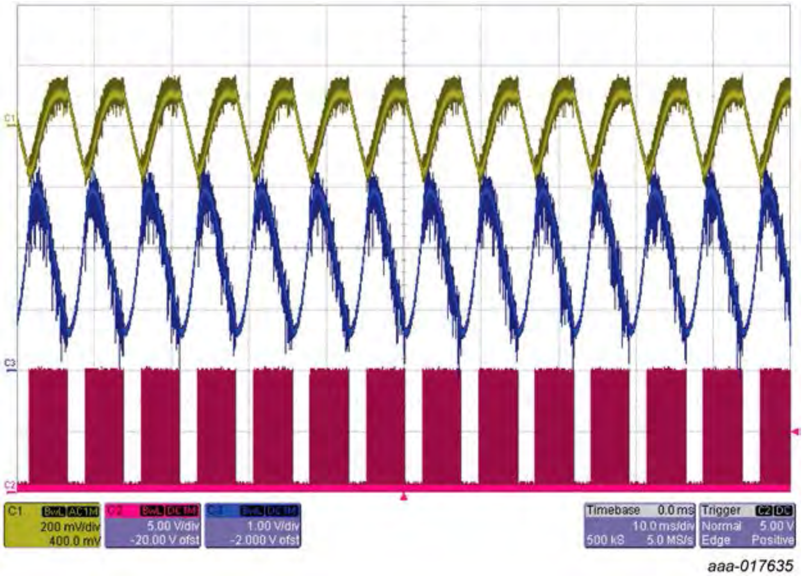


(1) C1 = V_o (AC coupled)

(2) C2 = $V_{FBDRIVER}$

(3) C3 = V_{FBCTRL}

Fig 12. Burst mode signals V_o = 48.5 V; I_o = 10 mA



(1) C1 = V_o (AC coupled)

(2) C2 = $V_{FBDRIVER}$

(3) C3 = V_{FBCTRL}

Fig 13. Burst mode signals V_o = 48.5 V; I_o = 50 mA

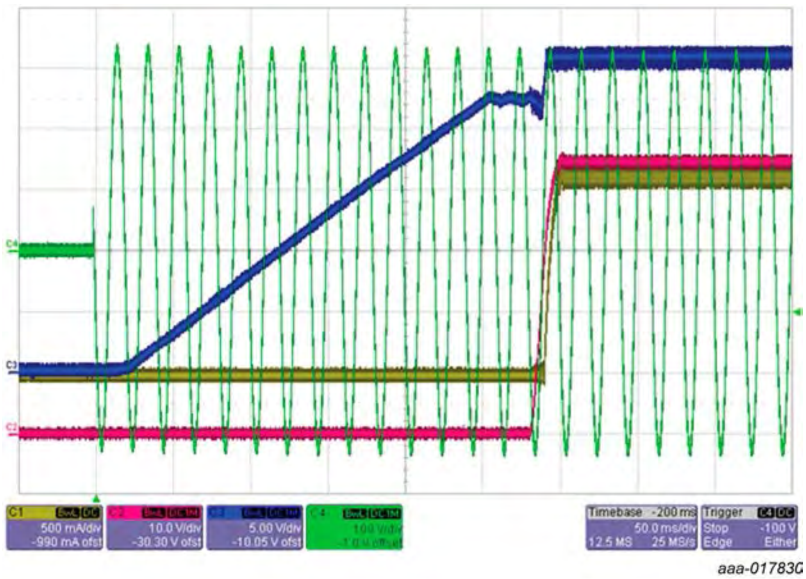
6.7 IC low-voltage supply circuit

An additional auxiliary winding on the FB transformer provides the VCC supply for the IC.

In Constant Voltage (CV) mode, V_o is fixed to 48.5 V. However, in Constant Current (CC) mode, V_o depends on the number of LEDs connected. To limit the supply voltage to the IC, a voltage regulator circuit is used. Because V_o is regulated to 48.5 V by the CV control loop, the auxiliary winding voltage is at its maximum in CV mode.

Due to the regulator voltage drop, the no-load input power $P_{i(noload)}$ is not the lowest possible value. For a better $P_{i(noload)}$ performance, check suggestions on the VCC as described in the *AN11486 application note*.

To achieve a short stat-up time at initial start-up, the HV pin current source charges VCC buffer capacitors C26 and C42 to $V_{startup}$ = 22.3 V with 5 mA = $I_{ch(high)}$.



(1) C1 = I_o

(2) C2 = V_o

(3) C3 = V_{CC}

(4) C4 = V_{mains}

V_{CC} was discharged to 0 V before start-up.

Fig 14. Start-up waveforms; V_{mains} = 230 V (AC)/50 Hz; V_{CC} discharged to 0 V; V_o = 44 V

Table 2. Start-up times (ms)

V_{mains}	V_{load} = 48 V	V_{load} = 24 V	R_{load} = 32 Ω	R_{load} = 128 Ω
100 V (AC)/60 Hz	288	287	287	289
120 V (AC)/60 Hz	288	263	277	278
230 V (AC)/50 Hz	295	276	285	291
277 V (AC)/60 Hz	274	254	266	274

6.8 Flyback feedback control loop

This LED driver example incorporates two output regulation loops:

- A Constant Voltage (CV) regulation loop
- A Constant Current (CC) regulation loop

In normal operation, one of the two loops is active/closed. The set points of the output terminal are $V_{o(max)}$ or $I_{o(max)}$.

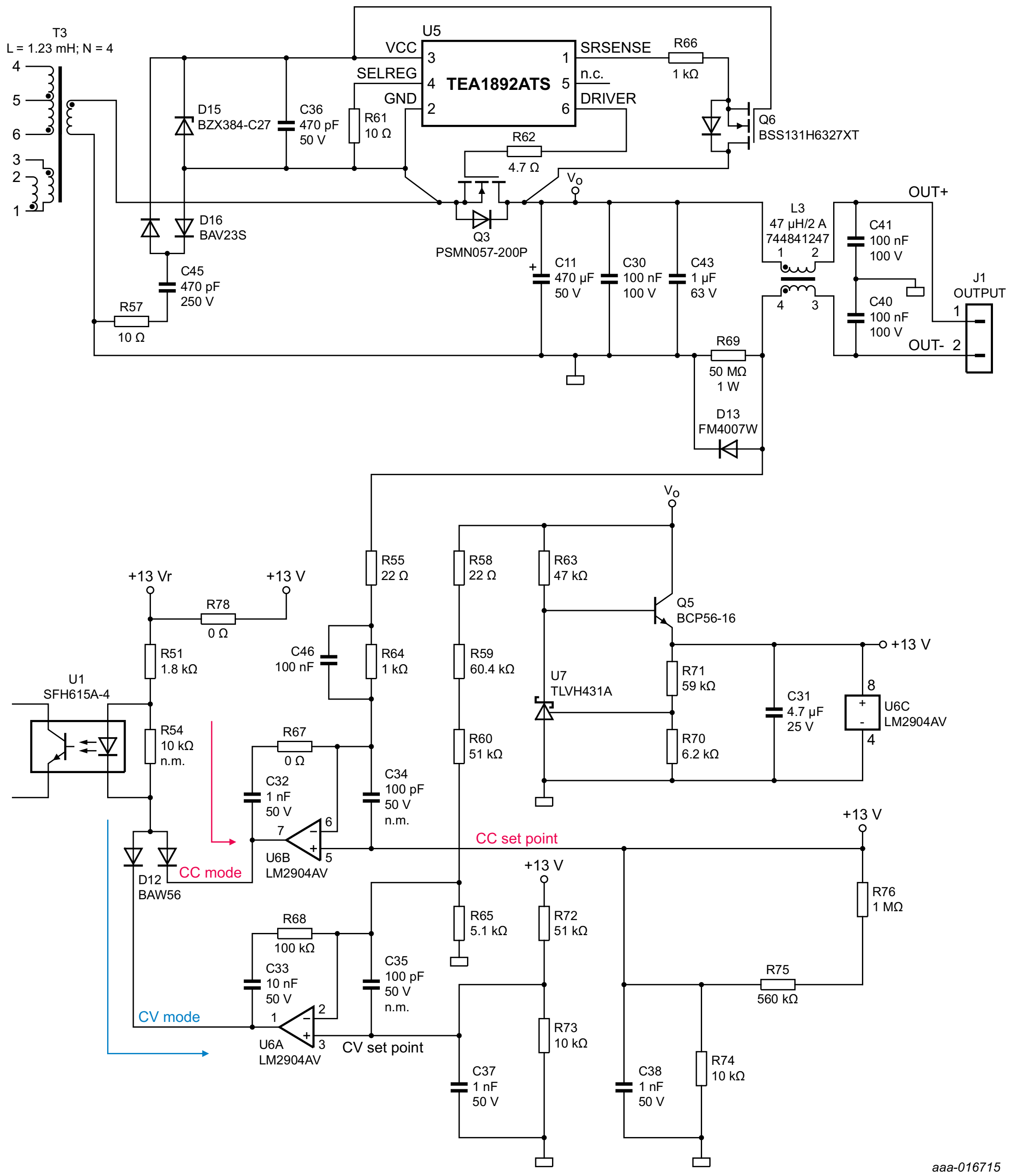


Fig 15. CV and CC control loops and SR circuit

6.9 Synchronous rectification

The synchronous rectifier control IC TEA1892ATS eliminates the secondary side heat sink. However, to provide cooling options for experiments with output diodes, the secondary heat sink is still mounted/available.

6.10 Output Constant Voltage (CV) control

The LED driver is intended to be connected with an LED module. The CV mode is intended for LED modules that include a DC-to-DC converter with optional PWM dimming, tunable white, or RGB color modules

The voltage control limits the output voltage when a load < 1.6 A is connected or when the LED module is broken (open-string). When the voltage control loop is closed (CV mode), the CC loop is open. In CV mode, the output is V_o is regulated at $V_{o(max)}$ = 48.5 V.

6.11 Output Constant Current (CC) control

The constant current regulation set point is derived from the accurate 13 V local supply (band gap referenced with U7). The set point is fixed to 81 mV.

Resistors R74, R75, and R76 set the accurate 9 mV lower limit.

The 13 V local supply draws current from V_o. The bias current is minimized to reduce losses by using a low current shunt regulator TLVH431 and a high gain optocoupler. Q5 dissipation is minimal for the specified V_o range.

6.12 Output short circuit conditions

Several features provide protection against component damage when the LED driver output is shorted.

Two conditions must be considered:

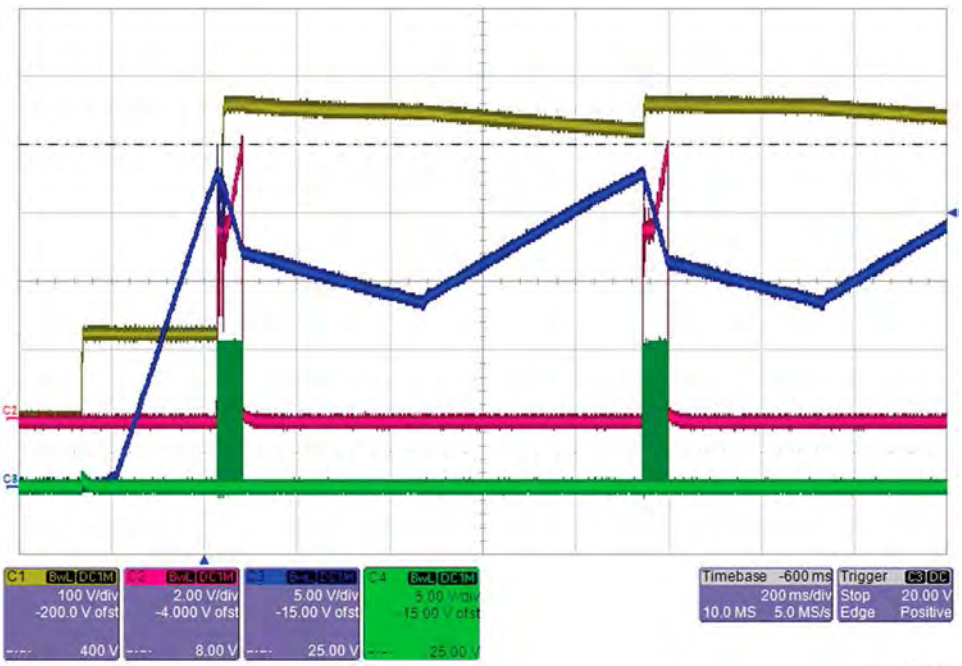
- Short circuit at start-up
- Short circuit during operation

The SSL8516BT protection features involved during output short circuit are:

- IC supply under voltage protection, pin V_{CC} threshold $V_{th(UVLO)}$
- flyback time-out via optocoupler feedback; pin FBCTRL
- flyback OverCurrent Protection (OCP) via pin FBSENSE

With a low ohmic output short circuit, the SSL8516BT time-out is triggered before $V_{th(UVLO)}$ is reached.

6.12.1 Output short circuit at start-up



C1 = V_{bus}

C2 = V_{FBCTRL}

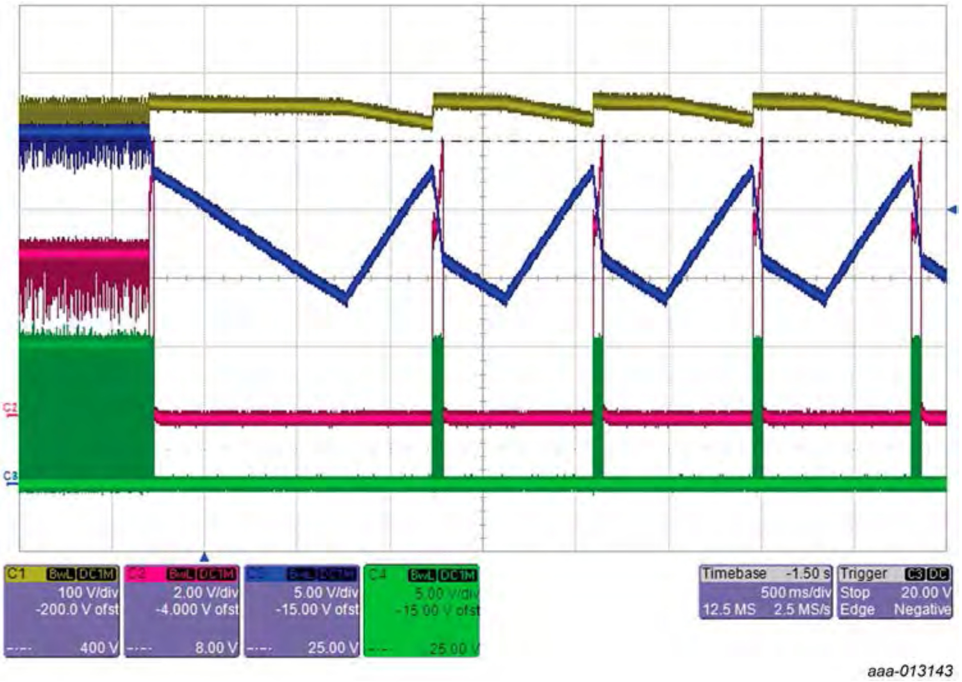
C3 = V_{VCC}

C4 = $V_{FBDRIVER}$

Fig 16. Oscillogram output short circuit at initial start-up

6.12.2 Output short circuit during operation

During operation, the total output capacitance is charged. Diode D13 (parallel to the LED current sense resistor) limits the voltage and the power and so protects the sense resistor and error amplifier.



C1 = V_{bus}

C2 = V_{FBCTRL}

C3 = V_{VCC}

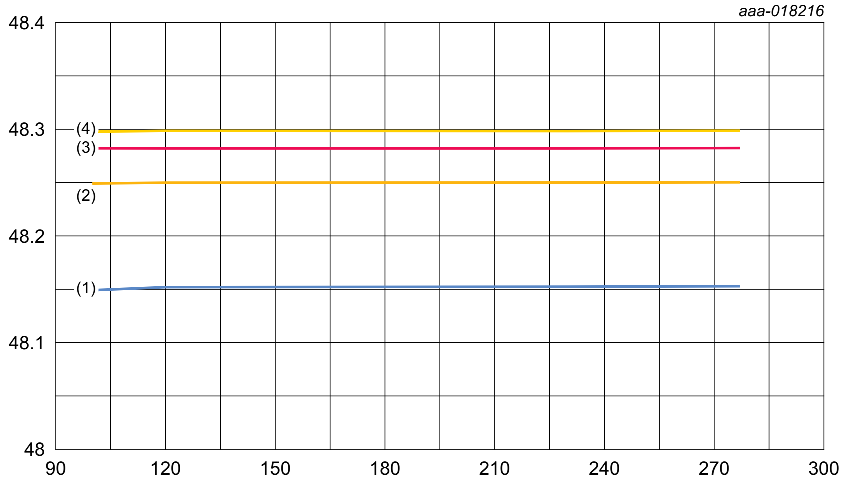
C4 = $V_{FBDRIVER}$

Fig 17. Oscillogram output short circuit during operation at full load

7. Performance

7.1 Line regulation and load regulation

Figure 18 shows the Constant Voltage (CV) regulation performance of the driver.



(1) R_{load} = 32 Ω

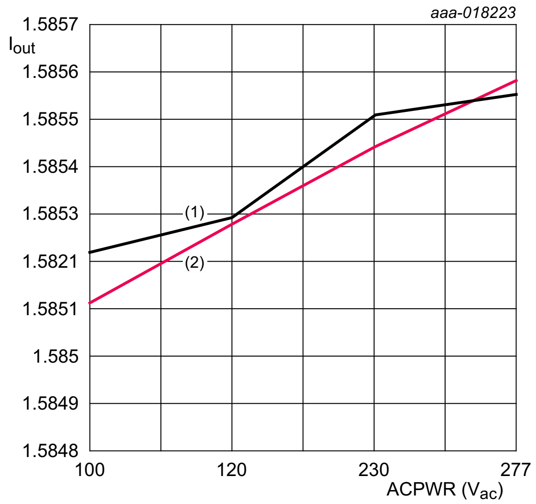
(2) R_{load} = 64 Ω

(3) R_{load} = 96 Ω

(4) R_{load} = 128 Ω

Fig 18. Output voltage variations for various load resistances and mains voltages

Figure 19 shows the Constant Current (CC) regulation performance of the driver with a voltage load with R_d = 10 Ω.



(1) V_{LED} = 24 V (DC)

(2) V_{LED} = 48 V (DC)

Fig 19. Output current variations for various constant voltage loads and mains voltages

7.2 Mains input measurements

When the supply is in CV mode, the mains input measurements are performed with an electronic load type 63115A in resistive mode.

Table 3. Output settings in CV mode

Output	P_o = 100 %	P_o = 50 %	P_o = 33 %	P_o = 25 %
load (Ω)	32	64	96	128

When the supply is in CC mode, the mains input measurements are performed with an electronic load type 63115A in LED mode with R_d = 10 Ω.

Table 4. Output settings in CC mode

Output	P_o = 100 %	P_o = 50 %	P_o = 33 %	P_o = 25 %
load (V)	48.0	24.0	-	-

7.2.1 Efficiency

Table 5. Efficiency

V_{mains}	Mode	P_o = 100 %	P_o = 50 %	P_o = 33 %	P_o = 25 %
100 V (AC)/60 Hz	CV	91.001	89.44	87.275	84.9
120 V (AC)/60 Hz	CV	91.69	89.742	87.388	84.896
230 V (AC)/50 Hz	CV	92.878	89.995	87.119	84.284
277 V (AC)/60 Hz	CV	93.004	89.85	86.763	83.808
100 V (AC)/60 Hz	CC	91.031	90.399	-	-

Table 5. Efficiency *...continued*

V_{mains}	Mode	P_o = 100 %	P_o = 50 %	P_o = 33 %	P_o = 25 %
120 V (AC)/60 Hz	CC	91.77	90.763	-	-
230 V (AC)/50 Hz	CC	93.015	91.131	-	-
277 V (AC)/60 Hz	CC	93.136	90.962	-	-

7.2.2 Power factor

Table 6. Power factor

V_{mains}	Mode	P_o = 100 %	P_o = 50 %	P_o = 33 %	P_o = 25 %
100 V (AC)/60 Hz	CV	0.99471	0.98931	0.97823	0.96737
120 V (AC)/60 Hz	CV	0.9933	0.98427	0.9708	0.95398
230 V (AC)/50 Hz	CV	0.97924	0.9493	0.91732	0.87379
277 V (AC)/60 Hz	CV	0.96365	0.90012	0.81958	0.74154
100 V (AC)/60 Hz	CC	0.99516	0.99019	-	-
120 V (AC)/60 Hz	CC	0.99345	0.98517	-	-
230 V (AC)/50 Hz	CC	0.98008	0.95016	-	-
277 V (AC)/60 Hz	CC	0.96578	0.90177	-	-

7.2.3 Total harmonic distortion

Table 7. Total harmonic distortion

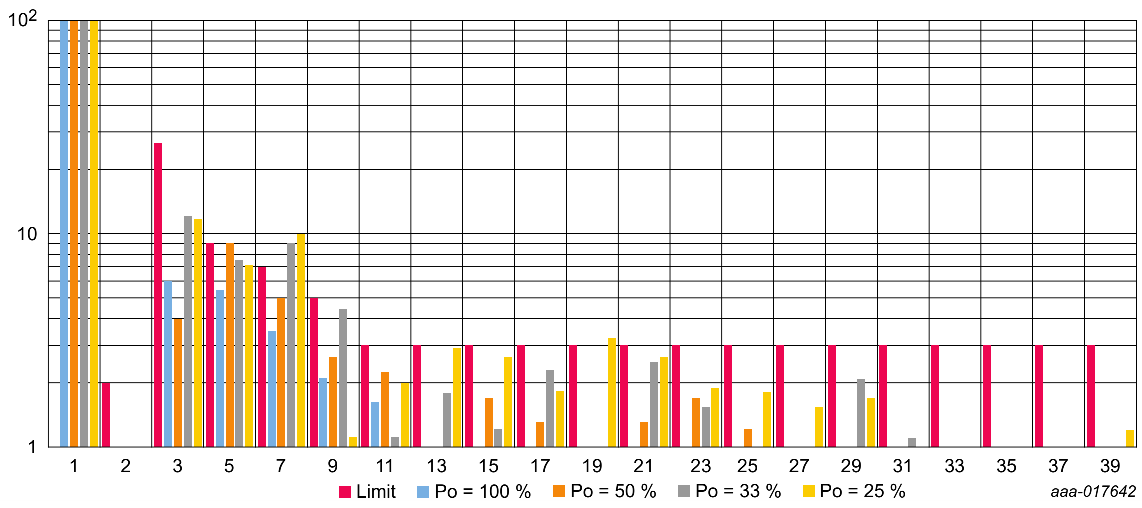
V_{mains}	Mode	P_o = 100 %	P_o = 50 %	P_o = 33 %	P_o = 25 %
100 V (AC)/60 Hz	CV	6.659	5.615	6.577	9.472
120 V (AC)/60 Hz	CV	6.769	6.464	8.707	10.368
230 V (AC)/50 Hz	CV	9.451	11.999	17.934	18.826
277 V (AC)/60 Hz	CV	8.514	13.75	14.903	17.681
100 V (AC)/60 Hz	CC	6.34	5.741	-	-
120 V (AC)/60 Hz	CC	6.902	6.53	-	-
230 V (AC)/50 Hz	CC	9.62	11.67	-	-
277 V (AC)/60 Hz	CC	8.345	14.544	-	-

7.2.4 Mains current harmonics

To indicate IEC 61000-3-2 class C compliance at 230 V (AC), the mains current harmonics are measured for several power levels.

Table 8. Mains current harmonics

R_{load}	PF	1	2	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
32	0.97924	100	0	6.1	5.4	3.5	2.1	1.6	1	0.3	0.4	0.6	0.5	0.4	0.2	0.5	0.7	0.6	0.4	0.2	0.2	0.3
64	0.9493	100	0.3	3.9	8.8	5	2.6	2.2	0.5	1.7	1.3	0.4	1.3	1.7	1.2	0	0.8	0.8	0.8	0.3	0.2	0.4
96	0.91732	100	0.4	12.2	7.5	9.1	4.5	1.1	1.8	1.2	2.3	0.7	2.5	1.5	1	0.9	2.1	1.1	0.2	0.2	1	0.7
128	0.87379	100	0.4	11.8	7.1	10	1.1	2	2.9	2.6	1.8	3.2	2.6	1.9	1.8	1.5	1.7	0.7	0.9	0.8	0.9	1.2
limit		0	2	26.2	9	7	5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3



(1) Red: IEC limit

(2) Green: P_o = 100 %

(3) Purple: P_o = 50 %

(4) Blue: P_o = 33 %

(5) Orange: P_o = 25 %

Fig 20. Mains current harmonics (%) of fundamental; 230 V (AC)/50 Hz

The results comply with the limits as described in IEC 61000-3-2 for class C equipment.

Table 9. IEC 61000-3-2 class C limits of harmonic current as percentage of fundamental

Harmonic order n	Limit
2	2 %
3	30 % × PF
5	10 %
7	7 %
9	5 %
11 ≤ n ≤ 39 (odd harmonic only)	3 %

7.2.5 No-load input power $P_{i(noload)}$; fault mode

The no-load input power $P_{i(noload)}$ is measured with nothing connected to the output connectors J1. V_o regulates to $V_{o(max)}$ by the CV control loop.

Table 10. $P_{i(noload)}$ measurement; PFC auto-off (default)

V_{mains}	$P_{i(noload)}$ (W)	I_{mains} (mA)
100 V (AC)/60 Hz	0.271	49
120 V (AC)/60 Hz	0.277	49
230 V (AC)/50 Hz	0.330	48
277 V (AC)/60 Hz	0.360	54

Optional, the SSL8516BT PFC can be forced on. During this measurement only, resistor R39 = 1 Ω is placed to force PFC always on.

Table 11. $P_{i(noload)}$ measurement; PFC forced on (optional)

V_{mains}	$P_{i(noload)}$ (W)	I_{mains} (mA)
100 V (AC)/60 Hz	0.984	50
120 V (AC)/60 Hz	0.908	51
230 V (AC)/50 Hz	0.451	48
277 V (AC)/60 Hz	0.453	54

7.2.6 Power-down input power ($P_{i(pd)}$)

Some LED drivers have a standby power supply and a microcontroller that enables/disables the main power supply. When using the SSL8516BT as controller of the main power supply, a microcontroller can pull down pin VINSENSE using a transistor.

The power-down input power ($P_{i(pd)}$) is measured with the VINSENSE pin pulled down with a switch.

Table 12. $P_{i(pd)}$ measurement

V_{mains}	$P_{i(pd)}$ (W)	I_{mains} (mA)
100 V (AC)/60 Hz	0.013	65
120 V (AC)/60 Hz	0.019	64
230 V (AC)/50 Hz	0.061	56
277 V (AC)/60 Hz	0.088	53

7.3 EMI measurements

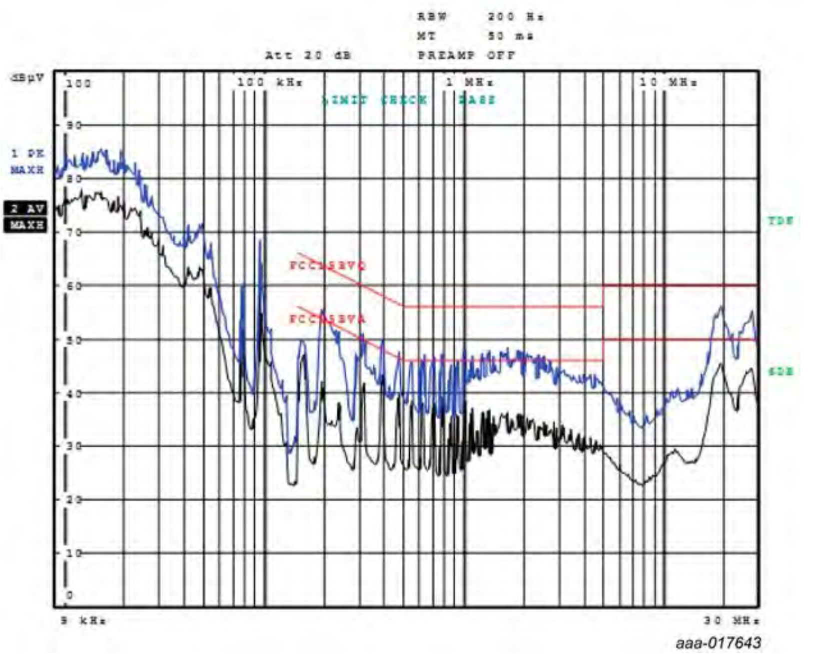


Fig 21. Conducted prescan: 120 V (AC); FCC15; peak and average

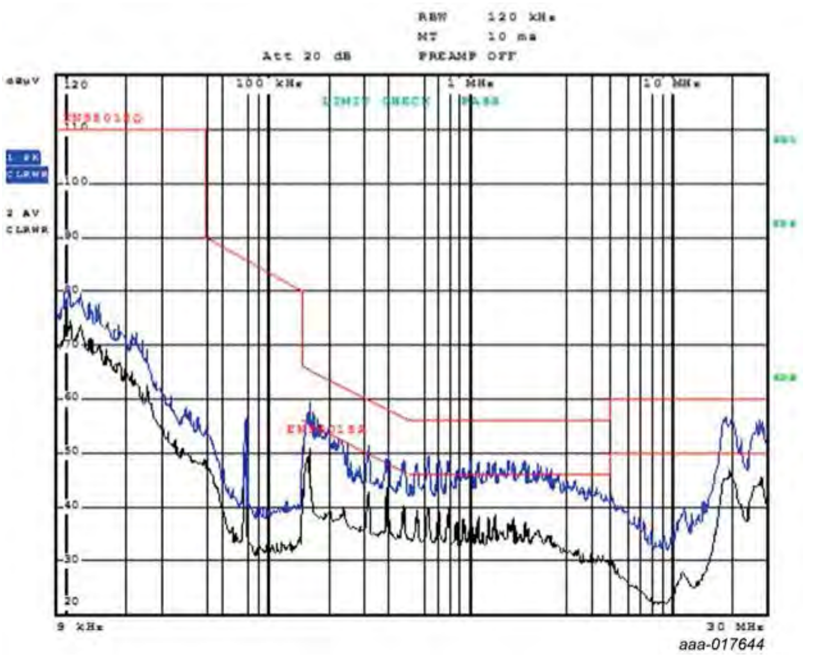


Fig 22. Conducted prescan: 230 V (AC); EN55015; peak and average

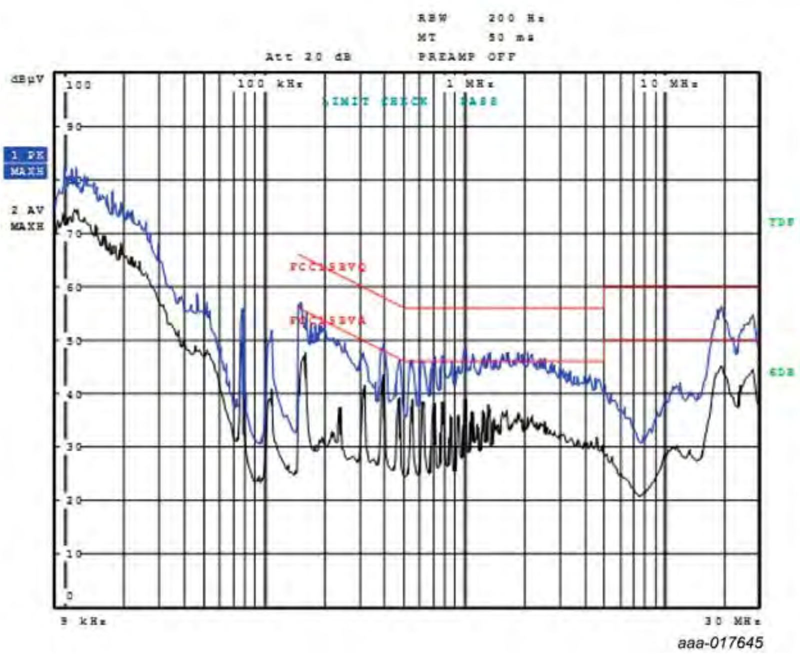


Fig 23. Conducted prescan: 277 V (AC); FCC15; peak and average

8. Schematic

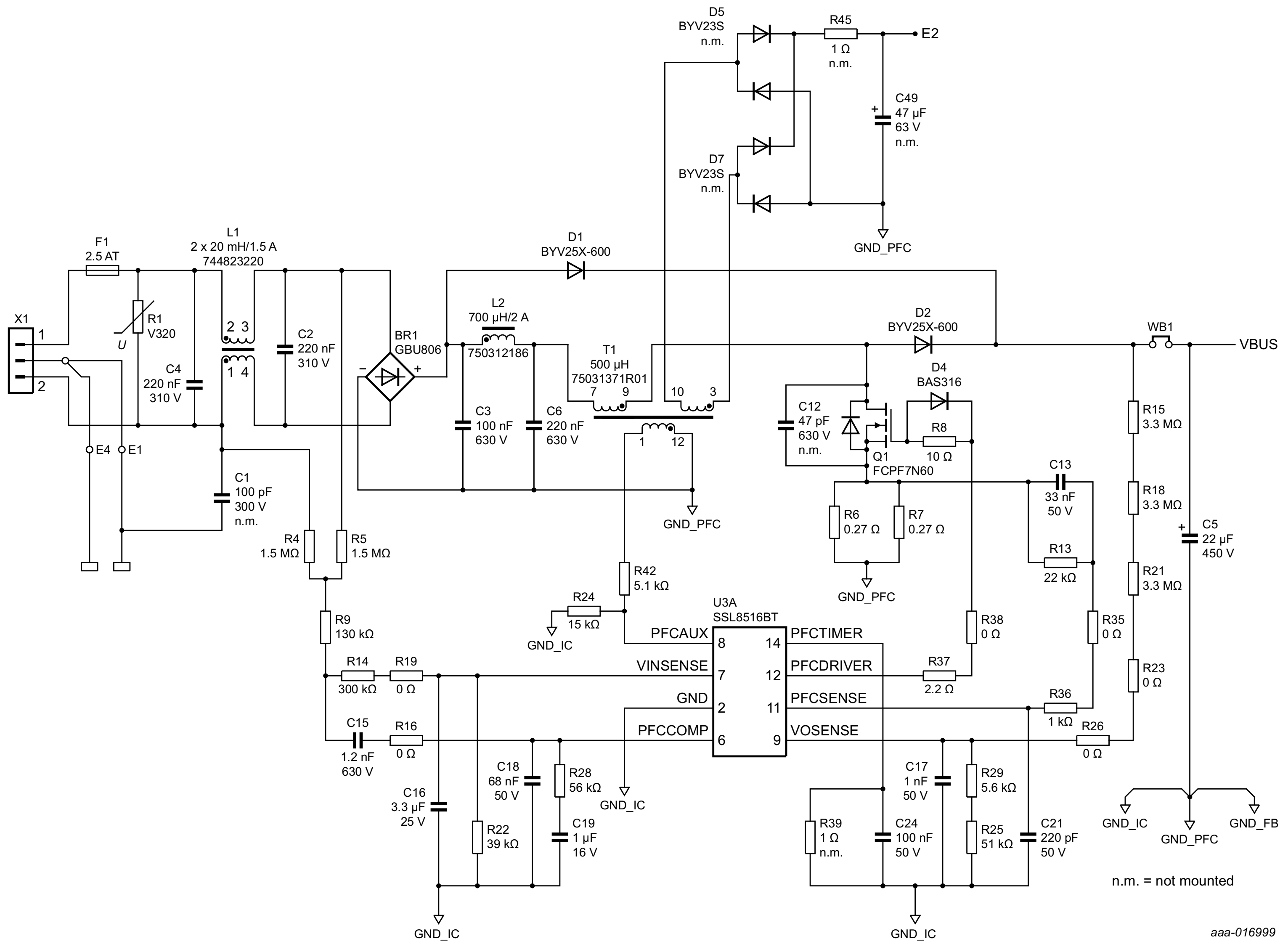


Fig 24. SSL8516BDB1317 demo board schematic: Mains input and PFC stage

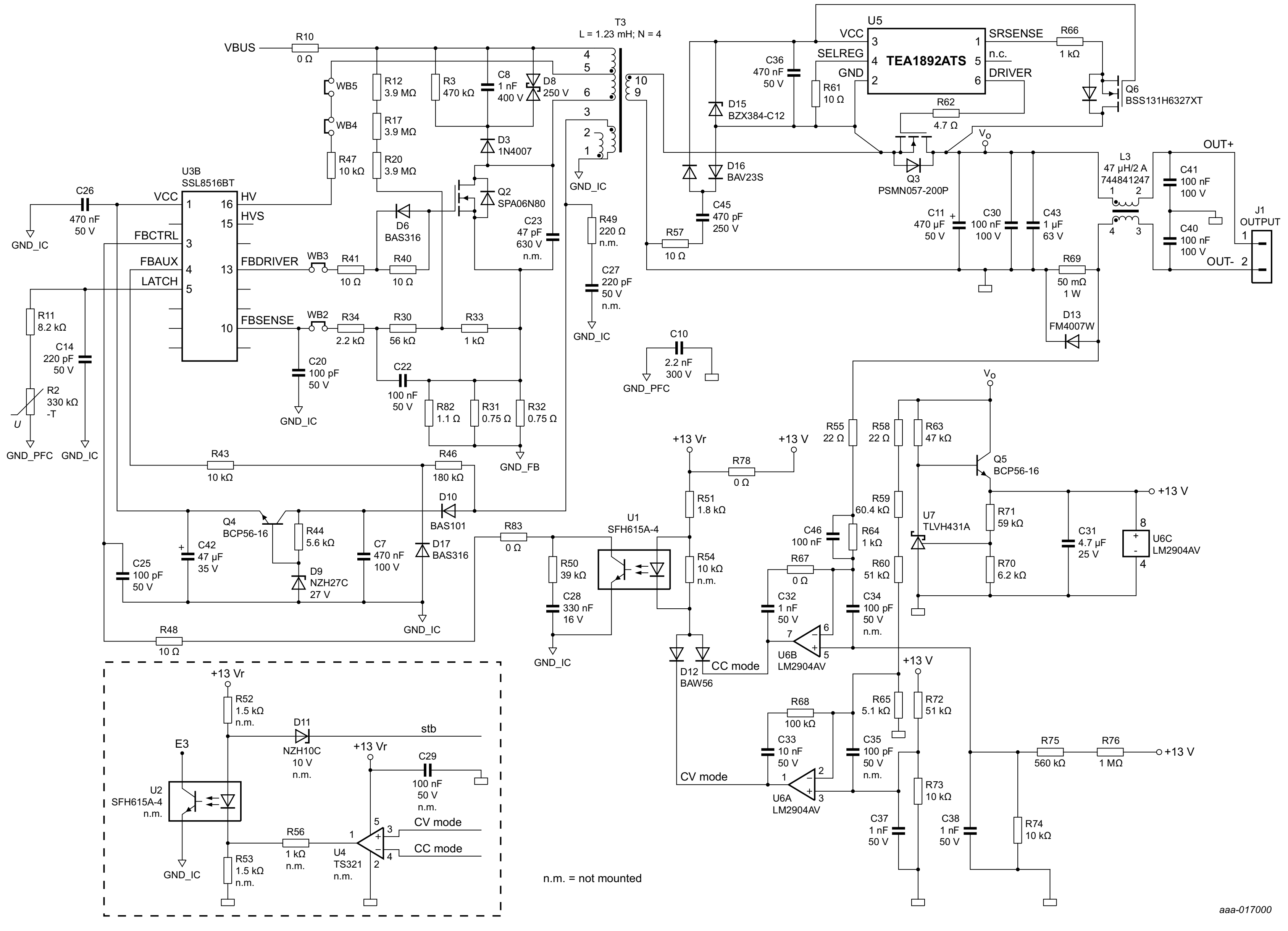


Fig 25. SSL8516BDB1317 demo board schematic: Flyback stage and output circuit

9. Bill Of Materials (BOM)

Table 13. SSL8516BDB1317 demo board bill of materials

Reference	Description and values	Part number	Manufacturer
BR1	bridge rectifier; 600 V; 8 A	GBU806	Diode Inc.
C1	capacitor; not mounted; 100 pF; 10 %; 300 V; Y5S; THT	VY2101K29Y5SG63V7	Vishay
C2; C4	capacitor; 220 nF; 20 %; 310 V; MKP; THT	BFC233922224	Vishay
C3	capacitor; 100 nF; 5 %; 630 V; PP; THT	ECW-FA2J104J	Panasonic
C5	capacitor; 22 μF; 20 %; 450 V; ALU; 16 mm × 20 mm	EEU-EE2W220S	Panasonic
C6	capacitor; 220 nF; 5 %; 630 V; CH3; THT	ECWFA2J224J	Panasonic
C7	capacitor; 470 nF; 10 %; 100 V; X7R; 0805	08051C474KAT2A	AVX
C8	capacitor; 1 nF; 10 %; 400 V; MMK; THT	MMK5102K400J01L16.5TR18	KEMET
C9	capacitor; not mounted; 47 μF; 20 %; 63 V; ALU; THT	EEU-FR1J470	Panasonic
C10	capacitor; 2.2 nF; 20 %; 300 V; VY2; THT	VY2222M35Y5US6TV7	Vishay
C11	capacitor; 470 μF; 20 %; 50 V; ALU; THT	50ZLH470MEFC12.5X20	Rubycon
C12; C23	capacitor; not mounted; 47 pF; 5 %; 630 V; C0G; 1206	GRM31A5C2J470JW01D	Murata
C13	capacitor; 33 nF; 10 %; 50 V; X7R; 0603	-	-
C14; C21	capacitor; 220 pF; 5 %; 50 V; C0G; 0603	-	-
C15	capacitor; 1.2 nF; 5 %; 630 V; C0G; 1206	CGA5F4C0G2J122J085AA	TDK
C16	capacitor; 3.3 μF; 10 %; 25 V; X7R; 0805	CGA4J1X7R1E335K125AC	TDK
C17; C32; C37; C38	capacitor; 1 nF; 10 %; 50 V; C0G; 0603	-	-
C18	capacitor; 68 nF; 10 %; 50 V; X7R; 0603	-	-
C19	capacitor; 1 μF; 10 %; 16 V; X7R; 0603	-	-
C20; C25	capacitor; 100 pF; 10 %; 50 V; X7R; 0603	-	-
C22; C24; C46	capacitor; 100 nF; 10 %; 50 V; X7R; 0603	-	-
C26; C36	capacitor; 470 nF; 10 %; 50 V; X7R; 0603	-	-

Table 13. SSL8516BDB1317 demo board bill of materials *...continued*

Reference	Description and values	Part number	Manufacturer
C27	capacitor; not mounted; 220 pF; 5 %; 50 V; C0G; 0603	-	-
C28	capacitor; 330 nF; 10 %; 16 V; X7R; 0603	-	-
C29	capacitor; not mounted; 100 nF; 10 %; 50 V; X7R; 0603	-	-
C30; C40; C41	capacitor; 100 nF; 10 %; 100 V; X7R; 0603	GRM188R72A104KA35D	Murata
C31	capacitor; 4.7 μF; 10 %; 25 V; X7R; 0805	TMK212AB7475KG-T	Taiyo Yuden
C33	capacitor; 10 nF; 10 %; 50 V; X7R; 0603	-	-
C34; C35	capacitor; not mounted; 100 pF; 10 %; 50 V; X7R; 0603		
C42	capacitor; 47 μF; 20 %; 35 V; ALU; 5 mm × 11 mm	35ZLJ47MTA5X11	Rubycon
C43	capacitor; 1 μF; 10 %; 63 V; PET; B32529	B32529C105K189	EPCOS
C45	capacitor; 470 pF; 5 %; 250 V; C0G; 0603	C1608C0G2E471J080AA	TDK
D1; D2	diode; 600 V; 5 A	BYV25X-600,127	NXP Semiconductors
D4; D6; D17	diode; 100 V; 200 mA	BAS316,135	NXP Semiconductors
D3; D13	diode; 700 V; 1 A	1N4007GP-E3-54	Vishay
D5; D7	diode; dual; not mounted; 200 V; 125 mA	BAV23S,215	NXP Semiconductors
D8	diode; TVS; 250 V; 1 A; 400 W; SMD	SMAJ250CA	Littelfuse
D9	diode; zener; 27 V; 250 mA	NZH27C,115	NXP Semiconductors
D10	diode; 300 V; 200 mA	BAS101	NXP Semiconductors
D11	diode; zener; not mounted; 10 V; 250 mA	NZH10C,115	NXP Semiconductors
D12	diode; dual; 90 V; 215 mA	BAW56,235	NXP Semiconductors
D15	diode; zener; 12 V; 250 mA	BZX384-C12	NXP Semiconductors
D16	diode; dual; 200 V; 125 mA	BAV23S,215	NXP Semiconductors
F1	fuse; 2.5 A; slow	SS-5H-2.5A-APH	Cooper Bussmann
HS1	heat sink primary	-	-
HS2	heat sink secondary	-	-
J1	connector; 5.08 mm	1508060000	Weidmüller
L1	inductor; common-mode; 20 mH; 1.5 A	744823220	Würth Elektronik
L2	inductor; 700 μH; 2 A	750312186	Würth Elektronik
L3	inductor; common-mode; 47 μH; 2 A	744841247	Würth Elektronik
Q1	transistor MOSFET-N; 600 V; 6.8 A	FCPF7N60NT	Fairchild
Q2	transistor MOSFET-N; 800 V; 6 A	SPA06N80C3	Infineon
Q3	transistor MOSFET-N; 200 V; 39 A	PSMN057-200P,127	NXP Semiconductors
Q4; Q5	transistor; BJT; NPN; 80 V; 1 A	BCP56-16,115	NXP Semiconductors

Table 13. SSL8516BDB1317 demo board bill of materials *...continued*

Reference	Description and values	Part number	Manufacturer
Q6	transistor MOSFET-N; 240 V; 100 mA	BSS131H6327XT	Infineon
R1	varistor; 320 V; 170 pF	V320LA10P	Littelfuse
R2	resistor; NTC; 330 kΩ; 5 %; THT	NTCLE100E3334JB0	Vishay
R3	resistor; 470 kΩ; 5 %; 2 W; PR02; THT	PR02000204703JR500	Vishay
R4; R5	resistor; 1.5 MΩ; 2 %; 250 mW; 1206	HV732BTTD155G	KOA Speer
R6; R7	resistor 0.27 Ω; 1 %; 500 mW; 1206	RCWE1206R270FKEA	Vishay
R8; R40; R41; R48; R57; R61	resistor; 10 Ω; 1 %; 100 mW; 0603	-	-
R9	resistor; 130 kΩ; 1 %; 250 mW; 1206	-	-
R10; R16; R19; R23; R26; R35; R38; R78; R83	resistor; 0 Ω; 1 %; 250 mW; 1206	-	-
R11	resistor; 8.2 kΩ; 1 %; 250 mW; 1206	-	-
R12; R17; R20	resistor; 3.9 MΩ; 1 %; 250 mW; 1206	-	-
R13	resistor; 22 kΩ; 1 %; 100 mW; 0603	-	-
R14	resistor; 300 kΩ; 1 %; 250 mW; 1206	-	-
R15; R18; R21	resistor; 3.3 MΩ; 1 %; 250 mW; 1206	-	-
R22; R50	resistor; 39 kΩ; 1 %; 100 mW; 0603	-	-
R24	resistor; 15 kΩ; 1 %; 100 mW; 0603	-	-
R25; R60; R72	resistor; 51 kΩ; 1 %; 100 mW; 0603	-	-
R28; R30	resistor; 56 kΩ; 1 %; 100 mW; 0603	-	-
R29	resistor; 5.6 kΩ; 1 %; 63 mW; 0603	-	-
R31; R32	resistor; 0.75 Ω; 1 %; 250 mW; 1206	-	-
R33; R36; R64; R66	resistor; 1 kΩ; 1 %; 100 mW; 0603	-	-
R34	resistor; 2.2 kΩ; 1 %; 100 mW; 0603	-	-
R37	resistor; 2.2 Ω; 1 %; 63 mW; 0603	-	-
R39; R45	resistor; not mounted; 1 Ω; 1 %; 63 mW; 0603	-	-
R42	resistor; 5.1 kΩ; 1 %; 250 mW; 1206	-	-
R43	resistor; 10 kΩ; 1 %; 100 mW; 0603	-	-
R44	resistor; 5.6 kΩ; 1 %; 250 mW; 1206	-	-
R46	resistor; 180 kΩ; 1 %; 63 mW; 0603	-	-
R47	resistor; 10 kΩ; 1 %; 250 mW; 1206	-	-
R49	resistor; not mounted; 220 Ω; 1 %; 63 mW; 0603	-	-
R51	resistor; 1.8 kΩ; 1 %; 250 mW; 1206	-	-
R52; R53	resistor; not mounted; 1.5 kΩ; 1 %; 250 mW; 1206	-	-
R54	resistor; not mounted; 10 kΩ; 1 %; 100 mW; 0603	-	-
R55; R58	resistor; 22 Ω; 1 %; 100 mW; 0603	-	-

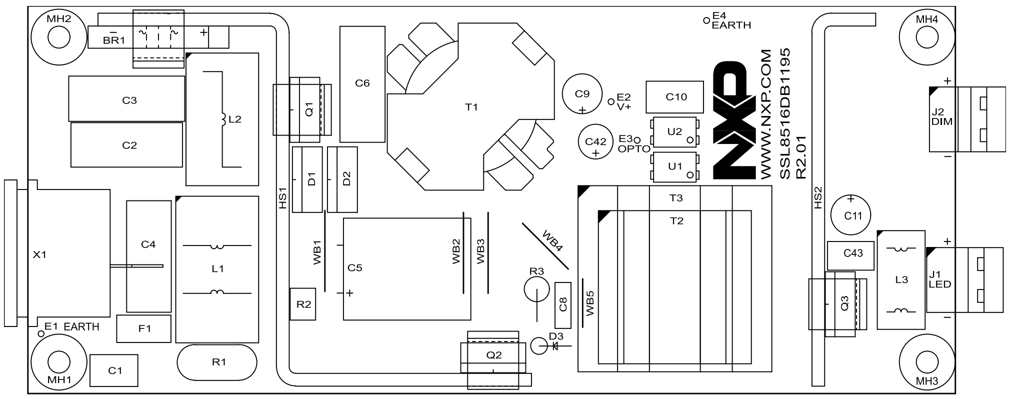
Table 13. SSL8516BDB1317 demo board bill of materials *...continued*

Reference	Description and values	Part number	Manufacturer
R56	resistor; not mounted; 1 kΩ; 1 %; 100 mW; 0603	-	-
R59	resistor; 60.4 kΩ; 1 %; 100 mW; 0603	-	-
R62	resistor; 4.7 Ω; 1 %; 63 mW; 0603	-	-
R63	resistor; 47 kΩ; 1 %; 250 mW; 1206	-	-
R65	resistor; 5.1 kΩ; 1 %; 100 mW; 0603	-	-
R67	resistor; 0 Ω; 1 %; 63 mW; 0603	-	-
R68	resistor; 100 kΩ; 1 %; 100 mW; 0603	-	-
R69	resistor; 50 mΩ; 1 %; 1 W; 2512	RL2512FK-070R05L	Yageo
R70	resistor; 6.2 kΩ; 1 %; 63 mW; 0603	-	-
R71	resistor; 59 kΩ; 1 %; 100 mW; 0603	-	-
R73; R74	resistor; 10 kΩ; 1 %; 100 mW; 0603	-	-
R75	resistor; 560 kΩ; 1 %; 63 mW; 0603	-	-
R76	resistor; 1 MΩ; 1 %; 63 mW; 0603	-	-
R82	resistor; 1.1 Ω; 1 %; 250 mW; 1206	-	-
T1	transformer; PFC; 500 μH; 3.5 A; RM10	750313715R01	Würth Elektronik
T3	transformer; flyback; 1.2 mH; N = 4; PQ2620	750314464R2	Würth Elektronik
U1	optocoupler; NPN; 70 V; 50 mA	SFH615A-4	Vishay
U2	optocoupler; NPN; not mounted; 70 V; 50 mA	SFH615A-4	Vishay
U3	PFC and flyback controller	SSL8516BT	NXP Semiconductors
U4	operational amplifier; single; not mounted	TS321AILT	ST
U5	synchronous rectifier	TEA1892ATS	NXP Semiconductors
U6	operational amplifier; dual	LM2904AVQDRQ1	Texas Instruments
U7	voltage regulator; 1.24 V; 1 %; 80 mA	TLVH431AQDBZR	Texas Instruments
X1	connector; mains	771W-BX2-01	Qualtek

10. PCB layout

The PCB of the SSL8516DB1195 demo board is reused for the SSL8516BDB1317 demo board. The PCB board information:

- Single layer
- Component numbering is starting at the mains connector
- Secondary heat sink HS2 is not required but mounted for experiments



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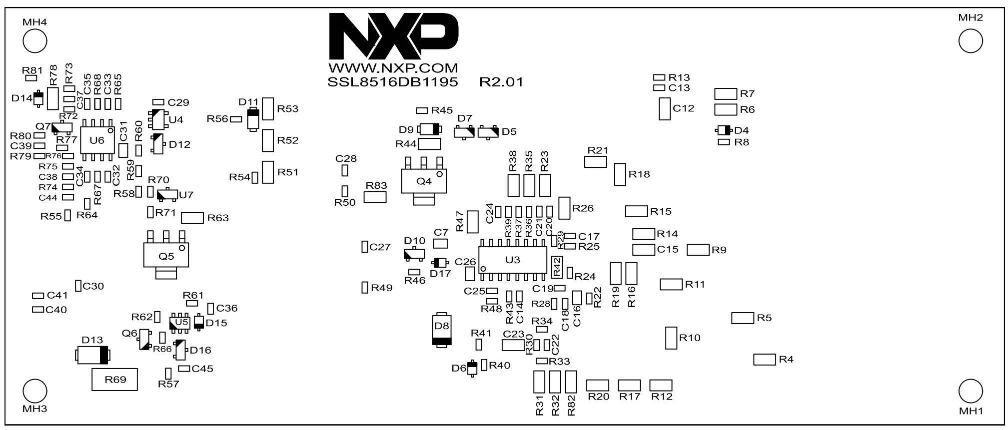
a. Top side



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b. Bottom side

Fig 26. SSL8516BDB1317 demo board component placement

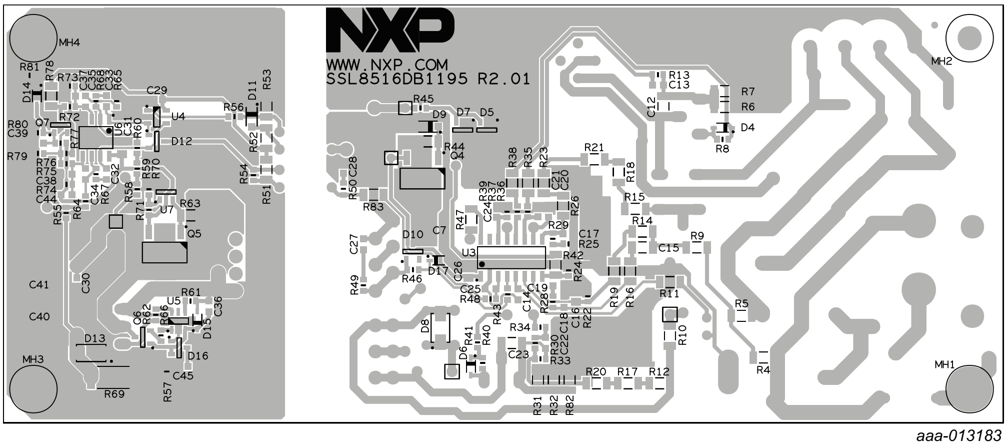
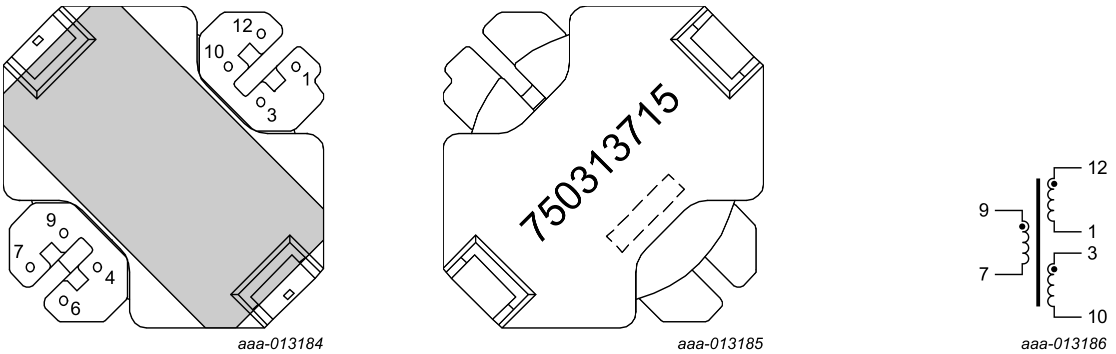


Fig 27. SSL8516BDB1317 demo board: bottom side copper and silk screen

11. Transformer information

11.1 PFC transformer

Wurth Electronics Midcom Inc.; part number 750313715



a. Bottom view   b. Top view   c. Winding pinout

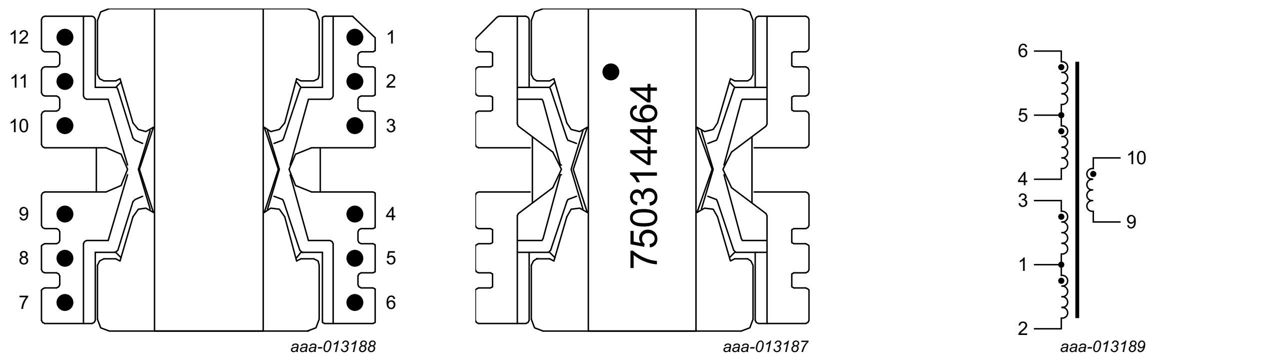
Fig 28. PFC transformer

Table 14. PFC transformer electrical specifications

Symbol	Parameter	Value	Condition
L_p	inductance	500 μH	pins 7 to 9
I_{sat}	saturation current	3.5 A	
N	turns ratio	17.33	(9-7):(12-1)
		13.00	(9-7):(3-10)
L_{lk}	leakage inductance	40 μH	tie 1 + 3 + 10 + 12
V_{ε}	dielectric rating	1000 V (AC)	pins 1 to 7
		1000 V (AC)	pins 3 to 7
		2000 V (AC)	pin 7 to core
R_{dc}	DC resistance	260 mΩ	pins 7 to 9
		100 mΩ	pins 3 to 10
		200 mΩ	pins 1 to 12

11.2 Flyback transformer

Wurth Electronics Midcom Inc.; part number 750314464



a. Bottom view b. Top view c. Winding pinout

Fig 29. Flyback transformer

Table 15. PFC transformer electrical specifications

Symbol	Parameter	Value	Condition
L_p	inductance	1.23 mH	pins 6 to 4
I_{sat}	saturation current	1.9 A	
N	turns ratio	1	(6-5):(5-4)
		4	(6-4):(3-1)
		4	(6-4):(10-9)
		18.66	(6-4):(1-2)
L_{lk}	leakage inductance	5 μH	tie 1 + 2 + 3, 9 + 10
V_{ε}	dielectric rating	4000 V (AC)	pins 2 to 10 (tie 3 + 4)
		2000 V (AC)	pins 1 to core (tie 3 + 4 + 9)
		625 V (AC)	pins 3 to 4
R_{dc}	DC resistance	525 mΩ	pins 6 to 4
		143 mΩ	pins 3 to 1
		69 mΩ	pins 10 to 9
		75 mΩ	pins 1 to 2

The bobbin is not conforming safety standards. To meet the required safety standards, use flying leads or an extended bobbin.

11.3 Winding turns and wire information

Core material: PQ2620 3C96

Table 16. Winding turns and wire information

	Turns	Wire
N0,0	26	3 × 0.16 mm
N0,1	26	3 × 0.16 mm
N1	13	3 × 0.16 mm
N2	13	2 × TIW 0.35 mm
N3	3	1 × 0.16 mm

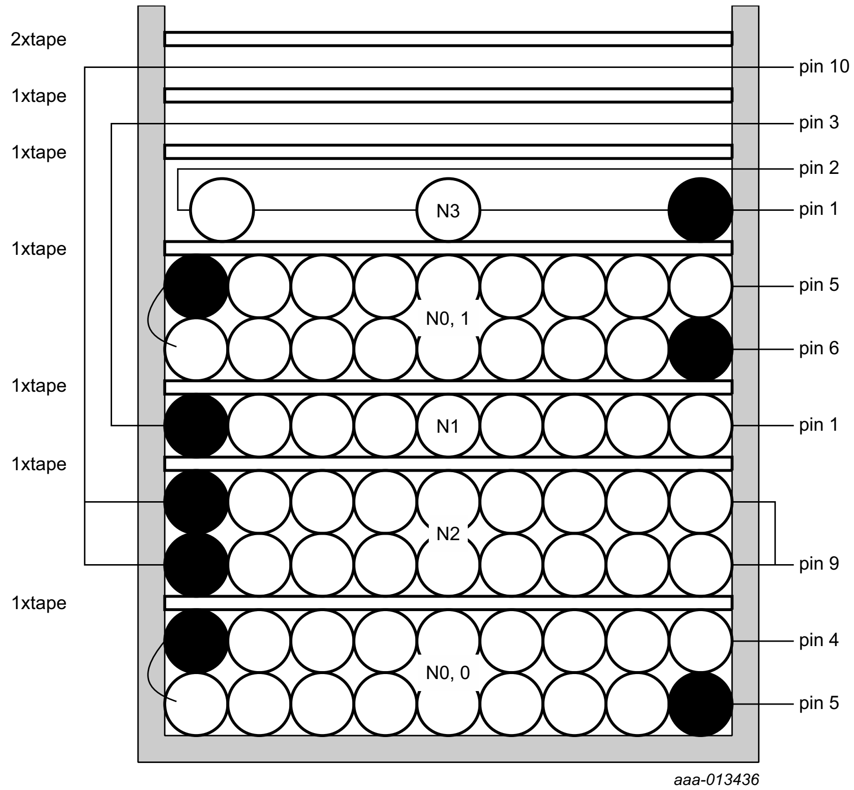


Fig 30. Flyback transformer winding build

12. Appendix: Mains current harmonics (MHR) improvement

The MHR can be improved over the full load range at the expense of the THD at full load. With the modifications shown in Figure 31, the THD at 230 V (AC) is < 15 % instead of < 10 %. The following modifications are required:

- PFCDRIVER injection 100 kΩ and 4.7 nF
- Speeding up R_{mains} capacitors: 2 × 150 pF

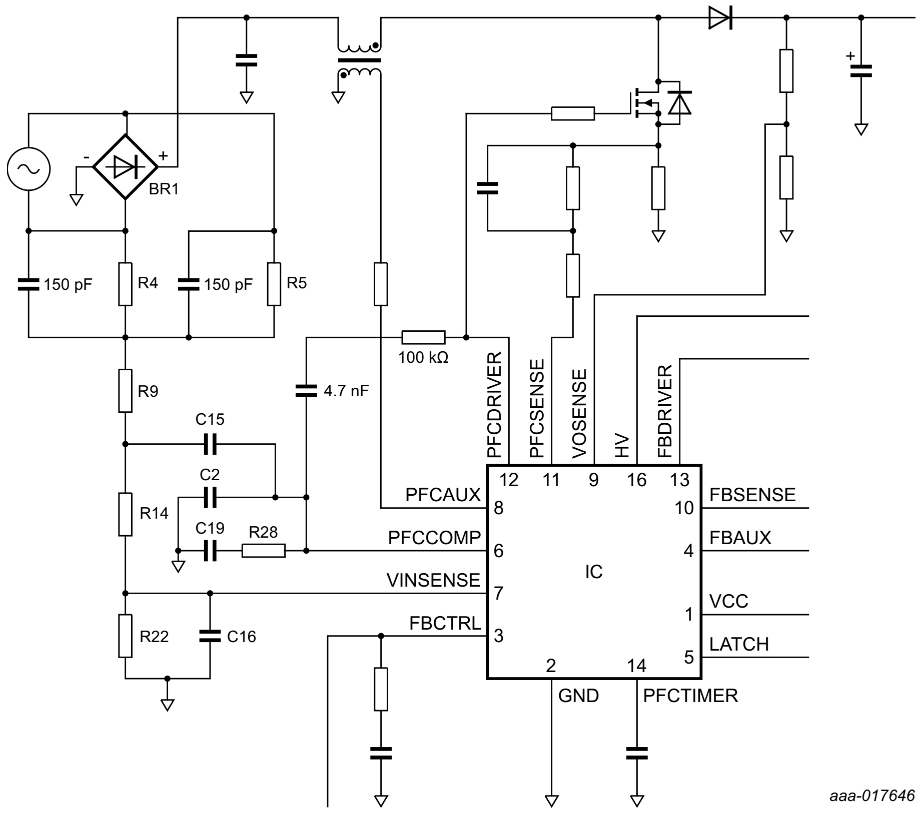
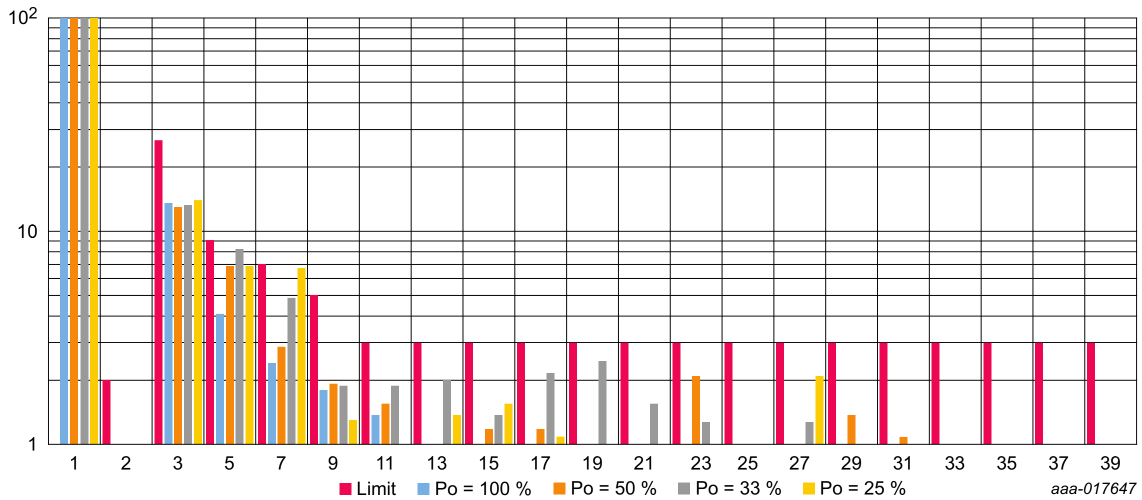


Fig 31. Simplified circuit diagram with MHR improvement modifications

Table 17. Mains current harmonics

R_{load}	PF	1	2	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
32	0.97841	100	0	13.7	4.1	2.4	1.8	1.4	0.9	0.1	0.5	0.7	0.5	0.1	0.5	0.7	0.6	0.5	0.1	0.2	0.4	0.4
64	0.95479	100	0.2	13.3	6.9	2.9	1.9	1.6	0.7	1.2	1.2	0.9	1	2.1	0.5	1	1.4	1.1	0.2	0.7	0.6	0.4
96	0.92344	100	0.4	13.5	8.3	4.9	1.9	1.9	2	1.4	2.2	2.5	1.6	1.3	0.4	1.3	0.8	0.9	0.4	0.4	1	0.7
128	0.88626	100	0.7	14.2	6.8	6.7	1.3	0.9	1.4	1.6	1.1	0.8	1	0.4	0.6	2.1	0.2	0.4	0.6	0.2	0.9	0.6
limit		0	2	26.6	9	7	5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3



(1) Red: IEC limit

(2) Green: P_o = 100 %

(3) Purple: P_o = 50 %

(4) Blue: P_o = 33 %

(5) Orange: P_o = 25 %

Fig 32. Mains current harmonics in % of fundamental; with MHR improvement

Table 18. Total harmonic distortion; with MHR improvement

V_{mains}	Mode	P_o = 100 %	P_o = 50 %	P_o = 33 %	P_o = 25 %
100 V (AC)/60 Hz	CV	10.599	11.738	11.709	7.729
120 V (AC)/60 Hz	CV	11.326	12.132	12.017	10.976
230 V (AC)/50 Hz	CV	14.686	16.033	17.634	17.998
277 V (AC)/60 Hz	CV	11.675	15.063	19.13	21.646

13. Abbreviations

Table 19. Abbreviations

Acronym	Description
AC	Alternating Current
BCM	Boundary Conduction Mode
CC	Constant Current
CV	Constant Voltage
DC	Direct Current
DCM	Discontinuous Conduction Mode
EMI	ElectroMagnetic Interference
FR	Frequency Reduction
HV	High-Voltage
IC	Integrated Circuit
IEC	International Technical Commission
LED	Light-Emitting Diode
OCP	OverCurrent Protection
OPP	OverPower Protection
OVP	OverVoltage Protection
PCB	Printed-Circuit Board
PFC	Power Factor Control
PP	PolyPropylene
QR	Quasi-Resonant
SR	Synchronous Rectification
THD	Total Harmonic Distortion
THT	Through Hole Technology

14. References

[1] **SSL8516BT data sheet —** GreenChip PFC and flyback controller

[2] **SSL8516T data sheet —** GreenChip PFC and flyback controller

[3] **AN11486 application note —** GreenChip SSL8516T PFC and flyback controller

15. Legal information

15.1 Definitions

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