

# 42 W PFC-PSR-flyback reference design with ICL8810

## Flyback IC for lighting applications

Board sales name: REF\_ICL8810\_LED\_42W\_PSR

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## About this document

### Scope and purpose

Constant voltage primary-side regulated (PSR) topology is becoming more popular because of the lower cost compared with secondary-side regulated (SSR) topology. Components such as an optocoupler, a voltage reference and an error amplifier are no longer needed. It has excellent accuracy of  $\pm 3.5$  percent in the range of 100 to 10 percent of the output power. Constant voltage PSR topology is the best solution for on/off LED drivers or LED drivers with minimum dimming levels down to 5 percent.

### Intended audience

This document is intended for engineers and students designing a constant voltage high power factor correction PSR-flyback based on the ICL88xx family.

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## 1 System description

PSR topology is the best fit for on/off LED drivers and drivers with a minimum dimming of 5 percent. The main difference between SSR and PSR topology is based on the fact that for the PSR topology, the main channel output voltage is measured indirectly on the primary-side  $V_{cc}$  supply. So, good coupling between the main output and the  $V_{cc}$  primary-side windings improves regulation accuracy.

Low-pass filter R9 and C5 (**Figure 2**) must filter the rectified auxiliary winding signal on the primary side. If the crossover frequency is too low, e.g., 3 to 5 Hz, the feedback reaction would be very slow, making it not suitable for dynamic load. On the other hand, lower crossover frequency improves total harmonic distortion (THD) – it is a compromise between feedback reaction and iTHD.

Next, the signal must be inverted by the common emitter stage based on Q40. It converts voltage changes on the  $V_{cc}$  primary-side winding to the current sunk from the VS pin. R43 sinks a minimum current from the VS pin, which must be higher than 210  $\mu$ A to set the VS pin level at 1.6 V. R42 limits the maximum VS pin current and reduces the gain. The output voltage is set by the Zener D40 voltage and turns ratio between the main output and  $V_{cc}$  primary-side windings.

The combination of R22 and R1 sets output overvoltage protection (OVP). The protection has a 7 percent tolerance over the production and temperature range; this fact must be considered. If the overvoltage level is too close to the normal operation voltage, it may lead to a continuous overvoltage triggering. In this case, the feedback loop is slower than cycle by cycle overvoltage protection, and it can no longer control the output voltage within the very tight limit in the specific dynamic conditions like restart and fast load changes. The converter moves to hiccup mode. The OVP level must have a proper margin or special measures should be used to overcome the overvoltage triggering:

- Use dynamic feedback or a dynamic bleeder, which is active only when the voltage reaches a certain point. This adds complexity and increases cost.
- Accept hiccups, and restart at the light load of 5 to 10 percent. It makes sense to use this option in switch-on/off LED drivers with constant load or a minimum dimming of 5 to 10 percent.

As a default, the reference design board is assembled by a start-up circuit based on resistors R19, R29 and R30. After the first start, it is supplied from the auxiliary winding. If low standby consumption is mandatory, as an option, an additional daughter start-up board must be used when R35 is deleted.

**ICL8810** has a burst mode feature. This helps control the output voltage quite accurately down to a very low output power level, as shown in **Figure 9**. After this level, the IC moves gradually to burst mode, as shown in **Figure 11**, and finally to the OVP shown in **Figure 10**.

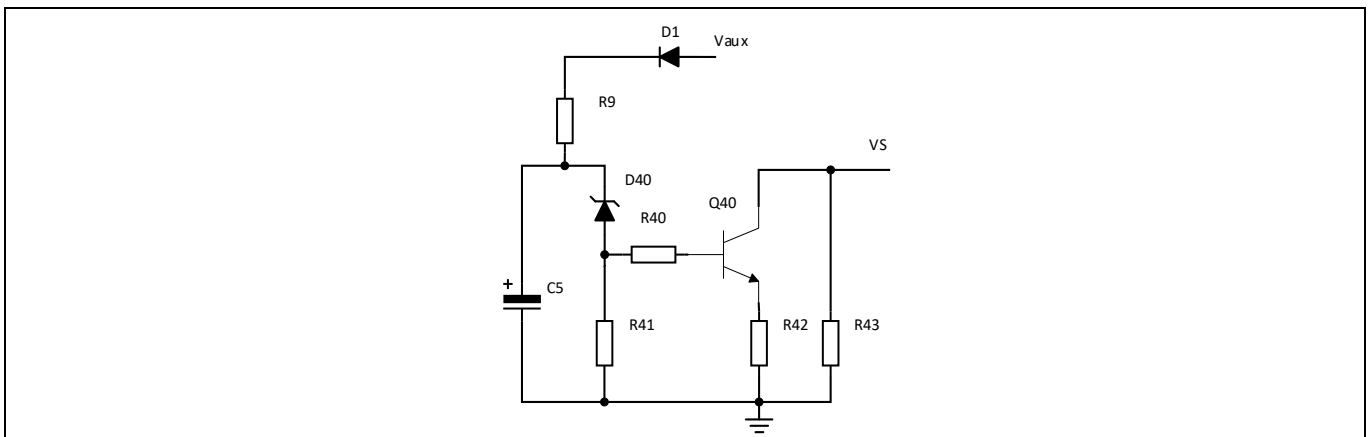
**Figure 12** shows the IC reaction to the immediate output power jump from 100 percent to 0 percent with quick and precise OVP.

## Design hints

## 2 Design hints

- Main output and the  $V_{cc}$  primary-side windings coupling affect accuracy. Place them close to each other to improve the coupling and achieve better regulation accuracy.
- Zener voltage tolerance and differential resistance also affect regulation accuracy. Choose one with a low tolerance  $< \pm 2$  percent and low dynamic resistance, e.g., 100 to 150 Ohm at 1 mA. Zener diodes with higher power dissipation capability, e.g., 500 mW or higher normally have lower dynamic resistance.
- Choose the output overvoltage protection level, including tolerance and output voltage deviation, so that it never triggers at a low power level. This level should be 10 percent higher than the voltage at the lowest power level; otherwise, it may trigger and cause flashes at the low dimming level.
- The external daughter start-up board is used as default, plug it in. In case low standby power is not demanded, solder R35 and unplug the daughter board.
- R18 decouples the feedback loop and the IC supply path to avoid noise coupling. Should be at least a few Ohm.

The additional circuit which transforms ICL8810 into PSR mode is shown in **Figure 1**. The output voltage is defined as  $V_{OUTmax} = \frac{N_{SEC}}{N_{P_{AUX}}} * (V_Z + I_{Zmin} * R_{41})$ ;  $V_Z$  is a Zener voltage,  $I_{Zmin}$  is a minimum Zener current.



**Figure 1** PFC-PSR-flyback circuit to transform ICL8810 into PSR mode

### 3 Schematics and performance

**Table 1 Board specifications**

Specification	Symbol	Value	Unit
Input AC voltage range	$V_{AC}$	100 to 264	$V_{rms}$
Nominal operational AC input frequency	$F_{line}$	47 ~ 63	Hz
CV output setpoint	$V_{out,setpoint}$	54	V
Output load current range	$I_{out}$	0 ~ 750	mA
Maximum output power	$P_{out,max}$	42	W
Maximum efficiency at $P_{out,max}$	$\eta_{min,at,P,out,max}$	91	%
Target minimum switching frequency at $P_{out,full}$	$f_{sw,min,at,P,out,max}$	52	kHz
<b>Standard compliance</b>			
Harmonics	–	EN 61000-3-2 class-C	–
EMI	–	EN55015	–
<b>Board dimensions</b>			
Size	L x B x H	Main board: 181 x 27 x 24	mm
Size	L x B	Plug-in: 22.6 x 11.5	mm

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## Flyback IC for lighting applications

### Schematics and performance

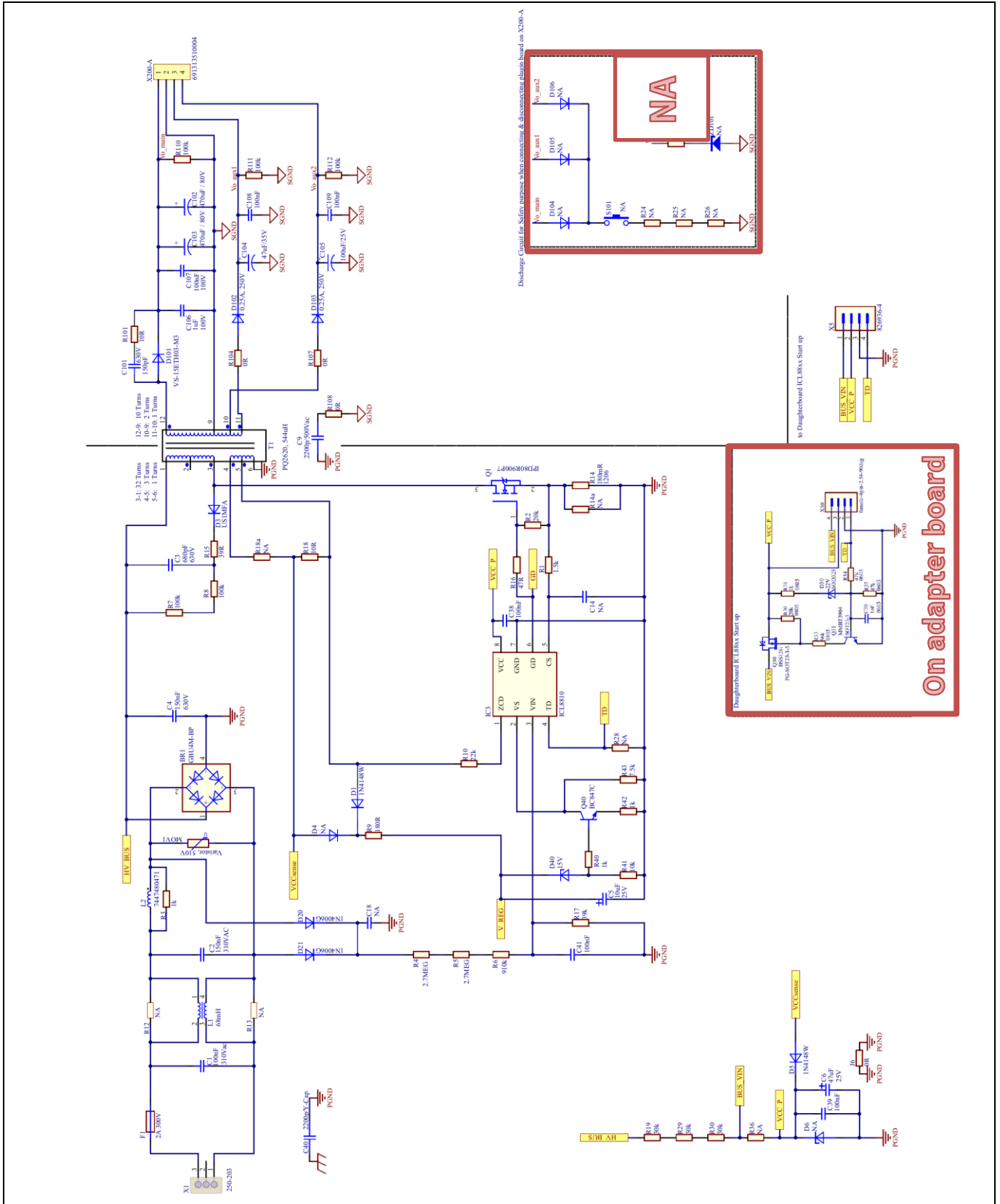
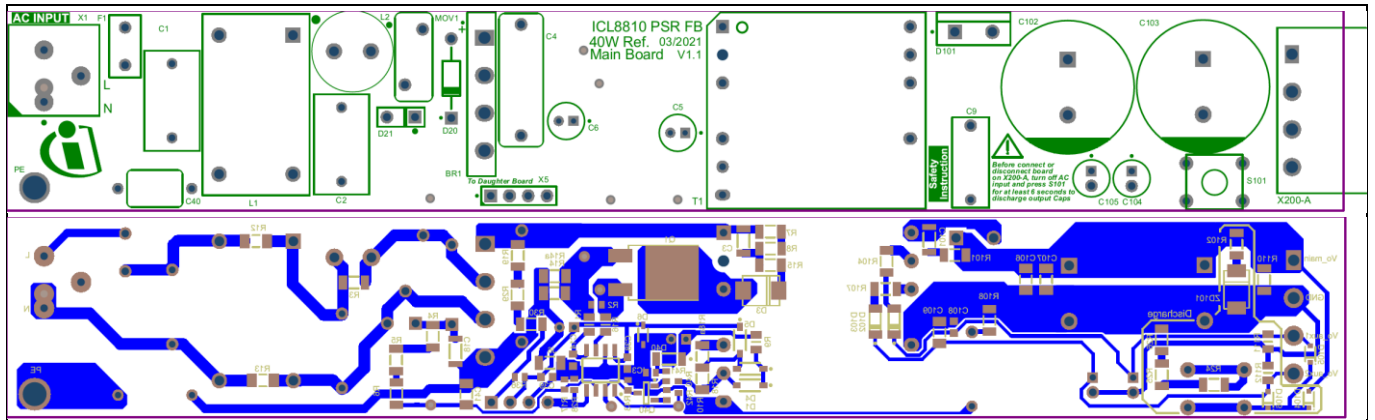


Figure 2 Schematics of the ICL8810 PFC-PSR-flyback reference design

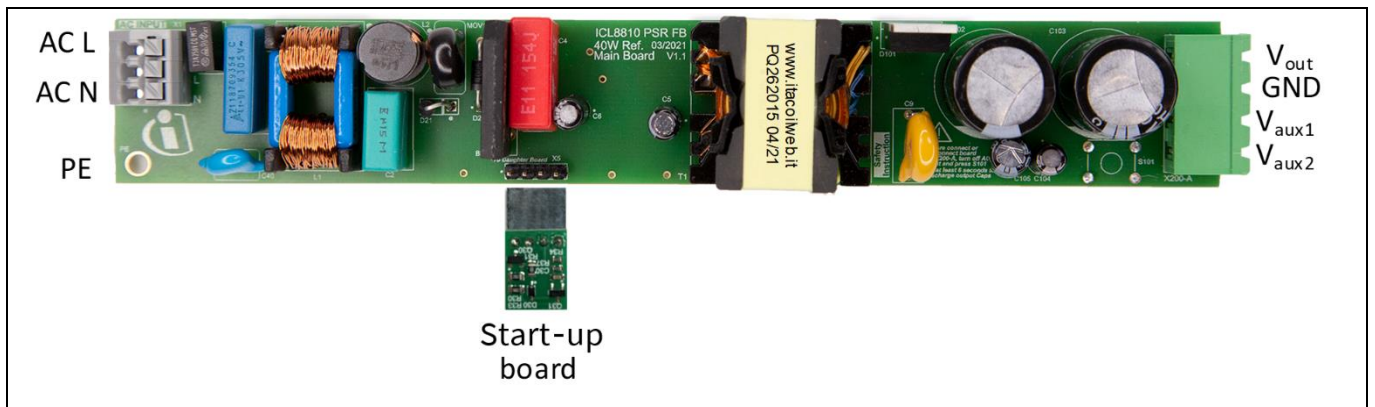
# 42 W PFC-PSR-flyback reference design with ICL8810

## Flyback IC for lighting applications

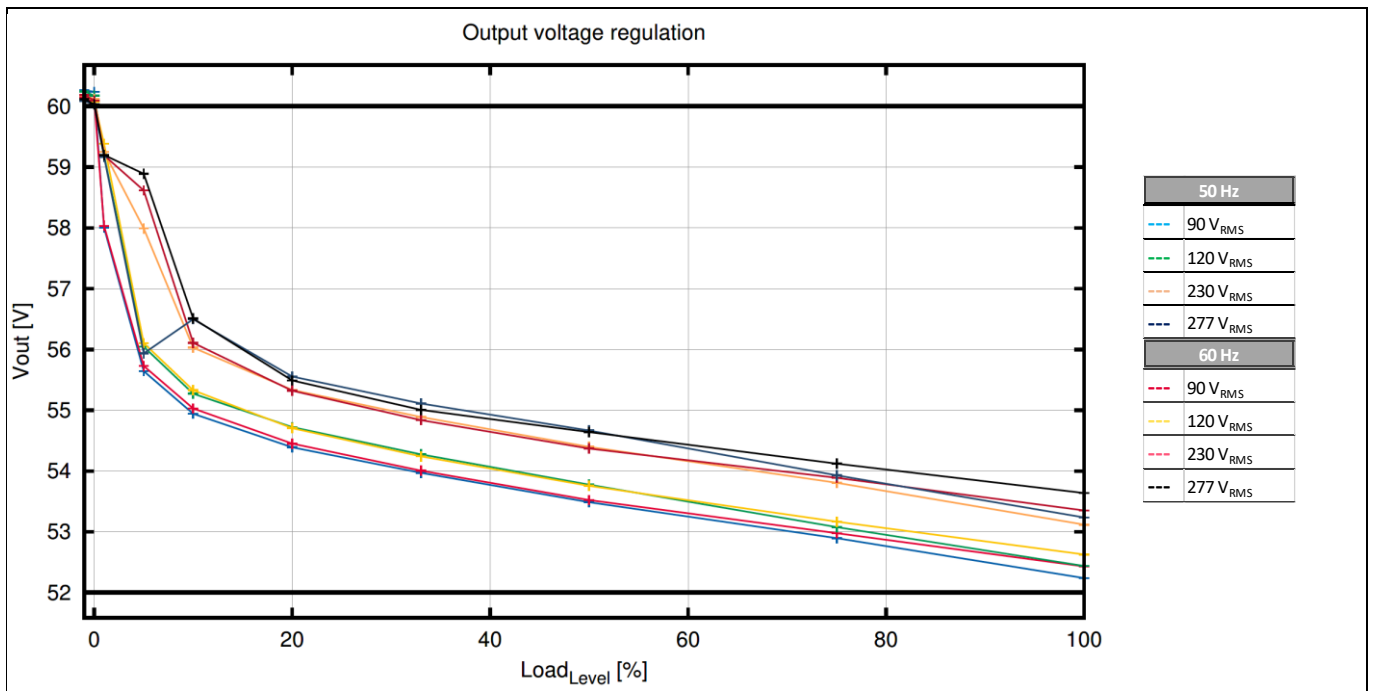
### Schematics and performance



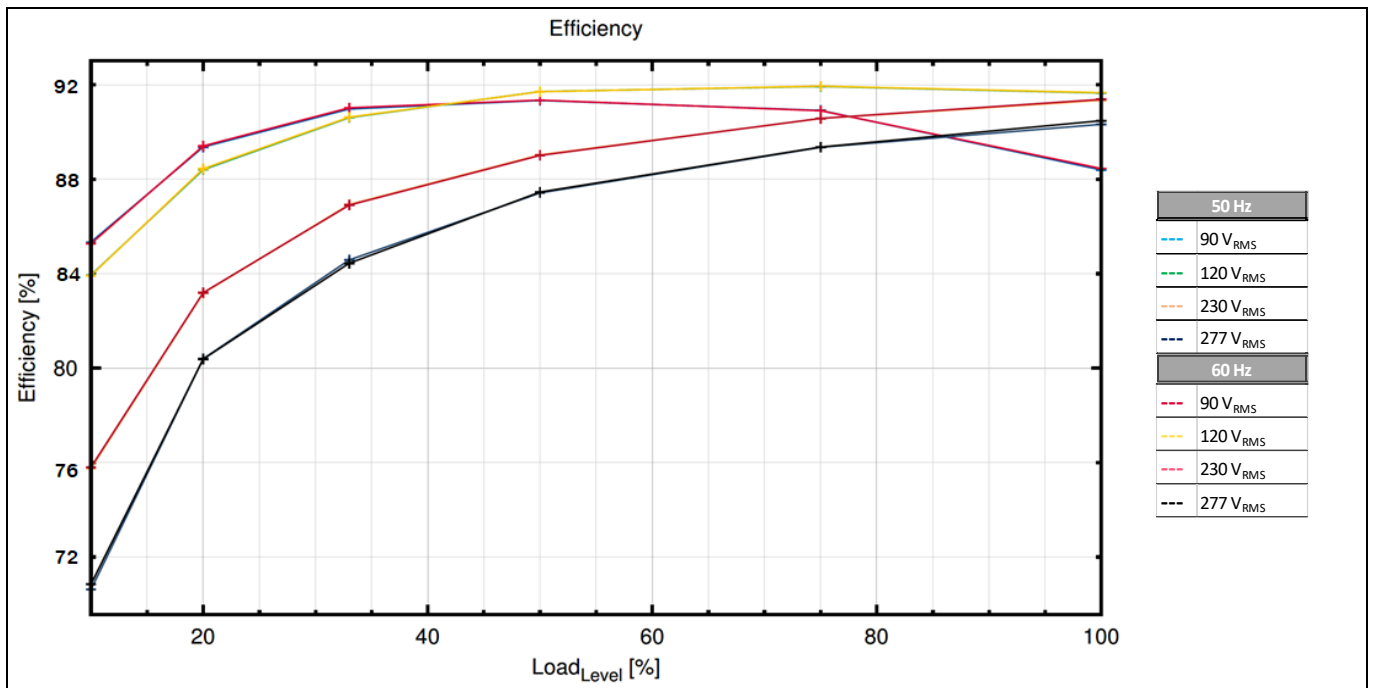
**Figure 3** Layout of the ICL8810 PFC-PSR-flyback reference design



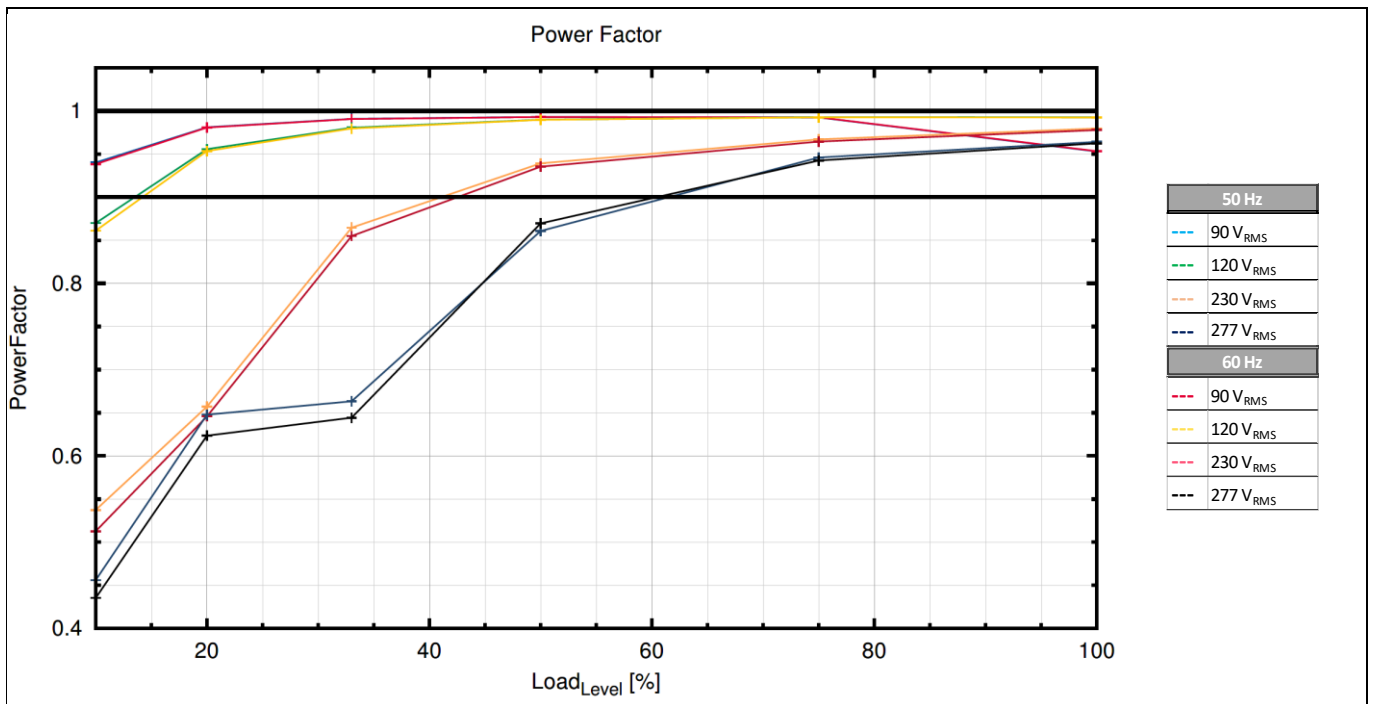
**Figure 4** ICL8810 PFC-PSR-flyback reference design connections



**Figure 5** ICL8810 PFC-PSR-flyback reference design output voltage regulation



**Figure 6** ICL8810 PFC-PSR-flyback reference design efficiency



**Figure 7** ICL8810 PFC-PSR-flyback reference design power factor

The board shows an excellent performance, such as the power factor shown in [Figure 7](#) and iTHD shown in [Figure 8](#). ITHD is below 10 percent down to 50 percent of the load level; PF is higher than 0.9 down to 60 percent of the load. [Figure 9](#) shows a minimal output power level when the power stage is not in burst mode, which means good regulation and minimum voltage ripple.

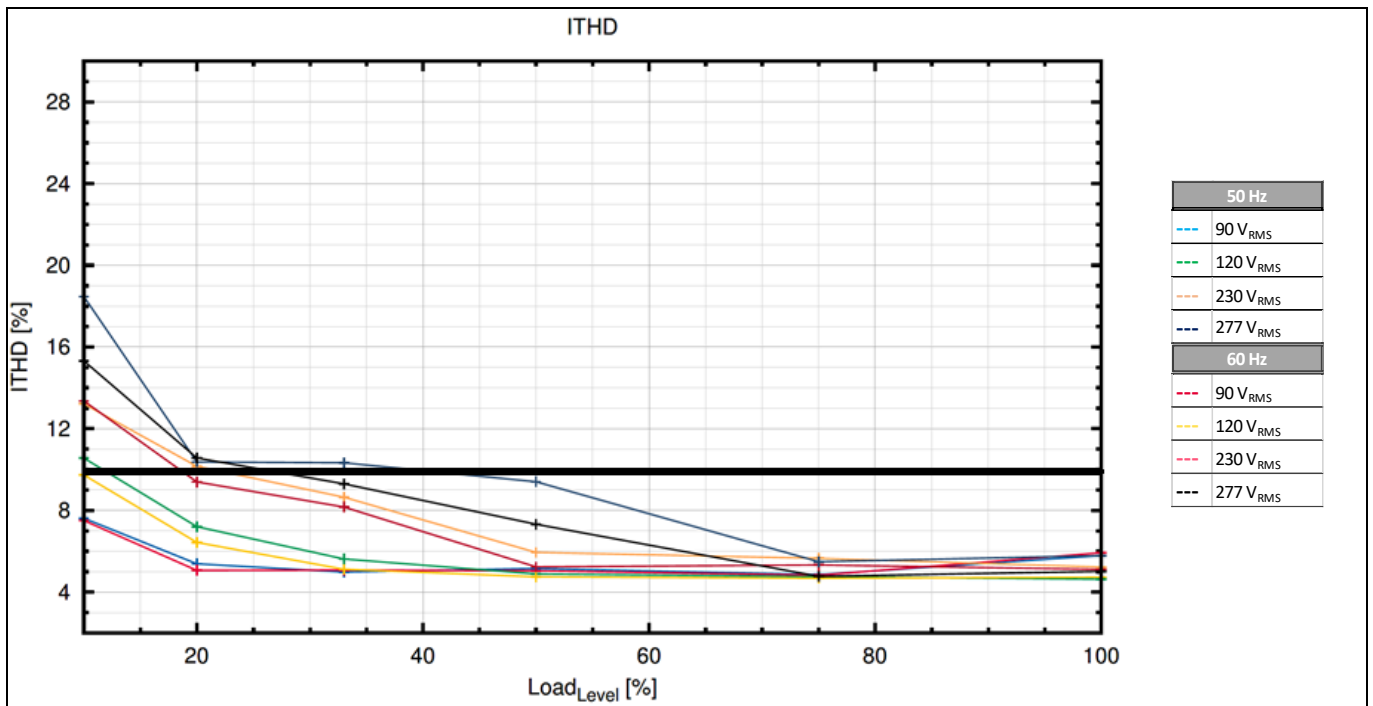


Figure 8 ICL8810 PFC-PSR-flyback reference design iTHD

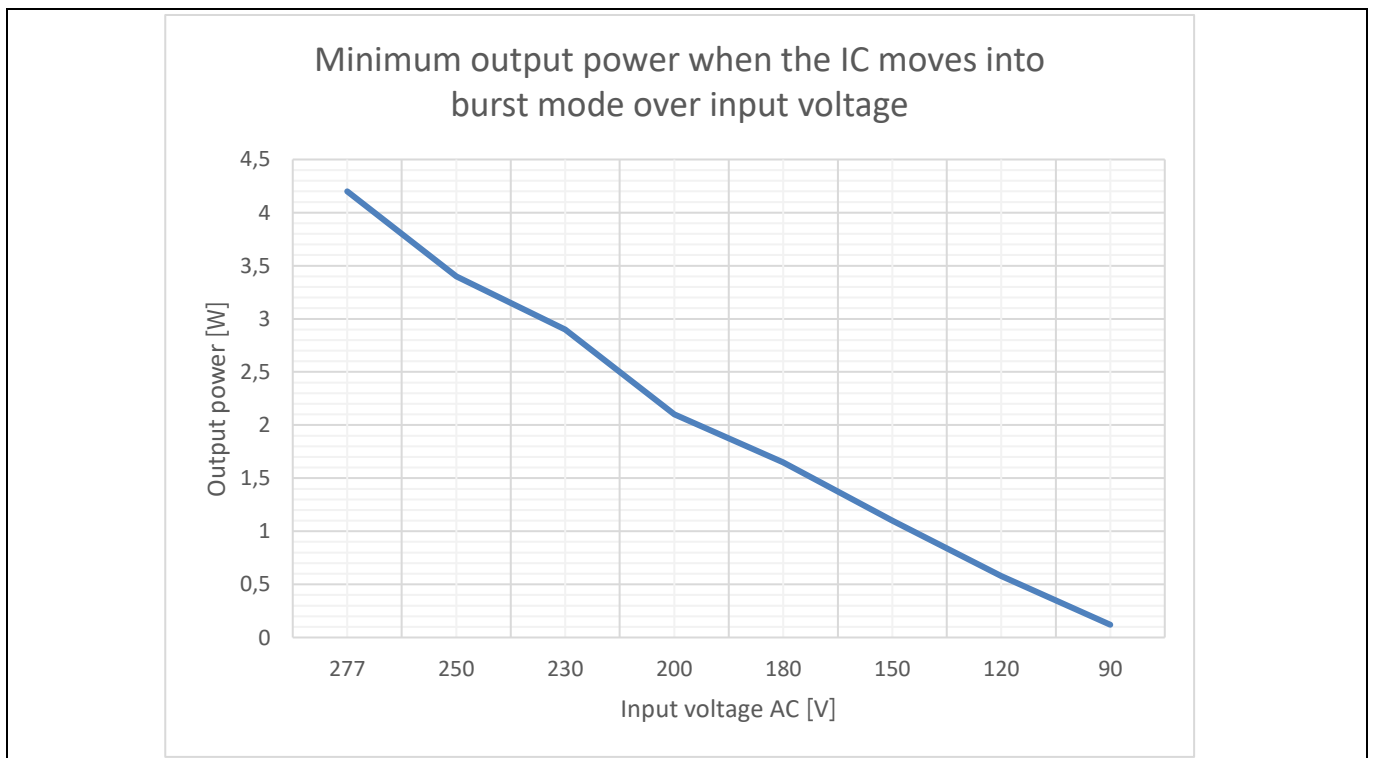
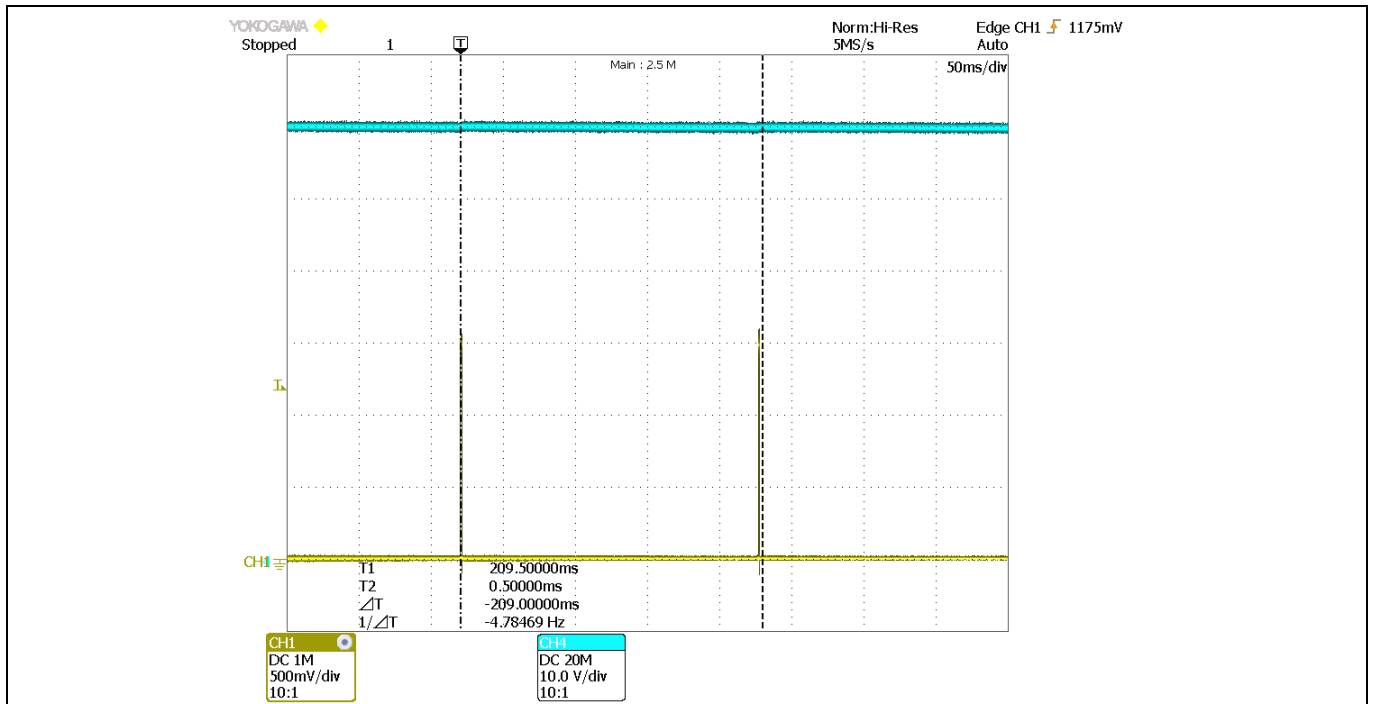
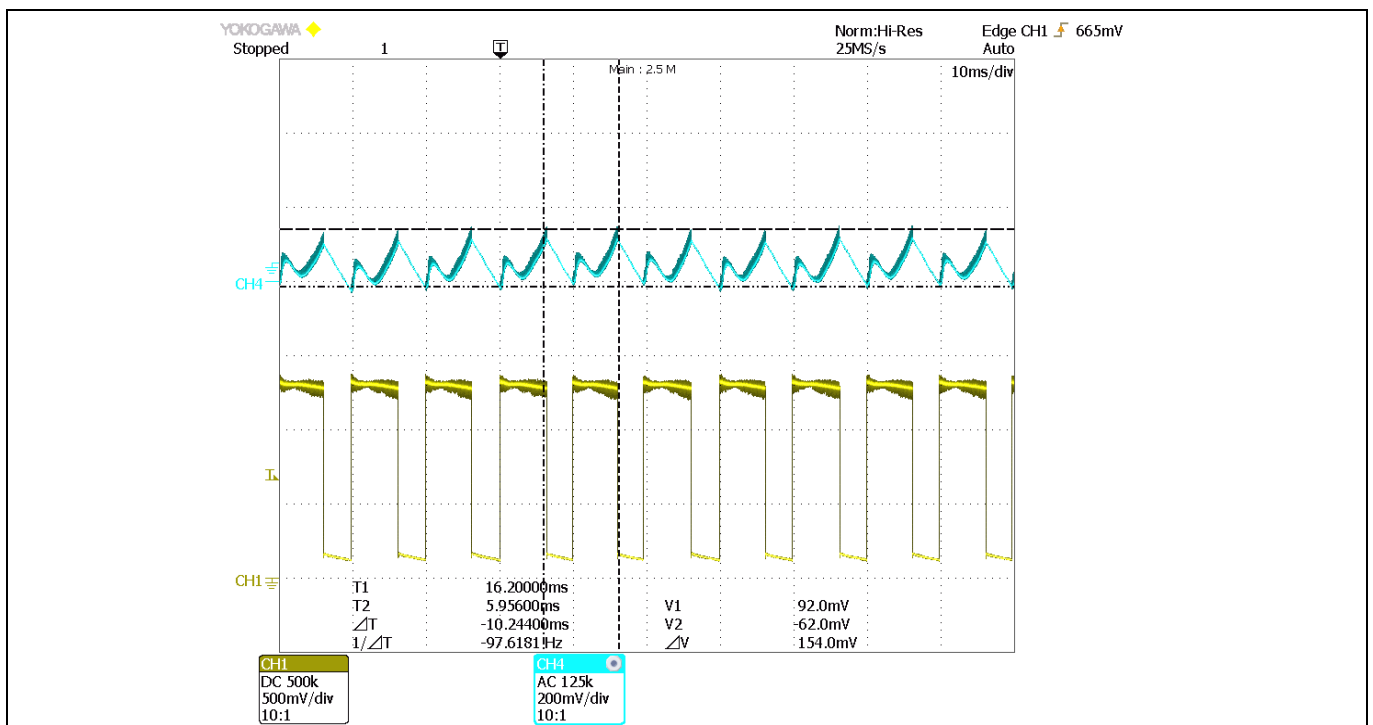


Figure 9 ICL8810 minimum output power when the IC moves into burst mode over input voltage



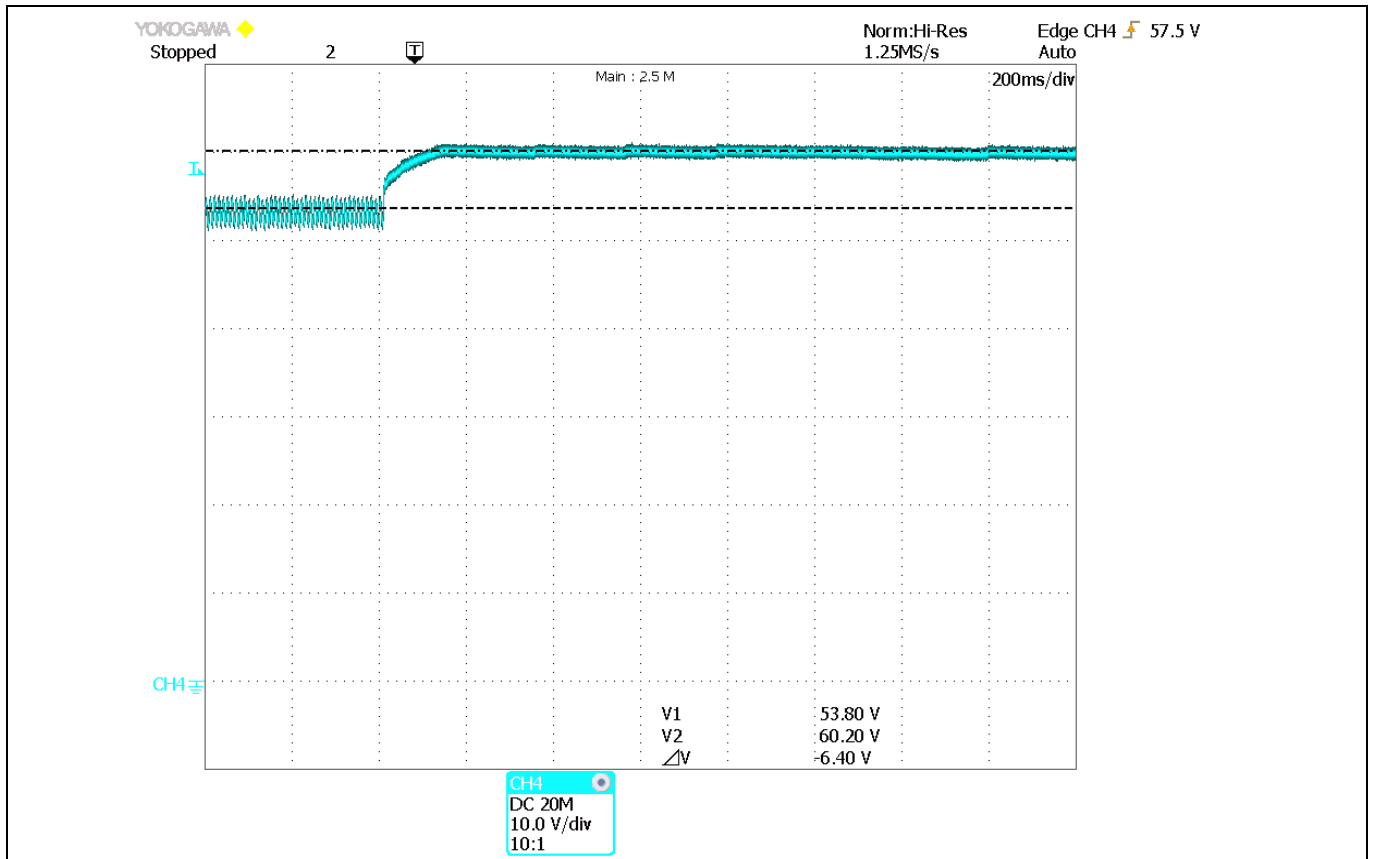


**Figure 10** ICL8810 PFC-PSR-flyback reference design in OVP mode. Blue is the output voltage, and yellow is the VS pin

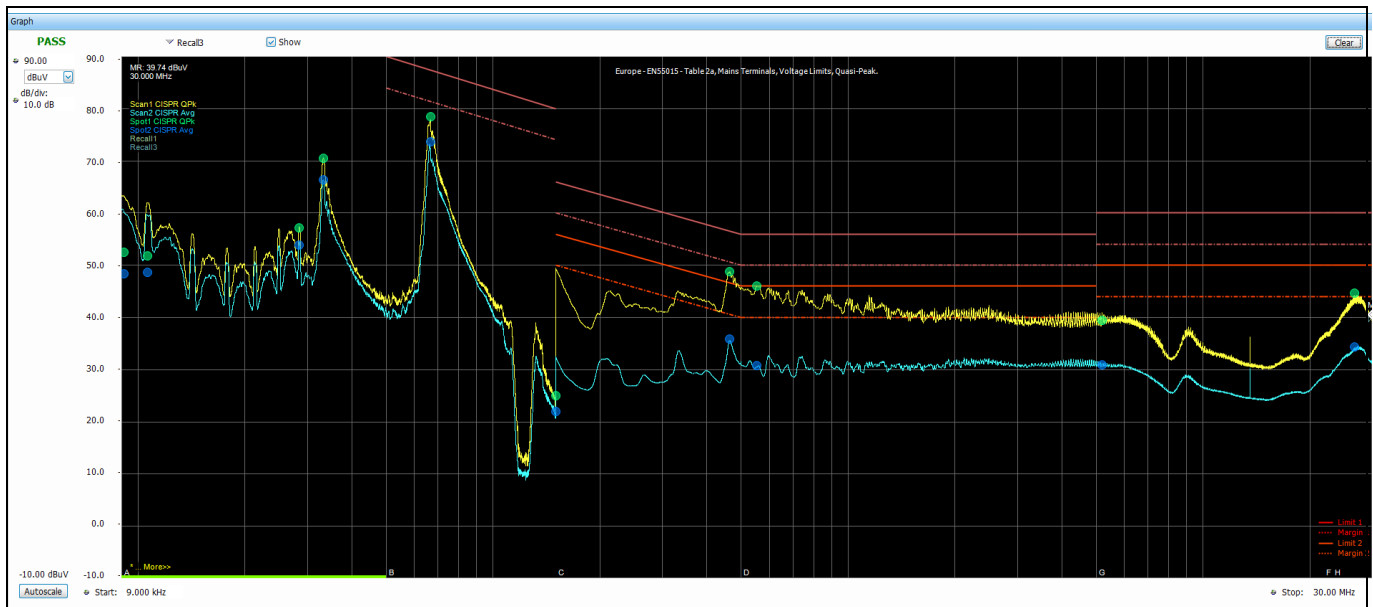


**Figure 11** ICL8810 PFC-PSR-flyback reference design in burst mode. Blue is the output voltage in AC coupling mode, and yellow is the VS pin

**Figure 10** shows overvoltage protection, when 200 ms short pulses appear on VS pin. **Figure 12** shows the dynamic transition from full to zero, when the power stage moves into the overvoltage protection.



**Figure 12** ICL8810 PFC-PSR-flyback reference design IC reaction to immediate output power jump from 100 percent to 0 percent with OVP



**Figure 13** ICL8810 PFC-PSR-flyback reference design EMC pre-compliance report. Input voltage 120 V<sub>AC</sub>, 60 Hz, output power 42 W

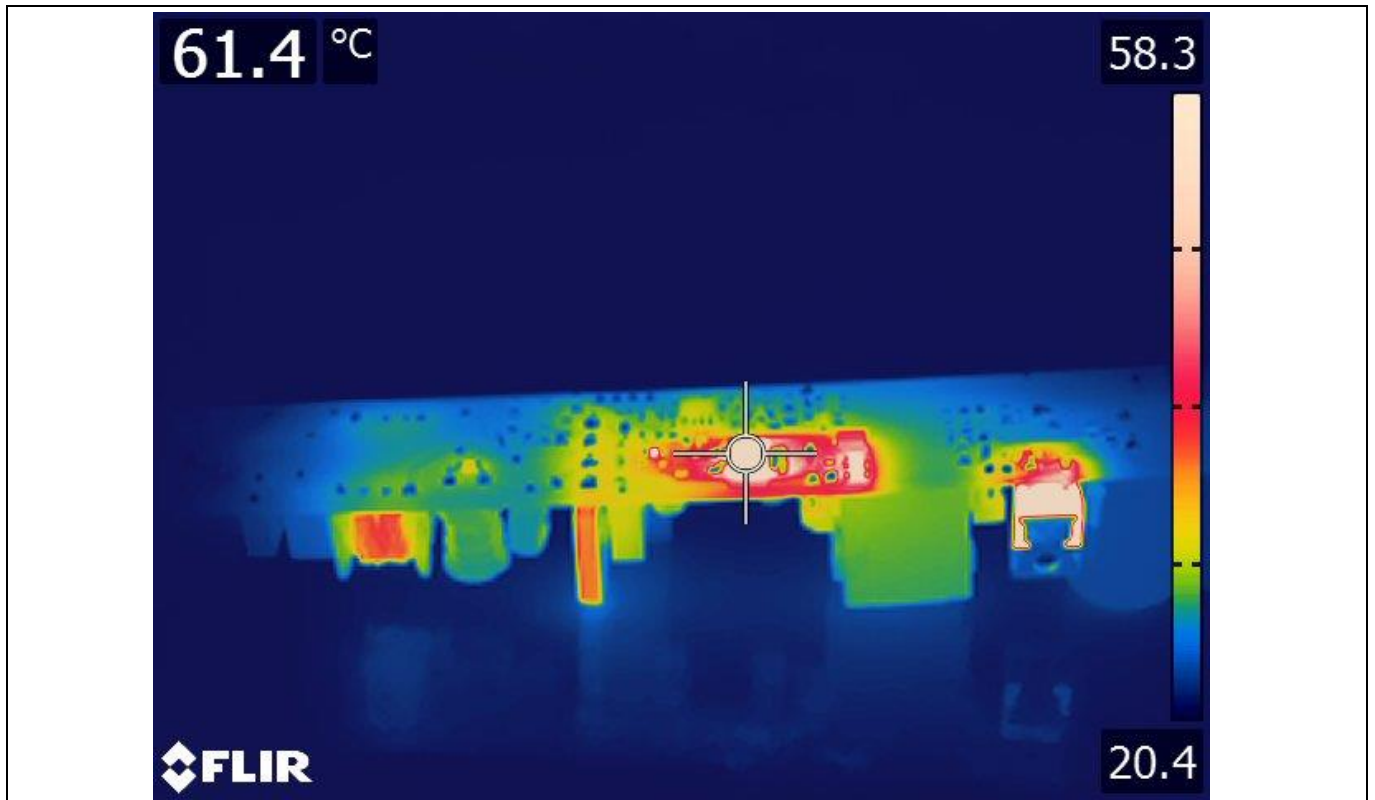


Figure 14 ICL8810 PFC-PSR-flyback reference design infrared measurement – top side  $V_{in} = 100 V_{AC}$ ,  $P_{out} = 42 W$

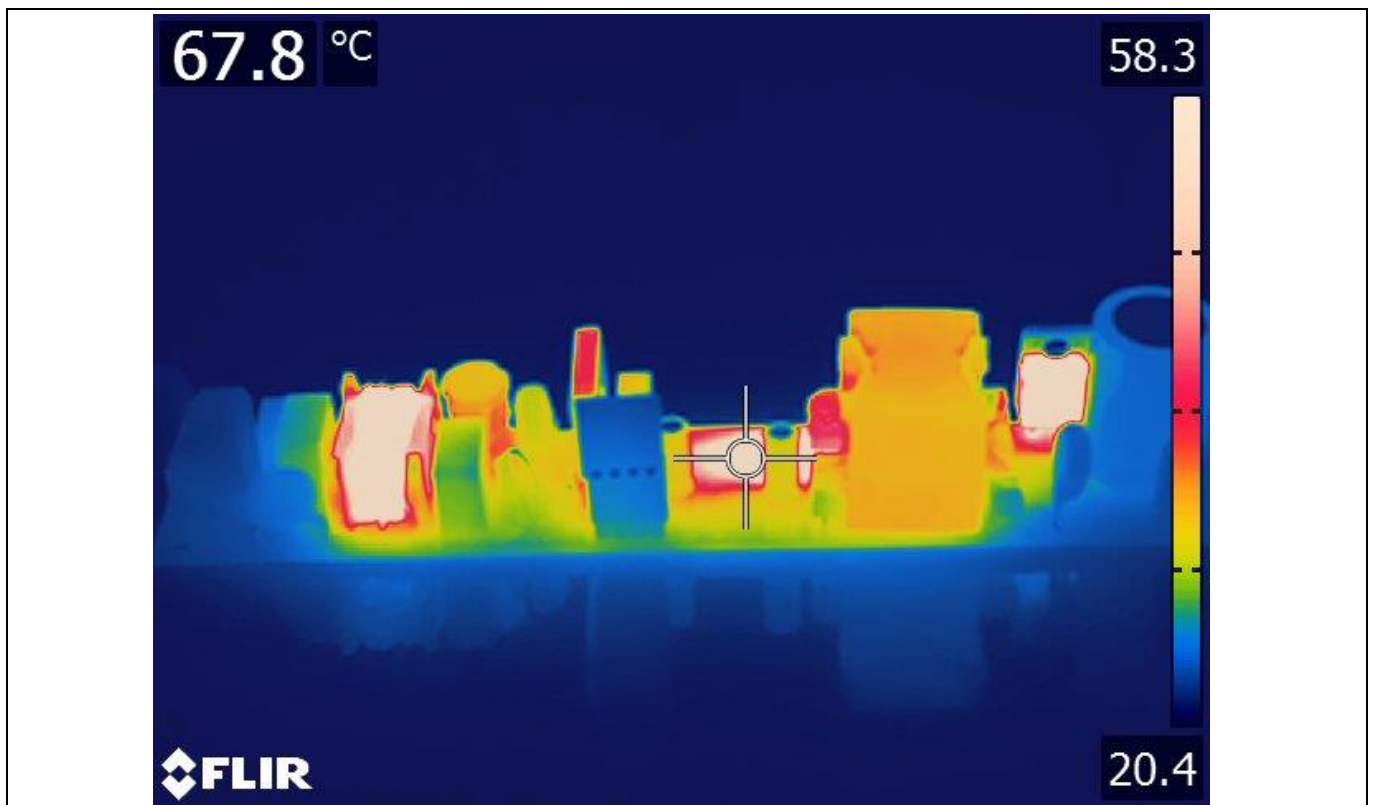


Figure 15 ICL8810 PFC-PSR-flyback reference design infrared measurement – bottom side  $V_{in} = 100 V_{AC}$ ,  $P_{out} = 42 W$

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## Flyback IC for lighting applications

### Schematics and performance



		<b>DATASHEET</b>		11/07/2019		<b>REV</b>		00					
		<b>EDITED</b>		Davide Maida		<b>APPROVED</b>		Dario Radaelli					
<b>FINAL P/N</b>	PQ262015	<b>REV</b>	00	<b>SAMPLING CODE</b>		PQ262015-240619A							
<b>PRELIMINARY P/N</b>	OP1901015			<b>CUSTOMER P/N</b>									
<b>CUSTOMER</b>	INFINEON TECHNOLOGIES AG (Munich)												
<b>DESCRIPTION</b>		Flyback Transformer PQ2620 low loss core											
<b>TEST/FEATURES</b>													
Inductance Pri1A+Pri2A		544,0 $\mu$ H $\pm$ 10,0%				10KHz / 100mV							
Leakage Inductance Pri1A+Pri2A		5,0 uH max (short-circuit on Sec+AuxP1+AuxP2+AuxS1+AuxS2)				10KHz / 100mV							
Dielectric Strength		Pri1A+Pri1B+AuxP1+AuxP2+Pri2A+Pri2B / Sec+AuxS1+AuxS2				3,0kVac / 2sec.							
<b>WINDINGS</b>													
Pri1A	16ts - 2x0,20 - gr.2 130° (1UEW)												
Pri2A	16ts - 2x0,20 - gr.2 130° (1UEW)				1 Ts PE ad.tape 0,06mm 130° yellow								
Sec	10ts - 3x0,35 - TIW 130° EN60950				1 Ts PE ad.tape 0,06mm 130° yellow								
AuxP1	1ts - 0,16 - gr.2 130° (1UEW)												
AuxP2	3ts - 0,16 - gr.2 130° (1UEW)				1 Ts PE ad.tape 0,06mm 130° yellow								
Pri1B	16ts - 2x0,20 - gr.2 130° (1UEW)												
Pri2B	16ts - 2x0,20 - gr.2 130° (1UEW)				1 Ts PE ad.tape 0,06mm 130° yellow								
AuxS1	1ts - 0,20 - TIW 130° EN60950												
AuxS2	2ts - 0,20 - TIW 130° EN60950				2 Ts PE ad.tape 0,06mm 130° yellow								
<b>LAYOUT (bottom view)</b>					<b>DRAWING</b>								
<b>DIMENSIONS (mm)</b>													
<b>A</b>	28,0 max	<b>B</b>	30,5 max	<b>H</b>	21,8 max	<b>X</b>	7,5 typ	<b>X1</b>	3,8 typ				
<b>X2</b>	22,7 typ	<b>Y</b>	25,5 typ	<b>D<math>\phi</math></b>	0,6 typ	<b>L</b>	3,0 min						
<b>COMPONENT</b>					<b>THERMAL CLASS</b>								
Bobbin					150°C (B)								
Copper Wire					155°C (F)								
Tape					130°C (B)								
Tube					200°C (N)								
Varnish					180°C (H)								
<b>NOTES</b>													
REACH & RoHS compliant													
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1ST ITALIAN MANUFACTURER OF PCB TRANSFORMERS WITH ISO CERTIFIED QUALITY MANAGEMENT SYSTEM													
		I T A C O I L s.r.l. • via delle Gerole, 7 • I-20867 CAPONAGO (MB) Tel. +39 02 95745131 • Fax +39 02 95745133 e-mail <a href="mailto:contatto@itacoilmail.it">contatto@itacoilmail.it</a> • <a href="http://www.itacoilweb.com">www.itacoilweb.com</a> Cap. soc. Euro 81600 i.v. • p.IVA, cod.fisc., N° reg.impr.MI 03071100964				Quality System <b>UNI EN ISO 9001</b> Certified CEI Member Italian and Asian production sites Powered by <b>zero impact*</b> renewable energy							

Figure 16 Transformer specification

**Table 2 Bill of materials**

#	Quantity	Designator	Description	Manufacturer	Manufacturer part number
1	1	BR1	BRIDGE RECTIFIER/4 A/1000 V/ / SIP345W114P508L2205H2125Q4B/	MCC	GBU4M-BP
2	1	C1	Cap 100 nF/ 310 V <sub>AC</sub> / Radial/ /10%	Würth Elektronik	890334023023CS
3	1	C2	150 nF/ 310 V <sub>AC</sub> / L13_W7_H13_P10_CS/ /	Würth Elektronik	890334023025CS
4	1	C3	Cap 680 pF/ 630 V/ 1206/ C0G/5%	Murata	GRM31B5C2J681JW01
5	1	C4	Cap 150 nF/ 630 V/ Radial type/ /10%	TDK Corporation	B32672P6154
6	1	C5	Cap 10 uF/ 25 V/ THT/ /20%	Würth Elektronik	860020472003
7	1	C6	Cap 47 uF/ 25 V/ THT/ /20%	Würth Elektronik	860020472006
8	1	C9	2200p/500 V <sub>AC</sub> rad/ 500 V <sub>AC</sub> / Disc/ Y5U/20%	Vishay	VY1222M47Y5UQ63V0
9	3	C38, C39, C108	Cap 100 nF/ 50 V/ 0603/ X7R/10%	AVX	06035C104K4Z2A
10	1	C40	2200p/Y-Cap/ / CAPRR1000W60L750T500H1150B/	Murata	DE1E3KX222MN4AP01F
11	2	C41, C109	Cap 100 nF/ 50 V/ 1206/ X7R/5%	Murata	GRM319R71H104JA01
12	1	C101	Cap 150 pF/ 630 V/ CAPC3216X100N/ U2J/5%	Murata	GCM31A7U2J151JX01
13	2	C102, C103	470 uF/80 V/20%RADIAL/ / CAPPRD750W80D1825H2200B-1 - duplicate/ /	United Chemi-Con	EKZE800ELL471MM20S
14	1	C104	ECap/47 uF/35 V/20%/ / CAPPRD200W50D500H1200B/ /	Lelon	RGA470M1VBK-0611G
15	1	C105	ECap/100 uF/25 V/20%/ / CAPPRD200W50D500H1200B/ /	Nichicon	UKA1E101MED1TD
16	1	C106	Cap 1 uF/ 100 V/ 1206/ X7R/10%	Murata	GRM31CR72A105KA01
17	1	C107	Cap 100 nF/ 100 V/ 1206/ X7R/10%	Murata	GRM319R72A104KA01
18	1	D1	Dio 1N4148W/ / SOD123/ /	Diodes Incorporated	1N4148W-7-F
19	1	D3	Dio US1MFA/ / SOD-23FL/ /	ON Semiconductor	US1MFA
20	1	D5	Dio 1N4148W/ / SOD123/ /	Diodes Incorporated	1N4148W-7-F
21	1	D20	Dio 1N4006G/ 800 V/ DO-41 (Case 59-10)/ /	ON Semiconductor	1N4006G
22	1	D21	Dio 1N4006G/ 800 V/ DO-41 (Case 59-10)/ /	ON Semiconductor	1N4006G
23	1	D40	Dio 15 V/ / SOD80C/ /	Nexperia	BZV55-C15,115
24	1	D101	HyperFast, 15 A, 300 V/ / TO508P450X1000X1965-2B/ /	Vishay	VS-15ETH03-M3
25	2	D102, D103	0.25 A, 250 V/ 250 V/ SOD80C/ /	NXP Semiconductors	BAV103,115
26	1	F1	FUSE 300 V/2 A/ 300 V/ FUSRR508W62L835T430H820B/ /	BUSSMANN BY EATON	SS-5H-2A-APH

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## Flyback IC for lighting applications

### Schematics and performance



27	1	IC3	ICL8810/ / SOIC127P600X175-8N-2/ /	Infineon	ICL8810
28	4	J6, R104, R107, R108	Res 0R/ 200 V/ 1206/ /0R	Vishay	CRCW12060000Z0
29	1	L1	Ind 68 mH/ / D_CHOKE_B82732F/ /30%	Epcos	B82732F2601B001
30	1	L2	470UH/1.15 A/ / 7447480471 (WRU)/ /	Würth Elektronik	7447480471
31	1	MOV1	Varistor, 510 V/ 510 V/ Radial type/ /10%	PANASONIC	ERZE08A511
32	1	Q1	MOSFET, 0.9 Ohm, 800 V, DPAK/ / TO-252AA (DPAK) - small/ /	Infineon	IPD80R900P7
33	1	Q40	Tra BC847C/ / SOT23 (TO-236AB)/	Nexperia	BC847C,215
34	1	R1	Res 1.5k/ 150 V/ 0805/ /1%	Vishay	CRCW08051K50FK
35	1	R2	Res 20k/ 75 V/ 0603/ /1%	Vishay	CRCW060320K0FK
36	1	R3	Res 1k/ 200 V/ 1206/ /1%	Vishay	CRCW12061K00FK
37	2	R4, R5	Res 2.7MEG/ 200 V/ 1206/ /1%	Vishay	CRCW12062M70FK
38	1	R6	Res 910k/ 200 V/ 1206/ /1%	Vishay	CRCW1206910KFK
39	3	R7, R8, R110	Res 100k/ 200 V/ 1206/ /1%	Vishay	CRCW1206100KFK
40	1	R9	Res 180R/ 150 V/ 0805/ /1%	Vishay	CRCW0805180RFK
41	1	R10	Res 22k/ 75 V/ 0603/ /1%	Vishay	CRCW060322K0FK
42	1	R14	Res 180mR/ 200 V/ 1206/ /1%	Vishay	WSL1206R1800FEA
43	1	R15	Res 39R/ 200 V/ 1206/ /1%	Vishay	CRCW120639R0FK
44	1	R16	Res 47R/ 150 V/ 0805/ /1%	Vishay	CRCW080547R0FK
45	1	R17	Res 39k/ 75 V/ 0603/ /1%	Vishay	CRCW060339K0FK
46	1	R18	Res 10R/ 200 V/ 1206/ /1%	Vishay	CRCW120610R0FK
47	3	R19, R29, R30	Res 30k/ 200 V/ 1206/ /1%	Vishay	CRCW120630K0FK
48	2	R40, R42	Res 1k/ 75 V/ 0603/ /1%	Vishay	CRCW06031K00FK
49	1	R41	Res 10k/ 75 V/ 0603/ /1%	Vishay	CRCW060310K0FK
50	1	R43	Res 7.5k/ 75 V/ 0603/ /1%	Vishay	CRCW06037K50FK
51	1	R101	Res 10R/ 200 V/ 1206/ /1%	Vishay	CRCW120610R0FK
52	2	R111, R112	Res 100k/ 150 V/ 0805/ /1%	Vishay	CRCW0805100KFK
53	1	T1	PQ2620, 544 uH/ / PQ2620/ /	itacoil	PQ262015
54	1	X1	250-203/ / WAGO_250-203/ /	WAGO	250-203
55	1	X5	Con 826936-4/ / CON-M-THT-826936-4/ /	TE Connectivity	826936-4
56	1	X200-A	Terminal block/4 pins/5.08 mm pitch/ / 691313510004/ /	Würth Elektronik	691313510004

**Revision history**

**Revision history**

<b>Document version</b>	<b>Date of release</b>	<b>Description of changes</b>
V 1.0	2021-06-02	First release
V 1.1	2021-08-18	Figures, BOM update