

UM10520

TEA1721 isolated 3-phase universal mains flyback converter demo board

Rev. 1.2 — 15 May 2013

User manual

Document information

Info	Content
Keywords	TEA1721, isolated, 3-phase universal mains, AC/DC conversion, flyback converter, Switched Mode Power Supply (SMPS)
Abstract	This user manual describes the application of the TEA1721ADB1062 demo board. The demo board is designed as an isolated 24 V, 5 V and 3.3 V AC/DC SMPS for supplying up to 5 W into a load.



Revision history

Rev	Date	Description
v.1.2	20130515	updated issue
Modifications:		Figure 5 "TEA1721 3-phase SMPS circuit diagram" has been updated.
v.1.1	20130501	updated issue
v.1	20120123	first issue

Contact information

For more information, please visit: <http://www.nxp.com>

For sales office addresses, please send an email to: salesaddresses@nxp.com

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.

This user manual describes the application of the TEA1721ADB1062 demo board. The demo board is designed as an isolated 24 V, 5 V and 3.3 V AC/DC SMPS for supplying up to 5 W to a load.

On the input side, single phase, 2-phase or 3-phase Universal Mains power can be connected. The switch-mode converter operates in flyback mode at a maximum frequency of around 50 kHz. Overcurrent and short-circuit protection are built in. The power consumption is below 50 mW under no-load conditions.

EMI filtering and surge protection using TVS diodes is implemented in this circuit. This application is intended as a 3-phase low-power SMPS which is especially suited for 3-phase industrial and multi-phase e-metering SMPS applications.

Do not exceed an RMS input voltage of 560 V (AC) across any combination of the J1.x connectors. 560 V (AC) corresponds to a maximum instantaneous voltage difference of 800 V.

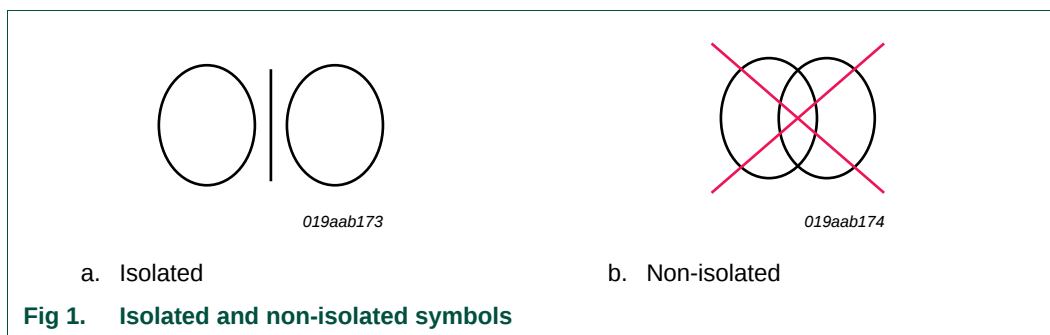
An additional high surge protection using MOVs can be implemented if necessary.

1.1 Features and benefits

- Compatible with 3-phase universal mains
- Tolerant with respect to "missing neutral"
- Inrush current limitation
- EMI filtering to meet EMC requirements of EN55022
- ESD protection on the TEA1721
- Optional high-surge protection companion circuit option
- Power Line Communication (PLC) decoupling extension

2. Safety warning

The demo board is powered by AC mains voltage. Avoid touching the board when power is applied. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments. Always provide galvanic isolation of the mains phase using a variable transformer. The following symbols identify isolated and non-isolated devices.

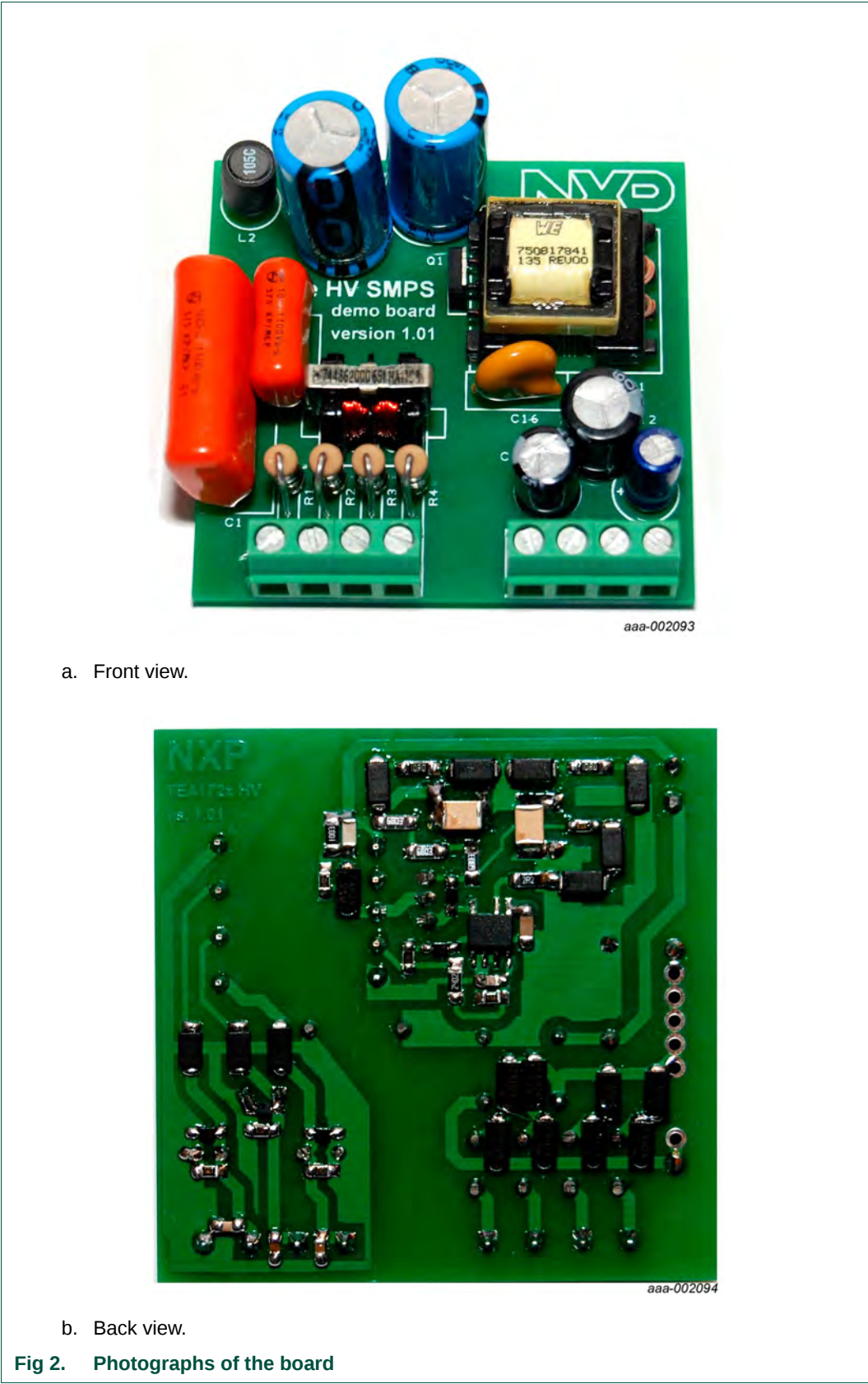


3. Specification

Table 1. Demo board specification

Parameter	Value	Comment
AC line input voltage	single-phase:	
	85 V (AC) to 560 V (AC)	supplied to any pair of the J1.x terminals
	2-phase or 3-phase:	
	50 V (AC) to 320 V (AC) ^[1]	assuming 120° phase angle. The Phase and the Neutral wires from the mains utility system can be connected randomly to the J1.x terminals.
output voltage	24 V (DC), 5 V (DC) and 3.3 V (DC)	supplied from connectors:
		J2.1 = 24 V, GND
		J2.2 = 5 V
		J2.3 = 3.3 V
maximum output current	24 V = 200 mA 5 V = 300 mA 3.3 V = 300 mA	
maximum output power	5 W	
output voltage accuracy	±5 %	depends primarily on the accuracy of the secondary winding construction of transformer T1
output voltage stability	±5 %	strongly depends on the magnetic coupling of the secondary and auxiliary winding of transformer T1
efficiency	76.7 % at 115 V/60 Hz	
	79.6 % 230 V/50 Hz	
operating temperature	−40 °C to 85 °C	
EMC Compliance	EN 55022	
board dimensions	82 mm × 62 mm × 35 mm	L × B × H

[1] Each phase, measured between the neutral and the phase wire



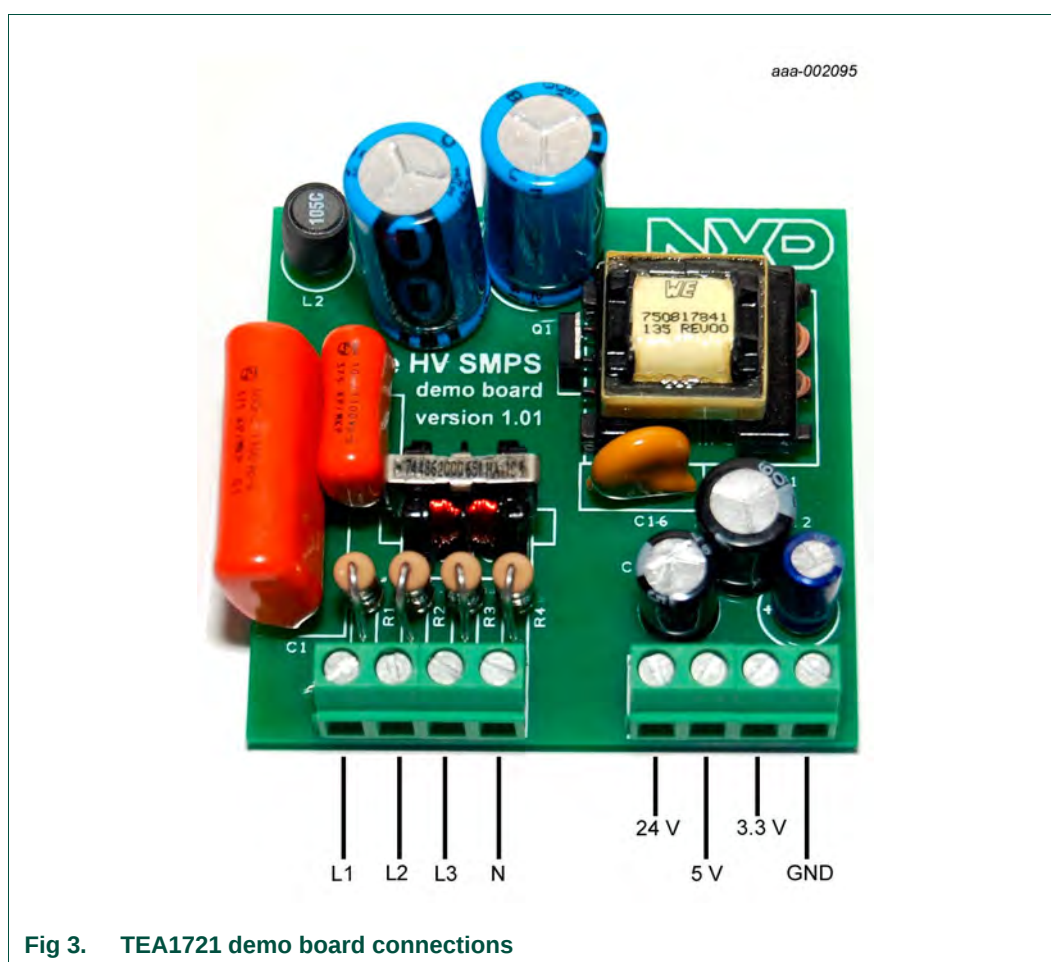
4. Demo board connections

The isolated 3-phase flyback demo board has an input and an output terminal block.

The input terminal block (left on the picture) is connected to the utility mains. Either 1, 2 or 3 phases can be connected using 2, 3 or 4 wires respectively. The input wires (L1, L2, L3 and N) can be connected to the terminals of the left terminal block randomly.

The output terminal block provides the 24 V (DC), 5 V (DC) and 3.3 V (DC) output voltages, all referenced to a common ground (GND).

Remark: Mount the board in a shielded or isolated box for demonstration purposes.



5. Operation and performance

Basic operation of the IC is described in the NXP Semiconductors *TEA1721 data sheets*.

5.1 No-load power consumption

Table 2. Typical no-load power consumption

Power supply	Energy Star 2.0 requirement	No-load power consumption
115 V (AC)/60 Hz	< 300 mW	36 mW
230 V (AC)/50 Hz	< 300 mW	38 mW

The typical no-load power consumption of the TEA1721 3-phase SMPS exceeds the Energy Star 2.0 level V requirement by nearly a factor of 10.

5.2 Efficiency

Table 3. Typical efficiency data

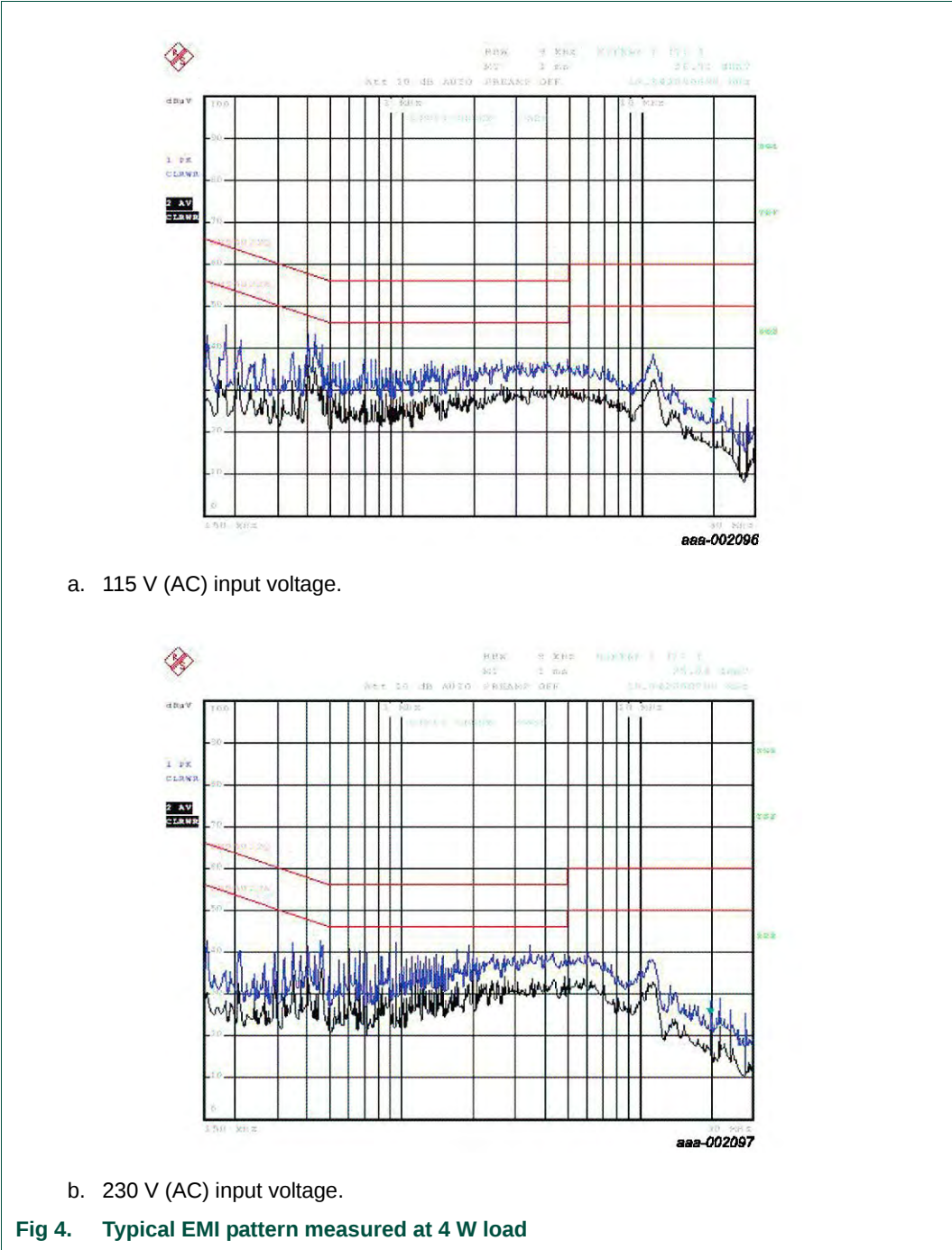
Parameter	Energy Star 2.0 level V (%)	Efficiency (%)				
		average	25 % load	50 % load	75 % load	100 % load
115 V (AC)/60 Hz	72.3	76.7	77.6	78.5	76.7	74.1
230 V (AC)/50 Hz	72.3	79.6	79.1	80.7	79.9	78.7

The typical efficiency of the TEA1721 3-phase SMPS exceeds the Energy Star 2.0 level V requirement by more than 5 % on average. Efficiency was measured by having a load on the 24 V output only.

6. Test results

6.1 ElectroMagnetic Interference

EMI was measured with 4 W load (80 % load) on the joint outputs of the TEA1721 3-phase SMPS. Measurement results are shown in [Figure 4](#). The TEA1721 3-phase SMPS is EMC compliant according to EN55022 and the margin with respect to the limits is more than 10 dB.



7. Demo board schematic

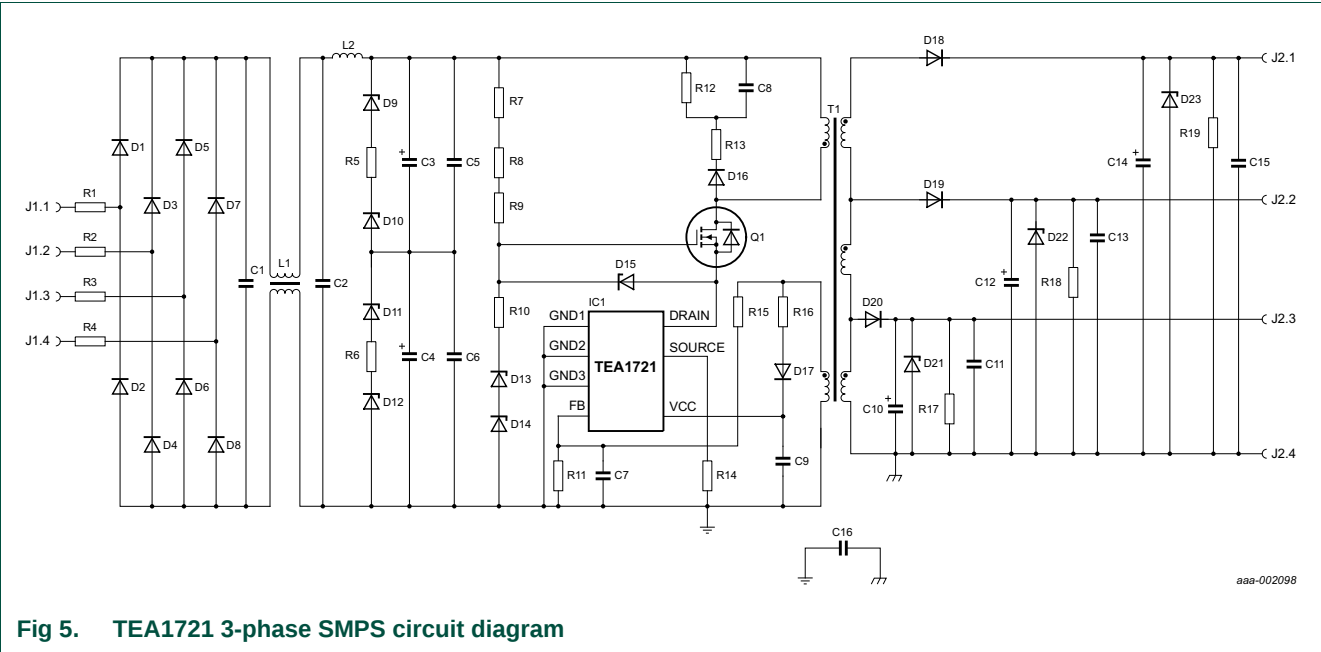


Fig 5. TEA1721 3-phase SMPS circuit diagram

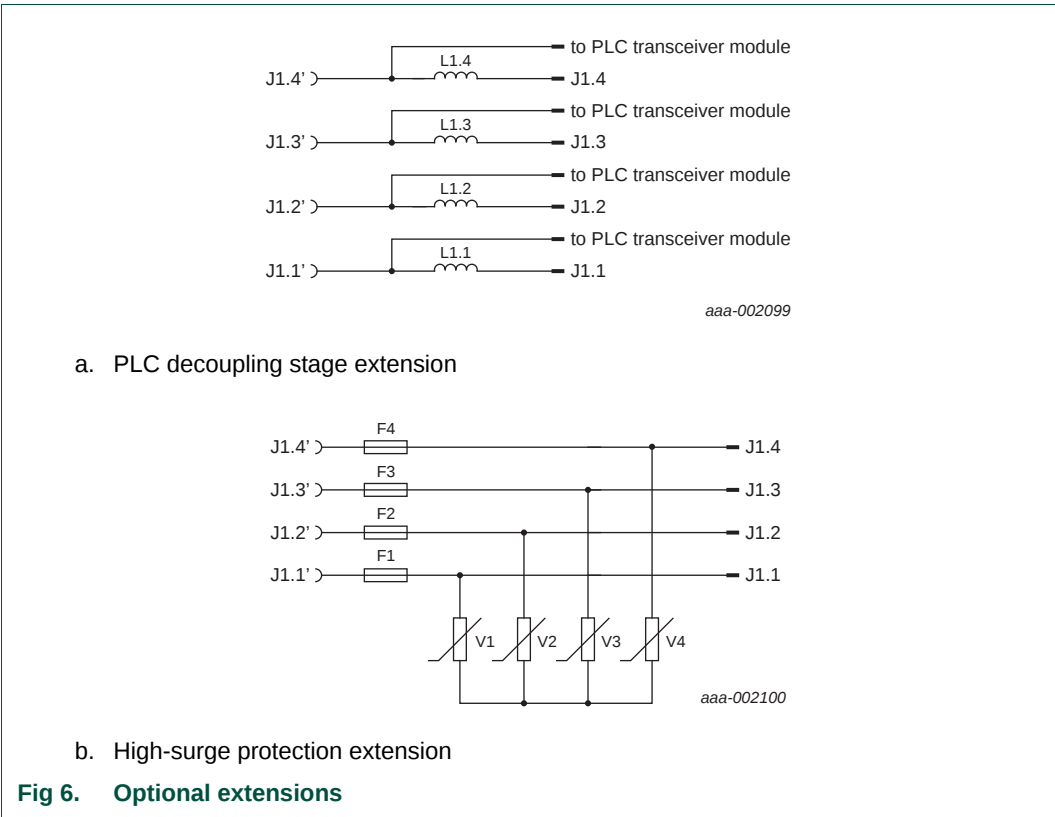


Fig 6. Optional extensions

8. PCB components

Table 4. Demo board components

Reference	Description and value	Part number	Manufacturer
C1	100 nF; 1 kV	-	-
C2	10 nF; 1 kV	-	-
C3	electrolytic capacitor; 22 μ F; 400 V	-	-
C4	electrolytic capacitor; 22 μ F; 400 V	-	-
C5	100 nF; 500 V; 1812	-	-
C6	100 nF; 500 V; 1812	-	-
C7	10 pF; 25 V; 0805	-	-
C8	220 pF; 500 V; 1206	-	-
C9	ceramic capacitor; 1 μ F; 50 V; 1206	-	-
C10	electrolytic capacitor; 1 mF; 6.3 V	-	-
C11	100 nF; 25 V; 0805	-	-
C12	electrolytic capacitor; 470 μ F; 10 V	-	-
C13	100 nF; 25 V; 0805	-	-
C14	electrolytic capacitor; 100 μ F; 35 V	-	-
C15	100 nF; 50 V; 0805	-	-
C16	Y-capacitor; 2.2 nF; 1 kV	-	-
D1	S1M; SMA	S1M (or equivalent)	-
D2	S1M; SMA	S1M (or equivalent)	-
D3	S1M; SMA	S1M (or equivalent)	-
D4	S1M; SMA	S1M (or equivalent)	-
D5	S1M; SMA	S1M (or equivalent)	-
D6	S1M; SMA	S1M (or equivalent)	-
D7	S1M; SMA	S1M (or equivalent)	-
D8	S1M; SMA	S1M (or equivalent)	-
D9	BZG03-C200; SMA	BZG03-C200	-
D10	BZG03-C200; SMA	BZG03-C200	NXP Semiconductors
D11	BZG03-C200; SMA	BZG03-C200	NXP Semiconductors
D12	BZG03-C200; SMA	BZG03-C200	NXP Semiconductors
D13	BZG03-C240; SMA	BZG03-C240	NXP Semiconductors
D14	BZG03-C240; SMA	BZG03-C240	NXP Semiconductors
D15	BZX384-C13; SOD323	BZX384-C13	NXP Semiconductors
D16	S1M; SMA	S1M	-
D17	BAS316; SOD323	BAS316	NXP Semiconductors
D18	BYG22D; SMA	BYG22D	-
D19	PMEG4050EP; SOD128	PMEG4050EP	NXP Semiconductors
D20	PMEG3050EP; SOD128	PMEG3050EP	NXP Semiconductors
D21	BZX384-C3V6; SOD323	BZX384-C3V6	NXP Semiconductors
D22	BZX384-C5V6; SOD323	BZX384-C5V6	NXP Semiconductors

Table 4. Demo board components ...continued

Reference	Description and value	Part number	Manufacturer
D23	BZX384-C30; SOD323	BZX384-C30	NXP Semiconductors
IC1	TEA1721; SO7	TEA1721AT	NXP Semiconductors
L1	2 × 25 mH; 80 mA; 500 V (AC)	744862250	Würth Elektronik
L2	1 mH; 80 mA	-	-
Q1	STD3NK60Z; IPAK	STD3NK60Z	-
R1	carbon resistor; 33 Ω	-	-
R2	carbon resistor; 33 Ω	-	-
R3	carbon resistor; 33 Ω	-	-
R4	carbon resistor; 33 Ω	-	-
R5	10 Ω; 0.25 W; 1206	-	-
R6	10 Ω; 0.25 W; 1206	-	-
R7	680 kΩ; 0.125 W; 1206	-	-
R8	680kΩ; 0.125 W; 1206	-	-
R9	680kΩ; 0.125 W; 1206	-	-
R10	100 Ω; 0805	-	-
R11	4.7 kΩ; 1 %; 0805	-	-
R12	100 kΩ; 0.5 W; 1206	-	-
R13	470 Ω; 0805	-	-
R14	1.8 Ω; 0.25 W; 1206	-	-
R15	25.5 kΩ; 1 %; 1206	[2]	-
R16	10 Ω; 0805	-	-
R17	5.6 kΩ; 0805	-	-
R18	12 kΩ; 0805	-	-
R19	270 kΩ; 0805	-	-
T1	custom transformer [1]	750817841	Würth Elektronik

[1] Custom transformer: primary winding inductance 2.4 mH; turns ratio Primary: Secondary: Auxiliary = 10 : 3 : 2. The secondary winding must have a tap for the 5 V and the 3.3 V output voltage. The magnetic coupling between the secondary and the auxiliary winding must be optimal.

[2] To set the output voltage with greater accuracy, fine-tuning is required.

9. Optional modifications implementation guidelines

- The output voltages are adjusted using resistors R11 and R15. The secondary winding on transformer T1 turns ratio defines the ratio between the three output voltages. Using a different transformer makes other output voltages and/or other output voltage ratios available.
- To achieve good voltage regulation, the secondary winding and the auxiliary winding of the transformer must have a tight magnetic coupling.
- The maximum output power and output current levels are adjusted using resistor R14. The maximum current allowed in the TEA1721 IC switching MOSFET is 700 mA. Take care that under no circumstances, the peak current in the primary winding of the T1 transformer exceeds 700 mA.
- Resistors R1, R2, R3 and R4 limit the inrush current. The resistor must be a carbon resistor because metal film resistors can act as a fuse in this position. If no inrush current limiting is required, the resistor can be replaced with a short-circuit.
- EMI-filtering is implemented using separate stages for common mode (L1) and differential mode (L2). Depending on the requirements, the filtering stage can be adapted. For example, inductor L1 can be chosen to ensure that its leakage inductance takes care of differential filtering. As a consequence L2 can be omitted.
- Surge voltage protection is implemented using TVS diodes D9, D10, D11, D12 and capacitors C5/C6. The surge protection limits the DC bus voltage to 800 V. The TVS diodes choice determines the maximum allowable surge pulse energy.
- Resistors R17, R18 and R19 form small pre-loads for the converter. When the output voltages are adjusted, also adjust the pre-load resistors to ensure that they consume roughly the same amount of power. Depending on the connected load, eliminate the resistors.
- Zener diodes D21, D22 and D23 are an elementary output OverVoltage Protection (OVP). When OVP is not needed, eliminate the diodes.
- Capacitors C11, C13 and C15 are used to obtain additional (HF) voltage stability and noise suppression. Eliminate the capacitors when the feature is not needed.
- Capacitor C16 is a Y-capacitor. If the T1 transformer construction provides the required EMI performance without the use of capacitor C16, omit the capacitor.
- Additional high surge protection using MOVs (V1 to V4) is implemented using the dedicated companion circuit in the front end. Depending on the application requirements, fuses (F1 to F4) can be included in the circuit as required. The MOVs must be DC rated at approximately 400 V. For example, S10K320.
- Additional Power Line Communication (PLC) decoupling can be implemented when the SMPS is used in combination with a PLC transceiver module. For example in e-metering applications. Depending on the frequency band, choose the value for L1.1 to L1.4. Typically, the inductor values range between a few hundred μH up to several mH.

10. Board layout

A 61 mm × 59.7 mm sized evaluation PCB was created that accommodates an implementation of the TEA1721 3-phase SMPS.

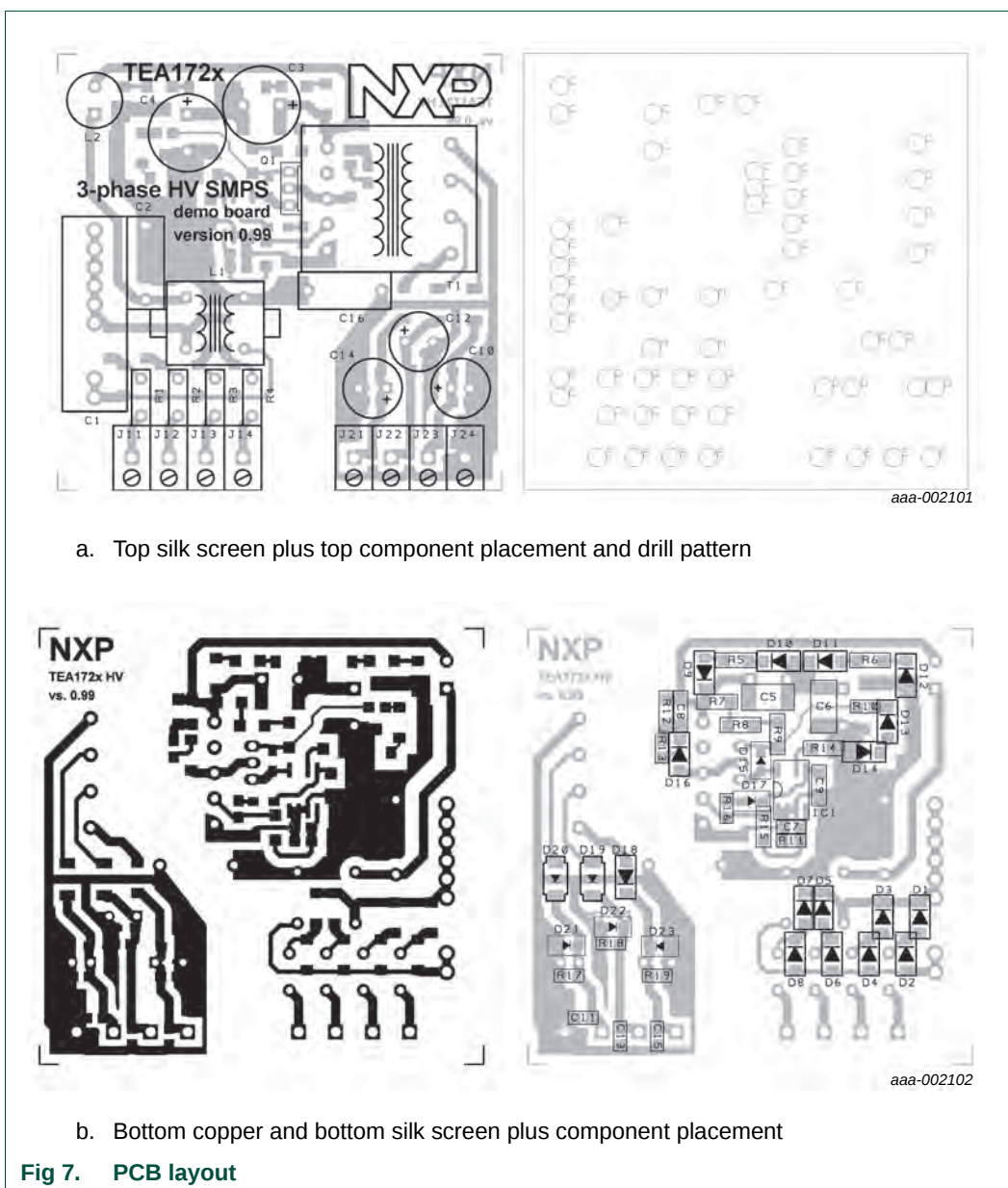


Fig 7. PCB layout

The bottom silk screen is normally not used in PCB production. Merged with the bottom copper, it is shown here as a component placement reference only. See [Table 4](#) for a list of components.

Table 5. Drill tool table

Drill tool code	Drill diameter
C	1 mm
D	0.9 mm
E	1.3 mm
M	0.8 mm

Gerber files are available from your local NXP Semiconductor sales representative, on request.

11. Abbreviations

Table 6. Abbreviations

Acronym	Description
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
OCP	OverCurrent Protection
OPP	OverPower Protection
OVP	OverVoltage Protection
OLP	Open-Loop Protection
PCB	Printed-Circuit Board
PFC	Power Factor Correction
SMPS	Switched Mode Power Supply
ZVS	Zero Voltage Switching

12. References

- [1] **TEA1721XT** - Ultra-low standby SMPS controller with integrated power switch
- [2] **AN11060** - TEA172X 5 W to 11 W power supply/USB charger

13. Legal information

13.1 Definitions

Draft — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

13.2 Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. NXP Semiconductors takes no responsibility for the content in this document if provided by an information source outside of NXP Semiconductors.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the *Terms and conditions of commercial sale* of NXP Semiconductors.

Right to make changes — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Suitability for use — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors and its suppliers accept no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

Evaluation products — This product is provided on an "as is" and "with all faults" basis for evaluation purposes only. NXP Semiconductors, its affiliates and their suppliers expressly disclaim all warranties, whether express, implied or statutory, including but not limited to the implied warranties of non-infringement, merchantability and fitness for a particular purpose. The entire risk as to the quality, or arising out of the use or performance, of this product remains with customer.

In no event shall NXP Semiconductors, its affiliates or their suppliers be liable to customer for any special, indirect, consequential, punitive or incidental damages (including without limitation damages for loss of business, business interruption, loss of use, loss of data or information, and the like) arising out of the use of or inability to use the product, whether or not based on tort (including negligence), strict liability, breach of contract, breach of warranty or any other theory, even if advised of the possibility of such damages.

Notwithstanding any damages that customer might incur for any reason whatsoever (including without limitation, all damages referenced above and all direct or general damages), the entire liability of NXP Semiconductors, its affiliates and their suppliers and customer's exclusive remedy for all of the foregoing shall be limited to actual damages incurred by customer based on reasonable reliance up to the greater of the amount actually paid by customer for the product or five dollars (US\$5.00). The foregoing limitations, exclusions and disclaimers shall apply to the maximum extent permitted by applicable law, even if any remedy fails of its essential purpose.

Safety of high-voltage evaluation products — 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 that is qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits.

The product does not comply with IEC 60950 based national or regional safety standards. NXP Semiconductors does not accept any liability for damages incurred due to inappropriate use of this product or related to non-insulated high voltages. Any use of this product is at customer's own risk and liability. The customer shall fully indemnify and hold harmless NXP Semiconductors from any liability, damages and claims resulting from the use of the product.

Translations — A non-English (translated) version of a document is for reference only. The English version shall prevail in case of any discrepancy between the translated and English versions.

13.3 Trademarks

Notice: All referenced brands, product names, service names and trademarks are the property of their respective owners.

14. Contents

1	Introduction	3
1.1	Features and benefits	3
2	Safety warning	4
3	Specification	5
4	Demo board connections	7
5	Operation and performance	8
5.1	No-load power consumption	8
5.2	Efficiency	8
6	Test results	9
6.1	ElectroMagnetic Interference	9
7	Demo board schematic	10
8	PCB components	11
9	Optional modifications implementation guidelines	13
10	Board layout	14
11	Abbreviations	15
12	References	15
13	Legal information	16
13.1	Definitions	16
13.2	Disclaimers	16
13.3	Trademarks	16
14	Contents	17

Please be aware that important notices concerning this document and the product(s) described herein, have been included in section 'Legal information'.

© NXP B.V. 2013.

All rights reserved.

For more information, please visit: <http://www.nxp.com>

For sales office addresses, please send an email to: salesaddresses@nxp.com

Date of release: 15 May 2013

Document identifier: UM10520