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

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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.

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

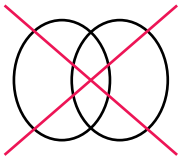
- Compatible with 3-phase universal mains
- Tolerant with respect to “missing neutral”
- Inrush current limitation
- EMI filtering to meet EMC requirements of EN55022
- ESD protection on the TEA1721
- Optional high-surge protection companion circuit option
- Power Line Communication (PLC) decoupling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

019aab173

a. Isolated



019aab174

b. Non-isolated

Fig 1. Isolated and non-isolated symbols

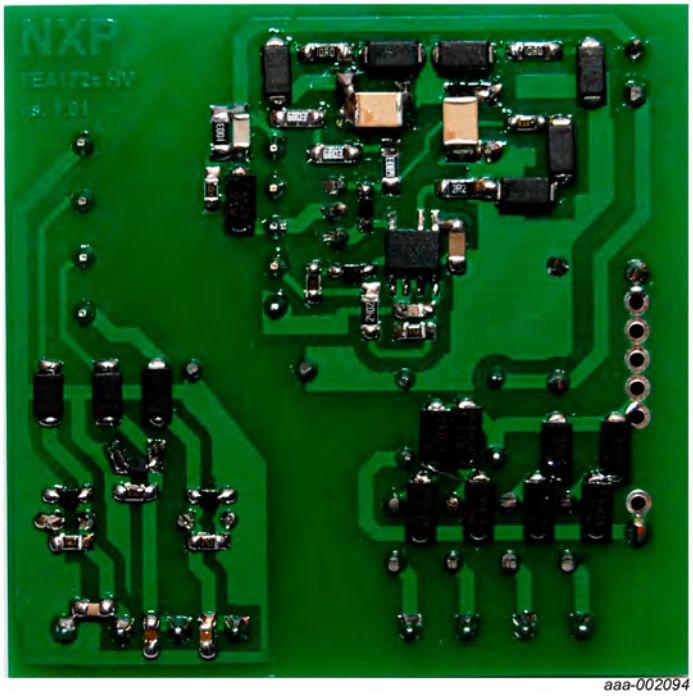
3. Specification

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
		J2.4 = 0 V, GND
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

a. Front view.



b. Back view.

Fig 2. Photographs of the board

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.

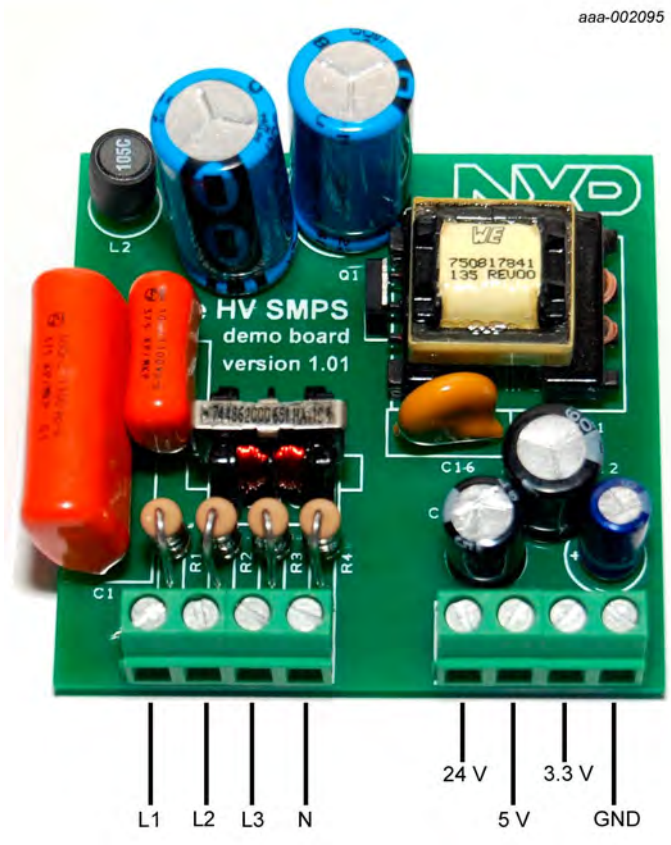


Fig 3. TEA1721 demo board connections

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

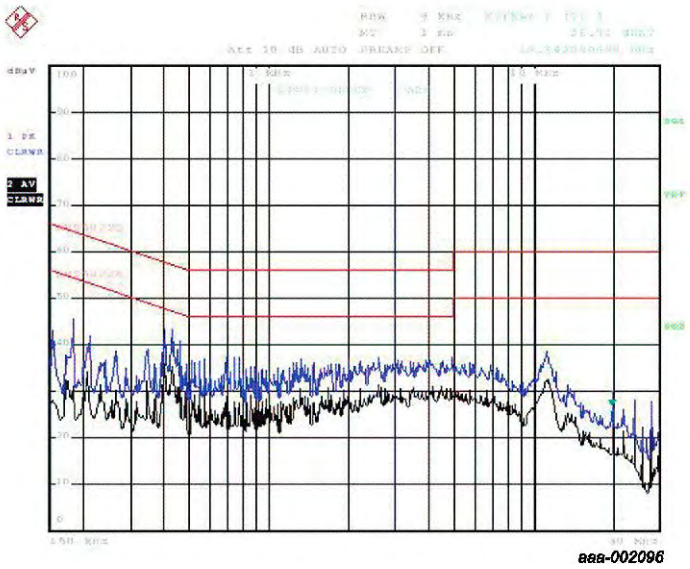
Parameter	Energy Star 2.0 level V (%)	Efficiency (%)				
		average	25 % load	50 % load	75 % load	100 % load
115 V (AC)/60 Hz	72.3	76.7	77.6	78.5	76.7	74.1
230 V (AC)/50 Hz	72.3	79.6	79.1	80.7	79.9	78.7

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.

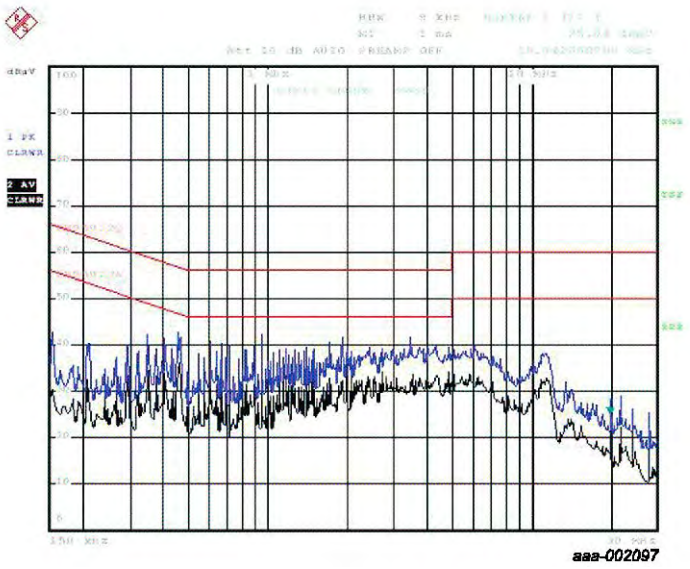
6. Test results

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.



a. 115 V (AC) input voltage.



b. 230 V (AC) input voltage.

Fig 4. Typical EMI pattern measured at 4 W load

7. Demo board schematic

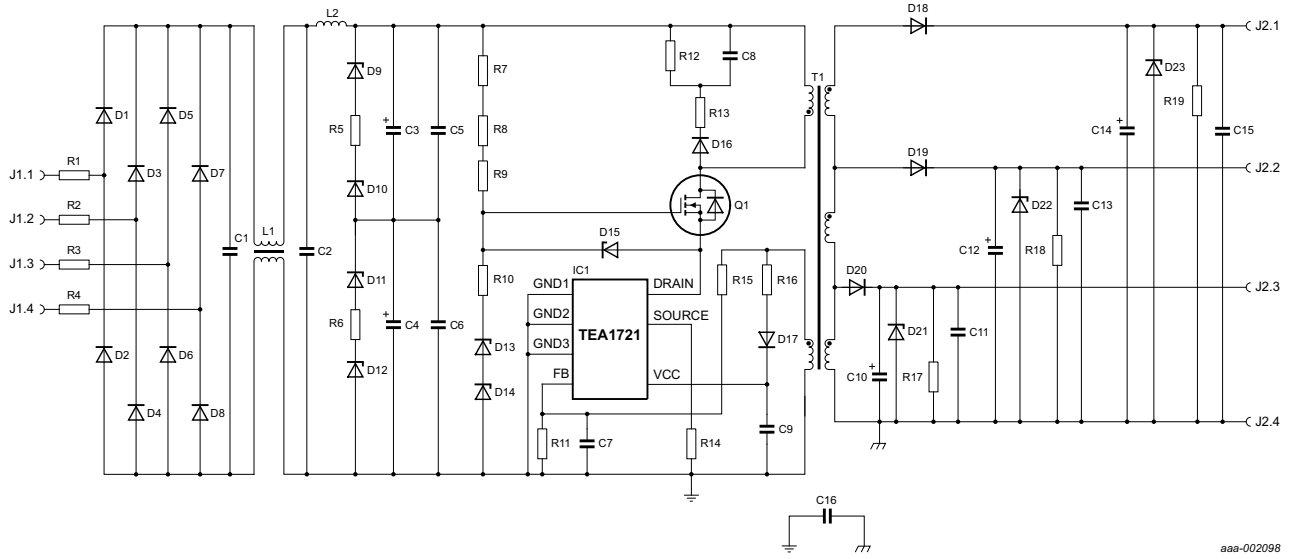
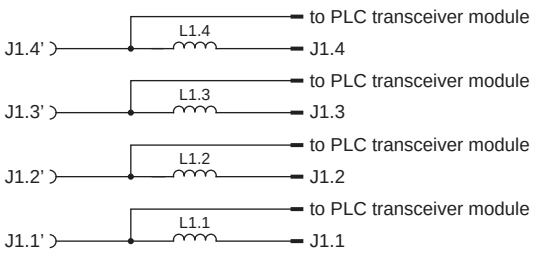
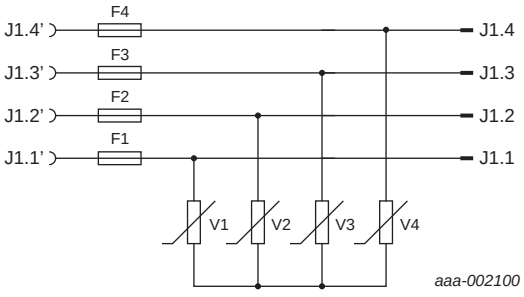


Fig 5. TEA1721 3-phase SMPS circuit diagram



a. PLC decoupling stage extension



b. High-surge protection extension

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 μF; 400 V	-	-
C4	electrolytic capacitor; 22 μF; 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 μF; 50 V; 1206	-	-
C10	electrolytic capacitor; 1 mF; 6.3 V	-	-
C11	100 nF; 25 V; 0805	-	-
C12	electrolytic capacitor; 470 μF; 10 V	-	-
C13	100 nF; 25 V; 0805	-	-
C14	electrolytic capacitor; 100 μF; 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.

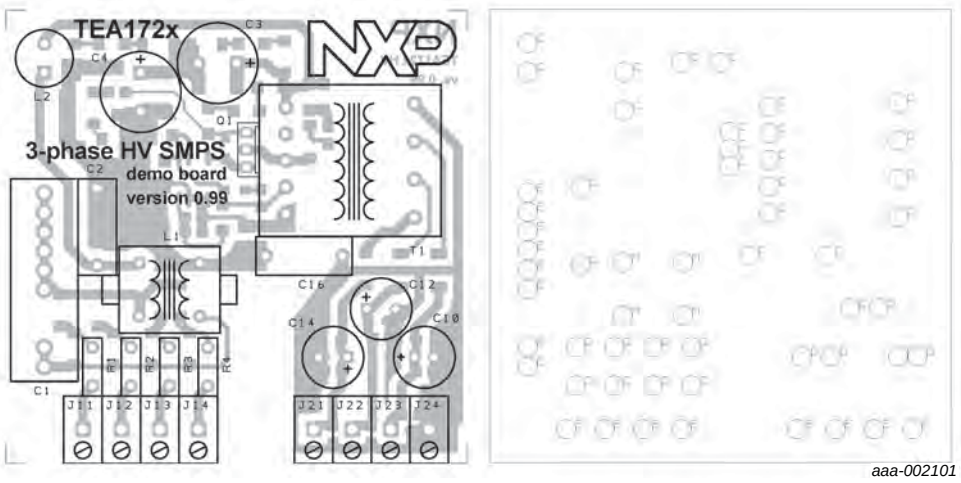
[2] To set the output voltage with greater accuracy, fine-tuning is required.

9. Optional modifications implementation guidelines

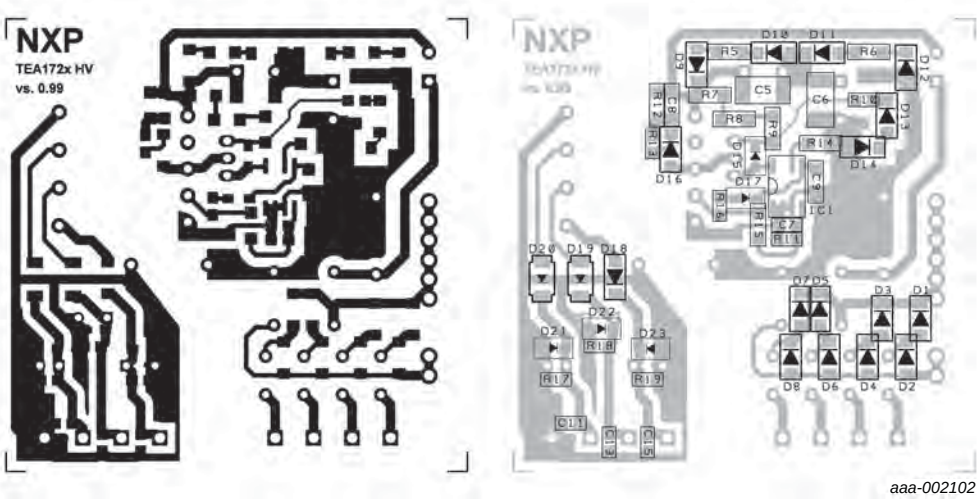
- The output voltages are adjusted using resistors R11 and R15. The secondary winding on transformer T1 turns ratio defines the ratio between the three output voltages. Using a different transformer makes other output voltages and/or other output voltage ratios available.
- To achieve good voltage regulation, 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 theT1 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.



a. Top silk screen plus top component placement and drill pattern



b. Bottom copper and bottom silk screen plus component placement

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

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