UM10557

TEA1716T 90 W notebook adapter demo board

Rev. 1 — 10 December 2012 User manual

Document information

Info	Content
Keywords	TEA1716T, 90 W notebook adapter, LLC, resonant, half-bridge, PFC, controller, converter, burst mode, power supply, demo board
Abstract	The TEA1716T includes a PFC controller as well as a controller for a half-bridge resonant converter. This document describes a 90 W resonant switching mode power supply for a typical notebook adapter design with the TEA1716T controller IC. The demoboard provides an output of 19.5 V/4.65 A. It operates in normal mode for medium and high-power levels and in burst mode for low-power levels. Burst mode operation provides a reduction of power losses to increase performance. The efficiency at high power is well above 90 % and the no-load power consumption is well below 200 mW. At 250 mW output power the input power is lower than 450 mW (EUP lot6 compliant).

Revision history

Rev	Date	Description
v.1	20121210	first issue

Contact information

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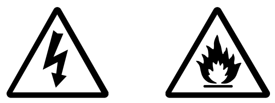
For sales office addresses, please send an email to: **salesaddresses@nxp.com**

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.

1.1 Scope of this document

This document describes the 90 W notebook adapter demo board using the TEA1716T. A functional description is given, including a set of measurements to show the main characteristics.

1.2 TEA1716T

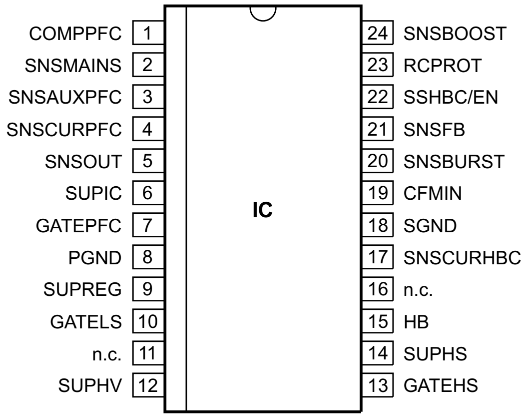
The TEA1716T integrates a controller for Power Factor Correction (PFC) and a controller for a half-bridge resonant converter (HBC). It provides the drive function for the discrete MOSFET for the upconverter and for the two discrete power MOSFETs in a resonant half-bridge configuration.

The resonant controller part is a high-voltage controller for a zero voltage switching LLC resonant converter. The resonant controller part of the IC includes a high-voltage level shift circuit. It also includes several protection features such as OverCurrent Protection (OCP), Open-Loop Protection (OLP), capacitive mode protection and a general purpose latched protection input.

In addition to the resonant controller, the TEA1716T contains a Power Factor Correction (PFC) controller. Functions such as quasi-resonant operation at high-power levels and quasi-resonant operation with valley skipping at lower power levels obtain the PFC's efficient operation. OCP, OverVoltage Protection (OVP) and demagnetization sensing, ensure safe operation under all conditions.

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

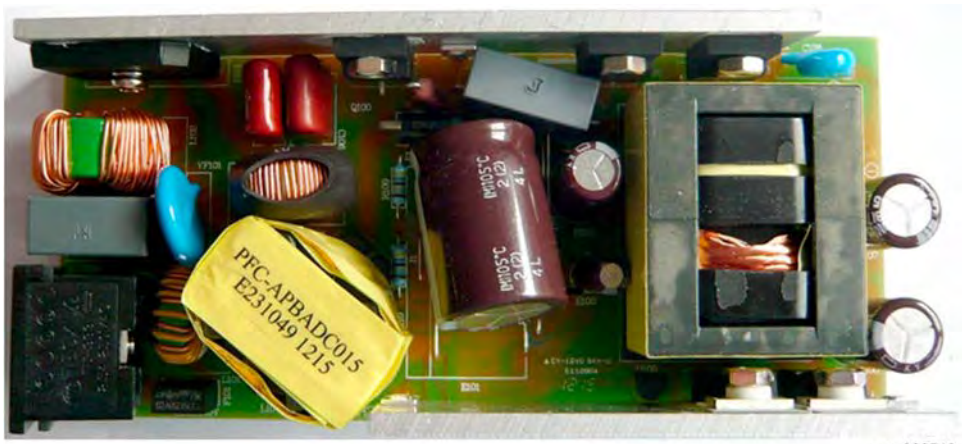
The combination of PFC and a resonant controller in one IC makes the TEA1716T very suitable for notebook adapter power supplies, desktop PCs and all-in-one PC applications.



aaa-000765

Fig 1. TEA1716T pin configuration

1.3 Setup of the 90 W notebook adapter



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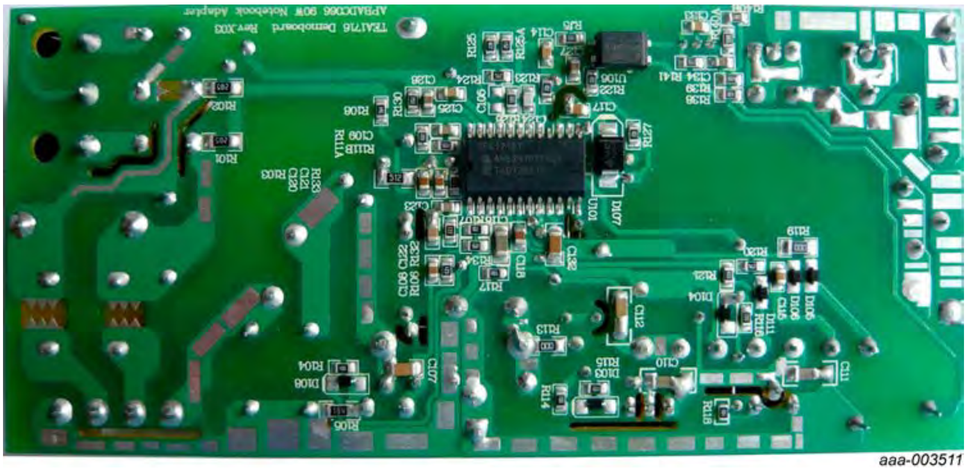
a. Top view



aaa-003511

b. Bottom view

Fig 2. TEA1716T evaluation board 90 W notebook adapter

The board can operate at a mains input voltage between 90 V and 264 V (universal mains).

The demo board contains two subcircuits:

- A Power Factor Converter (PFC): BCM type
- A Half-Bridge Converter (HBC): resonant LLC-type

The TEA1716T control both converters.

At low power, the converters operate in burst mode to reduce power losses.

The purpose of the demo board is to show the operation of the TEA1716T in a single output supply including burst mode operation. The performance is in alignment with current general standards, including the EuP lot6 requirements, and can be used as a starting point for further development.

1.4 Input and output properties

Table 1. Input data

Symbol	Description	Conditions	Specification	Unit
V_i	input voltage	AC	90 to 264	V (RMS)
f_i	input frequency		47 to 60	Hz
$P_{i(no-load)}$	No-load input power	at 230 V; 50 Hz	< 300	mW
$P_{i(load=250mW)}$	standby power consumption	at 230 V; 50 Hz	< 450	mW

Table 2. Output data

Symbol	Description	Conditions	Specification	Unit
V_o	output voltage		19.5	V
$V_{o(ripple)(p-p)}$	peak-to-peak output ripple voltage	bandwidth = 20 MHz	< 150	mV
I_o	output current	continuous	0 to 4.65	A

2. Safety warning

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

a. Isolated b. Not isolated

Fig 3. Variable transformer (Variac) isolation symbols

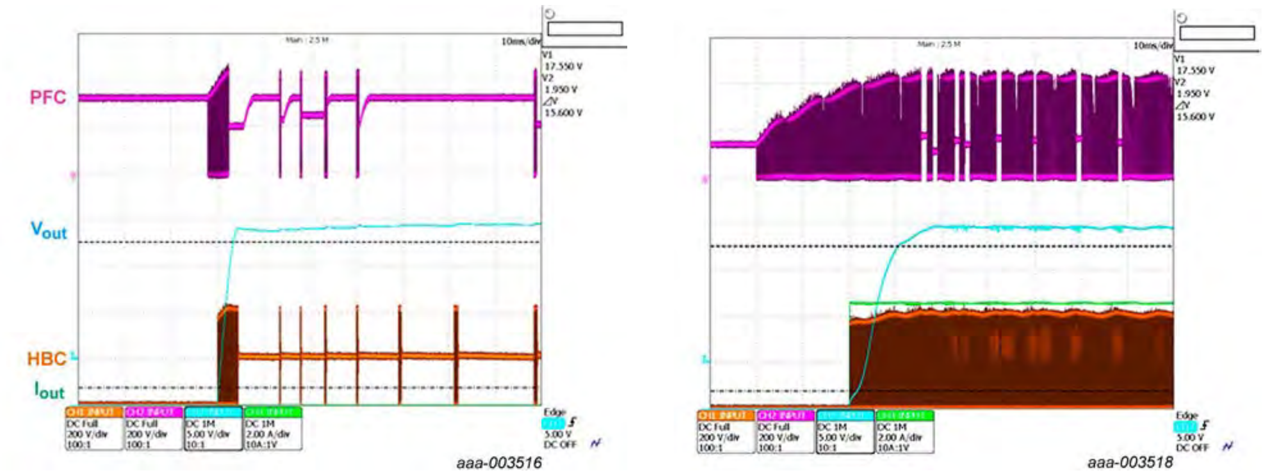
3. Measurements

3.1 Test facilities

- Oscilloscope: Yokogawa DL9140L
- AC Power Source: Agilent 6812B
- Electronic load: Agilent 6063B
- Digital power meter: Yokogawa WT210

3.2 Start-up behavior

The rise time of the output voltage (measured from the 10 % to the 90 % nominal output point) is between 3 ms and 10 ms, depending on the output current load.



a. Start-up at 230 V_{mains} and no-load (0 A)

b. Start-up at 100 V_{mains} and nominal load (4.65 A)

Fig 4. Start-up behavior

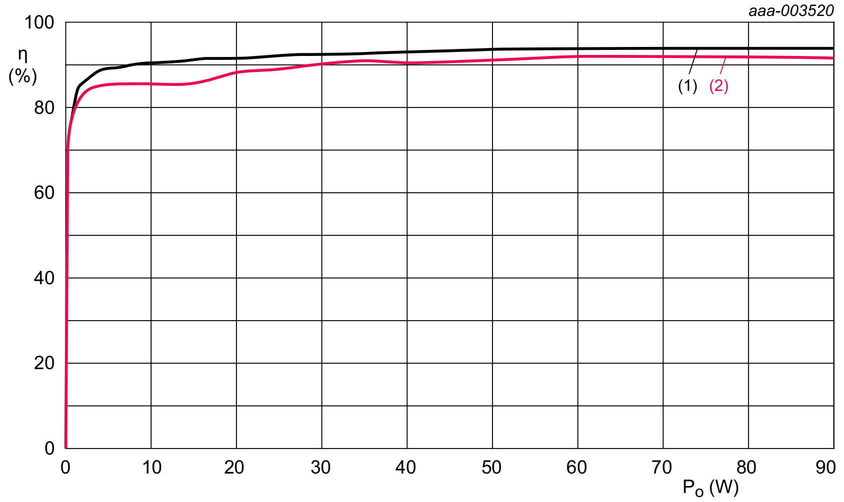
3.3 Efficiency

3.3.1 Efficiency characteristics

Efficiency measurements were made measuring the output voltage on the board (not taking into account the losses in an output connection cable).

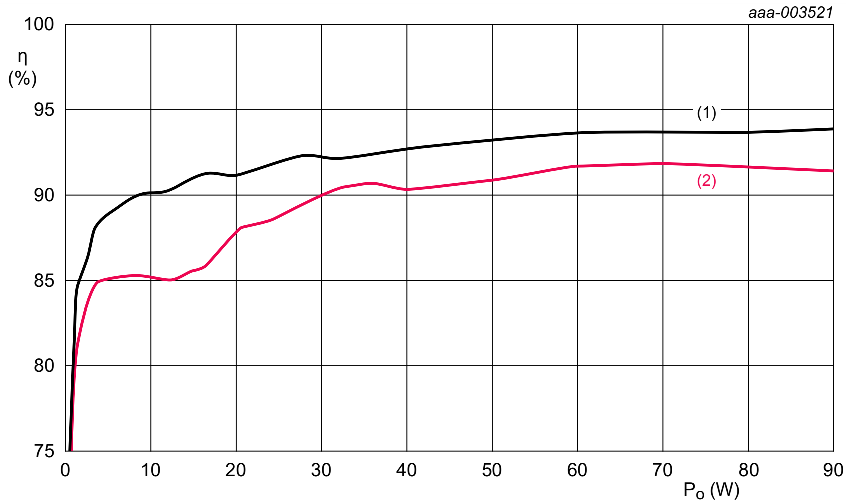
Table 3. Efficiency results

Condition	Energy star 2.0 efficiency requirement (%)	Efficiency (%)				
		Average	25 % load	50 % load	75 % load	100 % load
100 V; 60 Hz	> 87	90.7	88.5	90.8	91.8	91.5
230 V; 50 Hz	> 87	93.2	91.8	93.2	93.8	93.8



(1) V_{mains} = 230 V
(2) V_{mains} = 100 V

a. Efficiency as a function of output power (range 0 % to 100 %)



(1) V_{mains} = 230 V
(2) V_{mains} = 100 V

b. Efficiency as a function of output power (range 75 % to 100 %)

Fig 5. Efficiency as a function of output power

3.3.2 Power Factor Correction (PFC)

Table 4. Power factor correction

Condition	Energy Star 2.0 requirement	Output power (W)	Power factor
90 V; 60 Hz	-	90	0.99
100 V; 60 Hz	-	90	0.99
115 V; 60 Hz	≥ 0.9	90	0.98
230 V; 50 Hz	-	90	0.91
264 V; 50 Hz	-	90	0.88

3.3.3 No-load power consumption

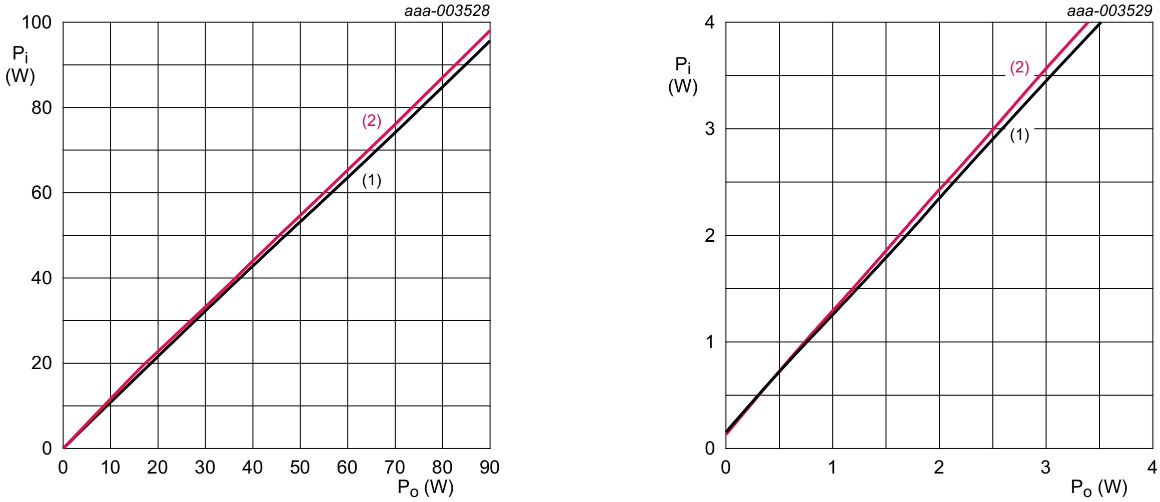
Table 5. Output voltage and power consumption at no-load

Condition	Energy Star 2.0 requirement (mW)	Output voltage (V)	No load power consumption (mW)
90 V; 60 Hz	≤ 500	19.5	140
100 V; 60 Hz	≤ 500	19.5	140
115 V; 60 Hz	≤ 500	19.5	140
230 V; 50 Hz	≤ 500	19.5	170
264 V; 50 Hz	≤ 500	19.5	170

3.3.4 Standby load power consumption

Table 6. Output voltage and power consumption in standby

Condition	Output voltage (V)	Power consumption (mW)
Output power = 250 mW		
90 V; 60 Hz	19.5	430
100 V; 60 Hz	19.5	430
115 V; 60 Hz	19.5	430
230 V; 50 Hz	19.5	445
264 V; 50 Hz	19.5	445



a. Full output power range (0 W to 90 W)

b. Enlargement of the low output power part of the characteristics

(1) V_{mains} = 100 V

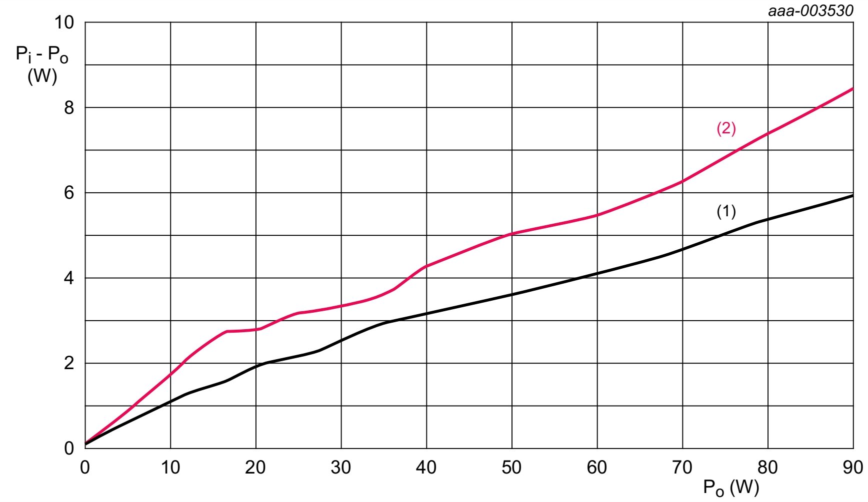
(2) V_{mains} = 230 V

Fig 6. Power consumption as a function of input power

3.4 Burst mode operation

Burst mode operation is implemented. It improves the performance at low output load, so no-load and standby power consumption requirements (see Section 3.3.3 and Section 3.3.4) can be achieved. The converter operates at less than approximately 30 W output power in burst mode. Between 30 W and 50 W output power the burst mode is triggered temporarily because of the ripple on the PFC output voltage.

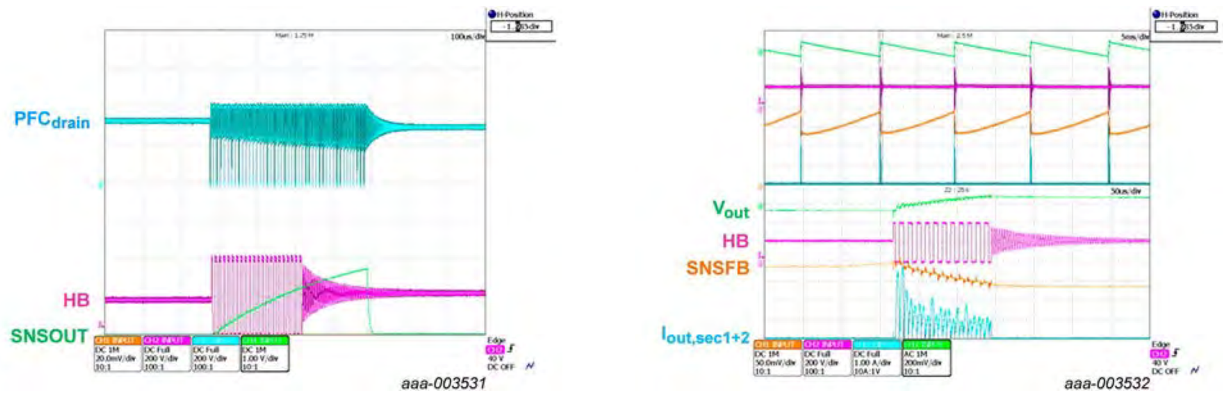
Without burst mode operation, the power supply consumes approximately 2 W at no-load output.



(1) V_{mains} = 100 V

(2) V_{mains} = 230 V

Fig 7. Reduction of power losses by burst mode operation at low output power



a. PFC continues switching until regulation level is reached

b. Output voltage ripple and current to the output

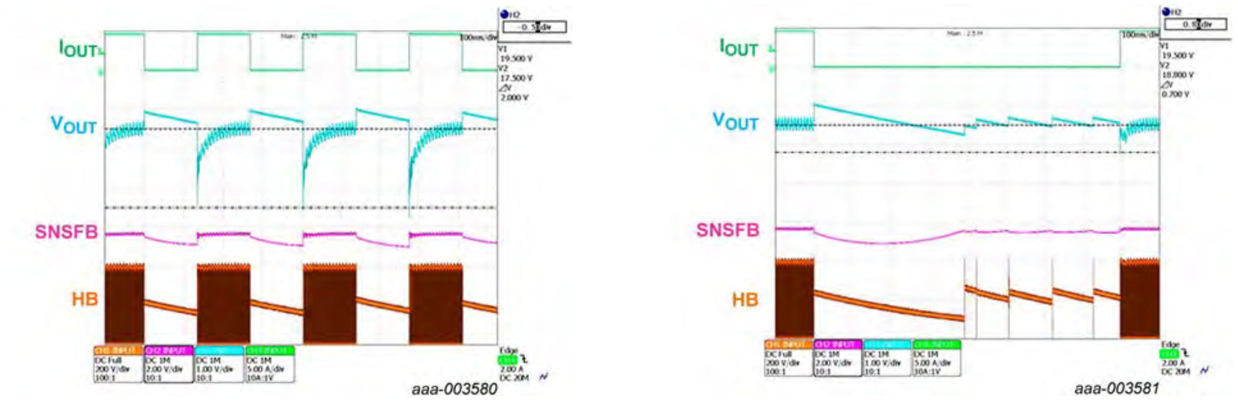
Fig 8. Burst mode operation

The interruptive character of burst mode can lead to the generation of unwanted audible noise. Because the system only operates in burst mode at low-power levels, audible noise levels are low.

3.5 Transient response

Normal load transients lead to a ripple on the output voltage ≤ 750 mV.

When a worse case timing sequence is applied, the voltage drop can be 2 V (–10 %).



a. Worse case test sequence

b. Normal case test sequence

Fig 9. Behavior of output current load step (0 - nominal) sequences: burst mode - normal mode

3.6 OverPower Protection (OPP)

Tested with a higher current (dynamic overload) on the output voltage, the OPP is activated when the current exceeds 6.3 A (123 W). This corresponds with a load condition that is 35 % higher than the rated power for continuous use. The SNSCURHBC function of the TEA1716T which monitors the primary resonant current detects the OPP. When the voltage on the SNSCURHBC pin exceeds 0.5 V (or –0.5 V), the protection timer is started.

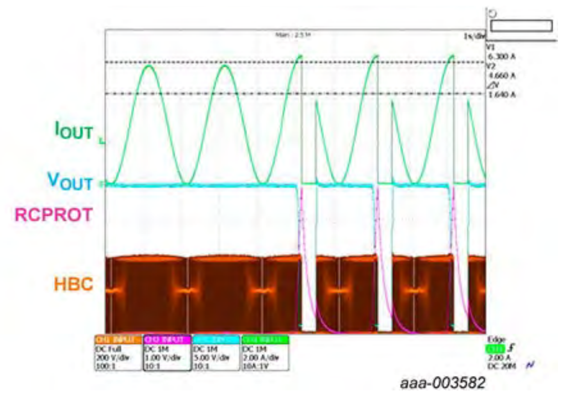


Fig 10. Overpower protection

In some test conditions, another protection function can be triggered to initiate a restart (for example the SUPIC_UVP, see Section 3.8).

3.7 Hold-up time

The output is set to full load and the mains supply voltage of 100 V disconnected. The time that passes before the output voltage falls below 90 % of its initial value, is measured. The hold-up time is 32 ms.

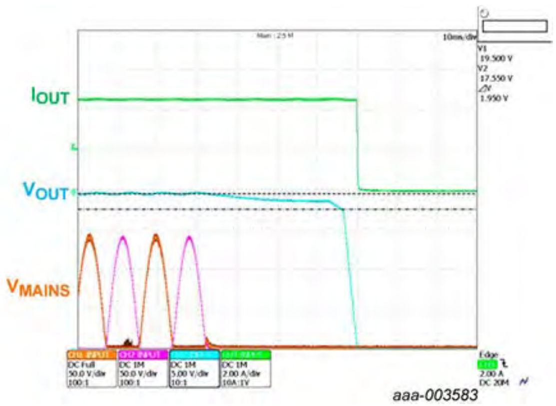


Fig 11. Hold-up time at V_{mains} = 100 V and nominal load

3.8 Short circuit protection

A short circuit on the output of the resonant converter causes the primary current to increase. The SNSCURHBC function detects the increase. It leads to running on a higher frequency (OCR) until the protection timer RCPROT reaches its protection level (4 V). The RCPROT function performs its restart timer function and restarts when the voltage has dropped to 0.5 V. When the short circuit situation is resolved, the converter starts up and runs normally again.

While SNSCURHBC is running in OCR, it reduces the amount of primary current. This reduction leads to a limited output current and voltage. It also affects the auxiliary supply that provides the supply voltage for the TEA1716T. In this demo board, the voltage drop on SUPIC reaches the UVP level (13 V) before the protection timer RCPROT has reached 4 V. The SUPIC-UVP function initiates the restart.

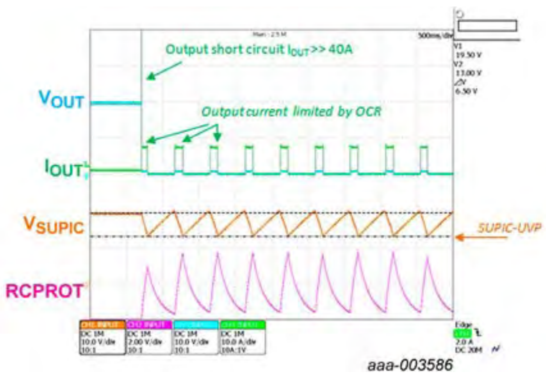
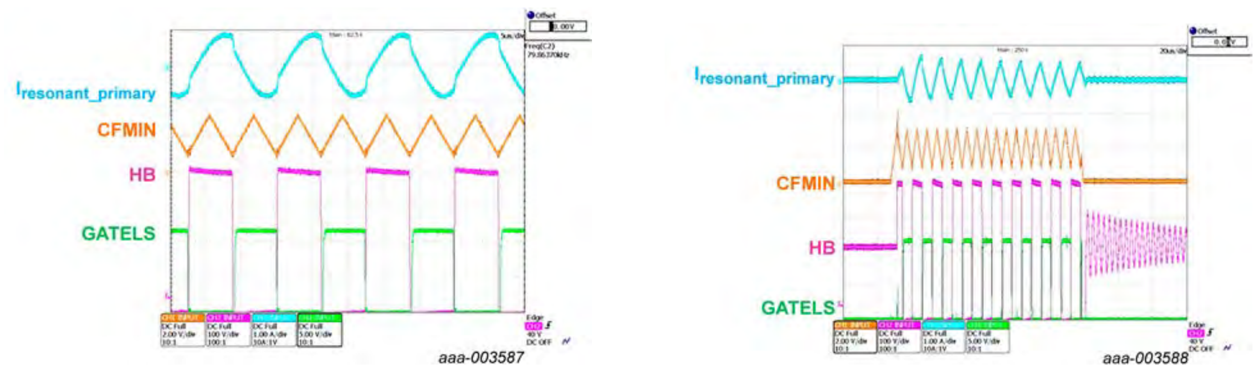


Fig 12. Protection and restart at output short circuit

3.9 Resonant switching



a. Normal operation at nominal output power

b. Burst mode operation at 250 mW output power

Fig 13. Resonant switching at primary side

4. Circuit diagram

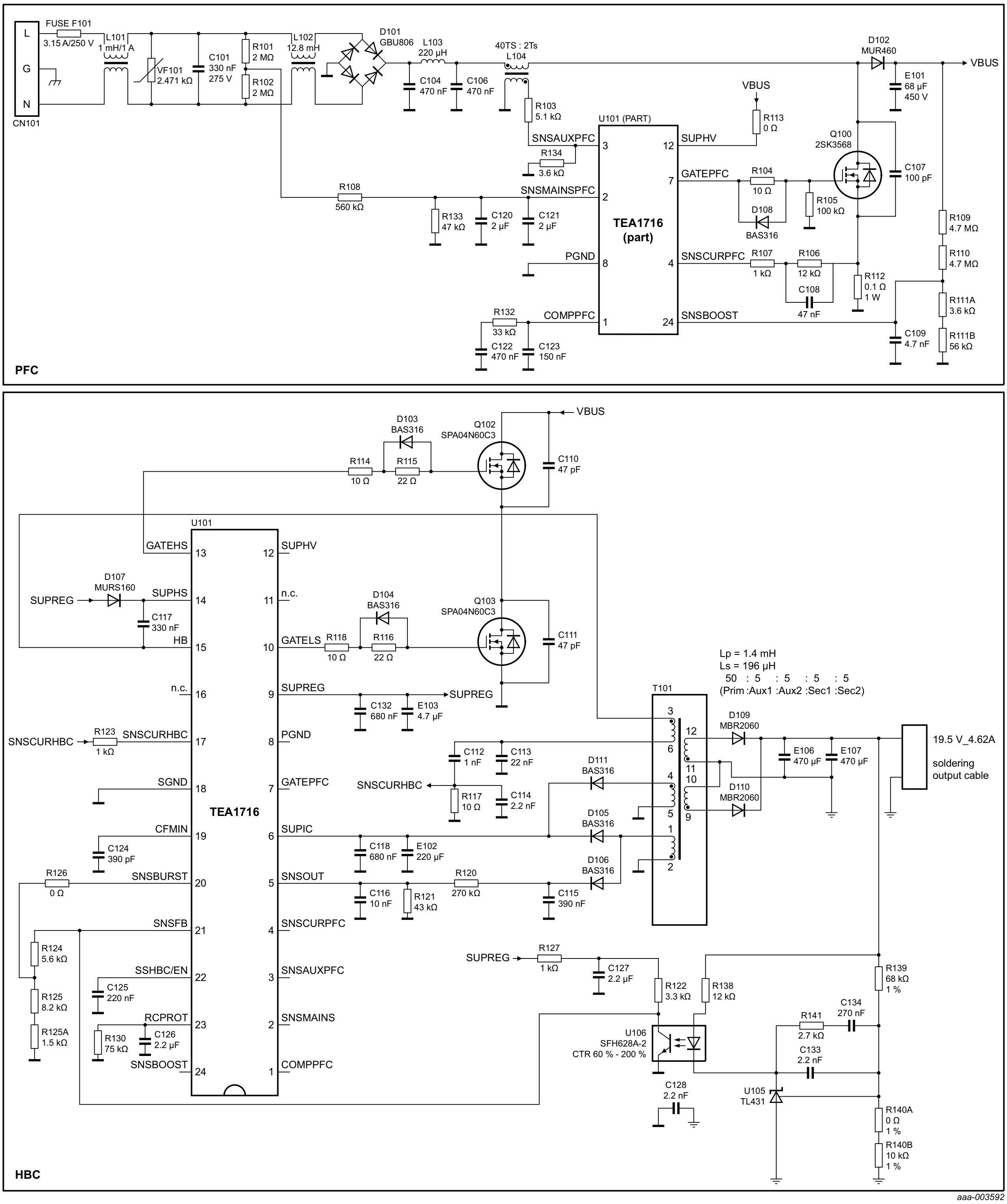


Fig 14. Circuit diagram TEA1716T 90 W evaluation board

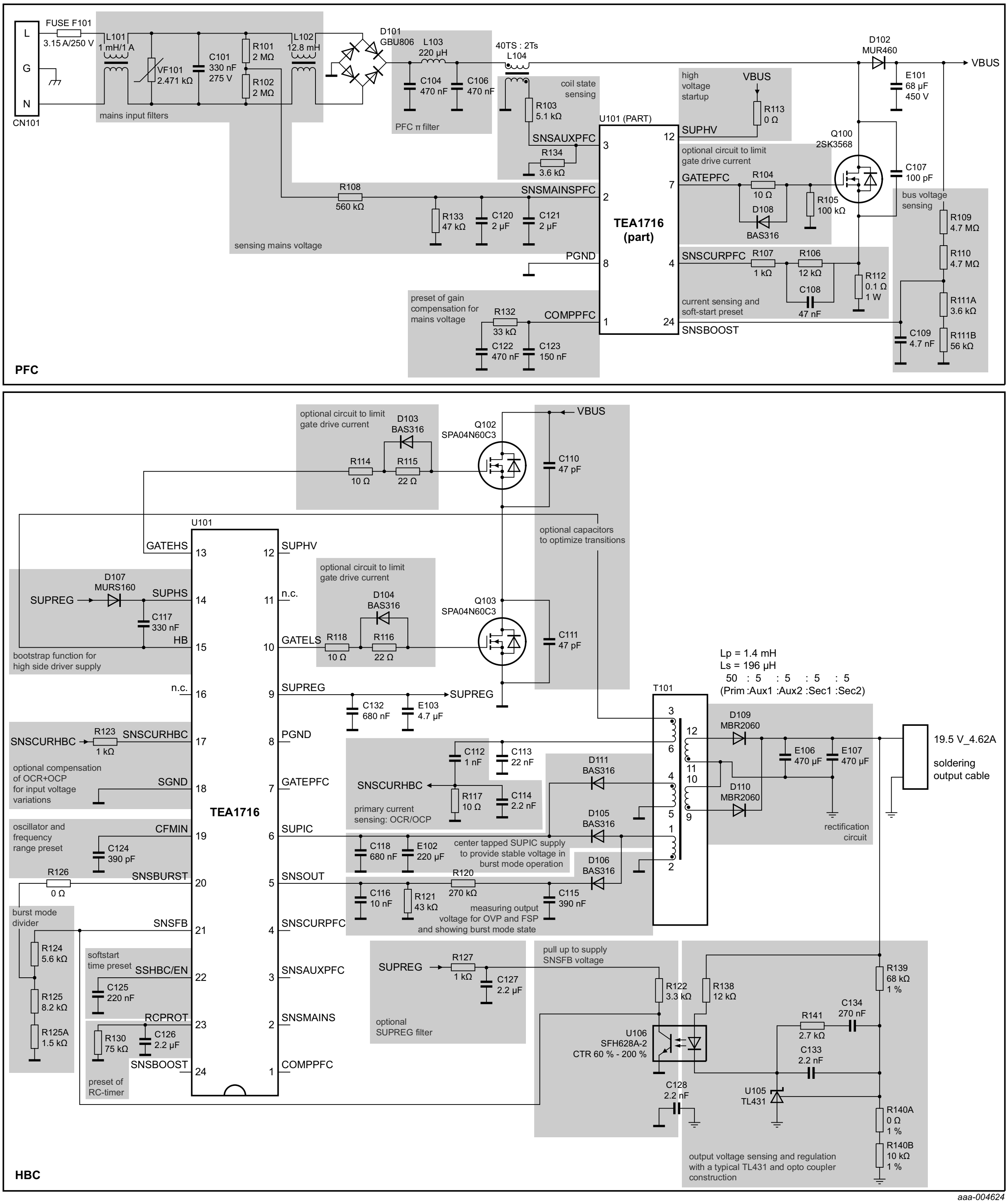
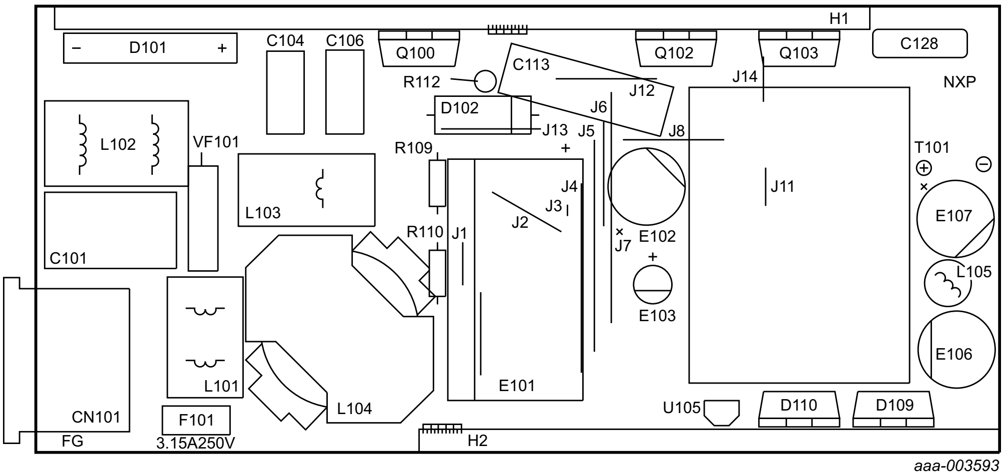
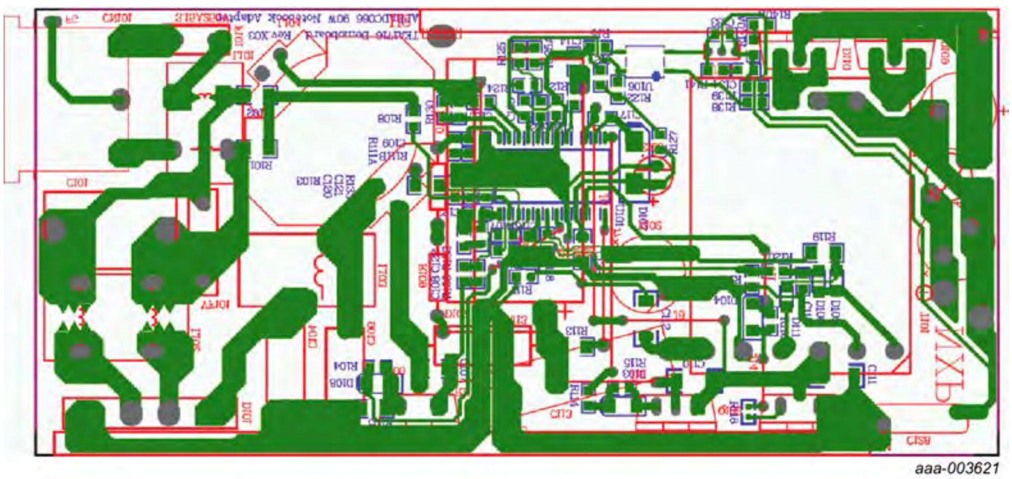


Fig 15. Circuit diagram TEA1716T 90 W evaluation board with comments

5. PCB layout



a. Components top view



b. Copper tracks and components bottom view (in blue) and components on top (in red)

Fig 16. Evaluation board PCB layout

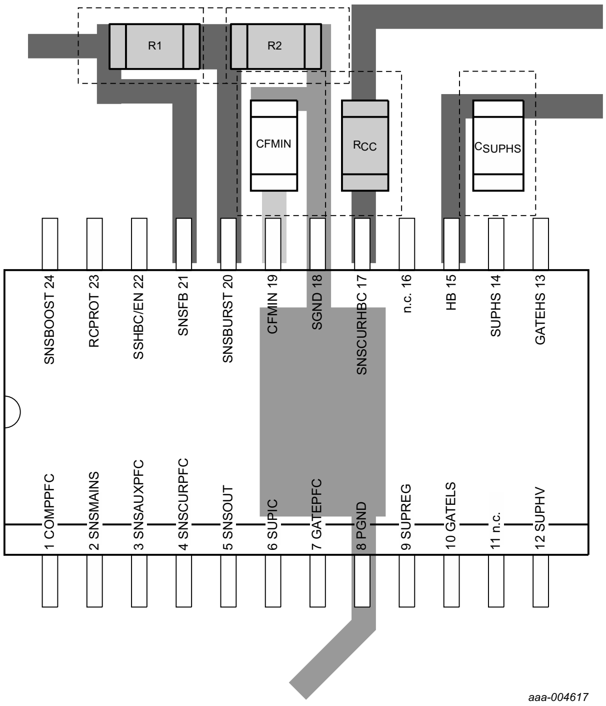


Fig 17. Layout area near CFMIN pin: Advice from *AN11179, "TEA1716 resonant power supply control IC with PFC"*

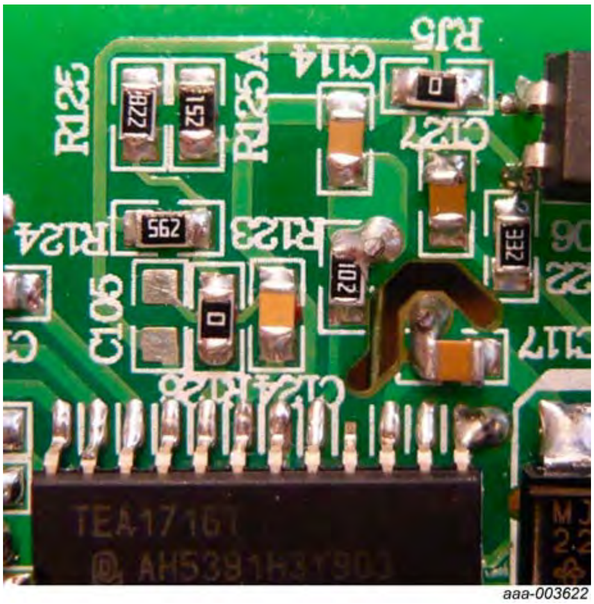


Fig 18. Layout area near CFMIN pin: Practical implementation in the demo board

6. Bill Of Materials (BOM)

Table 7. Bill of materials

Reference	Description and values	Part number	Manufacturer
C101	x-capacitor; 330 nF; 275 V; RAD0.6H	-	-
C104	thin film capacitor; 0.47 μF; 450 V; rad0.4V	-	-
C105	ceramic capacitor; 805	-	-
C106	thin film capacitor; 0.47 μF; 450 V; rad0.4V	-	-
C107	ceramic capacitor; 100 pF; 1 kV; 1206	-	-
C108	ceramic capacitor; 47 nF; 50 V; 805	-	-
C109	ceramic capacitor; 4.7 nF; 50 V; 805	-	-
C110	ceramic capacitor; 47 pF; 1 kV; 1206	-	-
C111	ceramic capacitor; 47 pF; 1 kV; 1206	-	-
C112	ceramic capacitor; 1 nF; 1 kV; 1206	-	-
C113	thin film capacitor; 22 nF; 1 kV; RAD0.6(0.8)-3P	-	-
C114	ceramic capacitor; 2.2 nF; 16 V; 805	-	-
C115	ceramic capacitor; 390 nF; 50 V; 805	-	-
C116	ceramic capacitor; 10 nF; 16 V; 1206	-	-
C117	ceramic capacitor; 330 nF; 50 V; 805	-	-
C118	ceramic capacitor; 680 nF; 50 V; 805	-	-
C120	ceramic capacitor; 2 μF; 50 V; 805	-	-
C121	ceramic capacitor; 2 μF; 50 V; 805	-	-
C122	ceramic capacitor; 470 nF; 16 V; 805	-	-
C123	ceramic capacitor; 150 nF; 16 V; 805	-	-
C124	ceramic capacitor; 390 pF; 16 V; 805	-	-
C125	ceramic capacitor; 220 nF; 16 V; 805	-	-
C126	ceramic capacitor; 2.2 μF; 16 V; 805	-	-
C127	ceramic capacitor; 2.2 μF; 16 V; 805	-	-
C128	Y1-capacitor; 2.2 nF; C10(0.6)-1F	-	-
C132	ceramic capacitor; 680 nF; 16 V; 1206	-	-
C133	ceramic capacitor; 2.2 nF; 16 V; 805	-	-
C134	ceramic capacitor; 270 nF; 16 V; 805	-	-
CN101	connector; 3.96X5	ST-A04-001JT6T4	-
D101	diode bridge	GBU806	Diodes
D102	diode; diode0.7	MUR460	Vishay
D103	diode; sc-76	BAS316	-
D104	diode; sc-76	BAS316	-
D105	diode; sc-76	BAS316	-
D106	diode; sc-76	BAS316	-
D107	diode; SMB	MURS160	Vishay
D108	diode; sc-76	BAS316	-
D109	diode; TO-220	MBR2060	ON Semiconductors

Table 7. Bill of materials *…continued*

Reference	Description and values	Part number	Manufacturer
D110	diode; TO-221	MBR2060	ON Semiconductors
D111	diode; sc-76	BAS316	-
E101	electrolytic capacitor; 68 μF; 450 V; EC16/8H	-	-
E102	electrolytic capacitor; 220 μF; 35 V; RB.1/.2	-	-
E103	electrolytic capacitor; 4.7 μF; 16 V; RB.1/.2	-	-
E106	electrolytic capacitor; 470 μF; 35 V; EC5/10H	-	-
E107	electrolytic capacitor; 470 μF; 35 V; EC5/10H	-	-
F101	fuse; 3.15 A; 250 V; FUSH_1	-	-
H1	108 × 23 × 3	-	-
H2	80 × 23 × 3	-	-
J1	jumper; 6.8 mm	-	-
J2	jumper: 9.2 mm	-	-
J3	jumper; 2.9 mm	-	-
J4	jumper; 31 mm	-	-
J5	jumper; 28 mm	-	-
J6	jumper; 31 mm	-	-
J7	jumper; 31 mm	-	-
J8	jumper; 15 mm	-	-
J9	jumper; 17.5 mm	-	-
J10	jumper; 20.9 mm	-	-
J11	jumper; 6.6 mm	-	-
J12	jumper; 13.9 mm	-	-
J13	jumper; 13.2 mm	-	-
J14	jumper; 6.6 mm	-	-
L101	common choke; 1 mH; 1 A; L0.2H	-	-
L102	common choke; 12.8 mH; L0.4	-	-
L103	inductor; 220 μH; EM1H	-	-
L104	PFC choke; RM8;	PFC_PQ2620	-
L105	jumper; 6.6 mm	-	-
Q100	MOSFET; TO-220H	2SK3568	Toshiba
Q102	MOSFET; TO-220H	SPA04N60C3	Infineon
Q103	MOSFET; TO-220H	SPA04N60C3	Infineon
R101	resistor; 2 MΩ; ±5 %; 1206	-	-
R102	resistor; 2 MΩ; ±5 %; 1206	-	-
R103	resistor; 5.1 kΩ; ±5 %; 1206	-	-
R104	resistor; 10 Ω; ±5 %; 805	-	-
R105	resistor; 100 kΩ; ±5 %; 1206	-	-
R106	resistor; 12 kΩ; ±5 %; 805	-	-
R107	resistor; 1 kΩ; ±5 %; 805	-	-

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

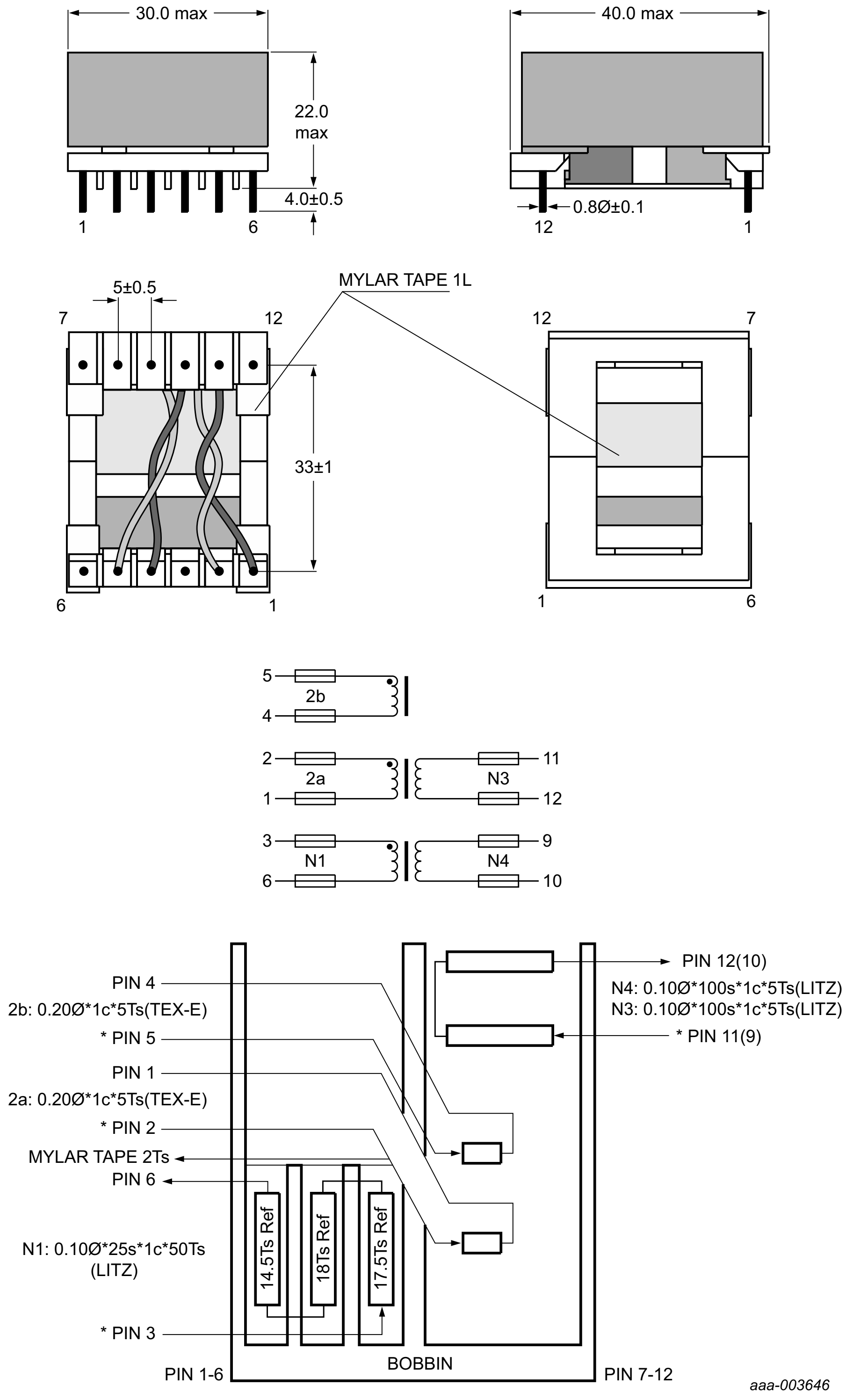
Reference	Description and values	Part number	Manufacturer
R108	resistor; 560 kΩ; ±5 %; 805	-	-
R109	resistor; 4.7 MΩ; ±1 %; axial0.4	-	-
R110	resistor; 4.7 MΩ; ±1 %; axial0.4	-	-
R111A	resistor; 3.6 kΩ; ±1 %; 805[1]	-	-
R111B	resistor; 56 kΩ; ±1 %; 805	-	-
R112	resistor; 100 mΩ; ±1 %; resV	-	-
R113	resistor; 0 Ω; 1206	-	-
R114	resistor; 10 Ω; ±5 %; 805	-	-
R115	resistor; 22 Ω; ±5 %; 805	-	-
R116	resistor; 22 Ω; ±5 %; 805	-	-
R117	resistor; 10 Ω; ±5 %; 805	-	-
R118	resistor; 10 Ω; ±5 %; 402	-	-
R119	resistor; 0 Ω; 1206	-	-
R120	resistor; 270 kΩ; 805	-	-
R121	resistor; 43 kΩ; 805	-	-
R122	resistor; 3.3 kΩ; 805	-	-
R123	resistor; 1 kΩ; 805	-	-
R124	resistor; 5.6 kΩ; 805	-	-
R125	resistor; 8.2 kΩ; 805	-	-
R125A	resistor; 1.5 kΩ; 805[1]	-	-
R126	resistor; 0 Ω; 805	-	-
R127	resistor; 1 kΩ; 805	-	-
R130	resistor; 75 kΩ; 805	-	-
R132	resistor; 33 kΩ; 805	-	-
R133	resistor; 47 kΩ; 805	-	-
R134	resistor; 3.6 kΩ; 805	-	-
R138	resistor; 12 kΩ; 805	-	-
R139	resistor; 68 kΩ; ±1 %; 805	-	-
R140A	resistor; 0 Ω; 805[1]	-	-
R140B	resistor; 10 kΩ; ±1 %; 805	-	-
R141	resistor; 2.7 kΩ; 805	-	-
RJ1	resistor; 0 Ω; 805	-	-
RJ2	resistor; 0 Ω; 805	-	-
RJ3	resistor; 0 Ω; 805	-	-
RJ4	resistor; 0 Ω; 805	-	-
RJ5	resistor; 0 Ω; 805	-	-

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

Reference	Description and values	Part number	Manufacturer
T101	transformer; TR2	LP-2920	Yujingtech
U101	IC; TEA1716T	SO-24	NXP Semiconductors
U105	IC; TL431BFDT	TO92/SOT54	NXP Semiconductors
U106	optocoupler; SMD	SFH628A-2	-
VF101	MOV; 2k471; rad0.4	-	-

[1] This value can be different in a batch of boards.

7. Appendix 1: Resonant transformer data



Dimensions are in millimeters (mm).

Fig 19. Resonant transformer LP-2920HA63

Table 8. Electrical specification
HP: 4284A ZENTECH: 3200B, 502A, F = 100 kHz, V = 1 V, at 25 °C

No	Start	Finish	Wire	Color	Turns	Inductance	DCR (mΩ)
L1	3	6	0.10 ∅ × 25 s × 1 ∅ (LITZ)	Y	50 ±0.5	1.4 mH ±10 %	334 max
L2a	2	1	0.20 ∅ × 1 ∅ (TEX-E)	Y	5 ±0.5	19.0 μH REF	250 max
L2b	5	4	0.20 ∅ × 1 ∅ (TEX-E)	Y	5 ±0.5	19.0 μH REF	250 max
L3	11	12	0.10 ∅ × 100 s × 1 ∅ (LITZ)	Y	5 ±0.5	12.0 μH REF	9 max
L4	9	10	0.10 ∅ × 100 s × 1 ∅ (LITZ)	Y	5 ±0.5	12.0 μH REF	9 max
Lk	3	6	0.10 ∅ × 25 s × 1 ∅ (LITZ)	Y	50 ±0.5	225 μH ±10 % at secondary short	

8. Appendix 2: PFC coil data

8.1 Transformer schematic diagram

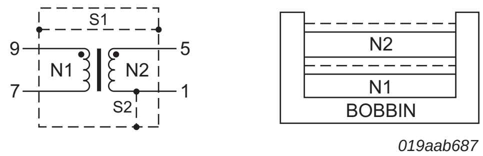


Fig 20. Transformer schematic diagram

8.2 Winding specification

Table 9. Winding specification

No	Pin		Wire	Turns	Winding method	Margin tape		Insulation	
	Start	Finish				Primary	Secondary	Turn	Width
N1	9	7	0.1 ∅ × 30	40	center	-	-	1	10 mm
N2	5	1	0.22 ∅ × 2	2	center	-	-	1	10 mm
S1	-	-	0.05 t × 14 mm	1	center	-	-	1	14 mm (S2)
S2	-	1	0.05 t × 14 mm	1	center	-	-	1	14 mm (S1)

8.3 Electrical characteristics

Table 10. Electrical characteristic

	Pins	Specification	Remarks
Inductance	9 to 7	250 μH ±10 %	60 kHz, 1 V
Leakage inductance	9 to 7	N/A	-

8.4 Core, bobbin and marking

Core and bobbin:

- Core: RM-10 (Ferroxcube RM/I or equivalent)
- Bobbin: RM-10 (12 pin, vertical type)
- Ae: 96.6 mm^2

Marking:

- PFC-APBADC015

9. Abbreviations

Table 11. Abbreviations

Acronym	Description
BCM	Boundary conduction Mode
CMP	Capacitive Mode Protection
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
FSP	Failed Start Protection
HBC	Half-Bridge resonant Converter
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
RMS	Root Mean Square
SOI	Silicon-On-Insulator
ZVS	Zero Voltage Switching

10. References

[1] **TEA1716T —** Data sheet: Resonant power supply control IC with PFC

[2] **AN11179 —** Application note: TEA1716 resonant power supply control IC with PFC

[3] **Calculation sheet —** http://www.nxp.com/technical_support/designportal/llc

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