

UM10450

TEA1713 demo board for 90 W notebook adapter

Rev. 1 — 11 April 2011

User manual

Document information

Info	Content
Keywords	TEA1713T, 90 W, notebook adapter, LLC, resonant, half-bridge, PFC, controller, converter, burst mode, power supply, demo board.
Abstract	<p>The TEA1713T includes a Power Factor Correction (PFC) controller as well as a controller for a Half-Bridge resonant Converter (HBC).</p> <p>This user manual describes a 90 W resonant switching mode power supply for a typical notebook adapter design based on the TEA1713T. The board 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.</p> <p>The efficiency at high power is well above 90 % and the no load power consumption is well below 500 mW.</p>



Revision history

Rev	Date	Description
v.1	20110411	first release

1. Introduction

1.1 Scope of this document

This document describes the 90 W notebook adapter demo board using the TEA1713T. A functional description is provided, supported by a set of measurements to show the notebook adapter characteristics.

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.

1.2 TEA1713T

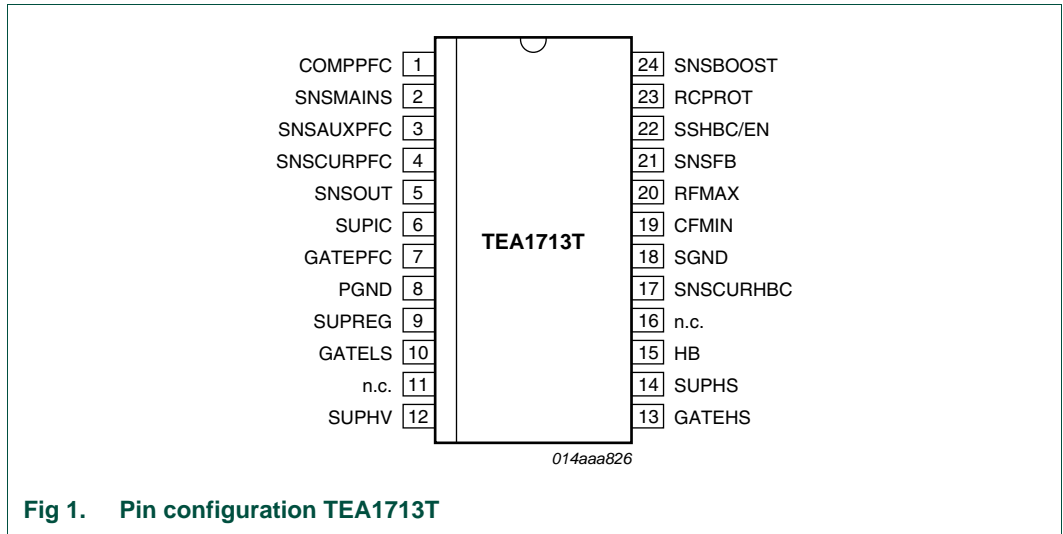
The TEA1713T integrates a controller for PFC and a controller for a HBC. It provides the drive function for the discrete MOSFET of the up-converter and for the two discrete power MOSFETs in a resonant half-bridge configuration.

The resonant controller part is a high voltage controller for a Zero Voltage Switching (ZVS) LLC resonant converter. It includes a high voltage level shift circuit and several protection features such as OverCurrent Protection (OCP), Open-Loop Protection (OLP), Capacitive Mode Protection (CMP) and a general purpose latched protection input.

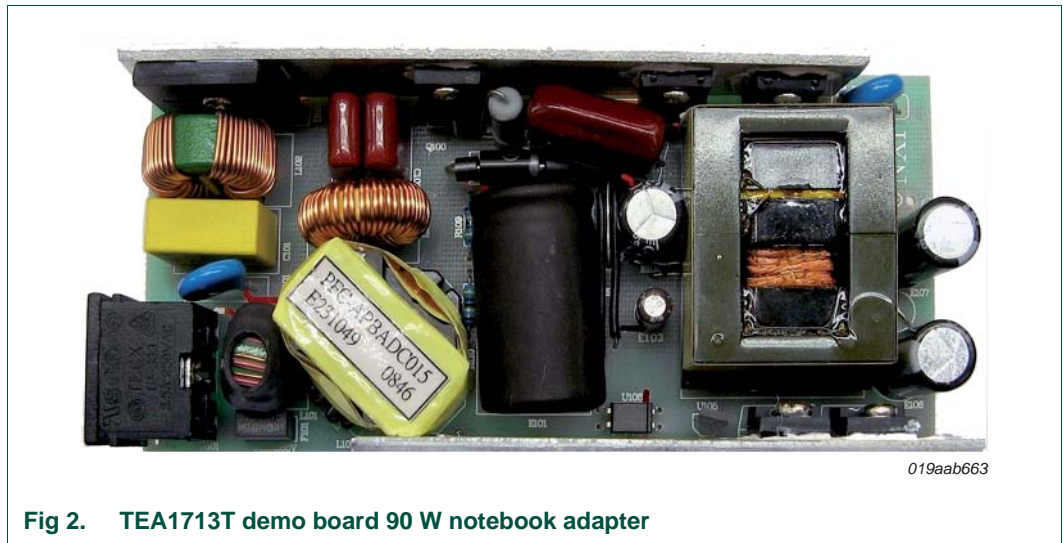
In addition to the resonant controller, the TEA1713T contains a PFC controller. The efficient operation of the PFC is obtained by functions such as quasi-resonant operation at high power levels and quasi-resonant operation with valley skipping at lower power levels. OCP, OverVoltage Protection (OVP) and demagnetization sensing, ensures safe operation in all conditions.

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

The combination of PFC and a resonant controller in one IC makes the TEA1713T very suitable for notebook adapters.



1.3 Setup of the 90 W notebook adapter



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

The demo board contains two sub-circuits:

- A PFC of BCM-type
- A HBC of resonant LLC-type

Both converters are controlled by the TEA1713T.

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

The purpose of the demo board is to demonstrate the operation of the TEA1713T in a single output supply including burst mode operation. The performance is according today's general standards 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
$P_{i(\text{no load})}$	no load input power	230 V, 50 Hz	< 500	mW

Table 2. Output data

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

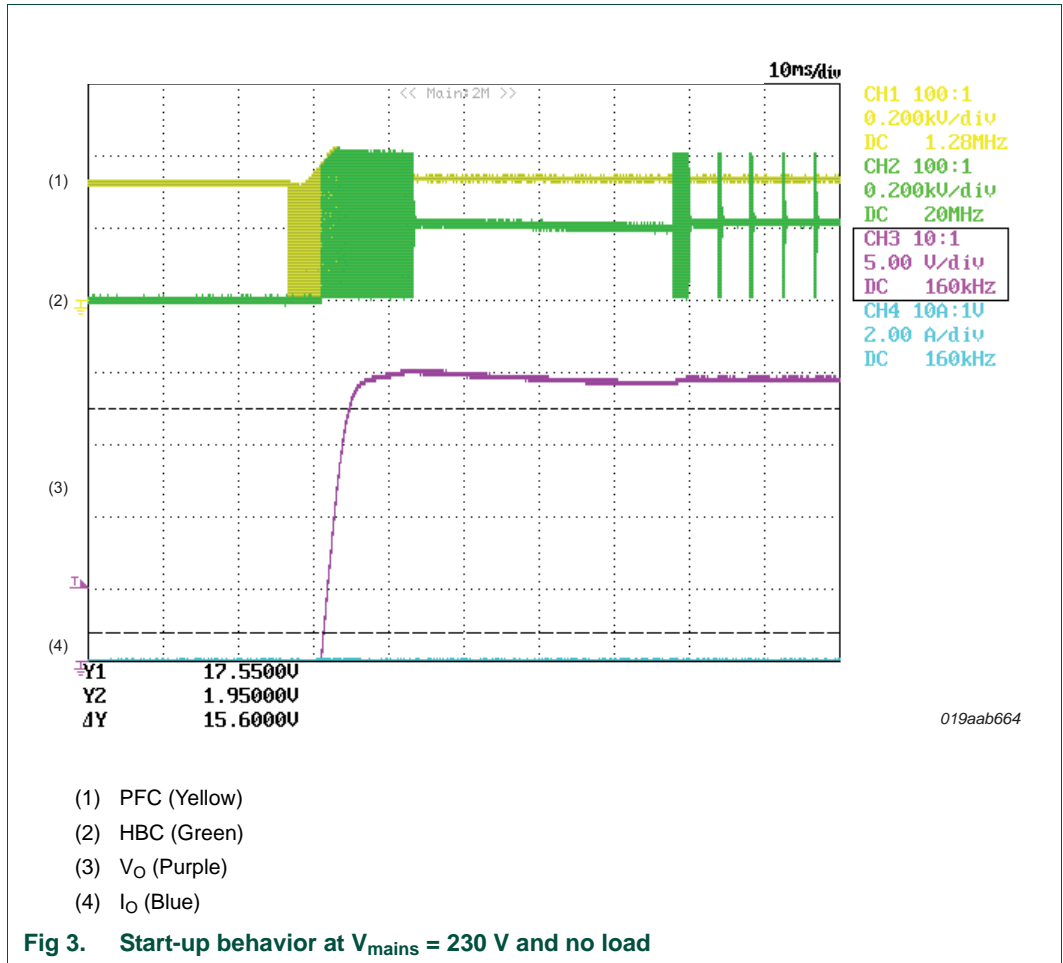
2. Measurements

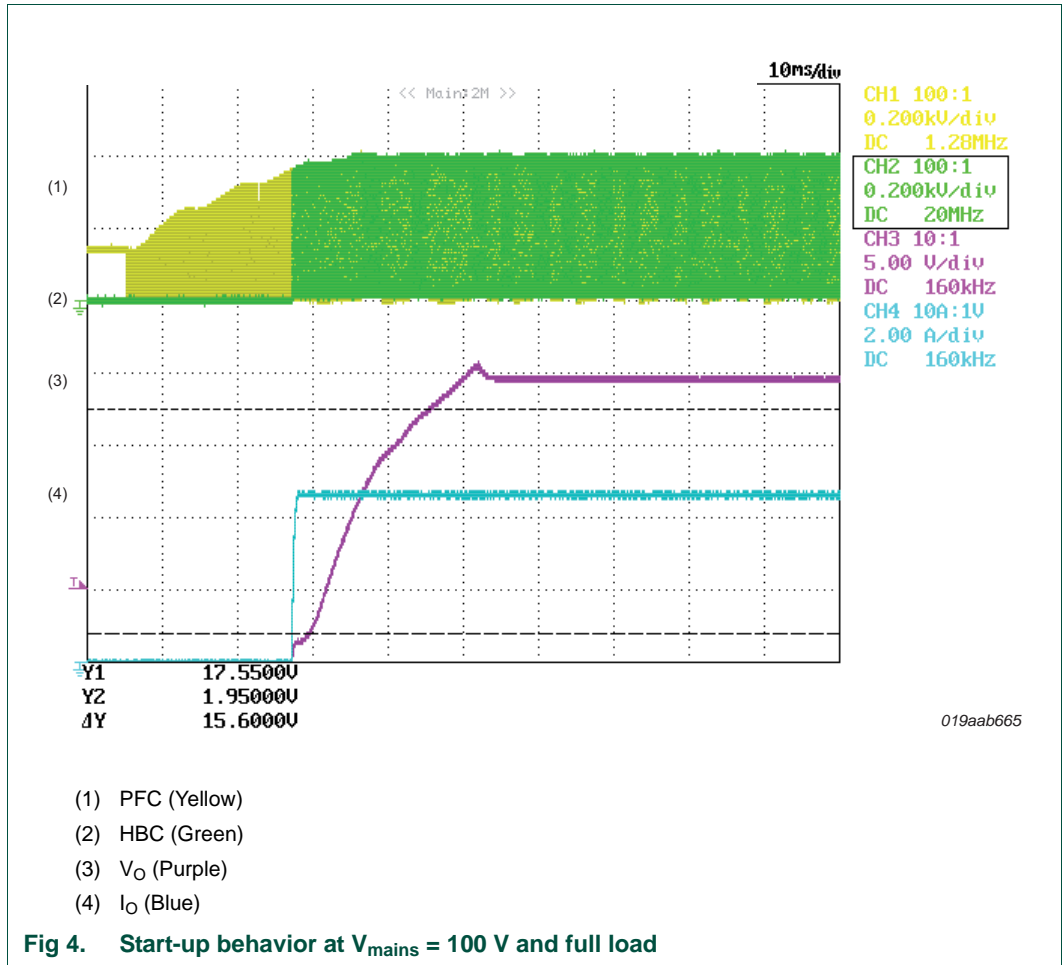
2.1 Test facilities

- Oscilloscope: Yokogawa DL1640L
- AC power source: Agilent 6812B
- Electronic load: Agilent 6063B
- Digital power meter: Yokogawa WT210

2.2 Start-up behavior

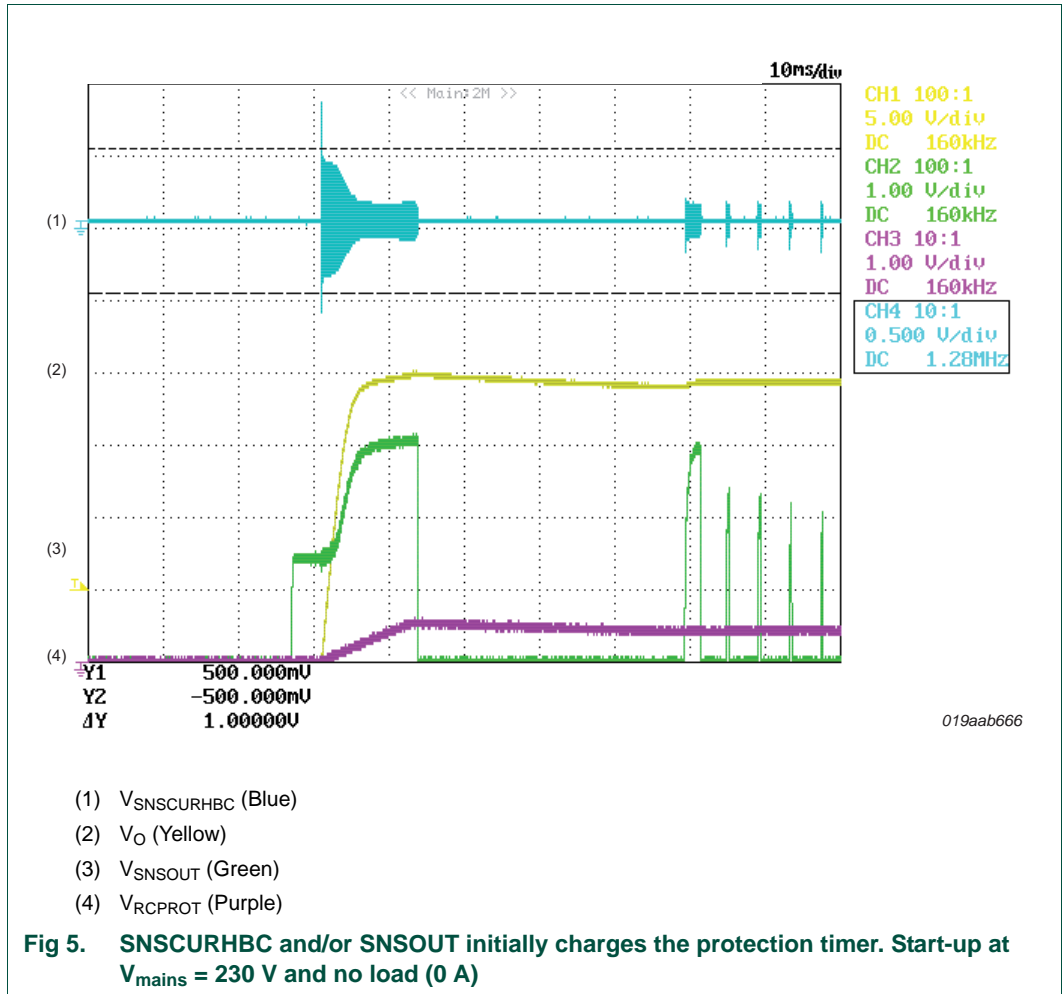
The rise time of the output voltage (measured from 10 % to 90 % point of the nominal output) is between 3 ms to 15 ms, depending on the output current load.

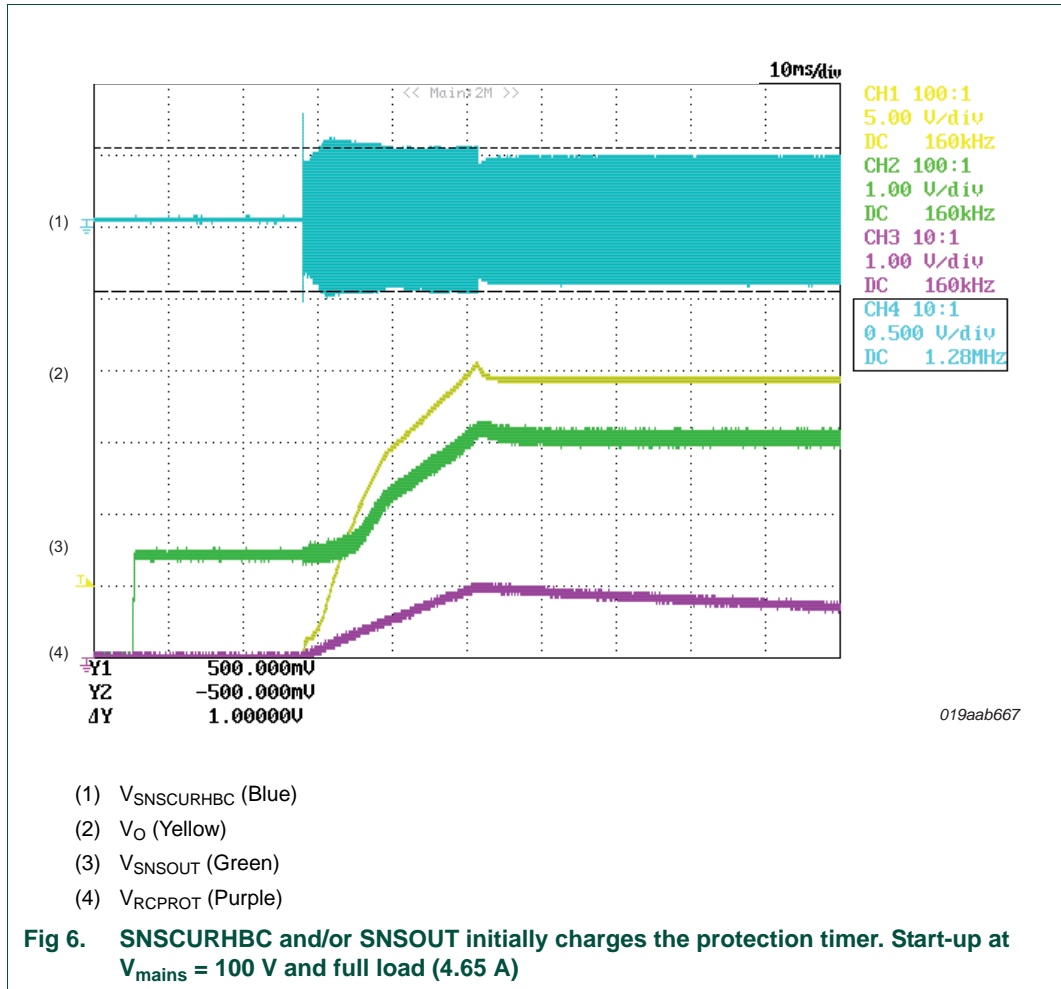




2.3 Protection levels on SNSCURHBC and SNSOUT during start-up

During start-up the voltage at pin RCPROT (protection timer) always rises. SNSCURHBC detects the initial high primary current and SNSOUT starts at a low voltage. After the first switching cycles the levels become normal for operation and the charging of RCPROT ends. The voltage level on RCPROT now decreases to zero again by the external discharge resistor that is part of the RCPROT system. During normal start-up the initial charging of RCPROT must not trigger a protection (4 V level).





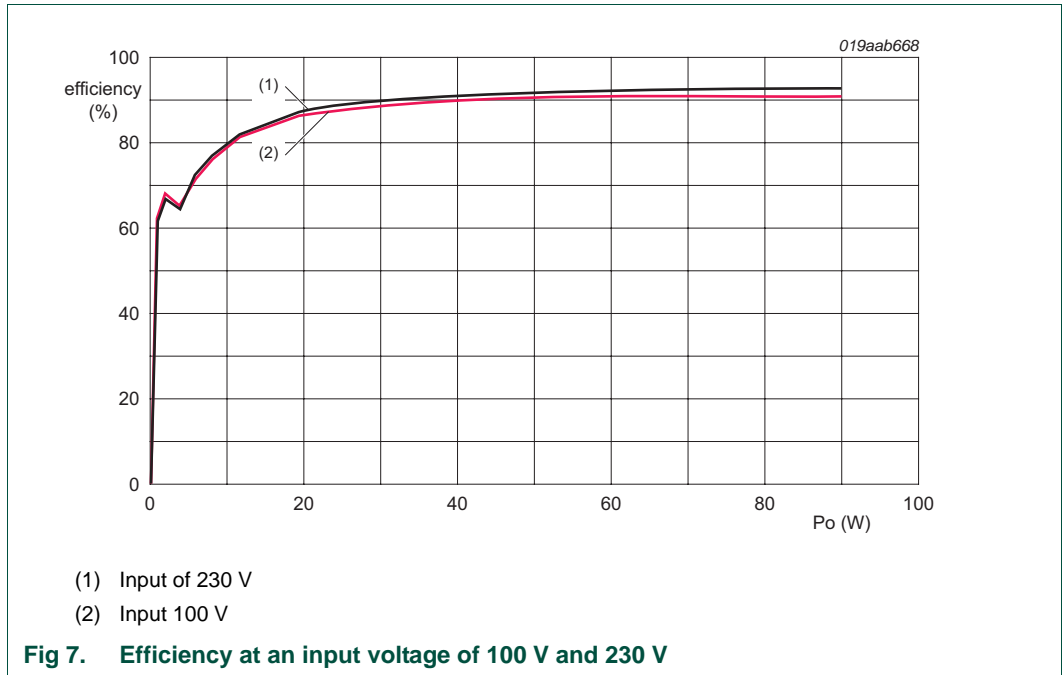
2.4 Efficiency

2.4.1 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

Conditions	Energy star 2.0 efficiency requirement (%)	Efficiency (%)				
		Average	25 % load	50 % load	75 % load	100 % load
100 V, 60 Hz	> 87	90.0	87.5	90.4	91.1	91.1
230 V, 50 Hz	> 87	91.2	88.1	91.5	92.6	92.5



2.4.2 Power Factor Correction (PFC)

Table 4. Power Factor correction (PFC)

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	0.89

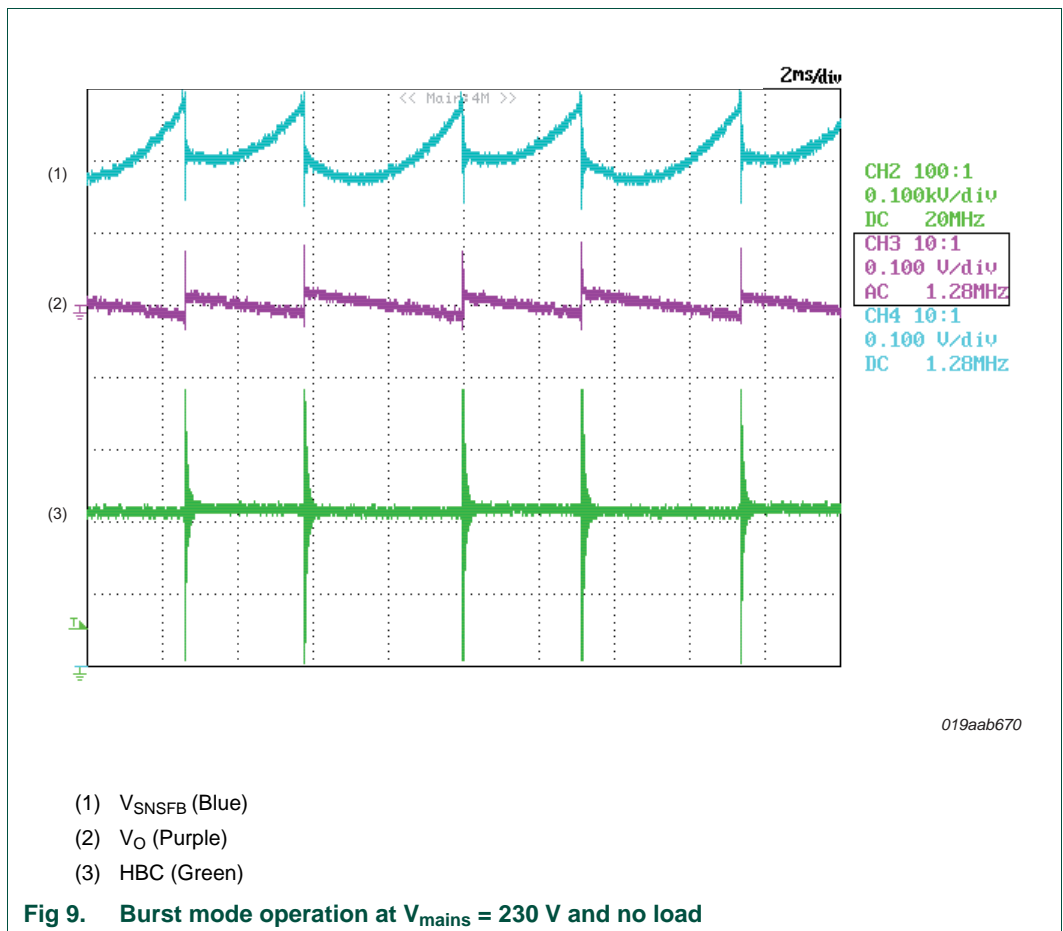
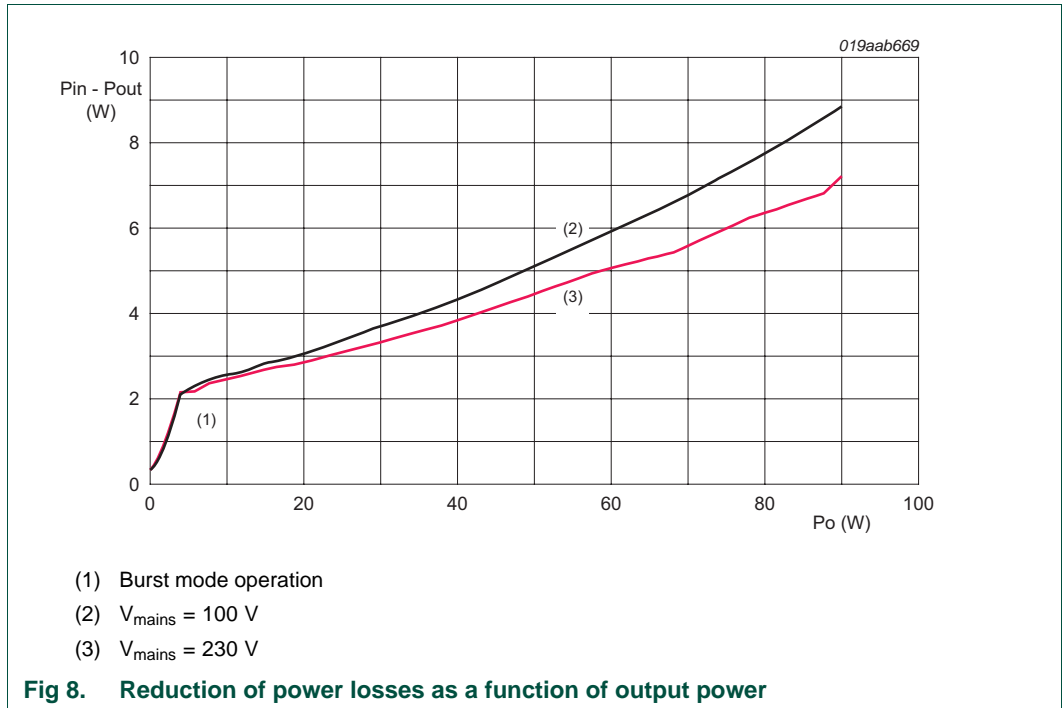
2.4.3 No load power consumption

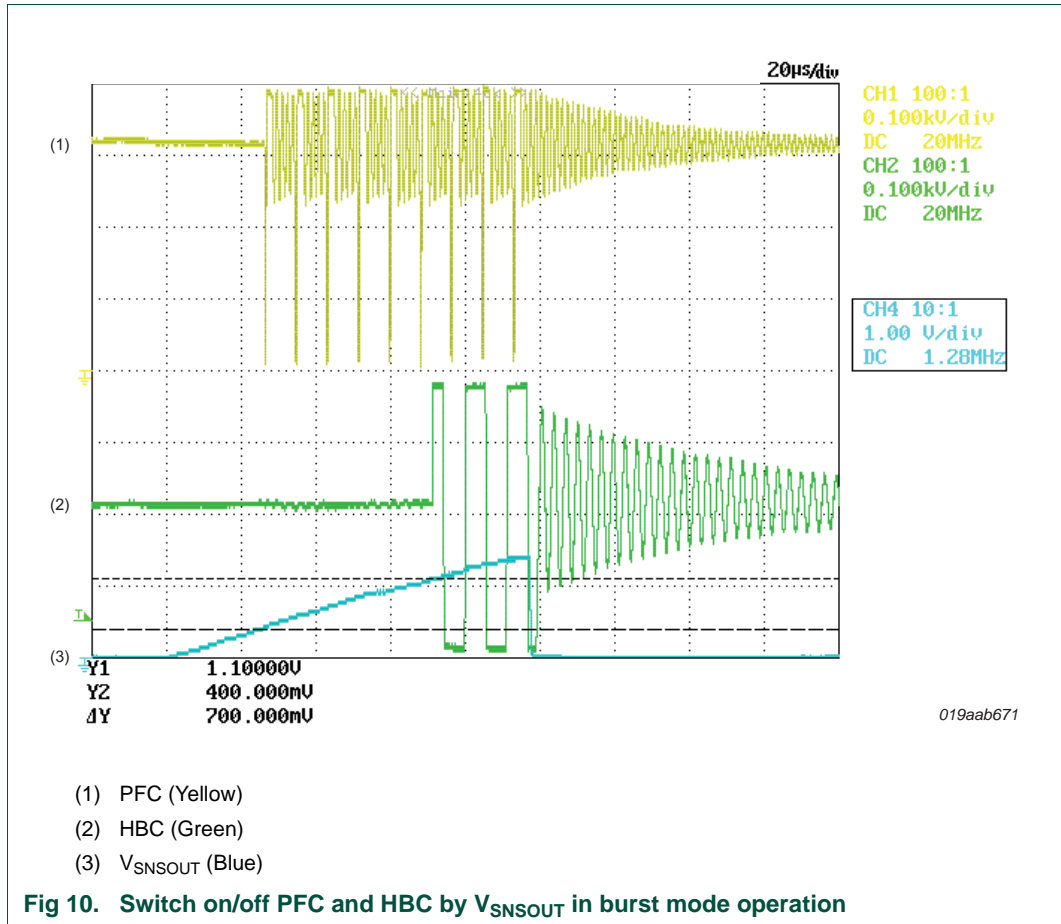
Table 5. Output voltage and power consumption at no load

Condition	Energy Star 2.0 requirement (mW)	Output voltage (V)	No load power consumption (mW)
90 V, 60 Hz	≤ 500 mW	19.5	340
100 V, 60 Hz	≤ 500 mW	19.5	340
115 V, 60 Hz	≤ 500 mW	19.5	340
230 V, 50 Hz	≤ 500 mW	19.5	380
264 V, 50 Hz	≤ 500 mW	19.5	385

2.5 Behavior in burst mode operation

In order to reach the no load power consumption requirements (see [Section 2.4.3](#)), burst mode operation is implemented to improve the performance at low output load. For the demo board burst mode is active below approximately 5 W output power.

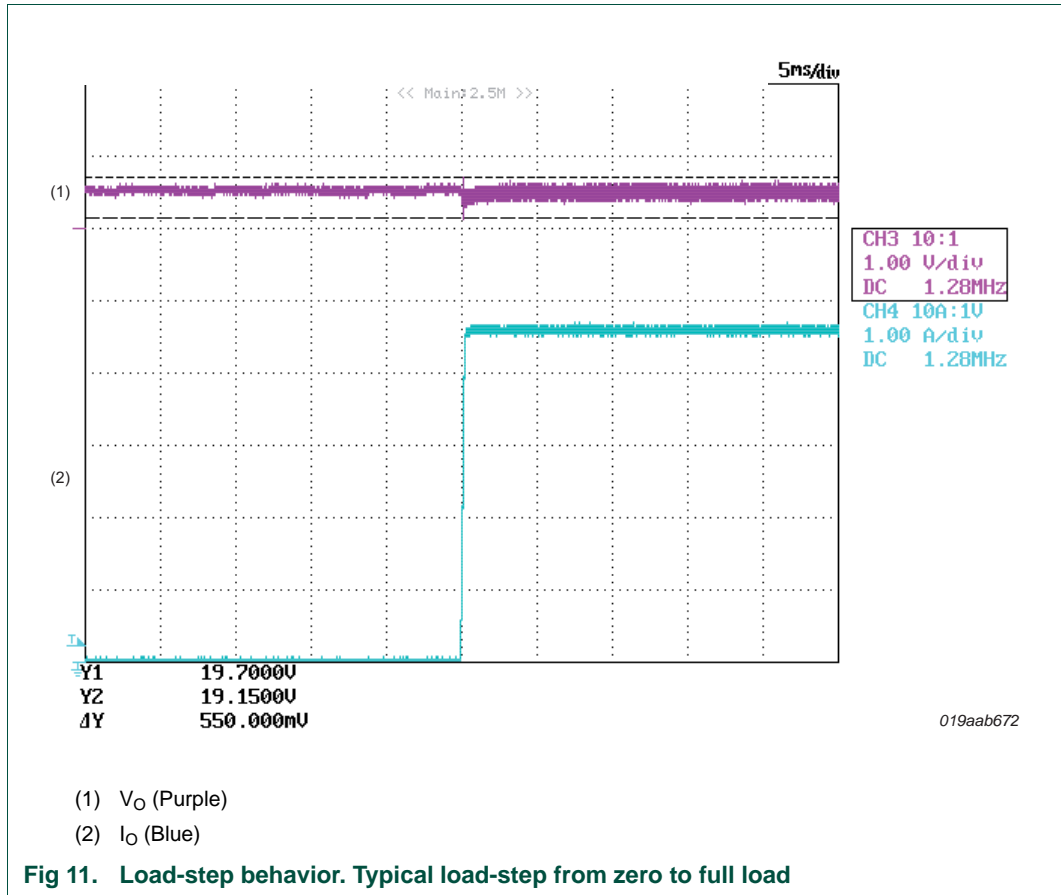




The interruptive character of burst mode can lead to the generation of unwanted audible noise. As the supply in burst mode only operates at low power levels, audible noise levels are low.

2.6 Transient response

Normal load transients lead to a ripple on the output voltage of < 550 mV.



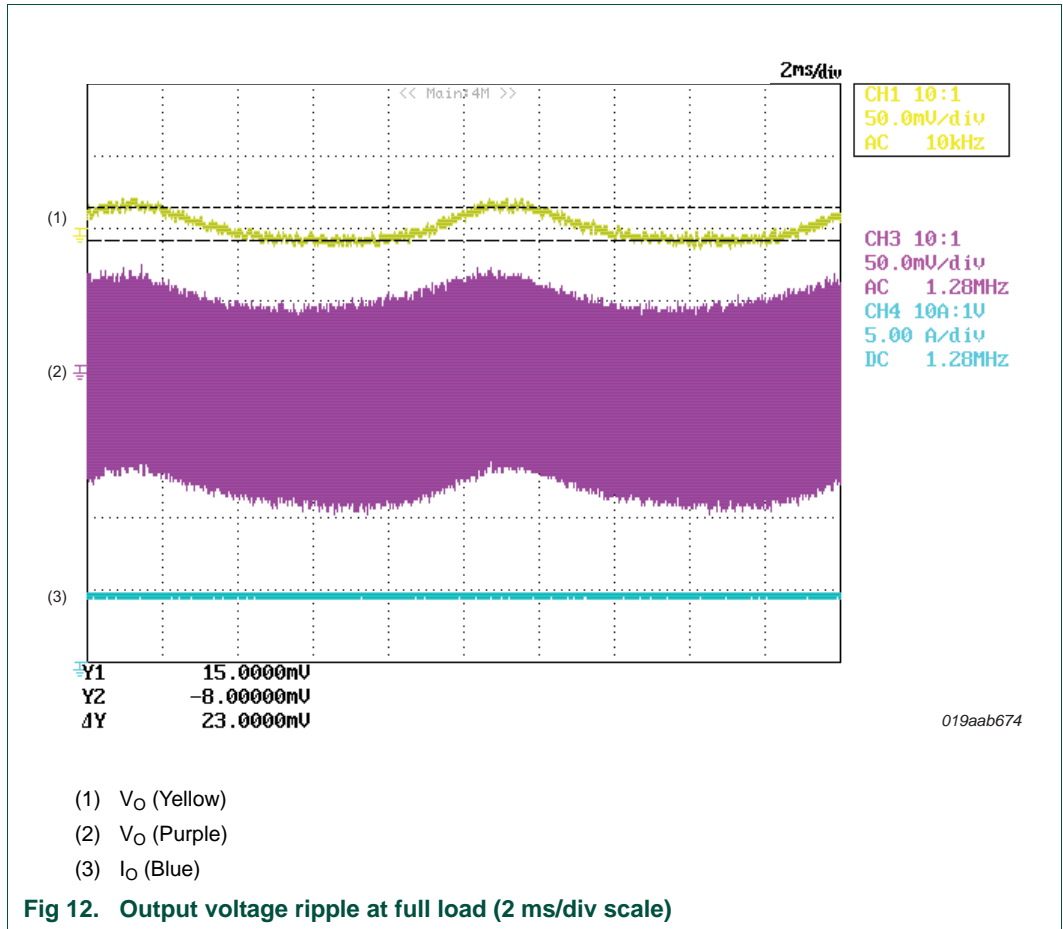
2.7 Output ripple voltage and noise

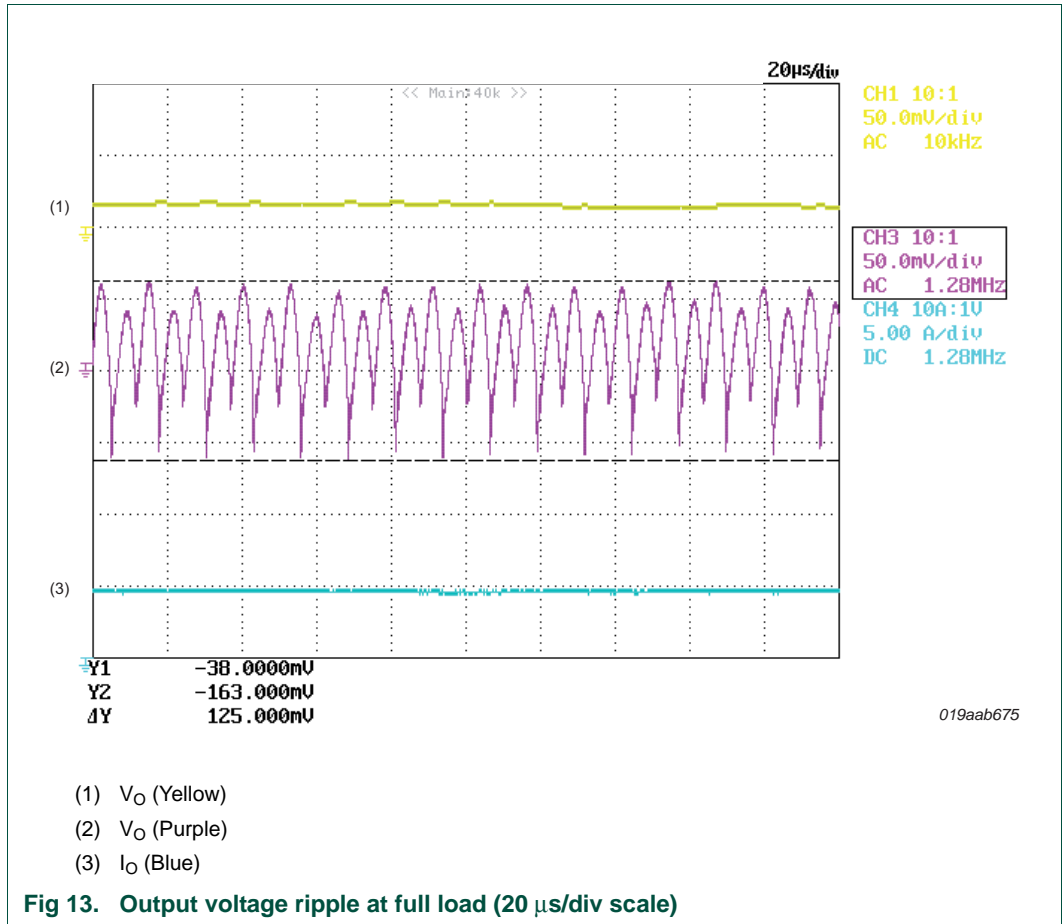
Ripple and noise are measured at full output load, buffered with a 10 μF capacitor in parallel with a high-frequency 0.1 μF capacitor.

The varying input voltage of the resonant converter causes a frequency component in the output ripple voltage that is related to the mains voltage frequency: 50 Hz or 60 Hz. The switching frequency of the resonant converter causes the other component in the output ripple voltage.

Table 6. Ripple and noise test results

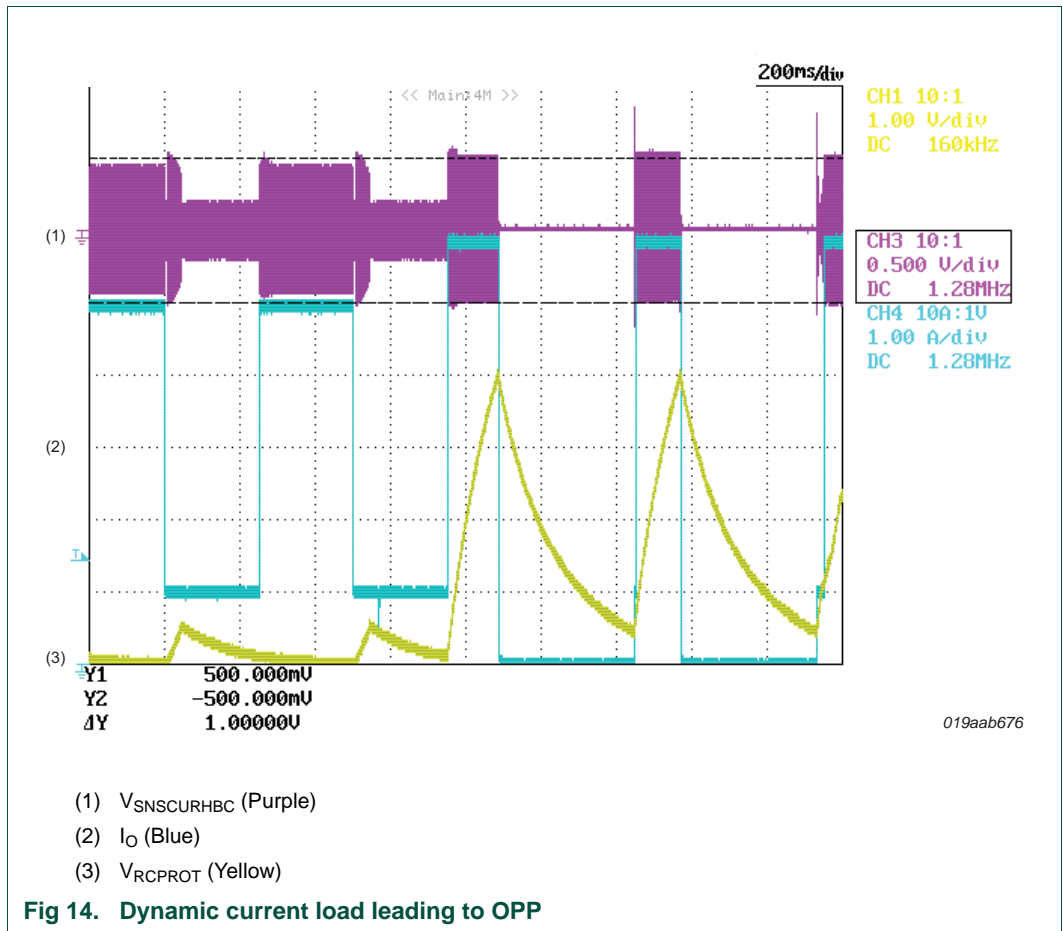
Mains voltage	Mains frequency	Output power	Ripple frequency	Voltage ripple
90 V to 264 V	50 Hz or 60 Hz	90 W	50 Hz or 60 Hz	23 mV (p-p)
90 V to 264 V	50 Hz or 60 Hz	90 W	75 kHz	125 mV (p-p)





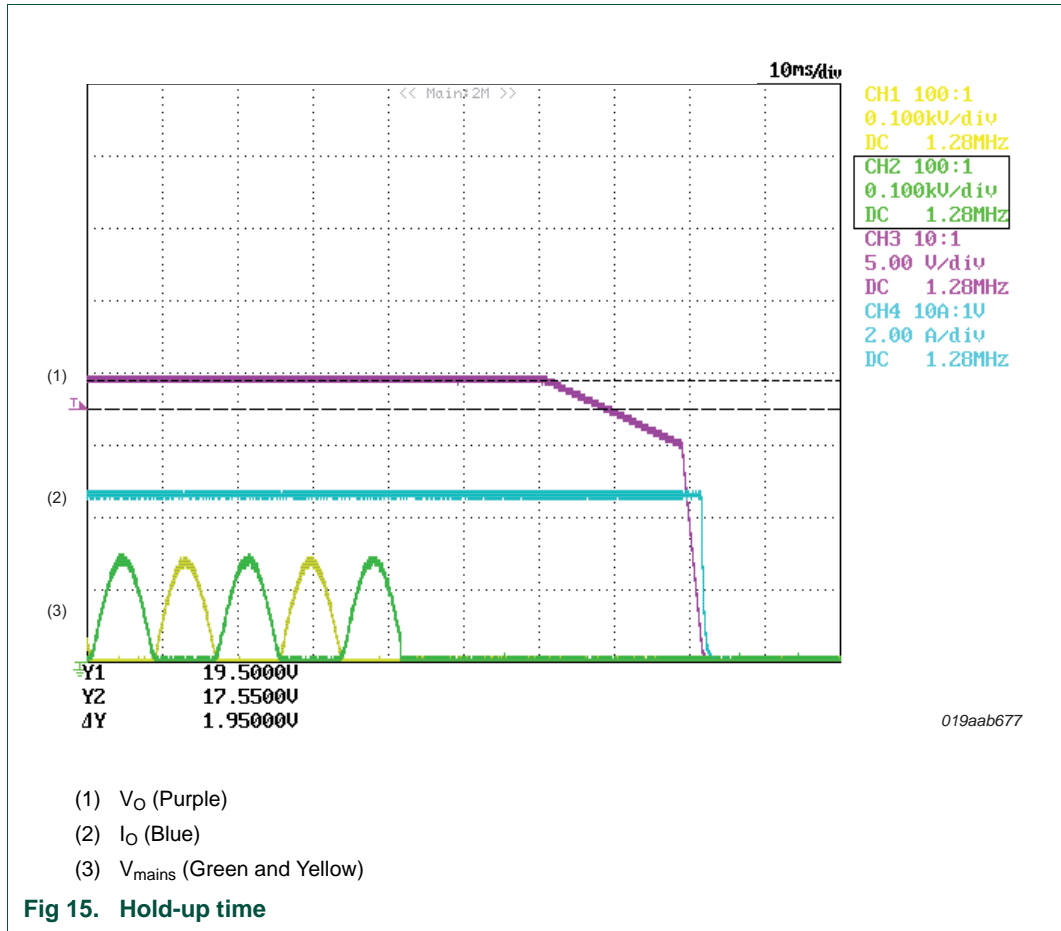
2.8 OverPower Protection (OPP)

Tested with a higher current (dynamic overload) on the output voltage, the OPP is activated when the current exceeds 6 A (117 W). This corresponds to a load condition that is 30 % higher than the rated power for continuous use. The OPP is detected by the SNSCURHBC function of the TEA1713T that monitors the primary resonant current. When the voltage on the SNSCURHBC pin exceeds 0.5 V (or -0.5 V) the protection timer is started.



2.9 Hold-up time

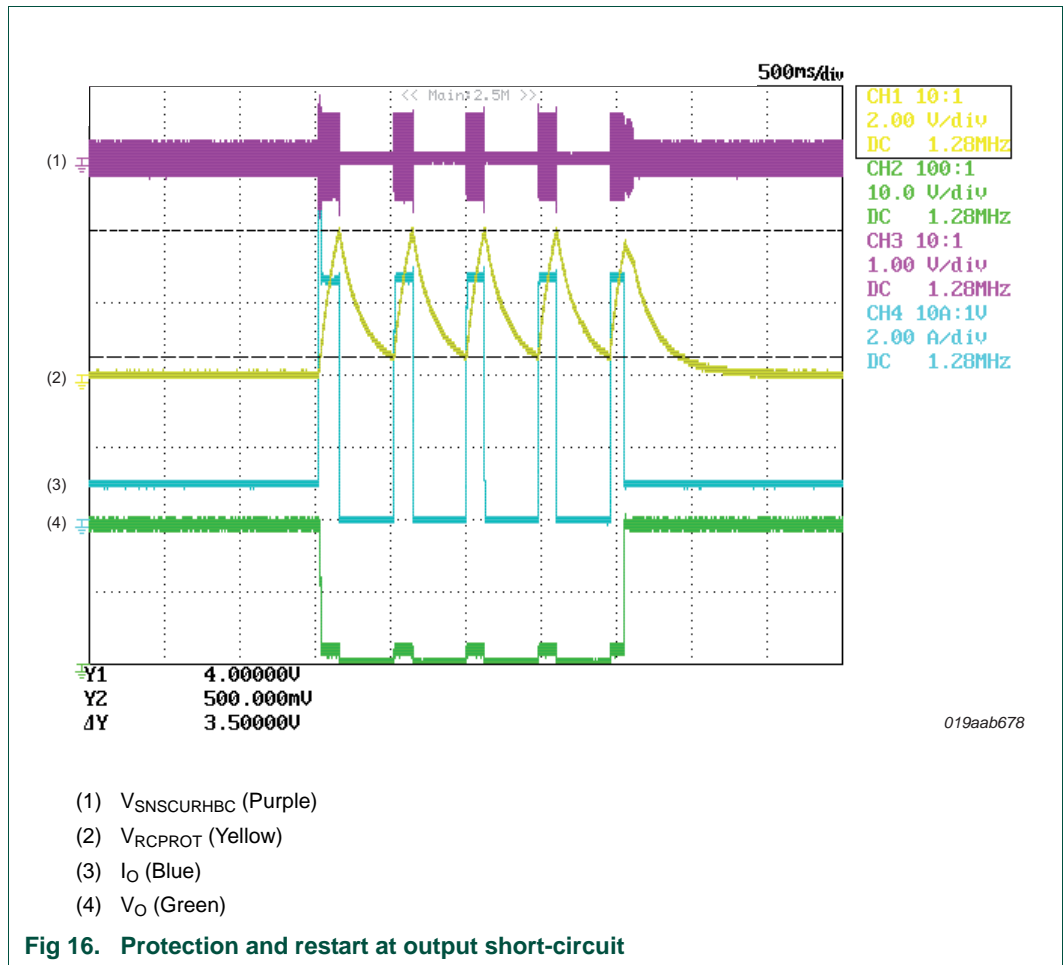
The output is set to full load and the mains supply voltage of 100 V is disconnected. The time that passes before the output voltage falls below 90 % of its initial value is then measured. The hold-up time is 28 ms.



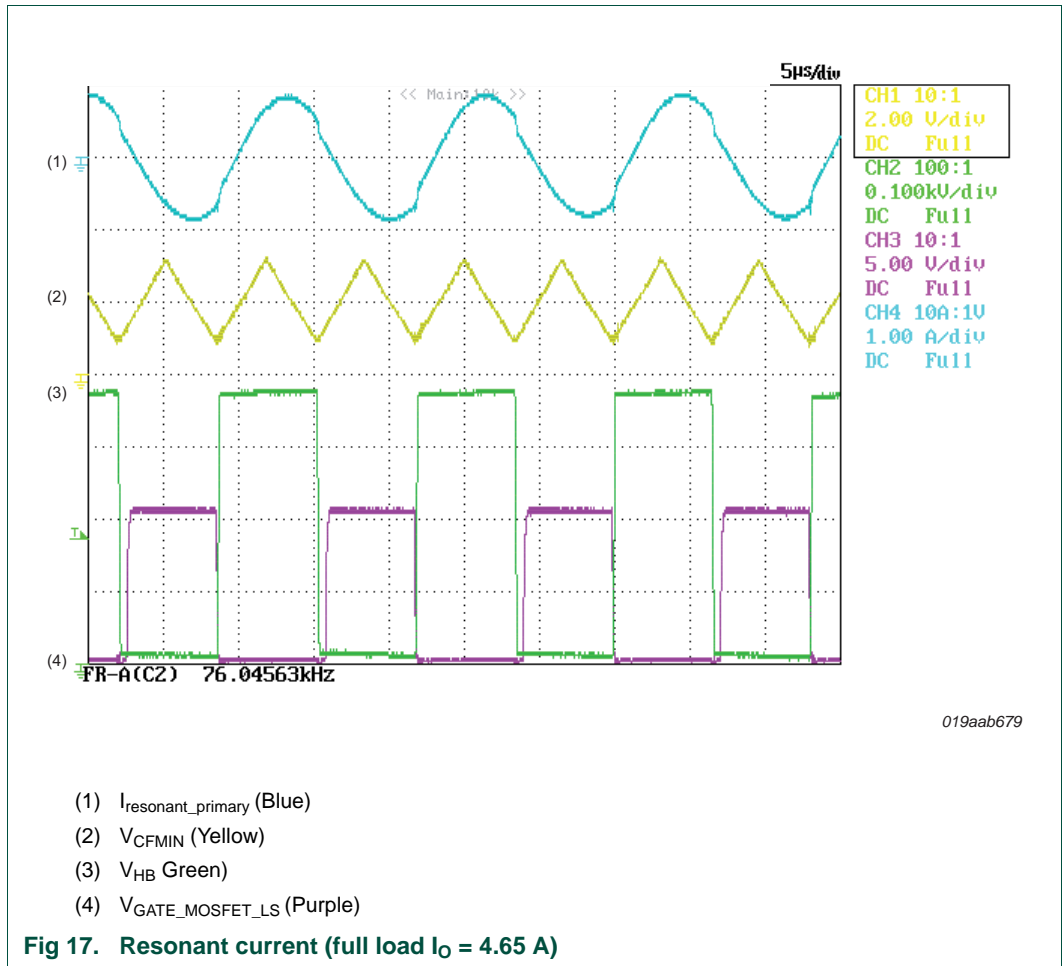
2.10 Short-circuit protection

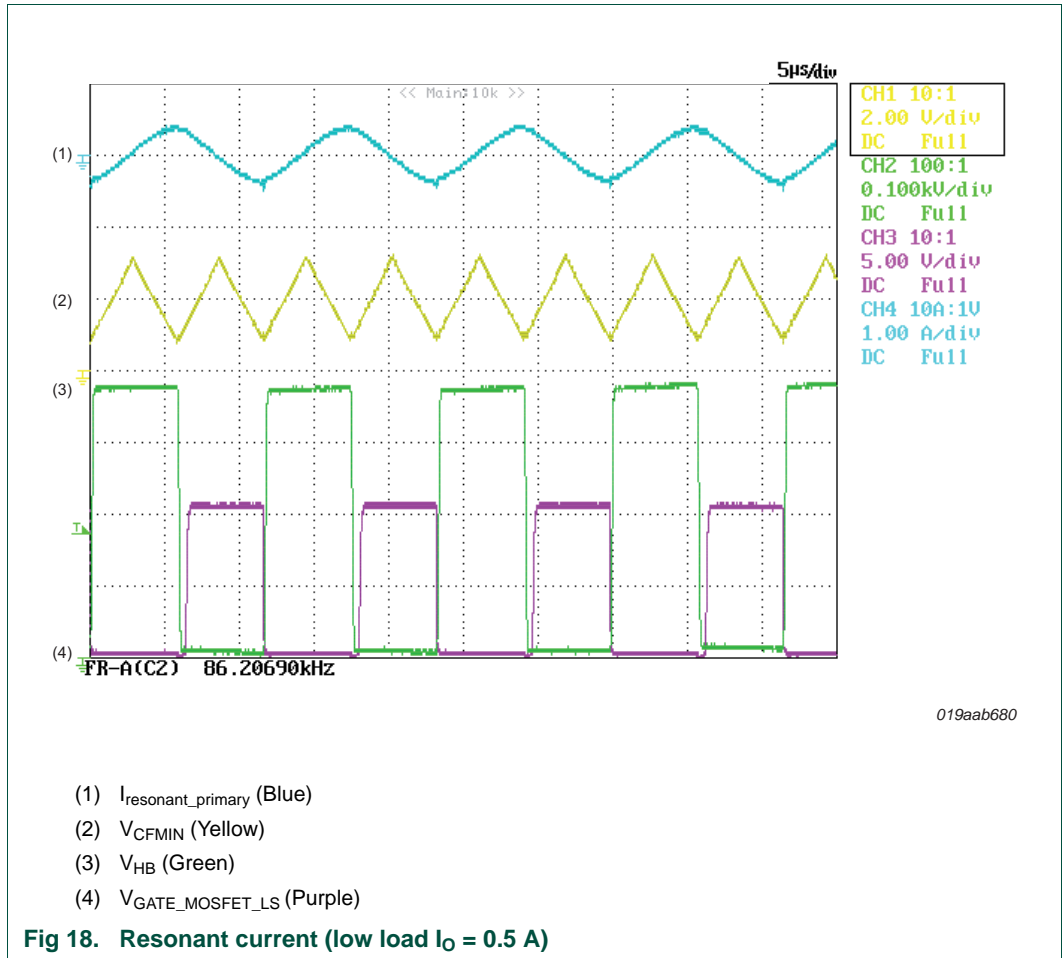
A short circuit on the output of the resonant converter causes the primary current to increase. This is detected by the SNSCURHBC function leading to running on maximum frequency until the protection timer RCPROT reaches its protection level (4 V). The RCPROT function performs its restart timer function and restarts again when the voltage has dropped to 0.5 V. When the short-circuit is removed, the converter starts up and operates as normal.

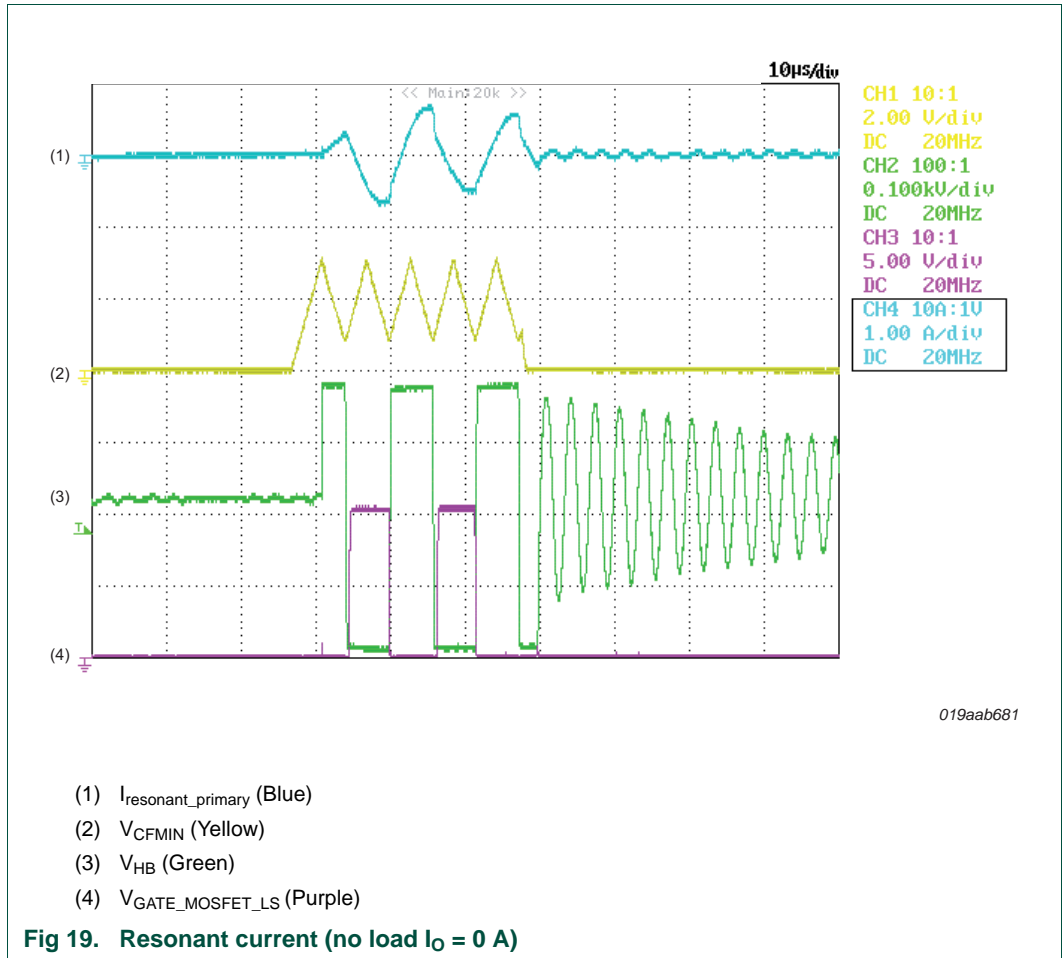
This is the main protection mechanism. Under certain conditions other protections can be activated during the output short circuit test.



2.11 Resonant current measurements







2.12 Temperature measurement

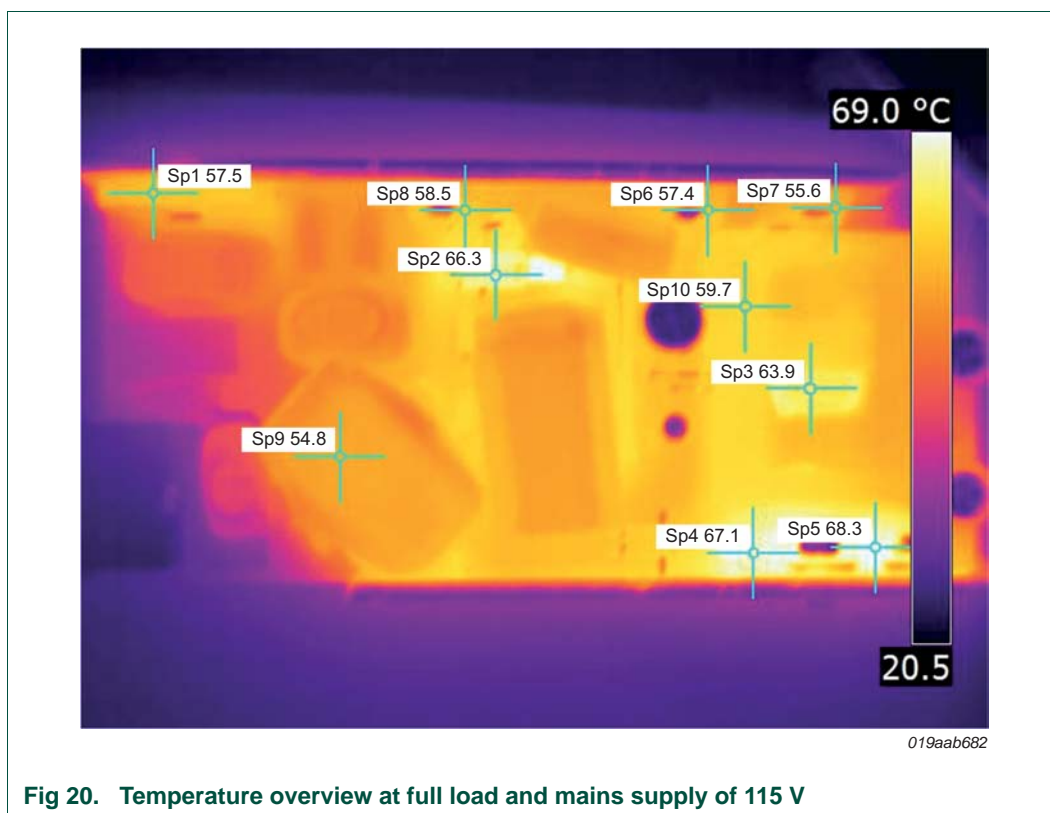


Fig 20. Temperature overview at full load and mains supply of 115 V

2.13 EMI performance

Conditions:

- Type: Conducted EMC measurement
- Frequency range: 150 kHz to 30 MHz
- Output power: Full load condition
- Supply voltage: 115 V and 230 V
- Measuring time: 50 ms
- Secondary ground connected to mains earth ground

3. Circuit diagram

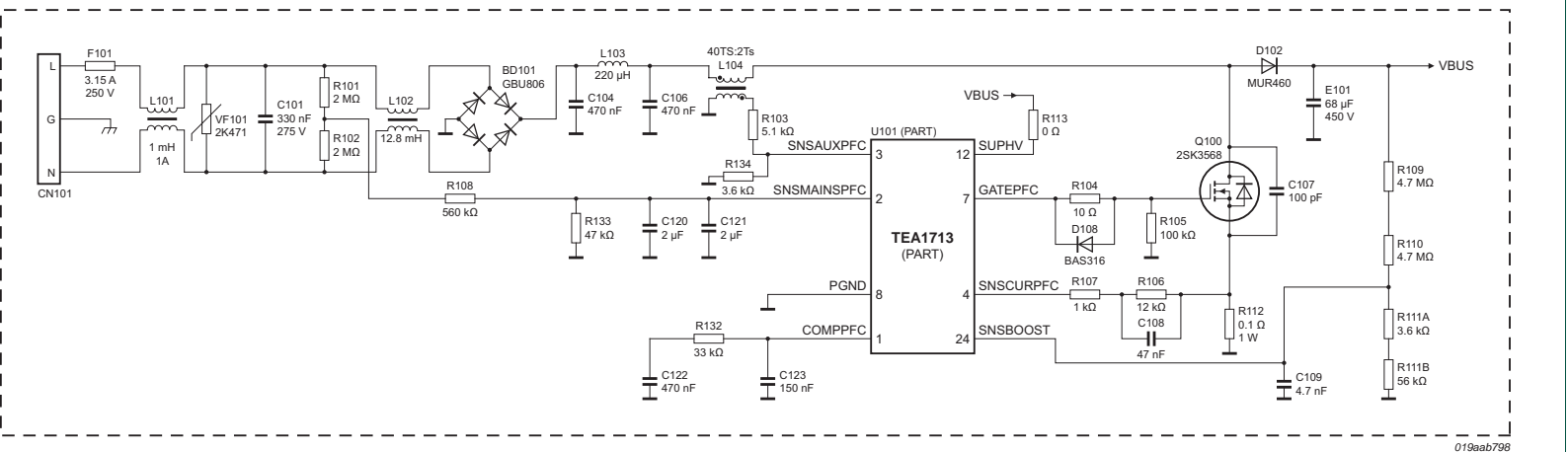
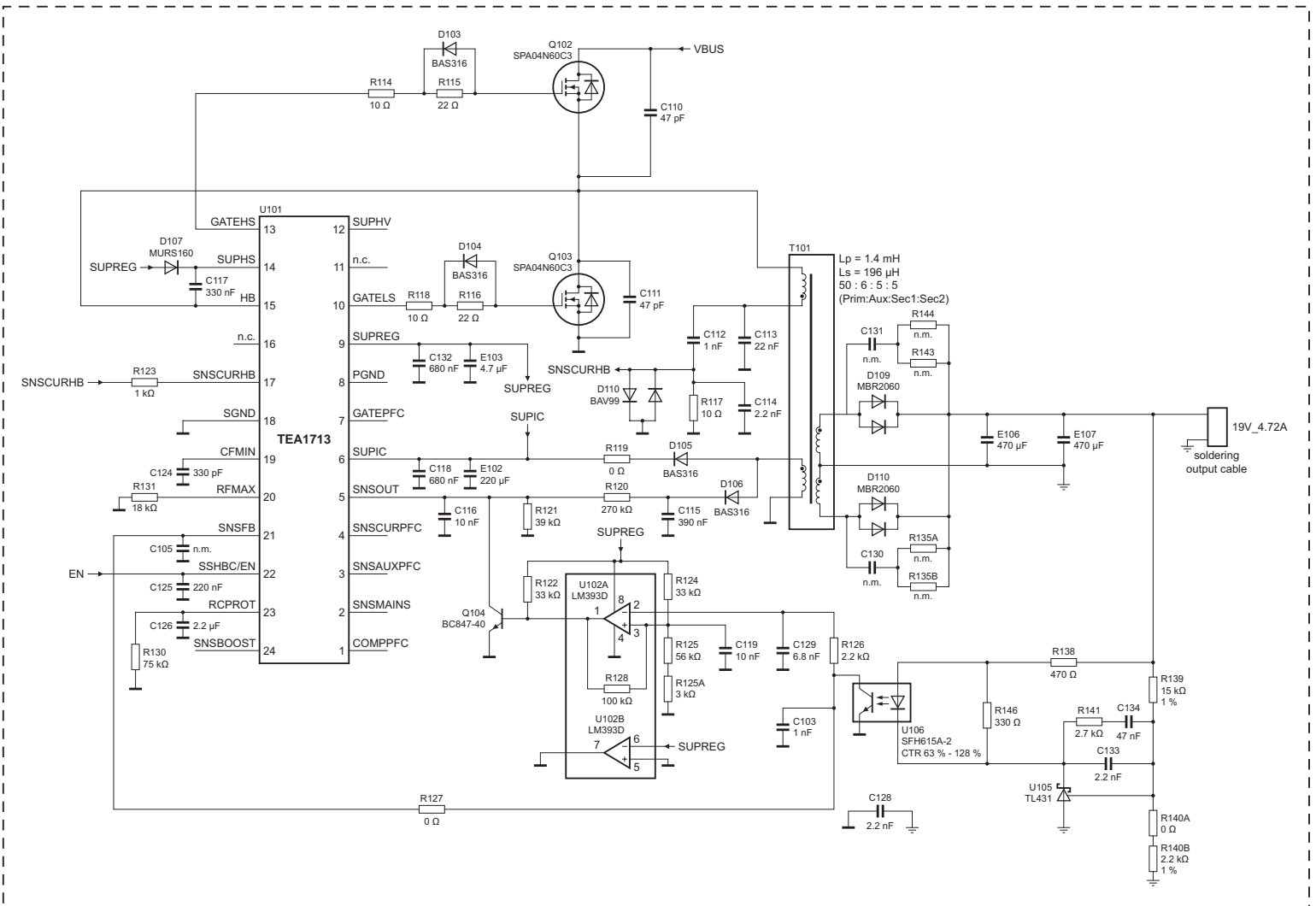
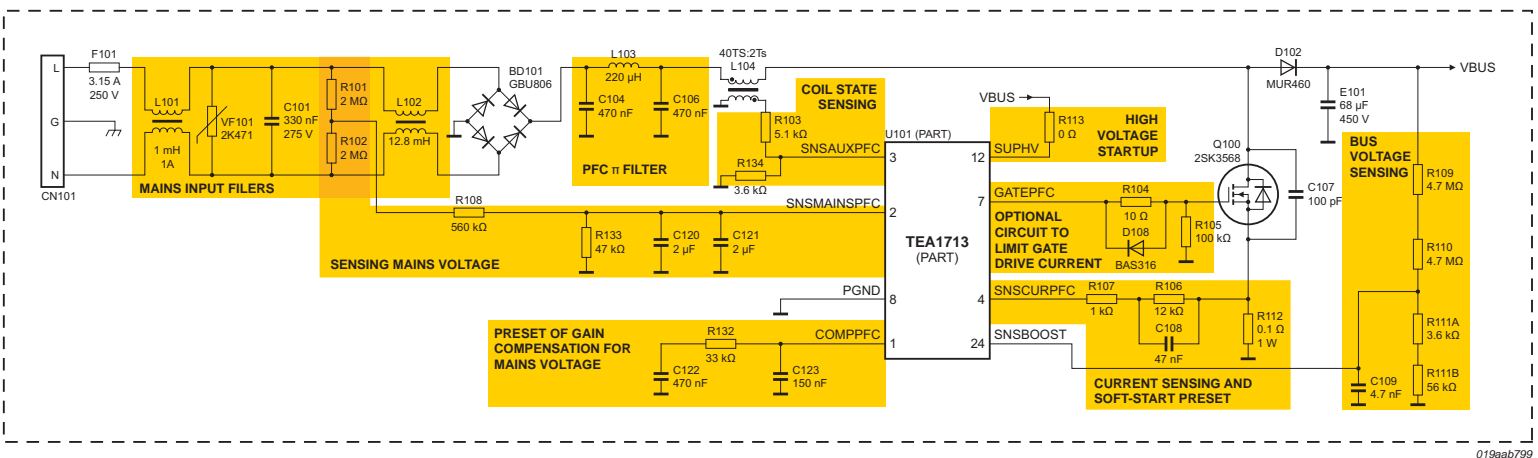


Fig 21. Circuit diagram TEA1713T 90 W demo board (PFC part)



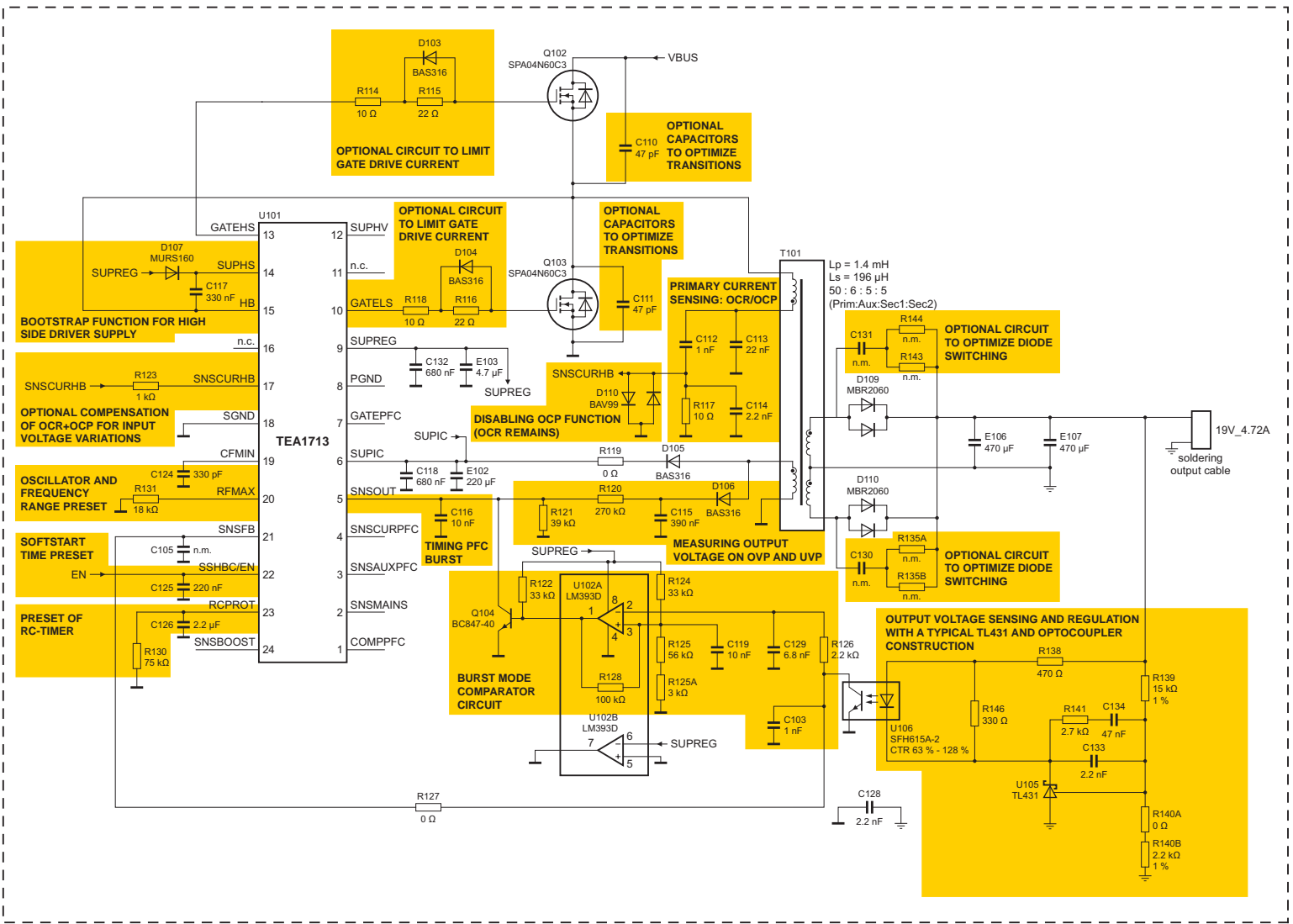
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Fig 22. Circuit diagram TEA1713T 90 W demo board (HBC part)



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Fig 23. Circuit diagram TEA1713T 90 W demo board with comments (PFC part)



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Fig 24. Circuit diagram TEA1713T 90 W demo board with comments (HBC part)

5. Bill Of Materials (BOM)

[Table 7](#) provides detailed component information for the TEA1713T demo board for 90 W notebook adapter.

Table 7. BOM for the TEA1713T demo board

Reference	Component	Tolerance	Package	Remarks
C103	102/50 V		805	Ceramic cap
C105	not mounted		805	Ceramic cap
C107	101/1 KV		1206	Ceramic cap
C108	473/50 V		805	Ceramic cap
C109	472/50 V		805	Ceramic cap
C110	47P/1 KV		1206	Ceramic cap
C111	47P/1 KV		1206	Ceramic cap
C112	102/1 KV		1206	Ceramic cap
C114	222/16 V		805	Ceramic cap
C115	394/50 V		805	Ceramic cap
C116	103/16 V		1206	Ceramic cap
C117	334/50 V		805	Ceramic cap
C118	684/50 V		805	Ceramic cap
C119	103/16 V		805	Ceramic cap
C120	205/50 V		805	Ceramic cap
C121	205/50 V		805	Ceramic cap
C122	474/16 V		805	Ceramic cap
C123	154/16 V		805	Ceramic cap
C124	331/16 V		805	Ceramic cap
C125	224/16 V		805	Ceramic cap
C126	225/16 V		805	Ceramic cap
C129	682/16 V		805	Ceramic cap
C130	not mounted		1206	Ceramic cap
C131	not mounted		1206	Ceramic cap
C132	684/16 V		1206	Ceramic cap
C133	222/16 V		805	Ceramic cap
C134	473/16 V		805	Ceramic cap
L101	1 mH/1 A		L0.2H	Common choke
L102	12.8 mH		L0.4	Common choke
CN101	ST-A04-001JT6T4		3.96 × 5	SHINE
D102	MUR460		diode 0.7	Onsemi
D103	PMLL4148		1206-D	NXP Semiconductors
D104	PMLL4148		1206-D	NXP Semiconductors
D105	BAS316		sc-76	NXP Semiconductors

Table 7. BOM for the TEA1713T demo board ...continued

Reference	Component	Tolerance	Package	Remarks
D106	BAS316		sc-76	NXP Semiconductors
D107	MURS160		SMB	Onsemi
D108	PMLL4148		1206-D	NXP Semiconductors
D109A	MBR2060		TO-220	Onsemi
D109B	MBR2060		TO-221	Onsemi
D110	BAV99			NXP Semiconductors
D101	GBU806		bridge	Diode bridge
E101	68 μ F/450 V		EC16/8H	E-cap
E102	220 μ F		RB.1/.2	E-cap
E103	4.7 μ F		RB.1/.2	E-cap
E106	470 μ F/25 V		EC5/10H	E-cap
E107	470 μ F/25 V		EC5/10H	E-cap
F101	3.15 A/250 V		FUSH_1	Fuse
U101	TEA1713T		SO-24	NXP Semiconductors
U102	LM393D		SO-8	ST
U105	TL431ALP		TO-92A	Ti
L103	220 μ H		EM1H	Inductor
Q100	2SK3568		TO-220H	Toshiba
Q102	SPA04N60C3		TO-220H	Infineon
Q103	SPA04N60C3		TO-220H	Infineon
Q104	BC847-40		SOT-23	NXP Semiconductors
U106	SFH615A-2		DIP4	Optocoupler
L104	RM8		PFC_PQ2620	PFC choke
R101	205	± 5 %	1206	Resistor
R102	205	± 5 %	1206	Resistor
R103	512		1206	Resistor
R104	10R	± 5 %	805	Resistor
R105	104	± 5 %	1206	Resistor
R106	123	± 5 %	805	Resistor
R107	102	± 5 %	805	Resistor
R108	564		805	Resistor
R109	475	1 %	axial0.4	Resistor
R110	475	1 %	axial0.4	Resistor
R111A	362	1 %	805	Resistor
R111B	563	1 %	805	Resistor
R112	0.1,1 W		ResV	Resistor
R113	0R		1206	Resistor

Table 7. BOM for the TEA1713T demo board ...continued

Reference	Component	Tolerance	Package	Remarks
R114	10	±5 %	805	Resistor
R115	22R	±5 %	805	Resistor
R116	22R	±5 %	805	Resistor
R117	10R	±5 %	805	Resistor
R118	10		axial0.3	Resistor
R119	0R		1206	Resistor
R120	274		805	Resistor
R121	393		805	Resistor
R122	333		805	Resistor
R123	102		805	Resistor
R124	333		805	Resistor
R125	513		805	Resistor
R125A	302 [1]		805	Resistor
R126	222		805	Resistor
R127	0		805	Resistor
R128	104		805	Resistor
R130	753		805	Resistor
R131	183		805	Resistor
R132	333		805	Resistor
R133	473		805	Resistor
R134	362		805	Resistor
R135A	not mounted		1206	Resistor
R135B	not mounted		1206	Resistor
R138	470R		805	Resistor
R139	15	1 %	805	Resistor
R140A	0R		805	Resistor
R140B	222	1 %	805	Resistor
R141	272		805	Resistor
R143	not mounted		1206	Resistor
R144	not mounted		1206	Resistor
R146	330R		805	Resistor
C104	0.47 µF/450 V		rad0.4 V	Thin film cap
C106	0.47 µF/450 V		rad0.4 V	Thin film cap
C113	22 nF/1000 V		RAD0.6(0.8)-3 P	Thin film cap
T101	TR2		LP-2920	Transformer
C101	334/275 V		RAD0.6H	X cap
C128	222		C10(0.6)-1F	Y1 cap
VF101	2k471		rad0.4	MOV
J1	6.8 mm			Jumper
J2	9.2 mm			Jumper

Table 7. BOM for the TEA1713T demo board ...continued

Reference	Component	Tolerance	Package	Remarks
J3	2.9 mm			Jumper
J4	31 mm			Jumper
J5	28 mm			Jumper
J6	31 mm			Jumper
J7	31 mm			Jumper
J8	15 mm			Jumper
J9	17.5 mm			Jumper
J10	20.9 mm			Jumper
J11	6.6 mm			Jumper
J12	13.9 mm			Jumper
J13	13.2 mm			Jumper
H1	108 × 23 × 3			
H2	90 × 23 × 3			

[1] R125A: a different value can be used for fine tuning burst mode.

6. Appendix 1 - Resonant transformer data

6.1 Transformer diagram

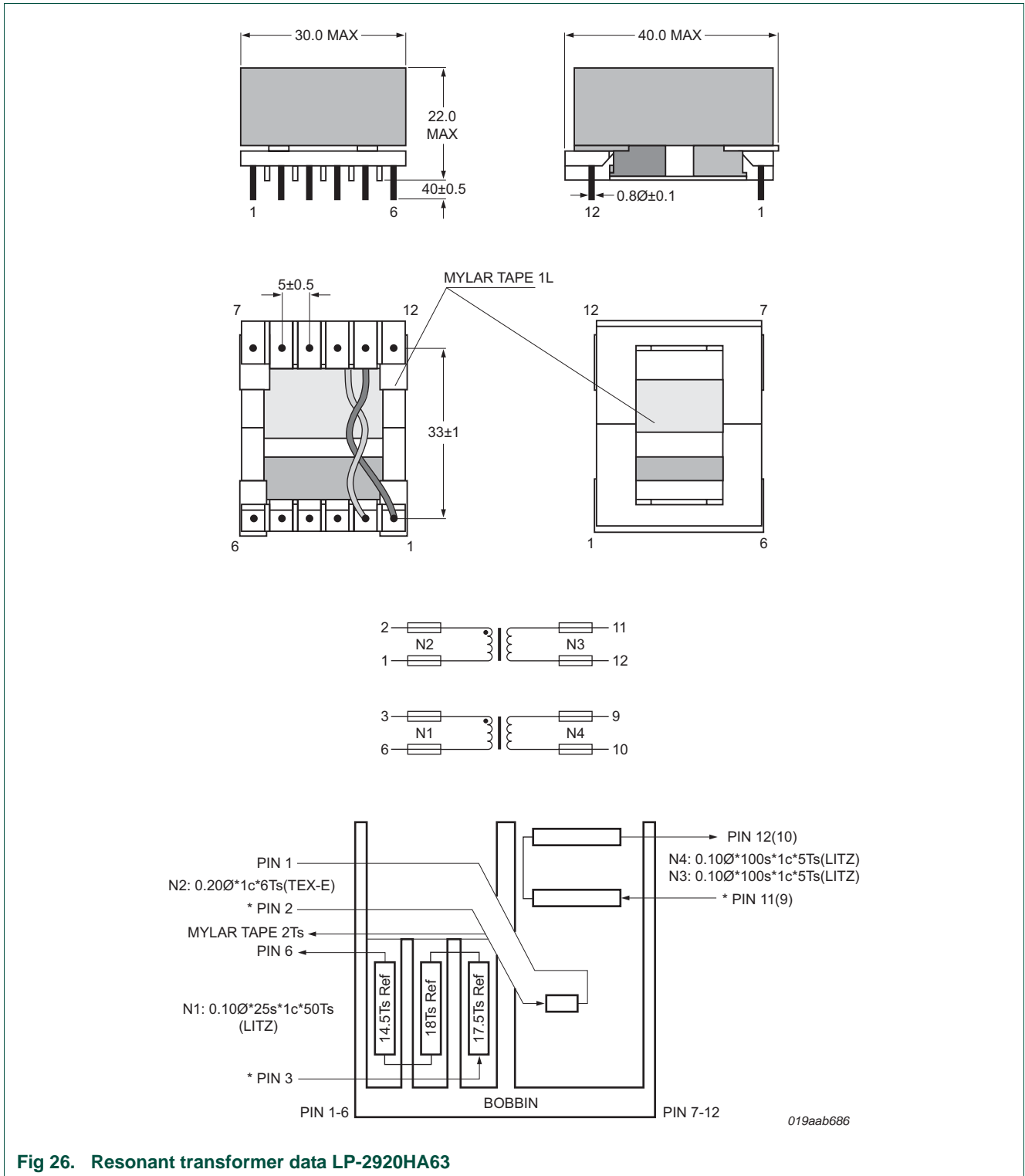


Fig 26. Resonant transformer data LP-2920HA63

6.2 Transformer electrical specification

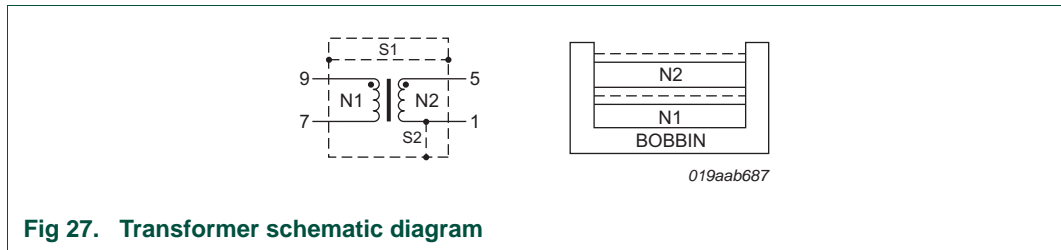
Table 8. Electrical specification

HP: 4284A ZENITECH: 3200B, 502A, $F = 100 \text{ kHz}$, $V = 1 \text{ V}$, at $25 \text{ }^\circ\text{C}$

No	Start	Finish	Wire	Color	Turns	Inductance	DCR (mΩ)
L1	3	6	0.10 $\varnothing \times 25 \text{ s} \times 1 \varnothing$ (LITZ)	Y	50 ± 0.5	1.4 mH $\pm 10 \%$	334 max
L2	2	1	0.20 $\varnothing \times 1 \varnothing$ (TEX-E)	Y	6 ± 0.5	19.0 μH REF	250 max
L3	11	12	0.10 $\varnothing \times 100 \text{ s} \times 1 \varnothing$ (LITZ)	Y	5 ± 0.5	12.0 μH REF	9 max
L4	9	10	0.10 $\varnothing \times 100 \text{ s} \times 1 \varnothing$ (LITZ)	Y	5 ± 0.5	12.0 μH REF	9 max
Lk	3	6	0.10 $\varnothing \times 25 \text{ s} \times 1 \varnothing$ (LITZ)	Y	50 ± 0.5	225 μH $\pm 10 \%$ at secondary short	

7. Appendix 2 - PFC coil data

7.1 Transformer schematic diagram



7.2 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 $\varnothing \times 30$	40	center	-	-	1	10 mm
N2	5	1	0.22 $\varnothing \times 2$	2	center	-	-	1	10 mm
S1	-	-	0.05t $\times 14 \text{ mm}$	1	center	-	-	1	14 mm (S2)
S2	-	1	0.05t $\times 14 \text{ mm}$	1	center	-	-	1	14 mm (S1)

7.3 Electrical characteristics

Table 10. Electrical characteristic

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

7.4 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 mm²

Marking:

- PFC-APBADC015

8. Abbreviations

Table 11. Abbreviations

Acronym	Description
BCM	Boundary conduction Mode
CMP	Capacitive Mode Protection
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
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

9. References

- [1] **TEA1713T** — data sheet - resonant power supply control IC with PFC
- [2] **AN10881** — application note - resonant power supply control IC with PFC
- [3] **UM10379** — user manual - 250 W LCD-TV demo board
- [4] **Calculation sheet** — http://www.nxp.com/technical_support/designportal/llc

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10.1 Definitions

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Date of release: 11 April 2011

Document identifier: UM10450