UM10834

TEA1720ADB1132 10 W EPC17 demo board

Rev. 1 — 5 November 2014 User manual

Document information

Info	Content
Keywords	TEA1720ADB1132, TEA1720B3T, TEA1705, ultra-low standby power, constant output voltage, constant output current, primary sensing, integrated high-voltage start-up, smartphone and tablet charger, 5 V/2.0 A supply, SMPS transient controller
Abstract	This user manual describes the TEA1720ADB1132 10 W Constant Voltage/Constant Current (CV/CC) universal input power supply for tablet adapters/chargers. This demo board is based on the GreenChip Smart Power TEA1720B3T and the TEA1705 transient controller. The TEA1720B3T and TEA1705 application enables a no-load power consumption of less than 20 mW and a low external component count for cost-effective applications. In addition, the TEA1720B3T provides advanced control modes for optimal performance. The TEA1705 transient controller continuously monitors the output voltage. When the output voltage drops below the detection level V_{det} (V_{CC}), a transient interrupt signal is generated to wake up the TEA1720B3T.

Revision history

Rev	Date	Description
v.1	20141105	first issue

Contact information

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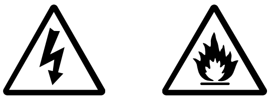
1. Introduction

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 TEA1720ADB1132 10 W Constant Voltage or Constant Current (CV/CC) universal input power supply for tablet adapters and chargers. This demo board is based on the TEA1720B3T GreenChip SP-integrated circuit.

The TEA1720B3T GreenChip SP provides ultra-low no-load power consumption without using additional external components. Designs are cost-effective using the TEA1720B3T GreenChip SP because only a few external components are needed in a typical application.

The additional TEA1705 transient controller ensures excellent transient response in no-load mode.

Remark: All voltages are in V (AC) unless otherwise stated

2. Safety warning

The complete demo board application is AC mains voltage powered. 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.

a. Isolated

b. Not Isolated

Fig 1. Isolation symbols

3. Features

3.1 Power features

- Low component count for cost-effective design
- Universal mains input
- Isolated output
- Highly efficient > 80 %
- Primary sensing for control of the output voltage without optocoupler and secondary feedback circuitry
- Built-in emitter switch for driving low-cost NPN high-voltage transistor
- Minimizes audible noise in all operation modes
- Energy Star 2.0 compliant
- Jitter function for reduced EMI
- Excellent transient performance with ultra low no-load power and small output capacitors
- Cable compensation 0.3 V at maximum power

3.2 Green features

- No-load power consumption < 20 mW
- Very low supply current in no-load condition with energy save mode
- Incorporates a high-voltage start-up circuit with zero current consumption under normal switching operation

3.3 Protection features

- OverVoltage Protection (OVP) with auto-restart
- UnderVoltage LockOut (UVLO) and OverVoltage Protection (OVP) on IC supply pin
- OverTemperature Protection (OTP)
- Sense pin short protection
- Hiccup function for automatic switch-off at continuous too low output voltage
- Demagnetization protection for guaranteed discontinuous conduction mode operation
- Open and short-circuit protection of the Feedback control (FB) pin
- Short-circuit protection of the charger output

4. Technical specifications

Table 1. Input specifications

Parameter	Conditions	Value	Remark
input voltage	-	90 V to 265 V	universal AC mains
input frequency	-	47 Hz to 63 Hz	-
average no-load input power consumption	no-load	17.5 mW	average of 115 V and 230 V

Table 2. Output specifications

Parameter	Conditions	Value	Remark
output voltage	-	5.0 V	-
nominal output current	-	2.0 A	-
nominal output power	-	10.0 W	-

5. Board photographs

a. Top view

b. Bottom view

Fig 2. TEA1720ADB1132 10 W EVD15 demo board

6. Performance data

6.1 No-load input power consumption

The no-load input power has been measured 20 minutes after switch-on. Table 3 and Figure 3 show the results.

Table 3. No-load input power consumption

V_{mains} (V)	Output voltage (V)	Power consumption (mW)
90	5.183	18.1
115	5.18	17.5
230	5.164	17.4
265	5.158	18.2

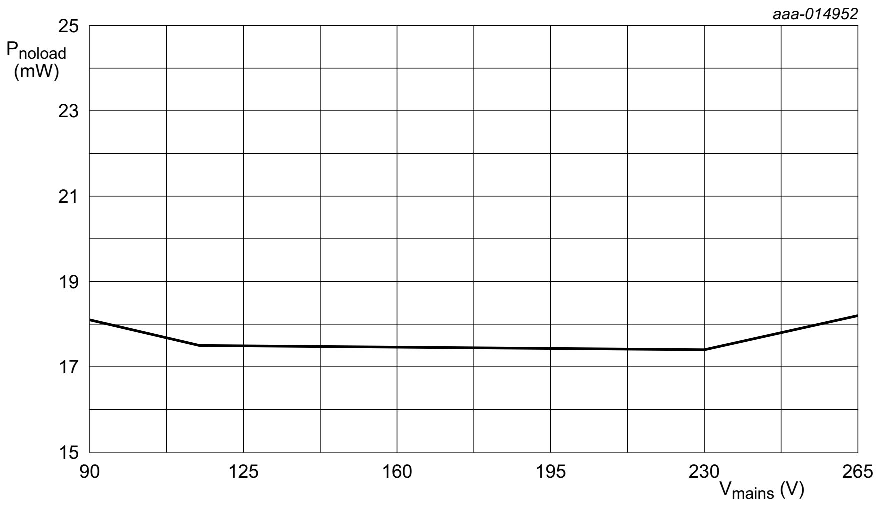
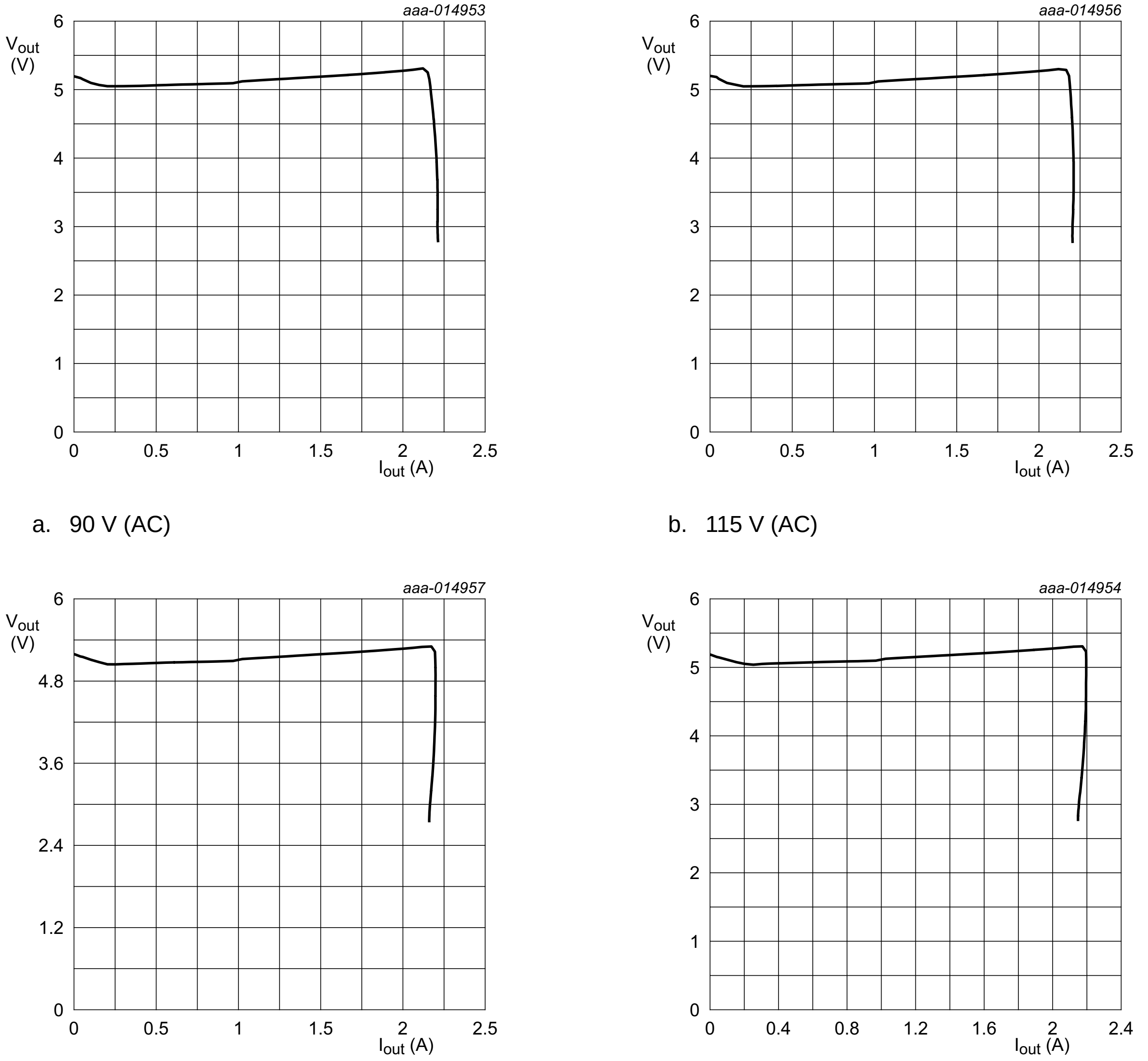


Fig 3. No-load input power consumption

6.2 VI curves

Figure 4 shows the VI characteristics measured at the PCB end.



a. 90 V (AC)

b. 115 V (AC)

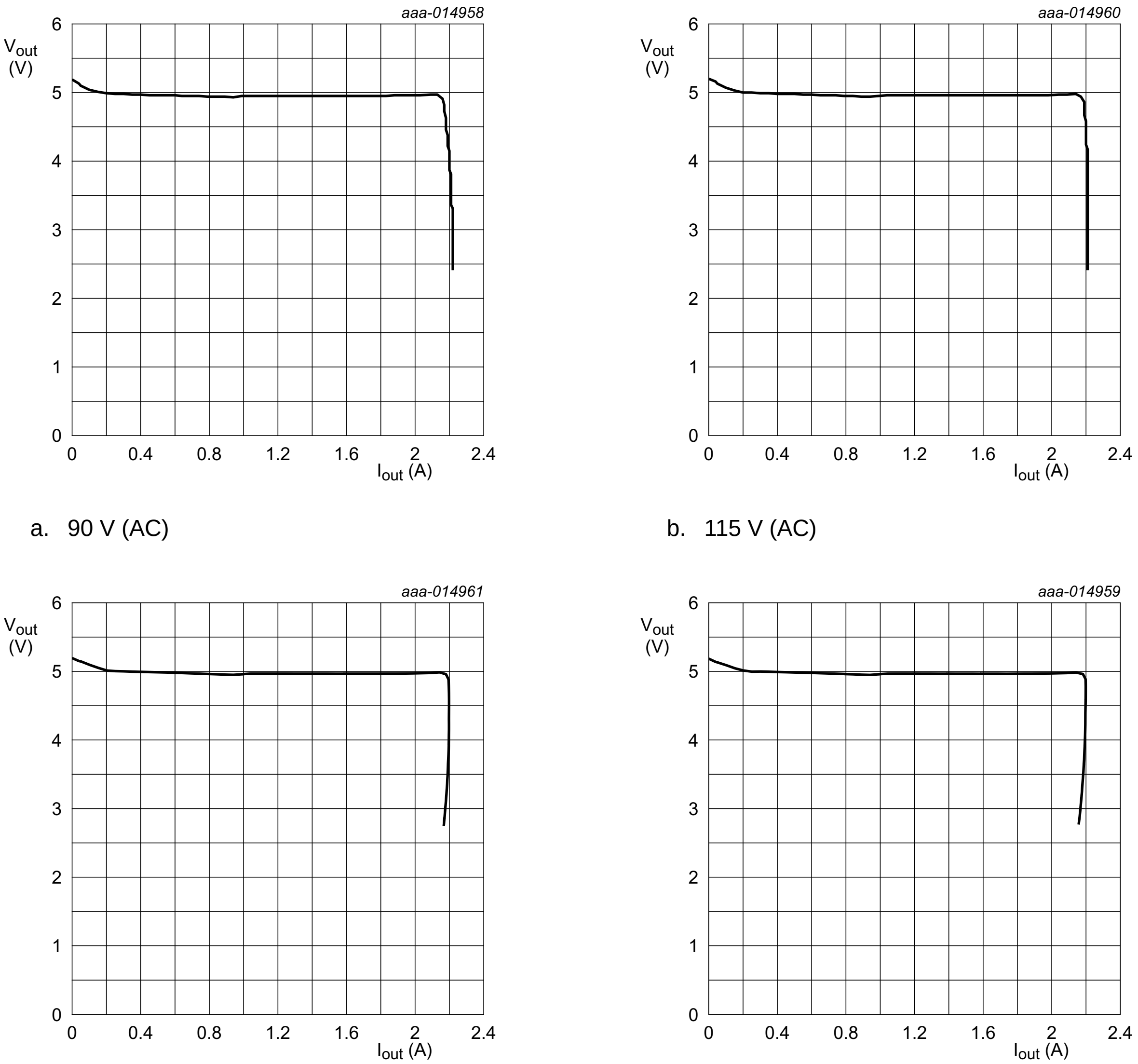
c. 230 V (AC)

d. 265 V (AC)

Fig 4. VI characteristics (PCB end)

Below V_{out} = 2.7 V at the PCB end, the controller enters the hiccup mode.

Figure 5 shows the VI characteristics measured at the cable end.



a. 90 V (AC)

b. 115 V (AC)

c. 230 V (AC)

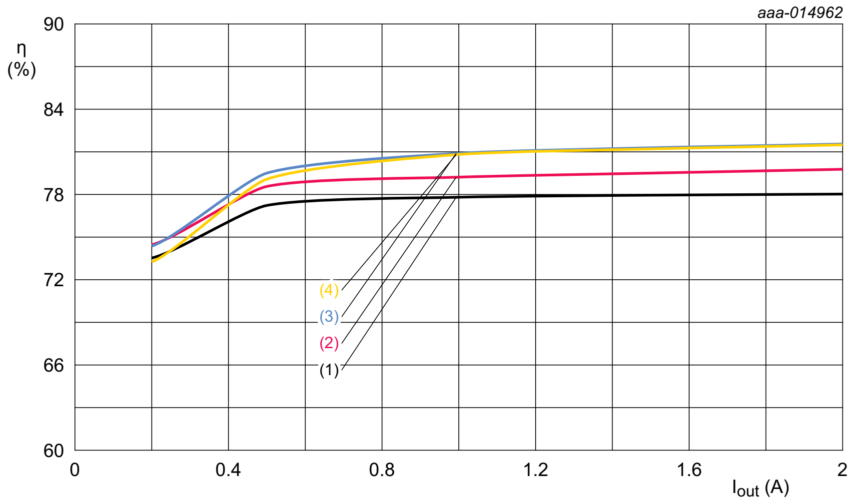
d. 265 V (AC)

Fig 5. VI characteristics (cable end)

Below V_{out} = 2.4 V at the cable end the controller enters the hiccup mode.

6.3 Efficiency

Figure 6 shows the efficiency at 90 V, 115 V, 230 V and 265 V.



(1) Efficiency at 90 V (AC)
(2) Efficiency at 115 V (AC)
(3) Efficiency at 230 V (AC)
(4) Efficiency at 265 V (AC)

Fig 6. Efficiency as a function of output current at the PCB end

Table 4. Efficiency PCB end

V_{in} (V (AC))	I_{out} (A)	V_{out} (V)	Pin (W)	efficiency (%)	Average 0.5 A to 2.0 A
90	0.200	5.012	1.361	73.534	77.753
	0.499	5.040	3.258	77.224	
	0.999	5.108	6.557	77.806	
	1.500	5.192	9.990	77.951	
	2.000	5.292	13.561	78.029	
115	0.200	5.009	1.342	74.463	79.265
	0.499	5.035	3.199	78.561	
	0.999	5.105	6.435	79.219	
	1.500	5.187	9.783	79.504	
	1.999	5.284	13.242	79.774	
230	0.200	5.014	1.346	74.366	80.807
	0.499	5.043	3.167	79.497	
	0.999	5.109	6.308	80.895	
	1.500	5.193	9.581	81.285	
	2.000	5.283	12.953	81.551	

Table 4. Efficiency PCB end *...continued*

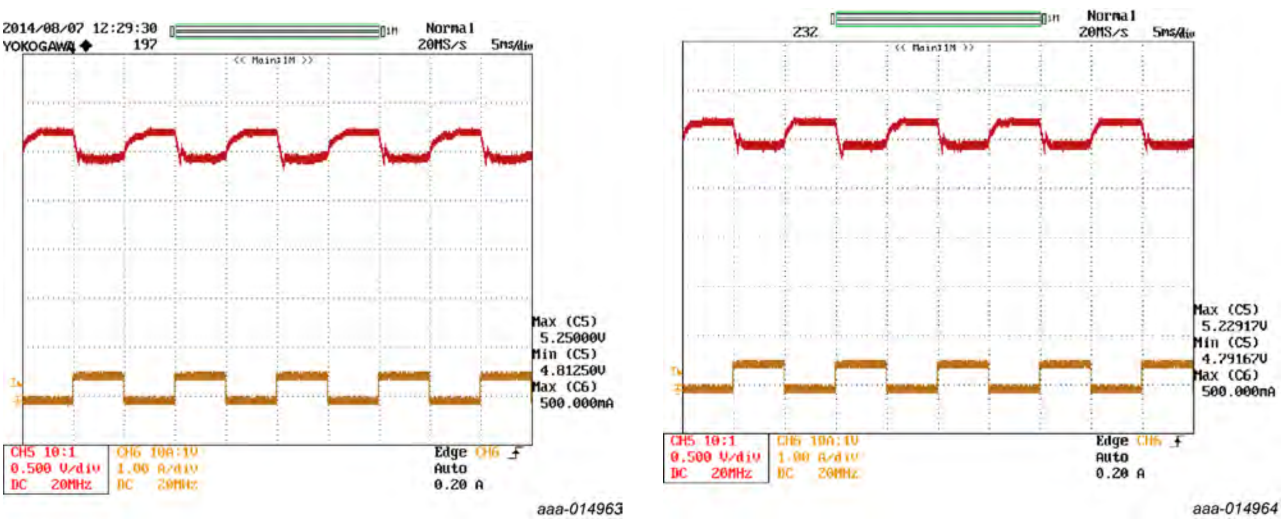
V_{in} (V (AC))	I_{out} (A)	V_{out} (V)	Pin (W)	efficiency (%)	Average 0.5 A to 2.0 A
265	0.200	5.020	1.368	73.260	80.646
	0.499	5.044	3.185	79.068	
	0.999	5.111	6.317	80.814	
	1.500	5.195	9.594	81.207	
	2.000	5.286	12.969	81.494	

6.4 Transient response TEA1720B3T

The transient response for the TEA1720B3T (300 mV cable compensation) has been tested with load steps at 90 V and 265 V at the PCB end and at the end of the cable from:

- 0 A → 0.5 A → 0 A
- 0 A → 1.0 A → 0 A
- 0 A → 2.0 A → 0 A

Figure 7 to Figure 9 show the load step response, measured at PCB end.



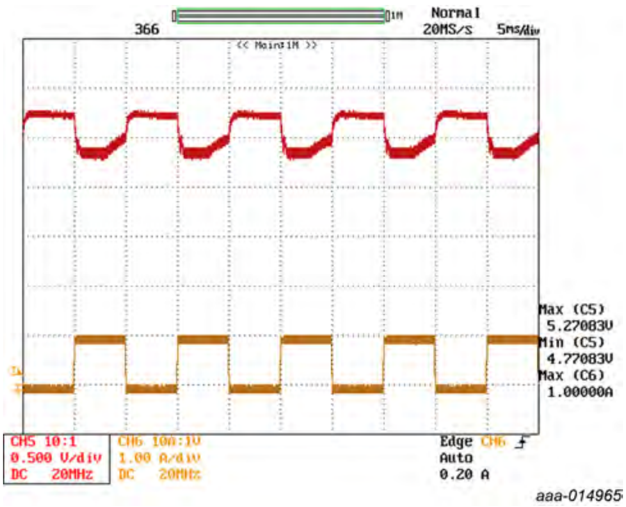
Red = V_{out}
Orange = I_{out}

a. 90 V (AC)

Red = V_{out}
Orange = I_{out}

b. 265 V (AC)

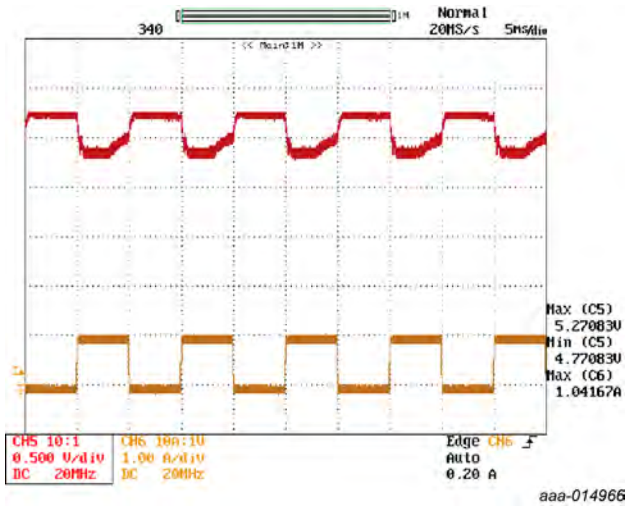
Fig 7. Load step 0 A → 0.5 A → 0 A at PCB end



Red = V_{out}

Orange = I_{out}

a. 90 V (AC)

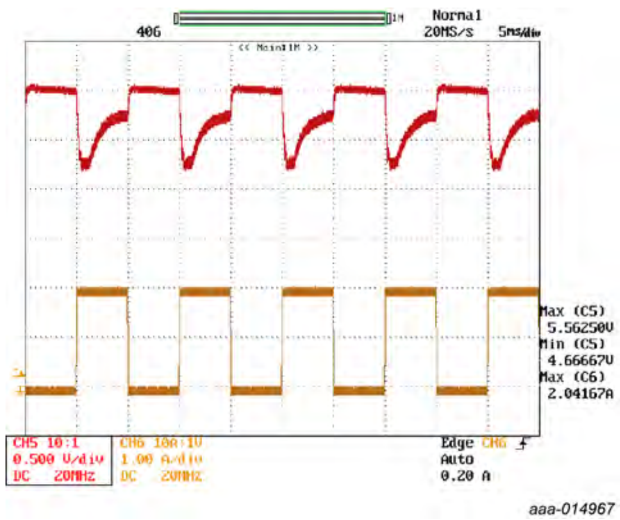


Red = V_{out}

Orange = I_{out}

b. 265 V (AC)

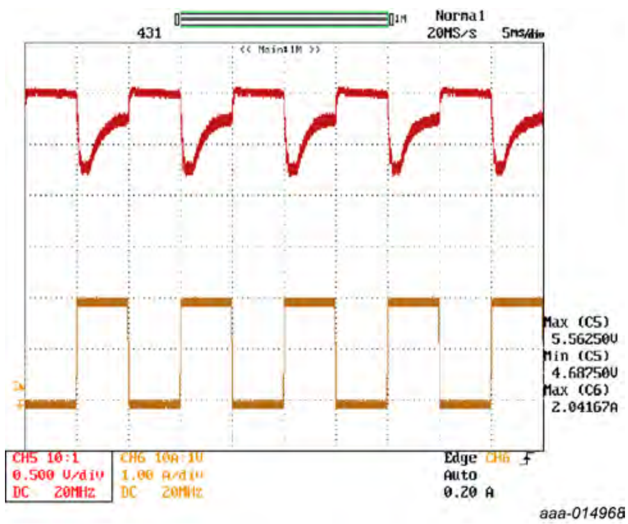
Fig 8. Load step 0 A → 1.0 A → 0 A at PCB end



Red = V_{out}

Orange = I_{out}

a. 90 V (AC)



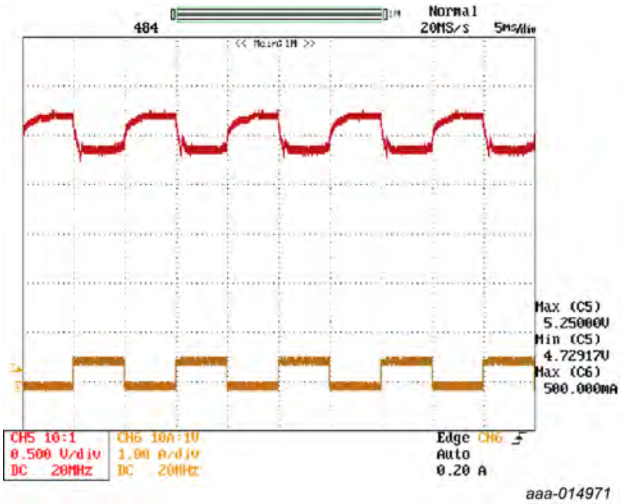
Red = V_{out}

Orange = I_{out}

b. 265 V (AC)

Fig 9. Load step 0 A → 2.0 A → 0 A at PCB end

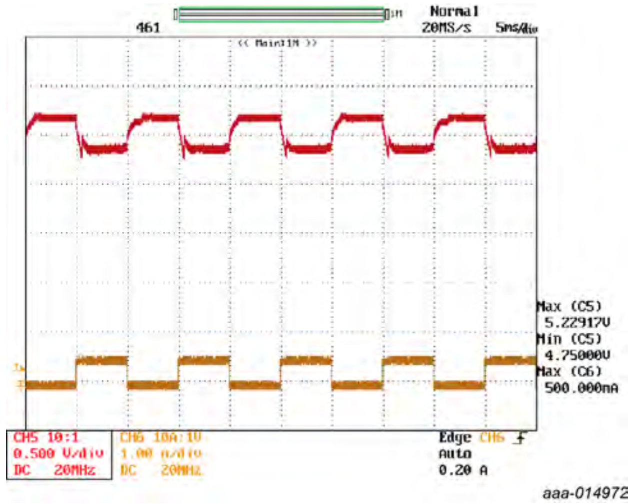
Figure 10 to Figure 12 show the load step response measured at cable end (0.15 Ω).



Red = V_{out}

Orange = I_{out}

a. 90 V (AC)

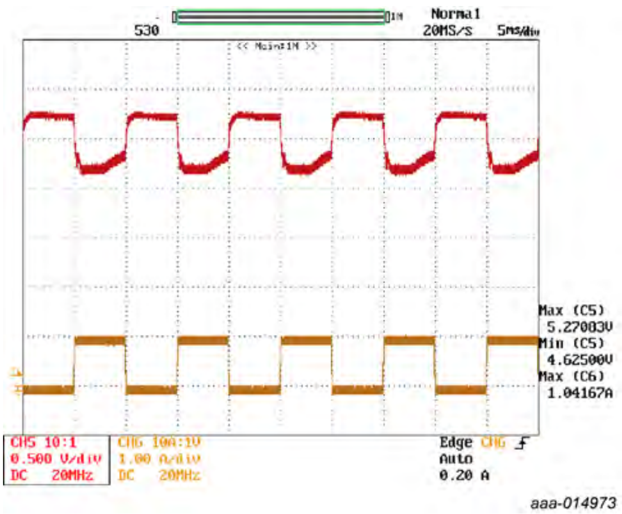


Red = V_{out}

Orange = I_{out}

b. 265 V (AC)

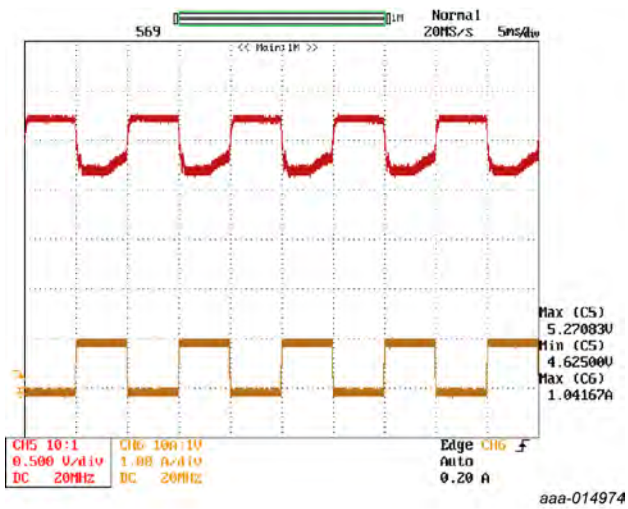
Fig 10. Load step 0 A → 0.5 A → 0 A at cable end (0.15 Ω)



Red = V_{out}

Orange = I_{out}

a. 90 V (AC)

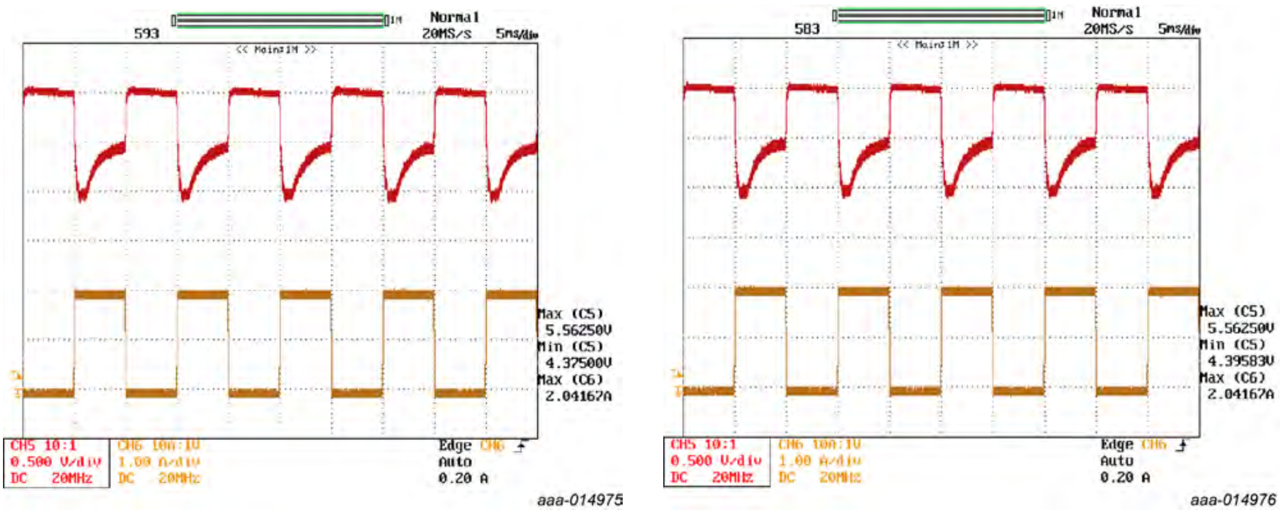


Red = V_{out}

Orange = I_{out}

b. 265 V (AC)

Fig 11. Load step 0 A → 1.0 A → 0 A at cable end (0.15 Ω)



Red = V_{out}

Orange = I_{out}

a. 90 V (AC)

Red = V_{out}

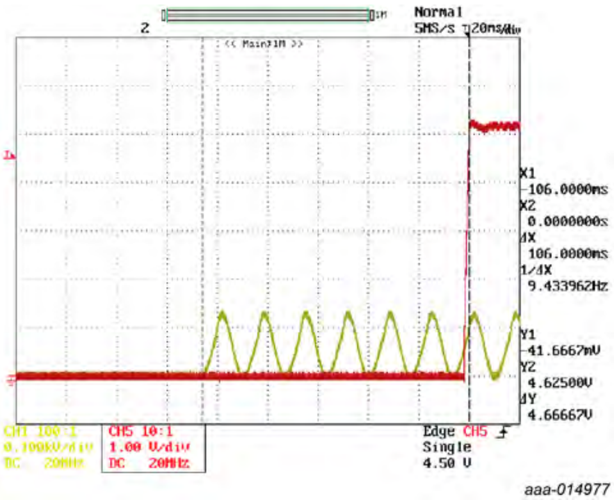
Orange = I_{out}

b. 265 V (AC)

Fig 12. Load step 0 A → 2.0 A → 0 A at cable end (0.15 Ω)

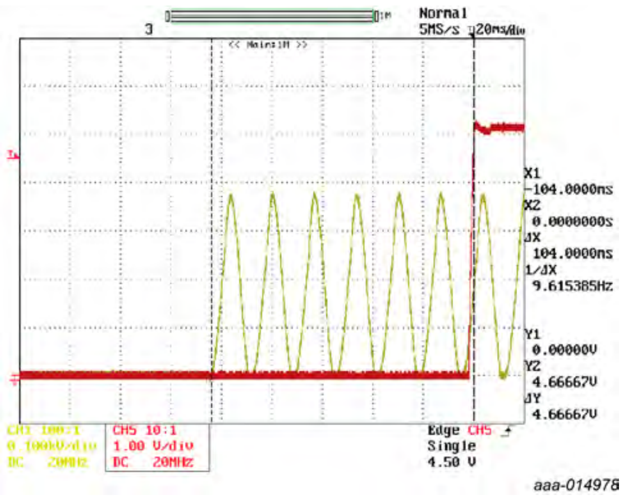
6.5 Turn-on delay and output rise time

Figure 13 shows the turn-on the delay of the output of the supply at 90 V and 265 V with no-load and 2 A load.



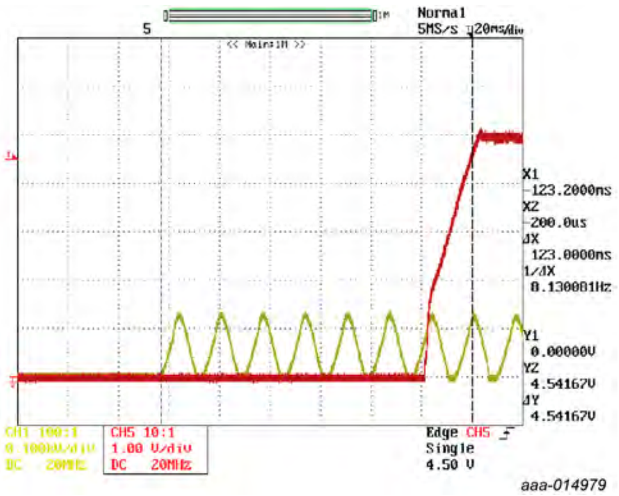
Turn-on delay time = 106 ms

a. 90 V (AC); no-load



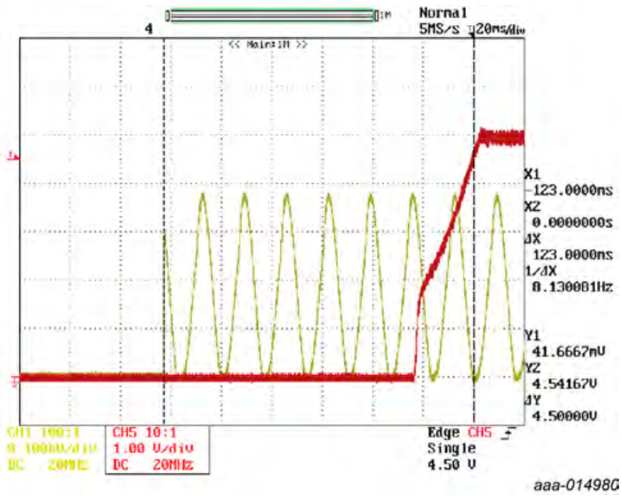
Turn-on delay time = 104 ms

b. 265 V (AC); no-load



Turn-on delay time = 123 ms

c. 90 V (AC); 2 A load

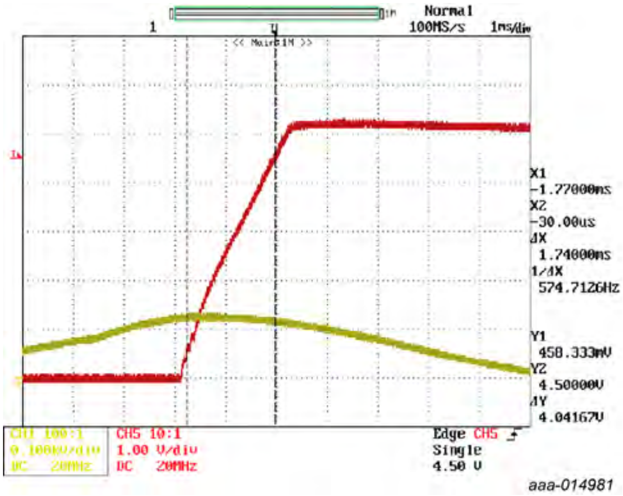


Turn-on delay time = 123 ms

d. 265 V (AC); 2 A load

Fig 13. Turn-on delay times at no-load and 2 A load

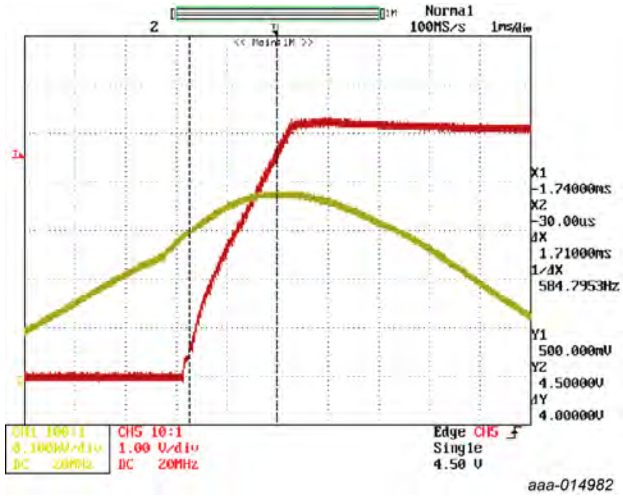
Figure 14 shows the rise time of the output from 10 % to 90 % at 90 V and 265 V with no-load and 2 A load.



(1) Rise time: 10 % => 90 % = 1.74 ms

(2) Rise time: 0 % => 100 % = 2.12 ms

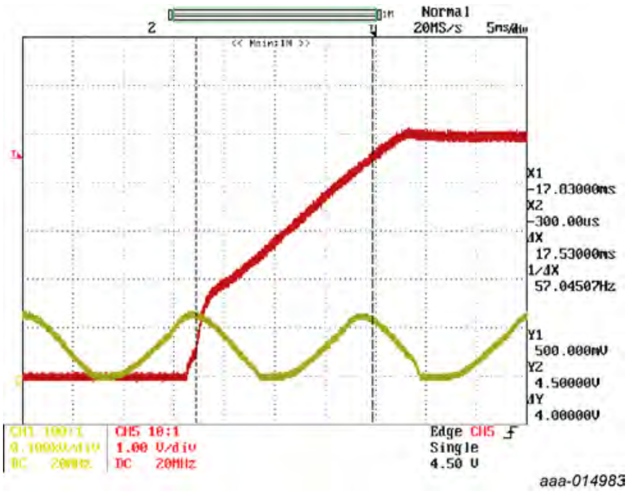
a. 90 V (AC); no-load



(1) Rise time: 10 % => 90 % = 1.71 ms

(2) Rise time: 0 % => 100 % = 2.12 ms

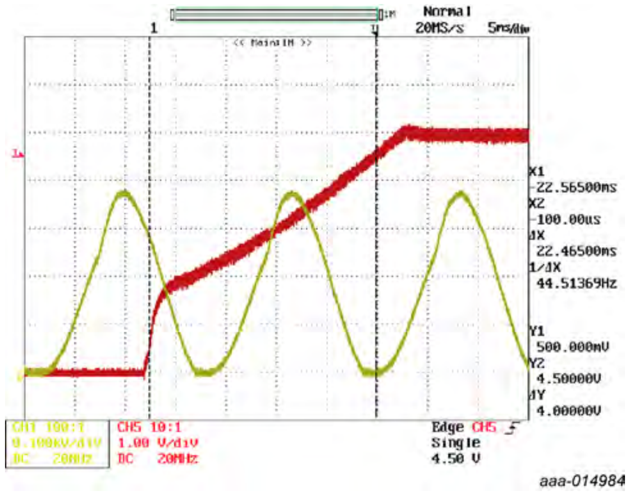
b. 265 V (AC); no-load



(1) Rise time: 10 % => 90 % = 17.5 ms

(2) Rise time: 0 % => 100 % = 21.7 ms

c. 90 V (AC); 2 A load



(1) Rise time: 10 % => 90 % = 22.5 ms

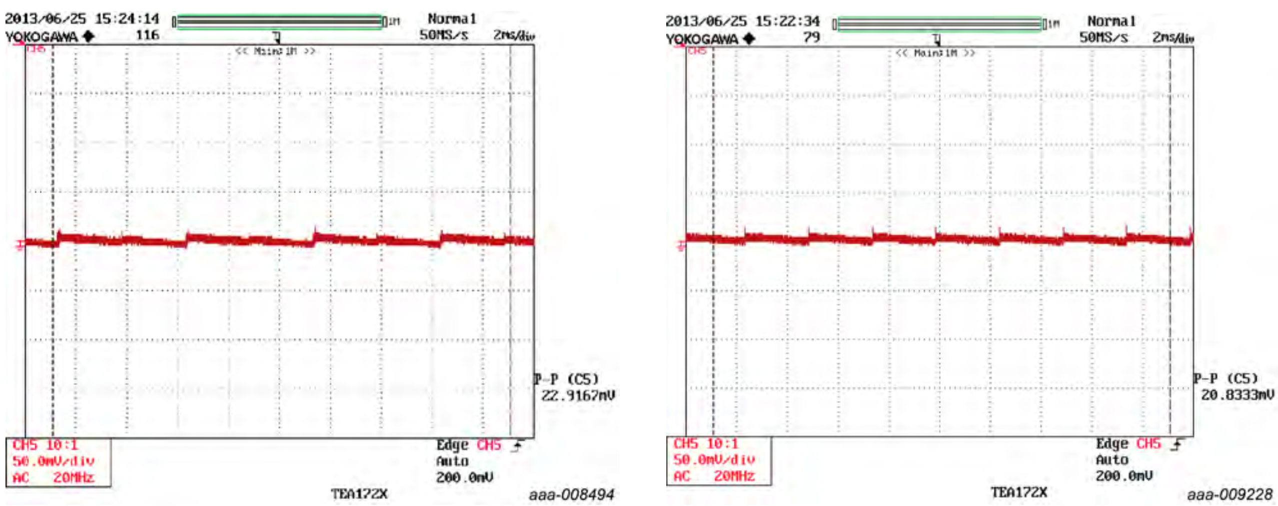
(2) Rise time: 0 % => 100 % = 25.6 ms

d. 265 V (AC); 2 A load

Fig 14. Output rise time 10 % ≥ 90 % at no-load and 2 A load

6.6 Output voltage ripple and noise performance

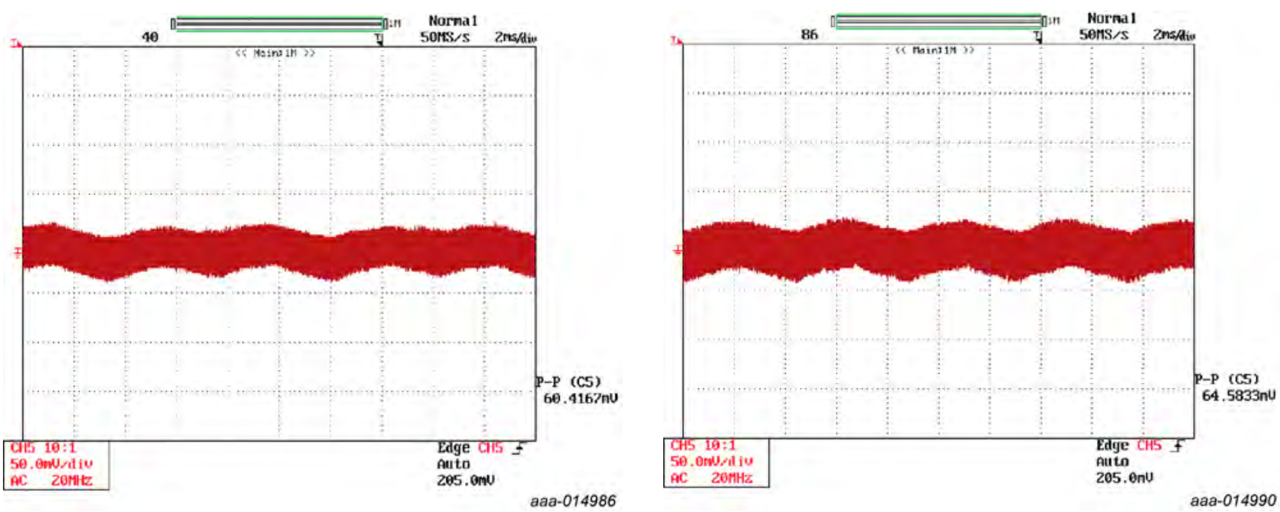
The output voltage ripple and noise performance has been measured with an oscilloscope probe connected to the output of the demo board. A probe tip was used with a very short GND connection. A 100 nF ceramic capacitor and a 10 μF electrolytic capacitor are used in parallel with the probe tip to terminate the output. The output voltage ripple and noise has been measured at 90 V and 265 V both at no-load and 2 A load. Figure 15 and Figure 16 show the results.



a. 90 V (AC)

b. 265 V (AC)

Fig 15. Output voltage ripple and noise; no-load; cable end (0.15 Ω)



a. 90 V (AC)

b. 265 V (AC)

Fig 16. Output voltage ripple and noise; 2 A load; cable end (0.15 Ω)

6.7 Inrush current

The inrush current is limited in the demo board by an NTC in series with the mains.

Table 5 shows the value of the peak inrush current.

Table 5. Inrush current (A peak)

V_{in} (V)	90 V	115 V	230 V	265 V
I_{out} = 0 A	8.3 A peak	11.0 A peak	23.3 A peak	27.3 A peak
I_{out} = 2 A	8.6 A peak	11.1 A peak	24.1 A peak	27.6 A peak

6.8 Short circuit

When the output is shorted, the controller enters hiccup mode. The input power and average output current is given in Table 6.

Table 6. Short circuit input power and average output current

Shorted output	90 V (AC)	265 V (AC)
input power	0.97 W	0.87 W
average output current	0.88 A	0.63 A

6.9 Conducted EMI

The conducted EMI is measured according to EN55022 without the secondary GND connected to the protective mains ground and from 150 kHz to 30 MHz. Figure 17 and Figure 18 show the results. The red crosses show the quasi peak values.

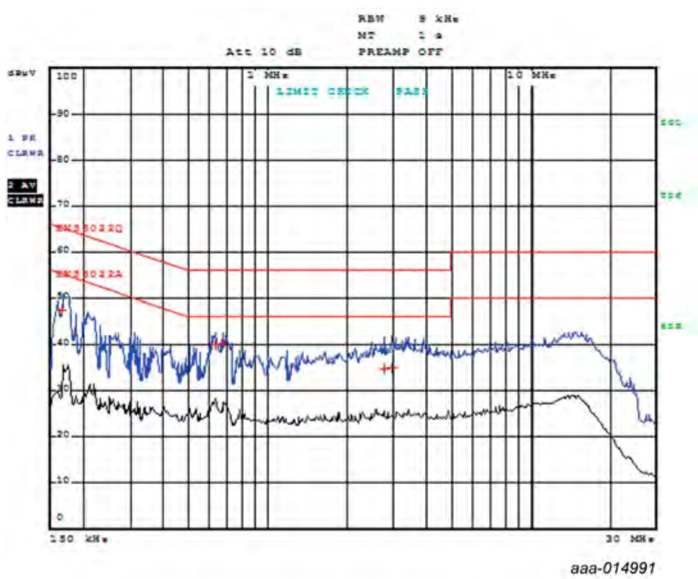


Fig 17. Conducted EMI 115 V; no ground; 2 A load

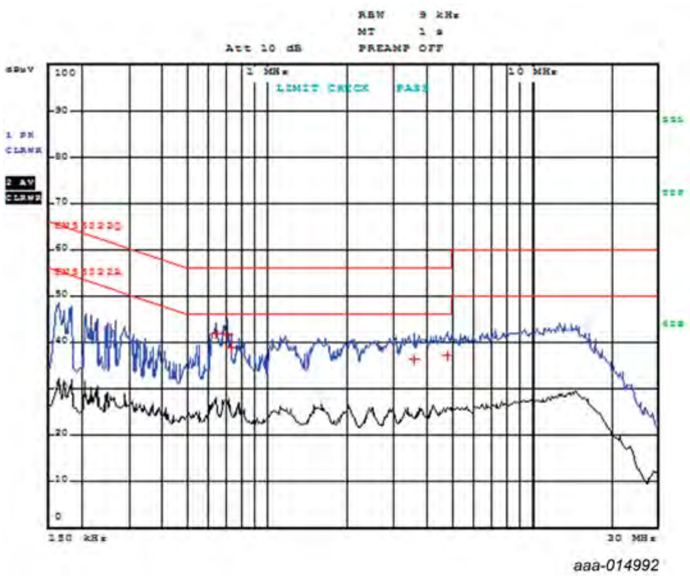


Fig 18. Conducted EMI 230 V; no ground; 2 A load

6.10 Radiated EMI

The radiated EMI is measured according to EN 55022 (30 MHz to 1 GHz). Figure 19 and Figure 20 show the measured results.

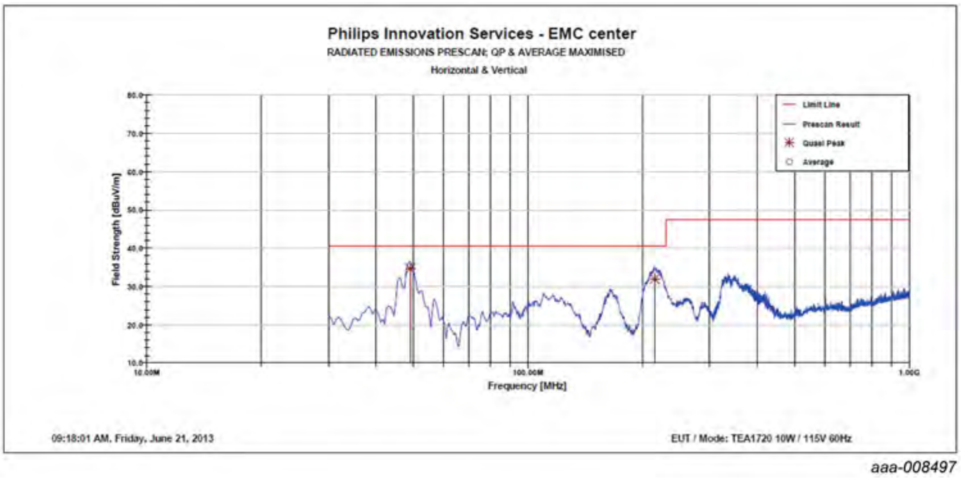


Fig 19. Radiated EMI at 115 V/2 A load

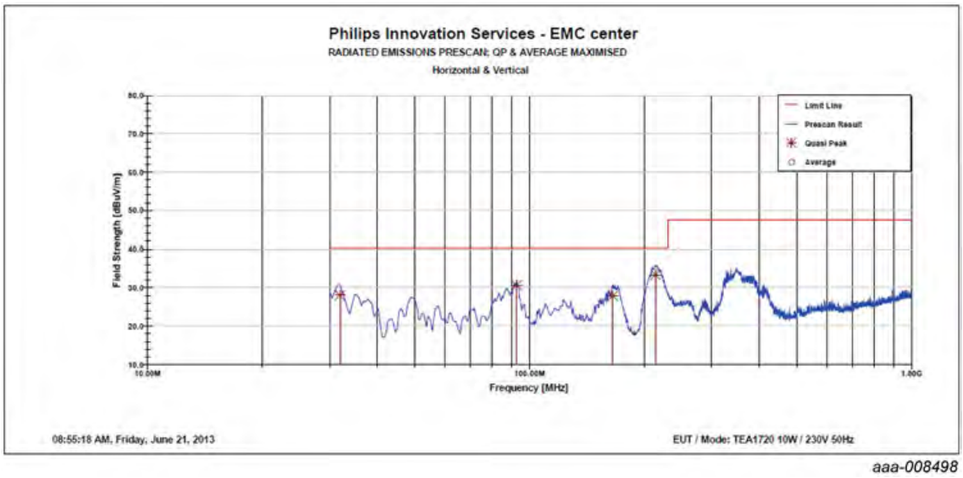


Fig 20. Radiated EMI at 230 V/2 A load

6.11 Common-mode noise

Figure 21 shows the result of the EPS switching frequency component of the common-mode noise test. The switching component is below 2 V_{pp}.

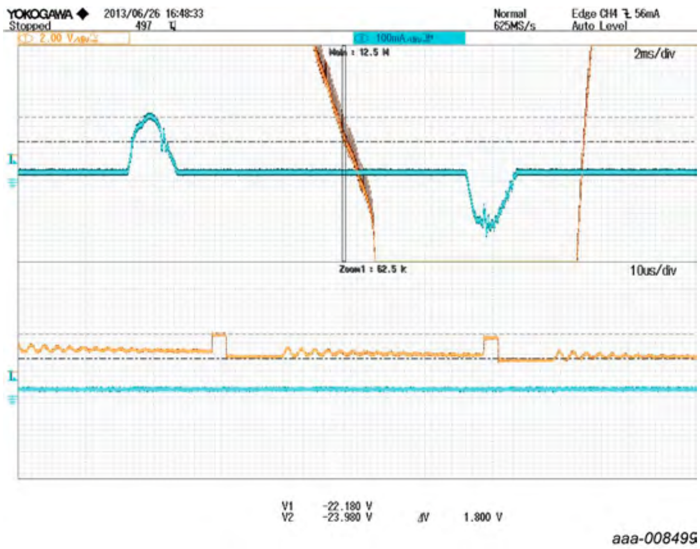


Fig 21. Common-mode noise EPS switching frequency component at 265 V

6.11.1 Test description

The TEA1720ADB1132 demo board has been connected to a 265 V (AC) power source where one or the other of the AC mains is a neutral conductor. It has been connected to the protected earth ground either at the upstream service transformer, or locally in the laboratory environment.

The demo board has been loaded with a 5 Ω, 1 %, resistive load, at the end of a 1 meter USB cable. The 5 Ω load is located in a metal box that represents the equivalent capacitive load of a generic mobile terminal. The EPS switching component has been measured with an 1:100 oscilloscope probe (50 MΩ // 7.5 pF) between the metal box ground and the protective earth ground.

The level of the common-mode noise is measured at the worst position, which is around the mains voltage zero crossing in this case.

The test has been repeated with a 2.5 Ω resistor load. The test result was equal to the 5 Ω test result.

6.12 Thermal measurements

The component temperatures were measured using a temperature chamber. The PCB was placed inside an encasing. To avoid influence of the air flow, the encasing itself is placed inside a box (see Figure 22).

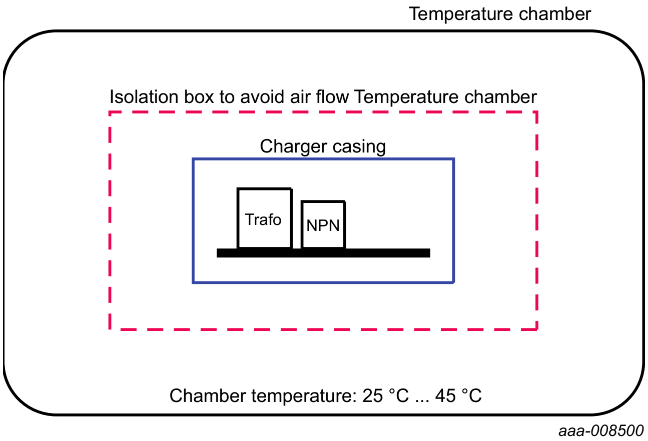


Fig 22. Measurement setup temperature chamber

The component temperatures are measured using thermocouples, glued on the components. The temperatures after 30 minutes warming-up time at 2 A load are shown in Table 7.

Table 7. Component temperatures at 2 A load and $T_{ambient}$ = 25 °C/45 °C

Chamber temperature		V_{in} = 90 V; I_{out} = 2 A		V_{in} = 265 V; I_{out} = 2 A	
		Temperature (°C)		Temperature (°C)	
		25	45	25	45
1 EPC17	transformer	67	83	66	84
2 TB100	NPN	83	99	90	109
3 TEA1720	controller	73	89	57	65
4 D50/D51	secondary diodes	73	88	72	88
5 R70/R71/R72	base resistors	90	103	73	92
6 C52	output capacitor	58	75	58	75
7 C2	input capacitor	69	83	60	78

7. Schematic

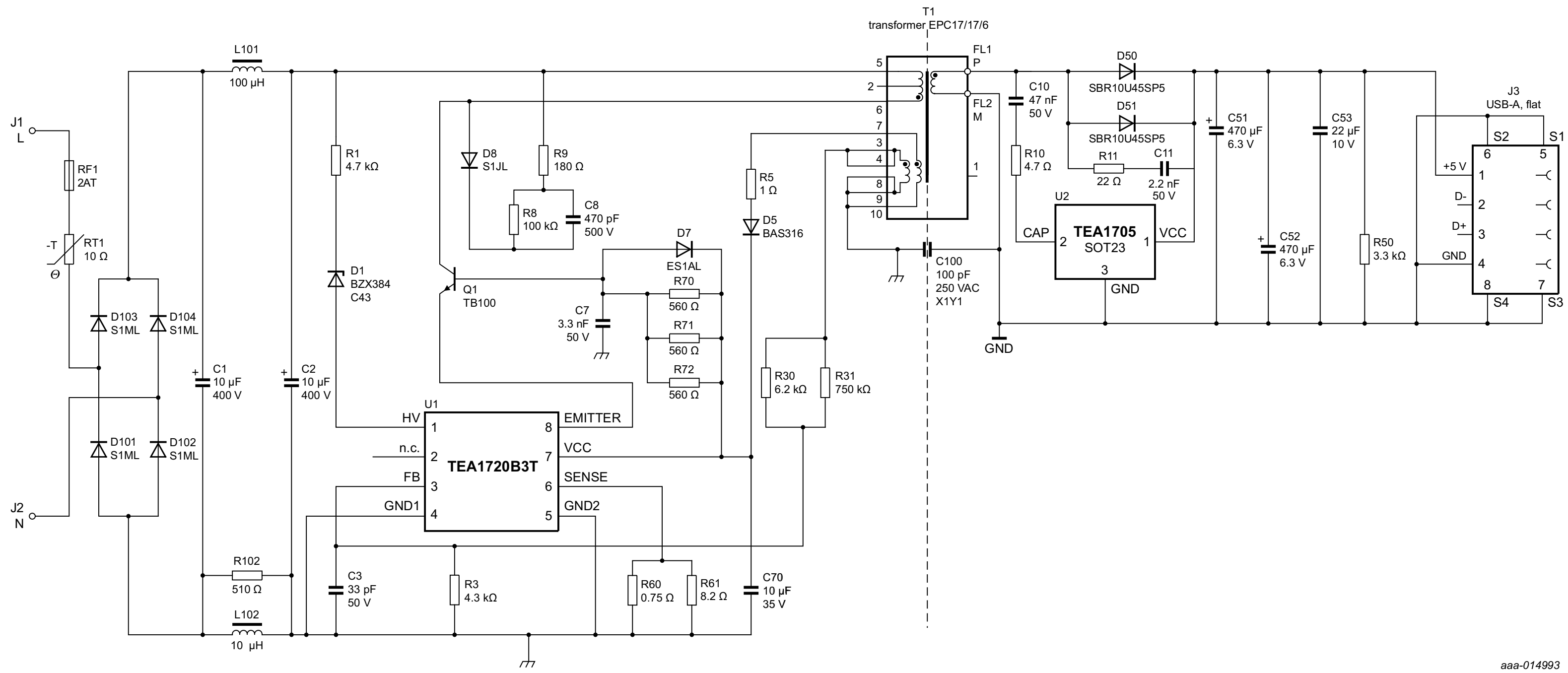


Fig 23. Schematic TEA1720ADB1132 10 W EPC17 demo board

8. Circuit description

The GreenChip TEA1720ADB1132 demo board consists of a single-phase full wave rectifier circuit, a filtering section, a switching section, an output section and a feedback section. The circuit diagram is shown in Figure 23 and the component list is shown in Table 8.

8.1 Rectification section

The bridge diodes D101 to D104 provide a single-phase full wave rectifier. Capacitors C1 and C2 function as reservoir capacitors for the rectified input voltage. Thermistor RT1 limits inrush current. Terminals J1 and J2 connect the input to the electricity utility network. Swapping these two wires has no effect on the operation of the converter.

8.2 Filtering section

Inductors L1 and L2, with capacitors C1 and C2, form π-filters to attenuate conducted differential-mode EMI noise.

8.3 TEA1720B3T section

The TEA1720B3T device (U1) contains the oscillator, CV/CC control, start-up control, protection functions, high-voltage start-up and emitter switch for switching the external NPN all in one IC.

One auxiliary winding on transformer T1 is used to provide the primary sensing information for the TEA1720B3T. A second auxiliary winding generates the supply voltage. This voltage is (half wave) rectified by diode D5 and capacitor C70. C70 is charged via the current limiter resistor R5. The voltage on C70 is the supply voltage for the VCC pin of the TEA1720B3T and delivers the base current for the NPN transistor.

The RCD-R clamp consisting of R8, C8, D8 and R9 limits drain voltage spikes caused by leakage inductance of the transformer.

8.4 Output section

Diodes D50 and D51, Schottky barrier type diodes, filtered by capacitors C51 and C52 rectify the secondary winding of transformer T1. Using a Schottky barrier type diode results in a higher efficiency of the demo board. C51 and C52 must have sufficient low ESR characteristics to meet the output voltage ripple and noise requirement without adding an LC output filter. Capacitor C11 damps high frequency ringing and reduces the voltage stress on the Schottky diodes. Resistor R50 provides a minimum load to maintain output control in no-load condition.

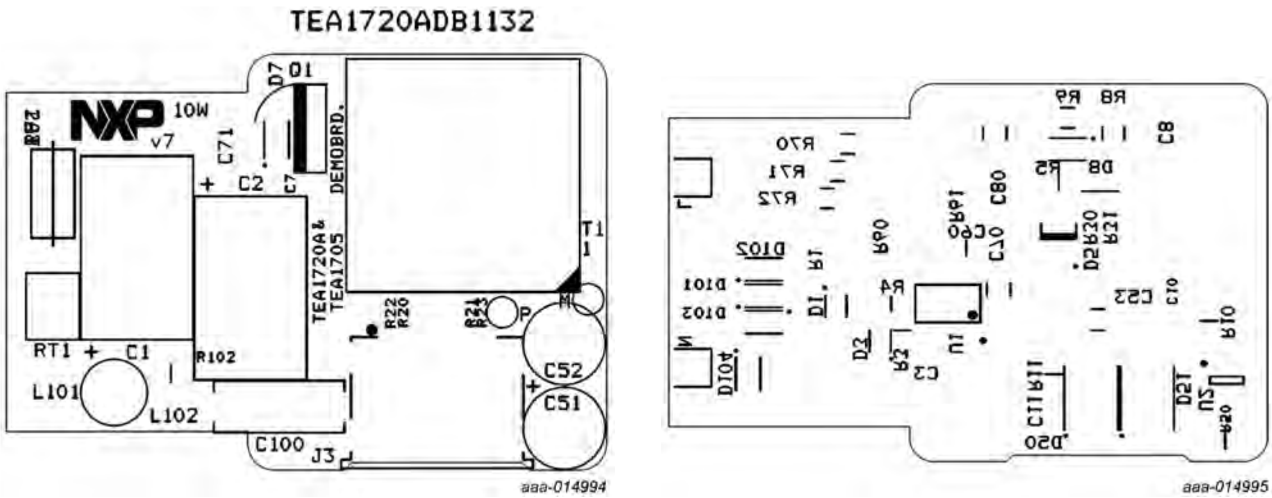
8.5 Feedback section

The TEA1720B3T controls the output by current and frequency control for CV / CC regulation. The auxiliary winding on Transformer T1 senses the output voltage. The FB pin of the TEA1720B3T senses the reflected output voltage via feedback resistors R30, R31 and R3. C3 is added for noise filtering.

8.6 Transient controller

The TEA1705 secondary side transient controller offers an excellent transient response of the TEA1720B3T controller, with ultra-low no-load power and minimum sized output capacitors. The output voltage is continuously monitored and when the output voltage is below the detection level V_{det} (V_{CC}), a transient interrupt signal is generated. This signal is transmitted via C10 and the transformer to the primary side to wake up the TEA1720B3T. This system reduces the volume of the output capacitors and makes it possible to build compact chargers.

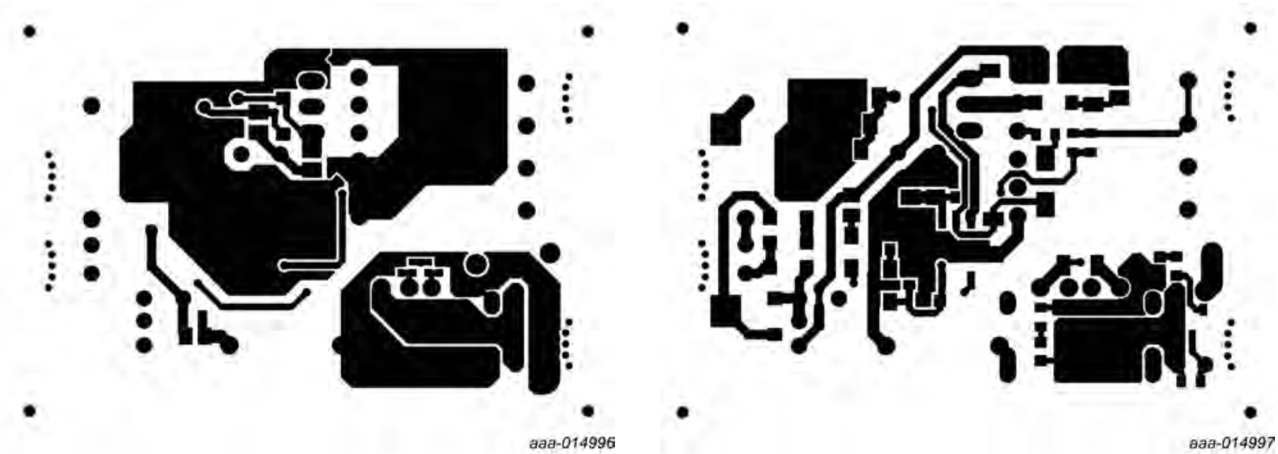
9. PCB layout



a. Top

b. Bottom

Fig 24. Silk screen layers



a. Top

b. Bottom

Fig 25. Copper layers

10. Bill Of Material (BOM)

Table 8. TEA1720ADB1132 bill of material

Reference	Description and values	Part number	Manufacturer
C1; C2	capacitor; 10 μF; 20 %; 400 V; ALU; 8.5 mm × 14 mm	ERK2GM100F12OT	Aishi
C3	capacitor; 33 pF; 5 %; 50 V; C0G; 0603	-	-
C7	capacitor; 3.3 nF; 10 %; 50 V; X7R; 0805	-	-
C8	capacitor; 470 pF; 5 %; 500 V; C0G; NP0; 0805	CC0805JRNPOBBN471	Yageo
C10	capacitor; 47 nF; 10 %; 50 V; X7R; 0603	-	-
C11	capacitor; 2.2 nF; 10 %; 50 V; X7R; 0603	-	-
C51; C52	capacitor; 470 μF; 20 %; 6.3 V; ALU; 6.3 mm × 8 mm	RS80J471MDNASQJT	Nichicon
C53	capacitor; 22 μF; 10 %; 10 V; X7R; 1206	GRM31CR71A226KE15L	Murata
C70	capacitor; 10 μF; 20 %; 35 V; X7R; 1206	C3216X7R1V106M160AC	TDK
C100	capacitor; 100 pF; 10 %; 250 V (AC); CD; X1Y1	CD70-B2GA101KYNS	TDK
D1	diode; Zener; 43 V; 200 mA	BZX384-C43	NXP Semiconductors
D5	diode; 100 V; 250 mA	BAS316	NXP Semiconductors
D7	diode; 50 V; 1 A	ES1AL	Taiwan Semiconductor
D8	diode; 600 V; 1 A	S1JL	Taiwan Semiconductor
D50; D51	diode; 45 V; 10 A	SBR10U45SP5-13	Diodes Inc.
D101; D102; D103; D104	diode, 1 kV; 1 A	S1ML	Taiwan Semiconductor
J3	connector; USB-A; flat	USB AF DIP - 94 - H	Gold Conn
L101	inductor; 100 μH; 10 %; 350 mA	11R104C	Murata
L102	inductor; 10 μH; 20 %; 520 mA; 0805	CB2012T100MR	Taiyo Yuden
Q1	transistor; NPN; 400 V; 1 A	TB100	NXP Semiconductors
R1	resistor; 4.7 kΩ; 1 %; 0.1 W; 0805	-	-
R3	resistor; 4.3 kΩ; 1 %; 0.1 W; 0603	-	-
R5	resistor; 1 Ω; 1 %; 0.1 W; 0603	-	-
R8	resistor; 100 kΩ; 1 %; 0.25 W; 1206	-	-
R9	resistor; 180 Ω; 1 %; 0.25 W; 1206	-	-

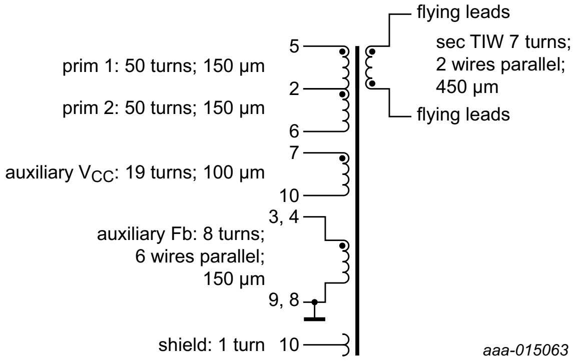
Table 8. TEA1720ADB1132 bill of material *...continued*

Reference	Description and values	Part number	Manufacturer
R10	resistor; 4.7 Ω; 1 %; 0.1 W; 0603	-	-
R11	resistor; 22 Ω; 1 %; 100 mW; 0603	-	-
R30	resistor; 6.2 kΩ; 1 %; 0603	-	-
R31	750 kΩ; 1 %; 0603	-	-
R50	resistor; 3.3 kΩ; 1 %;0.1 W; 0603	-	-
R60	resistor; 0.75 Ω; 1 %; 0.25 W; 0805	-	-
R61	resistor; 8.2 Ω; 1 %; 0.25 W; 0805	-	-
R70; R71; R72	resistor; 560 Ω; 1 %; 500 mW; 1206	-	-
R102	resistor; 510 Ω; 1 %; 200 mW; 0603	-	-
RF1	fuse; slow blow; 250 V; 2 A	MCPMP 2A 250V	Multicomp
RT1	thermistor; NTC; 10 Ω; 5 %	NTCLE100E3109JB0	Vishay
T1	transformer; EPC17/17/6; 4:6 pins	750313911	Würth Elektronik
U1	flyback converter, TEA1720B3T	TEA1720B3T	NXP Semiconductors
U2	IC; TEA1705, SOT23	TEA1705	NXP Semiconductors

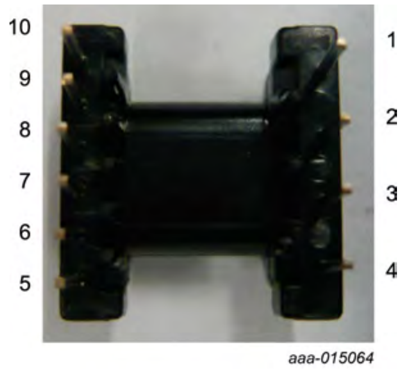
11. Transformer design

11.1 Transformer schematic design and winding construction

The transformer used in the TEA1720ADB1132 demo board has size EPC17.



a. Schematic



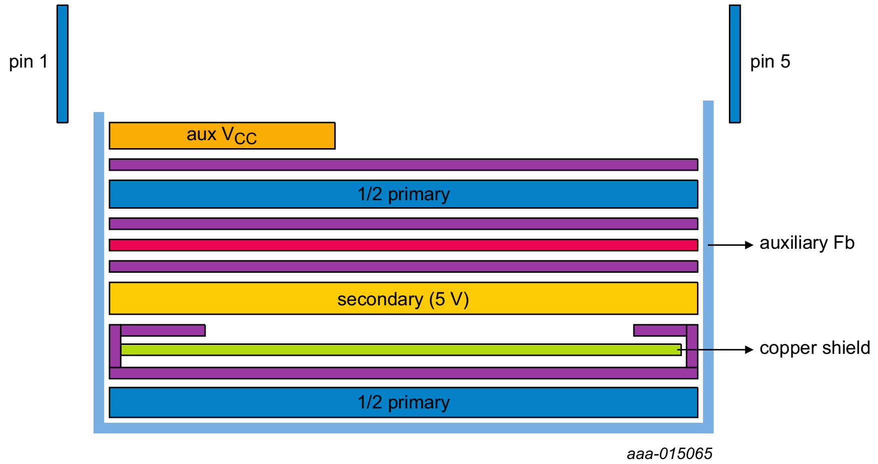
b. Bottom view

Fig 26. EPC17 transformer schematic and bottom view

Table 9. Transformer specifications

Feature	Values
bobbin	EPC17
ferrite material	3C90 or equivalent
output voltage	5.3 V at 2 A (150 mΩ cable compensation)
input voltage	90 V to 265 V (AC)
output current	2 A
maximum switching frequency	52 kHz
inductance	880 µH; ±3 %

11.2 Construction



(1) Amber: auxiliary winding
(2) Purple: isolation tape
(3) Blue: primary winding
(4) Purple: isolation tape
(5) Red: Fb winding
(6) Purple: isolation tape
(7) Yellow: secondary winding
(8) Purple: only side areas isolation tape
(9) Green: copper foil shield
(10) Purple: isolation tape
(11) Blue: primary winding

Fig 27. EPC17 construction

Table 10. Wiring description

Wire	Description
1/2 primary 1 layer	50 turns; wire thickness = 150 μm
shield	1 turn
secondary 1 layer	7 turns; two wires in parallel; wire thickness = 450 μm TIW
auxiliary Fb	8 turns; 6 wires in parallel; wire thickness 150 μm
1/2 primary 1 layer	50 turns; wire thickness = 150 μm
auxiliary V_{CC}	19 turns; wire thickness = 150 μm

Primary-inductance = 880 μH

12. Points of attention

When testing the CC-mode of the TEA1720B3T, it is necessary to use a DC electronic load in resistive mode, not in current mode. The current in CC-mode has a small fold back characteristic (see Figure 4 and Figure 5). When current mode of a DC electronic load is used, the output voltage drops immediate to zero when the maximum current is exceeded. When the output voltage becomes zero, causing the input voltage of the used DC electronic load to become zero as well, many DC electronic loads can no longer adjust the current. Using the resistive mode of the DC electronic load avoids this problem.

Below V_{out} = 2.7 V at the PCB end, the TEA1720B3T enters hiccup mode to limit the output power.

Remark: This behavior of the TEA1720B3T controller is not incorrect. It is only required to test it in the correct way.

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