UM12002

TEA2376DB1602v2 300 W interleaved PFC demo board

Rev. 1 — 6 February 2024 **User manual**

Document information

Information	Content
Keywords	TEA2376, TEA2376DB1602, 300 W, PFC, interleaved, controller, converter, burst mode, shedding, efficiency, power supply, demo board, TEA2209T, active bridge rectifier, programmable settings, I^2C, TEA2016DB1514, RDK01DB1563, TEA2376DB1011
Abstract	The TEA2376 is a digital configurable two-phase interleaved PFC controller for high efficiency power supplies. The PFC operates in discontinuous conduction mode (DCM) or critical conduction mode (CCM) with valley switching to optimize efficiency. The TEA2376 allows you to build an interleaved power factor converter, which is easy to design with a low number of external components. The digital architecture is based on a configurable hardware state machine ensuring reliable real-time performance. During power supply development, many PFC controller operation and protection settings can be customized by loading new settings into the device using I^2C to meet specific application requirements. Input current shaping is used for a high power factor and a low THD. For a low-load operation with good efficiency, phase shedding and burst mode operation are included. In the burst mode, the power consumption of the IC is reduced. The TEA2376 contains many protections, such as internal and external overtemperature protection (OTP), overcurrent protection (OCP), double overvoltage protections (OVP), inrush current protection (ICP), pin open protection, pin short protection, and phase fail protection. The protections can be configured independently via programmable parameters. The TEA2376DB1602v2 demo board shows an interleaved PFC converter (TEA2376) with an active bridge rectifier (TEA2209T) without heat sinks. The converter can provide 300 W output power in laboratory conditions without forced cooling.

1 Important notice

IMPORTANT NOTICE

For engineering development or evaluation purposes only

NXP provides the product under the following conditions:

This evaluation kit or reference design is for use of ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY.

It is provided as a sample IC pre-soldered to a printed circuit board to make it easier to access inputs, outputs, and supply terminals. This evaluation kit or reference design may be used with any development system or other source of I/O signals by connecting it to the host MCU or computer board via off-the-shelf cables. Final device in an application will be heavily dependent on proper printed circuit board layout and heat sinking design as well as attention to supply filtering, transient suppression, and I/O signal quality.

The product provided may not be complete in terms of required design, marketing, and or manufacturing related protective considerations, including product safety measures typically found in the end device incorporating the product. Due to the open construction of the product, it is the responsibility of the user to take all appropriate precautions for electric discharge. To minimize risks associated with the customers' applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards. For any safety concerns, contact NXP sales and technical support services.

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FCC NOTICE: This kit is designed to allow:

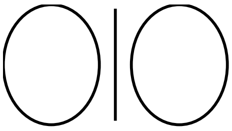
1. Product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and
2. Software developers to write software applications for use with the end product.

This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

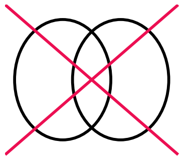
2 Safety warning

The application board is AC-mains voltage powered. Avoid touching the board while it is connected to the mains voltage and when it is in operation. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments. Galvanic isolation from the mains phase using a fixed or variable transformer is always recommended.

Figure 1 shows the symbols on how to recognize these devices.



a. Isolated



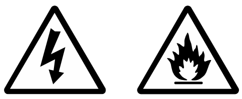
b. Not isolated

Figure 1. Isolation symbols

3 Introduction

WARNING

Lethal voltage and fire ignition hazard

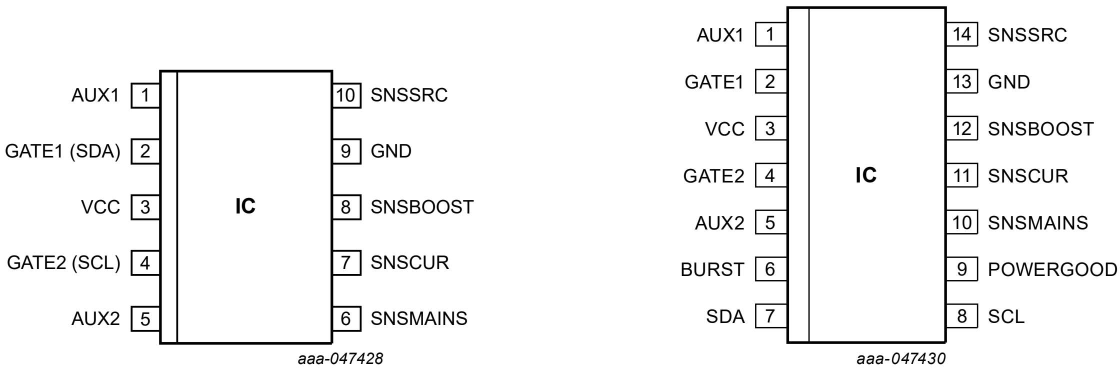


The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire. This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

3.1 TEA2376

The TEA2376 provides high efficiency at all power levels. Together with a TEA2209T active bridge rectifier controller, a TEA2376AT LLC controller, and a TEA19161 SR controller, a high-performance cost-effective resonant power supply can be designed, which meets modern power supply efficiency regulations.

An extensive number of parameter settings can define the operation modes and protections. These settings can be stored/programmed in an internal memory. This feature provides flexibility and ease of design to optimize controller properties to application-specific requirements or even optimize/correct performance during power supply production. At start-up, the IC loads the parameter values for operation. For easy design work during product development, the most extended version, TEA2095, can be used to change settings on the fly.



a. TEA2376AT (SO10)

b. TEA2095 (SO14)

Figure 2. Pinning diagrams

3.2 TEA2209T

The TEA2209T is an active bridge rectifier controller replacing the traditional diode bridge. Using the TEA2209T with low-ohmic high-voltage external MOSFETs significantly improves the efficiency of the power converter. The reason is that the typical rectifier diode-forward conduction losses are eliminated. In addition, the TEA2209T includes an X-capacitor discharge function. To reduce power consumption at a standby condition, an external signal via the COMP pin can disable the TEA2209T.

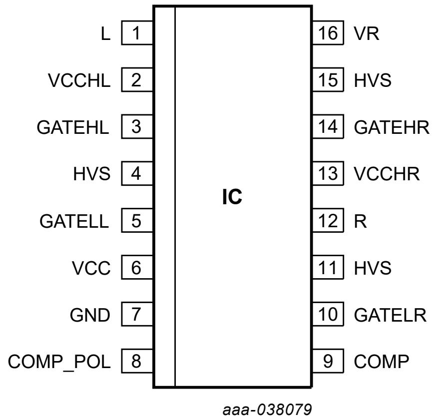


Figure 3. TEA2209T pinning diagram

3.3 Demo board

The TEA2376DB1602v2 demo board can operate on a mains input voltage between 90 V (RMS) and 264 V (RMS), universal mains voltage.

The TEA2376DB1602v2 demo board incorporates two subcircuits:

- Active bridge rectifier
- Interleaved PFC converter

The purpose of the demo board is to demonstrate and evaluate the operation of the TEA2376DT and TEA2209T in a single output power supply, including the modes of operation in a typical design. The performance supports common standards, including current low-load and standby requirements. It can be used as a starting point for developing power supplies using the TEA2376 and TEA2209 controller ICs.

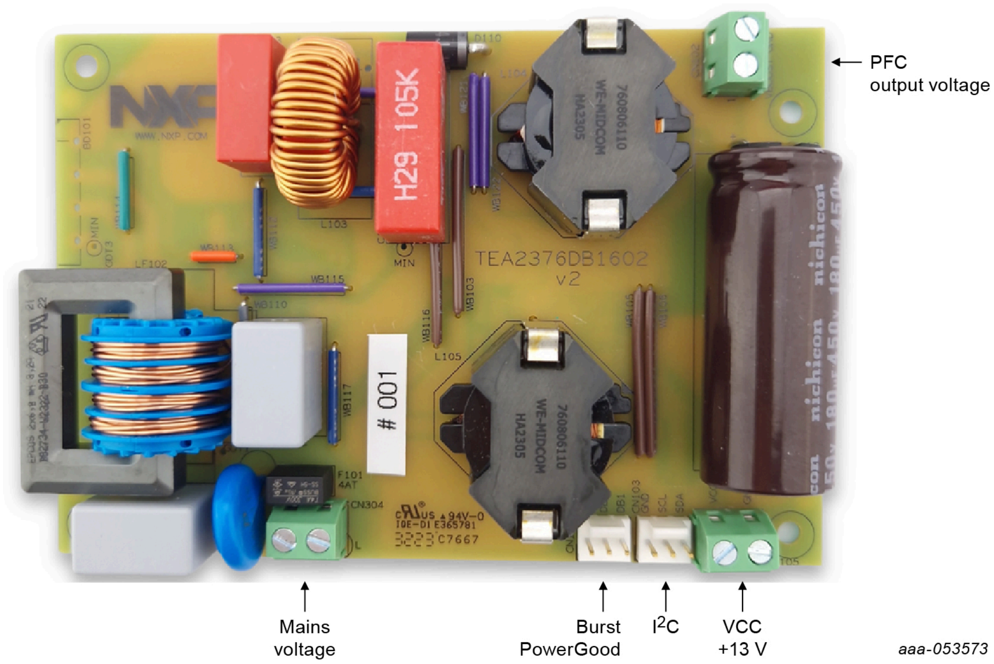


Figure 4. TEA2376DB1602v2 demo board

To show the benefits of an interleaved PFC with an active bridge rectifier, the TEA2376DB1602V2 board design was made on a single-sided copper PCB with standard MOSFET types and without heat sinks.

At an output power of 300 W, the temperature of the components remains acceptable at nominal mains voltage values in lab conditions. Higher output power levels are possible, but they require fan cooling.

3.4 TEA2376 Ringo software and USB-I^{2}C interface

On the TEA2376DB1602v2 board, the TEA2376DT (SO14) version is used. This version includes two dedicated pins for I^{2}C communication that supports access to parameter modifications, which is useful for product development. During the power supply operation, settings can be modified and status information of the operation can be monitored.

3.4.1 TEA2376DT: Dedicated SDA and SCL pins

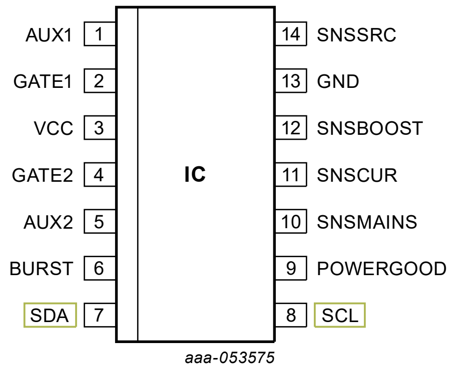


Figure 5. TEA2376DT: I^{2}C connections on pin 7 and pin 8

3.4.2 TEA2376AT and TEA2376BT: SDA and SCL on combined pins

In the basic TEA2376 versions, the I^{2}C interface is available on combined GATE1 (SDA) and GATE2 (SCL) pins (pin 2 and pin 4). To program the IC, the IC must be disabled at start-up with 0 V on SNSMAINS.

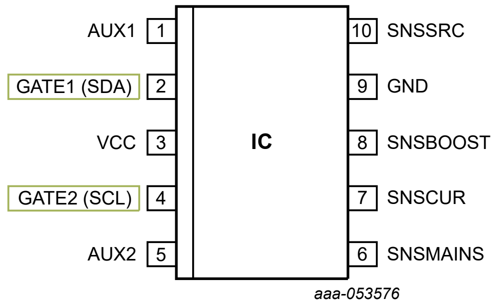


Figure 6. TEA2376AT: I^{2}C connections on pin 2 and pin 4

3.4.3 Ringo software with graphical user interface (GUI) and USB-I^{2}C interface

During power supply development, the communication with the IC can be done using the Ringo software on a Windows OS PC with a USB-I^{2}C interface (TEA2016DB1514 available as part of the RDK01DB1563 kit). The TEA2376 Ringo software with GUI provides the correct protocol and offers several options and tools to work with the IC settings and the readout status information.

The Ringo user manual (Ref. 6) and USB-I^{2}C interface user manuals and the TEA2016DB1514 USB to I^{2}C hardware interface user manuals show how to work with it.

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a. On the fly

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b. Standalone

Figure 7. Two TEA2376 programming setups

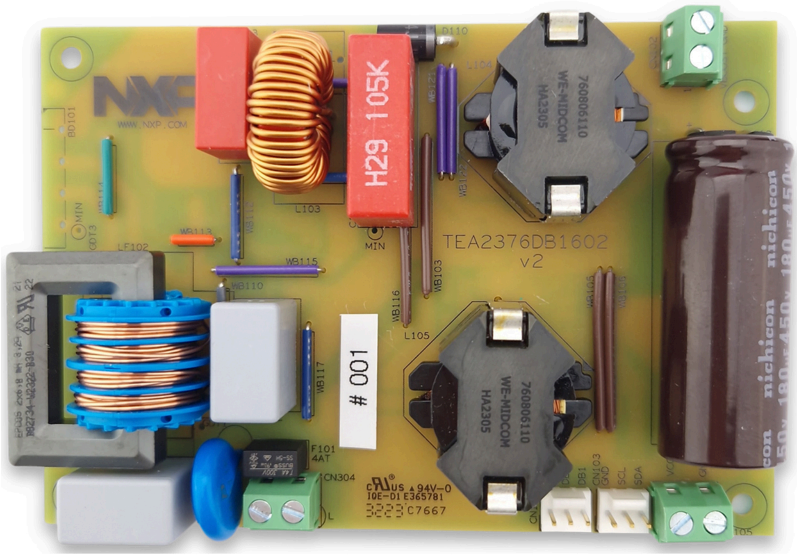
4 Finding kit resources and information on the NXP website

NXP Semiconductors provides information for the devices on the TEA2376DB1602 demo board at www.nxp.com.

5 Getting ready

5.1 Box contents

The box contains the TEA2376DB1602v2 demo board. Figure 8 shows the top side and bottom side of the evaluation board.



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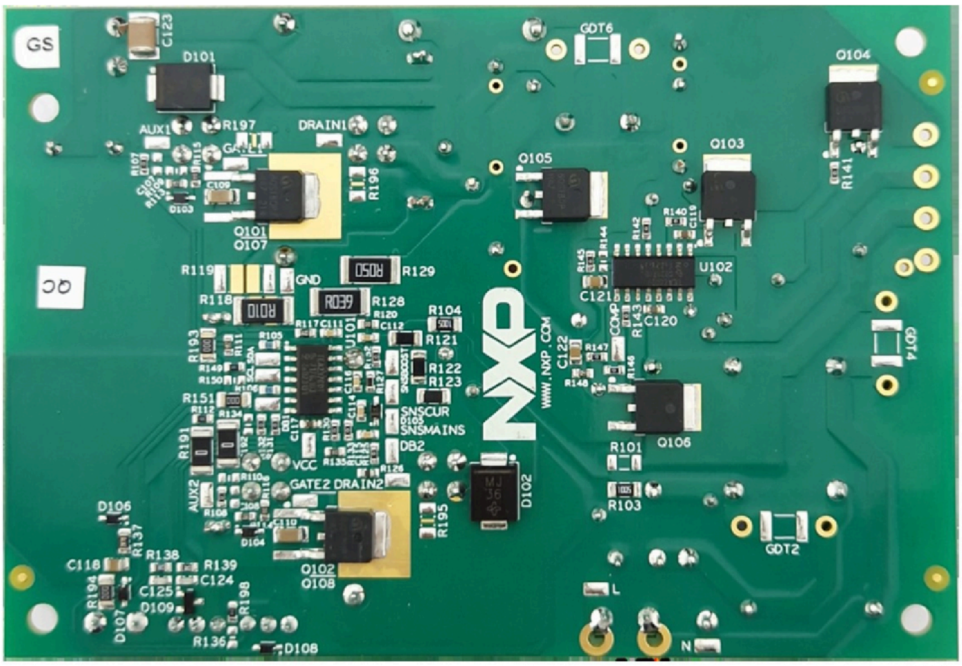
a. Top side



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b. Bottom side

Figure 8. TEA2376DB1602 demo board photographs

6 Getting to know the hardware

6.1 Specifications

Table 1. Specifications

Symbol	Description	Conditions	Values	Unit
V_i	input voltage	AC	90 to 264	V (RMS)
F_i	input frequency	-	47 to 63	Hz
$P_{i(no\ load)\_mains}$	no-load input power	at 230 V/50 Hz	< 35	mW
$P_{i(no\ load)\_VCC}$	no-load input power	at VCC = 16 V (DC)	< 15	mW
V_o	output voltage	normal mode	395	V
$V_{o(min,max)}$	output voltage variations	load-step response	< 10	%
I_o	output current	continuous	0 to 0.76	A
I_o	output current	peak at nominal Vo	> 1	A
t_{start}	start time	115 V/60 Hz, Io = 0.76 A	100	ms
PF	power factor	Io = 0.76 A	0.99	-
η	efficiency	115 V/60 Hz, Io = 0.76 A	> 96	%
η	efficiency	230 V/50 Hz, Io = 0.76 A	> 98	%

6.2 TEA2376 features

6.2.1 Distinctive features

- Interleaved PFC controller in an SO10 package (TEA2376AT) or an SO14 package (TEA2376BT and TEA2376DT)
- Programmable phase shedding and burst mode operation
- Dual output over voltage protection
- Inrush current protection
- High power factor (PF) and low total harmonic distortion (THD), also at high input voltages
- Many parameters can be configured during evaluation with the use of a user-friendly graphical user interface (GUI)
- Good phase control over the full input voltage range
- Low audible noise
- TEA2376DT: Power good output and a burst mode input pin
- TEA2376DT: Live monitoring of (internal) IC status values over time with the help of the user-friendly GUI similar to oscilloscope reading
- TEA2376DT: I^2C communication while in operation

6.2.2 Green features

- Valley/zero voltage switching for minimum switching losses
- High efficiency from high load to medium load and low load by phase shedding and burst mode operation

6.2.3 Protection features

- Protections can independently be set to latched, safe restart, or latched after several attempts to restart
- Dual output overvoltage protection (OVP)
- Supply undervoltage protection (UVP) and overvoltage protection (OVP)
- Internal and external overtemperature protection (OTP)
- Overcurrent protection (OCP)
- Inrush current protection (ICP)
- Brownin/brownout protection
- Open and short pin protection
- Coil short protection
- Output diode short protection
- Open control loop protection
- Phase fail protection

7 Performance measurements

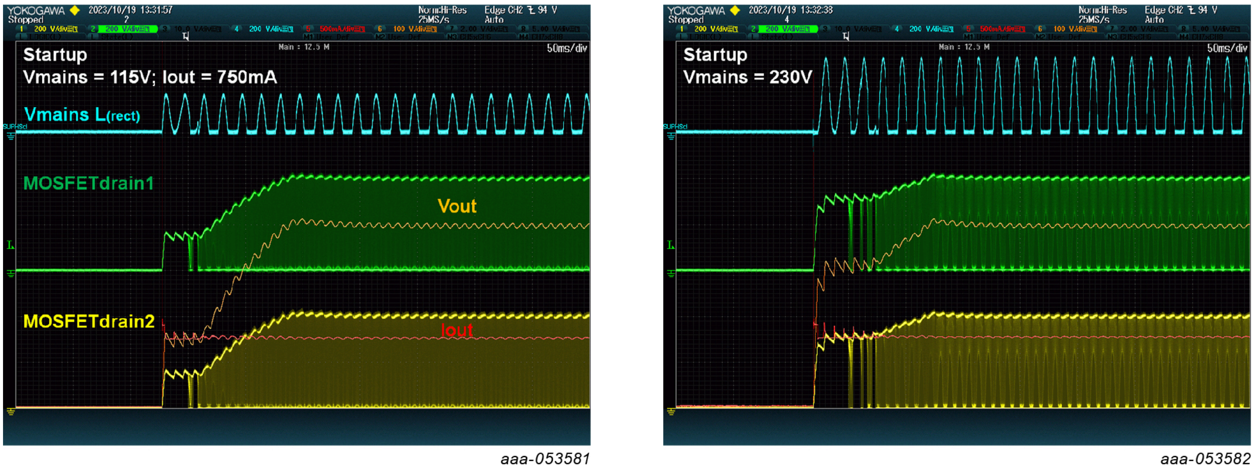
7.1 Test facilities

- Oscilloscope: Yokogawa DLM4038
- AC power source: Agilent 6812B
- Electronic load: Keithley 2380-500-30
- Digital power meter: Yokogawa WT210

7.2 Start-up and switch-off behavior

7.2.1 Output voltage rise time

The rise time of the output voltage is approximately 100 ms.



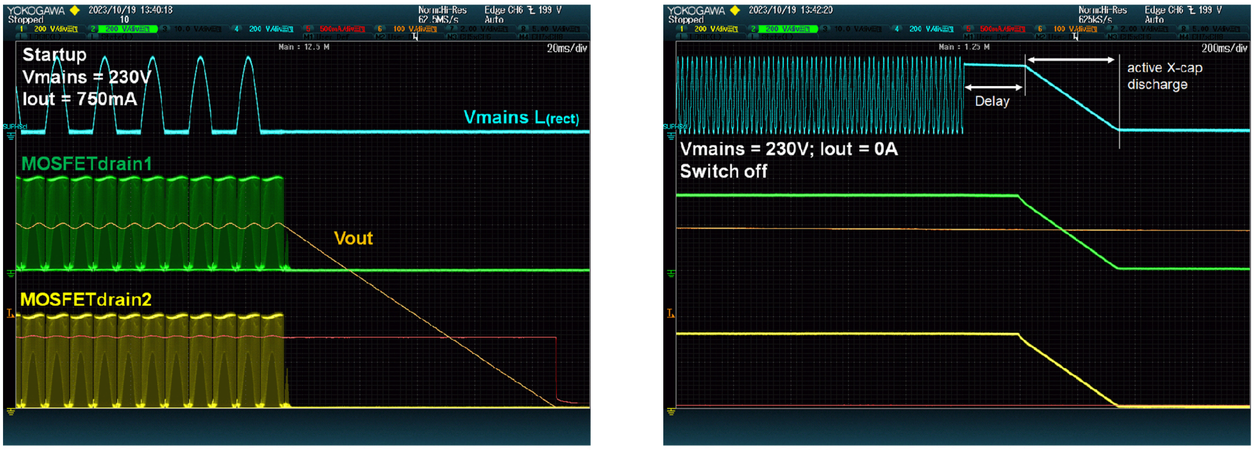
a. 115 V

b. 230 V

Figure 9. Start-up behavior

7.2.2 Mains switch-off and X-capacitor discharge

At low-load conditions, the TEA2209T X-capacitor discharge function is activated.



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a. start-up: 230 V/750 mA

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b. Switch-off: 230 V/0 mA

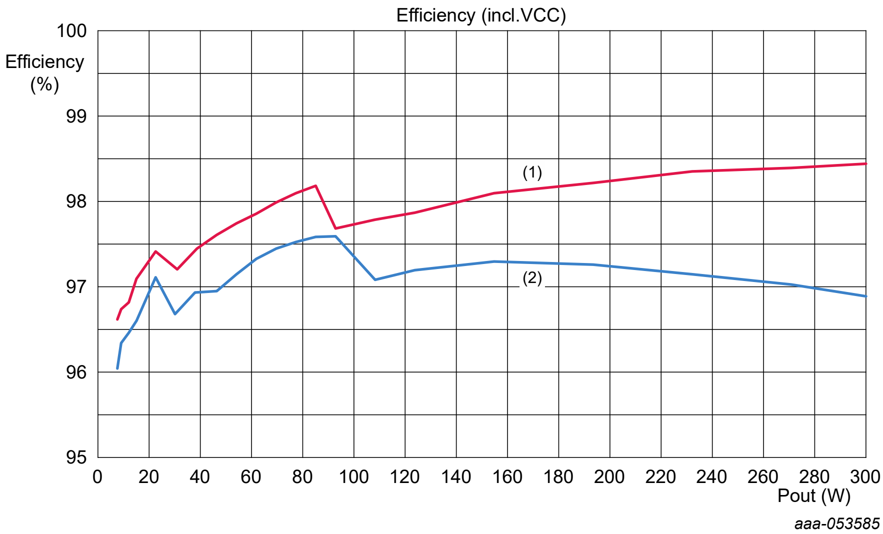
Figure 10. Mains switch-off behavior

7.3 Efficiency

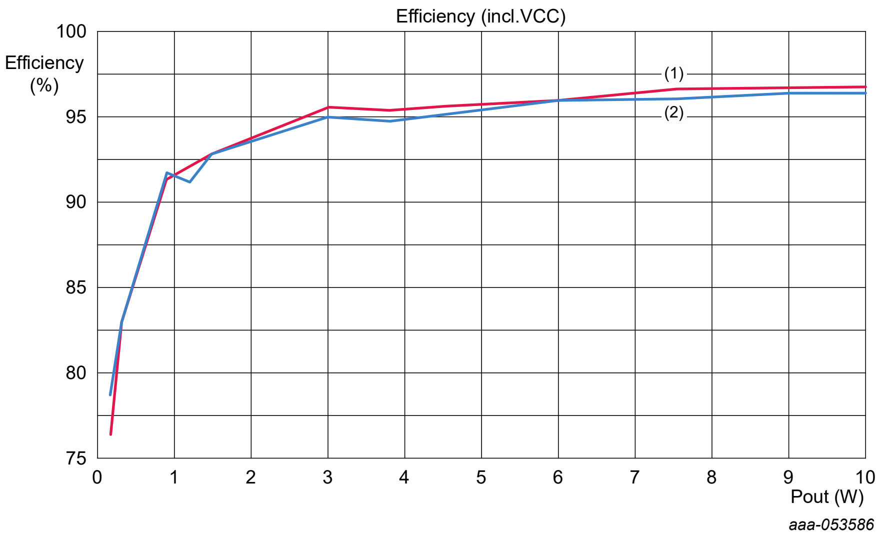
7.3.1 Efficiency characteristics

Table 2. Efficiency results

Condition	Average (%)	25 % load	50 % load	75 % load	100 % load
115 V/60 Hz	97.2	97.5	97.2	97.3	96.9
230 V/50 Hz	98.2	98.0	98.1	98.3	98.4



(1) V_{mains} = 230 V (AC)
(2) V_{mains} = 115 V (AC)



(1) V_{mains} = 230 V (AC)
(2) V_{mains} = 115 V (AC)

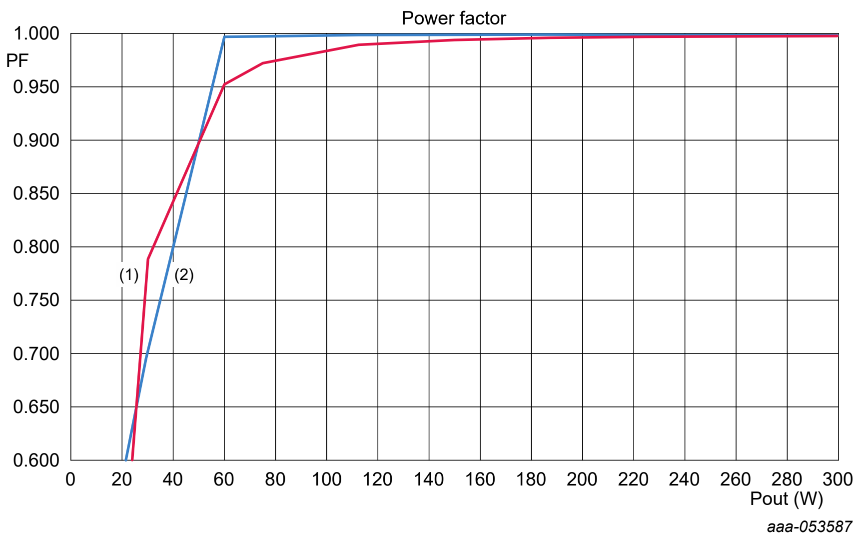
Figure 11. Efficiency graphs

7.3.2 No-load power consumption

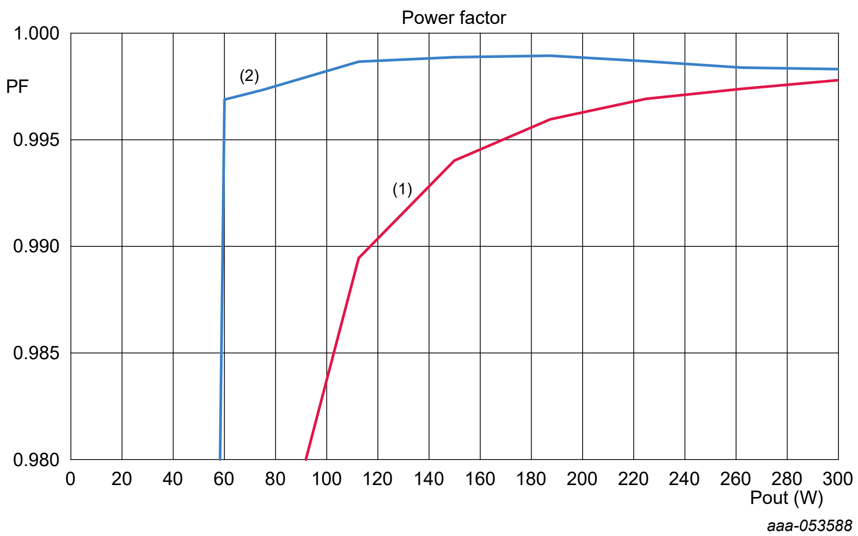
Table 3. Power consumption at no load

Condition	Requirement	No-load power consumption
VCC = 16 V	≤ 15 mW	9 mW
115 V/60 Hz	≤ 35 mW	25 mW
230 V/50 Hz	≤ 35 mW	30 mW

7.3.3 Power factor



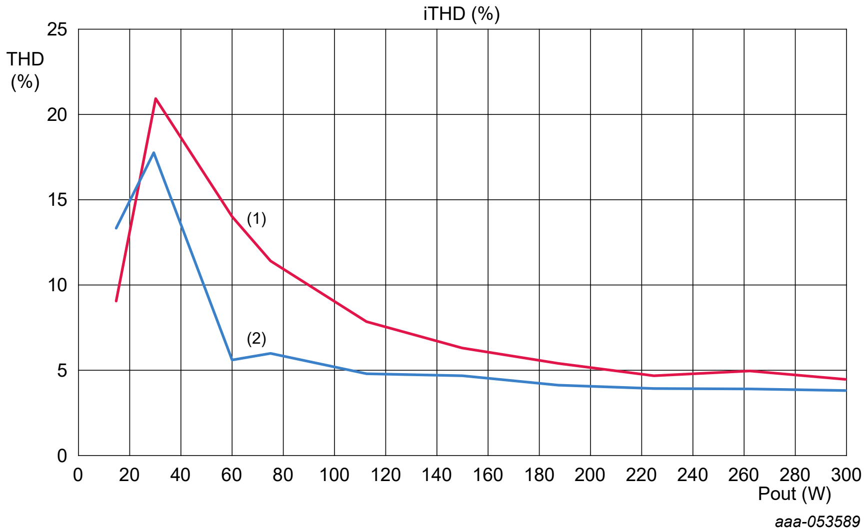
(1) V_{mains} = 230 V (AC)
(2) V_{mains} = 115 V (AC)



(1) V_{mains} = 230 V (AC)
(2) V_{mains} = 115 V (AC)

Figure 12. Power factor graphs

7.3.4 Harmonic distortion



(1) V_{mains} = 230 V (AC)
(2) V_{mains} = 115 V (AC)

Figure 13. Harmonic distortion (iTHD) graph

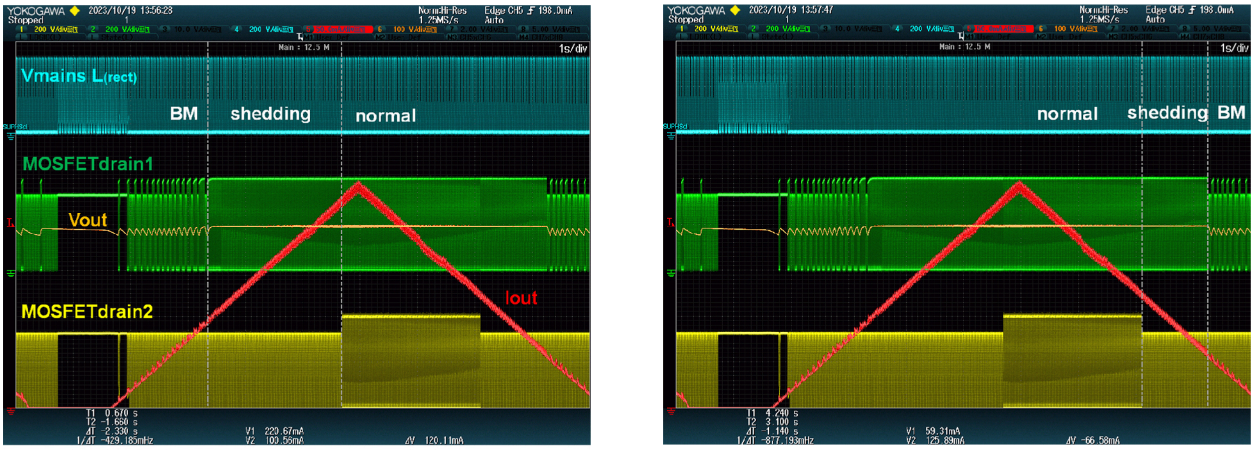
7.4 Operation mode transitions

There are three modes of operation:

- Normal mode
- Phase shedding
- Burst mode (BM)

The transition level can be modified using programmable MTP settings.

7.4.1 Mode transitions at V_{mains} = 230 V



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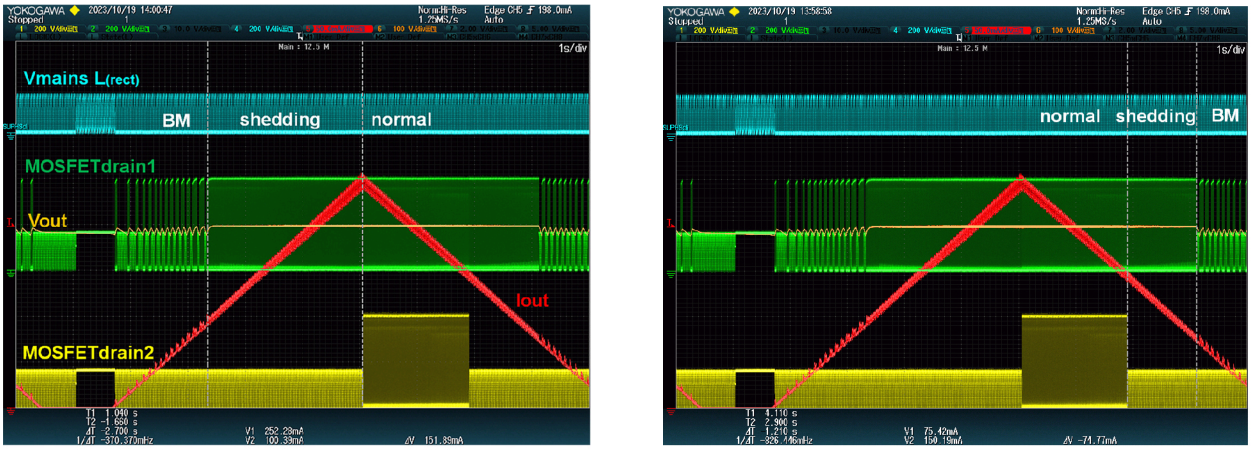
Load sweep: Slowly varying the output current to observe mode transitions.

Figure 14. V_{mains} = 230 V; operating mode transitions BM - phase shedding - normal operation

- BM to phase shedding: P_{out} = 39 W
- Phase shedding to normal mode: P_{out} = 86 W
- Normal mode to phase shedding: P_{out} = 50 W
- Phase shedding to BM: P_{out} = 23 W

7.4.2 Mode transitions at V_{mains} = 115 V



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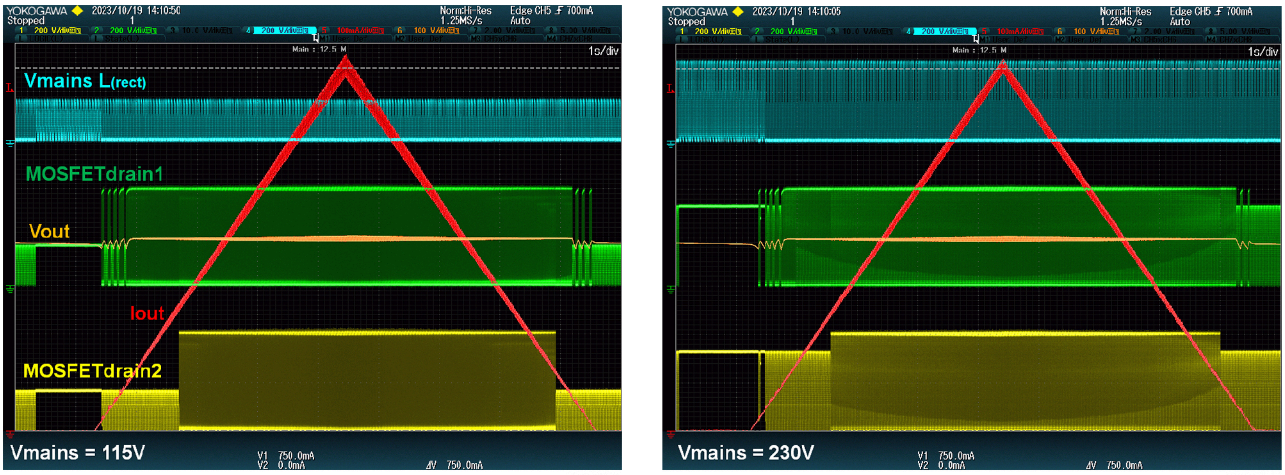
Load sweep: Slowly varying the output current to observe mode transitions.

Figure 15. V_{mains} = 115 V; Operating mode transitions BM - phase shedding - normal operation

- BM to phase shedding: P_{out} = 39 W
- Phase shedding to normal mode: P_{out} = 99 W
- Normal mode to phase shedding: P_{out} = 59 W
- Phase shedding to BM: P_{out} = 29 W

7.4.3 Load sweep from 0 W to 300 W



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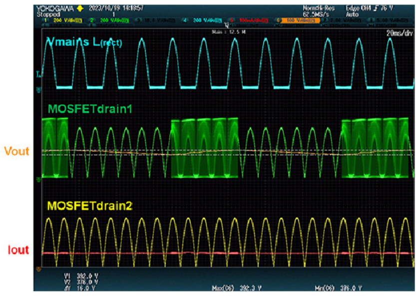
Load sweep: Slowly varying the output current to observe behavior and mode transitions.

Figure 16. Load sweep from 0 W to 300 W

7.4.4 Burst mode operation

Auto burst mode operation with 105 mV selected SNSBOOST hysteresis resulting in 16 Vpp ripple on the PFC output voltage.



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a. I_{out} = 50 mA

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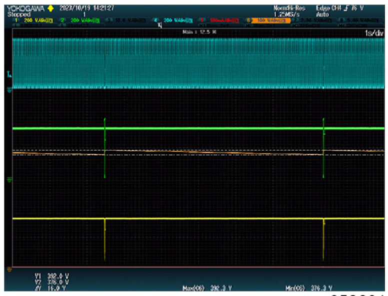
b. I_{out} = 10 mA



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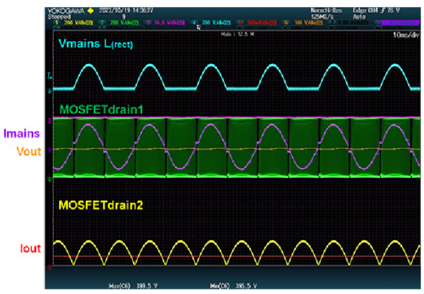
c. I_{out} = 0 mA

Figure 17. Burst mode operation at V_{mains} = 230 V

7.4.5 Phase shedding and normal operation



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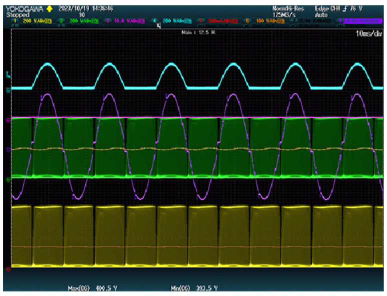
a. I_{out} = 150 mA - phase shedding mode



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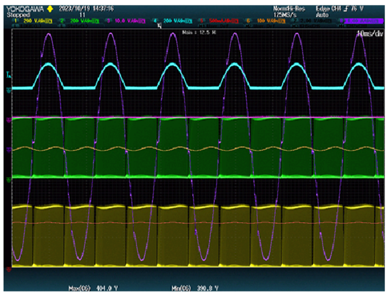
b. I_{out} = 350 mA



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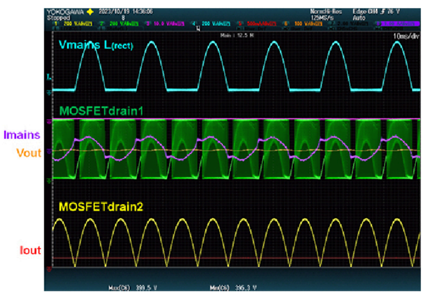
c. I_{out} = 750 mA

Figure 18. Phase shedding and normal operation at V_{mains} = 115 V



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a. I_{out} = 150 mA - phase shedding mode

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b. I_{out} = 350 mA

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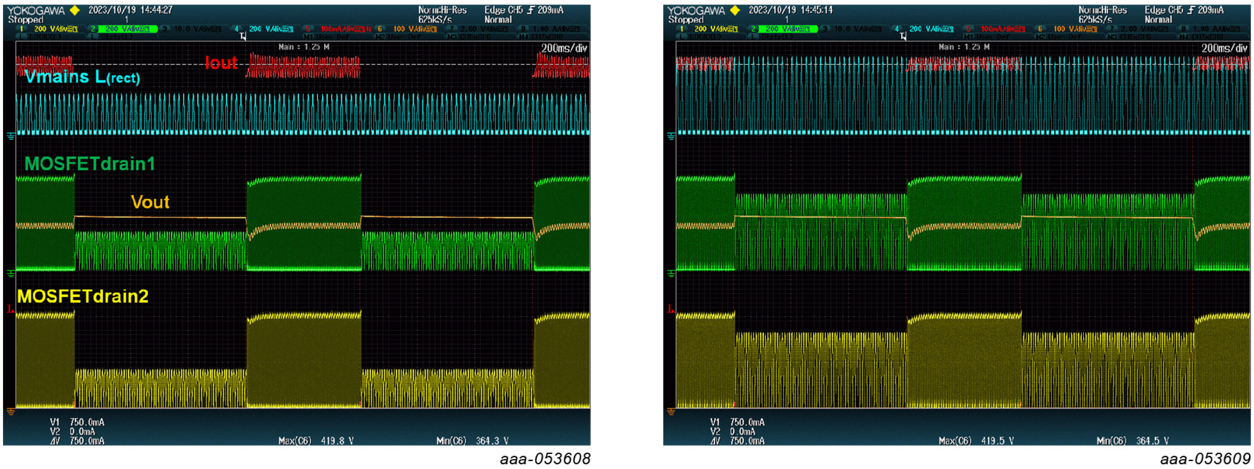
c. I_{out} = 750 mA

Figure 19. Phase shedding and normal operation at V_{mains} = 230 V

7.5 Dynamic load response

Worse case load steps 0 mA (0 %) to 750 mA (100 %) show output voltage variations:

- V_{mains} = 115 V; output voltage: 364 V to 420 V (−8 %, +6 %)
- V_{mains} = 230 V; output voltage: 364 V to 420 V (−8 %, +6 %)



a. V_{mains} = 115 V

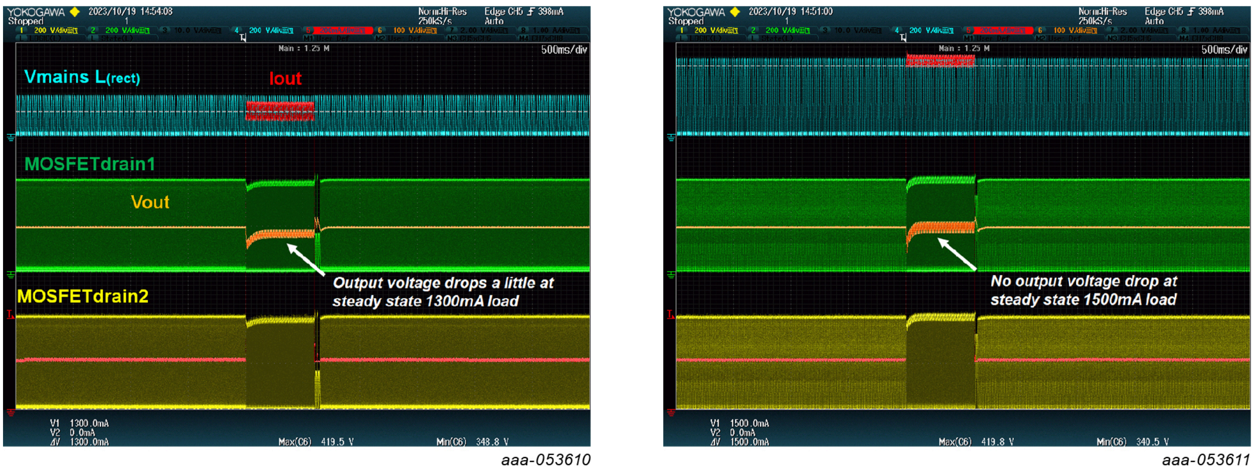
a. V_{mains} = 230 V

Figure 20. Load step behavior 0 mA (500 ms) to 750 mA (500 ms)

7.6 Peak output power capability

The maximum peak output power with nominal output voltage (395 V) is limited, depending on the mains voltage.

- Nominal P_{out} = 300 W (100 %)
- Maximum P_{out} at 115 V mains = 510 W (170 %)
- Maximum P_{out} at 230 V mains > 600 W (200 %)



With a short load step, the maximum output power can be found. The output voltage starts dropping.

a. V_{mains} = 115 V

a. V_{mains} = 230 V

Figure 21. Maximum peak output power (at nominal output voltage)

7.7 Thermal information

To show the benefits of an interleaved PFC with an active bridge rectifier circuit, the TEA2376DB1602v2 board design was made on a single-sided copper PCB with standard MOSFET types and without using heat sinks.

At 300 W output power, the temperature of the components remains acceptable at nominal mains voltage values in a lab condition. It mainly concerns the MOSFETs remaining below 100 °C at 25 °C room temperature. Because of the small board size, there is considerable influence of components heating each other.

At 115 V mains and P_{out} = 300 W, the measured maximum temperature was 82 °C.

At 100 V mains and P_{out} = 300 W, the measured maximum temperature was 100 °C.

Higher output power levels are possible, however, to avoid damage by overheating, they require fan cooling.

8 Schematic, bill of materials, layout

8.1 Schematic

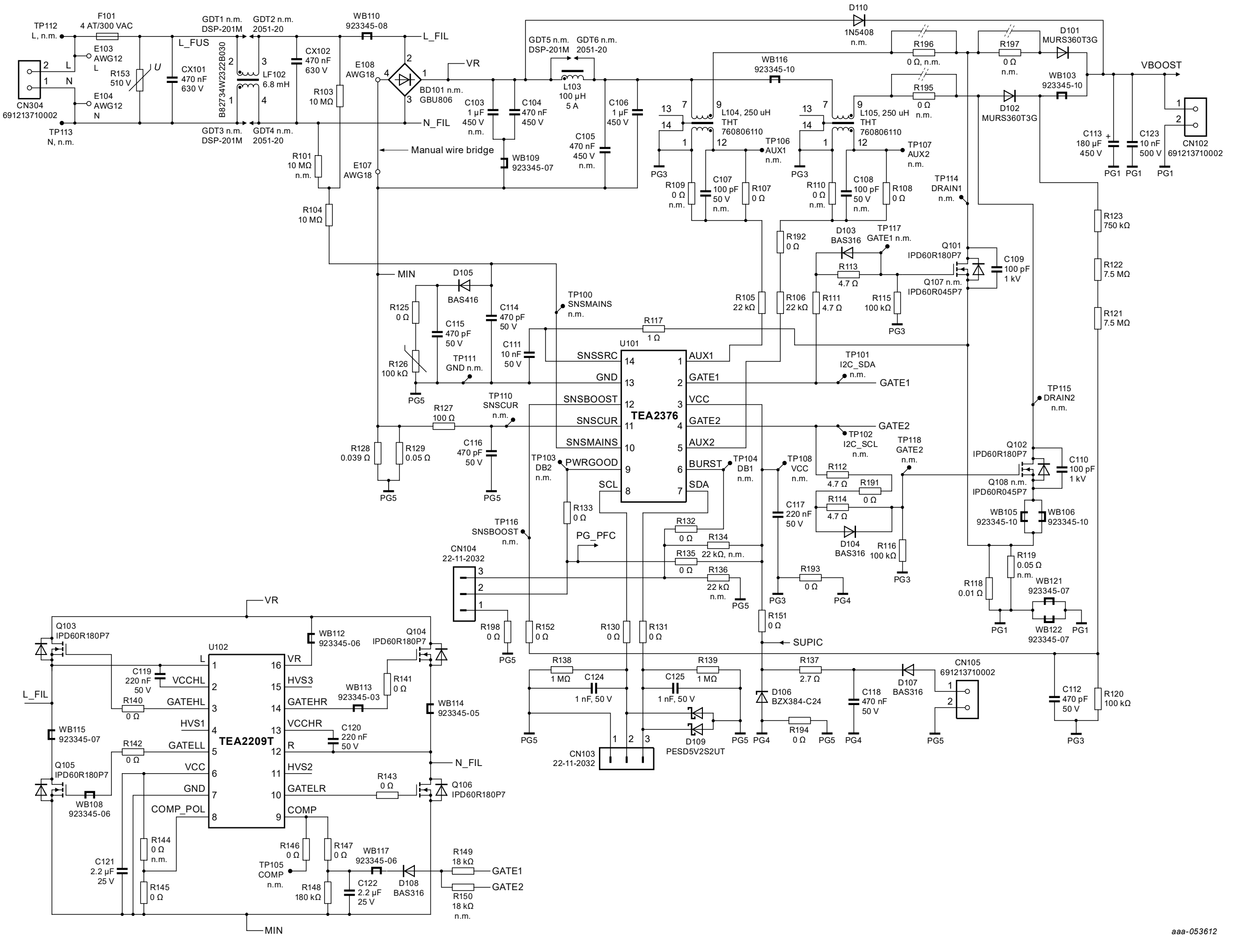


Figure 22. TEA2376DB1602v2 schematic diagram

8.2 Bill of materials (BOM)

Table 4. Bill of materials

Part	Description and values	Part number	Manufacturer
BD101	bridge rectifier; not mounted; 600 V; 8 A	GBU806	Diodes Inc
C103	capacitor; not mounted; 1 μF; 10 %; 450 V; PET; THT	ECQE2W105KH	Panasonic
C104	capacitor; 470 nF; 10 %; 400 V; PET	890334025039	Würth Elektronik
C105	capacitor; not mounted; 470 nF; 10 %; 450 V; PET; THT	ECQE2W474KH	Panasonic
C106	capacitor; 1 μF; 10 %; 400 V; PET	890283426008CS	Würth Elektronik
C106'	capacitor; not mounted; 2.2 μF; 10 %; 450 V; PET; THT	ECQE2W225KH	Panasonic
C107; C108	capacitor; not mounted; 100 pF; 10 %; 50 V; C0G; 0603	-	-
C109; C110	capacitor; 100 pF; 10 %; 1 kV; X7R; 1206	-	-
C111	capacitor; 10 nF; 10 %; 50 V; X7R; 0603	-	-
C112; C114; C115; C116; C118	capacitor; 470 pF; 10 %; 50 V; X7R; 0603	-	-
C117; C119; C120	capacitor; 220 nF; 10 %; 50 V; X7R; 0603	-	-
C121; C122	capacitor; 2.2 μF; 10 %; 25 V; X7R; 0805	-	-
C123	capacitor; 10 nF; 10 %; 500 V; X7R; 1812	C1812C103KCRACTU	KEMET
C124; C125	capacitor; 1 nF; 5 %; 50 V; C0G; 0603	-	-
CN102; CN105; CN304	receptacle; connection terminal block; 1x2-way; 5.00 mm	691213710002	Würth Elektronik
CN103; CN104	Header; Straight; Gold Plated; 1x3-way; 2.54 mm;	22-11-2032	Molex
CX101; CX102	capacitor; 470 nF; 20 %; 630 V; MKP; THT; X2	BFC233922474	Vishay
D101; D102	diode; 600 V; 3 A	MURS360T3G	ON Semiconductor
D103; D104; D107; D108	diode; 100 V; 250 mA	BAS316	NeXPeria USA Inc.
D105	diode; 85 V; 200 mA	BAS416	NeXPeria USA Inc.
D106	diode; Zener; 24 V; 300 mW	BZX384-C24	NeXPeria USA Inc.
D109	diode; ESD; double; unidirectional; 5.2 V; maximum 15 A; 30 kV	PESD5V2S2UT	NeXPeria USA Inc.
D110	diode; 1 kV; 3 A	1N5408	Vishay
F101	fuse; slow blow; 300 V (AC); 4 A	SS-5H-4A-APH	Cooper Bussmann
GDT1; GDT3; GDT5	gas discharge tube; not mounted; 200 V; 20 %; THT	DSP-201M	Mitsubishi Semiconductor

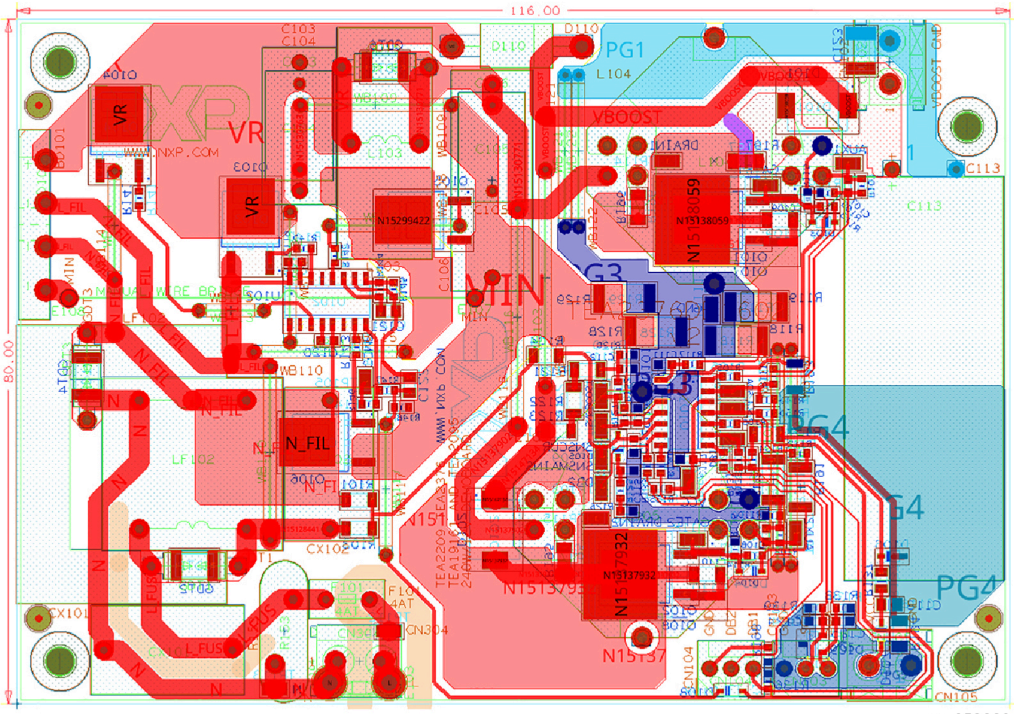
Table 4. Bill of materials...*continued*

Part	Description and values	Part number	Manufacturer
GDT2; GDT4; GDT6	gas discharge tube; not mounted; 200 V; 25 %; SMT	2051-20-SM-RPLF	Bourns Inc.
L103	inductor; 100 µH; 5 A	7447070	Würth Elektronik
L104; L105	inductor; PFC; 250 µH; 5.7 A	760806110	Würth Elektronik
LF102	inductor; common mode; 6.8 mH; 3.2 A	B82734W2322B030	EPCOS
Q101; Q102; Q103; Q104; Q105; Q106	MOSFET-N; 650 V; 11 A	IPD60R180P7	Infineon Technologies
Q107; Q108	MOSFET-N; not mounted; 650 V; 38 A	IPB60R045P7	Infineon Technologies
R101	resistor; not mounted; 10 MΩ; 1 %; 250 mW; 1206	-	-
R103; R104	resistor; 10 MΩ; 1 %; 250 mW; 1206	-	-
R105; R106	resistor; 51 kΩ; 1 %; 63 mW; 0603	-	-
R107; R108; R125; R130; R131; R132; R133; R140; R141; R142; R143; R145; R146; R147; R152	resistor; jumper; 0 Ω; 63 mW; 0603	-	-
R109; R110; R144	resistor; jumper; not mounted; 0 Ω; 63 mW; 0603	-	-
R111; R113; R114	resistor; 4.7 Ω; 1 %; 63 mW; 0603	-	-
R112	resistor; 4.7 Ω; 1 %; 100 mW; 0603	-	-
R115; R116; R120; R135	resistor; 100 kΩ; 1 %; 63 mW; 0603	-	-
R117	resistor; 1 Ω; 1 %; 63 mW; 0603	-	-
R118; R129	resistor; 0.01 Ω; 1 %; 1 W; 2512	RL2512FK-070R01L	Yageo
R119	resistor; not mounted; 0.05 Ω; 1 %; 1 W; 2512	RL2512FK-070R05L	Yageo
R121; R122	resistor; 7.5 MΩ; 1 %; 250 mW; 1206	CRCW12067M50FKEA	Vishay
R123	resistor; 750 kΩ; 1 %; 250 mW; 1206	-	-
R126	resistor; NTC; 100 kΩ; 1 %; 100 mW; 4250 K	NCU18WF104F60RB	Murata
R127	resistor; 100 Ω; 1 %; 63 mW; 0603	-	-
R128	resistor; 0.039 Ω; 1 %; 1 W; 2512	RL2512FK-070R039L	Yageo
R134; R136	resistor; not mounted; 22 kΩ; 1 %; 63 mW; 0603	-	-
R137	resistor; 2.7 Ω; 1 %; 125 mW; 0805	-	-
R138; R139	resistor; 1 MΩ; 1 %; 63 mW; 0603	-	-
R148	resistor; 180 kΩ; 1 %; 63 mW; 0603	-	-
R149	resistor; 18 kΩ; 1 %; 63 mW; 0603	-	-

Table 4. Bill of materials *...continued*

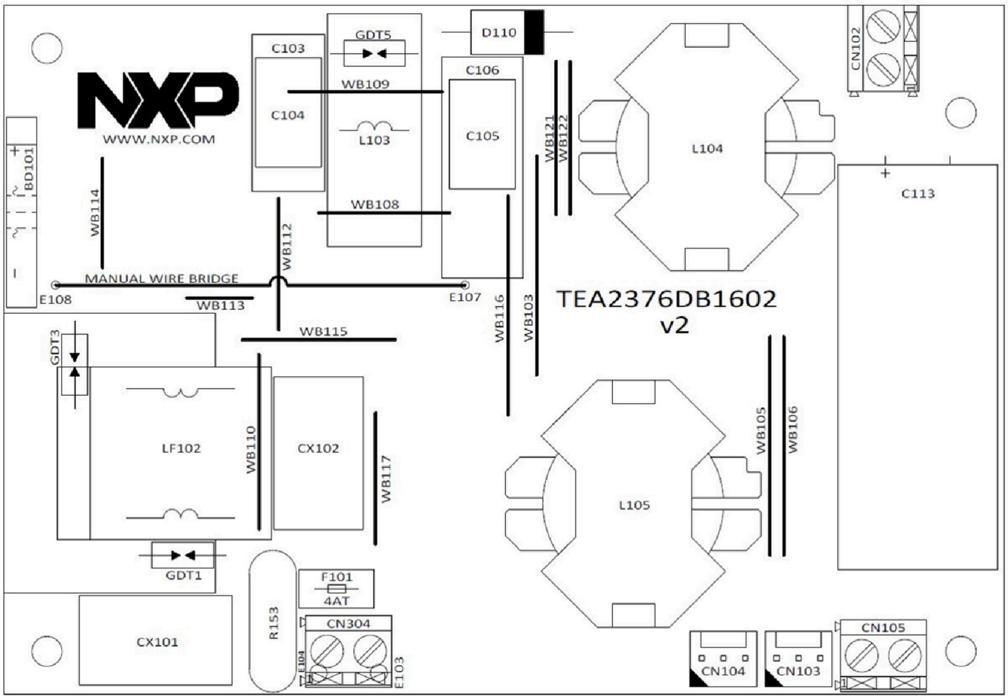
Part	Description and values	Part number	Manufacturer
R150	resistor; not mounted; 18 kΩ; 1 %; 63 mW; 0603	-	-
R151; R193; R194	resistor; jumper; 0 Ω; 250 mW; 1206	-	-
R153	resistor; VDR; 510 V; 125 J	MOV-14D511K	Bourns Inc.
R191; R192	resistor; jumper; 0 Ω; 750 mW; 2010	RC2010JK-070RL	Yageo
R195; R196; R197	resistor; not mounted; jumper; 0 Ω; 250 mW; 1206	-	-
R198	resistor; jumper; 0 Ω; 100 mW; 0603	-	-
TP101; TP102; TP103; TP104; TP105; TP106; TP107; TP108; TP109; TP110; TP111; TP112; TP113; TP114; TP115; TP116; TP117; TP118	Test point; not mounted; 0805	RCT-0C	TE Connectivity
U101	interleaved PFC; TEA2376DT (SO14)	TEA2376DT	NXP Semiconductors
U102	active bridge rectifier controller	TEA2209T	NXP Semiconductors
WB103; WB105; WB106; WB116	wirebridge; 0.8 mm; P = 25.40 mm	923345-10	3M
WB108; WB112; WB117	wirebridge; 0.8 mm; P = 15.24 mm	923345-06	3M
WB109; WB115; WB121; WB122	wirebridge; 0.8 mm; P = 17.18 mm	923345-07	3M
WB113	wirebridge; 0.8 mm; P = 7.62 mm	923345-03	3M

8.3 Board layout

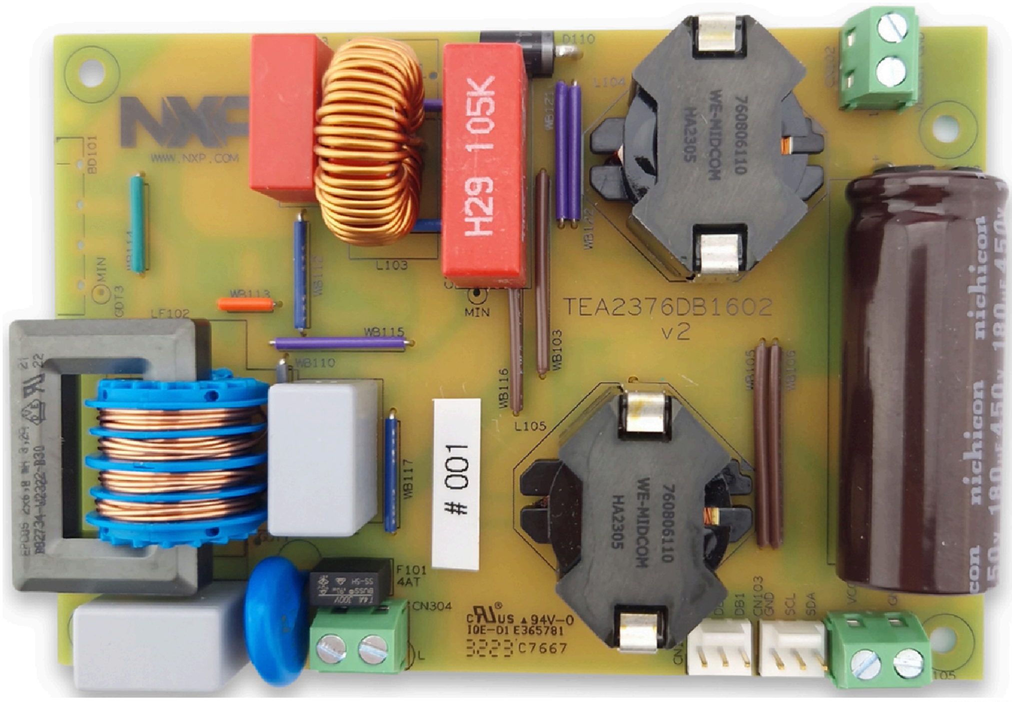


aaa-053660

Figure 23. TEA2376DB1602v2 PCB layout design

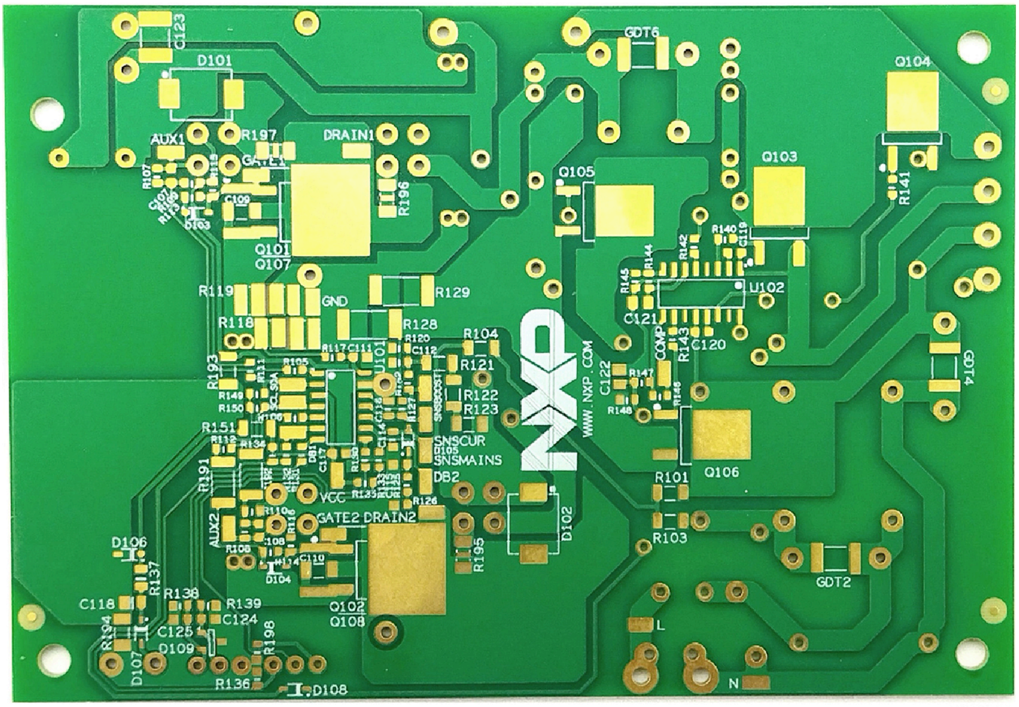


aaa-053661

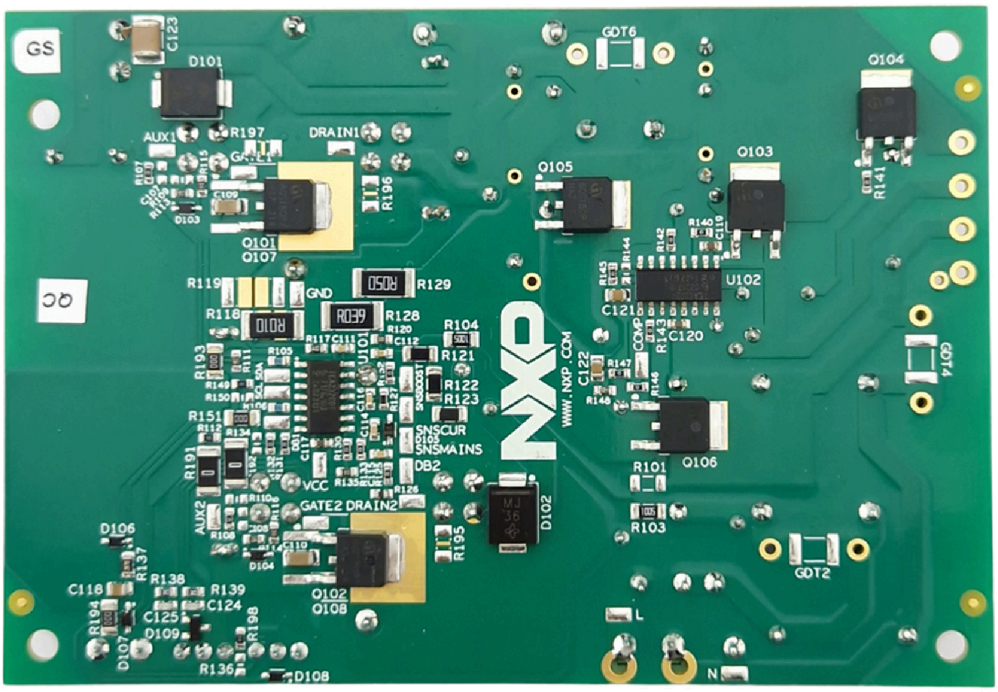


aaa-053662

Figure 24. TEA2376DB1602v2 PCB pictures top side



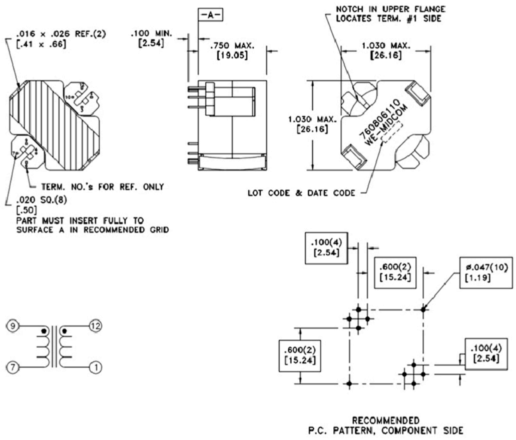
aaa-053663



aaa-053664

Figure 25. TEA2376DB1602v2 PCB pictures bottom side

8.4 PFC coil specification



ELECTRICAL SPECIFICATIONS @ 25°C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	9–7	@20°C	0.15 ohms max.
D.C. RESISTANCE	12–1	@20°C	0.05 ohms max.
INDUCTANCE	9–7	10kHz, 100mVAC, Ls	250uH ±10%
SATURATION CURRENT		20% rolloff from initial	5.7A typ.
DIELECTRIC	9–12	1200VAC, 1 second	1000VAC, 1 minute
TURNS RATIO		(9–7):(12–1)	13.3:1, ±2%

GENERAL SPECIFICATIONS:
OPERATING TEMPERATURE RANGE: –40°C to +125°C including temp rise.

aaa-053665

Figure 26. PFC coil

9 Parameter settings

Table 5 provides a list of the parameters in the TEA2376DT MTP, which is in this demo board. It shows the parameter name and the value. Parameter values that differ from the TEA2376DT's default programming are highlighted in italics.

The Ringo GUI export function can generate a list with the MTP settings of an IC. It provides an overview of the selected values and can be used for comparison, checking, or sharing the information. The settings can also be stored as a .mif file, which can be reloaded in the Ringo GUI software later or shared with others.

Table 5. TEA2376 MTP parameter settings in TEA2376DB1602v2

	Ringo parameter name	IC parameter name	Value	Unit	Binary value
1	VCC OVP	mtp_vcc_ovp	OK	-	0
2	AUX OVP	mtp_aux_ovp	OK	-	0
3	SNSBOOST short	mtp_snsboost_short	OK	-	0
4	SNSMAINS OVP	mtp_mains_ovp	OK	-	0
5	SNSSRC OCP	mtp_snssrc_ocp	OK	-	0
6	SNSCUR OCP	mtp_snscur_ocp	OK	-	0
7	SNSCUR short	mtp_snscur_short	OK	-	0
8	DIFF PHASE	mtp_diff_phase_fail	OK	-	0
9	POSAUX	mtp_posaux_fail	OK	-	0
10	NEGAUX	mtp_negaux_fail	OK	-	0
11	External OTP	mtp_eotp	OK	-	0
12	Internal OTP	mtp_iotp	OK	-	0
13	MTP read failure	mtp_read_fail	OK	-	0
14	Start up soft start time	mtp_t_start	25.6	ms	0
15	PFC voltage loop gain	mtp_vgain	0.4375	-	9
16	I2C ending delay on GATE	mtp_i2c_mode_to_sel	100	ms	0
17	Protection register logging	mtp_prot_reg_mtp_en	disabled	-	0
18	MTP writing	write_lock	enabled	-	0
19	MTP reading	read_lock	enabled	-	0
20	Brownin Level	mtp_brown_in_lvl	*6.3*	*μA*	*8*
21	Brownin/brownout hysteresis	mtp_brown_in_hys	*0.3*	*μA*	*2*
22	Brownout delay	mtp_brown_out_delay	50	ms	0
23	PFC valley switching	mtp_valleysw	enabled	-	1
24	Filter delay compensation	mtp_t_filt_delay	277	μs	0
25	Mains sensitivity	mtp_mains_sensitivity	low	-	0
26	Mains sensing resistor value	mtp_rmains	20	MΩ	1
27	Notch filter in regulation loop	mtp_notch_en	enabled	-	1
28	PFC gamma value	mtp_pfc_gamma	36	-	36
29	Mains peak zero crossing detection	mtp_pk_pos_detect	enabled	-	1

Table 5. TEA2376 MTP parameter settings in TEA2376DB1602v2*...continued*

	Ringo parameter name	IC parameter name	Value	Unit	Binary value
30	Mains sense wait time after NTC	mtp_t_snsmains_discharge	500	μs	0
31	Disable NTC during startup	mtp_ntc_chk_en	enabled	-	1
32	SNSMAINS phase factor	mtp_phase_factor	0.9375	-	0
33	SNSBOOST level low gain increase	mtp_level_gm_low	off	-	0
34	SNSBOOST low gain increase	mtp_gain_gm_low	2x	-	0
35	VCC stop level	mtp_vcc_stop	8	V	0
36	Mains sensing resistors	mtp_nr_resistors	1 resistor	-	0
37	VCC start level	mtp_vcc_start	11	V	0
38	AUX sensing filter	mtp_fc_aux	5	MHz	0
39	AUX blanking time	mtp_t_aux_blank	600	ns	0
40	AUX high time for sec stroke	mtp_t_wait_aux_high	750	ns	0
41	Time slot for measuring NTC	mtp_t_meas_ntc	450	μs	0
42	NTC circuit diode voltage drop	mtp_udiode_dig0	460	mV	0
43	Number of phases controller	mtp_phase1_only	2	phase	0
44	Startup delay for AC/DC detection	mtp_wait_for_acdc	*normal*	-	*0*
45	Phase when no valley switching	mtp_force_phase_valley_dis	phase 180	-	0
46	Min switch on delay between phases	mtp_min_tps_diff_delay	204	ns	0
47	Max switch on delay between phases	mtp_max_tps_diff_delay	2	μs	0
48	Ipfc_peak for Fmin	mtp_vrsense_fmin	55	-	0
49	Delta Ipfc_peak for Fmax-Fmin	mtp_vrsense_fmax_fmin	110	-	0
50	Min PFC freq phase value	mtp_phi_imin	0.18	-	0
51	Max-min PFC freq phase value	mtp_phi_imin_imax	0.14	-	0
52	Minimum switching frequency	mtp_fmin	40	kHz	0
53	Maximum switching frequency	mtp_fmax	130	kHz	0
54	Power level for leaving Shedding	mtp_pshed_high_perc	30	%	3
55	Hysteresis for entering Shedding	mtp_pshed_hys_perc	10	%	0
56	Time delay for entering Shedding	mtp_time_shed	140	ms	0
57	Value of AUX measurement resistor	mtp_raux	33	kΩ	0
58	Duty cycle reduction at OCP	mtp_ocp_red	0.75	-	0
59	Soft start time BM	mtp_softstart_time	normal	-	0
60	Ton steps in soft stop CCM	mtp_softstop_tonstep	normal	-	0
61	Initial on time at startup	mtp_scale_duty_init	normal	-	0
62	Slope current	mtp_cur_limit_dc	0.75	-	0
63	Proportional loop gain	mtp_pgain	10	-	0
64	Regulation Vin compensation	mtp_vincomp	enabled	-	1

Table 5. TEA2376 MTP parameter settings in TEA2376DB1602v2...*continued*

	Ringo parameter name	IC parameter name	Value	Unit	Binary value
65	Regulation Vin current compensation	mtp_cur_vincomp	enabled	-	1
66	Regulation Tring compensation	mtp_tringcomp	enabled	-	1
67	QR mode switching	mtp_en_qr	enabled	-	1
68	CCM allowed	mtp_sel_ipfc_ok	when needed	-	0
69	AUX min oscillation level	mtp_osc_amin	17	V	0
70	AUX scaling oscillation to valley	mtp_osc_scale	1	-	0
71	AUX delay compensation	mtp_osc_offset	93	ns	0
72	AUX valley detection time out	mtp_osc_timeout	3	μs	0
73	AUX valley detection hysteresis	mtp_osc_hys	2	-	0
74	AUX demag time out	mtp_wait_mag	3	μs	0
75	Minimum GATE off time	mtp_toffmin	1	μs	0
76	Notch filter for mains frequency	mtp_ton_fir_filt	enabled	-	1
77	PFC current loop gain	mtp_igain	*25*	-	*0*
78	PFC current scaler	mtp_kdes	2.013	-	13
79	Limit the power at start	mtp_pwr_limit_start	255; no limit	-	0
80	Minimum secondary stroke time	mtp_minsecstroke	1	μs	0
81	Minimum stretch time	mtp_stretchmin	200	ns	0
82	Minimum Ides clamp level	mtp_idesmax_min	13	%	0
83	Ides clamp slope K	mtp_k_idesclamp	1	-	2
84	Ipfc clamp function	mtp_idesclamp_en	enabled	-	1
85	Slope clamp value	mtp_slope_clamp	512	-	0
86	SNSBOOST high gain increase	mtp_gain_gm_high	4x	-	0
87	3ms blanking BI after BO	mtp_bi_blank	enabled	-	1
88	External OTP protection Level	mtp_gotp_limit	88	-	0
89	External OTP delay time	mtp_t_eotp	4	s	0
90	FLR only when protection	mtp_flr_only_at_prot	disabled	-	0
91	SNSBOOST low clears all protections	mtp_snsb_short_clr_prots	disabled	-	0
92	Fast latch reset delay time	mtp_flr_delay	50	ms	0
93	External OTP level multiplier	mtp_mult_gntc	32x	-	0
94	Safe Restart Time	mtp_restart_time	1	s	0
95	VCC OVP delay	mtp_vcc_ovp_delay	1000	μs	0
96	AUX OVP level	mtp_aux_ovp_value	215	-	0
97	SNSMAINS OVP level	mtp_snsmains_ovp_value	420	mV	0
98	SNSBOOST OVP level	mtp_snsboostovp	2.63	V	0

Table 5. TEA2376 MTP parameter settings in TEA2376DB1602v2*...continued*

	Ringo parameter name	IC parameter name	Value	Unit	Binary value
99	VCC OVP level	mtp_vcc_ovp_limit	24	V	0
100	Max pos AUX voltage difference	mtp_min_auxpos_value	*20*	*(dig)*	*0*
101	Fast Latch Reset function	mtp_fast_latch_reset	disabled	-	0
102	PFC shortwinding delay cycles	mtp_max_drain_short_count	2500	-	0
103	OCP blanking time	mtp_ocp_blanking_time	250	ns	0
104	SNSCUR short detection level	mtp_snscur_short_det_lvl	30	-	0
105	Max SNSCUR cycles to show short	mtp_nr_snscur_short_cycles	200	cycles	3
106	Max AUX voltage difference in phases	mtp_max_vout_diff	25	(dig)	3
107	AUX voltage measurement filter	mtp_aux_v_filt_setting	4	cycles	0
108	AUX min time for valid stroke	mtp_tmin_pk_hold	750	ns	0
109	Max missed AUX primary strokes	mtp_max_missed_prim_strokes	100	cycles	0
110	Max missed AUX secondary strokes	mtp_max_missed_sec_strokes	100	cycles	0
111	SNSCUR current ratio	mtp_snscur_ratio	128	-	0
112	SNSBOOST pulldown at brownout	mtp_snsboost_pulldown_brownout	0	ms	0
113	SNSMAINS OVP prot follow up	mtp_mains_ovp_mode	disabled	-	0
114	VCC OVP prot follow up	mtp_vcc_ovp_mode	safe restart	-	0
115	AUX OVP prot follow up	mtp_aux_ovp_mode	*safe restart*	-	*0*
116	SNSBOOST short prot follow up	mtp_snsb_short_mode	auto continue	-	0
117	SNSSRC overcurrent prot follow up	mtp_snssrc_oc_mode	safe restart	-	0
118	Allow startup with mains DC	mtp_allow_startup_dc_load	disabled	-	0
119	SNSCUR overcurrent prot follow up	mtp_snscur_oc_mode	safe restart	-	0
120	SNSCUR short protect follow up	mtp_snscur_short_mode	safe restart	-	0
121	Internal OTP prot follow up	mtp_iotp_mode	safe restart	-	0
122	External OTP prot follow up	mtp_eotp_mode	safe restart	-	0
123	AUX phase fail prot follow up	mtp_pf_vout_diff_mode	safe restart	-	0
124	AUX pos phase fail prot follow up	mtp_pf_pos_aux_mode	safe restart	-	0
125	AUX neg phase fail prot follow up	mtp_pf_neg_aux_mode	safe restart	-	0
126	Duration soft start/stop operation	mtp_bm_end_soft_start_stop	infinite	-	0
127	Burst mode SNSBOOST ripple	mtp_bmripple	105	mV	0
128	BM soft start	mtp_skip_soft_start	softstart	-	0
129	BM soft stop	mtp_skip_soft_stop	softstop	-	0
130	Burst mode delay time	mtp_burstdelay	0	s	0
131	Burst mode level	mtp_bmpth_low	10.9	%	0
132	Burst on/off level on VCC	mtp_bmvccth	10	V	0
133	Burst mode type	mtp_bm	auto	-	0

Table 5. TEA2376 MTP parameter settings in TEA2376DB1602v2*...continued*

	Ringo parameter name	IC parameter name	Value	Unit	Binary value
134	BM boost recover	mtp_boostrecover	disabled	-	0
135	External BM control pin	mtp_bm_ctrl_sel	BURST normal	-	0
136	BM depending on shedding	mtp_bm1phase	1 phase only	-	1
137	Burst starts with 1 phase	mtp_single_phase_burst_restart	disabled	-	0
138	BM hysteresis	mtp_bmpth_hys	3.1	%	0
139	SNSBOOST level to stop PG	mtp_pwrgood_stop_pct	0.5	-	0
140	Power good at mains brownout	mtp_pwrgood_bo_stop	enabled	-	1
141	SNSBOOST level for power good	mtp_pwrgood_start_lvl	2.3	V	6
142	Power Good polarity	mtp_pwrgood_pol	normal	-	0
143	PG stopped by SNSBOOST	mtp_pwrgood_lvl_stop	enabled	-	1
144	Vendor code	mtp_code	*0x0000*	-	*0*

10 Abbreviations

Table 6. Abbreviations

Acronym	Description
CCM	critical conduction mode
DCM	discontinuous conducting mode
GUI	graphical user interface
ICP	inrush current protection
OCP	overcurent protection
OTP	overtemperature protection
OVP	overvoltage protection
PFC	power factory correction
SR	synchronouos rectifier
THD	Total harmonic distortion

11 References

Many documents are included in the GUI of the Ringo software that can be downloaded from www.nxp.com.

[1] **TEA2376AT data sheet** — Digital configurable interleaved PFC controller; 2023, NXP Semiconductors

[2] **TEA2376DT data sheet** — Digital configurable interleaved PFC controller; 2023, NXP Semiconductors

[3] **UM11235 user manual** — TEA2016DB1514 USB to I2C hardware interface; 2019, NXP Semiconductors

[4] **AN14200** — TEA2376 application note (working title)

[5] **UM12042** — TEA2376 Ringo

12 Revision history

Table 7. Revision history

Document ID	Release date	Description
UM12002 v.1.0	06 February 2024	• Initial version

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