UM11348

TEA2208DB1576 Active bridge rectifier controller demo board

Rev. 2.2 — 30 October 2020 User manual

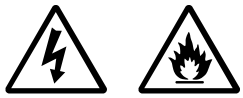
Document information

Information	Content
Keywords	TEA2208T, TEA2208DB1576, active bridge rectifier controller, X-capacitor discharge, self-supplying, high efficiency, traditional diode bridge, power supply, demo board
Abstract	The TEA2208T is an active bridge rectifier controller, which replaces the traditional diode bridge. Using the TEA2208T with low-ohmic high-voltage external MOSFETs, significantly improves the efficiency of the power converter as the typical rectifier diode-forward conduction losses are eliminated. Additionally, the TEA2208T incorporates an X-capacitor discharge function. This user manual describes how the TEA2208DB1576 demo board can be used to replace from diode bridge. It contains a TEA2208T and four low-ohmic high-voltage MOSFETs.

Revision history

Rev	Date	Description
v.2.2	20201030	Update of version 2.1
v.2.1	20200508	Update of second edition
v.2	20200409	Second edition
v.1	20200309	Initial edition

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 TEA2208DB1576 demo board. It provides a functional description, supported with instructions on how to connect the board to obtain the best results and performance.

The TEA2208T is the first product of a new generation of active bridge rectifier controllers replacing the traditional diode bridge.

Using the TEA2208T with low-ohmic high-voltage external MOSFETs, significantly improves the efficiency of the power converter as the typical rectifier diode-forward conduction losses are eliminated. Efficiency can improve up to about 1.4 % at 90 V (AC) mains voltage.

The TEA2208T is intended for power supplies with a boost-type power-factor controller as a first stage. The second stage can be a resonant controller, a flyback controller, or any other controller topology. It can be used in all power supplies requiring high efficiency such as adapters, servers, telecom power supplies, desktop PCs, all-in-all PC power supplies, and television power supplies.

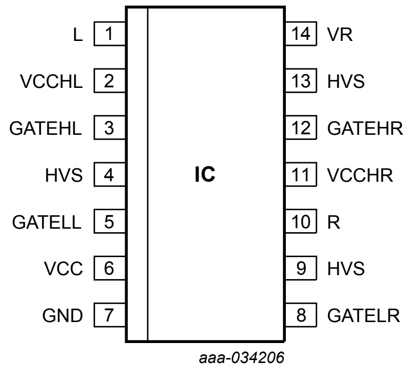


Figure 1. TEA2208T pinning diagram

1.1 Features

- Forward conduction losses of the diode rectifier bridge are eliminated
- Very low IC power consumption (2 mW).
- Integrated high-voltage level shifters
- Directly drives all four rectifier MOSFETs
- Very low external part count
- Integrated X-capacitor discharge (2 mA)
- Self-supplying
- Full-wave drive improving total harmonic distortion (THD)
- Undervoltage lockout (UVLO) for high-side and low-side drivers
- Drain-source overvoltage protection (OVP) for all external power MOSFETs
- Gate pull-down currents at start-up for all external power MOSFETs

2 Safety warning

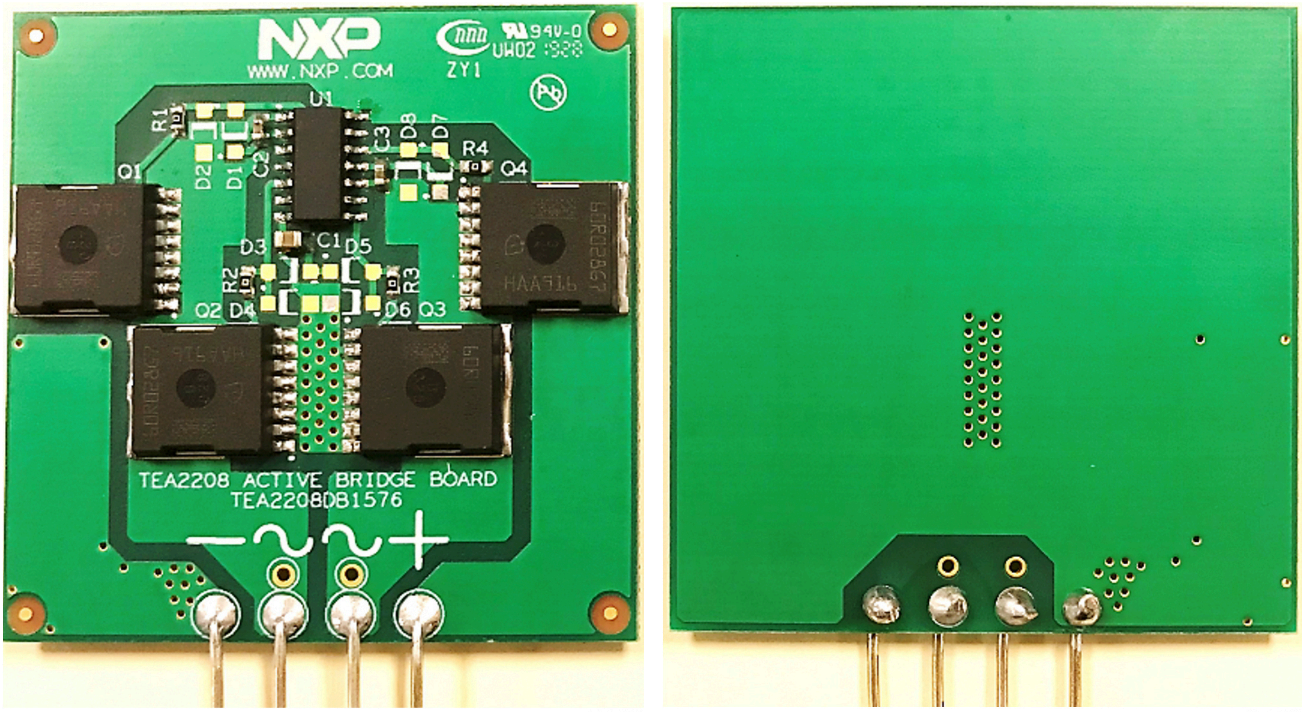
This demo board is connected to the mains voltage. Avoid touching the board while it is connected to the mains voltage and when it is in operation. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments. Galvanic isolation from the mains phase using a fixed or variable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

a. Isolated   b. Not isolated

Figure 2. Isolation symbols

3 Board photographs

The TEA2208DB1576 demo board consists of the TEA2208T in an SO14 package with four MOSFETs of 600 V/28 mΩ. Figure 3 shows the front side and back side of demo board.



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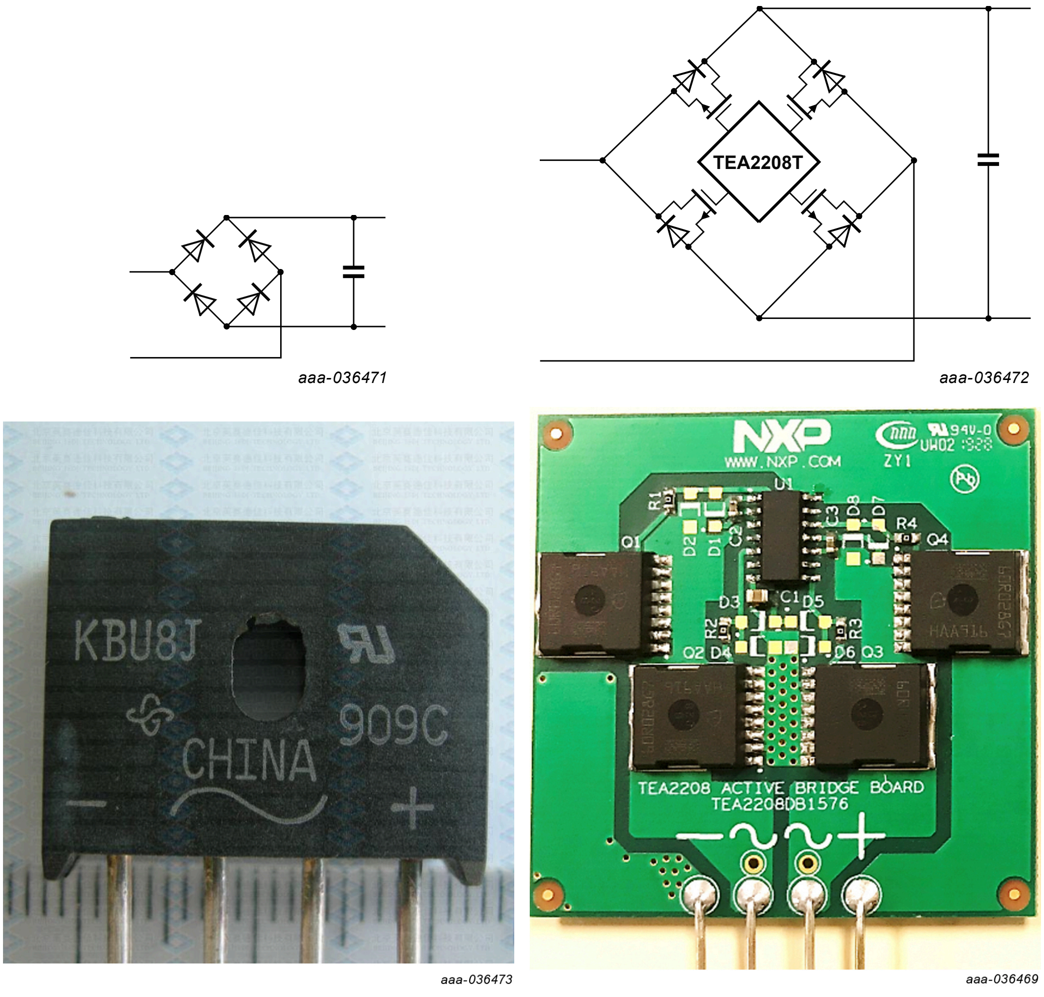
a. Front

b. Back

Figure 3. TEA2208DB1576 demo board

4 TEA2208DB1576 demo board setup

The demo board contains four 600 V/28 mΩ MOSFETs. It makes the board suitable for universal AC input (100 V to 240 V) and for up to 1 kW as reference. The TEA2208DB1576 demo board contains four leads that can easily replace a traditional diode bridge. The two inside leads are connected to AC mains lines. The two outside leads are connected to positive and negative rectified voltages. These four leads are pin-to-pin with typical bridge-rectifier diodes pins. Figure 4 describes the difference between bridge diodes and active bridge configurations.



a. Diode bridge

b. Active bridge

Figure 4. Diode bridge configuration versus TEA2208DB1576 demo board typical configuration

Figure 5 shows an example of a TEA2208DB1576 demo board mounted on an NXP Semiconductors TEA2016DB1519 demo board.

aaa-036475

Figure 5. TEA2208DB1576 demo board added to 240 W resonant adapter board

5 Operation

The TEA2208T is a controller IC for an active bridge rectifier. It can directly drive the four MOSFETs in an active bridge. Figure 6 shows a typical configuration. Since the output is a rectified sine wave, a boost-type power-factor circuit must follow the application.

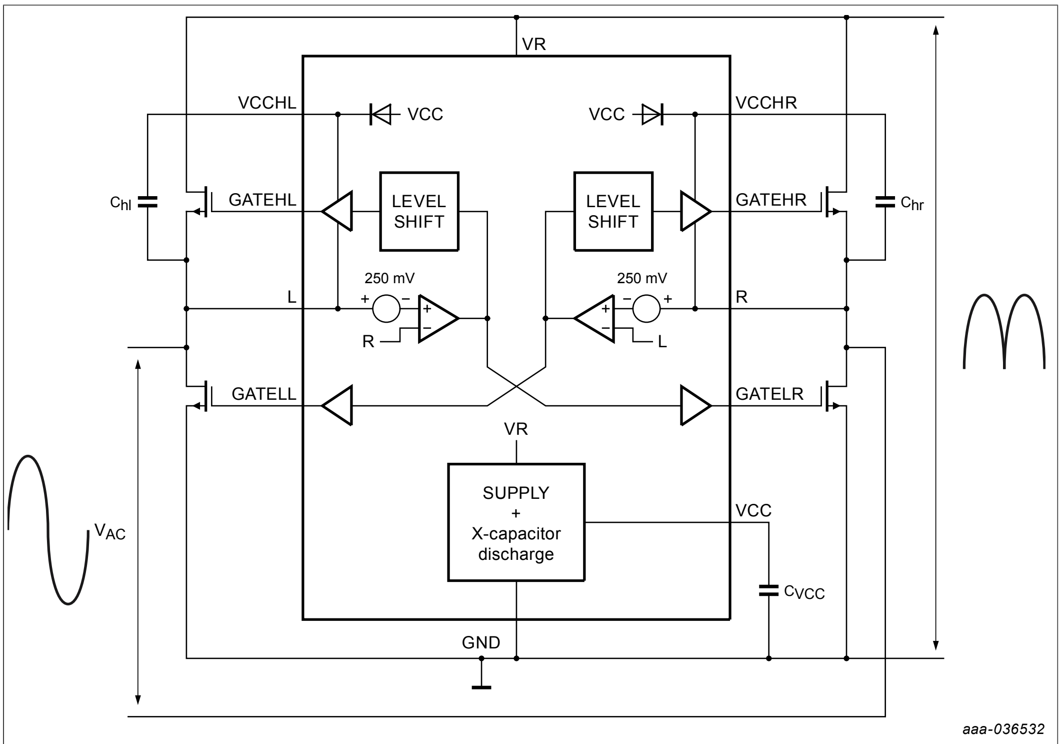


Figure 6. TEA2208DB1576 typical configuration

The control circuit of the TEA2208T senses the polarity of the mains voltage between pins L and R. Depending on the polarity, diagonal pairs of power MOSFETs are switched on or off. Depending on the slope polarity, the comparator in the control circuit, which compares the L and R voltages, has thresholds of 250 mV and −250 mV.

The gate drivers are high-current rail-to-rail MOS output drivers. An on-chip supply circuit which draws current from the rectified sine-wave pin VR generates the gate driver voltage. After a zero-crossing of the mains voltage, the supply capacitor C_{VCC} is charged to the regulation level V_{reg}. Then the discharge state is entered. The resulting power dissipation from the mains voltage is about 1 mW, excluding gate charge losses of the external power MOSFETs. These gate charge losses typically add a 1 mW dissipation.

At start-up, the body diodes of the power MOSFETs act as a traditional diode bridge. They cause a peak rectified voltage at pin VR. From this high voltage, the supply capacitor is first charged to the $V_{startup}$ voltage and then enters the start-up state. After a next zero-crossing of the mains voltage, the supply capacitor is charged to V_{reg} in the charging state. When the voltage at the supply capacitor exceeds V_{dis}, the gate driver outputs are enabled. The high-side drivers start up later than the low-side drivers. The floating supplies must be charged first and the drain-source voltage of the high-side power MOSFETs must be less than the drain-source protection voltage. When all drivers are active, the MOSFETs take over the role of the diodes. The result is a much lower power loss than a passive diode rectifier bridge.

In the discharge state, when the mains voltage is disconnected, the internal bias current discharges the supply capacitor. When the voltage at pin V_{CC} drops to below $V_{disable}$ the X-capacitor discharge state is entered, which draws a 2 mA current from pin VR to discharge the X-capacitor. The waiting time, t_d until the X-capacitor discharge starts is:

$$t_d = C_{VCC} * (V_{reg} - V_{dis}) / 20\ \mu A = 200\ k * C_{VCC} \quad (1)$$

Using a typical value of 2.2 μF for C_{vcc} yields about 0.45 s. While the VR pin discharges the X-capacitor, the mains can be reconnected. If the mains is reconnected, the charge mode is entered again while the VR pin discharges the X-capacitor. Figure 7 describes start-up, normal operation, and power-off of TEA2208T.

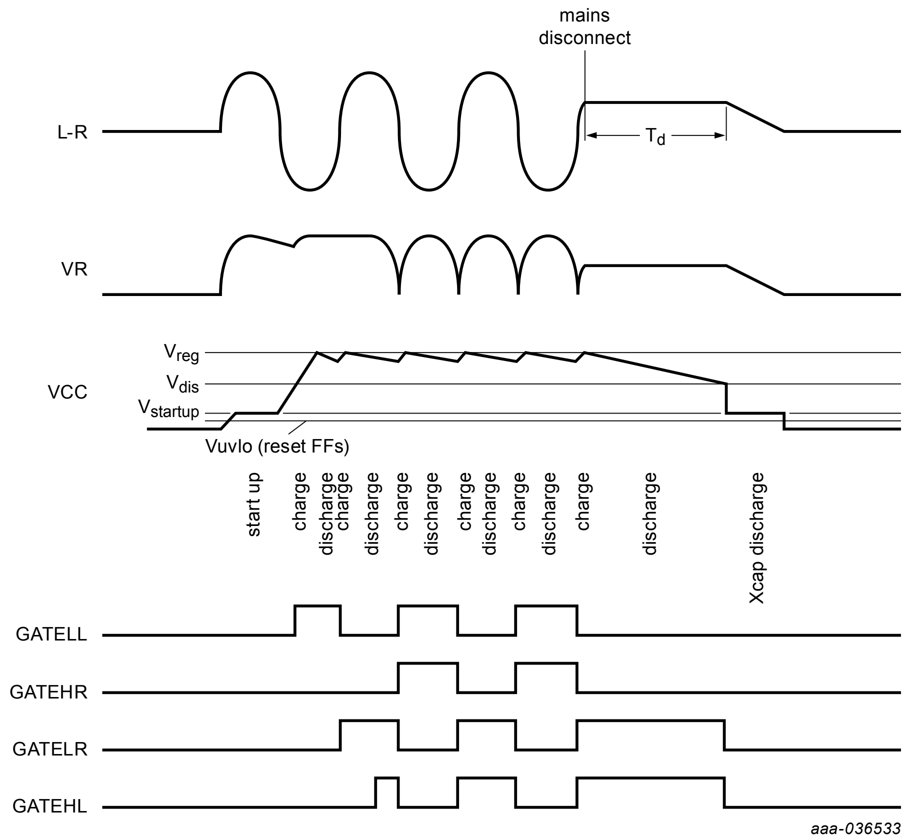


Figure 7. TEA2208T signals (start-up, normal operation, and power-off)

6 TEA2208DB1576 demo board performance

6.1 Test facilities

- Oscilloscope: AgilentTechnologiesDSO9064A
- AC power source: Chroma 61504
- Electronic load: Chroma 63600-2
- Digital power meter: WT210
- Power board:
  - TEA2016DB1519; Whole performance tests excepting surge and EMI tests
  - TEA1916DB1262; Surge, EMI, and standby power consumption tests

6.2 Test setup

To measure the system performance the TEA2208DB1576 is mounted on the TEA2016DB1519. The diode bridge rectifier, BD101, is removed from the TEA2016DB1519 and replaced by the TEA2208DB1576. Figure 8 shows details of the test setup.

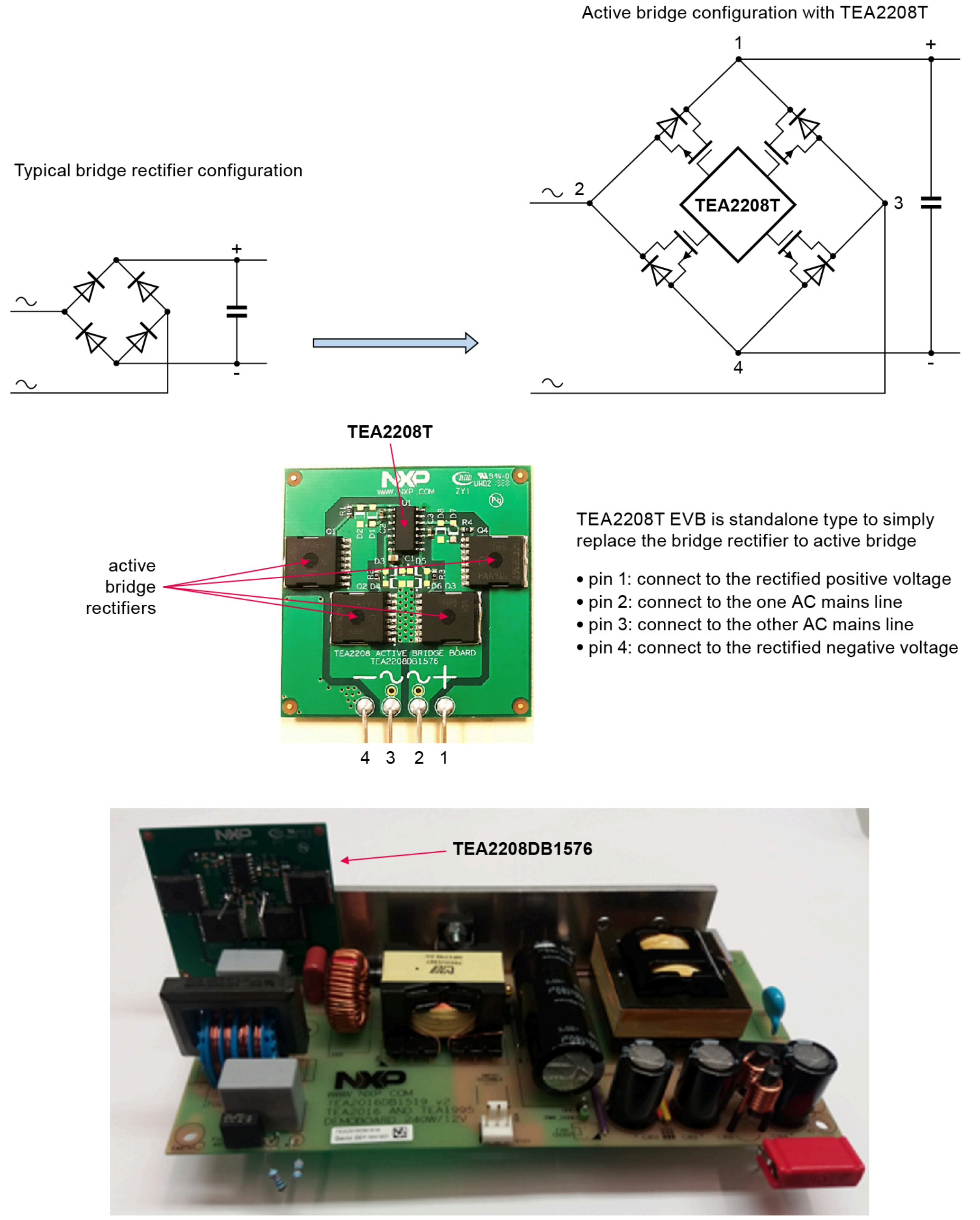
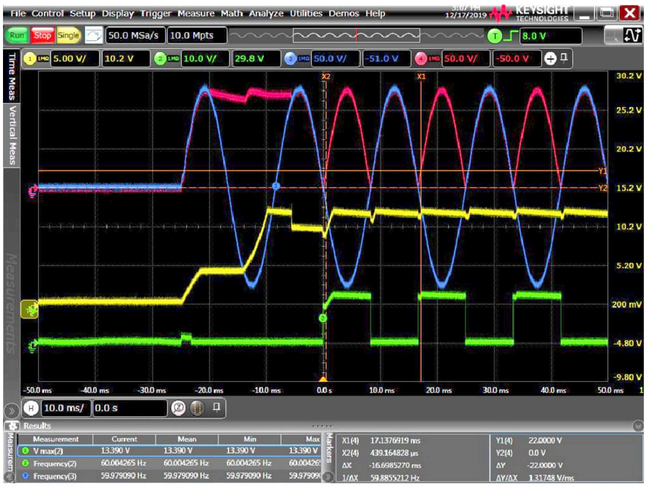


Figure 8. TEA2208 test setup on TEA2016DB1519

When the MOSFET pin open test for active bridge is required, add a diode in parallel to each active bridge MOSFET.

6.3 Start-up sequence

After AC mains voltage is applied, the body diodes of the MOSFET rectifiers are connected until the TEA2208T is enabled. The internal self-bias circuit from the rectified mains voltage, VR, supplies the VCC. To complete start up sequence, it typically takes 1.5 mains cycles.



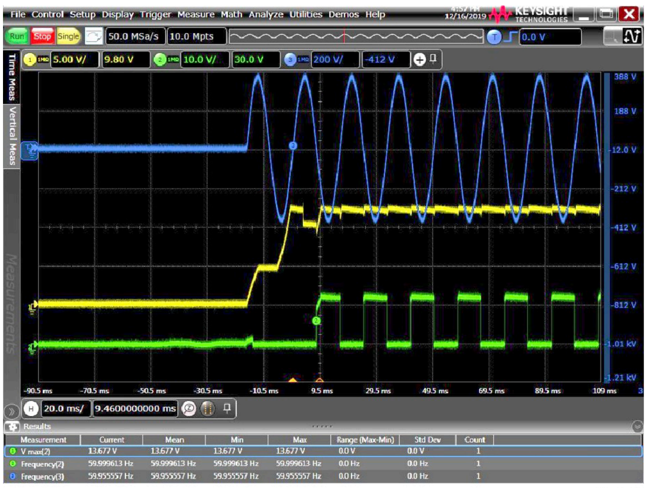
aaa-037210

CH1: VCC (5 V/div)
CH2: GATELL (10 V/div)
CH3: AC mains (50 V/div)
CH4: VR (50 V/div)
Time: 10 ms/div

aaa-037211

CH1: VCC (5 V/div)
CH2: GATELR (10 V/div)
CH3: AC mains (50 V/div)
CH4: VR (50 V/div)
Time: 10 ms/div

a. 90 V (AC)



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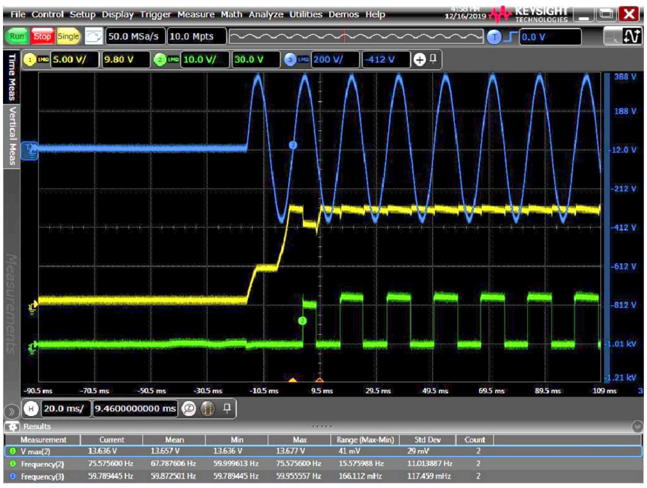
CH1: VCC (5 V/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
Time: 20 ms/div



aaa-037213

CH1: VCC (5 V/div)
CH2: GATELR (10 V/div)
CH3: AC mains (200 V/div)
Time: 20 ms/div

b. 264 V (AC)

Figure 9. Start-up sequence

6.4 Normal operation

When the voltage between L and R is higher than 250 mV, the GATEHL and the GATELR are enabled. When the voltage between L and R is lower than −250 mV, the GATEHR and the GATELL are enabled. According to the +250 mV and −250 mV detection thresholds, dead time occurs between the gates.

aaa-037214

CH1: AC mains current (1 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 5 µs/div

aaa-037215

CH1: AC mains current (1 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 10 µs/div

a. 90 V (AC)/60 Hz

aaa-037216

CH1: AC mains current (5 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 5 µs/div

aaa-037217

CH1: AC mains current (5 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 5 µs/div

b. 264 V (AC)/50 Hz

Figure 10. Normal operation; no-load condition

aaa-037218

CH1: AC mains current (5 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 5 μs/div

aaa-037219

CH1: AC mains current (5 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 5 μs/div

a. 90 V (AC)/60 Hz

aaa-037220

CH1: AC mains current (1 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 5 μs/div

aaa-037221

CH1: AC mains current (1 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 5 μs/div

b. 264 V (AC)/50 Hz

Figure 11. Normal operation; 240 W load condition

6.5 Output dynamic load condition operation

Output dynamic load is applied between 240 W and no load condition. And the dynamic load period is 20 ms. Regardless of the output load condition, the gates operate well according to mains polarity without shoot-through.

aaa-037222

CH1: LLC output load (20 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 10 µs/div

aaa-037223

CH1: LLC output load (20 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 10 µs/div

a. 90 V (AC)/60 Hz

aaa-037224

CH1: LLC output load (20 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 5 µs/div

aaa-037225

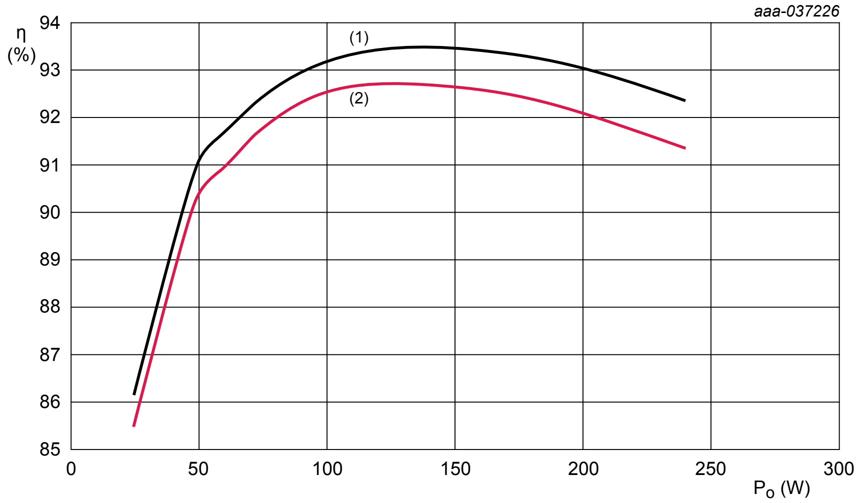
CH1: LLC output load (20 A/div)
CH2: GATELL (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELR (10 V/div)
Time: 20 ms/div and 5 µs/div

b. 264 V (AC)/50 Hz

Figure 12. Output dynamic load operation

6.6 Efficiency test result and R_{DSon} selection guidance

The efficiency test result below includes power losses of bridge rectifiers and other power stages, such as PFC and LLC. However, throughout the active bridge incorporated in the TEA2208T shows an efficiency improvement compared a diode bridge. Depending on the different R_{DSon} values of the active bridge MOSFET, the efficiency improvement can vary.

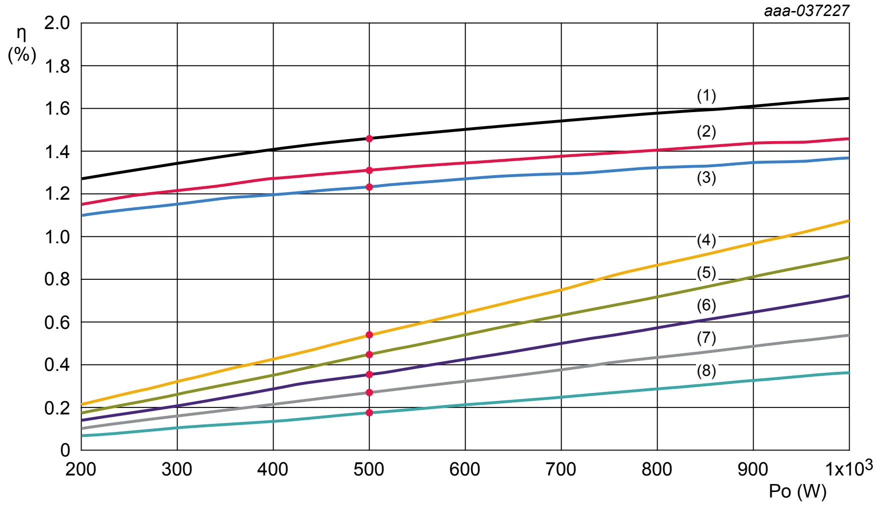


(1) Active bridge with TEA2208T

(2) Diode bridge

Figure 13. Efficiency comparison between diode and active bridge at 115 V (AC)/60 Hz

Figure 14 shows the comparison between different MOSFET Rds.on and the number of diodes in parallel at 115 V (AC). To see the improvement of active bridge with MOSFET at the worst condition, Efficiency is calculated at 125 °C junction temperature. Efficiency improvement can reduce the temperature on bridge rectifier, and it helps to increase power density.



Efficiency drop comparison calculation based on 115 V (AC) input and a die temperature of 125 °C (diode bridge: GSIB15A60,15 A 600 V)

(1) One diode bridge

(2) Two diode bridges parallel

(3) Three diode bridges parallel

(4) Active bridge with MOSFET R_{DSon} = 30 mΩ

(5) Active bridge with MOSFET R_{DSon} = 25 mΩ

(6) Active bridge with MOSFET R_{DSon} = 20 mΩ

(7) Active bridge with MOSFET R_{DSon} = 15 mΩ

(8) Active bridge with MOSFET R_{DSon} = 10 mΩ

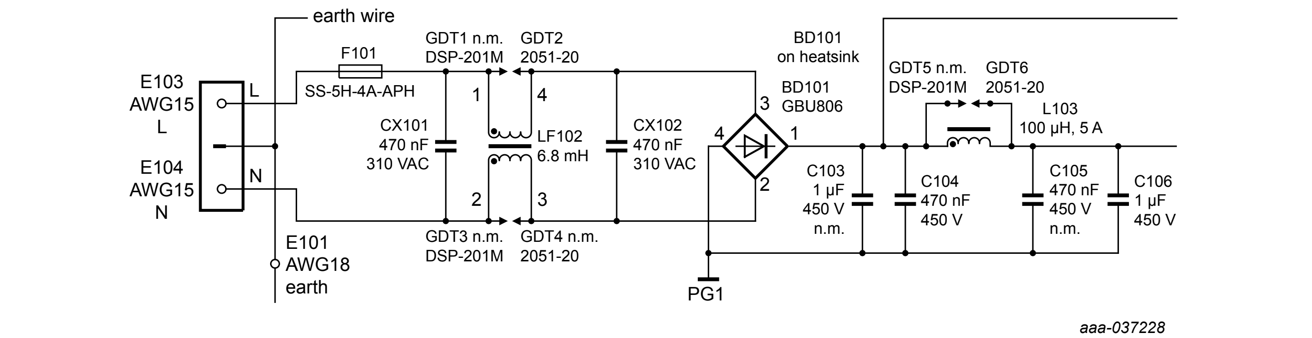
Example: When an R_{DSon} of 0.015 Ω is used on a MOSFET for a 500 W design, the efficiency improvement that can be achieved, when compared to a single diode for a diode bridge, is 1.2 %.

Figure 14. Efficiency improvement based on different R_{DSon} at 115 V (AC)

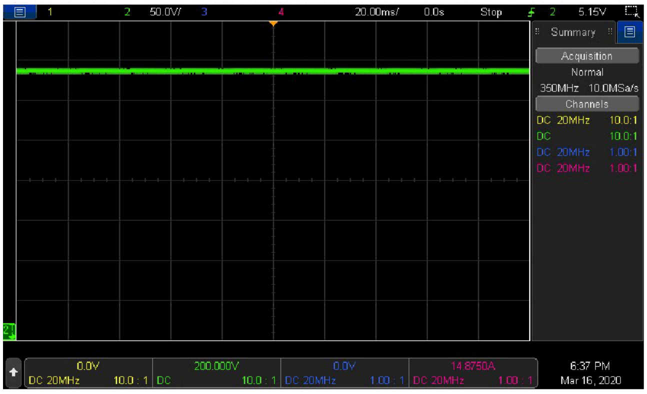
6.7 Standby power consumption test result and design guideline

6.7.1 TEA2208 operation at standby mode

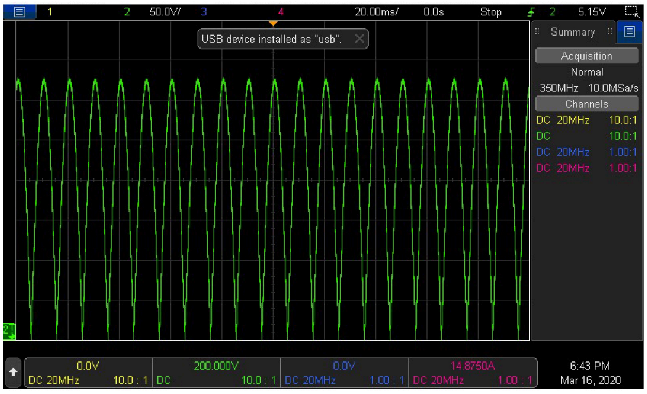
Figure 15(a) shows the original schematic with a diode bridge. With a diode bridge, the rectified AC mains voltage at C104 is almost a DC waveform as seen Figure 15(b) However, the rectified AC mains voltage after replacing the diode bridge with an active bridge is a full-wave rectified waveform (see Figure 15). Although a full wave rectified waveform achieves a better THD performance, it can make an additional current path on capacitors (C104 and C106) and result in extra power losses on these capacitors because of ESR.



a. TEA1916DB1262 AC mains circuit diagram with bridge rectifier (BD101)



b. The voltage on C104 with a diode rectifier.



c. The voltage after replacing the bridge rectifier (the voltage on C104) with an active bridge

Figure 15. Comparison of the voltages between a diode bridge and an active bridge after the bridge rectifier at 230 V (AC) and no load condition

6.7.2 Power losses on the capacitor

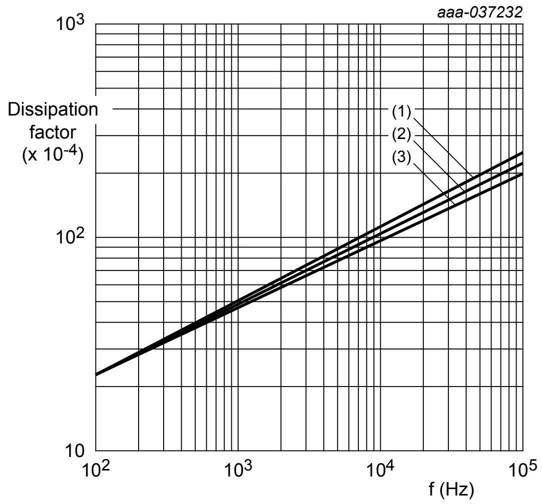
The power loss on the capacitor comes from the current flowing through ESR. Equation 2 shows the power loss on the capacitors when the active bridge rectifier is used. As the capacitance is higher and ESR value is higher, power loss is increased.

$$P_{cap\text{-}single} = \left(C_{IN} \times V_{IN.AC} \times 2\pi f_{LINE}\right)^2 \times ESR$$
$$P_{cap\text{-}total} = P_{cap\text{-}single} + P_{cap\text{-}single} + \ldots \qquad (2)$$

Where:

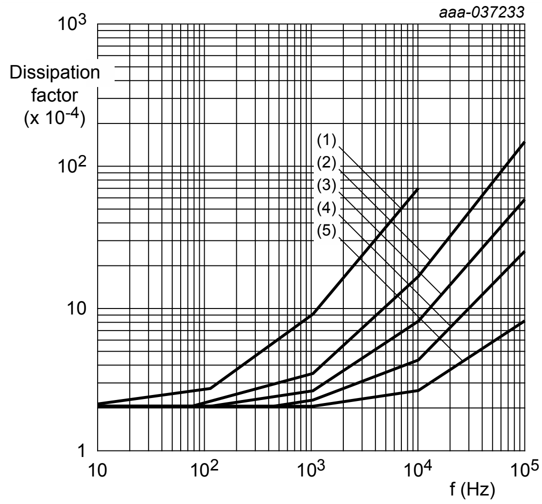
- C_{IN} is the capacitance of one capacitor
- $V_{IN.AC}$ is the mains voltage
- f_{LINE} is the line frequency
- ESR is the equivalent series resistance of the capacitor

When the system requires less standby power consumption, a smaller ESR value can be used. Typically, the polypropylene film capacitor has a smaller dissipation factor than the polyester film capacitor. Since the dissipation factor is proportional to the ESR value for the same capacitance, the polypropylene film capacitor can achieve less standby power consumption. Figure 16 shows that, at 100 Hz, the dissipation factor of the polypropylene film capacitor can be more than 10 times smaller than the polyester film capacitor. As the dissipation factor can be different because of a different manufacturer and/or a different capacitance, measure the standby power after a decision has been made about the capacitor type and the capacitance.



(1) 1.2 μF < C ≤ 2.2 μF
(2) 0.33 μF < C ≤ 1.2 μF
(3) C ≤ 0.33 μF

a. Polyester film capacitor



(1) C ≥ 10 μF
(2) 220 nF < C ≤ 1 μF
(3) 47 nF < C ≤ 220 nF
(4) 10 nF < C ≤ 47 nF
(5) C ≤ 10 nF

b. Polypropylene film capacitor

Figure 16. Dissipation factor curve

6.7.3 Standby power consumption measurement

The diode bridge does not make large ripple on the capacitor. So, the power consumption is similar regardless of different capacitor types (see Section 6.7.1). The first row of Table 1 shows the test result of TEA1916DB1262 with a diode bridge. That is, there is no modification to the original design. When the TEA2208T active bridge replaces the diode bridge, the standby power consumption increases with about 30 mW. A polypropylene film capacitor can reduce the standby power consumption. A lower capacitance can also reduce the standby power consumption. As the result, the standby power consumption can be similar to the diode bridge test result, with a difference of less than 10 mW. Because the burst frequency of TEA19162 is very low, the power consumption is integrated within 5 minutes.

Table 1. Standby power consumption on the TEA1916DB1262 at 230 V (AC) and a no-load condition

Bridge rectifier	Capacitor type	Capacitance	Standby power consumption	Standby power difference for unmodified TEA1916DB1262
Diode bridge (original design)	polyester film	0.47 μF and 1 μF	48.7 mW	-
TEA2208DB1576	polyester film	0.47 μF and 1 μF	78.7 mW	+30 mW

Table 1. Standby power consumption on the TEA1916DB1262 at 230 V (AC) and a no-load condition*...continued*

Bridge rectifier	Capacitor type	Capacitance	Standby power consumption	Standby power difference for unmodified TEA1916DB1262
TEA2208DB1576	polypropylene film	0.47 µF and 1 µF	58.8 mW	+10.1 mW
TEA2208DB1576	polypropylene film	0.47 µF and 0.47 µF	55.9 mW	+7.2 mW
TEA2208DB1576	polypropylene film	1 µF	56.5 mW	+7.8 mW

6.8 AC power-off sequence and X-capacitor discharge test

If the X-capacitor discharge function is implemented, the discharge current flows via the internal path of the IC from VR to Ground. After AC mains is disconnected, the VCC capacitor is discharged. While VCC is discharged to V_{dis}, the X-capacitor discharge current is not enabled. This delay time (t_d) can be adjusted with different VCC capacitors. After VCC is decreased to V_{dis}, the X-capacitor discharge current is enabled. It takes 220 ms to discharge the 940 nF X-capacitor and the 1470 nF capacitor on the rectified AC mains voltage.

Figure 17. X-capacitor discharge test at 264 V (AC)/50 Hz, no-load condition

6.9 AC mains transition test

When the AC mains is changed from high mains to low mains, or vice versa, there is no shoot-through issue. The active bridge operates normally.

aaa-037235

CH1: LLC output load (20 A/div)
CH2: GATELR (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELL (10 V/div)
Time: 100 ms/div and 5 ms/div

a. 90 V (AC) → 264 V (AC) at no-load condition

aaa-037236

CH1: LLC output load (20 A/div)
CH2: GATELR (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELL (10 V/div)
Time: 100 ms/div and 5 ms/div

b. 90 V (AC) → 264 V (AC) at 240 W load condition

aaa-037237

CH1: LLC output load (20 A/div)
CH2: GATELR (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELL (10 V/div)
Time: 100 ms/div and 5 ms/div

c. 264 V (AC) → 90 V (AC) at no-load condition

aaa-037238

CH1: LLC output load (20 A/div)
CH2: GATELR (10 V/div)
CH3: AC mains (200 V/div)
CH4: GATELL (10 V/div)
Time: 100 ms/div and 5 ms/div

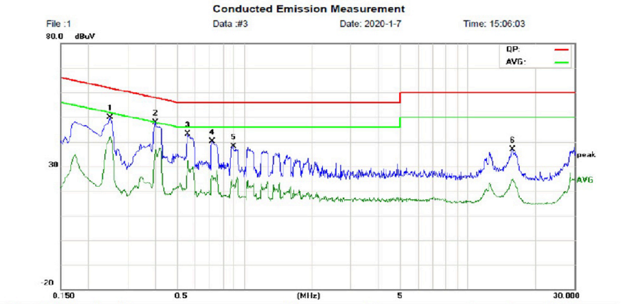
d. 264 V (AC) → 90 V (AC) at 240 W load condition

Figure 18. AC mains transition test

6.10 Conduction EMI test result

6.10.1 Conduction EMI at 110 V (AC)

To measure the EMI performance, the resistor load is connected to the output voltage. To see the worst case, the output power is 240 W. Figure 19 shows the comparison between a diode bridge and an active bridge. The active bridge test result is 2 dB to 3 dB less margin, worst case.

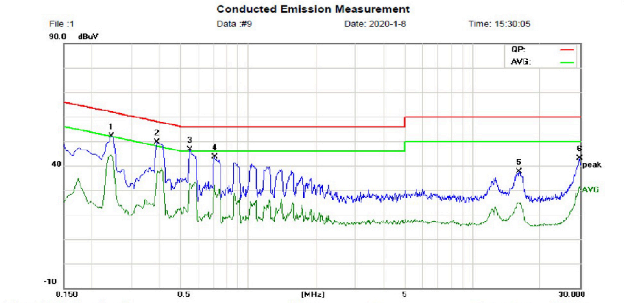


Site TOBY Chamber #1 | Phase: L1 | Temperature: 23.3 (C)
Limit: (CE)EN55032 class B_QP | Power: AC 110V/60Hz | Humidity: 49 %
EUT: 适配器
M/N: 12V240W
Mode: Normal Mode
Note: 整流桥

No.	Mk.	Freq. (MHz)	Reading Level (dBuV)	Correct Factor (dB)	Measure-ment (dBuV)	Limit (dBuV)	Over (dB)	Detector	Comment
1		0.2500	40.10	9.80	49.90	61.75	-11.85	peak	
2	*	0.3980	38.16	9.84	48.00	57.89	-9.89	peak	
3		0.5580	33.27	9.96	43.23	56.00	-12.77	peak	
4		0.7180	30.24	9.79	40.03	56.00	-15.97	peak	
5		0.8940	28.80	9.21	38.01	56.00	-17.99	peak	
6		15.8820	27.08	9.83	36.91	60.00	-23.09	peak	

aaa-037239

a. Line conduction for a diode bridge

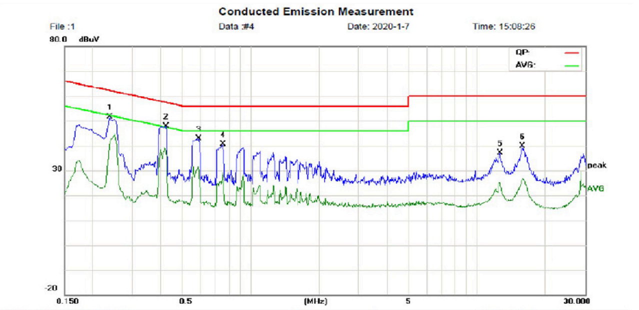


Site TOBY Chamber #1 | Phase: L1 | Temperature: 23.3 (C)
Limit: (CE)EN55032 class B_QP | Power: AC 110V/60Hz | Humidity: 43 %
EUT: 适配器
M/N: 12V240W
Mode: Normal Mode
Note: Mosfet

No.	Mk.	Freq. (MHz)	Reading Level (dBuV)	Correct Factor (dB)	Measure-ment (dBuV)	Limit (dBuV)	Over (dB)	Detector	Comment
1		0.2460	42.40	9.80	52.20	61.89	-9.69	peak	
2	*	0.3899	39.77	9.84	49.61	58.06	-8.45	peak	
3		0.5500	36.68	9.95	46.63	56.00	-9.37	peak	
4		0.7060	33.84	9.80	43.64	56.00	-12.36	peak	
5		16.0860	27.72	9.83	37.55	60.00	-22.45	peak	
6		29.8420	33.16	9.92	43.08	60.00	-16.92	peak	

aaa-037240

a. Line conduction for an active bridge

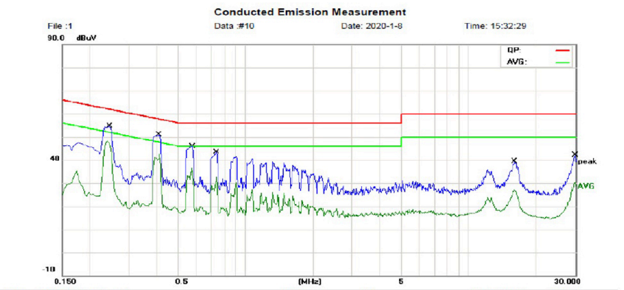


Site TOBY Chamber #1 | Phase: N | Temperature: 23.3 (C)
Limit: (CE)EN55032 class B_QP | Power: AC 110V/60Hz | Humidity: 49 %
EUT: 适配器
M/N: 12V240W
Mode: Normal Mode
Note: 整流桥

No.	Mk.	Freq. (MHz)	Reading Level (dBuV)	Correct Factor (dB)	Measure-ment (dBuV)	Limit (dBuV)	Over (dB)	Detector	Comment
1		0.2380	41.76	9.80	51.56	62.16	-10.60	peak	
2	*	0.4220	38.06	9.86	47.92	57.41	-9.49	peak	
3		0.5899	33.00	9.96	42.96	56.00	-13.04	peak	
4		0.7539	30.80	9.78	40.58	56.00	-15.42	peak	
5		12.5940	27.35	9.82	37.17	60.00	-22.83	peak	
6		15.8780	29.94	9.83	39.77	60.00	-20.23	peak	

aaa-037241

c. Neutral conduction for a diode bridge



Site TOBY Chamber #1 | Phase: N | Temperature: 23.3 (C)
Limit: (CE)EN55032 class B_QP | Power: AC 110V/60Hz | Humidity: 43 %
EUT: 适配器
M/N: 12V240W
Mode: Normal Mode
Note: Mosfet

No.	Mk.	Freq. (MHz)	Reading Level (dBuV)	Correct Factor (dB)	Measure-ment (dBuV)	Limit (dBuV)	Over (dB)	Detector	Comment
1		0.2460	43.70	9.80	53.50	61.89	-8.39	QP	
2	*	0.2460	37.49	9.80	47.29	51.89	-4.60	AVG	
3		0.4100	39.93	9.85	49.78	57.65	-7.87	QP	
4		0.4100	31.85	9.85	41.70	47.65	-5.95	AVG	
5		0.5780	34.31	9.96	44.27	56.00	-11.73	QP	
6		0.5780	22.83	9.96	32.79	46.00	-13.21	AVG	
7		0.7420	32.13	9.78	41.91	56.00	-14.09	QP	
8		0.7420	20.51	9.78	30.29	46.00	-15.71	AVG	
9		16.0260	23.30	9.83	33.13	60.00	-26.87	QP	

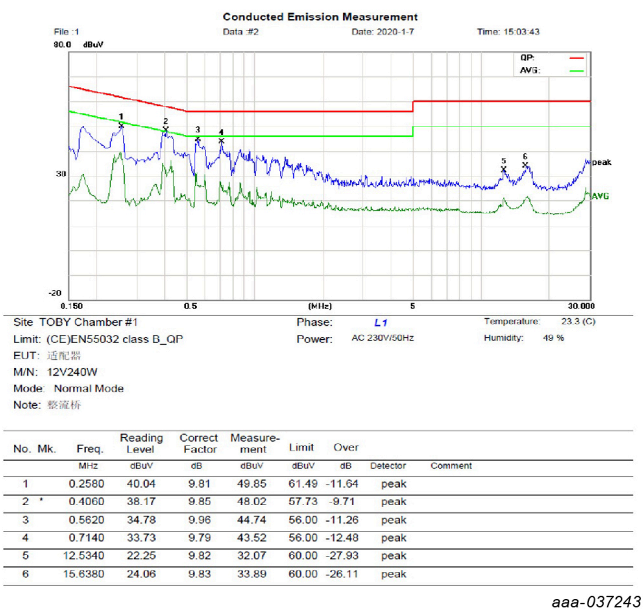
aaa-037242

c. Neutral conduction for an active bridge

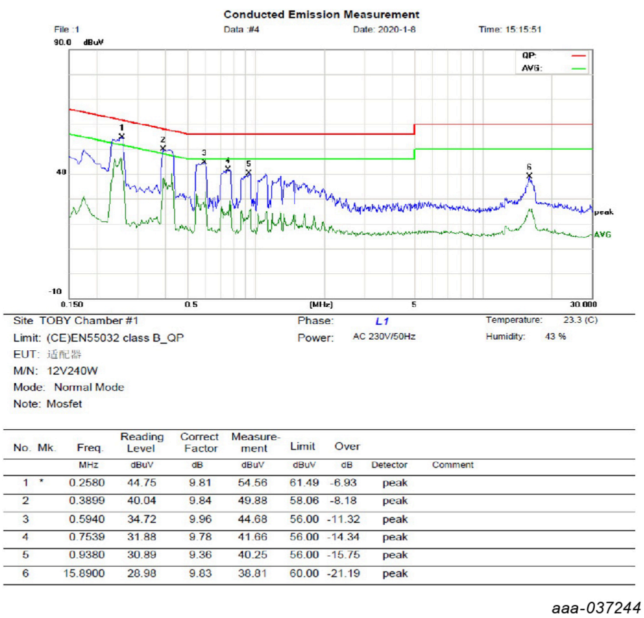
Figure 19. Conduction EMI comparison between a diode bridge and an active bridge at 110 V (AC)/240 W load condition

6.10.2 Conduction EMI at 230 V (AC)

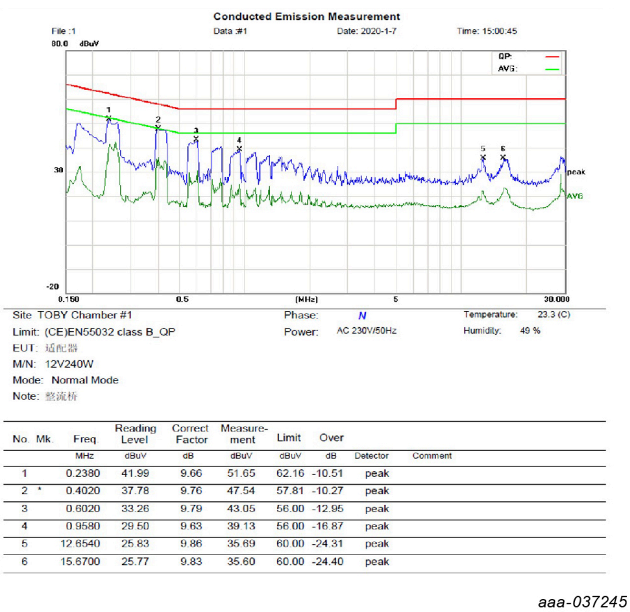
To measure the EMI performance, the resistor load is connected to the output voltage. To see the worst case, the output power is 240 W. Figure 20 shows the comparison between a diode bridge and an active bridge. The active bridge test result is a margin decrease of 4 dB, worst case.



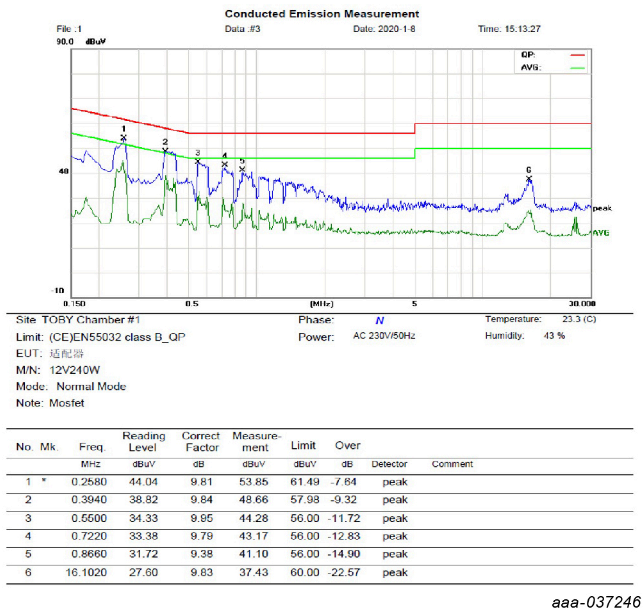
a. Line conduction for a diode bridge



b. Line conduction for an active bridge



c. Neutral conduction for a diode bridge



d. Neutral conduction for an active bridge

Figure 20. Conduction EMI comparison between a diode bridge and an active bridge at 230 V (AC)/240 W load condition

6.11 Surge test result

To test system surge, the TEA2208DB1576 is added on the TEA1916DB1262. In addition, one MOV, 14D511, is added between two AC mains lines. Figure 21 shows the MOV position. Surge test can pass up to 5 kV without damage, which is same test result as with the diode bridge.

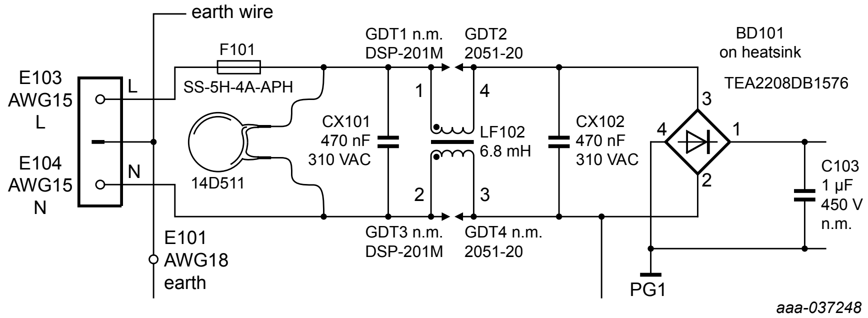


Figure 21. Circuit diagram which adding MOV 14D511 on the AC mains lines

7 Schematic

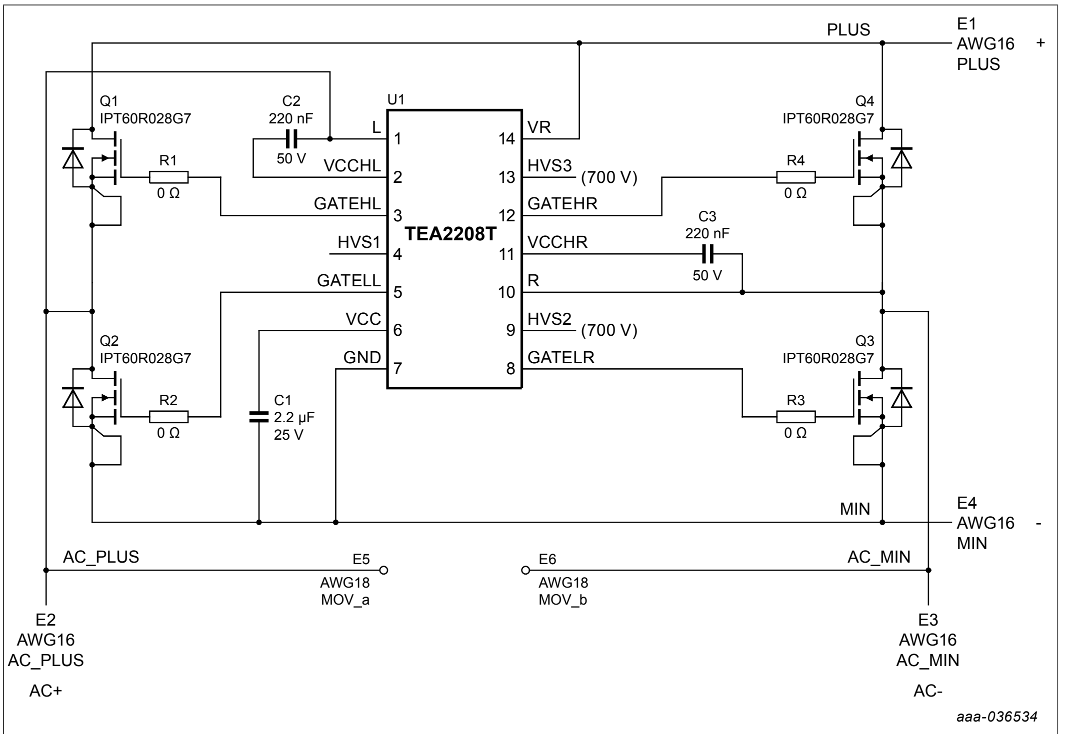


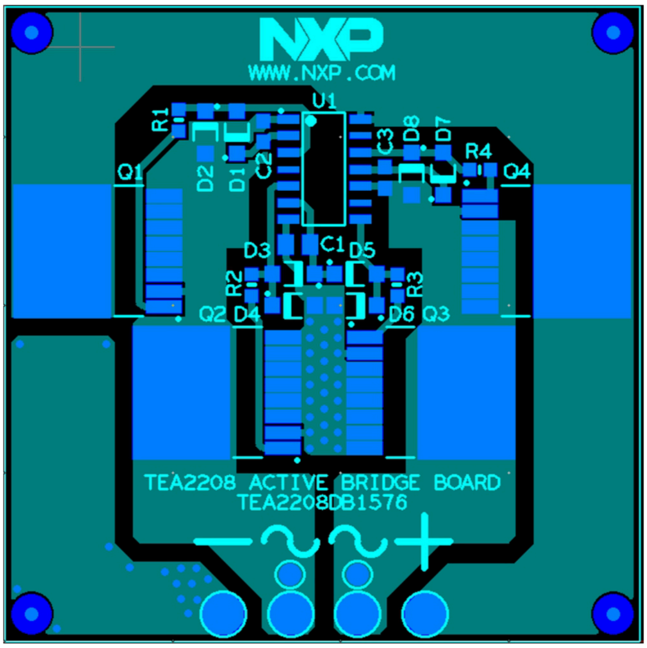
Figure 22. TEA2208DB1576 demo board schematic

8 Bill of materials (BOM)

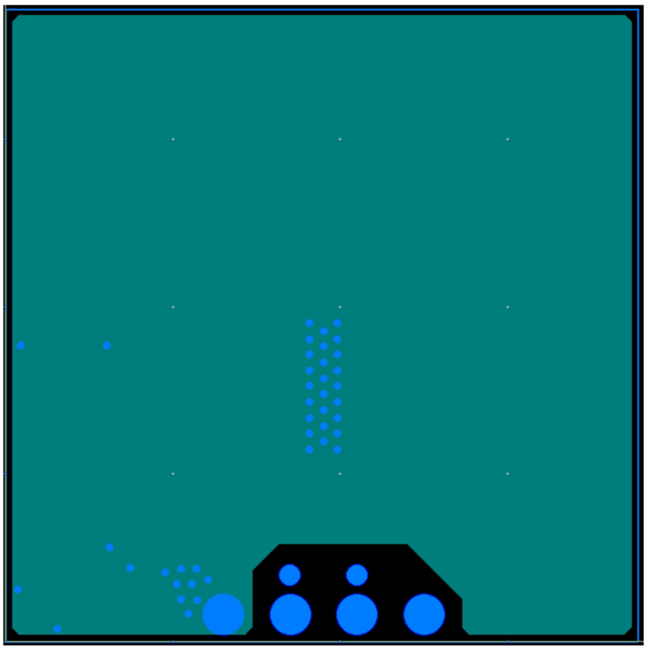
Table 2. Bill of materials (BOM)

Part reference	Values and description	Part number	Manufacturer
C1	capacitor; 2.2 µF; 10 %; 25 V; X7R; 0805	-	-
C2; C3	capacitor; 220 nF; 10 %; 50 V; X7R; 0603	-	-
Q1; Q2; Q3; Q4	MOSFET-N; 600 V; 75 A	IPT60R028G7	Infineon
R1; R2; R3; R4	resistor; jumper; 0 Ω; 100 mW; 0603	-	-
U1	active bridge rectifier controller	TEA2208T	NXP Semiconductors

9 Layout



a. Front view layout and assembly



b. Back view layout and assembly

Figure 23. TEA2208DB1576 demo board layout

10 Abbreviations

Table 3. Abbreviations

Acronym	Description
MOSFET	metal-oxide semiconductor field-effect transistor
UVLO	undervoltage lockout
THD	total harmonic distortion
PCB	printed-circuit board

11 References

[1] **TEA2208T data sheet** — Active bridge rectifier controller; 2020, NXP Semiconductors

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