UM10426

UBA2025 CFL 23 W, 230 V and 120 V demo board

Rev. 1 — 26 April 2011 **User manual**

Document information

Info	Content
Keywords	UBA2025, CFL, half-bridge, demo board
Abstract	This user manual describes the CFL 23 W, 230 V and 120 V demo board using the UBA2025 IC.

Revision history

Rev	Date	Description
v.1	20110426	first draft

Contact information

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1. Introduction

The UBA2025 is a high voltage power IC intended to drive and control electronically ballasted Compact Fluorescent Lamps (CFL). The UBA2025 IC includes two internal 600 V, 3 Ω Negative-channel Metal-Oxide Semiconductor (NMOS) half-bridges. This user manual focuses on the UBA2025 demo board as shown in Figure 1. The demo board can be setup for 230 V or 120 V ±20 % full-bridge 23 W (and below) lamp applications depending upon the installed components values as defined in Table 1.

The demo board includes open lamp, broken filament and broken lamp protection circuits.

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.

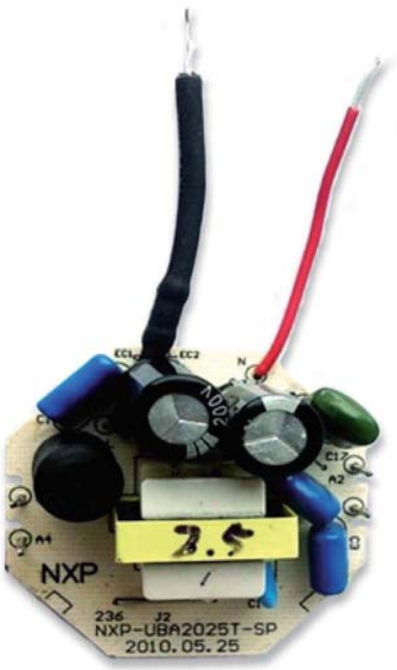

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Fig 1. Demo board

2. Features

Key demo board features include:

- Two internal 600 V, 3 Ω NMOS half-bridges

- Steady state half-bridge current up to 280 mA
- Ignition half-bridge currents up to 1.5 A
- Adjustable preheat and ignition time
- Adjustable preheat current
- Adjustable lamp power
- Lamp temperature stress protection at higher mains voltage
- Protection against low drive voltage for the power MOSFETs
- Capacitive mode protection

Figure 2 shows the pin assignment of the UBA2025 IC.

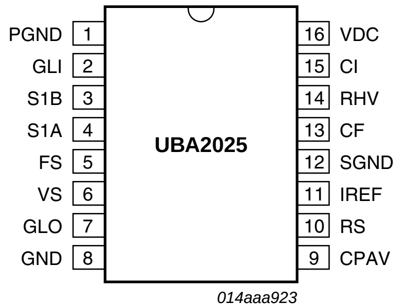

Fig 2. UBA2025 (SO16) pin assignment

Full circuit diagrams for the UBA2025 230 V and 120 V demo boards are shown in Section 3.

3. Circuit diagrams

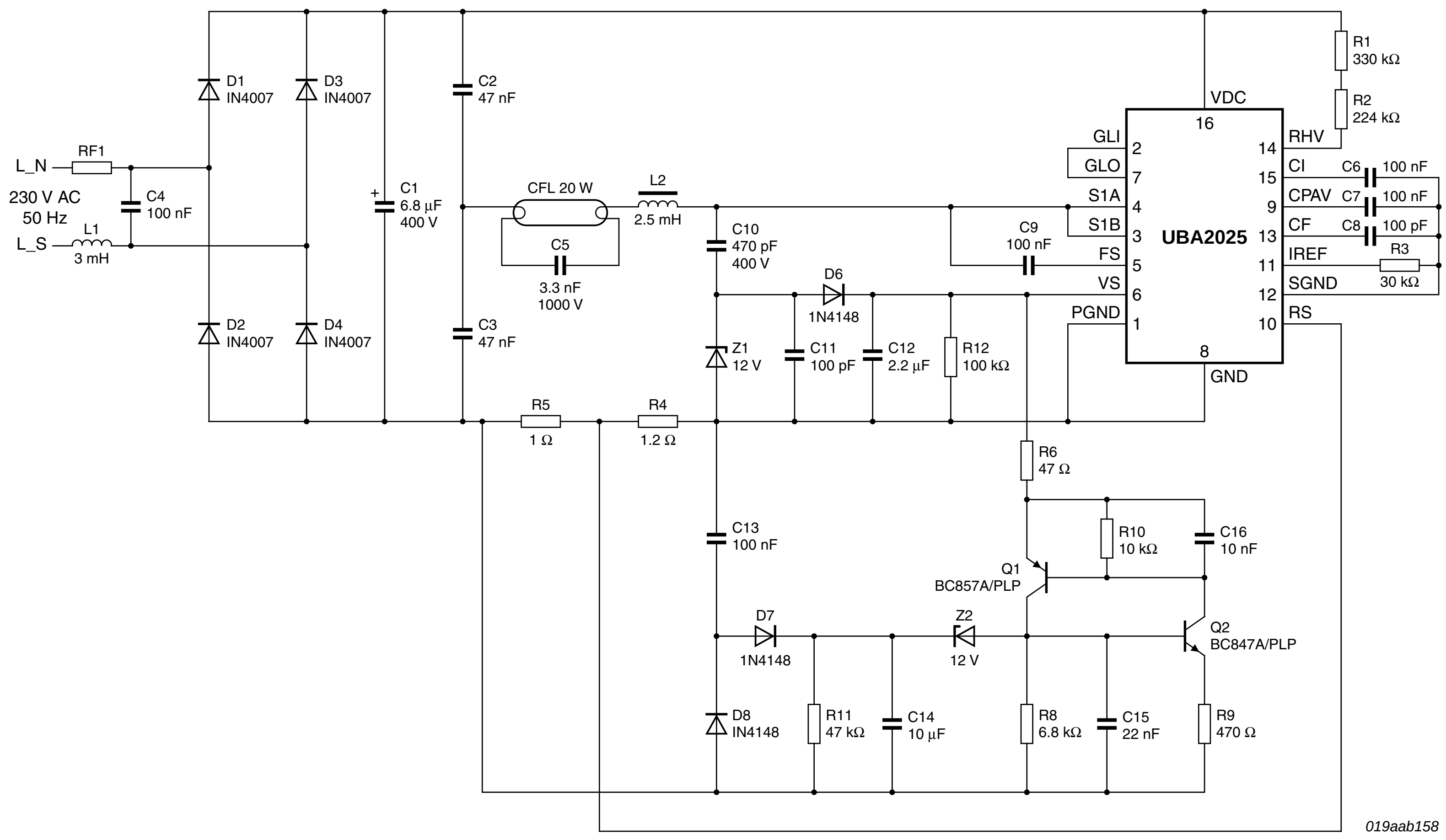

Fig 3. Circuit diagram (230 V)

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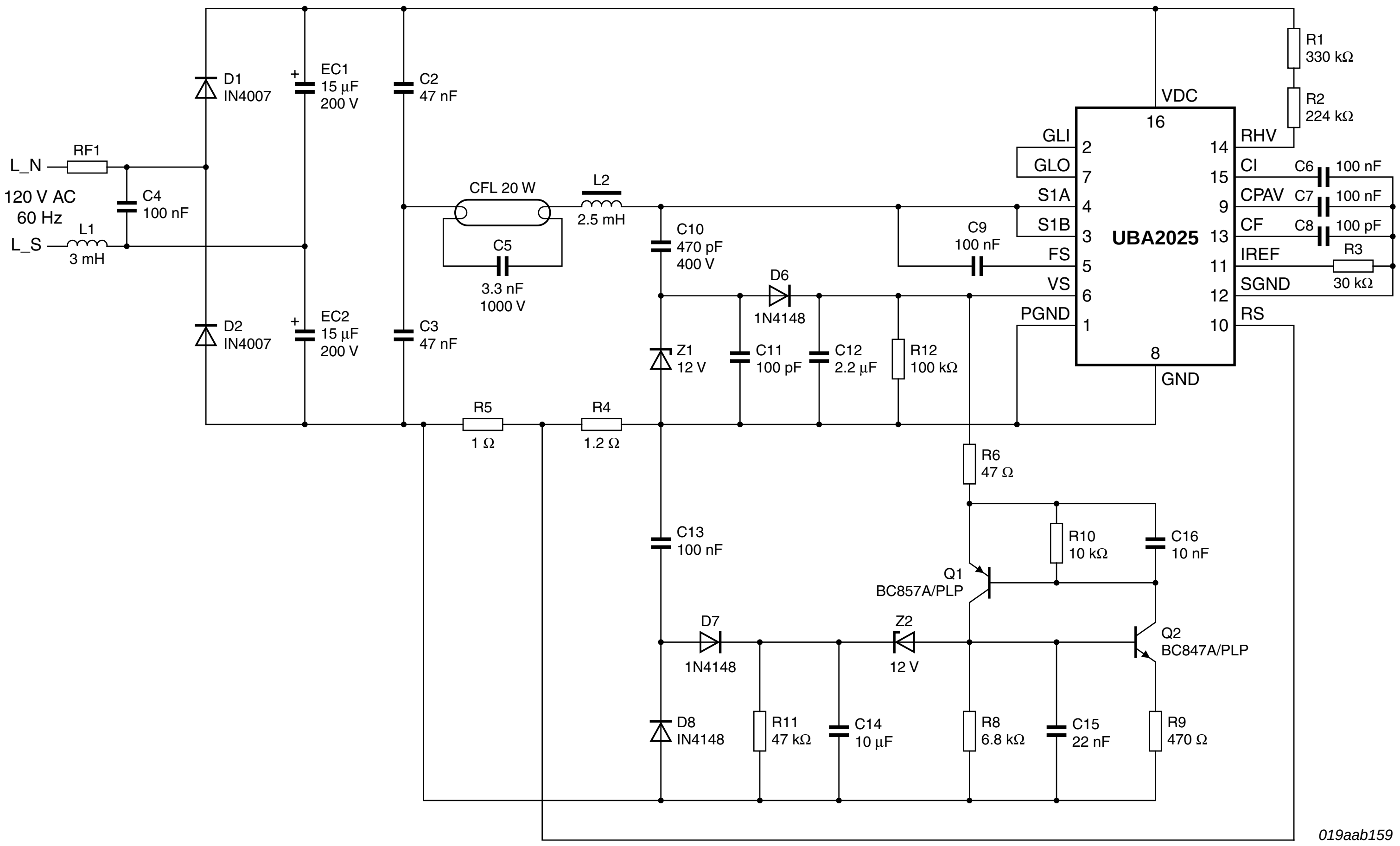

Fig 4. Circuit diagram (120 V)

4. Specification

4.1 Specification for the 230 V and 120 V demo board

The UBA2025 demo board is designed to drive a 20 W burner. The specification for the 230 V and 120 V configurations are as follows:

4.1.1 Specification for the 230 V setup

- Input voltage range: 230 V, ±20 %, 50 Hz
- Input power: 22 W at 230 V
- Input current: 180 mA at 230 V
- Power factor: 0.57
- Preheat frequency: 70 kHz, running frequency 45 kHz
- 1.5 s preheat

Burners:

- 20 W
- 4 pins
- Burner current 180 mA
- Burner voltage 110 V

Resonant inductor:

- EE19, PC40 core, 4 pins, gap 1.2 mm
- 2.5 mH +5 %, 240 Ts, wire width 0.19 mm x 2 mm

4.1.2 Specification for the 120 V setup

- Input voltage range: 120 V, ±20 %, 60 Hz
- Input power: 23 W at 120 V
- Input current: 180 mA at 120 V
- Power factor: 0.60
- Preheat frequency: 70 kHz, operating frequency 42 kHz
- 1.5 s preheat

Burners:

- 20 W
- 4 pins
- Burner current 180 mA
- Burner voltage 110 V

Resonant inductor:

- EE19, PC40 core, 4 pins, gap 1.2 mm
- 2.5 mH +5 %, 240 Ts, wire width 0.19 mm x 2 mm

4.2 Board connections

Figure 5 identifies the AC mains input and four burner filament connections.

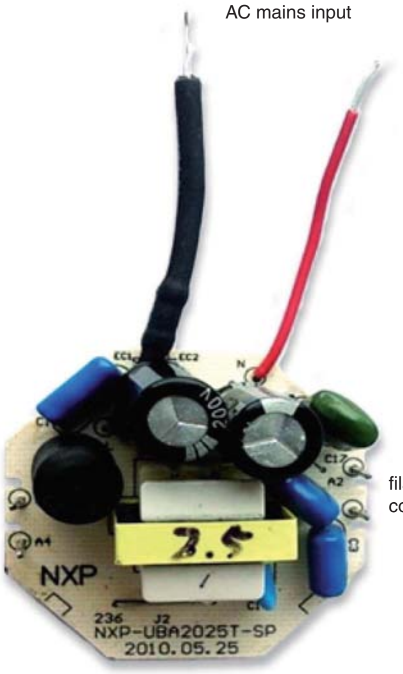

Fig 5. Demo board connections

5. Circuit considerations

5.1 Preheat time selection

Preheat time can be adjusted using capacitor C7 (CT pin) and resistor R3 (IREF pin). As R3 also defines f_{min}, it as more practical to change C7 to adjust the preheat time. Preheat time calculations can be determined using Equation 1:

$$T_{ph} = \frac{C7 \times R3}{(150 \times 10^{-9}) \times (30 \times 10^{3})}[s] \quad (1)$$

5.2 Preheat current selection

Preheat current can be adjusted using R4. Reducing the value of R4 increases filament preheating current. For optimal ignition, set the preheat current according to the burner specification. Preheating current calculations can be determined using Equation 2:

$$I_{ph(M)} = \frac{Vctrl(600mA)}{R4}[mA] \quad (2)$$

5.2.1 Results for the 230 V setup

With reference to Figure 6:

Preheat time = 1.27 s

Preheat current = 261 mA (RMS)

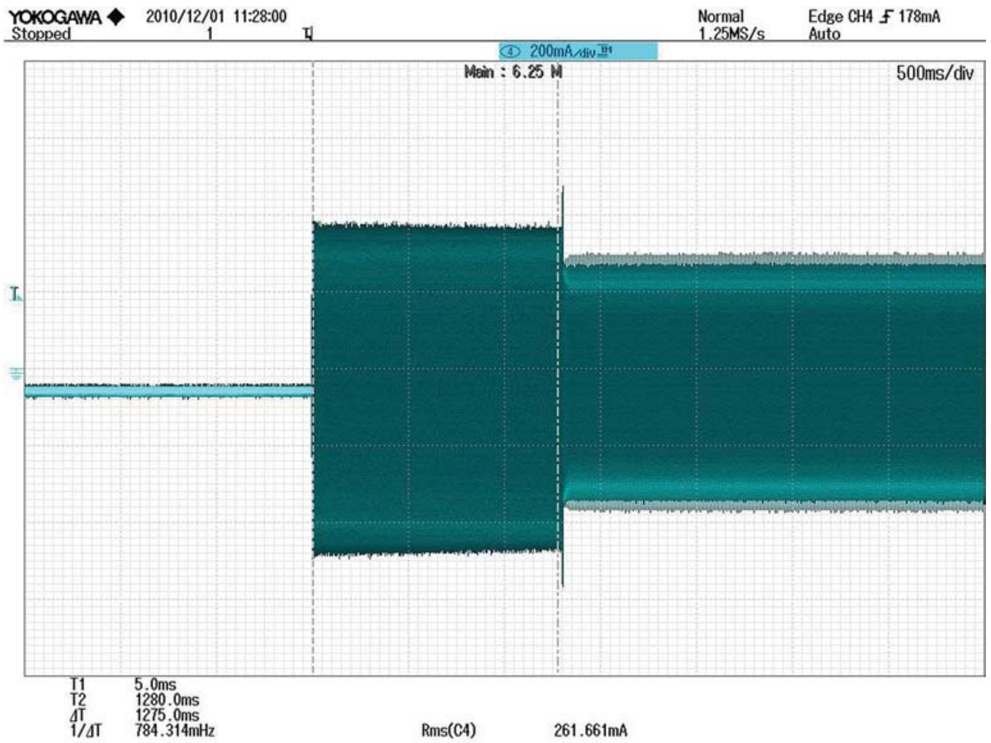

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Fig 6. Inductor current during preheat and burning state (230 V)

5.2.2 Results for the 120 V setup

With reference to Figure 7:

Preheat time = 1.38 s

Preheat current = 253 mA (RMS)

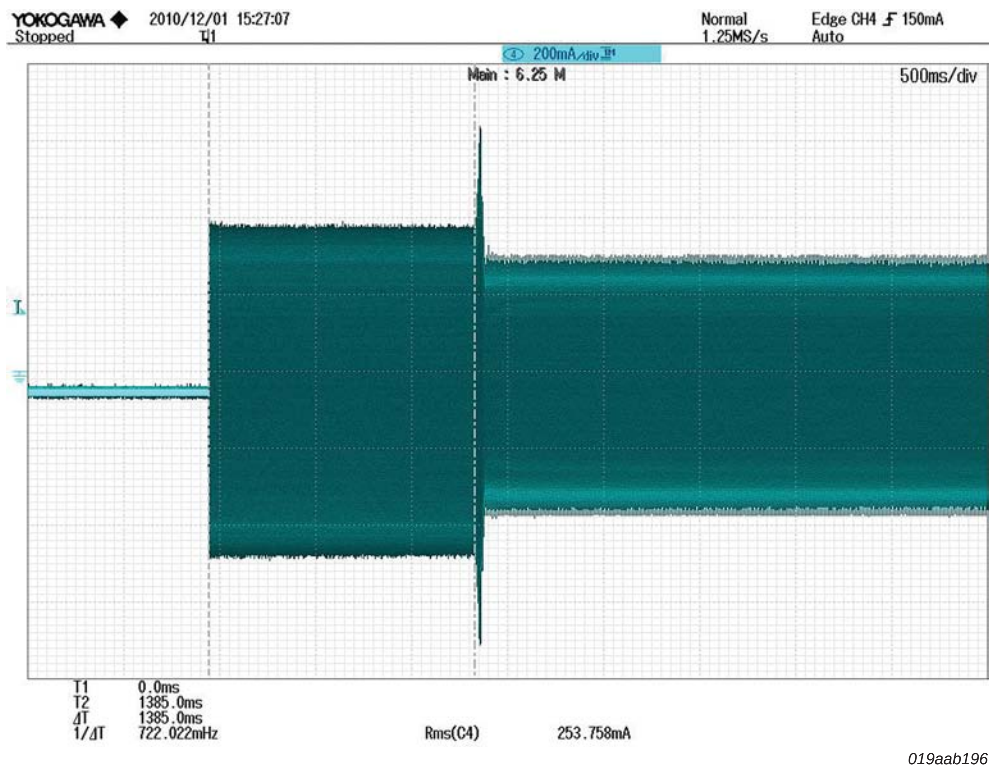

Fig 7. Inductor current during preheat and burning state (120 V)

5.3 Protection circuit

5.3.1 Protection circuit theory

The protection circuit includes components C13, R4, R5, D6, D7 C14, R11 Z2, R8, R9, C15, Q1, Q2, R10, C16 and R6. Under lamp removal, broken lamp or one broken filament conditions half-bridge voltage rise time reduces and high dV/dt current (dV/dt current $I_{dV/dt}$ = C10 × half-bridge voltage / half-bridge voltage rise time) passes through C10, Z1, C11, C13 and D7 charging C14. The voltage of Z2 cathode increases and Z2 starts to conduct with Vb (base voltage) of Q2 going high causing Q2 to conduct. As Q2 starts to conduct, Q1also starts conducting causing supply capacitor C12 to discharge through Q1 and Q2 resulting in a drop in the supply voltage.

When the supply voltage is lower than the oscillation low-level threshold, the UBA2025 stops oscillating. This causes the current through C10 to reduce to zero causing Q2 to move towards non-conduction. However, Q1 keeps Q2 conducting (Q1 and Q2 for discrete latch circuit) causing the voltage across the supply capacitor C12 to be maintained low enough to stop the circuit oscillating. The latch current is provided via R1 and R2 through the UBA2025 internal start-up path. It is only possible to start the circuit again after fitting the correct lamp and switching the mains voltage on/off, which causes the lamp to restart.

5.3.2 Protection circuit measurements

5.3.2.1 Measurements for the 230 V setup

When the lamp is working normally, during preheating the half-bridge rise and fall time is 600 ns at a working frequency of 72 kHz. The dV/dt current I_{dVdt} = C14 × dV/dt = 470 × 10^{-12} × 300 V/ (600 × 10^{-9}) A = 0.24 A.

This current charges, C14 causing the voltage of C14 to rise. However, as this current only charges C14 to around 1.4 V, it is not higher than the conducting voltage of Z2. Therefore, Z2 does not conduct and the protection circuit fails to operate.

The measurement of the half-bridge is shown in Figure 8 with the measurement of Z2 cathode voltage shown in Figure 9.

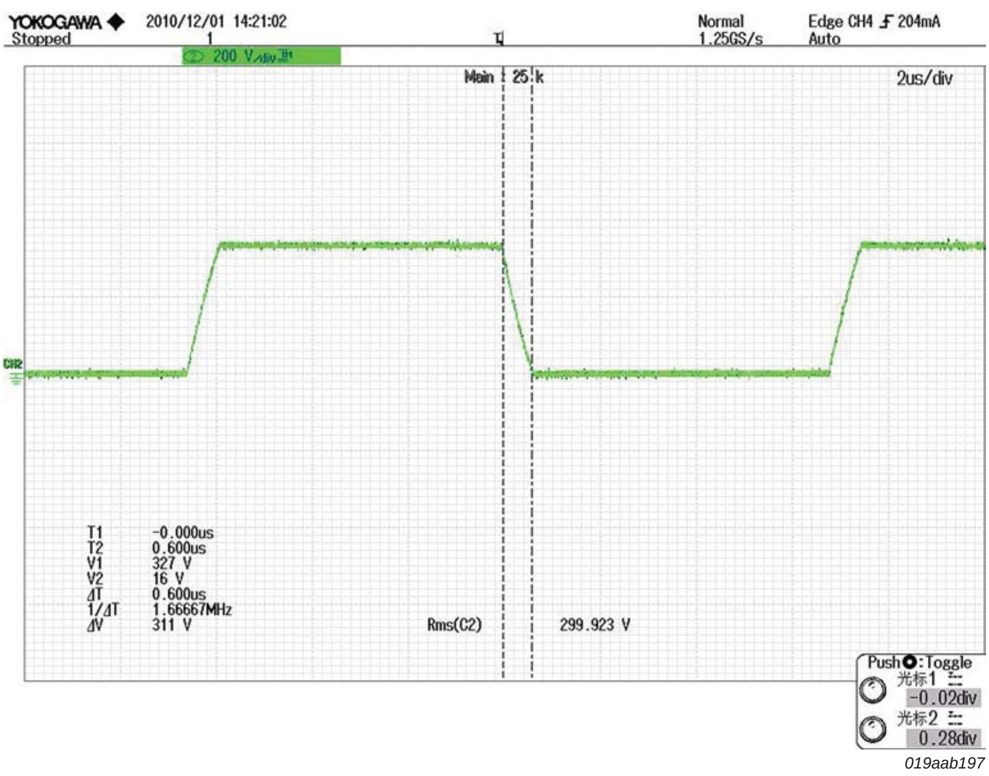

Fig 8. Half-bridge voltage during preheat (230 V)

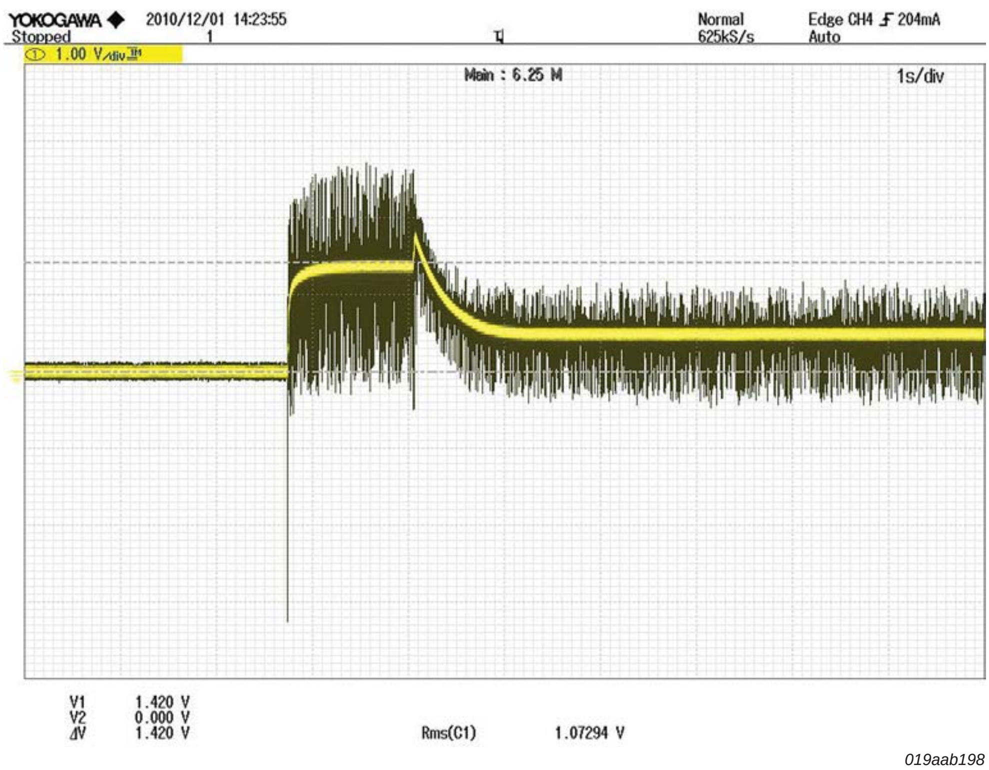

Fig 9. Z2 cathode voltage during preheat (230 V)

When the lamp is working normally, during burning the half-bridge rise and fall time is around 580 ns at a working frequency of 44 kHz. The dV/dt current $I_{dV/dt}$ = C14 × dV/dt = 470 × 10^{-12} × 300 V/ (580 × 10^{-9}) A = 0.24 A. This current charges, C14 causing the voltage of C14 to rise. However, as this current only charges C14 to around 0.56 V, it is not higher than the conducting voltage of Z2. Therefore, Z2 does not conduct and the protection circuit fails to operate.

The measurement of the half-bridge is shown in Figure 10 with the measurement of Z2 cathode voltage shown in Figure 11.

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Fig 10. Half-bridge voltage during burn state (230 V)

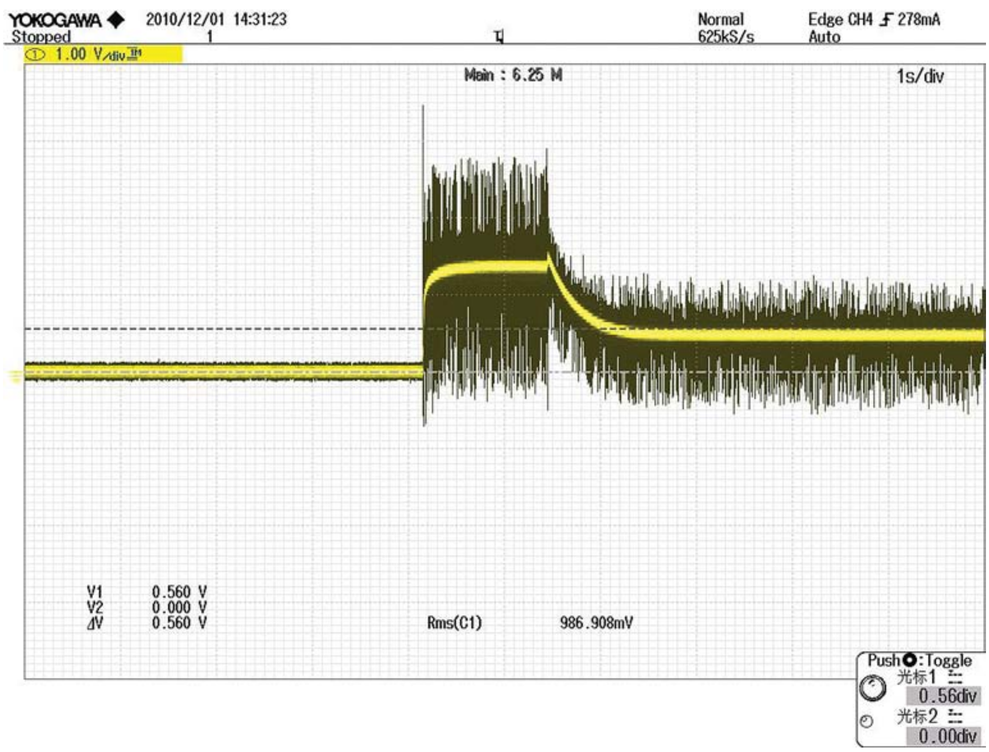

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Fig 11. Z2 cathode voltage during burn state (230 V)

When one filament is broken, the half-bridge rise and fall time is around 46 ns at a working frequency of 108 kHz. The dV/dt current $I_{dV/dt}$ = C14 × dV/dt = 470 × 10^{-12} × 300 V/(46 × 10^{-9}) A = 3.0 A. This current charges, C14 causing the voltage of C14 to rise allowing Z2 to conduct and the protection circuit to operate.

The measurement of the half-bridge voltage with one broken filament is shown in Figure 12. The measurement of the half-bridge voltage, Z2 cathode voltage and Vb voltage of Q2 with one broken filament is shown in Figure 13.

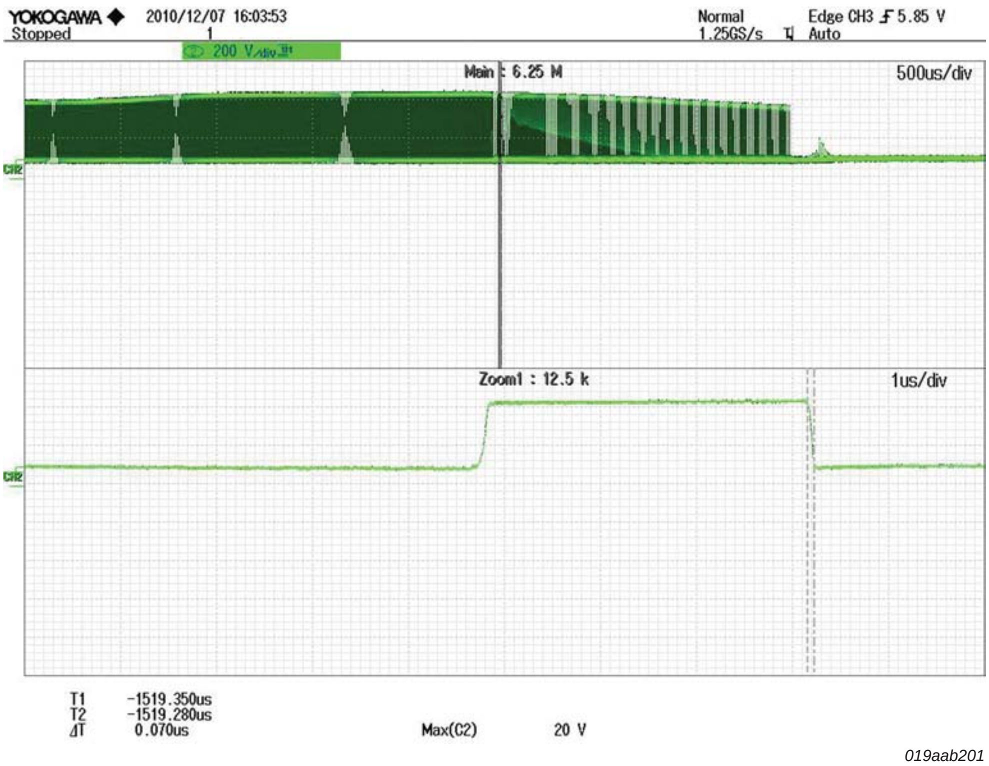

Fig 12. Half-bridge voltage with one broken filament (230 V)

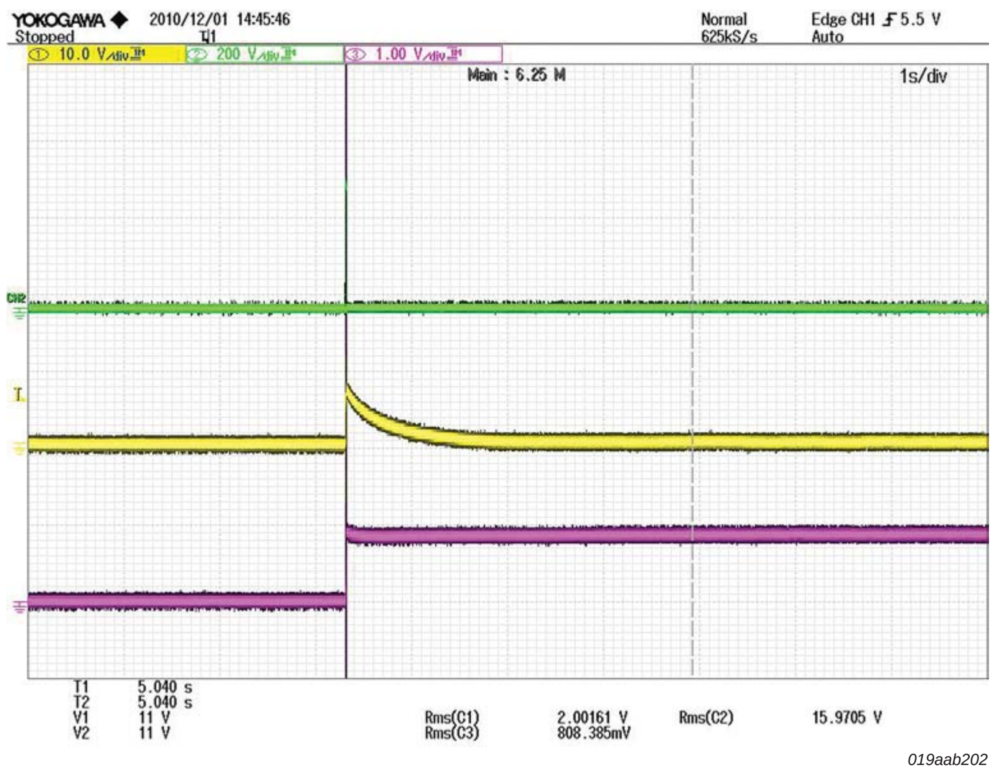

Fig 13. Half-bridge voltage, Z2 cathode voltage and Vb voltage of Q2 (230 V)

5.3.2.2 Measurements for the 120 V setup

When the lamp is working normally; during preheating the half-bridge rise and fall time is 450 ns at a working frequency of 72 kHz. The dV/dt current $I_{dV/dt}$ = C14 × dV/dt = 470 × 10^{-12} × 300 V/ (450 × 10^{-9}) A = 0.31 A. This current charges, C14 causing the voltage of C14 to rise. However, as this current only charges C14 to around 1.25 V, it is not higher than the conducting voltage of Z2. Therefore, Z2 does not conduct and the protection circuit fails to operate.

The measurement of the half-bridge is shown in Figure 14 with the measurement of Z2 cathode voltage shown in Figure 15.

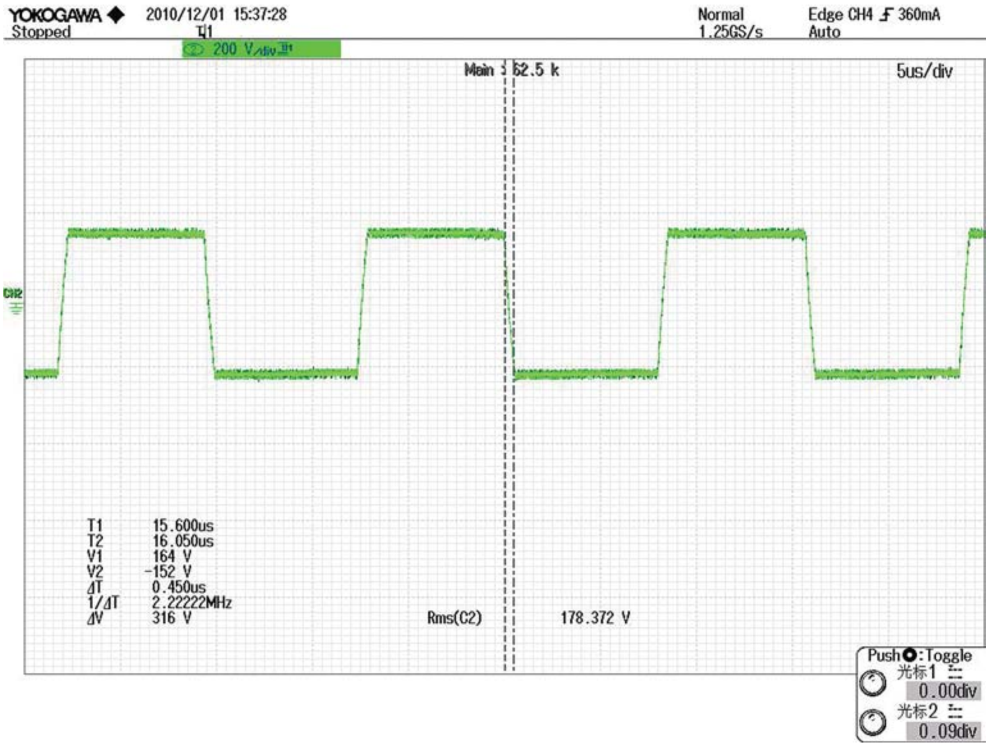

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Fig 14. Half-bridge voltage during preheat (120 V)

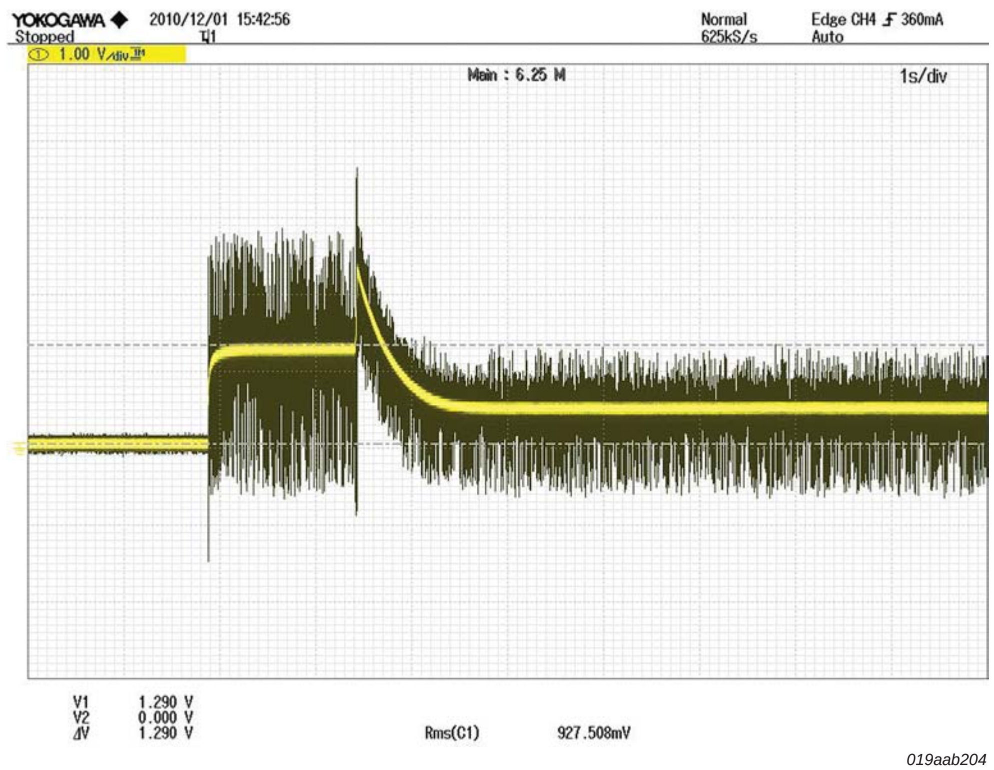

Fig 15. Z2 cathode voltage during preheat (120 V)

When the lamp is working normally, during burning the half-bridge rise and fall time is around 640 ns, at a working frequency of 44 kHz. The dV/dt current $I_{dV/dt} = C14 \times dV/dt = 470 \times 10^{-12} \times 300\ V/ (640 \times 10^{-9})\ A = 0.22\ A$. This current charges, C14 causing the voltage of C14 to rise. However, as this current only charges C14 to around 0.53 V, it is not higher than the conducting voltage of Z2. Therefore, Z2 does not conduct and the protection circuit fails to operate.

The measurement of the half-bridge is shown in Figure 16 with the measurement of Z2 cathode voltage shown in Figure 17.

Fig 16. Half-bridge voltage during burn state (120 V)

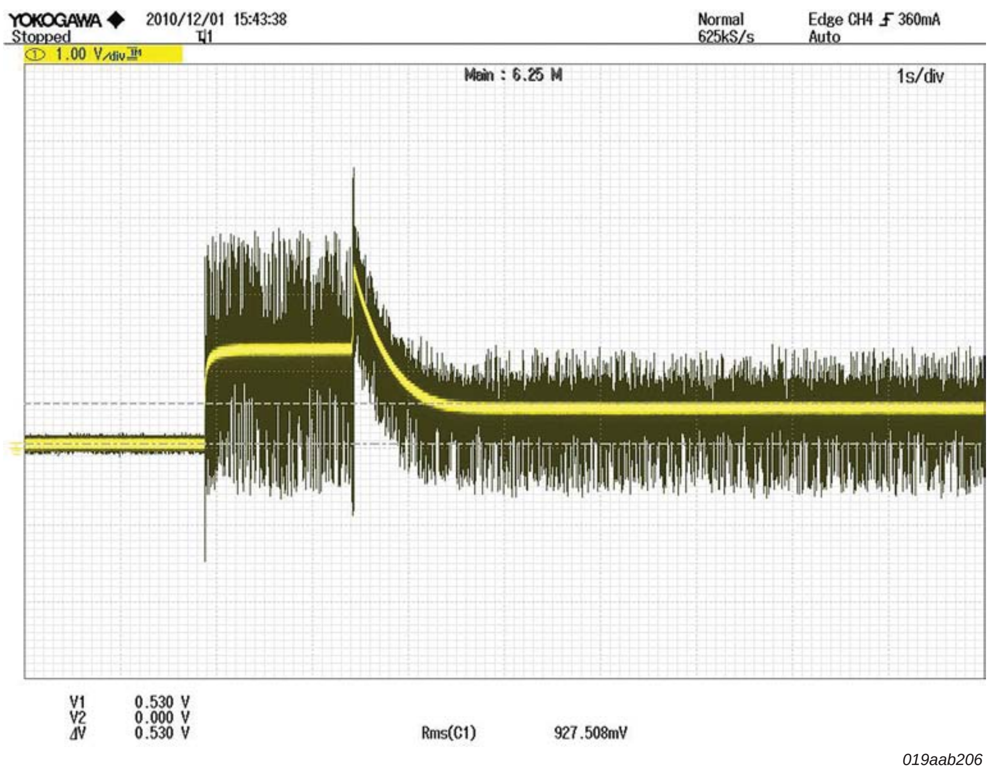

Fig 17. Z2 cathode voltage during burn state (120 V)

When one filament is broken the half-bridge rise and fall time is around 54 ns at a working frequency of 108 kHz. The dV/dt current $I_{dV/dt}$ = C14 × dV/dt = 470 × 10^{-12} × 300 V/(54 × 10^{-9}) A = 2.6 A. This current charges, C14 causing the voltage of C14 to rise allowing Z2 to conduct and the protection circuit to operate.

The measurement of the half-bridge voltage with one broken filament is shown in Figure 18. The measurement of the half-bridge voltage, Z2 cathode voltage and Vb voltage of Q2 with one broken filament is shown in Figure 19.

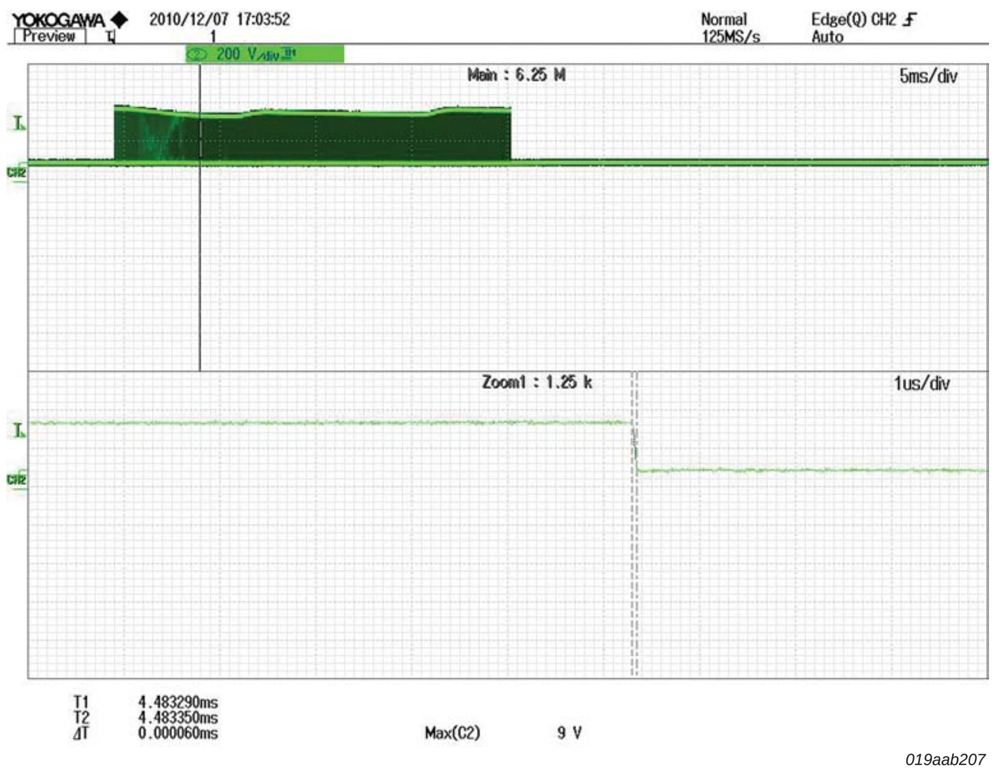

Fig 18. Half-bridge voltage with one filament broken (120 V)

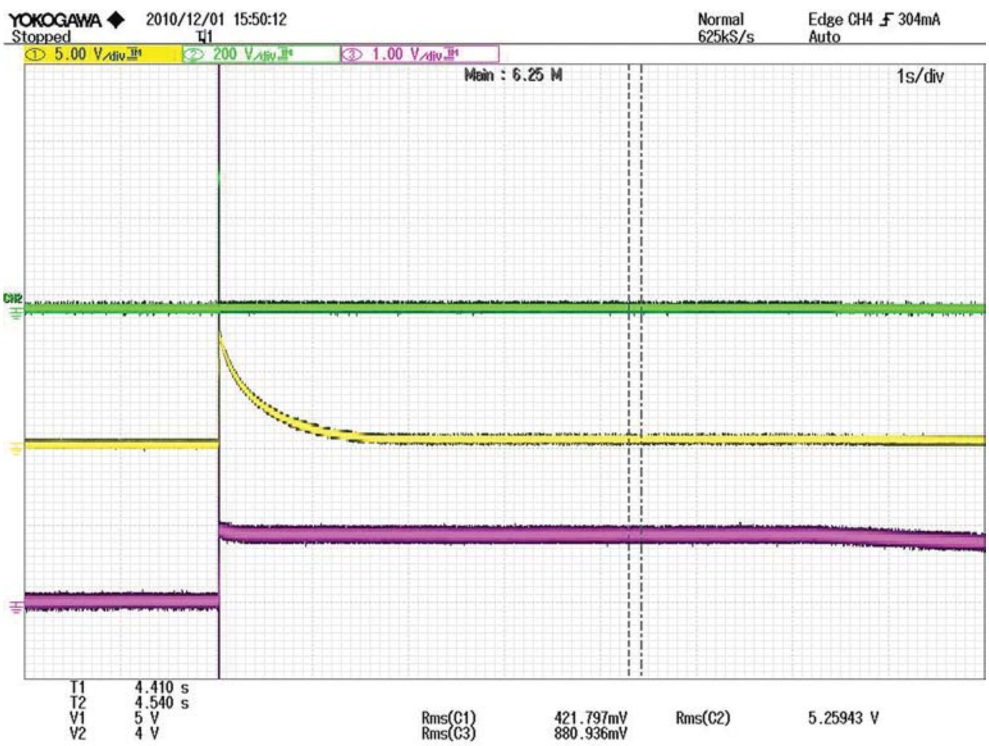

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Fig 19. Half-bridge voltage, Z2 cathode voltage and Vb voltage of Q2 (120 V)

5.3.3 Simulation of protection circuit

Based on the simulation tool LTSPICE, the simulated protection circuit build as shown in Figure 20 provides a view on how to select the correct components to obtain the correct level of protection during different conditions.

Remark: part numbers in the simulation circuit shown in Figure 20 are as the real circuit except that V1 replaces the half-bridge voltage and I1 and D1 replaces the VS pin.

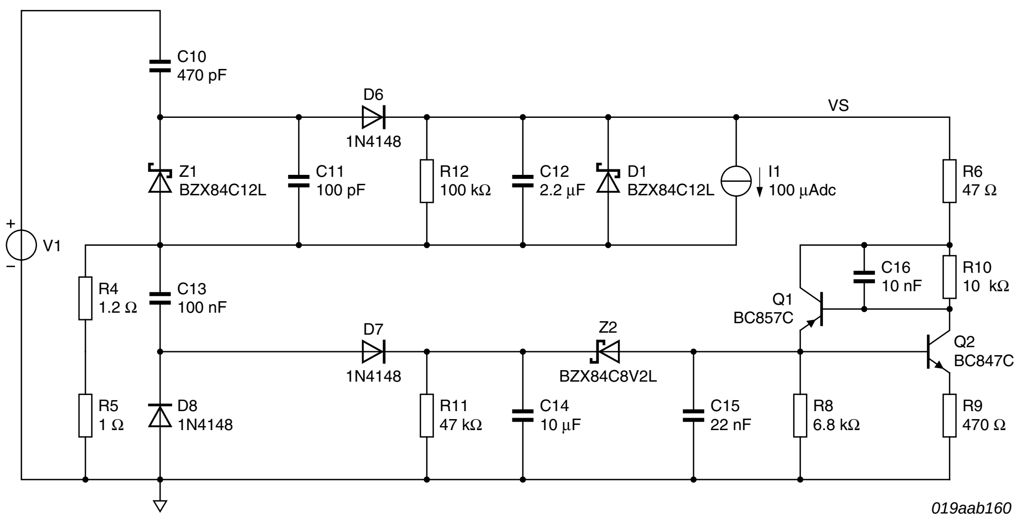


Fig 20. Protection circuit simulation mode

The voltage of VS and Vb of Q2 based on the simulation circuit in Figure 20 sweeps as shown in Figure 21. From the simulation result shown in Figure 21, the voltage of VS is maintained at 12 V before 28 ms and VS voltage drops to 1 V after 28 ms. Under this condition VS is latched and the UBA2025 stops oscillating.

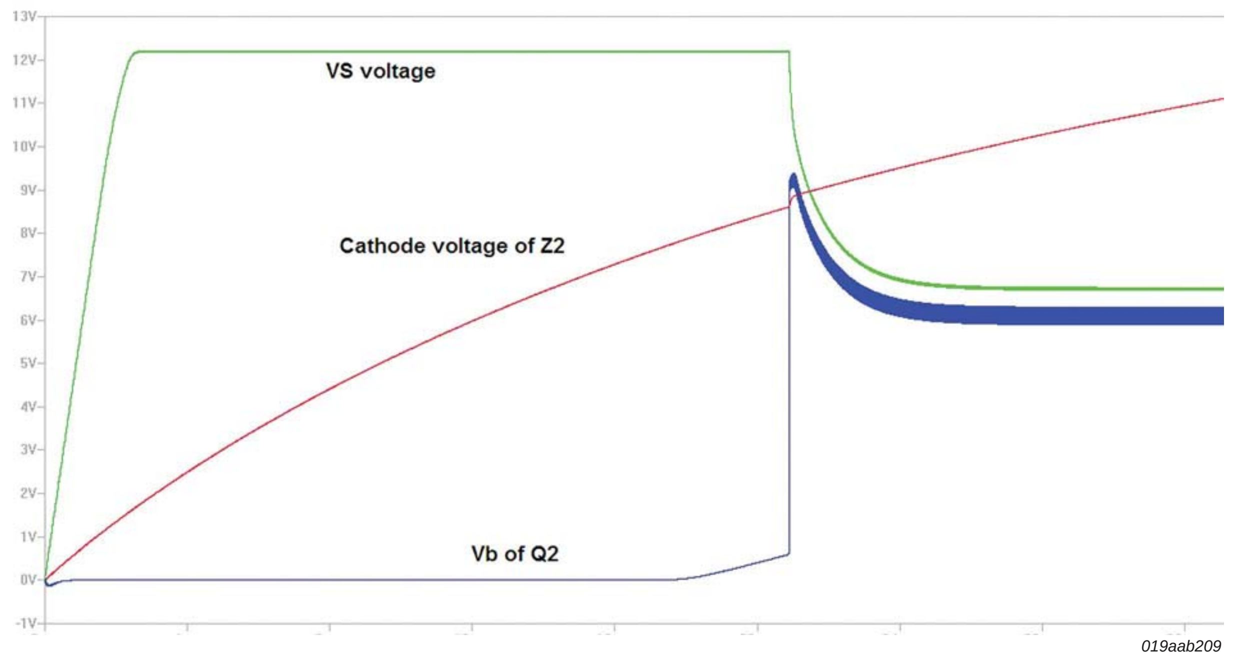
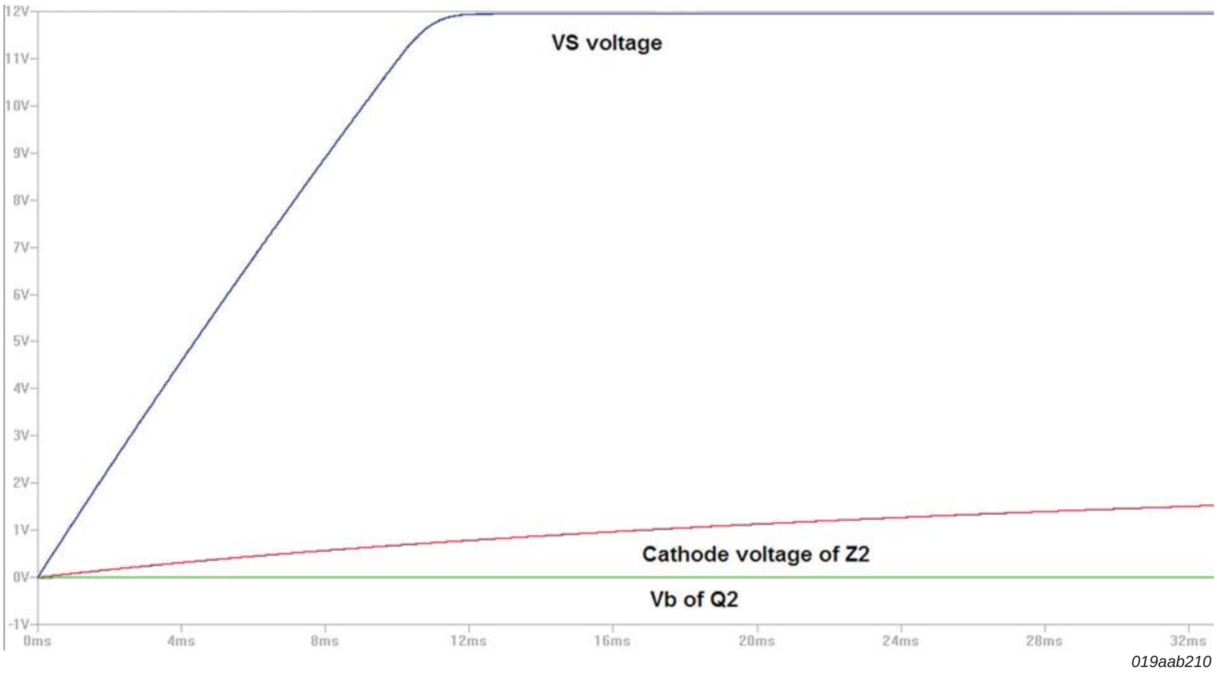


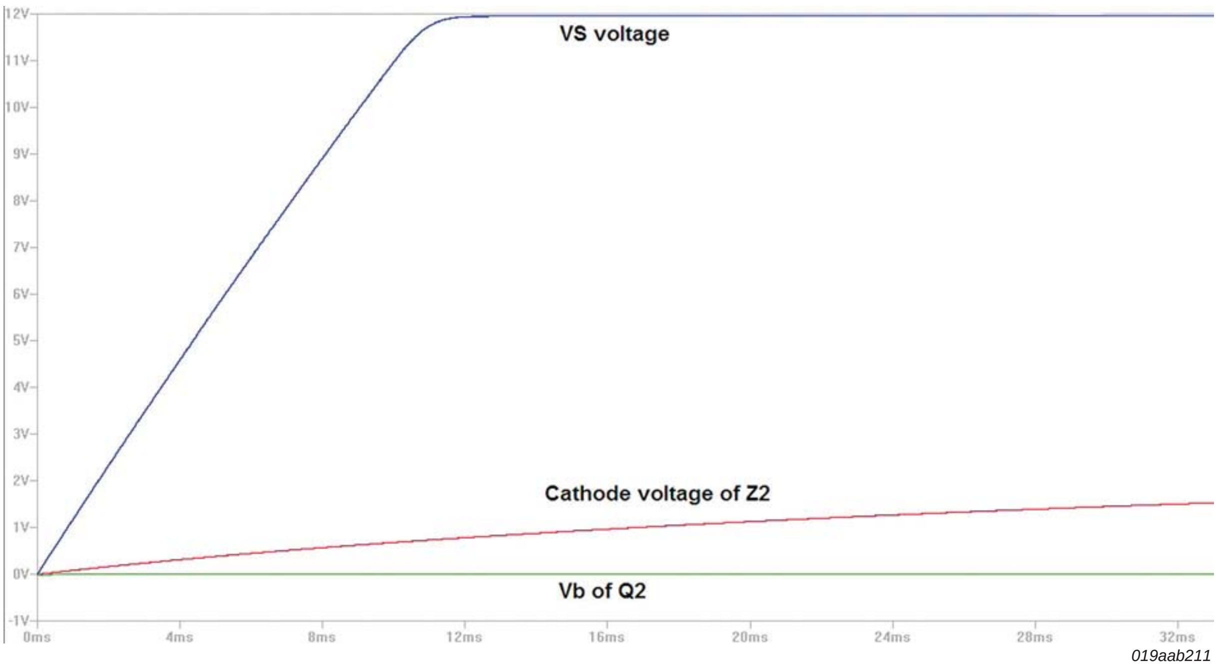
Fig 21. Simulation result of VS, cathode voltage of Z2 and Vb of Q2 during protection

For the correct protection during different conditions, some components i.e. C10 and R5 can be selected based on the simulation. Figure 22 and Figure 23 show the simulated results where different values of C10 and R5 are selected.



(1) Where C10 = 100 pF, the protection circuit does not provide protection.

Fig 22. VS voltage, cathode voltage of Z2 and Vb of Q2 with C10 (100 pF)



(1) Where R5 = 0 W, the protection circuit does not provide protection.

Fig 23. VS voltage, cathode voltage of Z2 and Vb of Q2 with R5 (0 Ω)

Based upon the simulation results, the correct protection is achieved if during component selection the following guidelines are observed:

- C10: select a large value
- R5: select a large value.

Remark: The value of R5 must not be too large as it affects system efficiency.

5.3.4 Temperature effect of protection circuit

5.3.4.1 Simulation temperature effect of protection circuit

To ensure correct protection at high temperatures, complete a simulation using a temperature sweep range from 25 °C to 110 °C with half-bridge rise time of 500 ns and 46 ns (for the 230 V setup) or 460 ns and 54 ns (for the 120 V setup).

Figure 24 shows that the VS voltage is maintained at 12 V as the temperature sweeps from 25 °C to 110 °C with a half-bridge rise time 500 ns (for the 230 V setup) or 460 ns (for the 120 V setup).

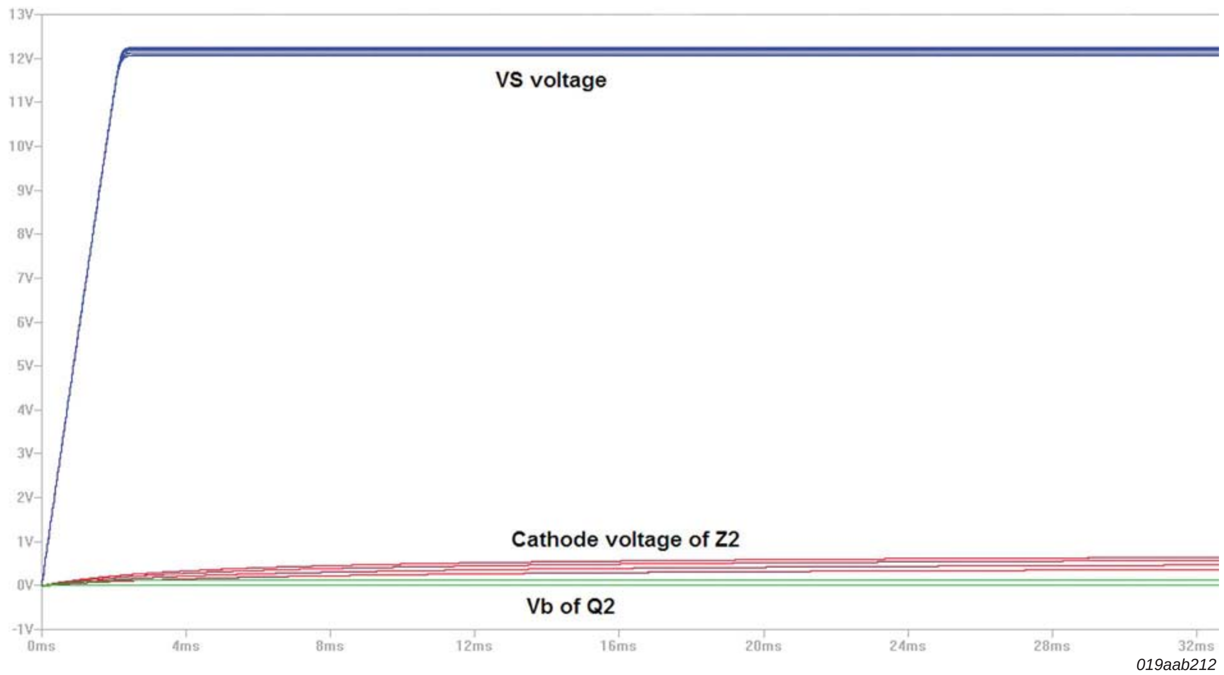


Fig 24. VS, cathode voltage of Z2 and Vb of Q2 with temperature range 25 °C to 110 °C

Figure 25 shows the VS voltage drops to almost the same voltage after 25 ms as the temperature sweeps from 25 °C to 110 °C with a half-bridge rise time of 46 ns. The temperature does affect the protection circuit trigger time slightly.

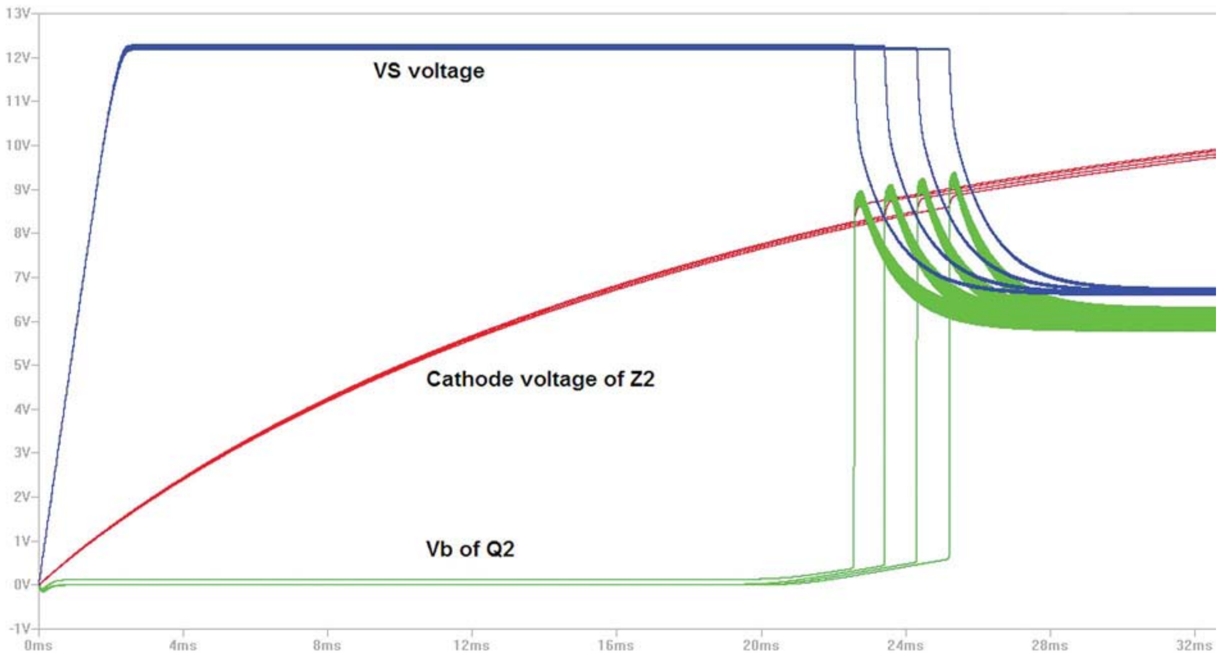


Fig 25. VS, cathode voltage of Z2 and Vb of Q2 with temperature range 25 °C to 110 °C

5.3.4.2 Test temperature effect of protection circuit

With the lamp placed in an oven at 80 °C for 1 hour and switching the lamp on/off no detection issues were found. From these two simulations/tests, the effect of temperature on the protection circuit is acceptable.

6. Conduction emission test

6.1 Emission test 230 V setup

The results of emissions measured in the neutral and line wires using a pre-compliance test setup using a 230 V line voltage and taking into consideration the limits for the lighting applications. The EN55015 limits are shown in Figure 26.

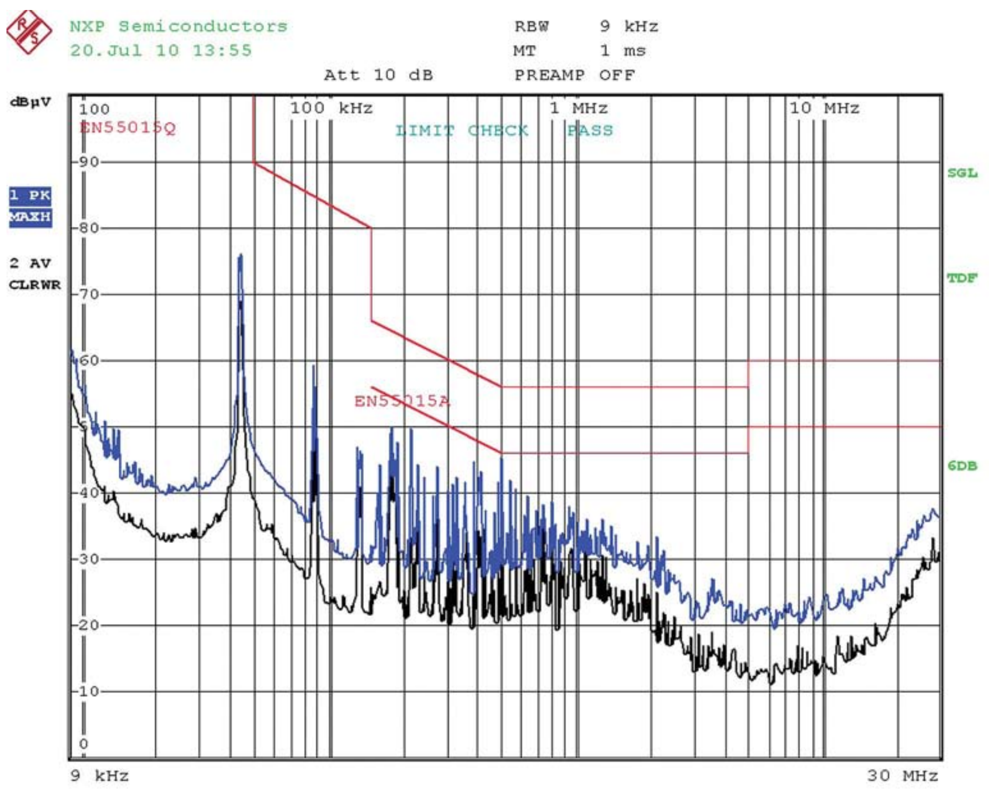


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Fig 26. Conduction EMI measurement (230 V)

6.2 Emission test 120 V setup

The results of emissions measured in the neutral and line wires using a pre-compliance test setup using a 120 V line voltage and taking into consideration the limits for the lighting applications. The FCC15 limits are shown in Figure 27.

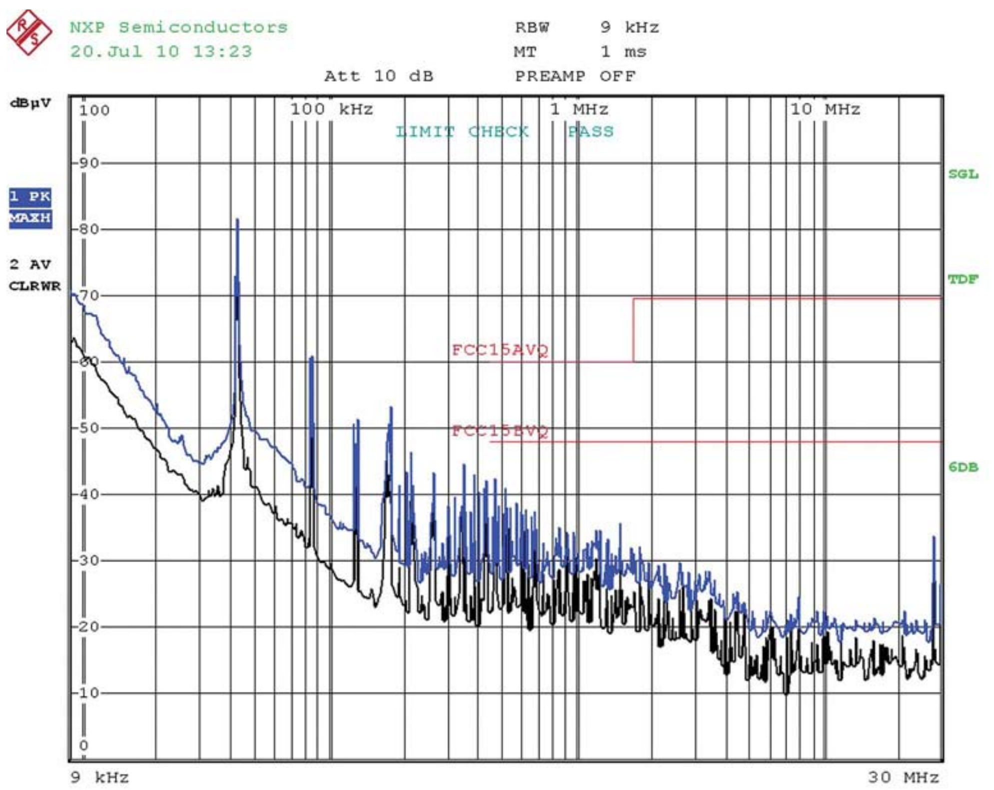

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Fig 27. Conduction EMI measurement (120 V)

7. Bill of Materials (BOM)

Table 1. BOM for the 230 V and 120 V demo board

Part number	Type	Value
Rf1	RFX	4.7 Ω, 0.5 W
R1	334/1206	0.25 W, ±5 %
R2	224/1206	0.25 W, ±5 %
R3	303/0805	0.125 W, ±5 %
R4	1R2/1206	0.25 W, ±5 %
R5	1R0/1206	0.25 W, ±5 %
R6	470/0805	0.125 W, ±5 %
R8	682/0805	0.125 W, ±5 %
R9	471/0805	0.125 W, ±5 %
R10	103/0805	0.125 W, ±5 %
R11	473/0805	0.125 W, ±5 %
R12	473/0805	0.125 W, ±5 %
C1	CL21/104J	400 V, P = 10 mm
C2, C3	CL21/473J	400 V
C5	CL11/332J	1200 V
C6, C9, C12, C13	104/0805	25 V, ±10 %
C7	104/0805	25 V, ±10 %
C8, C11	101/0805	25 V, ±1 %
C10	471	1 kV, P = 5 mm
C14	106/1206	25 V, ±10 %
C15	223/0805	25 V, ±10 %
C16	103/0805	10 V, ±10 %
D1, D2, D3, D4	IN4007	-
D6, D7, D8	4148	-
Z1	-	12 V, 0.5 W
Z2	-	8.2 V, 0.5 W
Q1	2SA1037/SOT-23	-
Q2	2SC2412/SOT-23	-
U1	UBA2025T (SO16)	-
L1	-	3.0 mH, ±10 %
L2	-	2.5 mH, ±5 %
UBA2025 (230 V)		
E1	HXA/6.8UF	400 V, 105 °C
UBA2025 (120 V)		
EC1, EC2	HXB/15UF	200 V, 105 °C

8. PCB layout

Figure 28 shows the top and bottom view of the demo board PCB.

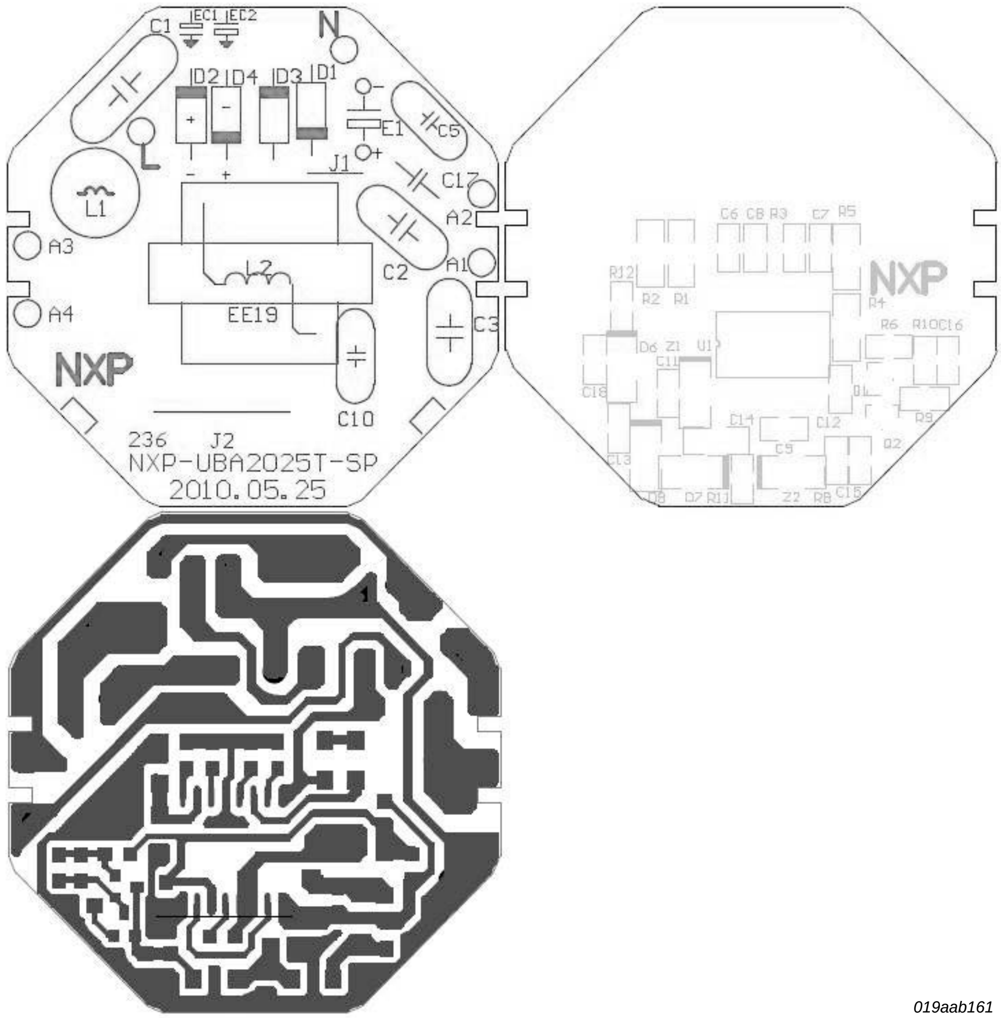

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Fig 28. PCB Top and bottom view

9. Abbreviations

Table 2. Abbreviations

Acronym	Description
CFL	Compact Fluorescent Lamps
EMI	ElectroMagnetic Interference
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
NMOS	Negative-channel Metal-Oxide Semiconductor
PCB	Print-Circuit Board
RMS	Root Mean Square

10. References

[1] **UBA2025 —** Data sheet: CFL power IC

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Notwithstanding any damages that customer might incur for any reason whatsoever (including without limitation, all damages referenced above and all direct or general damages), the entire liability of NXP Semiconductors, its affiliates and their suppliers and customer's exclusive remedy for all of the foregoing shall be limited to actual damages incurred by customer based on reasonable reliance up to the greater of the amount actually paid by customer for the product or five dollars (US$5.00). The foregoing limitations, exclusions and disclaimers shall apply to the maximum extent permitted by applicable law, even if any remedy fails of its essential purpose.

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The product does not comply with IEC 60950 based national or regional safety standards. NXP Semiconductors does not accept any liability for damages incurred due to inappropriate use of this product or related to non-insulated high voltages. Any use of this product is at customer's own risk and liability. The customer shall fully indemnify and hold harmless NXP Semiconductors from any liability, damages and claims resulting from the use of the product.

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In the event that customer uses the product for design-in and use in automotive applications to automotive specifications and standards, customer (a) shall use the product without NXP Semiconductors' warranty of the product for such automotive applications, use and specifications, and (b) whenever customer uses the product for automotive applications beyond NXP Semiconductors' specifications such use shall be solely at customer's own risk, and (c) customer fully indemnifies NXP Semiconductors for any liability, damages or failed product claims resulting from customer design and use of the product for automotive applications beyond NXP Semiconductors' standard warranty and NXP Semiconductors' product specifications.

11.3 Trademarks

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12. Tables

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13. Figures

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14. Contents

Please be aware that important notices concerning this document and the product(s) described herein, have been included in section ‘Legal information’.

For more information, please visit: http://www.nxp.com
For sales office addresses, please send an email to: salesaddresses@nxp.com

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