UM10389

36 W TLD application with UBA2014

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Document information

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Abstract	The UBA2014 integrated half bridge driver IC has been designed for driving electronically ballasted fluorescent lamps.The IC provides the drive function for two discrete power MOSFETs.

founded by Philips

Revision history

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01	20091002	First issue, replaces application note AN10181

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1. Introduction

The UBA2014 integrated half bridge driver IC has been designed for driving electronically ballasted fluorescent lamps. The IC provides the drive function for two discrete power MOSFETs. Besides the drive function the IC also includes a level-shift circuit, an oscillator, a lamp voltage monitor, a current control function a timer function, and protections.

This user manual gives a description of a typical integrated 36 W TLD application. The voltage fed half bridge is supplied by a constant 400 V (DC) supply (either an external or a PFC supply). According IEC61000-3-2 (limits for harmonic current emission), power factor correction for loads over 25 W is required, see Figure 1).

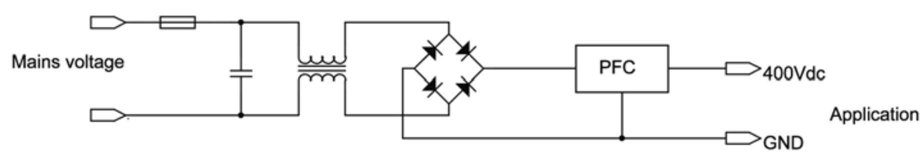


Fig 1. Input circuitry using a PFC

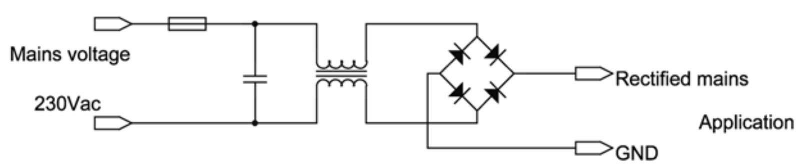


Fig 2. Normal input circuitry

If complying with the IEC61000-3-2 standard is not required, a normal input circuit like in Figure 2, can be used. Keep in mind that the lamp power is not constant over a big input voltage range (e.g. 190 V (AC) to 264 V (AC)). The voltage fed half bridge topology allows for operating easily in Zero Voltage Switching (ZVS) series resonant mode, thus reducing the transistor switching losses and the electromagnetic interference. During the preheat time the UBA2014 controls the current which flows in the filament of the lamp. The preheat timer and control system determine the optimal preheat time and preheat current to make sure the lamp has a long life and an efficient ignition. After the preheat time the lamp must be ignited by reducing the switching frequency, in this way increasing the voltage across it. The IC controls the maximum ignition voltage and the ignition timer determines the maximum ignition time. During this phase the capacitive mode protection ensures a safe operation of the power MOSFETs. In the burn phase the lamp current is controlled by the average current system. In this phase the lamp can be dimmed to a low level by frequency dimming.

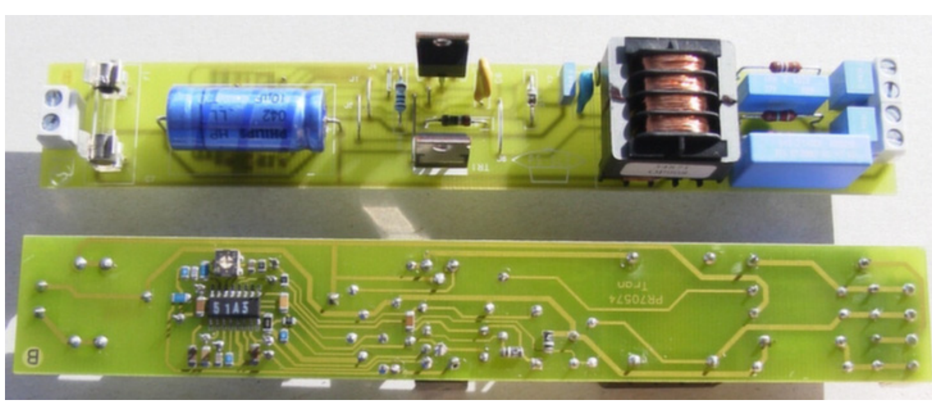
The UBA2014 has protections for lamp ageing, lamp failures, and lamp removal. The power-down function can safely switch off the power inverter.

2. Features

- Integrated half bridge power IC for fluorescent applications
  - Integrated high side/low side, including bootstrap circuitry
  - Based on the BCD 650 V power logic technology
  - Accurate oscillator and timer
  - Adjustable frequency range (with fixed f_{max}/f_{min} ratio)
  - Adaptive non-overlap time control
  - Capacitive mode protection
  - Adjustable preheat current and time control
  - Single ignition attempt
  - Power-down function
- Soft start by frequency sweep down from start frequency
- Adjustable ignition voltage control
- Lamp current control
- Down to 10 % dimming
- Protection against lamp failures or lamp removal
- SO16, DIP16 package

3. General description

3.1 Printed-circuit board



Remark: this controller had no official number.

Fig 3. The printed-circuit board of the UBA2014 application

3.2 Block diagram

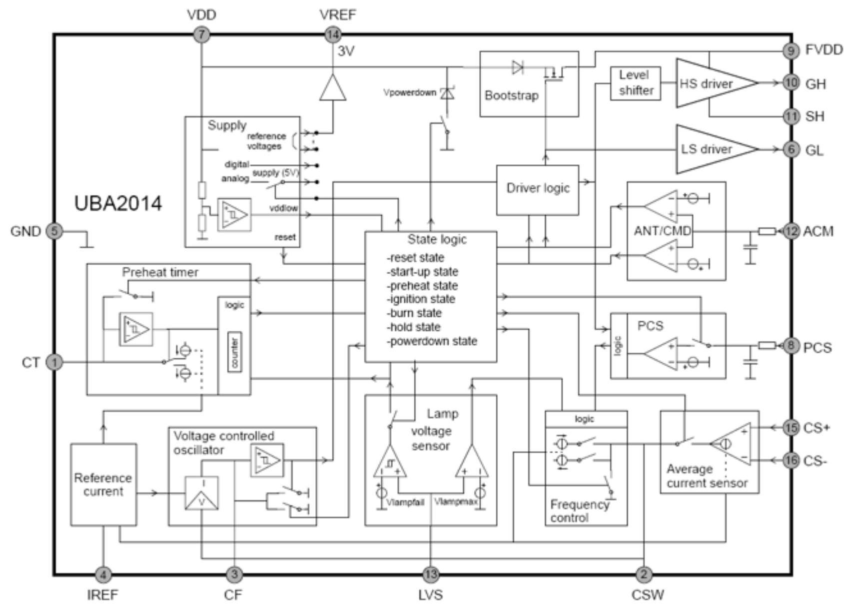


Fig 4. UBA2014 block diagram

Figure 4 shows the block schematic diagram of the UBA2014. The block state logic forms the heart of the controller and controls all other internal functions. Initial start-up is achieved by means of charging an external capacitor (C15 in Figure 5) connected to pin 7. The state logic will be reset and both outputs GL and GH are set to low (reset state). Reaching a voltage of 13.6 V, the controller enables the blocks voltage controlled oscillator (VCO), the Adaptive Non-overlap Time (ANT), the PReheat Timer (PRT), the Preheat current sensor (PCS), and the Lamp Voltage Sensor (LVS).

The VCO generates a sawtooth shaped voltage between 2.5 V and 0 V. The frequency is determined by the value of the capacitor connected to pin 3 (C14), the resistor connected to pin 4 (R12), and the voltage at pin 2. The minimum frequency is determined by R12 and C14, see also Section 4. The maximum frequency, at which the circuit starts oscillating, is 2.5 times the minimum frequency. The comparator in the VCO changes the sawtooth into a block voltage, which drives the driver logic. The driver logic drives the HS-driver and the LS-driver, but with a frequency which is half the VCO frequency. The first switching cycle the drive signal for the LS-driver is made extra long to enable the bootstrap to charge the externally connected bootstrap capacitor (between pins 9 and 11). The gates of the power MOSFETs are connected to GH and GL.

The ANT ensures that both power MOSFETs have the same on-time which is independent of the frequency. The voltage at pin 12 is measured across externally connected resistor R16 (see Figure 5).

The PRT is included to determine the preheat time and ignition time. The preheat time is defined by the capacitor connected to pin 1 (C12) and resistor R12 connected to pin 4. It consists of seven pulses at C12. The maximum ignition time is one pulse at C12. The circuit is operational during start-up and in case of a fault condition, for example when no lamps are connected.

The preheat time begins as soon as the circuit starts oscillating. Capacitor C13 (at pin 2) is connected to the input of the VCO and will be discharged, ensuring a defined a frequency sweep which starts at the maximum frequency. By charging the capacitor with a constant current controlled by the PCS, the frequency will decrease until the preheat voltage measured at pin 8 exceeds an internally fixed voltage of 0.6 V. This voltage is measured across externally connected resistor R14.

After the preheat time, the state logic disables the PCS and the frequency further sweeps down until the lamp circuit reaches the resonance frequency of the lamp capacitor and ballast coil. Two voltage levels have been defined to ensure that the lamp will ignite: $V_{lampfail}$ and $V_{lampmax}$, measured at pin 13 (LVS). The ignition level is between them. Passing the $V_{lampfail}$ enables the ignition timer. If the lamp ignites, the lamp voltage will and the voltage measured at pin 13 (LVS) will drop. The ignition stops and the increasing voltage at pin 2 will force the controller to the minimum frequency. At this point the controller enters the burn state and the Averaging Current Sensor (ACS) circuit is enabled.

The average current is measured across a resistor (R14) and fed to pin 16 (CS–). Pin 15 (CS+) is externally connected, via resistors, to the reference voltage of 2.95 V. If the CS voltage reaches the CS+ level, the ACS circuit will take over the control of the lamp current. The output voltage of the ACS circuit is fed to the VCO and regulates the frequency and, as a result, the lamp current.

If the lamp does not ignite, the LVS voltage reaches the $V_{lampmax}$ level. The frequency control will keep its frequency. In this way the lamp voltage cannot increase any further. After the adjusted ignition time the state logic will disable all internal circuits and the controller enters the power-down state. The circuit can be started up again by lowering the voltage at pin 7 to below the reset level of 5.5 V.

If one disconnects the lamp during normal operation, the lamp voltage will pass the $V_{lampfail}$ level and the ignition timer will start. After a short period, the $V_{lampmax}$ level is reached and after the ignition time the controller enters the power-down state.

3.3 Circuit diagram

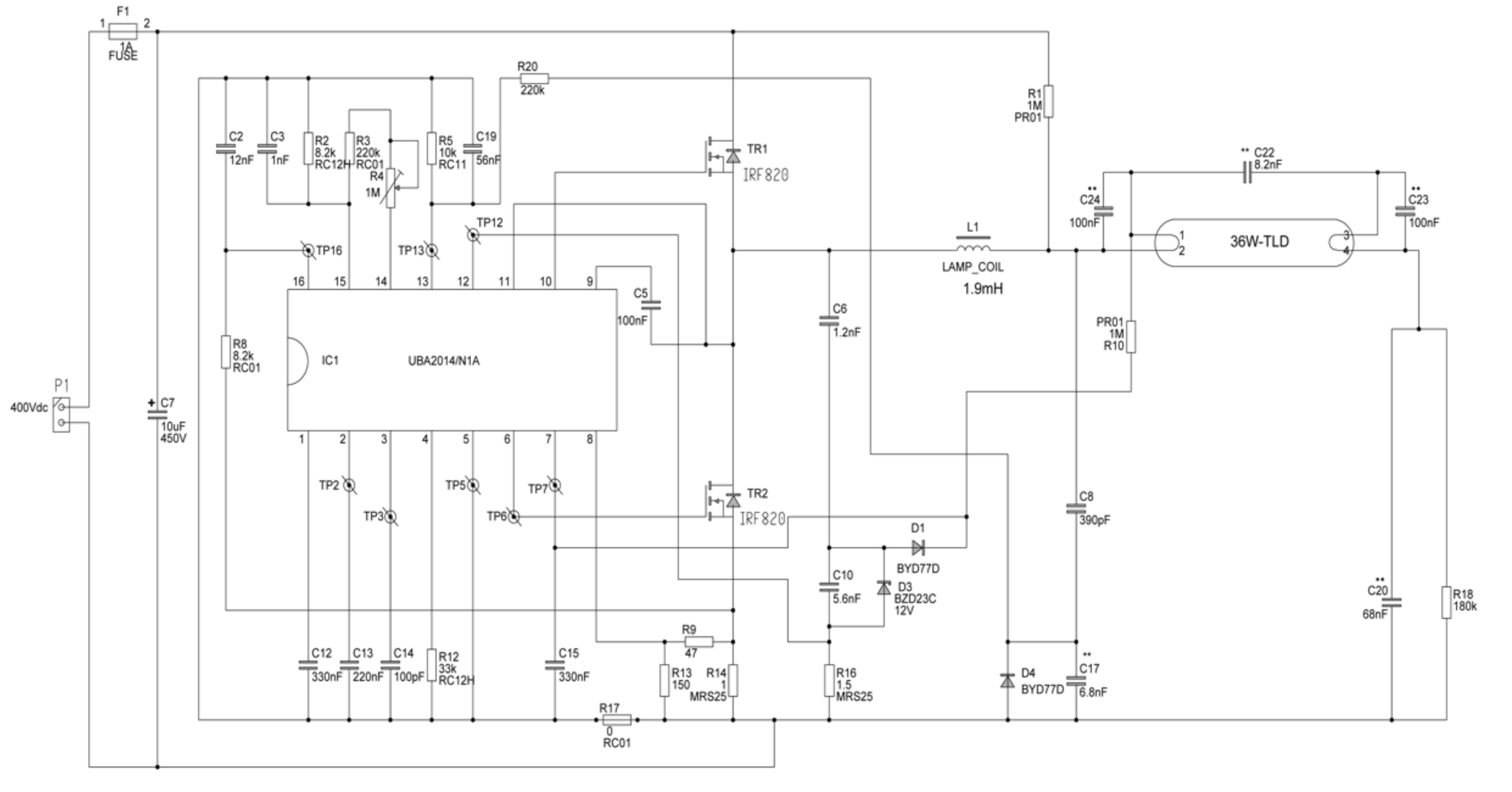


Fig 5. Circuit diagram

3.4 Bill of materials

Table 1. Bill of materials

Reference	Part no.	Component	Series	Rating	Tolerance	Vendor	Geometry
C2	2222-591-16628	12 nF	12NC_update	50 V	5 %	PHYCOMP	C1206
C3	2222-861-12102	1 nF	12NC_update	50 V	5 %	PHYCOMP	C0805
C5	2222-581-16641	100 nF	12NC_update	50 V	5 %	PHYCOMP	C1206
C6	ECKA3A122KBP	1.2 nF	Hi_voltage	1000 V	10 %	Panasonic	C_B3_L7_P5mm
C7	2222-043-17109	10 µF	ASH 043	450 V	−20 %	BC	CASE_A03
C8	DE0707391K	390 pF	Hi_voltage	2000 V	10 %	muRata	CER3_1
C10	2222-591-16624	5.6 nF	12NC_update	50 V	5 %	PHYCOMP	C1206
C12	2238-911-15656	330 nF	X7R	25 V	10 %	PHYCOMP	C1206
C13	2222-911-16654	220 nF	12NC_update	25 V	10 %	PHYCOMP	C1206
C14	2222-861-12101	100 pF	12NC_update	50 V	5 %	PHYCOMP	C0805
C15	2222-911-16656	330 nF	12NC_update	25 V	10 %	PHYCOMP	C1206
C17	2222-370-41682	6.8 nF	MKT 370	250 V	10 %	BC	C370_A
C19	2222-590-16637	56 nF	12NC_update	50 V	10 %	PHYCOMP	C0805
C20	2222-379-54683	68 nF	MKP 379	400 V	5 %	BC	C_B5_L17.5_P15mm
C22	2222-376-82822	8.2 nF	KP/MMKP 376	1600 V	5 %	BC	C_B7_L26_P22mm5
C23	2222-370-41104	100 nF	MKT 370	250 V	10 %	BC	C370_D
C24	2222-370-41104	100 nF	MKT 370	250 V	10 %	BC	C370_D
D1	9338-123-60115	BYD77D	Rectifier	-	-	NXP	SOD87
D3	9337-534-10153	Voltage regulator	BZD23C	12 V	-	NXP	SOD81
D4	9338-123-60115	BYD77D	Rectifier	-	-	NXP	SOD87
F1	2412-086-28238	1 A	SLOW	-	-		GLAS_HOLDER
IC1	PN-UBA2014/N1A	UBA2014/N1A	IC_Universal	-	-	NXP	SOT109
L1	3128-138-34871	LAMP_COIL	Coil	1.9 mH	-		LAMP_coil
P1	2422-015-19387	SCREW_CON_2P	SINGLE_ARRAY	-	-	MAG45	SCREW_CON_2P
P4	2422-015-19387	SCREW_CON_2P	SINGLE_ARRAY	-	-	MAG45	SCREW_CON_2P
P5	2422-015-19387	SCREW_CON_2P	SINGLE_ARRAY	-	-	MAG24	SCREW_CON_2P
R1	2322-193-13105	1 MΩ	PR01	-	5 %	BC	PR01
R2	2322-734-68202	8.2 kΩ	RC12H	-	1 %	PHYCOMP	R0805
R3	2322-711-61224	220 kΩ	RC01	-	5 %	PHYCOMP	R1206
R4	3314J-1M	1 MΩ	Typ3314	-	-0.2	BOURNS	3314J
R5	2322-730-61103	10 kΩ	RC11	-	5 %	PHYCOMP	R0805

Table 1. Bill of materials *…continued*

Reference	Part no.	Component	Series	Rating	Tolerance	Vendor	Geometry
R8	2322-711-61822	8.2 kΩ	RC01	-	5 %	PHYCOMP	R1206
R9	2322-730-61479	47 Ω	RC11	-	5 %	PHYCOMP	R0805
R10	2322-193-13105	1 MΩ	PR01	-	5 %	BC	PR01
R12	2322-734-63303	33 kΩ	RC12H	-	1 %	PHYCOMP	R0805
R13	2322-734-61501	150 Ω	RC12H	-	1 %	PHYCOMP	R0805
R14	2322-156-11008	1 Ω	MRS25	-	1 %	BC	MRS25
R16	2322-156-11508	1.5 Ω	MRS25	-	1 %	BC	MRS25
R17	2322-711-91032	0	RC01	-	5 %	PHYCOMP	R1206
R18	2322-193-13184	180 kΩ	PR01	-	5 %	BC	PR01
R20	2322-730-61224	220 kΩ	RC11	-	5 %	PHYCOMP	R0805
TP2	2422-034-15068	SOLDER-PIN_small	-	-	-		SOLDER_PIN_small
TP2	2422-034-15068	SOLDER-PIN_small	-	-	-		SOLDER_PIN_small
TP5	2422-034-15068	SOLDER-PIN_small	-	-	-		SOLDER_PIN_small
TP6	2422-034-15068	SOLDER-PIN_small	-	-	-		SOLDER_PIN_small
TP7	2422-034-15068	SOLDER-PIN_small	-	-	-		SOLDER_PIN_small
TP12	2422-034-15068	SOLDER-PIN_small	-	-	-		SOLDER_PIN_small
TP13	2422-034-15068	SOLDER-PIN_small	-	-	-		SOLDER_PIN_small
TP16	2422-034-15068	SOLDER-PIN_small	-	-	-		SOLDER_PIN_small
TR1		IRF820	fets	-	-	INT. RECT.	TO220
TR2		IRF820	fets	-	-	INT. RECT.	TO220

4. Lamp circuit operation and dimensioning

In this chapter a description will be given how the lamp circuit for a 36 W TLD lamp can be dimensioned. It is assumed that the supply of 400 V is constant and that typical working frequency f_{typ} is equal to 45 kHz. The RMS value of the half bridge voltage V_{hb} using the first harmonic approximation can be calculated with Equation 1:

$$V_{hb} = \frac{\sqrt{2}}{\pi} \cdot 400\ V = 180\ V \quad (1)$$

The minimum frequency is determined by R12 and C14 (see also the *UBA2014 data sheet*). Equation 2 shows the calculation of f_{max}:

$$f_{min} = 1.2 \cdot 10^{-2} \cdot R12 \cdot C14 = 40\ kHz \quad (2)$$

As a result the maximum frequency is equal to (Equation 3):

$$f_{max} = 2.5 \cdot f_{min} = 100\ kHz \quad (3)$$

During the start-up phase the working frequency starts at the maximum frequency. As the load on the half bridge circuit consists of the series connected LC circuit, this is a safe frequency at which currents and voltages are low. The electrodes must be preheated to secure a long lifetime and an efficient ignition of the lamp. During the preheating phase the preheat timer determines the preheating time (Equation 4):

$$t_{ph} = 1.7 \cdot 10^{-4} \cdot R12 \cdot C12 = 1.85\ s \quad (4)$$

The preheating current I_{ph}, which flows through the electrodes and the lamp capacitor, is controlled by the preheating current sensor circuit (PCS, pin 8 of the controller, see Figure 4) and is determined by R14, R13, and R9. If the voltage on pin 8 reaches 0.6 V, which means the current has a (peak) value of 0.788 A, the controller enters the preheat state. The RMS value of the preheat current I_{ph} is 0.56 A then. As the lamp voltage and lamp current of the 36 W TLD lamp are known (V_{lamp} = 102 V, I_{lamp} = 0.32 A, R_{lamp} = 319 Ω, and 0.52 A < I_{ph} < 0.96 A at T_{ph} = 1.85 s), one can define the transfer ration in burning condition with Equation 5:

$$|H| = \frac{V_{lamp}}{V_{hb}} = \frac{R_{lamp}}{\sqrt{(R_{lamp} - \omega^2 \cdot L1 \cdot C22 \cdot R_{lamp})^2 + (\omega \cdot L1)^2}} = 0.57 \quad (5)$$
$$\text{with } \omega = 2 \cdot \pi \cdot f_{typ}$$

L1 and C22 are the missing parameters. For the required transfer ratio many combinations for L1 and C22 will do. Choosing a (standard E12) value for C22, like 8.2 nF, L1 can be calculated with 1.9 mH as result. The next step is to define the preheat frequency with these components, which must be higher than the minimum frequency. The preheat voltage has to be calculated also to prevent the lamp from igniting too early.

During preheating, the transfer is only determined by L1 and C22, because the lamp has not ignited yet. Defining of some equations:

The resonance frequency of L1 and C22 (Equation 6):

$$\omega_0 = \frac{1}{\sqrt{L1 \cdot C22}} \quad \text{and} \quad f_0 = \frac{\omega_0}{2 \cdot \pi} \tag{6}$$

Characteristic impedance (Equation 7):

$$Z_0 = \sqrt{\frac{L1}{C22}} \tag{7}$$

Frequency deviation (Equation 8):

$$\Delta = \frac{\omega_{ph}}{\omega_0} \tag{8}$$

Transfer ratio during preheat (Equation 9):

$$|H_{ph}| = \frac{|V_{ph}|}{V_{hb}} = \frac{1}{1 - \omega_{ph}{}^2 \cdot L1 \cdot C22} = \frac{1}{1 - \Delta^2 \cdot \omega_0{}^2 \cdot L1 \cdot C22} \tag{9}$$

Then yields (Equation 10):

$$|V_{ph}| = \frac{1}{|1 - \Delta^2|} \cdot V_{hb} \tag{10}$$

For the preheat current yields (Equation 11):

$$I_{ph} = \frac{j \cdot \omega_{ph} \cdot C22}{1 - \omega_{ph}{}^2 \cdot L1 \cdot C22} \cdot V_{hb} = \frac{j \cdot \Delta}{1 - \Delta^2} \cdot \frac{V_{hb}}{Z_0} \tag{11}$$

Filling in the known values for I_{ph}, Z_0 and V_{hb} yields (Equation 12):

$$\left| I_{ph} \cdot \frac{Z_0}{V_{hb}} \right| = \frac{\Delta}{\Delta^2} = 1.5 \tag{12}$$

This equation has two solutions (Equation 13 and Equation 14):

$$\frac{\Delta}{1 - \Delta^2} = 1.5 \tag{13}$$

$$\frac{\Delta}{\Delta^2 - 1} = 1.5 \tag{14}$$

Solving this two equations give four results for Δ. Keeping in mind that Δ is the ratio between ω_{ph} and ω_0 and that ph > 0 (inductive mode), the result is a value of 1.39. So, $f_{ph} = 1.39 \cdot f_0 = 55.6\ kHz$.

The other solutions for are 0.72 (capacitive mode) and –0.72 and –1.39 (theoretically possible, but negative frequencies do not exist).

The preheat voltage then is (Equation 15):

$$|V_{ph}| = \frac{1}{|1 - 1.39^2|} \cdot V_{bh} = 193\ V \quad (15)$$

or a 273 V peak (see Figure 6) low enough to prevent early ignition (the minimum ignition voltage for a TLD36W is 290 V (RMS)).

During the ignition phase the working frequency is decreased because of the charging of C13 by an internally fixed current. During this continuously decrease in frequency, the circuit approaches the resonance frequency f_0 of the ballast coil and lamp capacitor (40 kHz). The ignition voltage of the lamp is designed above the $V_{lampfail}$ level. If the lamp voltage passes the $V_{lampfail}$ level the ignition timer is started. If the preheating of the electrodes was correct, the increasing voltage across the lamp will ignite it. Because of the ignited lamp, the voltage across the lamp will drop below the $V_{lampfail}$ level and the ignition timer will stop. The frequency will further decrease until the minimum frequency is reached. Then the lamp is ignited and the burn state begins. If, however, at the end of the ignition time the lamp voltage still exceeds the lamp fail level ($V_{lamp} > V_{lampfail}$), then the assumption is that the lamp has not ignited and the IC enters the power-down state.

During the ignition of the lamp and the burn phase the capacitive mode protection (ACM) ensures a safe operation of the power MOSFETs. However, the ignition voltage increases with the ageing of the lamp. To avoid overload of the key components, the maximum ignition voltage ($V_{lampmax}$) is limited and controlled by the LVS circuit (pin 13). The maximum ignition time, in which the lamp should ignite, is determined by (Equation 16):

$$t_{ign} = 3.1 \cdot 10^{-5} \cdot R12 \cdot C12 \quad (16)$$

In the burn state the ACS of the UBA2014 controls the lamp current. As the system efficiency is high, the lamp power (P_{lamp}) is almost equal to input power. As the 400 V supply voltage is constant, P_{lamp} can be kept constant by controlling the averaged voltage across resistor R14. In this way the lamp current is controlled.

Dimming is performed by changing the reference level at the CSP pin (pin 15) by turning potentiometer R4. In this way the input voltage of the voltage controlled oscillator regulates the frequency and so indirectly also the lamp current.

The start-up current for the UBA2014 is derived from the 400 V via R1, R10, and one of the lamp electrodes. If the lamp is not present, the IC will not start-up. As soon as VDD_{high} is exceeded the IC starts oscillating. The half bridge voltage V_{hb} (approximately 180 V) together with dv/dt capacitors behave like a current source, which supplies not only the IC and the gates of the MOSFETs but also generates a stable 12 V supply.

More information about the controller can be found in the *UBA2014 data sheet*. For more information about HF driving the 36 W T8 lamp see *IEC60081 sheet 7420*.

5. Quick measurements

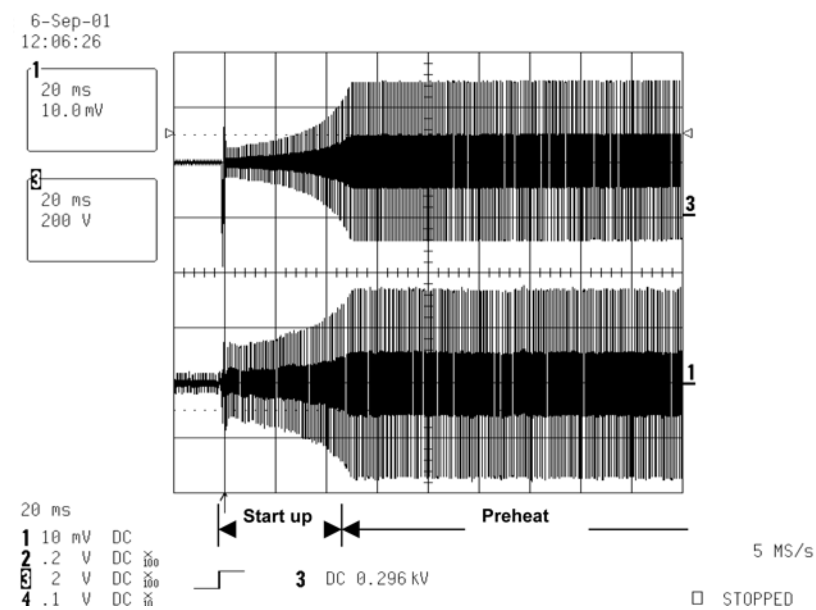


Fig 6. $I_{electrode}$ (1) and V_{lamp} (3) during start-up and preheat phase (273 V peak)

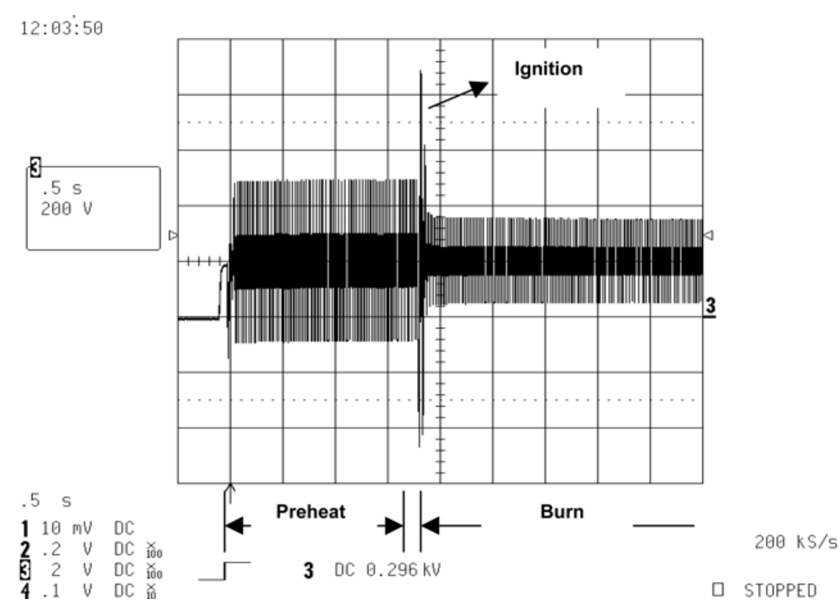
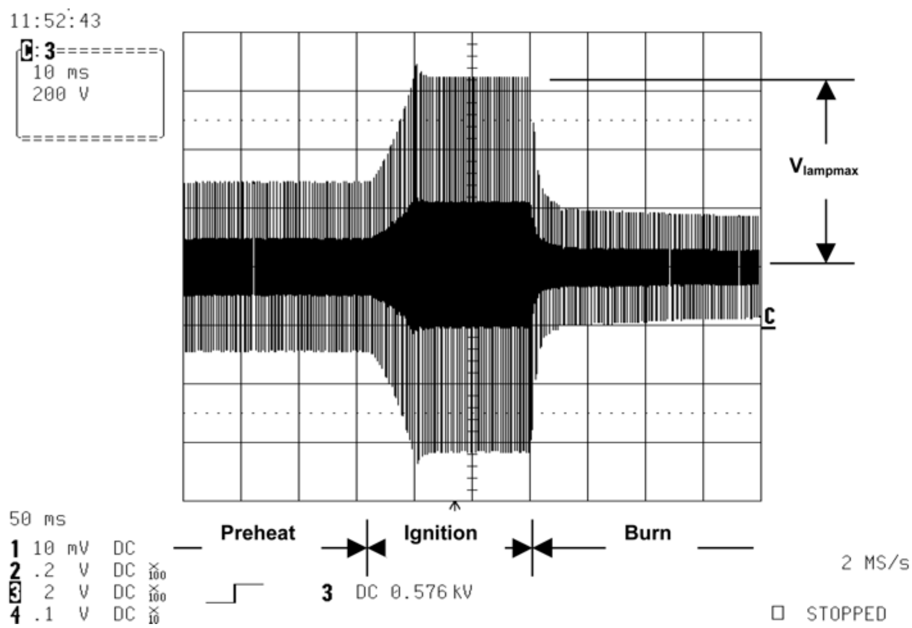


Fig 7. V_{lamp} during the preheat, ignition, and burn phase



The lamp voltage is controlled at the calculated $V_{lampmax}$ level. After 20 ms the lamp ignites and we see the transition to the burn phase. If the lamp does not ignite at the end of the ignition time, the IC enters power-down state.

Fig 8. V_{lamp} during the ignition phase

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7. Contents

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