36W TLD application with UBA2014

Application Note

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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 2 discrete power mosfets. Besides the drive function the IC also includes the level-shift circuit, the oscillator , a lamp voltage monitor, a current control function a timer function and protections.

This application note will give a description of a typical integrated 36W TLD application. The voltage fed half bridge is supplied by a constant 400Vdc supply (either an external or a PFC supply). According IEC61000-3-2 (Limits for harmonic current emission), power factor correction for loads over 25W is required, see figure 1.

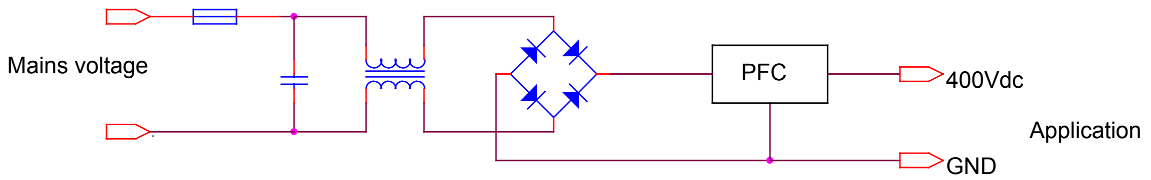

Figure 1. Input circuitry using a PFC.

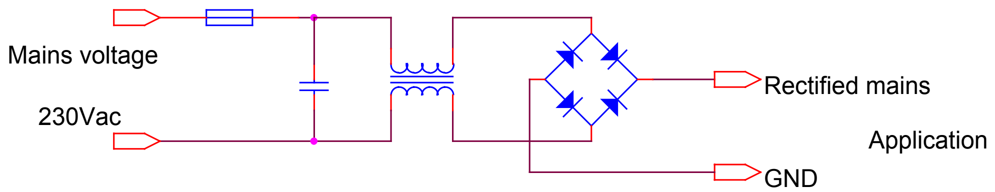

Figure 2. Normal input circuitry.

If one doesn't have to comply with IEC61000-3-2, just a normal input circuit like in figure 2, can be used, but keep in mind that the lamp power is not constant over a big input voltage range (like 190Vac..264Vac). The voltage fed half bridge topology allows to operate 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. To provide long life and insure an efficient ignition of the lamp the preheat timer and control system determine the optimal preheat time and preheat current. After the preheat time the lamp must be ignited by reducing the switching frequency and thus 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 upon BCD 650V power-logic technology
    - accurate oscillator and timer
    - adjustable frequency range (with fixed fmax/fmin ratio)
    - adaptive non-overlap time control
    - capacitive mode protection
    - adjustable preheat current and time control
    - single ignition attempt
    - powerdown 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. APPLICATION PHOTO

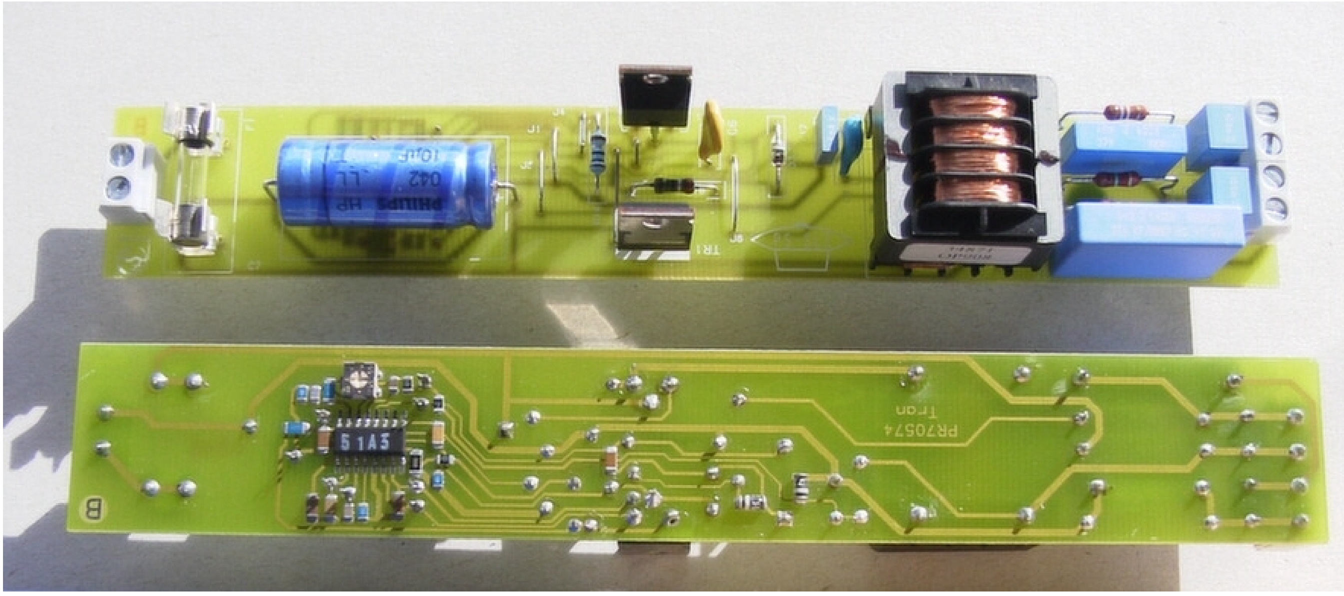

Figure 3. The Printed Circuit Board of the UBA2014 application. Remark: this controller had no official number.

4. BLOCK SCHEMATIC DIAGRAM

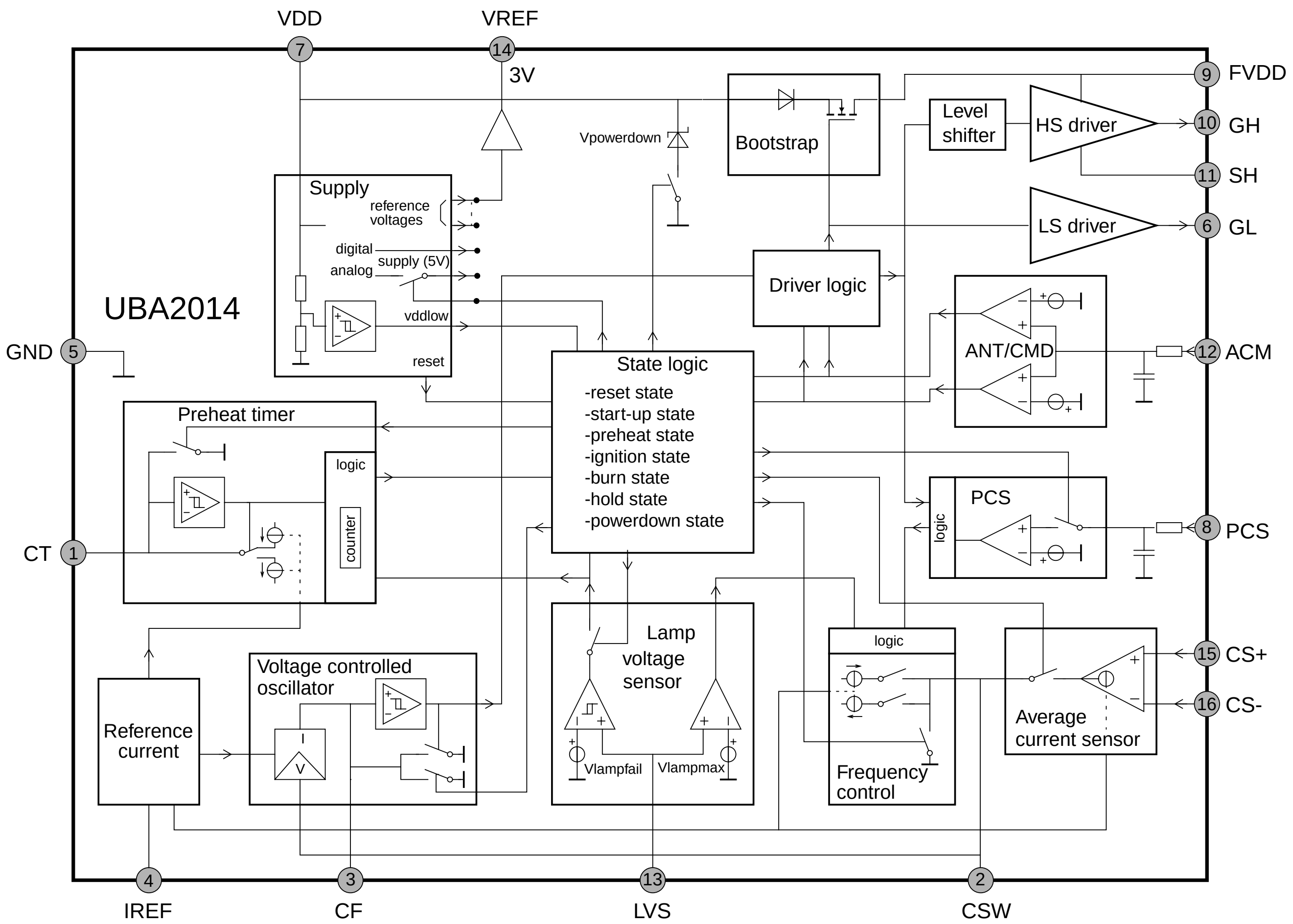

Figure 4. Block schematic diagram UBA2014.

In figure 4 the block schematic diagram of the UBA2014 is shown. 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 low (reset state). Reaching a voltage of 13.6V, the controller enables the blocks *Voltage controlled oscillator (VCS)*, *Adaptive non overlap (ANT)*, *Preheat timer (PRT)*, *Preheat current sensor (PCS)* and *Lamp voltage sensor (LVS)* .

The *VCO* generates a sawtooth shaped voltage between 2.5V and 0V. 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 chapter 7; 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*. On it's turn the *Driver logic* drives the *HS- and LS-driver*, but with a frequency 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 independent to 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, and consists of 7 pulses at C12. The maximum ignition time is 1 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 at the moment when 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 0.6V. 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. To ensure that the lamp will ignite, two voltage levels have been defined: $V_{lampfail}$ 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 drop and also the voltage measured at pin 13 (*LVS*) will drop as well. 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 will be 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 2.95V. If the *CS-* voltage reaches the *CS+* level, the *ACS* circuit will take over the control over 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 it's frequency. In this way the lamp voltage can not 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 start up again by lowering the voltage at pin 7 below the reset level of 5.5V.

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 will be reached and after the ignition time the controller enters the power down state.

5. CIRCUIT DIAGRAM

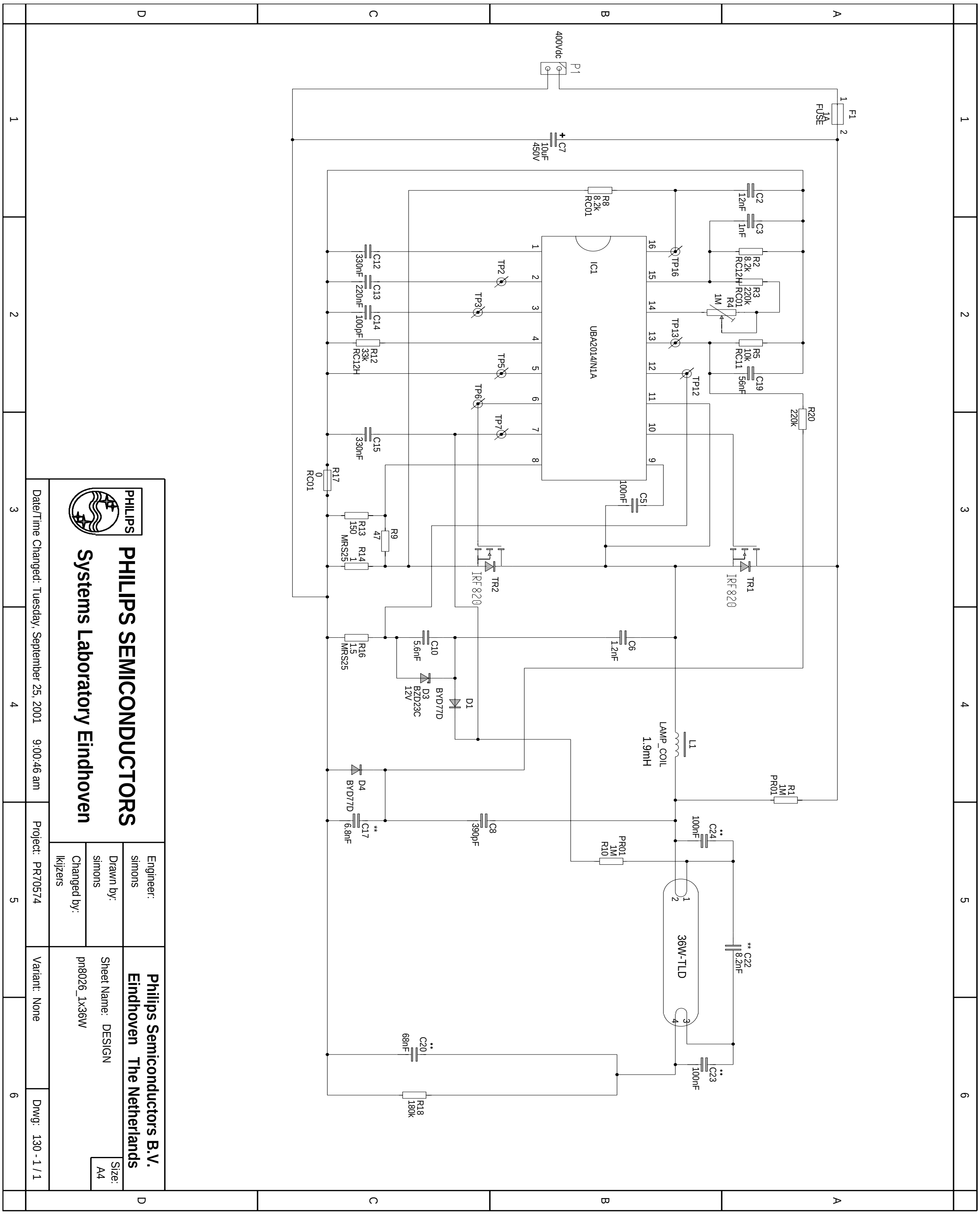

Figure 5. Circuit diagram.

6. PARTSLIST

REFERENCE	PART_NO	COMPONENT	SERIES	RATING	TOLERANCE	VENDOR	GEOMETRY
C2	2222-591-16628	12nF	12NC_update	50V	5%	PHYCOMP	C1206
C3	2222-861-12102	1nF	12NC_update	50V	5%	PHYCOMP	C0805
C5	2222-581-16641	100nF	12NC_update	50V	5%	PHYCOMP	C1206
C6	ECKA3A122KBP	1.2nF	Hi_voltage	1000V	10%	Panasonic	C_B3_L7_P5mm
C7	2222-043-17109	10uF	ASH 043	450V	-20%	BC	CASE_A03
C8	DE0707391K	390pF	Hi_voltage	2000V	10%	muRata	CER3_1
C10	2222-591-16624	5.6nF	12NC_update	50V	5%	PHYCOMP	C1206
C12	2238-911-15656	330nF	X7R	25V	10%	PHYCOMP	C1206
C13	2222-911-16654	220nF	12NC_update	25V	10%	PHYCOMP	C1206
C14	2222-861-12101	100pF	12NC_update	50V	5%	PHYCOMP	C0805
C15	2222-911-16656	330nF	12NC_update	25V	10%	PHYCOMP	C1206
C17	2222-370-41682	6.8nF	MKT 370	250V	10%	BC	C370_A
C19	2222-590-16637	56nF	12NC_update	50V	10%	PHYCOMP	C0805
C20	2222-379-54683	68nF	MKP 379	400V	5%	BC	C_B5_L17.5_P15mm
C22	2222-376-82822	8.2nF	KP/MMKP 376	1600V	5%	BC	C_B7_L26_P22mm5
C23	2222-370-41104	100nF	MKT 370	250V	10%	BC	C370_D
C24	2222-370-41104	100nF	MKT 370	250V	10%	BC	C370_D
D1	9338-123-60115	BYD77D	Rectifier			PHILIPS	SOD87
D3	9337-534-10153	Voltage Regulator	BZD23C	12V		PHILIPS	SOD81
D4	9338-123-60115	BYD77D	Rectifier			PHILIPS	SOD87
F1	2412-086-28238	1A	SLOW			PHILIPS	GLAS_HOLDER
IC1	PN-UBA2014/N1A	UBA2014/N1A	IC_Universal			PHILIPS	SOT109
L1	3128-138-34871	LAMP_COIL	Coil	1.9mH		PHILIPS	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			MAG45	SCREW_CON_2P
R1	2322-193-13105	1M	PR01		5%	BC	PR01
R2	2322-734-68202	8.2k	RC12H		1%	PHYCOMP	R0805
R3	2322-711-61224	220k	RC01		5%	PHYCOMP	R1206
R4	3314J-1M	1M	Typ3314		-0.2	BOURNS	3314J
R5	2322-730-61103	10k	RC11		5%	PHYCOMP	R0805
R8	2322-711-61822	8.2k	RC01		5%	PHYCOMP	R1206
R9	2322-730-61479	47	RC11		5%	PHYCOMP	R0805
R10	2322-193-13105	1M	PR01		5%	BC	PR01
R12	2322-734-63303	33k	RC12H		1%	PHYCOMP	R0805
R13	2322-734-61501	150	RC12H		1%	PHYCOMP	R0805
R14	2322-156-11008	1	MRS25		1%	BC	MRS25
R16	2322-156-11508	1.5	MRS25		1%	BC	MRS25
R17	2322-711-91032	0	RC01		5%	PHYCOMP	R1206
R18	2322-193-13184	180k	PR01		5%	BC	PR01
R20	2322-730-61224	220k	RC11		5%	PHYCOMP	R0805
TP2	2422-034-15068	SOLDER-PIN_small	-			PHILIPS	SOLDER_PIN_small
TP3	2422-034-15068	SOLDER-PIN_small	-			PHILIPS	SOLDER_PIN_small
TP5	2422-034-15068	SOLDER-PIN_small	-			PHILIPS	SOLDER_PIN_small
TP6	2422-034-15068	SOLDER-PIN_small	-			PHILIPS	SOLDER_PIN_small
TP7	2422-034-15068	SOLDER-PIN_small	-			PHILIPS	SOLDER_PIN_small
TP12	2422-034-15068	SOLDER-PIN_small	-			PHILIPS	SOLDER_PIN_small
TP13	2422-034-15068	SOLDER-PIN_small	-			PHILIPS	SOLDER_PIN_small
TP16	2422-034-15068	SOLDER-PIN_small	-			PHILIPS	SOLDER_PIN_small
TR1		IRF820	fets			INT. RECT.	TO220
TR2		IRF820	fets			INT. RECT.	TO220

7. LAMP CIRCUIT OPERATION AND DIMENSIONING

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

$$V_{HB} = \frac{\sqrt{2}}{\pi} \cdot 400V = 180V.$$

The minimum frequency is determined by R12 and C14 (see also the UBA2014 datasheet) which results in:

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

As a result the maximum frequency is equal to:

$$f_{\max} = 2.5 \cdot f_{\min} = 100kHz$$

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. To obtain a long lifetime and an efficient ignition of the lamp, the electrodes must be preheated. During the preheating phase the preheat timer determines the preheating time:

$$T_{pre} = 1.7 \cdot 10^{-4} \cdot R12 \cdot C12 = 1.85s.$$

The preheating current I_{pre}, which flows through the electrodes and the lamp capacitor, is controlled by the preheating current sensor circuit (PCS, pin 8 of the controller, see also figure 4.) and is determined by R14, R13 and R9. If the voltage at pin 8 reaches 0.6V, what means that the current has (peak) value has a value of 0.788A, the controller will enter the preheat state. The RMS value of the preheat current I_{pre} then is 0.56A. As the lamp voltage and lamp current of the 36W TLD lamp are known (V_{lamp}=102V, I_{lamp}=0.32A, R_{lamp}=319Ω and 0.52A<I_{pre}<0.96A at T_{pre} =1.85s), one can define some equations. The transfer ratio in burning condition is equal to:

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

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 8.2nF, L1 can be calculated and is 1.9mH. The next step is to define the preheat frequency with these components, which must be higher than the minimum frequency. Also the preheat voltage has to be calculated to prevent that the lamp ignites too early.

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

Resonance frequency of L1 and C22:

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

Characteristic impedance:

$$Z_0 = \sqrt{\frac{L1}{C22}}.$$

Frequency deviation:

$$\Delta = \frac{\omega_{pre}}{\omega_0}.$$

Transfer ratio during preheat:

$$|H_{pre}| = \frac{|V_{pre}|}{V_{HB}} = \frac{1}{1-\omega_{pre}{}^2 \cdot L1 \cdot C22} = \frac{1}{1-\Delta^2 \cdot \omega_0{}^2 \cdot L1 \cdot C22}$$

Then yields:

$$|V_{pre}| = \frac{1}{|1-\Delta^2|} \cdot V_{HB}.$$

For the preheat current yields:

$$I_{pre} = \frac{j \cdot \omega_{pre} \cdot C22}{1-\omega_{pre}{}^2 \cdot L1 \cdot C22} \cdot V_{HB} = \frac{j \cdot \Delta}{1-\Delta^2} \cdot \frac{V_{HB}}{Z_0}.$$

Filling in of the known values for I_{pre}, Z_0 and V_{HB}, then yields:

$$\left| I_{pre} \cdot \frac{Z_0}{V_{HB}} \right| = \frac{\Delta}{|1-\Delta^2|} = 1.5.$$

This equation has two solutions:

$$\frac{\Delta}{1-\Delta^2} = 1.5 \text{ and } \frac{\Delta}{\Delta^2 - 1} = 1.5.$$

Solving this two equations give four results for Δ. Keeping in mind that Δ is the ratio between ω_{pre} and ω_0, and that $\omega_{pre} > \omega_0$ (inductive mode), one obtains for Δ a value of 1.39, so:

$$f_{pre} = 1.39 \cdot f_0 = 55.6kHz$$

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

The preheat voltage then is:

$$|V_{pre}| = \frac{1}{|1-1.39^2|} \cdot V_{HB} = 193V,$$

or 273V peak, see also figure 6, low enough to prevent early ignition (the minimum ignition voltage for a TLD36W is $290V_{RMS}$).

During the ignition phase the working frequency is decreased due to 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 (40kHz). 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. Due to 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 it is assumed that 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 it is assumed that the lamp is not ignited and the IC will be switched in 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. The ignition voltage increases however 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 lamp voltage sensor (LVS) circuit (pin 13). The maximum ignition time, in which the lamp should ignite, is determined by:

$$T_{ign} = 3.1 \cdot 10^{-5} \cdot R12 \cdot C12 \,.$$

In the burn state the average current sensor circuit (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 400V-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 CS+ pin (pin 15) by turning potentiometer R4. In this way the input voltage of the voltage controlled oscillator regulates the frequency and herewith the lamp current.

The start-up current for the UBA2014 is derived from the 400V 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 HB voltage V_{HB} (approximately 180V) together with dv/dt capacitors behave like a current source, which supplies not only the IC and the gates of the MosFets but generates also a stable 12V supply

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

8. QUICK MEASUREMENTS

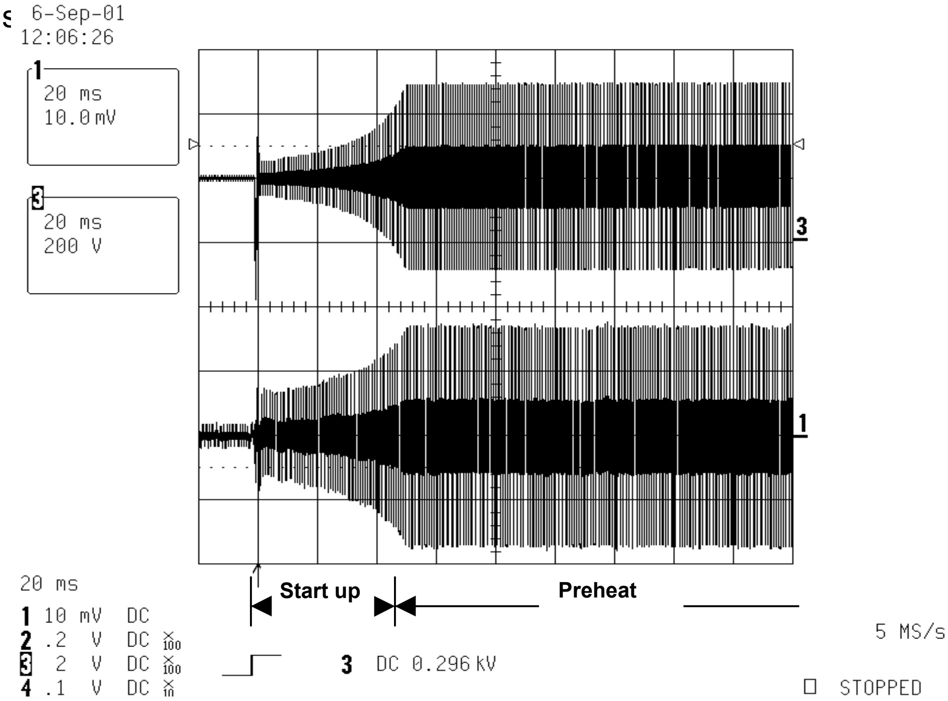

Figure 6. $I_{electrode}$ (1) and V_{lamp} (3) during start-up and preheat phase (273V peak).

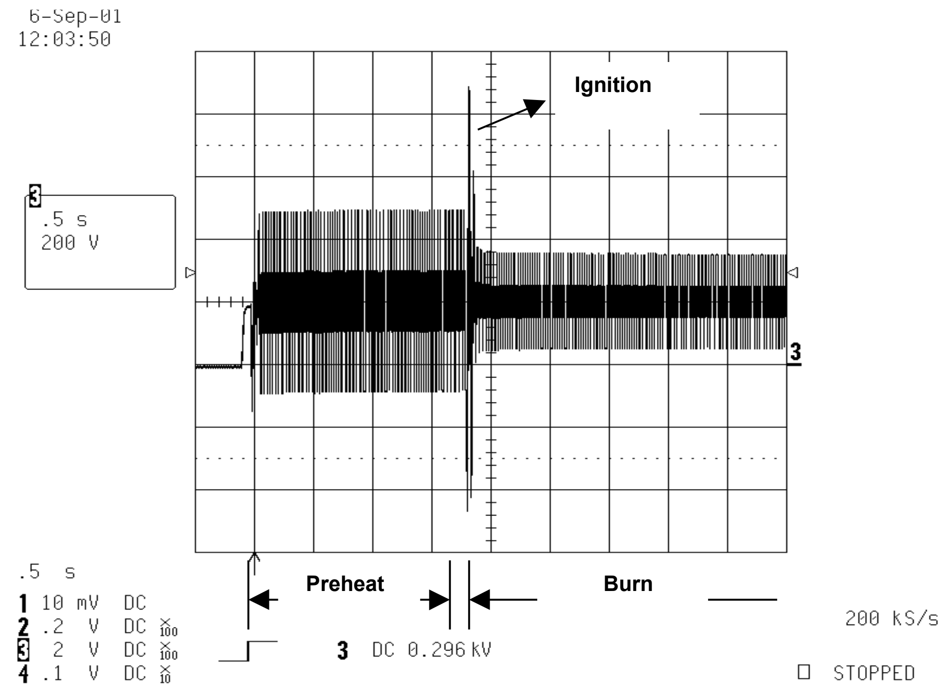

Figure 7. V_{lamp} during the preheat, ignition and burn phase.

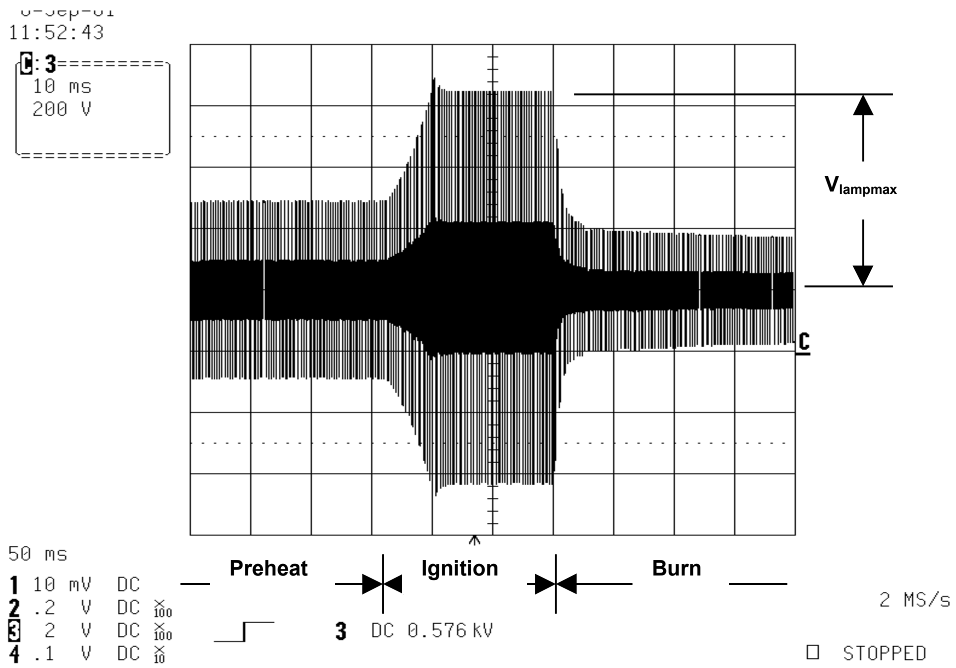

Figure 8. V_{lamp} during the ignition phase. The lamp voltage is controlled at the calculated $V_{lampmax}$ level. After 20ms the lamp ignites and we see the transition to the burn phase. If the lamp would be not ignited at the end of the ignition time, than the IC would be switched in the power down state.