APPLICATION NOTE

# CFL applications with the UBA2024T

Philips Semiconductors

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# CFL applications with the UBA2024T

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**UBA2024T**
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**S**ilicon **O**n **I**nsulator

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## 1 INTRODUCTION

The UBA2024T is an integrated half bridge power IC, designed for use in an integrated / sealed Compact Fluorescent Lamp (CFL) with a lamp current up to 150mA. Typical input voltages are 100-127Vac and 220-240Vac. Output power varies from 3 to 15W, depending on lamp and input voltage.

The UBA2024T is a high voltage (550V) monolithic integrated circuit made in the EZ-HV SOI process. It includes both half bridge power transistors with level-shifter and drivers, boots trap circuitry, an internal power supply, a precision oscillator and a start-up frequency sweep function for soft-start and/or pre-heating. It is mounted in a dedicated SO14 (Small Outline) package with optimised heat transfer.

Due to the high level of integration, only few external components are needed when building a lamp ballast with the UBA2024T. This application note will give descriptions of typical integrated CFL applications in the 3 to 15W range.

*(See datasheet for functional description of the UBA2024T)*

## 2 FEATURES

- based upon EZ-HV SOI (silicon on insulator) technology
- integrated half bridge power-IC for CFL applications (both powers and controller)
- accurate oscillator with adjustable frequency
- Soft start by frequency sweep down from start frequency
- Quasi preheat option (by use of larger sweep down timing)
- Allows for very compact integrated lamp ballast which fits a small shell
- Low cost Compact Fluorescent Lamp applications due to low component count
- Easy applicable
- Can withstand 550V maximum voltage surge

## 3 APPLICATION PHOTOS


*Figure 1: Photos of a 14W Compact Fluorescent Lamp with UBA2024T*

## 4 CIRCUIT DIAGRAM

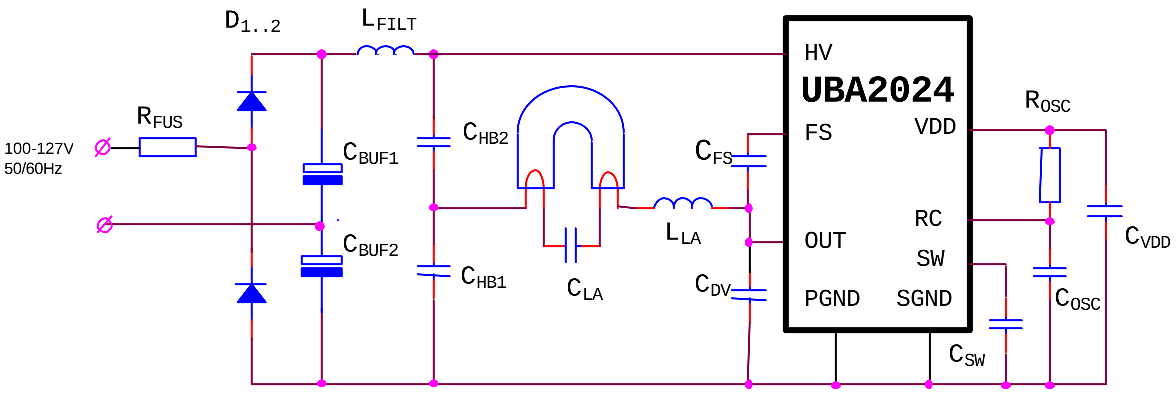



*Figure 2: Schematic of Compact Fluorescent Lamp application using the UBA2024T with voltage doubler input*

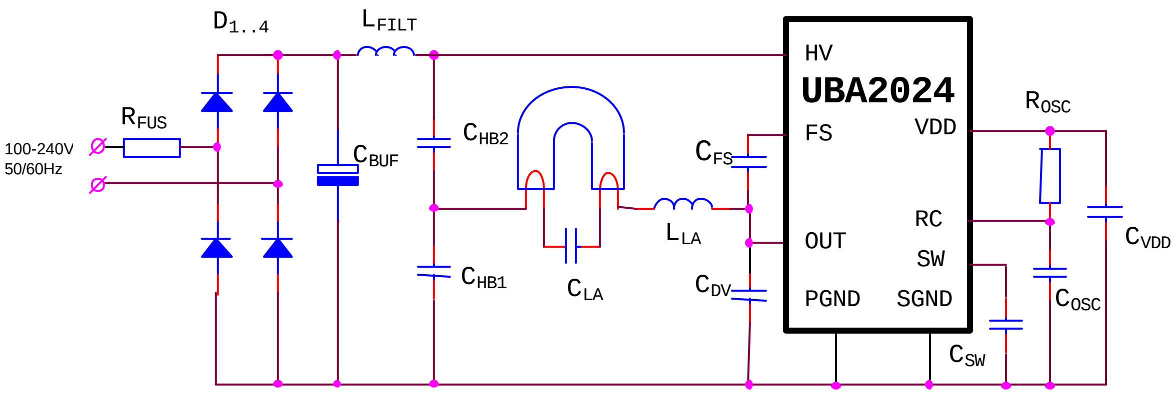



*Figure 3: Schematic of standard Compact Fluorescent Lamp application using UBA2024T*

**PINNING SO14**

| SYMBOL | PIN | DESCRIPTION | SYMBOL | PIN | DESCRIPTION |
|---|---|---|---|---|---|
| SGND | 1 | signal ground | SW | 8 | input for sweep timing |
| SGND | 2 | signal ground | SGND | 9 | signal ground |
| SGND | 3 | signal ground | SGND | 10 | signal ground |
| HV | 4 | high voltage supply | FS | 11 | floating supply high side |
| SGND | 5 | signal ground | PGND | 12 | power ground |
| VDD | 6 | internal low voltage supply | SGND | 13 | signal ground |
| RC | 7 | input for internal oscillator | OUT | 14 | half bridge output |

# 5 SELECTING COMPONENT VALUES

## 5.1 Selecting input configuration, buffer capacitor and fuse-resistor

Use of a voltage doubler (figure 2) or standard bridge rectifier (figure 3), values for the buffer capacitor ($C_{BUF}$) and the fusible inrush-current limiting resistor are given in table 2:

**Table 2: Adviced input configuration, buffer capacitor en fusible inrush-current limiting resistor**

| Input Voltage | Lamp Power# | Input configuration | $C_{BUF}$ | $C_{BUF1}$, $C_{BUF2}$ (each) | $R_{FUS}$ |
|---|---|---|---|---|---|
| 100-127Vac | ≤ 4 W | Standard (fig. 4) | 10µF/200V | (n.a.) | 18Ω (0.25W/23W)* |
| 100-127Vac | 5 – 6 W | | 15µF/200V | (n.a.) | 12Ω (0.5W/35W)* |
| 100-127Vac | 7 – 8 W | Voltage Doubler (fig.3) | (n.a.) | 10µF/200V | 10Ω (0.5W/47W)* |
| 100-127Vac | 9 –11 W | | (n.a.) | 15µF/200V | 8.2Ω (0.75W/70W)* |
| 100-127Vac | 12 – 14 W | | (n.a.) | 22µF/200V | 6.8Ω (1W/103W)* |
| 220-240Vac | ≤ 5 W | Standard (fig. 4) | 2.2µF/400V | (n.a.) | 47Ω (0.25W/23W)* |
| 220-240Vac | 6 – 8 W | | 3.3µF/400V | (n.a.) | 39Ω (0.25W/23W)* |
| 220-240Vac | 9 – 11 W | | 4.7µF/385V | (n.a.) | 33Ω (0.5W/32W)* |
| 220-240Vac | 12 – 15 W | | 6.8µF/385V | (n.a.) | 27Ω (0.5W/47W)* |

(# Overall lamp power including driver circuit)
(* Minimum continuous power rating / minimum peak power rating (≤20ms))

## 5.2 Choosing frequency, lamp inductor and lamp capacitor

Given a certain netto[1] lamp power $P_{lamp}$ and lamp current $I_{lamp}$, then $V_{lamp}=P_{lamp}/I_{lamp}$. If buffer capacitors are according to table 2, an approximation of the effective lamp inductor voltage $V_{Lla\_eff}$ is given[2] in table 3:

**Table 3: Approximated effective lamp inductor voltage**

| Input Voltage | frequency | Input configuration | V_lamp ≤20V | ≈30V | ≈40V | ≈50V | ≈60V | ≈80V | ≈100V |
|---|---|---|---|---|---|---|---|---|---|
| | | | $V_{Lla\_eff}$ [V] | | | | | | |
| 100 Vac | 60 Hz | Standard (fig. 4) | 58 | 53 | 46 | n.a. | n.a. | n.a. | n.a. |
| 115 Vac | | | 71 | 66 | 62 | 53 | n.a. | n.a. | n.a. |
| 127 Vac | | | 80 | 76 | 70 | 65 | n.a. | n.a. | n.a. |
| 100 Vac | 60 Hz | Voltage Doubler (fig.3) | 123 | 120 | 117 | 113 | 108 | 94 | n.a. |
| 115 Vac | | | 145 | 143 | 140 | 137 | 133 | 122 | 107 |
| 127 Vac | | | 164 | 162 | 160 | 157 | 154 | 144 | 131 |
| 220 Vac | 50 Hz | Standard (fig. 4) | 138 | 136 | 133 | 130 | 125 | 112 | 95 |
| 230 Vac | | | 145 | 143 | 140 | 138 | 134 | 122 | 106 |
| 240 Vac | | | 153 | 151 | 148 | 146 | 143 | 131 | 116 |

n.a.= not applicable (these combinations of lamp voltage and input voltage/configuration are not allowed)

The lamp inductor $L_{LA}$ and the lamp frequency $f_{out}$ have to comply to:

$$2\pi f_{out} L_{LA} = \frac{V_{Lla\_eff}}{I_{lamp}}$$

[1] of burner only, usually about 85% of overall lamp power.
[2] use linear interpolation to find values inbetween.

$f_{out}$ can be chosen freely up to 60kHz (the maximum nominal output frequency for the UBA2024, corresponding with a start-up frequency of 150kHz, see datasheet for start-up sequence description). However, usually $f_{out}$ is chosen between 25kHz and 30kHz or between 40kHz and 50kHz. This is because below 25kHz there may be audible noise, operation in the 30kHz to 40kHz band may result in interference with infra-red remote control and above 50kHz the third harmonic is in the range where conducted noise requirements for most countries have to be met. Since inductors and capacitors decrease in size and cost with increase in frequency, the 40 to 50kHz range is preferred. Throughout this application note we will presume the lamp frequency will be in this range.

$f_{out}$ is set by $R_{OSC}$ and $C_{OSC}$ according to the following formula:

$$f_{out} = \frac{1}{k_{OSC}\, R_{OSC}\, C_{OSC}}$$

Practical values for $R_{OSC}$ range from 50kΩ to 400kΩ. Note that the low values of $R_{OSC}$ will cause a larger VDD output current, thus increasing the total package dissipation. Practical values for $C_{OSC}$ range from 100pF to 1nF. Advised value for $C_{OSC}$ is 180pF for 40..50kHz and 270pF for 25..30kHz. The oscillator constant $k_{OSC}$ is shown in figure 4.

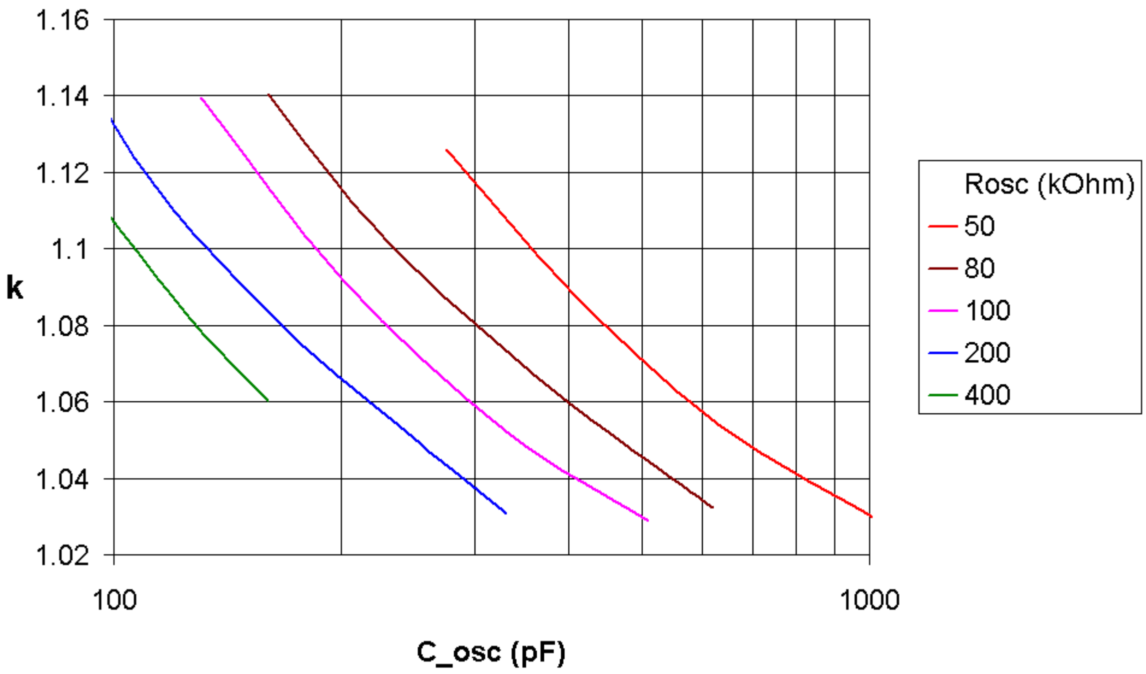



*Figure 4: Typical $k_{osc}$ dependency of $R_{osc}$ and $C_{osc}$ for UBA2024T.*

### 5.3 Ignition frequency and preheating

The IC starts at an output frequency of about $2^1/_2$ times the nominal output frequency, and gradually decreases this until the nominal output frequency is reached. The lamp inductor $L_{LA}$ and the lamp capacitor $C_{LA}$ will boost the lamp voltage gradually higher as the output frequency gets closer to their resonance frequency, until it is sufficient to ignite the lamp. In the mean time the current in the resonance circuit flows through the filaments thereby providing some preheating. The UBA2024 has a circuit that stops the frequency sweep at the resonance frequency if the lamp has not ignited yet (see UBA2024 specifications for details). This ensures maximum effort to ignite the lamp.

The ignition frequency $f_{ign}$ is higher than or equal to the resonance frequency of $L_{LA}$ and $C_{LA}$ ($f_{res}=1/(2\pi\sqrt{(L_{LA}C_{LA})})$ ). The resonance frequency should be choosen so that $1.6 \cdot f_{out} \leq f_{res} \leq 1.8 \cdot f_{out}$. The time needed to sweep down (set by $C_{SW}$) from the start frequency to $f_{res}$ can be used as an approximation for the ignition time. It's about 0.5s/100nF. For large values the ignition time is shorter, because the lamp ignites before the resonance frequency is reached. Typical ignition time is 1 s when $C_{SW}$=330nF.

$C_{SW}$ determines the sweep time. The larger $C_{SW}$, the longer the sweep time and better the preheating of the electrodes. However, the rise of the pre-ignition lamp voltage is also slower. Both a too short preheat as well as a too slow voltage rise increase the glow time of the lamp (that's when the lamp is not yet fully ignited, but it's not off anymore either), which decreases lamp life time. The best preheat time strongly depends on the lamp. Typical values for $C_{SW}$ are 33nF to 330nF.

### 5.4 Choosing the other components

- For D1..D4 plain low cost 1N4007 diodes can be used.
- For lamp current ≥150mA $C_{DV}$=220pF, for lower currents $C_{DV}$=100pF.
- The values for $C_{VDD}$ and $C_{FS}$ are $C_{FS}=C_{VDD}$=10nF.
- Advised half bridge capacitors ($C_{HB1}$ and $C_{HB2}$) are >47nF when $f_{out}$= 40–50kHz and >68nF when $f_{out}$= 25–30 kHz.
- The resonance frequency of the input filter, consisting of $L_{FILT}$ and $C_{HB}$ ($C_{HB}$ being de effective capacitor as seen on the HV pin of the IC, i.e. the series capacitance of $C_{HB1}$ and $C_{HB2}$), has to be at least two times lower than the nominal output frequency.

***Note:*** *Performance and lifetime can not be guaranteed by using the values given in this chapter only. Lamp and UBA2024 performance strongly interact with each other and need to be qualified together as a combination.*

### 5.5 About component tolerances

For all components, generally used tolerances can be used (20% for electrolytic capacitors, 10% for other capacitors (foil or ceramic) and 5% for resistors and inductors). Since $R_{OSC}$, $C_{OSC}$ and $L_{LA}$ determine the lamp current, their tolerance also determines the spread in the lamp current. Therefore, the required lamp current accuracy may require closer tolerance $R_{OSC}$, $C_{OSC}$ and $L_{LA}$.

Example 1: $R_{OSC}$ ±5%, $C_{OSC}$ ±10%, $L_{LA}$ ±5%, $C_{LA}$ ±10% and the IC's internal frequency ±3% then lamp current tolerance is 12.6% effective[3].

[3] Valid for component values with normal distribution.

Example 2: $R_{OSC}$ ±1%, $C_{OSC}$ ±5%, $L_{LA}$ ±5%, $C_{LA}$ ±5% and the IC's internal frequency ±3% then lamp current tolerance is 7.1% effective.

# 6 EXAMPLES OF CALCULATING COMPONENT VALUES

## 6.1 EXAMPLE 1: a 3W lamp (2.5W/90mA burner)

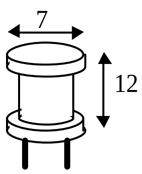
### Determining component values for 115V/60Hz mains

1) From table 2: Standard configuration, $C_{BUF}$=10µF, $R_{FUS}$=18Ω.
2) $V_{lamp}$≈2.5/0.090≈28V. From table 3: Effective lamp coil voltage $V_{Lla\_eff}$ ≈ 68V. For $L_{LA}$=3.9mH the output frequency must be $f_{out}=68/(0.090 \cdot 3.9 \cdot 10^{-3} \cdot 2 \cdot \pi)=30.8$kHz
3) We choose $C_{OSC}$=270pF, then $R_{OSC}=1/(1.07 \cdot 30.8 \cdot 10^{3} \cdot 270 \cdot 10^{-12})=112$kΩ. To stay below 30kHz and within E24-range we choose 120kΩ, so $f_{out}=1/(1.07 \cdot 120 \cdot 10^{3} \cdot 270 \cdot 10^{-12})=28.8$kHz.
4) The only E12-range value of $C_{LA}$ resulting in $f_{ign}/f_{out}$ between 1.6 and 1.8 is: 2.7nF ($f_{ign}/f_{out}$ ≈1.70).
5) Warm ignition. $C_{SW}$=220nF.
6) $D_1$..$D_4$=BYD13M (=1N4007 equivalent, but smaller), $C_{FS}$=10nF, $C_{VDD}$=10nF and $C_{DV}$=100pF (see section 6.4).
7) $C_{HB1}$=$C_{HB2}$=33nF (see section 6.4). $L_{FILT}$ is choosen 4.7mH.

### Determining component values for 230V/50Hz mains

1) From table 2: Standard configuration, $C_{BUF}$=2.2µF, $R_{FUS}$=47Ω.
2) $V_{lamp}$≈2.5/0.090≈28V. From table 3: Effective lamp coil voltage $V_{Lla\_eff}$ ≈ 143V. For $L_{LA}$=8.2 mH the output frequency must be $f_{out}=143/(0.090 \cdot 8.2 \cdot 10^{-3} \cdot 2 \cdot \pi)=30.8$kHz
3) We choose $C_{OSC}$=270pF, then $R_{OSC}=1/(1.07 \cdot 30.8 \cdot 10^{3} \cdot 270 \cdot 10^{-12})=112$kΩ. To stay below 30kHz and within E24-range we choose 120kΩ, so $f_{out}=1/(1.07 \cdot 120 \cdot 10^{3} \cdot 270 \cdot 10^{-12})=28.8$kHz.
4) The only E6-range value of $C_{LA}$ resulting in $f_{ign}/f_{out}$ between 1.6 and 1.8 is 1.0nF ($f_{ign}/f_{out}$ ≈1.76).
5) Warm ignition: $C_{SW}$=220nF.
6) $D_1$..$D_4$=BYD13M (=1N4007 equivalent, but smaller), $C_{FS}$=10nF, $C_{VDD}$=10nF and $C_{DV}$=100pF (see section 6.4).
7) $C_{HB1}$=$C_{HB2}$=47nF (see section 6.4). $L_{FILT}$ is choosen 4.7mH.

| REF | DESCRIPTION | REMARKS | 115V/60HZ | 230V/50Hz |
|---|---|---|---|---|
| $R_{FUS}$ | Fusible inrush current limiter resistor | *Special type, fusible, high peak power* | 18Ω | 47Ω |
| $D_1$..$D_4$ | Bridge rectifier diodes | | BYD13M | BYD13M |
| $C_{BUF}$ | Buffer capacitor | *High temperature electrolytic type* | 10µF/200V | 2.2µF/400V |
| $L_{FILT}$ | Filter inductor | *Axial type* | 4.7mH | 4.7mH |
| $C_{HB1}$, $C_{HB2}$ | Half bridge capacitors | | 47nF/200$V_{dc}$ | 47nF/200$V_{dc}$ |
| $C_{LA}$ | Lamp capacitor | *Foil type* | 2.7nF/1k$V_{dc}$ | 1.0nF/1k$V_{dc}$ |
| $L_{LA}$ | Lamp inductor | *BC7/12-Core (illustration at the side)* | 3.9mH. | 8.2mH |
| $C_{DV}$ | dV/dt limiting capacitor | | 100pF/500$V_{dc}$ | 100pF/500$V_{dc}$ |
| $C_{FS}$ | Floating Supply buffer capacitor | | 10nF/50V | 10nF/50V |
| $C_{VDD}$ | low voltage supply buffer capacitor | | 10nF/50V | 10nF/50V |
| $C_{OSC}$ | Oscillator capacitor | | 270pF/50V | 270pF/50V |
| $R_{OSC}$ | Oscillator resistor | | 120kΩ/1/8W | 120kΩ/1/8W |
| $C_{SW}$ | Sweep time capacitor | | 220nF/16V | 220nF/16V |



## 6.2 EXAMPLE 2: a 14W lamp (12W/150mA burner, suited for cold ignition)

### Determining component values for 115V/60Hz mains

1) From table 2: Voltage doubler configuration, $C_{BUF1}=C_{BUF2}=22\mu F$, $R_{FUS}=6.8\Omega$
2) $V_{lamp}\approx 12/0.150=80V$. From table 3: Effective lamp coil voltage $V_{Lla\_eff}\approx 122V$. For $L_{LA}=3.1mH$ the output frequency must be $f_{out}=122/(0.150\cdot 3.1\cdot 10^{-3}\cdot 2\cdot\pi)=41.8kHz$.
3) We choose $C_{OSC}=180pF$, then $R_{OSC}=1/(1.09\cdot 41.8\cdot 10^{3}\cdot 180\cdot 10^{-12})=122k\Omega$. To stay within E24-range we choose $120k\Omega$, so $f_{out}=1/(1.09\cdot 120\cdot 10^{3}\cdot 180\cdot 10^{-12})=42.5kHz$.
4) The only E6-range value of $C_{LA}$ resulting in $f_{ign}/f_{out}$ between 1.6 and 1.8 is 1.5nF ($f_{ign}/f_{out}\approx 1.74$).
5) This burner is suited for cold ignition: $C_{SW}=100nF$ (see paragraph 5.3)
6) $D_1=D_2=$1N4007, $C_{FS}=10nF$, $C_{VDD}=10nF$ and $C_{DV}=220pF$ (see section 6.4).
7) $C_{HB1}=C_{HB2}=47nF$ (see section 6.4). $L_{FILT}$ is choosen 2.7mH.

### Determining component values for 230V/50Hz mains

1) From table 2: Standard configuration, $C_{BUF}=6.8\mu F$, $R_{FUS}=27\Omega$
2) $V_{lamp}\approx 12/0.150=80V$. From table 3: Effective lamp coil voltage $V_{Lla\_eff}\approx 122V$. For $L_{LA}=3.1mH$ the output frequency must be $f_{out}=122/(0.150\cdot 3.1\cdot 10^{-3}\cdot 2\cdot\pi)=41.8kHz$.
3) We choose $C_{OSC}=180pF$, then $R_{OSC}=1/(1.09\cdot 41.8\cdot 10^{3}\cdot 180\cdot 10^{-12})=122k\Omega$. To stay within E24-range we choose $120k\Omega$, so $f_{out}=1/(1.09\cdot 120\cdot 10^{3}\cdot 180\cdot 10^{-12})=42.5kHz$.
4) The only E6-range value of $C_{LA}$ resulting in $f_{ign}/f_{out}$ between 1.6 and 1.8 is 1.5nF ($f_{ign}/f_{out}\approx 1.74$).
5) For cold ignition $C_{SW}=33nF$ (see paragraph 5.3)
6) $D_1..D_4=$1N4007, $C_{FS}=10nF$, $C_{VDD}=10nF$ and $C_{DV}=220pF$ (see section 6.4).
7) $C_{HB1}=C_{HB2}=47nF$ (see section 6.4). $L_{FILT}$ is choosen 2.7mH.

| REF | DESCRIPTION | REMARKS | 115V/60HZ | 230V/50Hz |
|---|---|---|---|---|
| $R_{FUS}$ | Fusible inrush current limiter resistor | *Special type, fusible, high peak power* | 6.8Ω | 27Ω |
| $D_1, D_2$ | Voltage doubler diodes | | 1N4007 | |
| $D_1..D_4$ | Bridge rectifier diodes | | | 1N4007 |
| $C_{BUF1}, C_{BUF2}$ | Buffer capacitors | *High temperature electrolytic type* | 22µF/200V | |
| $C_{BUF}$ | Buffer capacitor | *High temperature electrolytic type* | | 6.8µF/400V |
| $L_{FILT}$ | Filter inductor | *Axial type* | 2.7mH | 2.7mH |
| $C_{HB1}, C_{HB2}$ | Half bridge capacitors | | $47nF/200V_{dc}$ | $47nF/200V_{dc}$ |
| $C_{LA}$ | Lamp capacitor | *Foil type, capable of withstanding peak voltages of twice it's dc rating* | $1.5nF/400V_{dc}$ | $1.5nF/400V_{dc}$ |
| $L_{LA}$ | Lamp inductor | *E-16-Core* | 3.1mH | 3.1mH |
| $C_{DV}$ | dV/dt limiting capacitor | | $220pF/500V_{dc}$ | $220pF/500V_{dc}$ |
| $C_{FS}$ | Floating Supply buffer capacitor | | 10nF/50V | 10nF/50V |
| $C_{VDD}$ | low voltage supply buffer capacitor | | 10nF/50V | 10nF/50V |
| $C_{OSC}$ | Oscillator capacitor | | 180pF/50V | 180pF/50V |
| $R_{OSC}$ | Oscillator resistor | | 120kΩ/1/8W | 120kΩ/1/8W |
| $C_{SW}$ | Sweep time capacitor | | 100nF/25V | 33nF/50V |

### 6.3 Some other examples

8W lamp (7W/150mA burner, suited for cold ignition) ($f_{out}$=46kHz)

| REF | DESCRIPTION | REMARKS | 115V/60HZ | 230V/50Hz |
|---|---|---|---|---|
| $R_{FUS}$ | Fusible inrush current limiter resistor | *Special type, fusible, high peak power* | 10Ω | 39Ω |
| $D_1$, $D_2$ | Voltage doubler diodes | | 1N4007 | |
| $D_1..D_4$ | Bridge rectifier diodes | | | 1N4007 |
| $C_{BUF1}$, $C_{BUF2}$ | Buffer capacitors | *High temperature electrolytic type* | 10µF/200V | |
| $C_{BUF}$ | Buffer capacitor | *High temperature electrolytic type* | | 3.3µF/400V |
| $L_{FILT}$ | Filter inductor | *Axial type* | 2.2mH | 2.2mH |
| $C_{HB1}$, $C_{HB2}$ | Half bridge capacitors | | 47nF/200$V_{dc}$ | 47nF/200$V_{dc}$ |
| $C_{LA}$ | Lamp capacitor | *Foil type, capable of withstanding peak voltages of twice it's dc rating* | 1.5nF/400$V_{dc}$ | 1.5nF/400$V_{dc}$ |
| $L_{LA}$ | Lamp inductor | *E-16-Core* | 3.1mH | 3.1mH |
| $C_{DV}$ | dV/dt limiting capacitor | | 220pF/500$V_{dc}$ | 220pF/500$V_{dc}$ |
| $C_{FS}$ | Floating Supply buffer capacitor | | 10nF/50V | 10nF/50V |
| $C_{VDD}$ | low voltage supply buffer capacitor | | 10nF/50V | 10nF/50V |
| $C_{OSC}$ | Oscillator capacitor | | 180pF/50V | 180pF/50V |
| $R_{OSC}$ | Oscillator resistor | | 110kΩ/1/8W | 110kΩ/1/8W |
| $C_{SW}$ | Sweep time capacitor | | 100nF/25V | 33nF/50V |

11W lamp (9.5W/150mA burner, suited for cold ignition) ($f_{out}$=42.5kHz)

| REF | DESCRIPTION | REMARKS | 115V/60HZ | 230V/50Hz |
|---|---|---|---|---|
| $R_{FUS}$ | Fusible inrush current limiter resistor | *Special type, fusible, high peak power* | 8.2Ω | 33Ω |
| $D_1$, $D_2$ | Voltage doubler diodes | | 1N4007 | |
| $D_1..D_4$ | Bridge rectifier diodes | | | 1N4007 |
| $C_{BUF1}$, $C_{BUF2}$ | Buffer capacitors | *High temperature electrolytic type* | 15µF/200V | |
| $C_{BUF}$ | Buffer capacitor | *High temperature electrolytic type* | | 4.7µF/400V |
| $L_{FILT}$ | Filter inductor | *Axial type* | 2.7mH | 2.7mH |
| $C_{HB1}$, $C_{HB2}$ | Half bridge capacitors | | 47nF/200$V_{dc}$ | 47nF/200$V_{dc}$ |
| $C_{LA}$ | Lamp capacitor | *Foil type, capable of withstanding peak voltages of twice it's dc rating* | 1.5nF/400$V_{dc}$ | 1.5nF/400$V_{dc}$ |
| $L_{LA}$ | Lamp inductor | *E-16-Core* | 3.1mH | 3.1mH |
| $C_{DV}$ | dV/dt limiting capacitor | | 220pF/500$V_{dc}$ | 220pF/500$V_{dc}$ |
| $C_{FS}$ | Floating Supply buffer capacitor | | 10nF/50V | 10nF/50V |
| $C_{VDD}$ | low voltage supply buffer capacitor | | 10nF/50V | 10nF/50V |
| $C_{OSC}$ | Oscillator capacitor | | 180pF/50V | 180pF/50V |
| $R_{OSC}$ | Oscillator resistor | | 120kΩ/1/8W | 120kΩ/1/8W |
| $C_{SW}$ | Sweep time capacitor | | 100nF/25V | 33nF/50V |

13W lamp (11W/125mA burner, needing warm ignition) ($f_{out}$=42.5kHz)

| REF | DESCRIPTION | REMARKS | 115V/60HZ | 230V/50Hz |
|---|---|---|---|---|
| $R_{FUS}$ | Fusible inrush current limiter resistor | *Special type, fusible, high peak power* | 6.8Ω | 27Ω |
| $D_1$, $D_2$ | Voltage doubler diodes | | 1N4007 | |
| $D_1$..$D_4$ | Bridge rectifier diodes | | | 1N4007 |
| $C_{BUF1}$, $C_{BUF2}$ | Buffer capacitors | *High temperature electrolytic type* | 22µF/200V | |
| $C_{BUF}$ | Buffer capacitor | *High temperature electrolytic type* | | 6.8µF/400V |
| $L_{FILT}$ | Filter inductor | *Axial type* | 3.9mH | 3.9mH |
| $C_{HB1}$, $C_{HB2}$ | Half bridge capacitors | | 33nF/200V$_{dc}$ | 33nF/200V$_{dc}$ |
| $C_{LA}$ | Lamp capacitor | *Foil type, capable of withstanding peak voltages of twice it's dc rating* | 1.5nF/400V$_{dc}$ | 1.5nF/400V$_{dc}$ |
| $L_{LA}$ | Lamp inductor | *E-16-Core* | 3.5mH | 3.5mH |
| $C_{DV}$ | dV/dt limiting capacitor | | 100pF/500V$_{dc}$ | 100pF/500V$_{dc}$ |
| $C_{FS}$ | Floating Supply buffer capacitor | | 10nF/50V | 10nF/50V |
| $C_{VDD}$ | low voltage supply buffer capacitor | | 10nF/50V | 10nF/50V |
| $C_{OSC}$ | Oscillator capacitor | | 180pF/50V | 180pF/50V |
| $R_{OSC}$ | Oscillator resistor | | 120kΩ/1/8W | 120kΩ/1/8W |
| $C_{SW}$ | Sweep time capacitor | | 470nF/16V | 330nF/16V |

15W lamp (12.5W/180mA burner, suited for cold ignition) ($f_{out}$=40kHz)

| REF | DESCRIPTION | REMARKS | 230V/50Hz |
|---|---|---|---|
| $R_{FUS}$ | Fusible inrush current limiter resistor | *Special type, fusible, high peak power* | 27Ω |
| $D_1$..$D_4$ | Bridge rectifier diodes | | 1N4007 |
| $C_{BUF}$ | Buffer capacitor | *High temperature electrolytic type* | 6.8µF/400V |
| $L_{FILT}$ | Filter inductor | *Axial type* | 3.3mH |
| $C_{HB1}$, $C_{HB2}$ | Half bridge capacitors | | 47nF/200V$_{dc}$ |
| $C_{LA}$ | Lamp capacitor | *Foil type, capable of withstanding peak voltages of twice it's dc rating* | 1.8nF/400V$_{dc}$ |
| $L_{LA}$ | Lamp inductor | *E-16-Core* | 3.1mH |
| $C_{DV}$ | dV/dt limiting capacitor | | 220pF/500V$_{dc}$ |
| $C_{FS}$ | Floating Supply buffer capacitor | | 10nF/50V |
| $C_{VDD}$ | low voltage supply buffer capacitor | | 10nF/50V |
| $C_{OSC}$ | Oscillator capacitor | | 180pF/50V |
| $R_{OSC}$ | Oscillator resistor | | 130kΩ/1/8W |
| $C_{SW}$ | Sweep time capacitor | | 68nF/50V |

## 12W DEMO BOARD LAMP :

12W lamp (150mA burner, cold ignition, $f_{out}$=46kHz)

| REF | DESCRIPTION | REMARKS | 230V/50Hz |
|---|---|---|---|
| $R_{FUS}$ | Fusible inrush current limiter resistor | *Special type, fusible, high peak power* | 10Ω |
| $D_1..D_4$ | Bridge rectifier diodes | | 1N4007 |
| $C_{BUF}$ | Buffer capacitor | *High temperature electrolytic type* | 3.3µF/400V |
| $L_{FILT}$ | Filter inductor | *Axial type* | 1.8mH |
| $C_{HB1}$, $C_{HB2}$ | Half bridge capacitors | | 100nF/200V$_{dc}$ |
| $C_{LA}$ | Lamp capacitor | *Foil type, capable of withstanding peak voltages of twice it's dc rating* | 2.2nF/400V$_{dc}$ |
| $L_{LA}$ | Lamp inductor | *E-16-Core* | 2.7mH |
| $C_{DV}$ | dV/dt limiting capacitor | | 220pF/500V$_{dc}$ |
| $C_{FS}$ | Floating Supply buffer capacitor | | 10nF/50V |
| $C_{VDD}$ | low voltage supply buffer capacitor | | 10nF/50V |
| $C_{OSC}$ | Oscillator capacitor | | 180pF/50V |
| $R_{OSC}$ | Oscillator resistor | | 110kΩ/1/8W |
| $C_{SW}$ | Sweep time capacitor | | 33nF/50V |

# 7 QUICK MEASUREMENTS

**Table 4: Measured values compared with calculated values**

| Lamp power | Input voltage /frequency[4] | Input configuration | preheat | $f_{out}$ set | $f_{out}$ measured[5] | $I_{lamp}$ calculated using $f_{out}$ measured | $I_{lamp}$ measured |
|---|---|---|---|---|---|---|---|
| 3W | 115V/50Hz | standard | Yes | 28.8kHz | *29.1kHz* | 95mA | *97mA* |
| 3W | 230V/50Hz | standard | Yes | 28.8kHz | *29.0kHz* | 96mA | *94mA* |
| 8W | 115V/60Hz | doubler | No | 45.9kHz | *48.7kHz* | 145mA | *138mA* |
| 8W | 230V/50Hz | standard | No | 45.9kHz | *48.6kHz* | 147mA | *144mA* |
| 11W | 115/60Hz | doubler | No | 42.5kHz | *45.1kHz* | 148mA | *142mA* |
| 11W | 230V/50Hz | standard | No | 42.5kHz | *44.7kHz* | 150mA | *148mA* |
| 13W | 115/60Hz | doubler | maximum | 42.5kHz | *44.0kHz* | 120mA | *115mA* |
| 13W | 230V/50Hz | standard | maximum | 42.5kHz | *44.0kHz* | 120mA | *127mA* |
| 14W | 115V/60Hz | doubler | No | 42.5kHz | *45.2kHz* | 139mA | *129mA* |
| 14W | 230V/50Hz | standard | No | 42.5kHz | *44.8kHz* | 140mA | *141mA* |
| 15W | 230V/50Hz | standard | No | 39.7kHz | *41.4kHz* | 161mA | *171mA* |

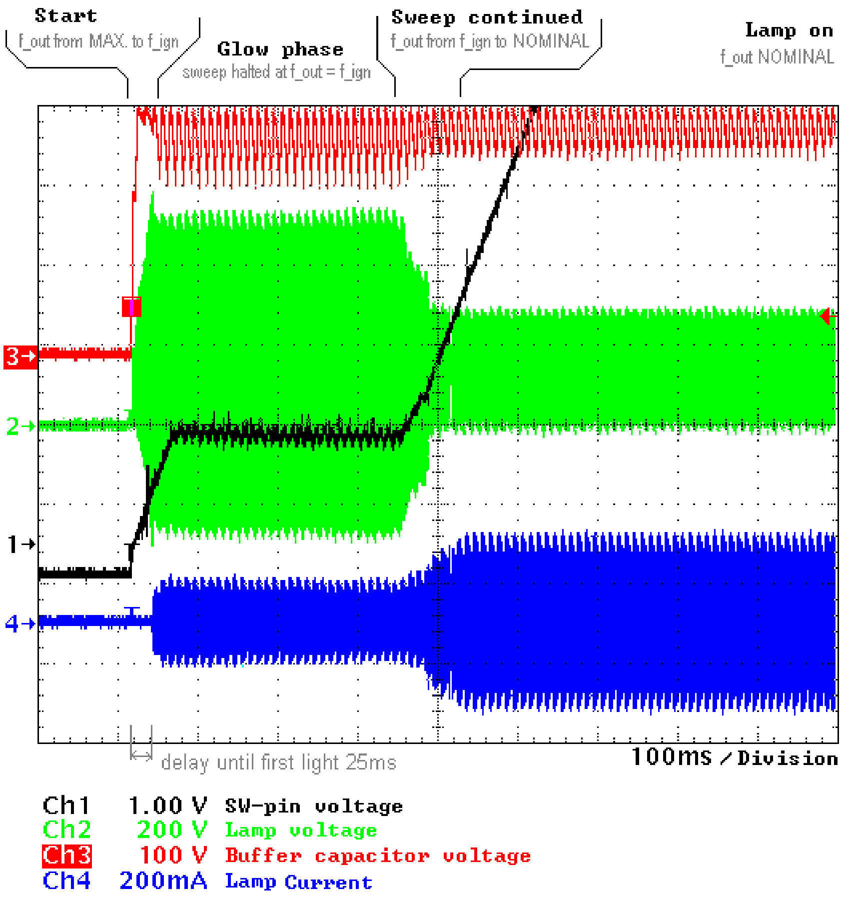



*Figure 5: Cold starting lamp waveforms.*
*($C_{SW}$=10nF)*

[4] Measurement for 115V/60Hz were done at 115V/50Hz with 15% extra capacitance added to $C_{BUF1}$ and $C_{BUF2}$.
[5] A 5% resistor was used for Rosc, and a 10% capacitor was used for Cosc. Tolerances of Rosc and Cosc both add to frequancy tolerance of IC. Use Rosc and Cosc with less tolerance if better match between calculated and measured frequency is needed.

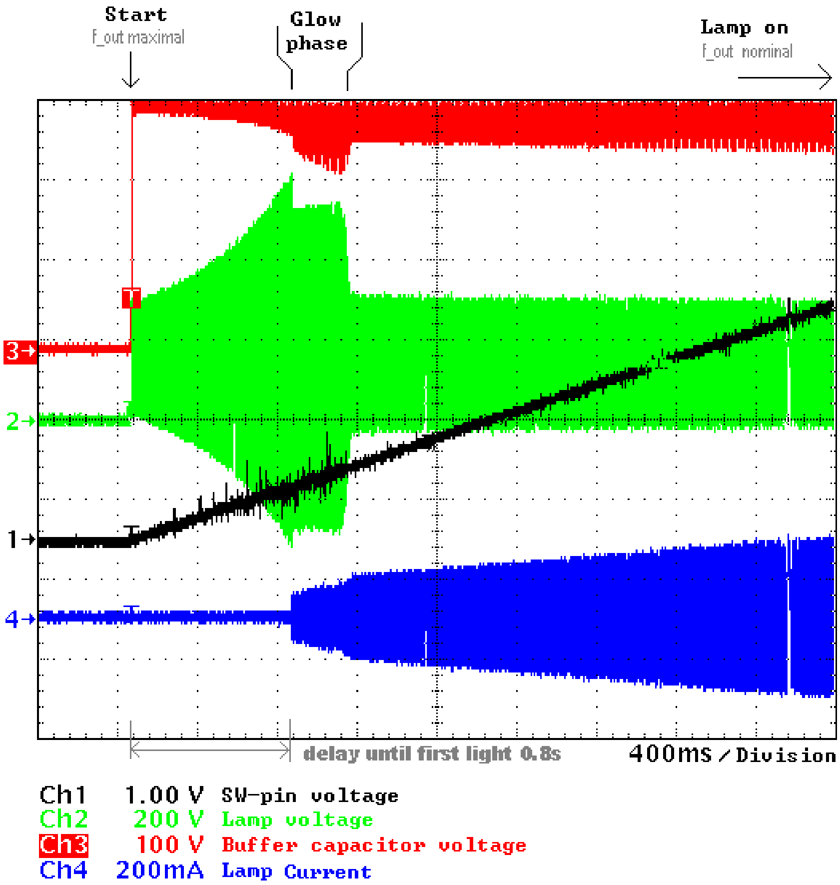



*Figure 6: Lamp start-up with 'warm' ignition.*
*($C_{SW}$=330nF)*

## APPENDIX 1 *Application board layout example*

The layout of the PCB on which the UBA2024T is mounted, has a considerable influence on the performance of the IC. Issues to be taken into account are:

- Coils with open magnetic circuit should not be placed above the IC (on the other side of the PCB). If an axial filter inductor is used for $L_{FILT}$ it should be placed in the same direction as the IC to minimize magnetic field pick-up.
- All output components ($C_{HB1}$, $C_{HB2}$, $L_{LA}$, $C_{LA}$ and $C_{DV}$) and their interconnections should be placed at the side of pin 1 and pin 14 of the IC.
- Oscilator pin (pin 7, “RC”) and sweep pin (pin 8, “SW”) should be shielded form output/lamp by a ground track. Components on these pins should be placed as close to the IC as possible.
- Capacitors $C_{VDD}$ and $C_{FS}$ should be placed close to the IC.
- For effective heat transfer all SGND pins need to be soldered to a copper plane which is also beneath the IC and extends besides the IC as much as possible. Fixing the IC to the board using thermal conductive glue also helps.

Of course, the size and shape of the PCB has to fit the lamp base. Below the layout of the demoboard, as is used for the measurements mentioned in this application note, is shown as an example. With it’s diameter of only 35mm it’s smaller then most currently used CFL-ballast PCBs. It’s suited for either use of the popular E16 core lamp inductor or a radial-type I-core inductor.

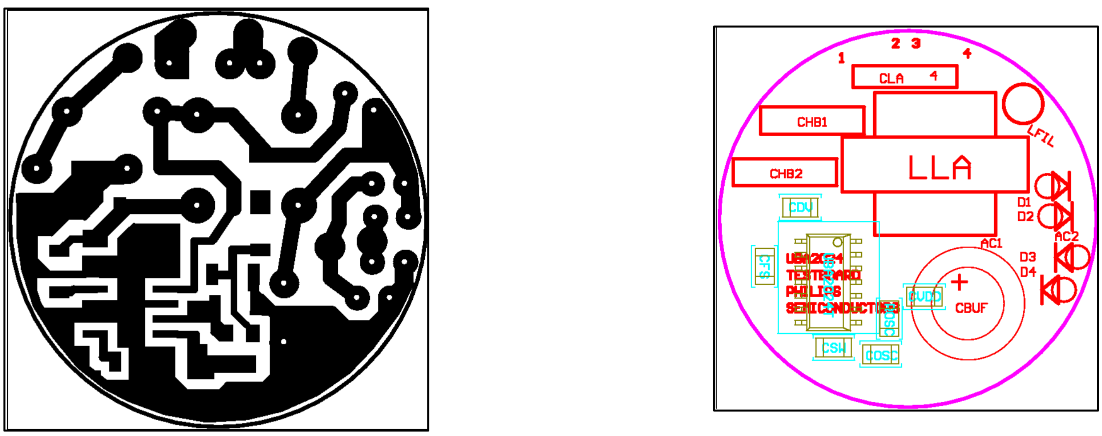



*Figure 7: Layout (left) and component placement (right) of application demoboard (actual size is 35mm diameter)*