EPCOS

FILM CAPACITORS FOR ELECTRONIC LIGHTING

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1. Introduction:

Fluorescent lamps have emerged as the preferred light source for industrial and domestic applications. Key factors are on the one hand a high luminous efficiency, and on the other hand the increased life - time compared to a filament lamp.
A standard filament lamp has a luminous efficiency of 14 lm/W compared to a standard compact fluorescent lamp with an average of 50 lm/W. As far as the average life - time is concerned, the result is equally impressive. A standard filament lamp has an average life - time of 1.000 hours. Compared to this, a standard halogen lamp has 2.000 hours, a low voltage halogen lamp 4.000 hours, and on top comes the fluorescent lamp with 6.000 to 12.000 hours.
In order to stabilize the working conditions and to avoid destruction of the lamp by rapidly increasing lamp current after ignition, ballast units are required.

Conventional ballasts (magnetic ballasts) use a simple construction of a copper wire wrapped around a ferrite core. Conventional systems (ballast + fluorescent lamp) result in an unacceptably high power dissipation. Further optimization leads to **low-loss conventional ballasts**, which are magnetic ballasts as well. These systems show an already reduced power dissipation of around 7%.
Tremendous improvements can be achieved by the use of **electronic ballast**, which results in an even further reduction of the power dissipation of around 25%.
Electronic ballasts are operating at high frequencies (25 – 80kHz). Due to this, other positive influences can be seen.

⇒ The average life - time is increased by 30 – 50% due to controlled preheating and reduced wear of the lamp electrodes.

⇒ The decreased heat dissipation of electronic ballast units reduces the costs for air-conditions.

⇒ Due to the fact that the lamp voltage is more stable in high frequency operation, the flickering can be diminished by 90% and stroboscope effects with rotating machines are prevented.

⇒ Weight and size of the lamp are reduced.

2. Fluorescent lamp operation

When a voltage is applied to the terminals of the fluorescent lamp, low-pressure mercury vapor in the tube is ionized. This ionized vapor radiates ultraviolet light, which is then converted into visible light while striking the fluorescent coating on the inner wall of the tube.

When a fluorescent lamp is first turned on, the AC line voltage of 110 or 220 V is not sufficient to start ionization of the vapor. High voltage pulses around 600 to 1200 V are needed.

Once the vapor has been ionized, the lamp current increases gradually. The more the current rises, the higher is the degree of ionization. Thus the lamp impedance becomes negative. In order to prevent the rising current from destroying the lamp, some form of current limiting device must be connected in series with it. This device is usually known as the ballast.

3. Electronic Ballasts:

There are three different basic kinds of electronic ballasts:

3.1 Voltage feed quasi-resonant circuit:

3.1.1 Energy Saving Lamp

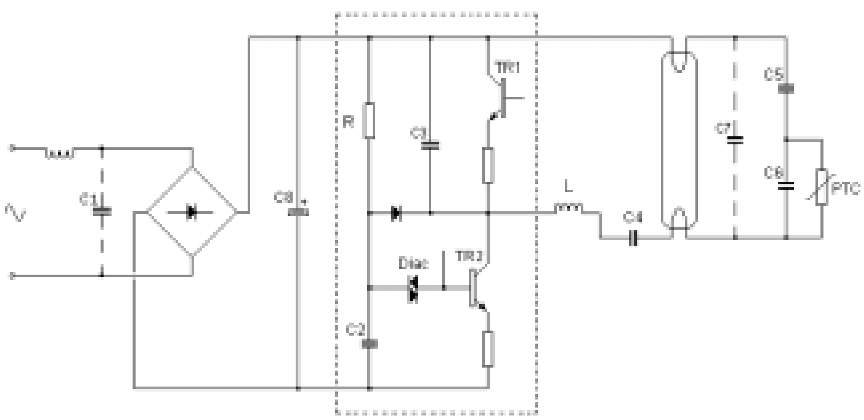


Fig. 1:Typical circuit diagram of an Energy Saving Lamp

This is the option normally used for ESL (Energy Saving Lamp), due to the simplicity of the circuit and the low costs.
The typical wave form in Fig. 2 reflects the three phases of operation of this circuit:

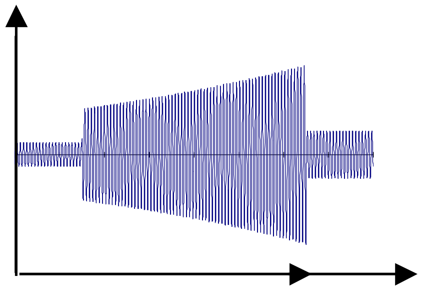


Fig. 2: Three phases of operation

A. Starting the oscillation: The capacitor C2, the resistor R and a DIAC are responsible for the first pulse to start the oscillation. After the lamp start-up, the circuit becomes inoperative, and the circuit is maintained in oscillation by positive feedback of the transformers.
B. The lamp start-up is achieved by means of an overvoltage across the capacitors C5 and C6, caused by resonance. Self-heating of the PTC leads to a varying resonance frequency of the circuit consisting of the inductor, C4, C5 and C6 (or C7 respectively) and finally to a peak voltage of 600-1200V across C5 and C6.
C. Steady state operation: once the tube is ionized, the operating frequency is defined by C4, as there is very low impedance in parallel to C5 and C6 (or C7). At this frequency, the voltage generated is lower than the starting phase, just to keep the lamp ionized.

The capacitor C1 is an X2 capacitor, which is generally not used in current designs anymore.

Capacitor C3 is a snubber capacitor used to protect the switching device. The voltage waveform is trapezoidal (Fig. 4) and the responding dV/dt is very high, worst case with more than 1000V/µs. Due to the high load it has to be checked if a polyester lead space (LS) 5 capacitor is able to withstand, or if a polypropylene capacitor is mandatory.
In case of a polyester capacitor the standard series B32529 can be chosen. If a polypropylene capacitor is necessary, EPCOS recommends the use of an MKP capacitor in stacked technology with series name B32620/621 due to the following reasons:

- very small dimension in LS 7.5 and 10

- very high dV/dt

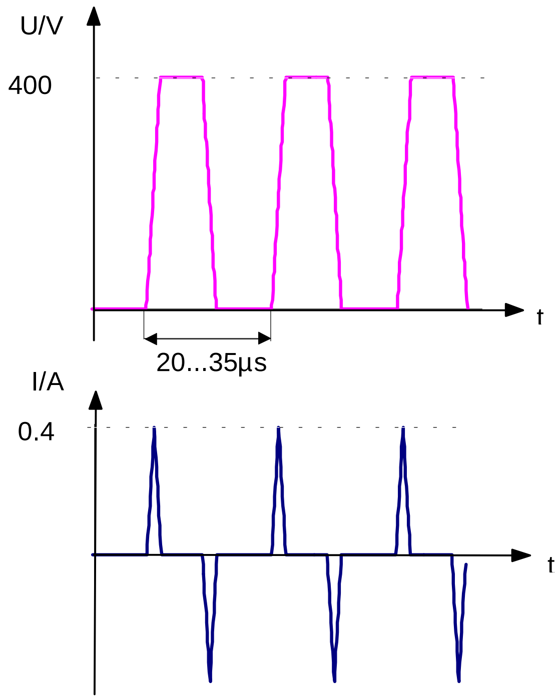


Fig. 3: Typical load diagram of C3

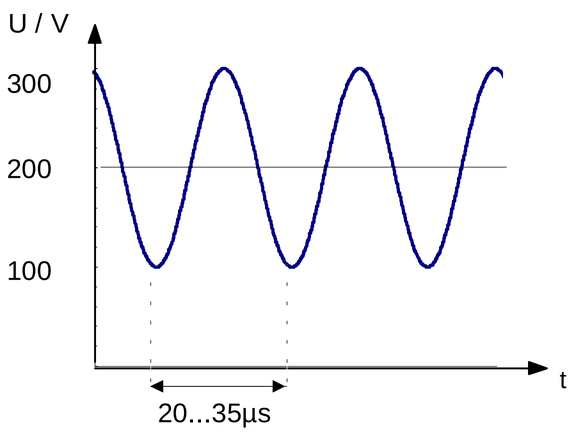


Fig. 4: Typical load diagram of C4

The capacitor C4, C5, C6 and C7 can be realized with a polyester capacitor. Possible solutions are a standard boxed capacitor in LS 5 (B32529 series) or a Silver Cap (capacitor without box) solution in LS 7.5 (B32560), which EPCOS recommends due to the following reasons:

- cheapest solution due to the absence of any encapsulation, available in LS 7.5, 10, 15, 22.5 and 27.5mm

- most volume - efficient film capacitor

- capacitor's geometry can be varied according to customers special demands

Capacitor	Type	Series	Typical dV/dt	Rated voltage	Capacitance
C1	X2	B81130		275Vac	47 - 100nF
C2	MKT	B32529 B32560		63V	22 - 100nF
C3	MKT MKP	B32529 B32620	1000V/µs	630 – 1000V	680pF – 1.5 nF
C4	MKT	B32529 B32560		250 – 400V	22 - 100nF
C5	MKT	B32560	<300V/µs	400 – 630V	4.7 - 10nF
C6	MKT	B32560	<300V/µs	400 – 630V	1.5 - 15nF
C7	MKT	B32560	<500V/µs	400 – 1000V	1.0 - 10nF
C8	ELKO				

3.1.2 Electronic ballast for EU-market

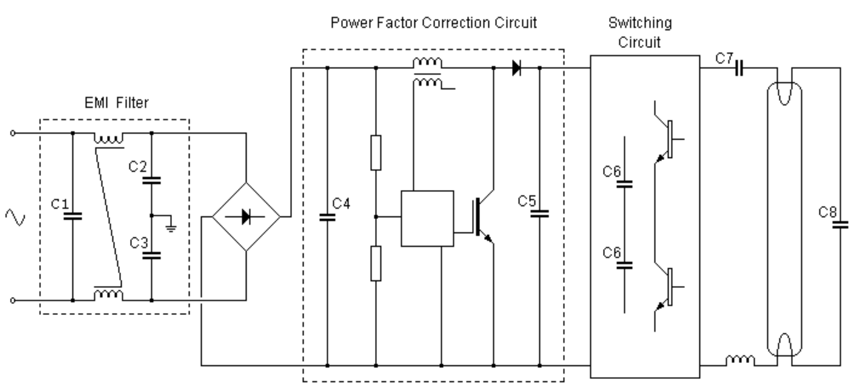


Fig.5: Typical circuit diagram for a ballast circuit

The circuit for the EU-ballast shown in Fig. 5 works according to a very similar concept in comparison with the circuit used for Energy Saving Lamps.
Main differences are that the circuits for the Energy Saving Lamp are designed on the basis of a low power application and a life - time of 10.000 hours. Due to this, mainly polyester capacitors are used in this application.

Compared to that, the electronic ballast requests a life - time of around 50.000 hours and is used in a higher power range. Therefore polypropylene capacitors are necessary.

The circuit is –in comparison with the ESL- expanded by an EMI filter and a Power Factor Correction (PFC) circuit. C5 is commonly realized by an electrolytic capacitor. Electrolytic capacitors have the disadvantage that they are not stable in long-life operation. A film capacitor replacement can be used, which allows a capacitance change lower than 5% during the life - time and therefore a lower nominal capacitance value in comparison with the electrolytic capacitor (e.g. electrolytic capacitor 15µF can be replaced by 10µF film capacitor). Additionally, the series resistance is very low and allows a reduction of electrical dissipation.
EPCOS provides solutions in Silver Cap stacked technology up to 6.8µF and in wound technology up to 15µF (B32231 or B32232).

Capacitor	Type	Series	Typical dV/dt	Rated voltage	Capacitance
C1	X2	B81130		275Vac	47 – 470nF
C2	Y2	B81122		250Vac	1 - 4.7nF
C3	Y2	B81122		250Vac	1 – 4.7nF
C4	MKT	B3252_ B3256_		250 – 630V	220nF - 1µF
C5	MKT	B3223_ B3256_		350 – 480V	4.7 - 15µF
C6	MKP	B3265_	<1000V/µs	400 - 1000V	680pF - 2.2nF
C7	MKP	B3265_	<300V/µs	630V	22 - 100nF
C8	MKP	B3265_	<500V/µs	1000 - 2000 V	470pF - 10nF

3.2. Current feed resonant circuit with PFC (typical circuit used in USA):

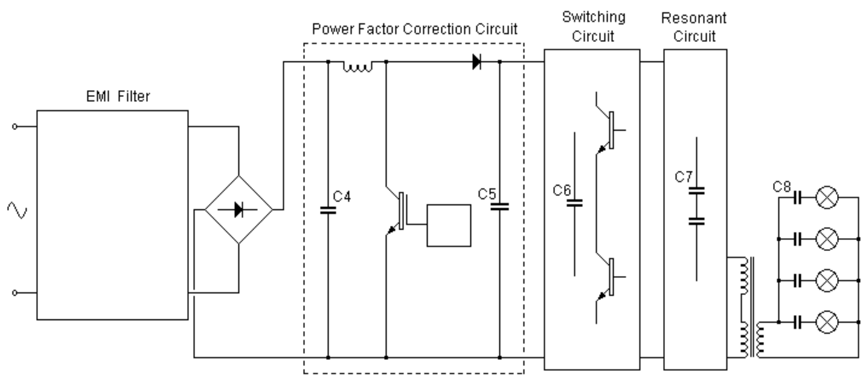


Fig.6: Typical circuit diagram of a US-ballast.

Main differences between the so called EU-ballasts and US-ballasts are that the US-ballast is normally used to control 4 lamps compared to the EU-ballast with 1-2 lamps. The operating principle is different as well, due to the fact that the US-ballast is working on a “permanent ignition” principle. This means that the requirements on the capacitor in terms of self-heating and corona discharge are much higher than for EU-ballasts.
In the past the operation frequency was typically 25kHz and has changed now to higher values of around 45-80kHz.

A. Starting the oscillation: The start-up circuit operates in the same way as in the voltage feed topology. Note that this circuit does not have a filament pre-heating, which means that the start-up voltage will be higher than the previous circuit analyzed.
B. Steady-state operation: After the ignition, the circuit operates in a resonance frequency of C6, C7 and the transformer. Capacitor C6, C7 and C8 are polypropylene capacitors. The requirement for C8 is a high AC-voltage between 700 to 1000Vac. EPCOS has developed typical capacitance values (1-10nF) in series B32652/B32653 with these AC-voltages (Vdc=1600-2500V).

C. PFC Circuit: C4 is an MKT capacitor, and C5 is an electrolytic capacitor, which can be replaced by an MKT capacitor as described in 3.1.2.

D. EMI Filter: The filter can be realized with a filter design with C1 as a X2 capacitor and C2,C3 as Y2 capacitors. Other possibilities are circuit designs with only one MKT capacitor C1*, who is not directly loaded by the supply voltage, because a varistor is in parallel.

Capacitor	Type	Series	Typical dV/dt	Rated voltage	Capacitance
C1	X2	B81130		275Vac	47 – 470nF
C2	Y2	B81122		250Vac	1 - 4.7nF
C3	Y2	B81122		250Vac	1 - 4.7nF
C1*	MKT	B3252_ B3256_	-	400V	100 - 470nF
C4	MKT	B3252_ B3256_	-	250 – 630V	220nF - 1µF
C5	MKT	B3223_ B3256_	-	350 – 480V	4.7 - 15µF
C6	MKP	B3265_ B3261_	<300V/µs	630 – 1600V	1.5 - 15nF
C7	MKP	B3265_ B3261_	<300V/µs	630 - 1600V	4.7 - 10nF
C8	MKP MFP	B3265_ B3261_ B3263_	<500V/µs	1000 ... 2500V	1.0 - 10nF

4. Electronic transformer

Electronic transformers are used as an interface to the low-voltage halogen lamps. The transformer is changing the primary supply voltage from 240V down to the secondary low voltage of 6V,12V or 24V

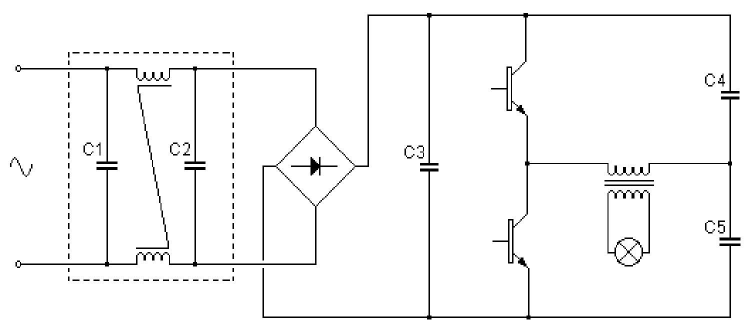
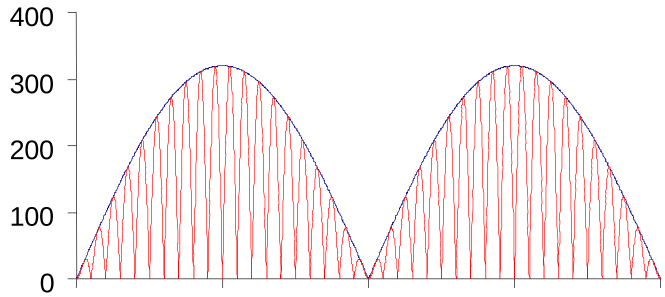


Fig.7: Typical circuit diagram of electronic transformer.

The circuit consists of a full wave rectifier, a filter (C3) and an oscillation circuit, which produces an amplitude modulation between 30kHz and 50kHz, reducing the voltage through a ferrite transformer. C4 and C5 supply the energy to the lamp.

C1 and C2 typically are X2 capacitors. Due to modification of the circuit, however, low cost solutions are possible using a standard MKT capacitor (boxed) or even better an EPCOS low - cost Silver Cap solution.
C3 is a smoothing capacitor. An MKT is suitable for this application.

C4 and C5 are snubber capacitors. In this application we see a high voltage associated with a high frequency, which makes the use of an MKP capacitor necessary, because it shows good performance regarding self-heating. Usually capacitors with small lead spaces are required, which recommends our MKP series B32620/621 in stacked technology. In some cases a very high AC-voltages is required, which has to be solved by the usage of an MKP wound construction (standard: B32652, upon request: B32651).



Capacitor	Type	Series	Frequency	Rated voltage	Capacitance
C1	X2	B81130		275Vac	100 - 470nF
C2	X2	B81130		275Vac	100 - 470nF
C3	MKT	B3252_ B3256_	-	400 - 500V	22 - 330nF
C4	MKP	B3262_	30-50kHz	1000V	10 - 47nF
C5	MKP	B3262_	30-50kHz	1000V	10 - 47nF

5. Summary and product information

In summary, this technical note is a short description of the general behavior of the three main different types of electronic ballasts and the principle of a transformer. The typical requirements for the film capacitors used are described and summarized in one table per application, which helps to choose the suitable capacitor.
EPCOS has developed the suitable capacitor for each position in terms of technical requirements as well in terms of cost effectiveness.
For further technical information, please do not hesitate to contact us:

www.epcos.de/products

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