Application Note, Rev. 1.0, August 2009

ICB2FL02G

Smart Ballast Control IC for Flourescent Lamp Ballasts

Dimming Demoboard 26W TC-TEL Single Lamp Design

www.infineon.com/smartlighting

Never stop thinking

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Table 1

ICB2FL02G

Revision History: 2009-08-07, Rev. 1.0

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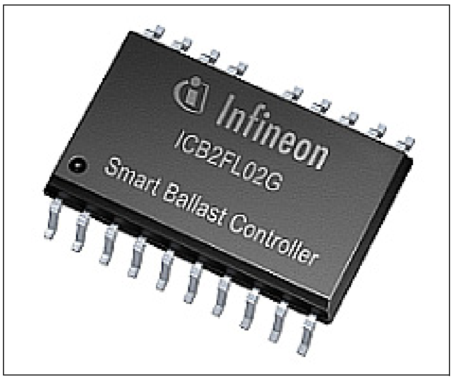
Smart Ballast Control IC for Flourescent Lamp Ballasts
Dimming Demoboard 26W TC-TEL Single Lamp Design

ICB2FL02G

Product Highlights



- Lowest Count of external Components
- 900V-Half-Bridge driver with Coreless Transformer Technology
- Supports Customer In-Circuit Test Mode for reduced Tester Time
- Supports Multi-Lamp Designs
- Integrated digital Timers up to 40 seconds
- Numerous Monitoring and Protection Features for highest Reliability
- Very high accuracy of frequencies and timers over the whole temperature range
- Very low standby losses
- Special detection thresholds for dimming applications

Features PFC

- Discontinuous Mode PFC for Load Range 0 to 100%
- Integrated digital Compensation of PFC Control Loop
- Improved Compensation for low THD of AC Input Current also in DCM operation
- Adjustable PFC Current Limitation

Features Lamp Ballast Inverter

- Adjustable Detection of Overload and Rectifier Effect (EOL)
- Detection of Capacitive Load operation
- Improved Ignition control allows for operation close to magnetic saturation of Inductors
- Restart with skipped Preheating at short interruptions of Line Voltage (for Emergency Lighting)
- Parameters adjustable by resistors only
- Pb-free Lead Plating; RoHS compliant

Type	Package
ICB2FL02G	PG-DSO-19-1 (300mil)

1 Dimming - Introduction

The fluorescent lamp ballast Controller ICB2FL02G is designed to control a boost converter as an active power factor correction (PFC) filter in critical/discontinuous conduction mode (CritCM/DCM) and a half-bridge topology as a lamp inverter with special detection thresholds for dimming applications. The intelligent control concept enables designers to develop cost-effective dimmable ballasts for fluorescent lamps (FL) that fulfil the requirements of a high performance T5 lamp ballast as well as multi lamp topologies, T8 and T4 designs. A state machine controlling the operating modes, a completely integrated digital control loop for the PFC output voltage and low tolerances for reference voltages and operating frequency over the whole temperature range are a result of the advanced mixed signal technology with only few required components externally. Combined with a high voltage level shift driver with Coreless Transformer Technology for the half-bridge inverter the IC offers a significant number of exceptional features for FL ballasts.

The FL-Ballast Controller ICB2FL02G has an improved and enlarged functionality that enables dimmable and high quality single or multi lamp ballasts with a low number of external components. Its benefit is to save system costs and to reach class A2 of the energy efficiency index (EEI) for fluorescent lamp ballasts easily.

This Application Note describes how an electronic ballast can be enhanced using the ICB2FL02G Smart Ballast controller to produce a dimmable electronic ballast. Figure 1 shows a picture of the Demoboard. The described circuitry is an example to demonstrate the principle of dimming with the ICB2FL02G. The dimming range is down to about 5% of maximal brightness. There are no limitations of the IC to realise dimming ballasts with much lower brightness levels.

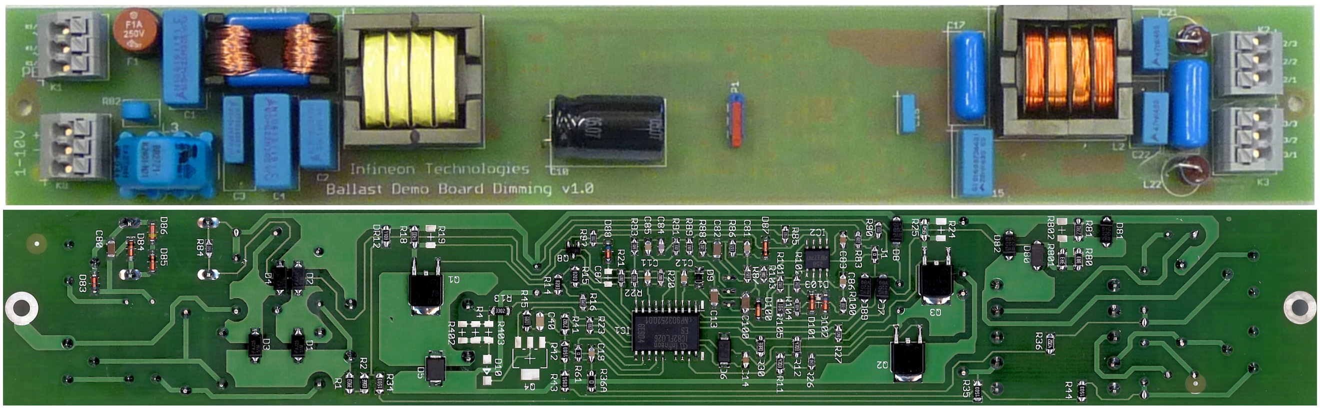


Figure 1 Picture of the dimmable Demoboard

A brief introduction of the fundamentals of dimming low-pressure discharge lamps is followed by a description of power and current controlled regulation, after which the 1-10V interface and Digital Addressable Lighting Interface (DALI) are described.

1.1 Characteristics of low-pressure discharge lamps Switch-on to dimming

During the preheating phase the gas discharge tube is flooded with electrons and in the process the cathodes warmed up to emission temperature with a specific energy. The necessary preheating energy is determined by the physical design of the cathodes and is produced by applying a current to them for a selected preheating time. When preheating times are lower than 0.4s, ensuring homogeneous heat distribution in the cathode filaments can be problematic because of their mass. A too long preheating time, on the other hand, is annoying for the user. For that reason the preheating time should be no longer than 2s. A mismatch during preheating will shorten the lifetime of the low-pressure discharge lamp especially when the ballast is switched off and on very often.

Adherence to the specified limits is checked by means of a substitute resistor RSUB for the cathode. The energy supplied during the specified preheating time is measured at this resistor. The minimum and maximum preheating energy limits are calculated using these values according to the following formulas:

$Q_{PH,min}$ [OS-KLTN-03]

$$Q_{PH,\min} = Q + P_{t\_PH}$$

$Q_{PH,max}$ [OS-KLTN-03]

$$Q_{PH,\max} = 1{,}75 \cdot Q_{vorheiz,\min}$$

If constant current or voltage preheating is used, then the currents or voltages necessary for proper preheating can be calculated using the formulas below:

$V_{PH,constant}$ [OS-KLTN-03]

$$V_{PH,constant} = \sqrt{\frac{Q \cdot R_{SUB}}{t_{PH}} + P \cdot R_{SUB}}$$

$I_{PH,constant}$ [OS-KLTN-03]

$$I_{PH,constant} = \sqrt{\frac{Q}{R_{SUB} \cdot t_{PH}} + \frac{P}{R_{SUB}}}$$

As an example, **Table 2** gives the values for an OSRAM Dulux® T/E 26W lamp for calculating the preheating voltages or currents:

Table 2 Preheating data for OSRAM Dulux® T/E 26W [OS-KLTN-03]

Lamp type	P [W]	Q [J]	R_{SUB} [Ω]
OSRAM Dulux® T/E 26W	0,8	1,0	9

So for the lamp used here, the result when the preheating time is 1s is a minimum necessary preheating voltage (voltage preheating) of:

$V_{PH,constant}$-values

$$V_{PH,constant} = \sqrt{\frac{Q \cdot R_{SUB}}{t_{PH}} + P \cdot R_{SUB}} = \sqrt{\frac{1J \cdot 9\Omega}{1s} + 0.8W \cdot 9\Omega} = 4{,}03V$$

The gas discharge tube must not ignite during the preheating phase, so the resonant circuit must be tuned in that way that the voltage across the lamp does not exceed the maximum permissible preheating voltage (see IEC 60081 and IEC 60901).

The frequency is changed during the ignition phase towards the resonant frequency. This causes the lamp voltage to rise until the gas discharge tube ignites. After successful ignition, the converter is driven by means of the working frequency. Adherence to all the limiting values specified by the lamp manufacturer must be ensured in all phases. The main operating parameters that have to be checked for a standard ballast are:

- the lamp current and lamp voltage
- the pin currents of the lamp's terminals

Compliance with various operating parameters is required so that dimming applied to low-pressure discharge lamps will not shorten the lamps' lifetime. At maximum brightness the current flowing through the gas discharge tube is sufficient to maintain gas discharging. The gas discharge tube does not have to be additionally enriched with electrons in this mode. The function of deactivating or drastically reducing cathode heating during operation is called cut-off technology, and reduces losses in the lamp.

Lighting manufacturers recommend operating new lamps for around 100 hours at maximum brightness prior to dimming so that the lifetime will not be adversely affected. Reducing the lamp current to values below 80 percent of the rated current requires the cathodes to be additionally heated to be maintained at their correct emission temperature.

Minimum and maximum limiting values have to be adhered to for cathode heating in the dimming mode to maintain the lamps' specified lifetime. Excessive heating will cause emitter material in the cathode filaments to evaporate and blacken the glass bulb in the region of the cathodes (end blackening). If the cathodes are not heated enough emitter material will be ejected (sputtering) and the cathodes will also be prematurely destroyed. Both these instances of incorrect heating will considerably shorten the lamp's lifetime. **Figure 2** shows that there is a target range within which cathode heating is optimally matched.

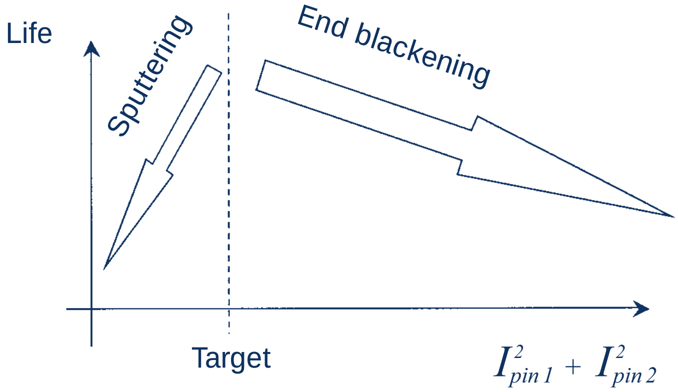


Figure 2 Cathode heating [OS-KLTN-03]

The continuous heating current cannot, without considerable effort, be directly measured with the gas discharge tube ignited because the heating current has the lamp current superimposed on it. For design reasons these currents can differ with respect to phase, frequency, and curve shape.

The variable that is critical for cathode heating is the electrically introduced heating power. The following approximation can be applied for this. [OS-KLTN-03]

$P_{heating}$

$$P_{heating} = P_{discharge} + P_{heating} = f\left(I^2{}_{discharge}, I^2{}_{heating}\right) \approx f\left(I^2{}_{discharge} + I^2{}_{heating}\right) \approx f\left(I^2{}_{Lead1} + I^2{}_{Lead2}\right)$$

The heating energy introduced can accordingly be determined by the sum of the respective cathode's squared pin currents. This makes cathode heating much easier to measure because the pin currents can be measured directly using an AC current probe.

The limiting values for the heating energy as well as the optimal working point for the dimming range can be calculated using the values from **Table 3**. These values are specified by lamp manufacturers and are given here by way of example for an OSRAM Dulux® T/E 26W lamp:

Table 3 Heating data for OSRAM Dulux® T/E 26W [OS-KLTN-03]

Lamp	$I_{Lampmin}$ [A]	m_{target} [A^2/A]	b_{target} [A^2]	m_{min} [A^2/A]	b_{min} [A^2]	m_{max} [A^2/A]	b_{max} [A^2]
OSRAM Dulux® T/E 26W	0.030	0.171	0.175	0.570	0.175	0.145	0.210

With the lamp current $I_{discharge}$, along with these parameters and the three formulas below, the limits and target curve can be entered in a chart, what is termed the dimming characteristic:

I^2_{Lead1}+I^2_{Lead2}target [OS-KLTN-03]

$$I^2{}_{Lead1} + I^2{}_{Lead2}\Big|_{target} = -m_{target} \cdot I_{discharge} + b_{target}$$

$^2{}_{Lead1}$+I^2_{Lead2}min [OS-KLTN-03]

$$I^2{}_{Lead1} + I^2{}_{Lead2}\Big|_{min} = -m_{min} \cdot I_{discharge} + b_{min}$$

$^2{}_{Lead1}$+I^2_{Lead2}max [OS-KLTN-03]

$$I^2{}_{Lead1} + I^2{}_{Lead2}\Big|_{max} = +m_{max} \cdot I_{discharge} + b_{max}$$

Figure 3 shows by way of example a dimming characteristic for an OSRAM Dulux® D/E 26W lamp.

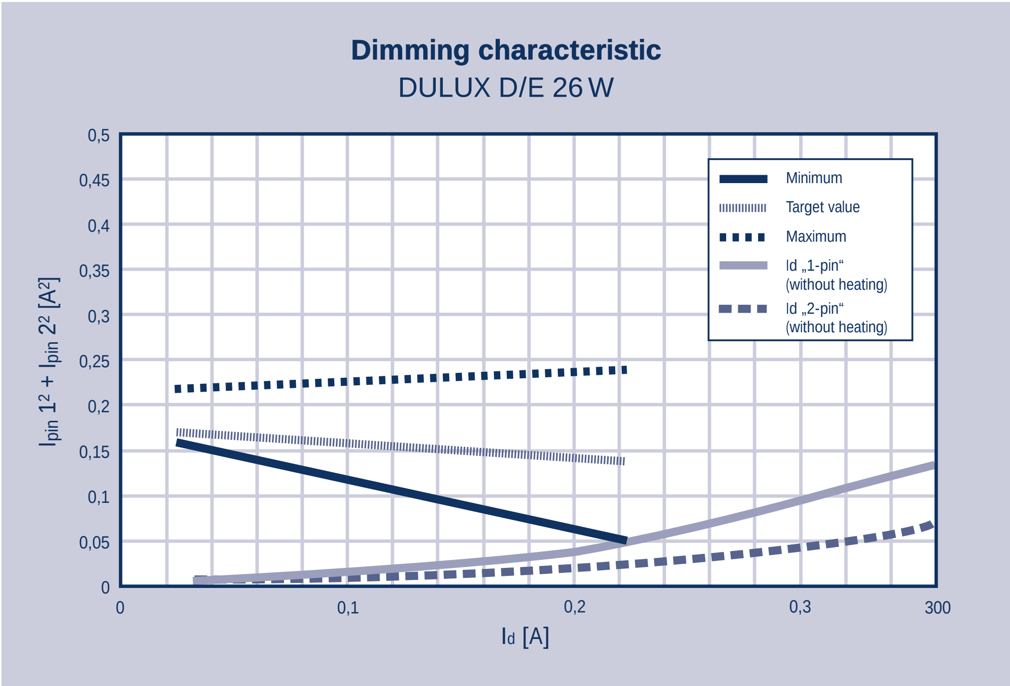


Figure 3 Dimming characteristic for OSRAM Dulux® D/E 26W [OS-KLTN-03]

Reducing the lamp current to below around 220mA requires additional heating of the cathodes. In practice, however, the cathodes should be further heated earlier because the target curve is higher than the minimum limiting value. Reliable information about the lamp's lifetime can, only be provided after continuous tests because exact operation along the target curve is scarcely possible.

1.2 Overview of dimming options

Dimming electronic ballasts by changing the input voltage is not possible except at considerable expense and effort. The PFC stage keeps the BUS voltage at a fixed value and compensates any fluctuations in the input voltage. For dimming by way of a change in the AC power supply voltage the PFC stage would need to be redesigned for the BUS voltage to change its value as a function of the AC power supply input voltage. The controlled BUS voltage ensures that the operating conditions for the converter are kept constant. So, lamp operation at a constant level will be ensured also in the presence of fluctuating AC power supply voltages. With the solution described here, the brightness is set by way of a change in converter frequency and a resulting change in the load circuit impedance. In that way it is possible to influence the lamp's working point.

It is possible to build a control which sets the lamp current as a function of a specified setpoint value by changing the converter's frequency. Another variant is to measure the lamp's output power and use that for the actual value. There is no point in adjusting to the lamp voltage since this is highly dependent on the operating conditions and can vary widely across different lamps.

The setpoint value is usually set via an external interface, what is termed the 1-10V interface for instance, or the DALI bus. Both systems will be briefly explained below following an explanation of power and current control.

1.2.1 Power control

With power control, the lamp's power output is controlled. The advantage of this type of control is that the lamp's power output is adjusted to the set value immediately after ignition. Problematic is the measurement of the lamp's actual power output. In practice, therefore, the compromise route is often taken of measuring the power of the half-bridge via a shunt resistor. However, with that configuration it is not possible to distinguish between the cathode heating power and that consumed in the gas discharge tube. At low brightness levels the cathode heating power is far greater than the power converted into light. The cathodes' characteristics are subject to wide tolerances and change over the lamp's lifetime. Specifically in the dimming mode, this has the disadvantage that large differences in brightness can occur among different lamps. Moreover, very small lamp currents are a problem to implement for the reasons cited above.

These problems can be eliminated by measuring the lamp's actual power output. That necessitates measuring the lamp burning voltage and lamp current. Multiplying these variables will result the lamp's power output. However, multiplications require many extra components or a lot of computing time and so are critical in the regulation process and more expensive to implement. That is why current regulation is often used instead.

1.2.2 Current control

With current control it is only necessary to measure the lamp current. This can be done in an easy way for example a shunt resistor in the lamp circuit, independently of the cathode currents. That enables constant brightness levels to be provided even when the lamp current is low. Different lamps having the same lamp currents can be operated using the same electronic ballast. This feature makes it possible to design electronic ballasts capable of driving different lamps. These general-purpose electronic ballasts greatly reduce storage and maintenance overheads for illuminating devices.

The lamp's transient response has a disadvantageous impact during current controlling. The lamp's voltage changes a certain time after ignition and so the lamp's power output can vary. This is not subsequently adjusted in the case of current control.

This type of control is applied in many types of electronic ballast because it can be constructed with relatively few components.

1.2.3 1-10V interface

The 1-10V interface is an interface for illuminating devices (electronic ballasts in the main) that is used to set their brightness. The market is at present still dominated by the 1-10V interface. It provides a standard for lamp manufacturers for dimming devices from different electronic ballast manufacturers. The interface provides a control current that produces a voltage drop at the interface via a potentiometer functioning as a current sink. The lamp is dimmed as a function of this voltage drop. It is also possible to inject a DC voltage level directly via a DC source in order to influence the brightness, where maximum brightness or operation at rated output power corresponds to an interface voltage of 10V. This operation is set with open interface terminals - for example. Minimum brightness is set with a shorted interface or using an interface voltage of 1V. The regulator side is electrically isolated from the electronic ballast's AC power supply. This precondition enables several electronic ballasts to be operated on different phases via the same control device. The electronic ballasts cannot be addressed individually when a 1-10V interface is used.

1.2.4 DALI (Digital Addressable Lighting Interface)

The Digital Addressable Lighting Interface is a standardized digital protocol with which illuminating devices can be controlled. DALI can be regarded as a successor to the 1-10V interface. It is a system that allows illuminating devices to be directly accessed individually via addresses. Like the 1-10V interface, the DALI interface is also electrically isolated from the AC power supply. As the line can be up to 300m in length, there are nearly no restrictions installing the system in large buildings. Moreover, it is possible to connect up to 64 illuminating devices together. DALI enables devices to be switched on and off directly via the BUS system by means of a control signal. This means it is not necessary to interrupt the AC power supply and the additional saving of an installation of a switch for disconnecting the operating voltage can reduce costs. [DALI-AG-03]

2 Dimming with the ICB2FL02G

Figure 4 shows the circuit diagram expanded to include the dimming function using the ICB2FL02G FL-Controller. An OSRAM Dulux® T/E 26W is used as the lamp.

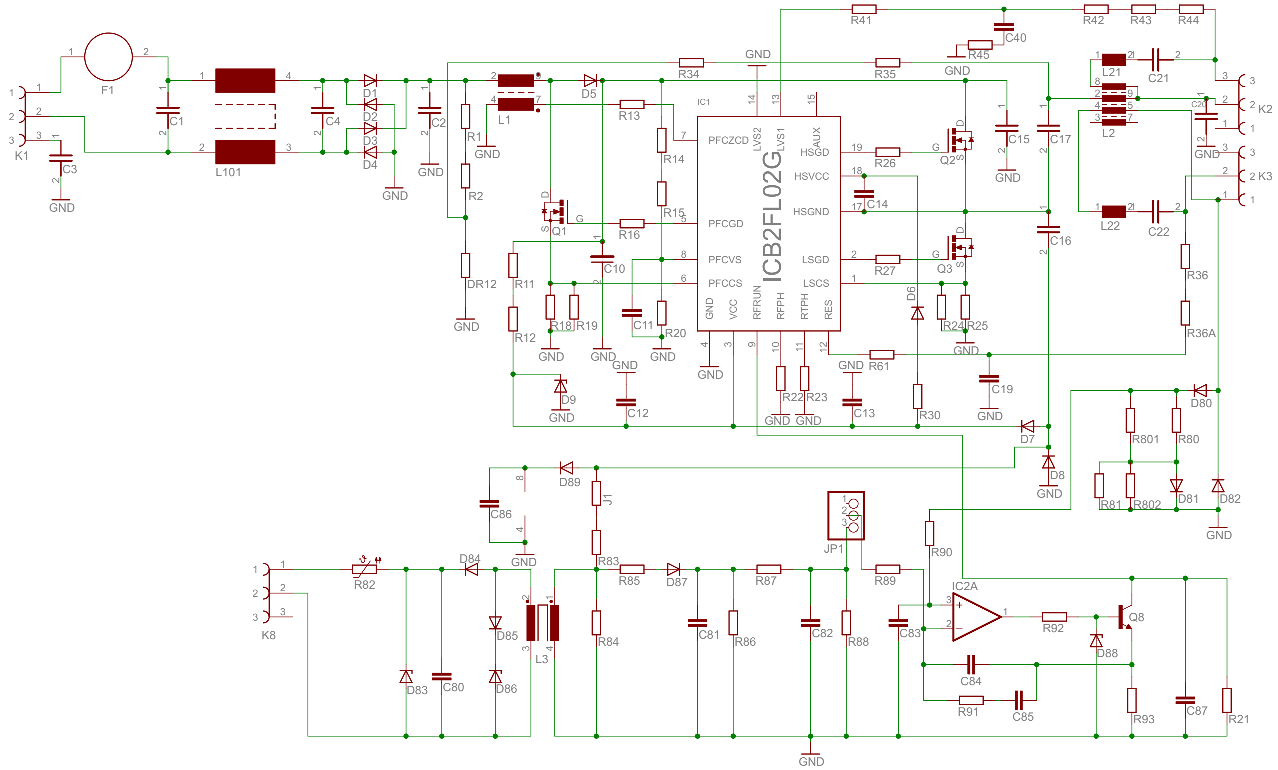


Figure 4 Dimmable Demoboard: Circuit diagram with dimming function

To change the working frequency during operation in this circuit it is necessary to influence the resistance at the RFRUN Pin. A voltage of 2.5V is provided at that pin from the IC. The current drawn from the pin is measured and the working frequency is varied as a function thereof. A higher current results in a higher working frequency. The lamp current is reduced due to the change in load-circuit impedance.

Continuous cathode heating is necessary to ensure that a sufficient cathode temperature is also attained in the dimming mode. For that, the heating circuit (consisting of L_{21} - C_{21} and L_{22} - C_{22}) needs to be matched to the frequency curve. This matching will be discussed in this first section, followed by a description of the solution using current controlled regulation with the 1-10V interface for setting the brightness.

2.1 Matching the heating circuit for cathode heating

With non-dimmable electronic ballasts, the function of the heating circuit for the cathodes is to maximize cathode heating during the preheating phase and drastically reduce it at the working frequency. Reduced losses in the lamp and increased efficiency in the run mode are the positive results. This is an expedient measure because at maximum brightness the lamp current suffices to maintain the cathodes at their emission temperature. The difficulty in the case of dimmable electronic ballasts is that the cathodes require additional heating when the lamp current is reduced. This is necessary because heating by means of the lamp current does not suffice to maintain gas discharging. This capability can be provided by matching the heating circuit to the respective frequency range. A brief overview of different matching is given to illustrate the voltage curve at the cathode over the frequency range. The resonant frequencies of these combinations are around 95kHz.

For this electronic ballast in a non-dimmable variant a combination using 127µH and 22nF is suitable. This combination reduces cathode heating drastically during operation. This feature is called cut off technology.

Figure 5 shows simulated voltage curves over the cathodes filament for different heating circuit matching.

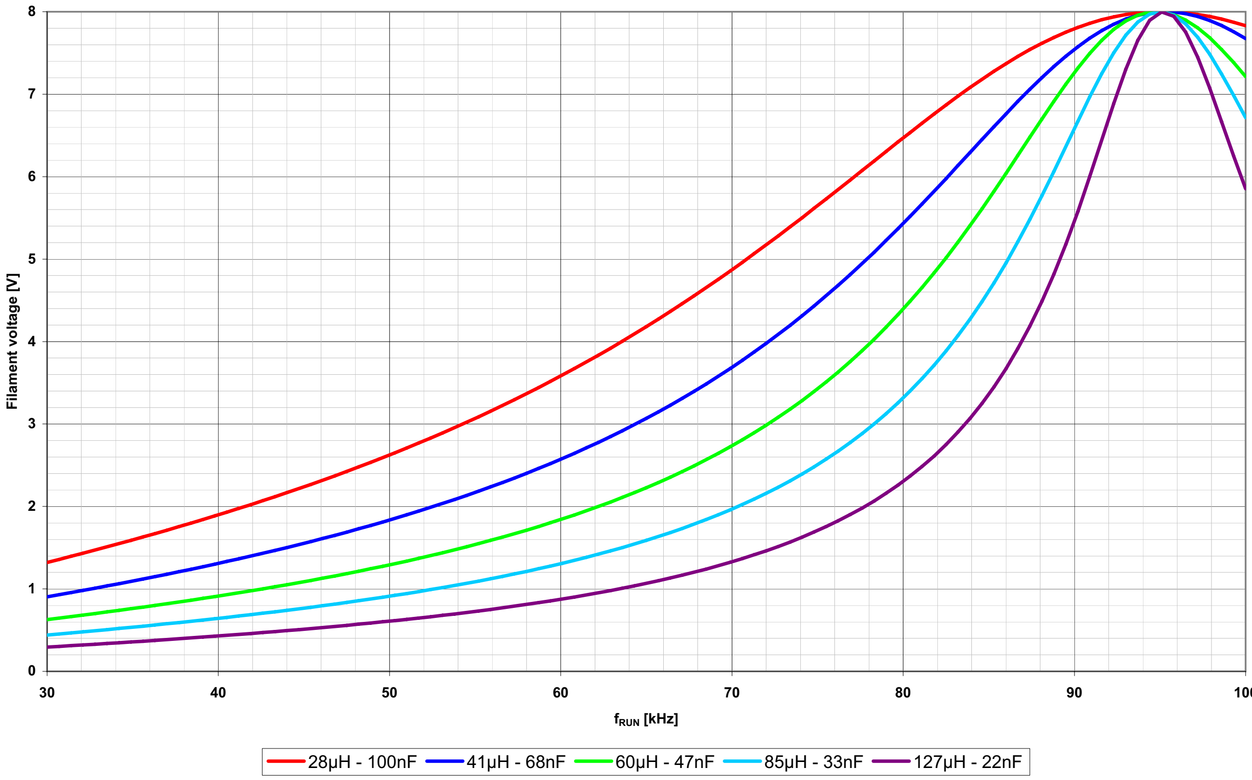


Figure 5 Heating circuit variants (simulation)

A reduction in cathode heating at the working frequency is achieved via the frequency-dependent change in impedance in the heating circuit. The preheating frequency is set in accordance with the heating circuit's resonant frequency to achieve maximum cathode heating at that working point.

By evaluating the dimming characteristic a check is carried out to determine if the cathode heating is sufficient in the case of dimmable electronic ballasts. The measurements performed for different heating circuits results in a combination of a 68µH inductor and 47nF capacitor as a good solution.

The resonant frequency of that combination is:

f_{Res}

$$f_{Res} = \frac{1}{2 \cdot \pi \cdot \sqrt{L \cdot C}} = \frac{1}{2 \cdot \pi \cdot \sqrt{68\mu H \cdot 47nF}} = 89kHz$$

This resonant frequency differs from that of the original heating circuit; the preheating frequency needs to be set to this value. The following formula for determining the preheating resistance RFPH is given in the ballast controller datasheet:

R_{RFPH}

$$R_{RFPH} = \frac{R_{RFRUN}}{\frac{fPH \cdot R_{RFRUN}}{5 \cdot 10^8 \Omega \cdot Hz} - 1} = \frac{12k\Omega}{\frac{89kHz \cdot 12k\Omega}{5 \cdot 10^8 \Omega \cdot Hz} - 1} = 10.56k\Omega \approx 11k\Omega$$

With a resistance of 11kΩ, the preheating frequency is very close to the resonant frequency of the heating circuit. This matching is retained for the following studies.

2.2 Operating principle

The aim of this concept is to build a regulator and to control the lamp current via a frequency change. For that it is necessary to measure and evaluate the lamp current. This is done using a combination of shunt resistor and diode. The setpoint value is set via a 1-10V interface and the control function is assumed by an operational amplifier (OP) working as a PI-Regulator. The OP output operates on a transistor that influences the resistance at the RFRUN Pin and in that way changes the working frequency. A new lamp current is set as a result.

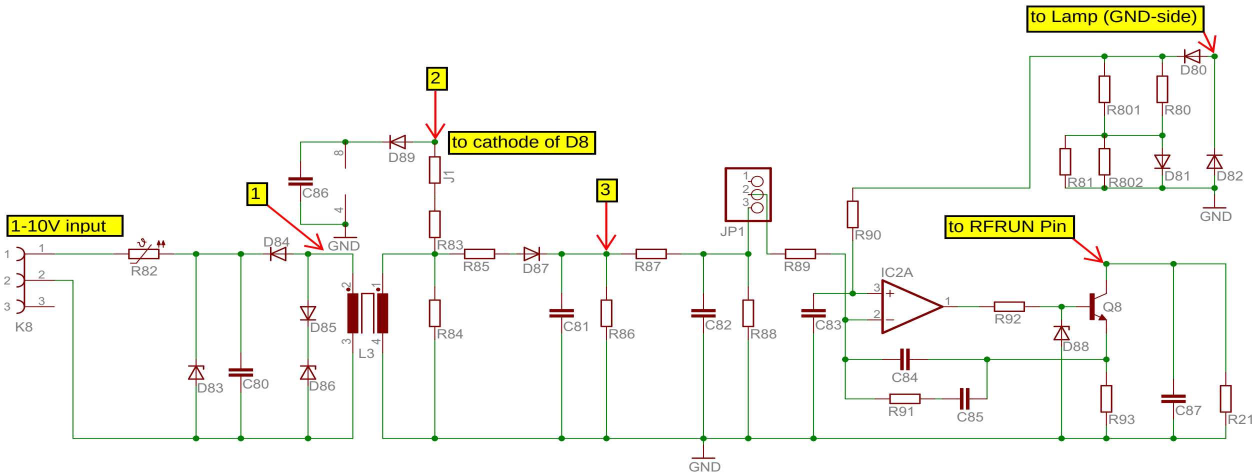


Figure 6 Dimming circuit

Figure 6 shows the additional circuitry required for expanding the original circuit into a dimmable ballast. The supply voltage for the operational amplifier is decoupled via D89 on the charge pump and smoothed at C86.

2.2.1 1-10V interface

The setpoint value for the brightness is set via the 1-10V interface. The red arrows in **Figure 6** indicate the respective measuring point for the two oscillograms shown further below and are labeled with the number of the respective channel.

Table 4 gives an overview of the individual components' functions.

Table 4 Overview of the individual components' functions

Reference	Function
R82	Protects against polarity reversal, overvoltage and inadvertent AC power supply connection at the interface
L3	1:1 transformer
D83	Protects C80 against overvoltage and polarity reversal of the interface in conjunction with R82
C80	Compensates disruptions on the interface voltage and smoothes the voltage during operation with an electronic potentiometer
D84	Blocks the interface voltage for the interface side of the transformer so that no DC will flow through it.
D85	Limit the maximum level on the transformer's interface side
D86	
R83	Limits the current for supplying the transformer
R84	Attenuates the transformer

Table 4 Overview of the individual components' functions

Reference	Function
R85	Decouple the positive voltage component over the transformer and perform smoothing
D87	
C81	
R86	Matches the voltage level at C81 to the desired value
R87	Divide the voltage to set V_{R86} to the desired range
R88	
C82	Delays changes in the setpoint value and prevents very fast changes. This capacitor can be increased in size if necessary to minimize flickering over the dimming range.

Described here is the mode of operation of the interface circuit when setting it via a DC level. The circuit section on the transformer's left-hand side is referred to the interface side and the section on its right-hand side is referred to the circuit side. The voltage injected at the interface can be measured at C80. If an AC voltage corresponding in amplitude at least to the forward voltage + interface voltage is then made available on the 1:1 transformer's circuit side, a current will flow on the interface side. The forward voltage of D84 is added to the applied voltage (measuring point 1, **Figure 7**, channel 1 red). This voltage amplitude is transformed to the circuit side and smoothed via R85 and D87 at C81 (measuring point 3, **Figure 7**, channel 3 green).

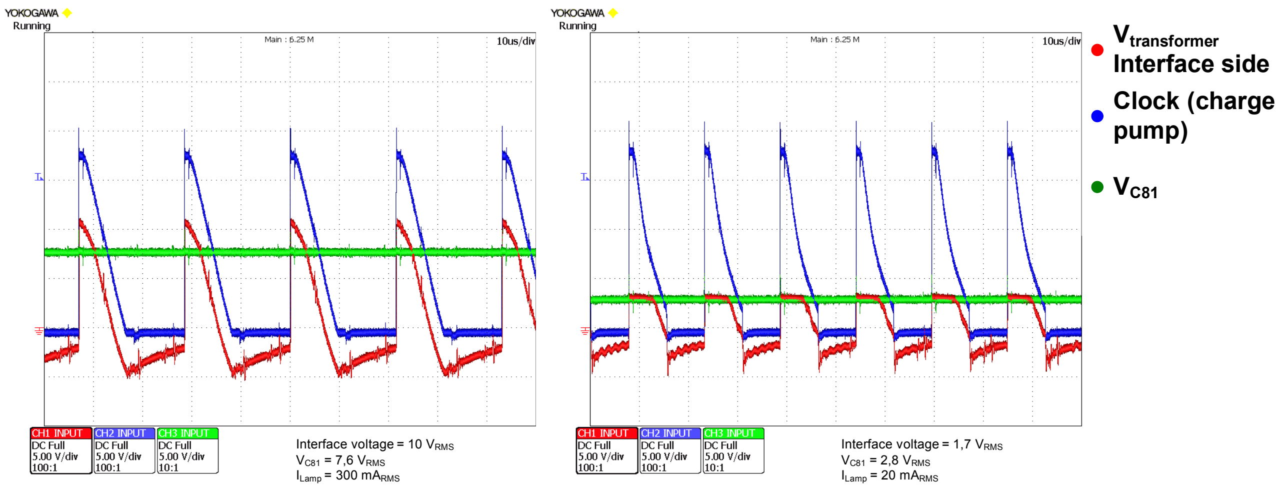


Figure 7 Oscillograms, interface

The voltage for driving the transformer is decoupled at the electronic ballast's charge pump (measuring point 2, **Figure 7**, channel 2 blue). This is done at the cathode of D8 (**Figure 4**). The minimum amplitude is determined by the forward voltage of D8, while the maximum amplitude is limited by D9 and D7 (**Figure 4**) to approximately 16V. This voltage is therefore very suitable for driving the interface transformer without the use of additional components. The change in frequency in the dimming range does not adversely affect the operation of the interface. The amplitude is set to the desired range for setpoint value setting via R87 and R88. C82 ensures a soft transition between different dimming settings. This capacitor can be further increased in size if necessary to achieve a greater time constant for changes in brightness.

If an electronic potentiometer is used for setting the setpoint value, then the basic function will - as described in the preceding section - be retained. However, no DC voltage for the basic level will be injected via C80 in this operating mode. This voltage drop is produced by the electronic potentiometer via the voltage pulses transmitted from the circuit side. In this operating mode, C80 has the additional function of voltage smoothing.

2.2.2 Lamp current sensing for the actual value

The lamp current is determined via a shunt resistor combined with a diode. The negative half-wave is routed directly to ground via D82. The positive half-wave, by contrast, is decoupled via D80 for measuring the actual value and generates a voltage drop at R80, R81 and D81. At high brightness levels or lamp currents the voltage drop is generated via R80 and D81. R81 has no effect in this mode because diode D81 is parallel to it and limits the voltage to its own threshold voltage. The maximum brightness can be set with R80. The minimum brightness is set with R81. In the case of small currents the voltage drop at R81 is not sufficient to exceed the threshold voltage of D81. For that reason the diode can be ignored when considering the minimum brightness. At maximum dimming the voltage drop is consequently generated via R80 and R81. So this circuit allows relatively independent setting of the minimum and maximum limiting values for controlling brightness.

2.2.3 Regulating circuit

A PI-Regulator is used for the controlling function. The setpoint value is passed by the 1-10V interface to the inverting OP (IC2) input via R89. The actual value is supplied to the OP via the low pass filter that consists of R90 and C83 and smoothes the voltage. R92 serves to limit the current, while Z-Diode D88 limits the voltage at the base of transistor Q8 so that the IC's RFRUN Pin will not be damaged in the event of large overswings. The minimum working frequency is set with R21 (in the non-dimmable variant, this resistor sets the working frequency to a fixed value). Via driving of Q8 the RFRUN Pin can be additionally loaded via resistor R93 and the working frequency thereby increased.

The control loop functions as follows: The actual value is proportional to the lamp current. If the current increases, the voltage will also increase at the non inverting OP input. The OP output will become more positive because of this voltage rise and the conductivity of transistor Q8 will increase. Loading of the RFRUN Pin will then increase the converter frequency. The lamp current decreases as the result of the higher working frequency. This compensates the previous deviation of the lamp current. So negative feedback occurs and the control loop is stable.

For calculating R93, which establishes the controller's possible correcting range, the following parameters were taken as the basis:

The RFRUN Pin's voltage source supplies 2.5V. Using the formula for calculating the resistance at different working frequencies, the following values are obtained:

R_{RFRUN_40kHz}

$$R_{RFRUN\_40kHz} = \frac{5 \cdot 10^8 \,\Omega \cdot Hz}{40kHz} = 12{,}5k\Omega \xrightarrow{selected} 12k\Omega := R_{21}$$

R_{RFRUN_80kHz}

$$R_{RFRUN\_80kHz} = \frac{5 \cdot 10^8 \,\Omega \cdot Hz}{80kHz} = 6{,}3k\Omega$$

All working points between these frequencies can be set via driving of Q8 with R93=6.8kΩ parallel to R21.

The operation of the regulator at the time of ignition is shown in **Figure 8** with the aid of an oscillogram.

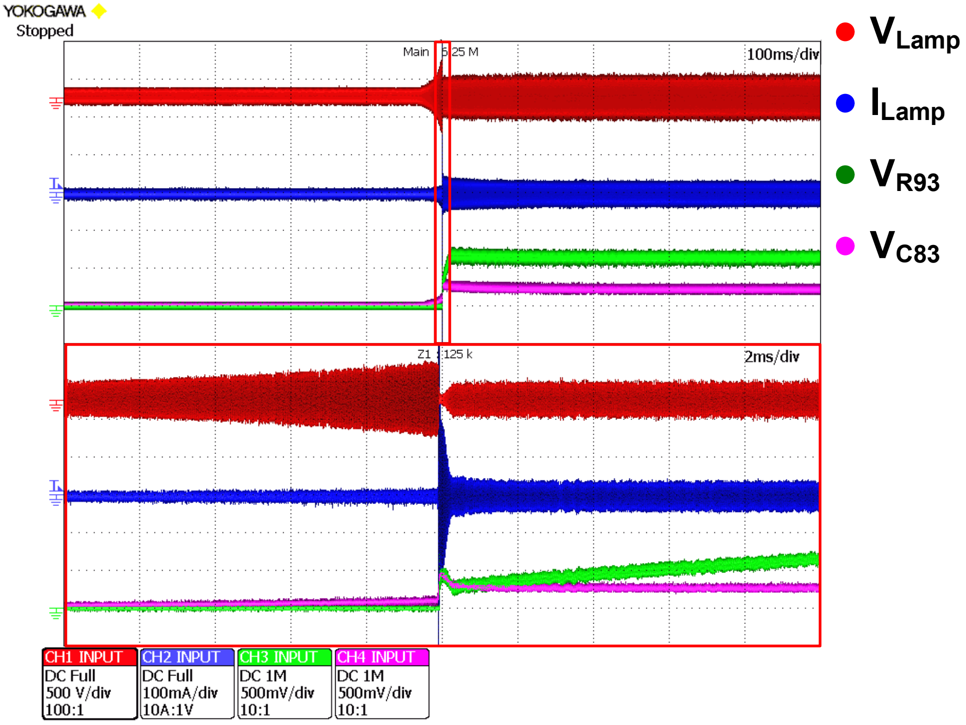


Figure 8 Regulator operation during ignition of the lamp

The oscillogram has two parts: The top part is set to a resolution of 100ms/Div, the bottom part is zoomed in to a resolution of 2ms/Div for observing the regulator's behaviour at the instant of ignition more closely.

2.2.4 Dimming characteristic

Figure 9 shows the dimming characteristic achieved using the solution described here. Heating circuit matching for cathode heating is 47nF and 68µH.

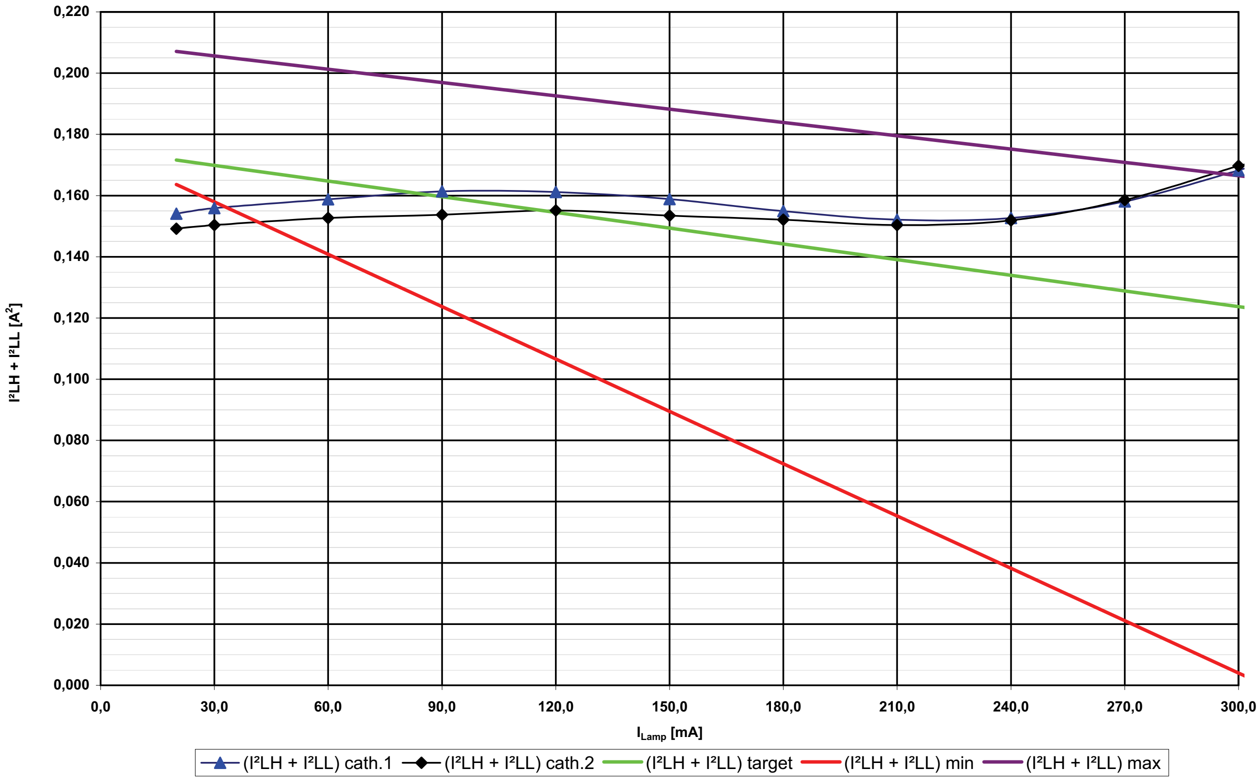


Figure 9 Dimming characteristic

It can be seen from the dimming characteristic that over a dimming range of about 10 to 100 percent, cathode heating is within the required limits. A further reduction in the lamp current to around five percent of the rated lamp current will result in cathode heating exceeding the required limiting values. The cathode heating circuit has to be modified by the components itself or by decoupling the windings on the swinging choke. In this way correct dimming operation down to one percent of the lamp's rated current can be implemented. There are no limitations of the IC to realise dimming ballasts with much lower brightness levels.

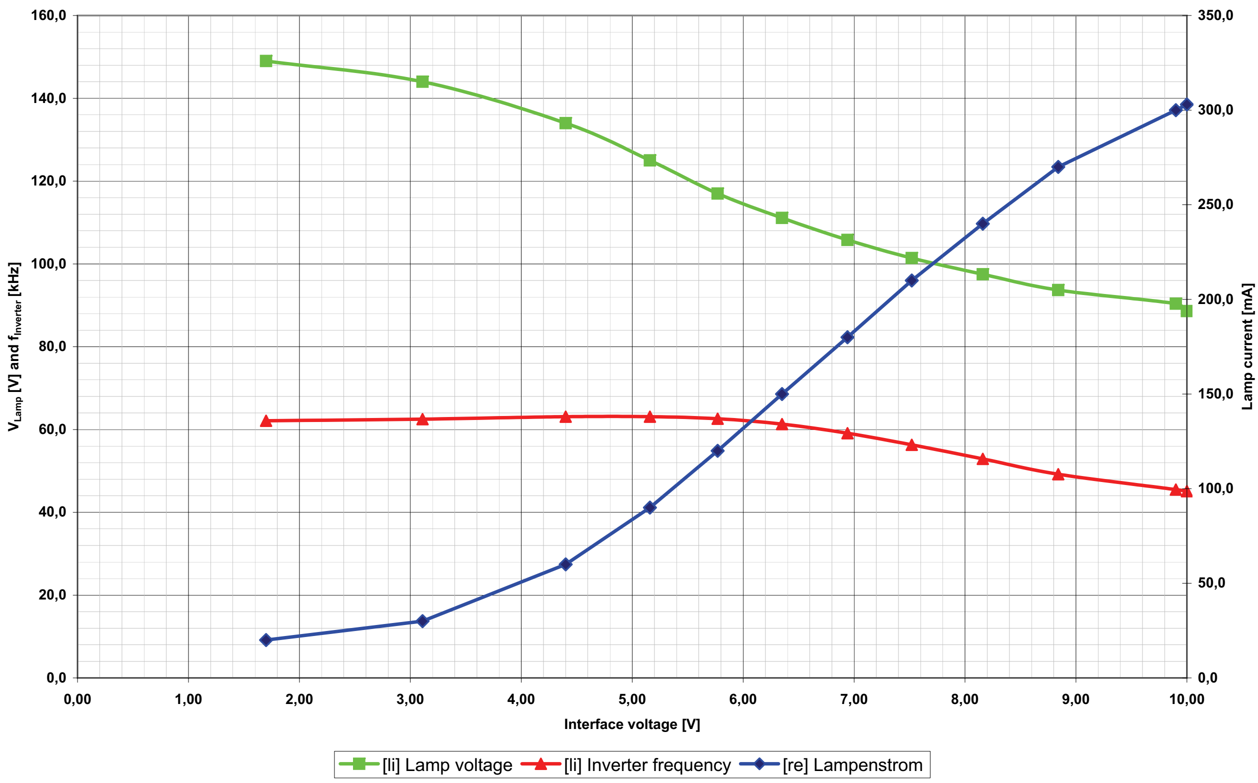


Figure 10 Interface: V, I, f characteristic

Figure 10 shows the correlation between lamp voltage, working frequency and lamp current as a function of the interface voltage. The lamp current slope here reduces in the direction of lower interface voltages. This accords with the human eye's sensitivity to brightness. A change in lamp current by, for instance, 10% is perceived far more intensely at minimum than at maximum brightness.

2.2.5 Notes

Figure 11 (left) shows the winding scheme of the swinging choke, with the winding distribution applied in this circuit for the heating windings. The decoupling windings are in each case located in the swinging choke's left hand and right hand winding chamber.

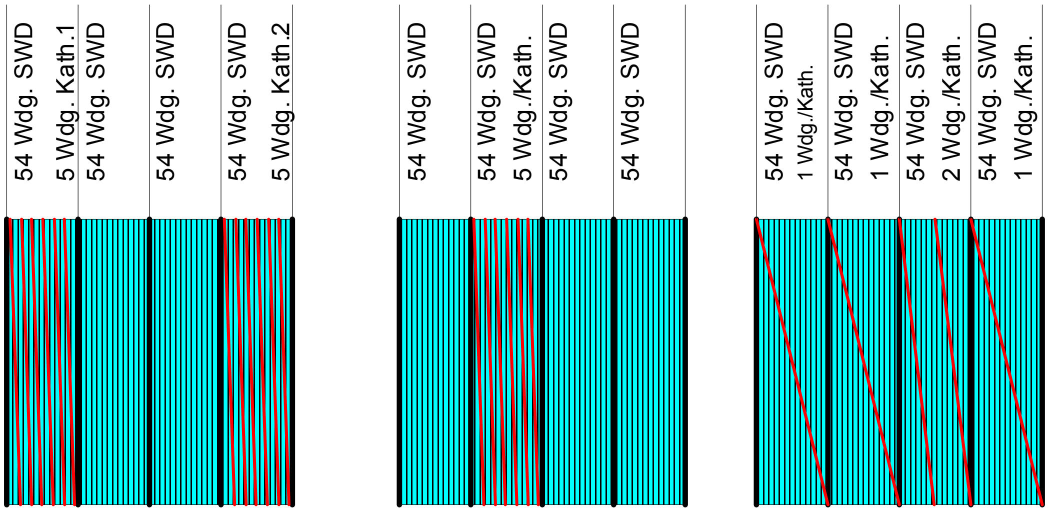


Figure 11 Swinging choke with chambers and windings

The best and most equal cathode heating will be attained if the decoupling windings are wound in the same chamber (Figure 11, center). In respect to mass production and in the case of devices containing many lamps, this is unfortunately rarely possible to put into practice since the available winding space is limited. Cathode heating will also be relatively equal if the decoupling windings for both cathodes are wound diagonally from one side to the other across the entire winding body. This winding scheme is shown on the right in Figure 11. This scheme can also be used when there are several lamps because the turns can be distributed evenly across all winding chambers. With this variant, however, it is especially important to consider the dielectric strength of the protecting lacquer because the ignition voltage is applied during the ignition phase between the cathodes and that can cause voltage breakdown between the windings. The position of the windings is also relevant to the output voltage level (heating voltage). The cathode heating voltage will be different when both windings are wound in one of the inner chambers. It will be somewhat higher if distribution diagonally from one side to the other. So there are numerous parameters for influencing cathode heating.

During adjustment of the overload detection it needs to be considered that the lamp voltage rises in the dimming mode. This characteristic can cause the overload detection to trigger even though no fault has occurred. Overvoltage of this kind in the dimming mode could conceivably be compensated by means of a frequency-dependent overload detection circuit.

Figure 12 shows, for comparison, two dimming curves with the same number of windings on the swinging choke. However, the heating windings are distributed differently on the winding body for the two measurements. The top diagram shows the results when the heating windings of both cathodes are wound absolute symmetrical to the air gap of the core. The bottom diagram shows the curve when the windings are distributed not exactly symmetrical to the air gap of the core.

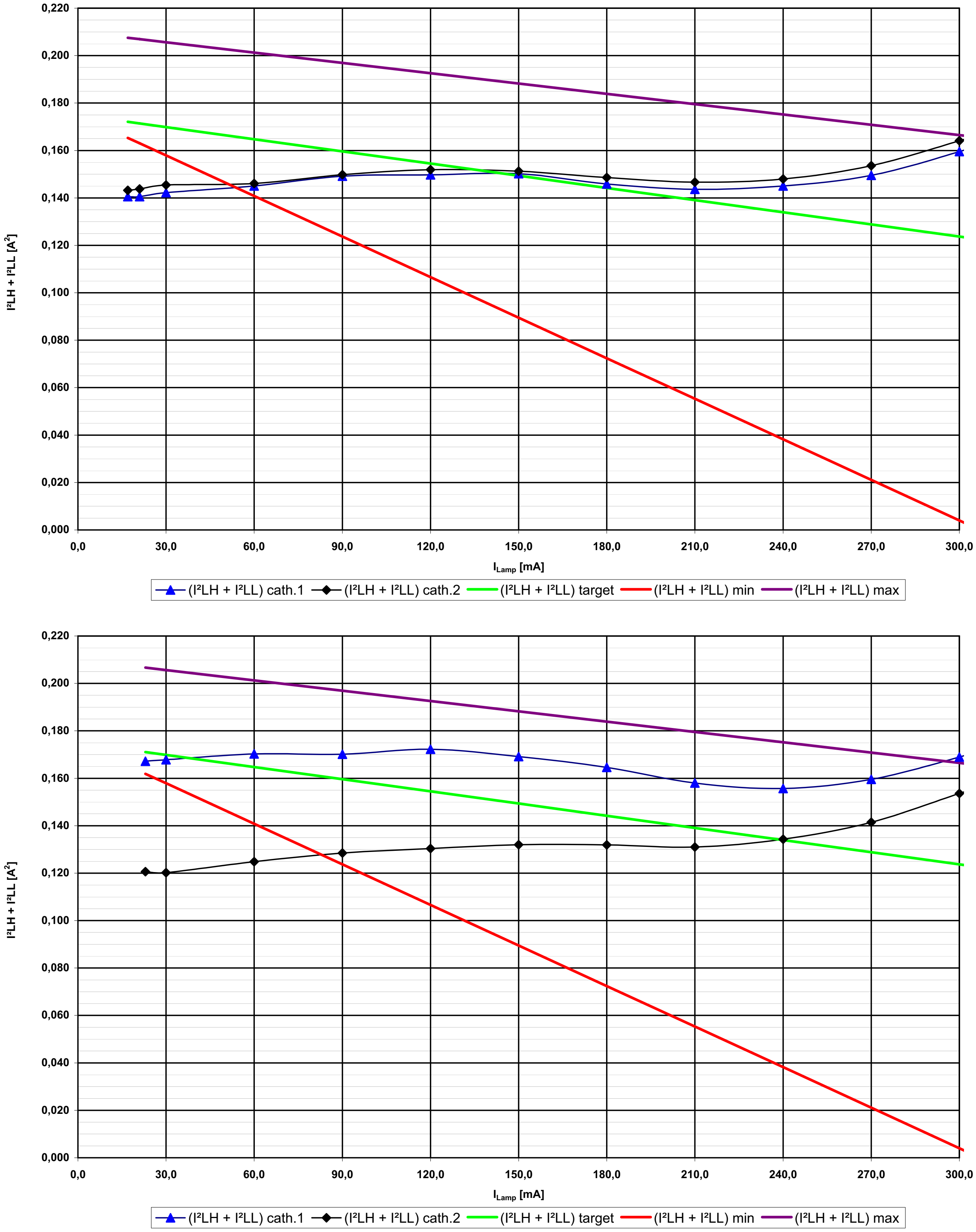


Figure 12 Cathode heating: Chamber distribution

As it can be seen from the dimming curves, even at low-brightness levels, differently distributed windings will already cause cathode heating to exceed the limiting values. To avoid subsequent re-matching, it should be considered that the winding distribution on the swinging choke can be implemented in volume production.

EOL1 detection must be matched so that the increased lamp voltage in the dimming mode will not result in detection of a failure.

Matching at the RES Pin for lamp detection needs to be adjusted because shunt resistors and diodes are inserted in the ground path for current sensing.

The temperature dependency of current sensing (diodes and resistors in the lamp's ground branch) influences the lamp current.

3 Layout, schematic and BOM

In this chapter the documentation for the demo board is included.

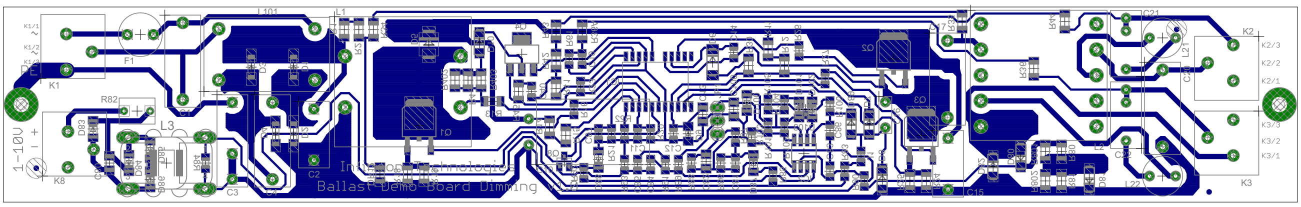


Figure 13 Demoboard PCB complete

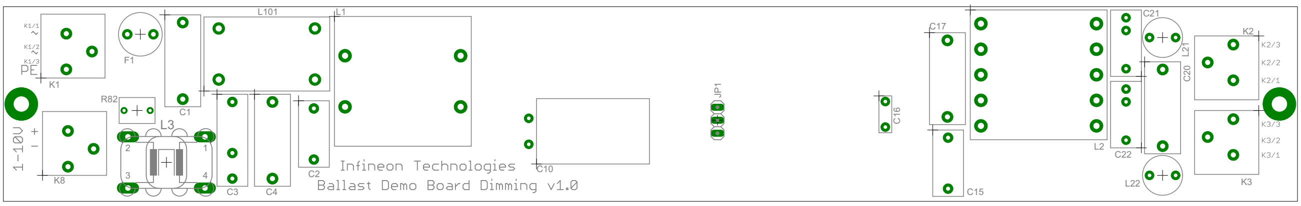


Figure 14 Demoboard mounting top

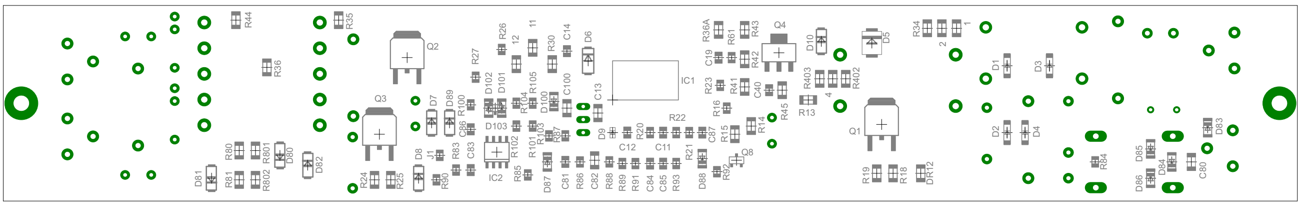


Figure 15 Demoboard mounting bottom

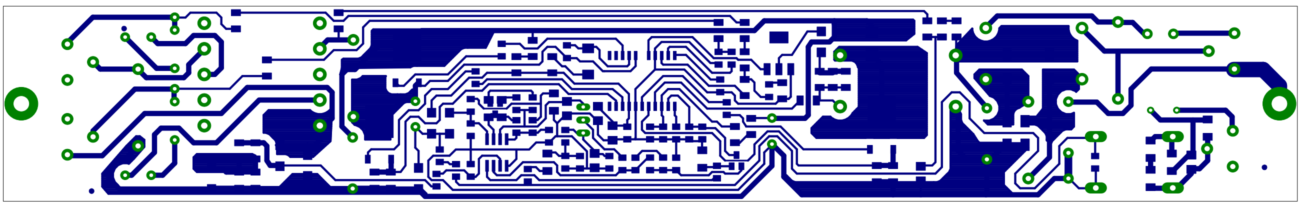


Figure 16 Demoboard copper bottom

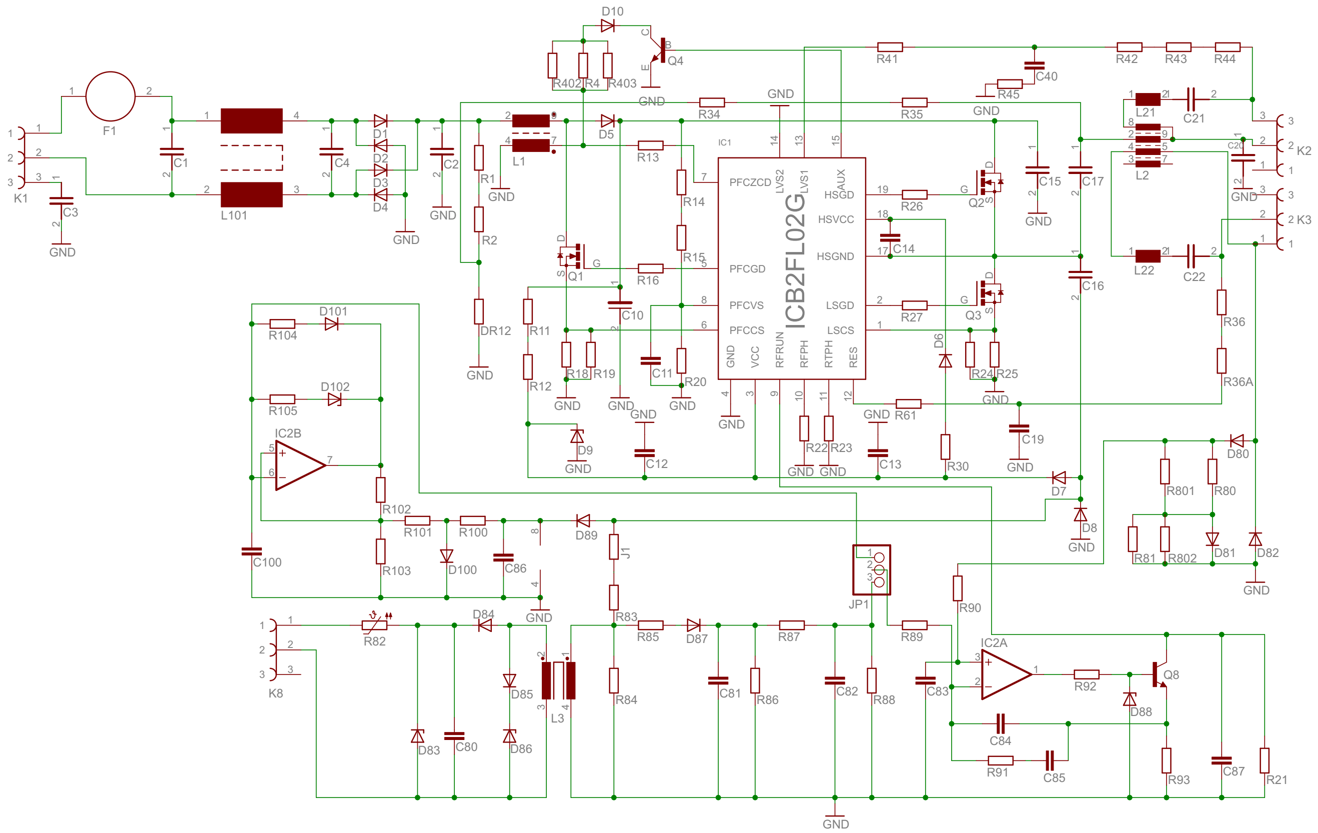


Figure 17 Extended Schematic - Dimming with ICB2FL02G with Auto Dim

Figure 17 shows an extended Schematic with an Auto-Dim functionality. In this mode, activation via a switch JP1, the ballast automatically dims between 5% and 100% up and down. This functionality can be additional assembled on the Demoboard for demonstration purposes.

The BOM (Figure 18) shows which components are necessary for realisation this functionality. An detailed explanation of this additional circuit is not given in this Application Note.

BOM: Demo-Dim 1x26W TC-TEL - VM - 180VAC to 270VAC - ICB2FL02G

ICB2FL02G

Input voltage = 180VAC to 270VAC

VBUS = 410 VRMS

				Package
F1	Fuse 1A fast	Wickmann	Typ 370	
	Fuse Holder			
K1/1	AC Input			
K1/2	AC Input		B-Nr: 250-203	
K1/3	PE			
K2/1	not connected			
K2/2	High Side Filament		B-Nr: 250-203	
K2/3	High Side Filament			
K3/1	Low Side Filament			
K3/2	Low Side Filament		B-Nr: 250-203	
K3/3	not connected			
K8/1	Dimming 1-10V (+)			
K8/2	Dimming 1-10V (-)		B-Nr: 250-203	
K8/3	not connected			
IC1	ICB2FL02G	Infineon		SO-20
Q1	SPD03N60C3	Infineon		D-Pack
Q2	SPD03N60C3	Infineon		D-Pack
Q3	SPD03N60C3	Infineon		D-Pack
D1…4	S1M	Fairchild	(1000V/1A/2µs)	DO-214AC
D5	MURS160T3	ON Semi	(600V/1A/75ns)	SMB
D6	BYG26J	Philips	(600V/1A/30ns)	SOD124
D7	BYG22D	Philips	(200V/1A/25ns)	DO214
D8	BYG22D	Philips	(200V/1A/25ns)	DO214
D9	BZX284C16	Philips		SOD110
L101	2x68mH/0.6A	Epcos	B82732F2601B001	
L1	1.58mH (PFC)	Epcos	B78326P7373A005	EFD25/13/9
L2	2.15mH	Epcos	T5639-51-01	EFD25/13/9
L21	68µH/800mA	Epcos	B82144B1683J	RM5
L22	68µH/800mA	Epcos	B82144B1683J	RM5
C1	220nF/305V/X2	Epcos	B32922C3224M000	RM15
C2	33nF/630V/MKT	Epcos	B32521N8333K000	RM10
C3	3,3nF/Y2	Epcos	B32021A3332K000	RM10
C4	220nF/X2/305V	Epcos	B32922C3224M000	RM15
C10	10µF/450V	Epcos	B43888C5106M000	single ended
C11	2,2nF/50V			.0805
C12	100nF/50V			.0805
C13	1µF/25V			.1206
C14	100nF/50V	Epcos		.0805
C15	22nF/630V/MKT	Epcos		RM10
C16	1nF/630V/MKT	Epcos	B32529C8102K000	RM5
C17	100nF/630V	Epcos	B32612A6104K008	RM15
C19	22nF/50V			.0805
C20	6,8nF/1600V/MKP	Epcos		RM15
C21	47nF/400V/MKT	Epcos	B32520-C6473K	RM7,5
C22	47nF/400V/MKT	Epcos	B32520-C6473K	RM7,5
C40	470nF/25V			.0805
R1	390kΩ			.1206
R2	390kΩ			.1206
DR12	110kΩ			.1206
R11	470kΩ			.1206
R12	470kΩ			.1206
R13	33kΩ			.1206
R14	820kΩ			.1206
R15	820kΩ			.1206
R16	22Ω			.0805
R18	1Ω			.1206
R19	not assembled			.1206
R20	10kΩ			.0805
R21	12kΩ (41,6kHz!)			.0805
R22	11kΩ (87,1kHz!)			.0805
R23	10kΩ (1000ms!)			.0805
R24	not assembled			.1206
R25	0.56Ω			.1206
R26	22Ω			.0805
R27	22Ω			.0805
R30	33Ω			.1206
R34	150kΩ			.1206
R35	150kΩ			.1206
R36	47kΩ			.1206
R36A	0Ω			.1206
LVS2 (pin14) is connected to GND				
R41	27kΩ			.1206
R42	150kΩ			.1206
R43	150kΩ			.1206
R44	150kΩ			.1206
R45	6,8kΩ			.1206
R61	0Ω			.0805
J1	0Ω			.0805

		Package
Components for Manual-Dimming		
IC2	LM258D	SO-8
JP1*	connect Pin 2 and 3 (0Ω)	1206
Q8	BC817	SOT23
D80	BYG22D	DO214
D81	BYG22D	DO214
D82	BYG22D	DO214
D83	Z-Diode 11V	MM1206
D84	LL4148	MM1206
D85	LL4148	MM1206
D86	Z-Diode 10V	MM1206
D87	LL4148	MM1206
D88	Z-Diode 2,7V	MM1206
D89	BYG22D	DO214
L3	2x27mH 1:1	
C80	2,2µF	.1206
C81	100nF	.0805
C82	4,7µF	.1206
C83	10nF	.0805
C84	82pF	.0805
C85	100nF	.0805
C86	100nF	.0805
C87	optional (1nF)	.0805
R80	3,3Ω	.1206
R801	3,3Ω	.1206
R81	27Ω	.1206
R802	not assembled	.1206
R82	PTC 884 (B59884C)	
R83	2,2kΩ	.0805
R84	15kΩ	.0805
R85	1,5kΩ	.0805
R86	120kΩ	.0805
R87	150kΩ	.0805
R88	12kΩ	.0805
R89	3,3kΩ	.0805
R90	3,3kΩ***	.0805
R91	3,3kΩ	.0805
R92	10kΩ	.0805
R93	6,8kΩ	.0805

***some older designs my have 10kΩ mounted, in this case please replace the 10kΩ resistor with 3,3kΩ.

Optional for AUX-Pin Damping		
D10	BYG26J	SOD124
Q4	BCP55	SOT-223
R4	300Ω	.1206
R402	300Ω	.1206
R403	300Ω	.1206
Optional for Auto-Dimming		
JP1	switch 3 pol.	
D100	LL4148	MM1206
D101	LL4148	MM1206
D102**	Z-Diode 11V	MM1206
D103	optional (BAS40-4)	SOT23
C100	4,7µF	.1206
R100	100kΩ	.0805
R101	33kΩ	.0805
R102	390kΩ	.0805
R103	18kΩ	.0805
R104	1MΩ	.0805
R105	10MΩ	.0805

* For Auto-Dimming functionality a 3 pol. Switch is required (see below)

** The polarity must be pole changed in respect to the Layout printing.

Figure 18 BOM of the Demoboard

4 Bibliographic references

Table 5 Bibliographic references

[DALI-AG-03]	DALI AG, http://www.dali-ag.org, May 2003
[OS-KLTN-03]	Osram, Osram Compact Fluorescent technical guide, January 1996

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