Application Note AN-1037

IR2167: Universal Input Dual Lamp Ballast Parallel Configuration for T8/32W and T8/36W

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This Application Note describes the IR2167 demo board for driving one or two fluorescent lamp types. The design contains an EMI filter, active power factor correction and a ballast control circuit.

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APPLICATION NOTE

AN-1037

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IR2167: Universal Input Dual Lamp Ballast Parallel Configuration forT8/32W and T8/36W

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Topics Covered

Features

- Drives 2 x 36W T8 or 2 x 32W T8 Lamp
- Can work with 1 or 2 lamps
- Universal Input Voltage: 90-250Vac
- High Power Factor/Low THD
- High Frequency Operation
- Lamp Fault Protection in both lamps (Open filament and broken lamp)
- Lamp Filament Preheating
- Low AC line and low DC bus Protection
- Failure to strike Protection
- Below resonance operation Protection
- End of Life Protection
- Thermal overload Protection
- **IR2167** HVIC Ballast Controller

Description

This Demo Board is a high efficiency, high power factor, fixed output electronic ballast designed for driving one or two fluorescent lamp types. The design contains an EMI filter, active power factor correction and a ballast control circuit using the IR2167. The IR2167 allows setting of the design parameters such as ignition voltage, preheat current and time, running voltage and power through external resistors and capacitors. This demo board is intended to ease the evaluation of the IR2167 Ballast Control IC, demonstrate PCB layout techniques and serve as an aid in the development of production ballasts using the International Rectifier IR2167.

Introduction

Driving two lamps in parallel as opposed to a series configuration has the advantage of lower voltage stress on the ballast output stage components, the wiring and the fixture sockets. Additionally, the resonant L and C associated with the lamps will be less sensitive to components tolerances due to the lower running lamp voltage compared to the series configuration. Parallel configuration also allows the ballast to continue working when 1 lamp is removed. For these reasons, the parallel configuration is becoming more popular.

NOTE: This configuration allows one lamp to remain running when the other is removed. This circuit switches off both lamps when 1 lamp fails, this avoids damaging the other lamp or the ballast. In case of a fault in one lamp you

have to reset the input line voltage, replace or remove the lamp damaged and re-apply the line. Never replace the lamp without resetting the line as this will not provide the correct preheat, ignition sequence.
In this application note we propose an additional circuit that is needed if automatic restart when replacing a failed lamp is necessary.

Electrical Characteristics

Parameter	Units	Value
Lamp Type		36W T8 or 32W T8
Input Power	[W]	74 for 36W T8 and 66 for 32W T8
Input Current	[Arms]	0.3
Preheat Mode Frequency	[kHz]	54
Preheat Mode Lamp Voltage	[Vppk]	630
Preheat Time	[s]	1
Ignition Ramp Mode Frequency	[kHz]	42
Ignition Voltage	[Vppk]	1600
Ignition Ramp time	[ms]	15
Run Mode Frequency	[kHz]	45KHz for 36W T8 48KHz for 32W T8
Lamp Run Voltage	[Vppk]	310 for 36W T8 420 for 32W T8
Input AC Voltage Range	[VACrms]	90..250VAC (50..60Hz)
Power Factor		0.99-0.98
Total Harmonic Distortion	[%]	10

Fault Protection Characteristics

Fault	Ballast	Restart Operation
Line voltage low	Deactivates	Increase line voltage
Upper filament broken	Deactivates	Reset Line and Lamp exchange
Lower filament broken	Deactivates	Reset Line and Lamp exchange
Failure to ignite	Deactivates	Reset Line and Lamp exchange
Open circuit (no lamp)	Deactivates	Reset Line and Lamp exchange
No 1 lamp	Activates	The other lamp stays on
End of Life	Deactivates	Reset Line and Lamp exchange

Functional Description

Overview

The IR2167 Demo Board consists of an EMI filter, an active power factor correction section, a ballast control section and a resonant lamp output stage. The output stage is for double lamp, parallel configuration, current-mode heating. The active power factor correction section is a boost converter operating in critical conduction mode with free-running frequency. The ballast control section provides frequency shifting control of a traditional RCL lamp resonant output circuit and is easily adaptable to a wide variety of lamp types. The ballast control section also provides the necessary circuitry to perform lamp fault detection, low line detection and shutdown. The circuit is designed to work with one or two lamps. If one of the lamps fails the ballast will shutdown and it is necessary to turn off the line and remove the faulty lamp to continue work with only a single lamp or to replace the faulty lamp.

Design Procedure to adapt the design to different lamp types

To adapt the design to different types of lamps you need to adjust the values of: LPFC, MPFC, MLO, MHO, CPH, RT, RPH, RRUN, RCS, ROC, CT, RDT, CRAMP, REOL4, CRES1, CRES2, LRES1 and LRES2. Do not change any others values !

1) Use the Ballast Designer Software to set the values of LRES1, LRES2, CRES1, CRES2, MPFC, MLO and MHO, RDT, CT, CRAMP, CS and to set the starting values of LPFC, CPH, RT, RPH, RRUN and ROC.

Cross both lamps (i.e. connect a filament or resistor to each lamp cathode position but not a good lamp) and measure the lamp voltage at ignition using a storage oscilloscope.

1) Set ROC to get the right ignition voltage ((decrease ROC to decrease the ignition voltage or decrease RCS to increase the ignition voltage)
2) Set RT to set the minimum frequency of the oscillator (increase RT to decrease the minimum frequency). Increase RT up to when the over-current protection is working in the worst case (i.e. the ballast shuts down at ignition) : One lamp connected normally and the second one crossed.
3) Select CPH to set the preheat time (increase CPH to increase the preheat time)
4) Set RPH to set the right preheat current (increase RPH to increase the preheat current)

Connect both lamps correctly and measure the input power

5) Select RRUN to set the correct power, RRUN is required only if the run frequency is above the ignition frequency (increase RRUN to increase the power on the lamp)

6) Verify the value of LPFC at each limit of the line/load range:

Minimum load and maximum input voltage:
If the COMP pin becomes less than 400mV the PF will not operate in a stable manner and it is necessary to increase LPFC.

Maximum load and minimum input voltage:
If the PF does not operate in a stable manner and audible noise can be heard from LPFC, it is necessary to decrease LPFC.

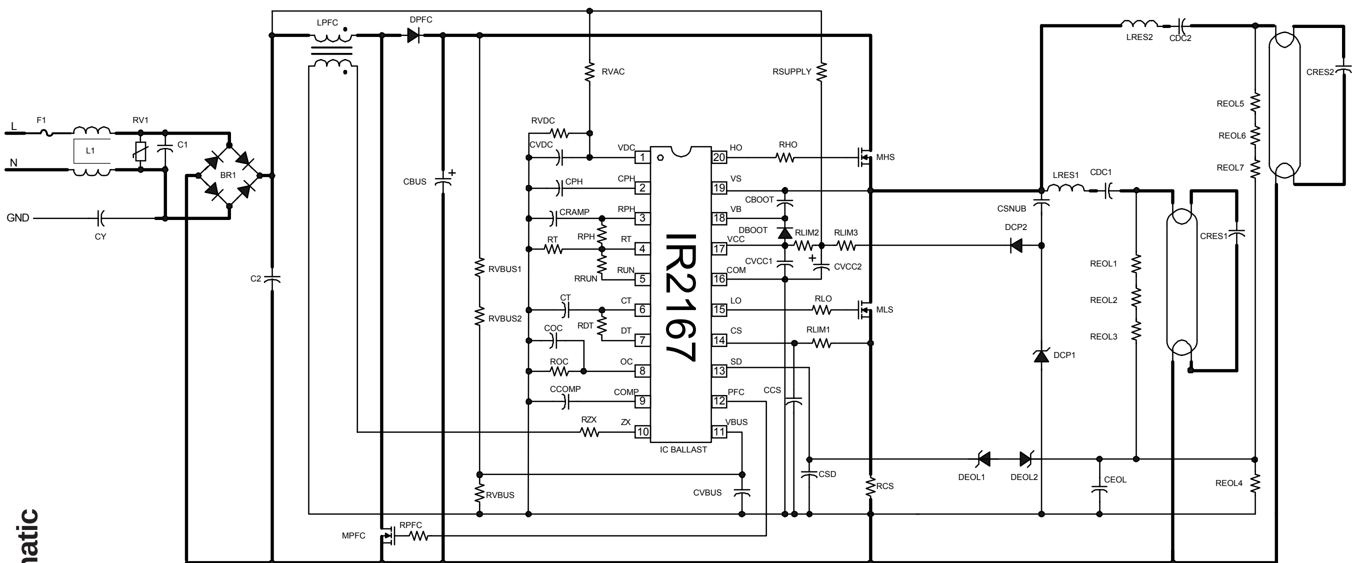
7) Set ROL4 to set the End of life protection to a percentage of the lamp voltage. For example, to set the protection threshold to 20% of the lamp voltage:

{(Vpklamp) x 20/100} x REOL4 / (REOL4 + REOL1 + REOL2 + REOL3)

should give approximately 7V.

(Fine tuning of this threshold can be done by trying different REOL4 values on the test bench)

2167 dual lamp parallel



Note: Thick traces represent high-frequency, high-current paths. Lead lengths should be minimized to avoid high-frequency noise problems

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Demo Board Schematic

Demo Board Bill of Materls

Item #	Qt	Manufacturer	Part Number	Description	Reference
1	1	International Rectifier	DF10S	Bridge Rectifier, 1A 1000V	BR1
2	1	Roederstein	WY0222MCMBF0K	Capacitor, 2.2nF 275 VAC Y Cap	CY
3	1	Dale	CW-1/2	Resistor, 0.5Ohm, 1/.2W	F1
4	1	Roederstein	F1772433-2200	Capacitor, 0.33uF 275 VAC	C1
5	3	Wima	MKP10	Capacitor, 0.1uF 400 VDC	C2, CDC1, CDC2
6	1	Panasonic	ERZ-V05D471	Transient Suppressor	RV1
7	1	Panasonic		Capacitor, 22uF 450VDC 105C	CBUS
8	1	Panasonic	ELF-15N007A	EMI Inductor, 1X10mH 0.7Apk	L1
9	1	B.I. technologies		PFC Inductor, 0.8mH 2.5Apk	LPFC
10	3	Panasonic	ECJ-2VB1HC104K	Capacitor, 0.1uF SMT 0805	CBOOT, CVCC1, COC
11	1	Panasonic	ECJ-2YB1C474K	Capacitor, 0.47uF SMT 0805	CSD
12	2			Capacitor, 0.47uF SMT 1206	CVDC, CRAMP
13	1			Capacitor, 0.56uF SMT 1206	CPH
14	1	Digi-key	PCC1900CT-N	Capacitor, 4.7uF 16V, SMT 1206	CEOL
15	1			Capacitor, 0.01uF SMT 0805	CVBUS
16	1	Panasonic	ECE-A1HGE02R2	Capacitor, 2.2uF 50VDC 105C	CVCC2
17	1	Panasonic		Capacitor, 0.68uF SMT 1206	CCOMP
18	1	Digi-key	311-1183-1-ND	Capacitor, 1nF 1KV SMT 1812	CSNUB
19	2	Panasonic		Capacitor, 8.2nF 1.6KV	CRES1, CRES2
20	1	Panasonic	ECU-V1H471KBN	Capacitor, 470pF SMT 0805	CT
21	2	Digi-key	MURS160DICT-ND	Diode, 1A 600V, SMT SMB	DBOOT, DPFC
22	2	Diodes	LL4148DICT-ND	Diode, 1N4148 SMT DL35	DCP2, DCP1
23	1	International Rectifier	IR2167	IC, Ballast Driver /PFC	IC BALLAST
24	2			Inductor, 2.0mH 2.5Apk	LRES1, LRES2
25	3	International Rectifier	IRF840	Transistor, MOSFET	MPFC, MHS, MLS
26	3	Panasonic	ERJ-8GEYJ22	Resistor, 22 ohm SMT 1206	RPFC, RLO, RHO
27	1	Panasonic		Resistor, 120K ohm SMT 1206	RVDC
28	1	Panasonic		Resistor, 39Kohm SMT1206	RPH
29	1	Panasonic		Resistor, 47K ohm SMT 1206	RRUN for T8 32W lamp
29	1	Panasonic		Resistor, 100K ohm SMT 1206	RRUN for T8 36W lamp
30	1	Yageo	270KQBK-ND	Resistor, 270K ohm ¼ watt	RSUPPLY
31	2	Panasonic	ERJ-8GEYJ680K	Resistor, 680K ohm SMT 1206	RVBUS1, RVBUS2
32	1	Panasonic		Resistor, 43K ohm SMT 1206	ROC
33	1	Panasonic		Resistor, 6.8K ohm SMT 1206	RDT
34	1			Resistor, 22K ohm SMT 1206	RT
35	2	Panasonic		Resistor, 10 ohm SMT 1206	RLIM2, RLIM3
36	1	Panasonic	ERJ-8GEYJ1K	Resistor, 1K ohm SMT 1206	RLIM1
37	1	Panasonic		Resistor, 0.68 ohm SMT 2010	RCS
38	1			Resistor, 2.2 megohm 1/4W	RVAC
39	1			Resistor, 22K ohm SMT 1206	RZX
40	1	Digi-Key	ZMM5231BDICTND	5.1V Zener 0.5W SMT	DEOL2
41	1	Digi-Key	ZMM5236BDICTND	7.5V Zener 0.5W SMT	DEOL1
42	1			Resistor, 13Kohm 1% SMT805	RVBUS
43	1			Capacitor, 100pF SMT 0805	CCS
44	6			Resistor, 220K ohm SMT 1206	REOL1, 2, 3, 5, 6, 7
45	1			Resistor, 160K ohm SMT 1206	REOL4
46	1	WAGO	235-203	Connector, 3 terminal	X1
47	1	WAGO	235-207	Connector, 7 terminal	X2
Total	67				

Inductor Specifications

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INDUCTOR SPECIFICATION

TYPE : LRES1, LRES2

CORE SIZE	E25/13/7 (EF25)	GAP LENGTH	1 mm
BOBBIN	HORIZONTAL	PINS	8

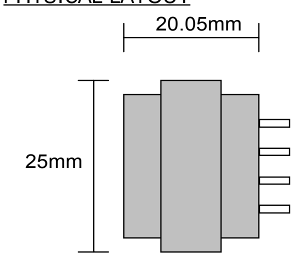
CORE MATERIAL: Philips 3C85, Siemens N27 or equivalent

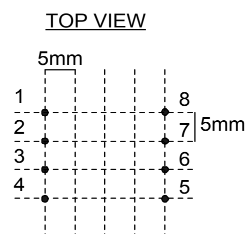
NOMINAL INDUCTANCE	2	mH
MAXIMUM CURRENT	2	Apk
MAXIMUM CORE TEMPERATURE	100	°C

WINDING	START PIN	FINISH PIN	TURNS	WIRE DIAMETER (mm)
MAIN	1	8	177	4 strands of AWG 32

ELECTRICAL LAYOUT

PHYSICAL LAYOUT





TEST (TEST FREQUENCY = 50kHz)

MAIN WINDING INDUCTANCE	MIN 1.9	mH	MAX 2.1	mH
MAIN WINDING RESISTANCE	MAX 1.5	Ohms		

NOTE : Inductor must not saturate at maximum current and maximum core temperature at given test frequency.

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INDUCTOR SPECIFICATION

TYPE : LPFC

CORE SIZE: E25/13/7 (EF25) — GAP LENGTH: 1 mm

BOBBIN: HORIZONTAL — PINS: 8

CORE MATERIAL: Philips 3C85, Siemens N27 or equivalent

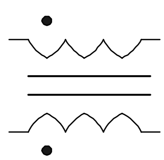
NOMINAL INDUCTANCE: 0.8 mH

MAXIMUM CURRENT: 2 Apk

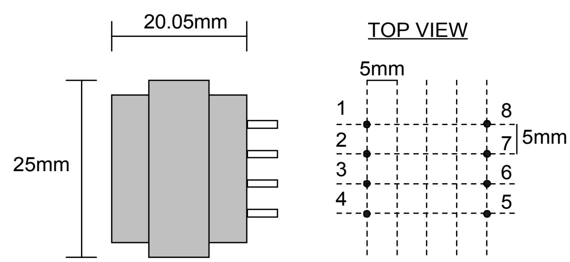
MAXIMUM CORE TEMPERATURE: 100 ºC

WINDING	START PIN	FINISH PIN	TURNS	WIRE DIAMETER (mm)
MAIN	1	6	111	4 strands of AWG 32
ZX	3	8	10	4 strands of AWG 32

ELECTRICAL LAYOUT



PHYSICAL LAYOUT



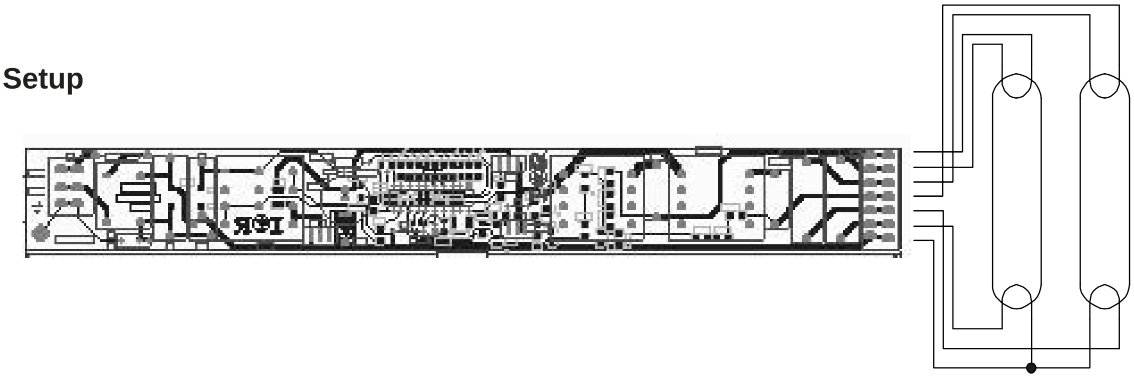
TEST (TEST FREQUENCY = 50kHz)

MAIN WINDING INDUCTANCE: MIN 0.7 mH — MAX 0.9 mH

MAIN WINDING RESISTANCE: MAX 1.5 Ohms

NOTE : Inductor must not saturate at maximum current and maximum core temperature at given test frequency.

Setup



Power Factor Correction Section

The power factor correction section contained in the IR2167 forms the control for a boost topology circuit operating in critical conduction mode. This topology is designed to step-up and regulate the output DC bus voltage while drawing sinusoidal current from the line (low THD) which is “in phase” with the AC input line voltage resulting in a high power factor.

Our simplified critical conduction mode power factor control circuitry has only four pins: VBUS which senses the output voltage from the PFC boost converter, COMP which is the error amplifier compensation pin, ZX which senses the inductor current and PFC which is the PFC FET gate driver.

No current sense input from the source of the PFC FET is required as our scheme does not use a multiplier and we do not need to sense the AC line. We also need only a single VCC supply because the PFC and ballast control are integrated on one IC. These features allow for a very reduced component count and a simplified PCB layout. The off time is determined from the inductor current detected at the ZX pin.

The on time is determined from the error amplifier which senses the bus voltage detected at the VBUS pin. We also have a further modulation of the on time in which near to the line zero-crossing it increases to reduce cross over distortion and therefore give a better THD.

The error amplifier can operate either with a high gain when we need fast response to changes in line or load or with a low gain when the line and load are constant and we need to optimize the power factor. Initially the gain is high to allow the DC bus to rise rapidly. The gain is also high during ignition so that the high current surge causes only a small transient in the DC bus voltage.
I
n RUN mode the gain is low because the load is effectively constant. We do not require rapid changes in the on time because this needs to remain constant during most of the AC line cycle to provide a good power factor.
In this way we do not need a trade off between bus regulation and good PF.

The power factor section works in conjunction with the ballast control section. The gain can be set high or low depending on the status of the ballast controller and also if the ballast is in fault mode, the PFC section will be disabled.

Protections

The fault logic includes the under voltage lockout and over temperature shutdown built into the IC.
There are three pins that sense the AC line voltage (VDC), the current (CS) and if there is no lamp connected or external shut down (SD).

Pin VDC is used for low AC line protection. RVDC set the protection threshold:
(RVDC / (RVDC + RVAC)) x VACmin = 5.1V.

Pin CS is used for undercurrent protection to protect for below resonance condition (the undercurrent threshold is fixed to 0.2V) and for over-current protection to protect for hard switching or current spikes due to failure to strike, lamp fault or no load.

Pin SD is the external shutdown pin combined with the end of life protection pin. It is internally polarized to 2V and inside the IC we have a 1 to 3V window comparator for end of life detection.

Ballast Control Section

The ballast control section of the IR2167 Ballast Control IC contains an oscillator, a high voltage half-bridge gate driver and lamp fault protection circuitry. The following page shows the operating sequence that occurs within the system.

Following that is a breakdown of the operation of the ballast in all of the different modes of operation.
Initially in the UVLO mode the IC draws very low current. Then VCC rises above the under voltage threshold and the oscillator starts up.

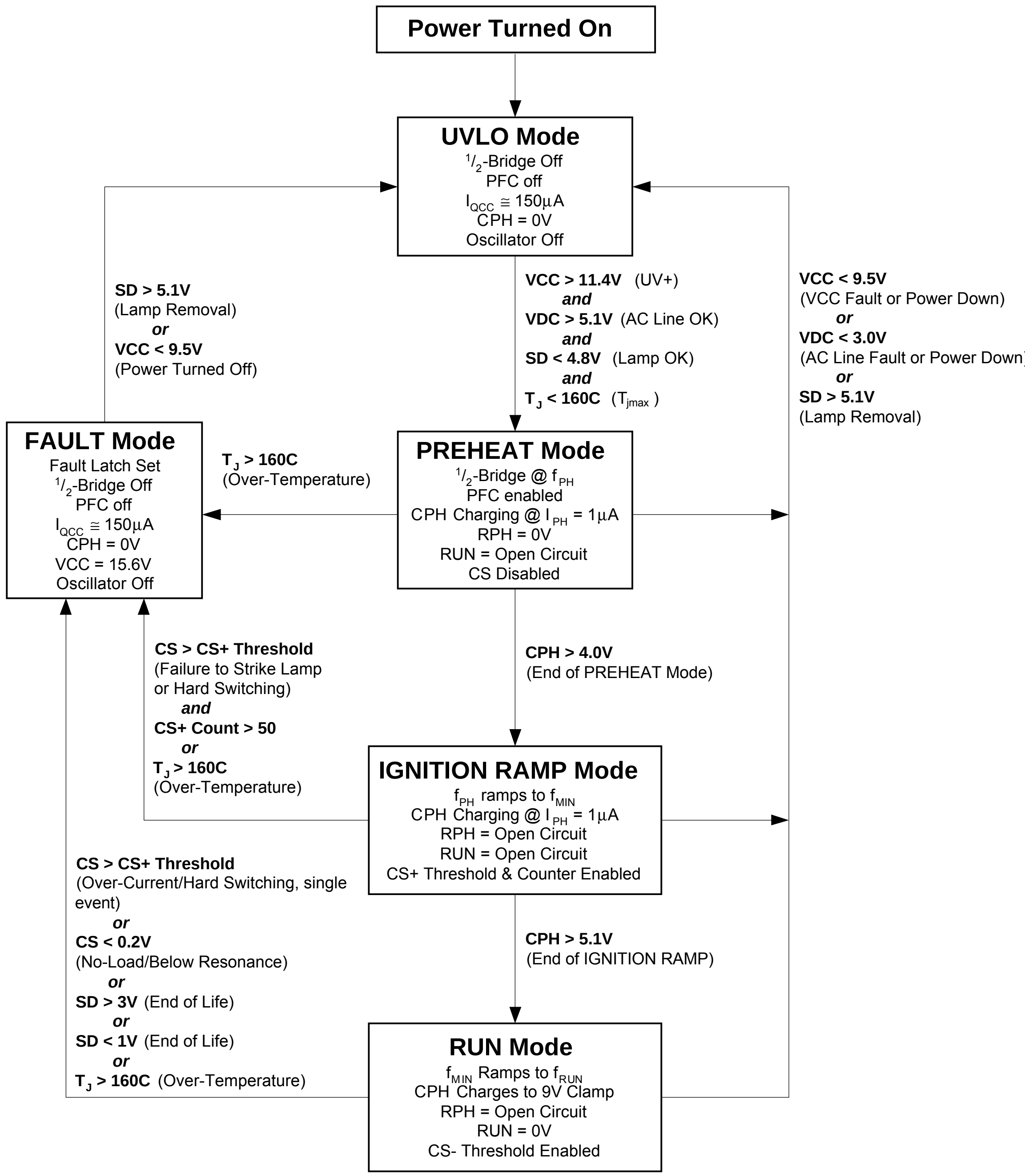
The oscillator runs initially at a very high start frequency and then it shifts to the preheat frequency until it sweeps down to ignition.

At ignition the oscillator runs at a frequency close to the resonant frequency of the LC output stage of the ballast producing a large voltage across the lamp.

After ignition the oscillator goes to the run frequency, which will provide the correct power to the lamp.
The IC will go into FAULT mode shutting down the oscillator if a fault condition occurs (over-current, under-current, over-temperature or end of life). In the FAULT state the IC is in a latched shutdown and will restart in the UVLO state only after resetting the line or removing the lamp.

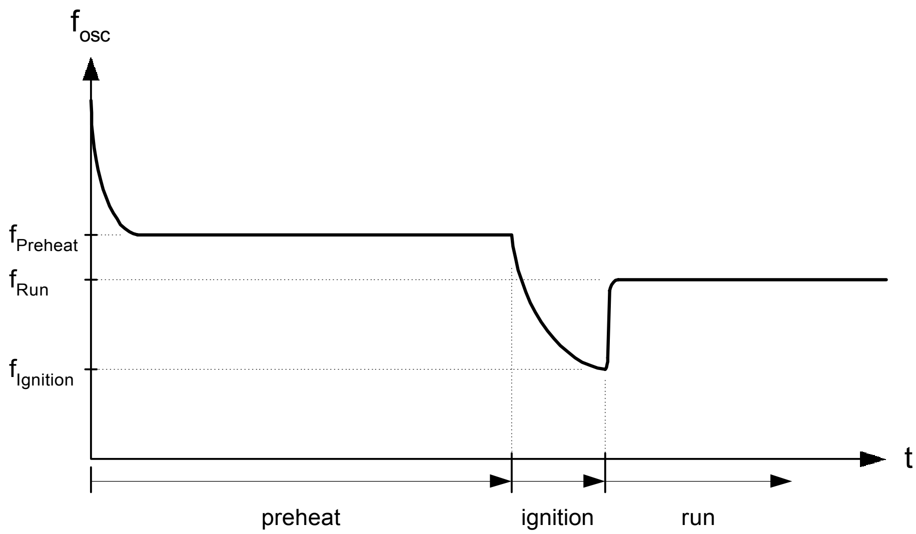
In case of low AC line, low DC bus or low VCC, the IC will go directly back to the UVLO state.

IR2167 Block Diagram



Operating sequence

This figure shows a plot of the half-bridge oscillation frequency as a function of time for all of the normal modes of operation: Preheat mode, Ignition Ramp mode and Run mode. As shown, there is an initial startup frequency that is much higher than the steady state Preheat mode frequency that lasts for only a short duration. This is done to



insure that the initial voltage appearing across the lamp at the startup of oscillation does not exceed the minimum lamp ignition voltage. If, at the initiation of oscillation of the half-bridge, the voltage across the lamp is large enough, a visible flash of the lamp can occur which should be avoided. This in effect is a cold strike of the lamp, which can reduce the life of the lamp

Startup Mode

When power is initially applied to the ballast, the voltage on the VCC pin of the IR2167 begins to charge up. The voltage for the IR2167 is derived from the current supplied from the rectified AC line through startup resistor RSUPPLY. During this initial startup when the VCC voltage of the IC is below its rising under-voltage lock-out threshold (11.4V), IC1 is in its UVLO and also its micro-power mode. When the voltage on IC1 reaches the rising under-voltage lockout threshold, the oscillator is enabled (this assumes that there are no fault conditions) and drives the half-bridge output MOSFETs. When the half-bridge is oscillating, capacitor Csnub, diodes DCP1 and DCP2 form a snubber /charge pump circuit which limits the rise and fall time at the half-bridge output and also supplies the current to charge capacitor CVCC2 to the VCC clamp voltage (approx. 15.6V) of IC1. When the rising under-voltage lockout threshold of IC1 is reached, it starts to oscillate and drive MOSFET MPFC to boost and regulate the bus voltage to 400 VDC. The power factor control starts only during preheat, so the bus is not yet boosted when the oscillator starts, this helps to prevent the lamp flash at the start up.

Preheat Mode

When the ballast reaches the end of the UVLO mode, the Preheat mode is entered. At this point the ballast control oscillator of the IR2167 has begun to operate and the half-bridge output is driving the resonant load (lamp) circuit. The ballast control section oscillator of the IR2167 is similar to oscillators found in many popular PWM voltage regulator ICs and consists of a timing capacitor and resistor connected to ground. Resistors RT and RPH program a current which determines the ramp up time of capacitor CT and resistor RDT determines the ramp down time. The downward ramping time of CT is the deadtime between the switching off of the LO (HO) and the switching on of the HO (LO) pins on the IR2167. The Preheat mode frequency of oscillation is selected such that the voltage appearing across the lamp is below the minimum lamp ignition voltage while supplying enough current to preheat the lamp filaments to the correct emission temperature within the Preheat mode period. The preheating of the lamp filaments is performed with a constant current during the Preheat mode.

The duration of the Preheat, as well as the mode of operation the ballast is operating in is determined by the voltage on the CPH pin of IR2167. At the completion of the UVLO mode, Preheat mode is entered and an internal current source is activated at the CPH pin, which begins to charge up capacitor CPH. The ballast remains in the Preheat mode until the voltage on the CPH pin exceeds the Ignition Ramp mode threshold (4V).

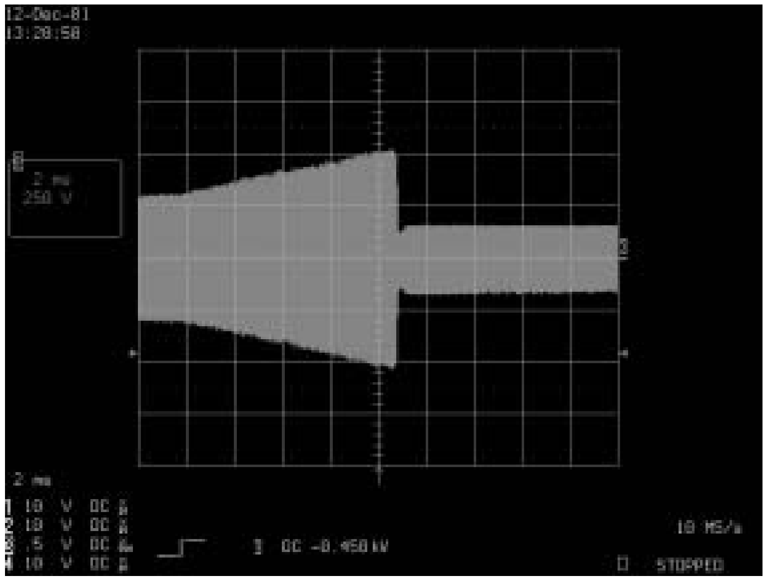
Ignition Ramp Mode

At the completion of the Preheat (4V < CPH pin < 5.1V) the ballast switches to the Ignition Ramp mode and the frequency ramps down to the ignition frequency. Resistor RPH is no longer connected directly in parallel with resistor RT. The shift in frequency does not occur in a step function but rather with an exponential decay because of capacitor CRAMP in series with resistor RPH to COM. The duration of this frequency ramp is determined by the time constant of the RC combination of capacitor CRAMP and resistor RPH. The minimum frequency of oscillation occurs at the end of this ramp and is determined by resistor RT and capacitor CT. This minimum frequency corresponds to the absolute maximum ignition voltage required by the lamp under all conditions. During this ramping downward of the frequency, the voltage across the lamp increases in magnitude as the frequency approaches the resonant frequency of the LC load circuit until the lamp ignition voltage is exceeded and the lamp ignites.

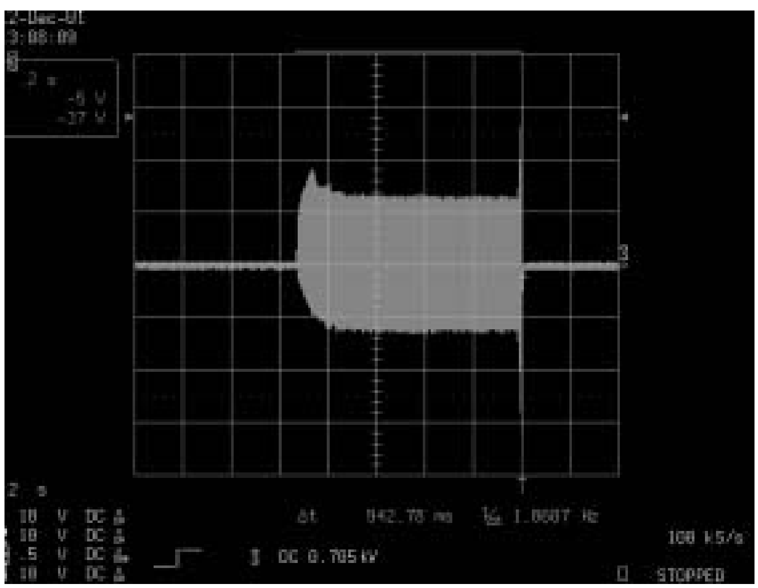
During the Ignition Ramp time the voltage on the CPH pin continues to ramp up until the voltage at the CPH pin of IC1 exceeds the Run mode threshold (5.1V). Over-current sensing, Under-current sensing and End of Life protection are enabled at the beginning of the Ignition Ramp mode.

Run Mode

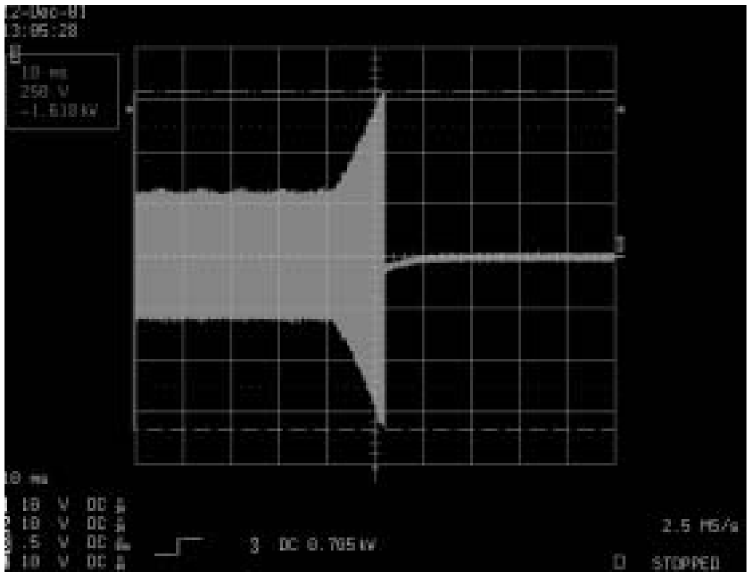
At the end of the Ignition Ramp mode (CPH pin > 5.1V) the ballast switches to the Run mode at which point the frequency is shifted to the run frequency. The run frequency is determined by the parallel combination of resistors RT and RRUN and capacitor CT. The running frequency is that at which the lamp is driven to the lamp manufacturer's recommended lamp power rating.



Preheat, Ignition and Run mode voltage in the lamp



Preheat, Ignition with 2 lamps crossed



Preheat and Ignition Ramp with 2 lamps crossed

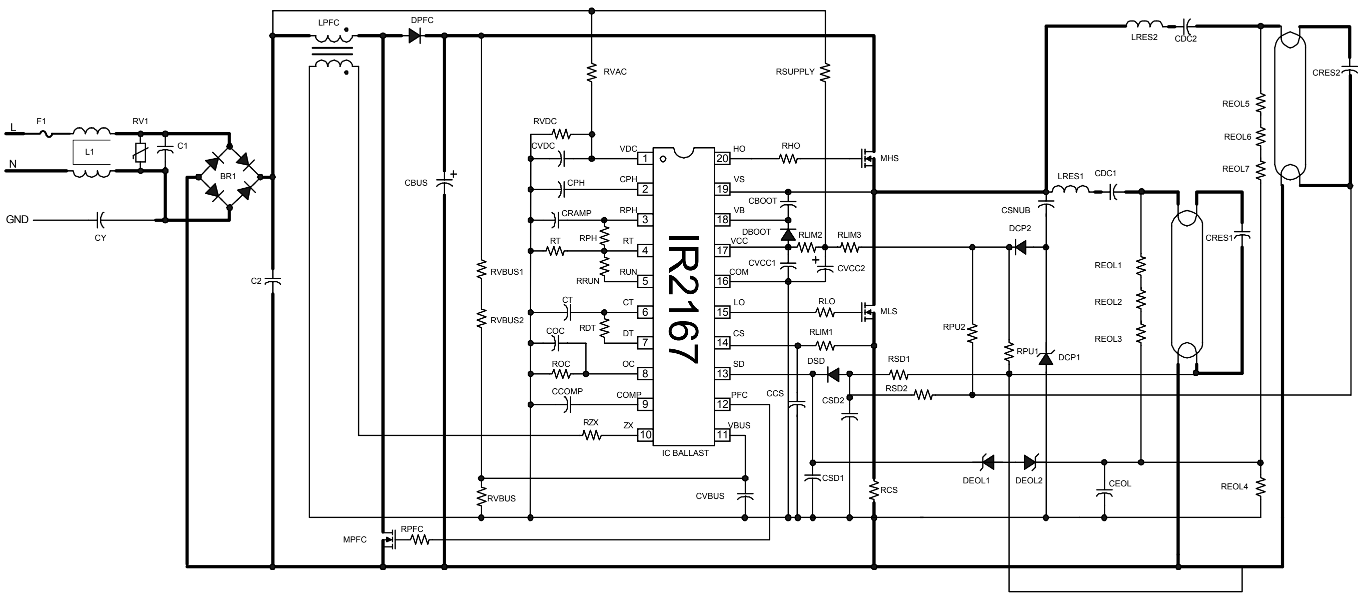
Control Circuit

If both lamps are removed or one lamp fails, hard switching will occur at the half-bridge and the resulting current will cause the voltage across the CS pin to trigger the over-current protection and shut-down. If one lamp fails, excessive voltage will appear across the other lamp and cause the ballast to shut down due to the over-current protection. If only one lamp is removed, the other will continue to work.

Additional Control Circuit for auto-restart after lamp replacing

The figure in the next page shows the additional control circuitry for lamp presence detection and automatic restart. The circuit discussed before can operate with only one lamp and, when replacing the other lamp, we will have cold strike of the lamp. This cold strike is not a problem in this case because of the way we have set the frequencies. We have verified that it does not cause hard switching and stress in the circuit. However, the cold strike is a problem when removing both lamps and replacing only one lamp, in this case, a cold strike can damage the lamp and over-stress the circuit. The circuit discussed before does not start automatically when we remove both lamps and we replace one lamp. It requires the line to be reset, to avoid cold strike.

In the new circuit in figure, the ballast re-starts automatically when reinserting one lamp. The additional circuit allows the reset of the IC to allow the ballast start in preheat mode. In this new circuit, when one lamp is replaced and in good condition, the ballast starts automatically with the right start sequence (start, preheat, ignition and run). When the second lamp is replaced, we will have a cold strike, however it is not dangerous.



Note: Thick traces represent high-frequency, high-current paths. Lead lengths should be minimized to avoid high-frequency noise problems

In case of removal of one or both lamps, an over-current condition causes the IC to go in a fault state (“FAULT” in the block diagram of the IR2167) where the IC is in latched shutdown. To return to micro-power state and restart from preheat, it is necessary to pull the SD pin above the threshold 5.1V.

The values of the network RPU1, RPU2, RSD1, RSD2, CSD1 are chose to allow the voltage on the DSD anode less than 2.6V with only 1 lower cathode connected. In this way, when one or both of the lower cathodes of the 2 lamps are in place, the shutdown pin (SD) is 2V and the DSD diode does not conduct. When both lamps are removed, VCC pulls the voltage at the anode of DSD high through the pull up resistors (RPU1, RPU2), when this voltage is more than 2.6V the diode will conduct and the SD pin of the IC is pulled above 5.1V and the IC enters micro-power mode. When one of the lower filaments is reinserted the SD pin is pulled low through resistor RSD and the small lower cathode resistance of the lamp so the IC returns to the preheat mode.

Fault Protection Characteristics

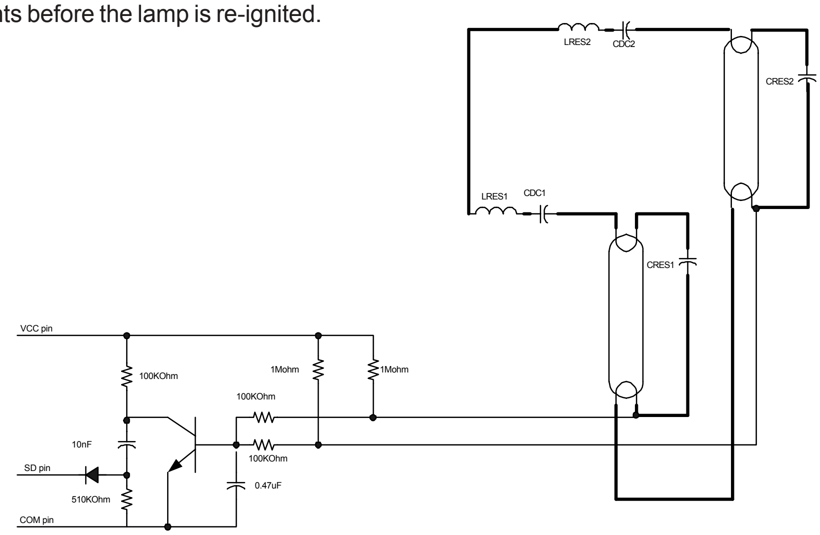
Fault	Ballast	Restart Operation
Line voltage low	Deactivates	Increase line voltage
Upper filament broken	Deactivates	Lamp exchange
Lower filament broken	Deactivates	Lamp exchange
Failure to ignite	Deactivates	Lamp exchange
Open circuit (no lamp)	Deactivates	Lamp exchange
No 1 lamp	Activates	The other lamp stays on
End of Life	Deactivates	Lamp exchange

Item #	Qt	Manufacturer	Part Number	Description	Reference
1	1	Panasonic	ECJ-2YB1C474K	Capacitor, 0.47uF	CSD1
2	1			Capacitor, 0.47uF	CSD2
3	1	Diodes	LL4148DICT-ND	Diode, 1N4148	DSD
4	2	Panasonic	ERJ-8GEYJ680K	Resistor, 100Kohm	RSD1, RSD2
5	2			Resistor, 1Mohm	RPU1, RPU2
Total	7				

Additional Control Circuit to avoid cold strike

The SD circuit has to be modified in this way to have auto-restart with preheat when one lamp is re-inserted when the other lamp is still running.

This figure shows the additional control circuitry for lamp presence detection and automatic restart. When one of the lamps is removed, the base of the transistor (an NPN bipolar transistor may be used e.g. FMMT2222ACT Zetex) is pulled high. This turns Q1 on discharging the capacitor, but does not affect SD, which remains at 2V. The other lamp will therefore remain running. When the lamp is reinserted, Q1 is turned off and a short voltage pulse appears in the SD pin via the diode (you can use 1N4148 diode). This pulse momentarily pulls SD above the 5.1V threshold and resets the IR2167. As SD falls back to 2V, the IR2167 is restarted in preheat mode. This ensures proper heating of the filaments before the lamp is re-ignited.



Additional Control Circuit to avoid striations during start-up

After initial start-up you could have some striations (visible dark rings) on the lamps for a short period (a few minutes) particularly when the lamp has been off for some time and is cold. The simplest way to avoid this problem is to add a resistor in parallel to CDC1 and a resistor in parallel to CD2. The value should in the order of 100kOhm 0.5W.

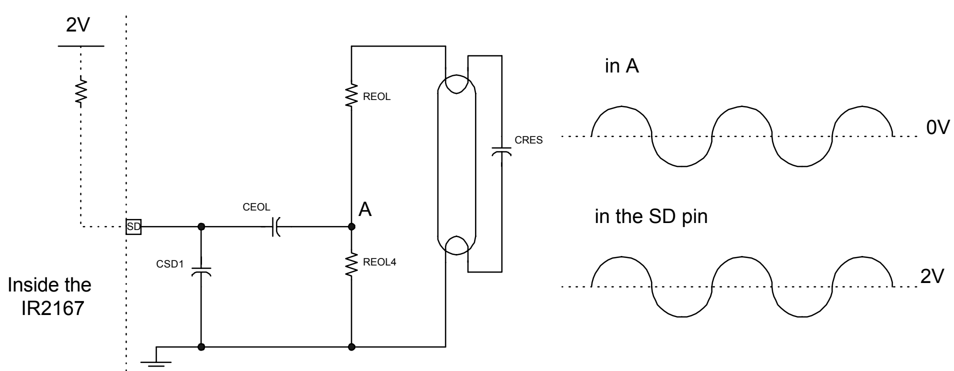
During Preheat however, this resistor adds some DC current in the lamp. This small DC component on the current solves the striations problem, but causes the CEOL capacitor to charge to several volts during preheat which can cause the end-of-life protection circuit to be triggered at the beginning of run mode when the SD pin becomes enabled.

A possible solution to this problem is to introduce a delay greater than the preheat time for this protection by increasing the value of the CEOL capacitor. In this case the capacitor value that is required is large 50-100uF and the capacitor cannot be polarized since it needs to be able to go negative as well as positive depending on the direction of the lamp voltage asymmetry caused by the rectifying effect at end of life, unless back to back electrolytics were to be used.

To avoid the need for such a large capacitor it is possible to place a diode between RPH pin and shutdown pin (anode to SD pin). This diode will limit the voltage that the capacitor can charge to during preheat (RPH is switched to 0V inside the IC during preheat then charges to 2V during ignition and stays 2V during run mode). When the RPH voltage increases to 2V the SD pin is released and operates normally (RPH will not sink current during in run mode). In this way the value of the CEOL capacitor can be reduced (we did not test this solution in our lab).

Improved End of Life solution

The same PCB can be used with a different end of life configuration. It is needed to put a capacitor in the place of DEOL1 diode (100nF), to short DEOL2 (0 Ohm resistor) and to reduce the capacitor in the SD pin CSD1 (100pF). The resultant circuit is shown in the following figure.



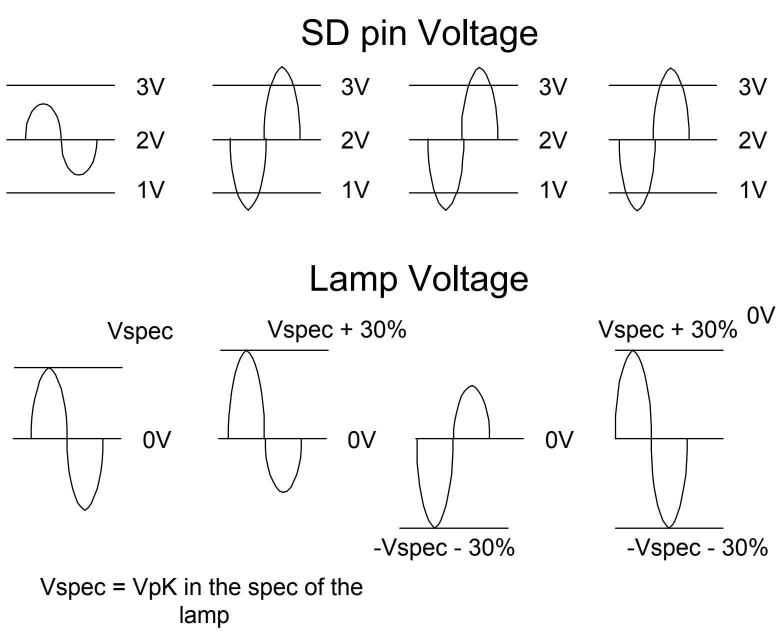
Improved End-of-life circuit

The value of REOL4 is changed so that the lamp voltage during normal running produces a signal with 1.5 Vppk at the point (A) were the capacitor CEOL connects it to the SD pin. The SD pin is internally biased at 2V with 1Mohm impedance and therefore at the SD pin a signal varying between 1.25V and 2.75V will normally be present due to the AC coupling of the 100nF capacitor (CEOL).

During end of life the lamp voltage may increase either symmetrically (AC end of life, due to a similar deterioration in both cathode) or asymmetrically (DC end of life, due to a deterioration only in one cathode). This circuit has the advantage of detecting both failure modes.

The peak to peak voltage at the SD pin will increase (with 2V DC offset) in either case until the positive peak exceeds 3V and/or the negative peak drops below 1V, therefore triggering the window comparator shutdown. The threshold of end of life can be adjusted by changing the value of REOL4 (usually 30% Vlamp is required).

The following Figure shows the voltage in the SD pin and the voltage on the lamp in these 4 cases: no end of life, DC end of life (upper cathode deteriorated and lower cathode deteriorated) and AC end of life (both filaments deteriorated in the same way).



Voltage in the SD pin and voltage on the lamp in these 4 cases: no end of life, DC end of life and AC end of life.