International
IOR Rectifier

IRPLDIM1

IR2159 Dimming Ballast Control IC Design Kit

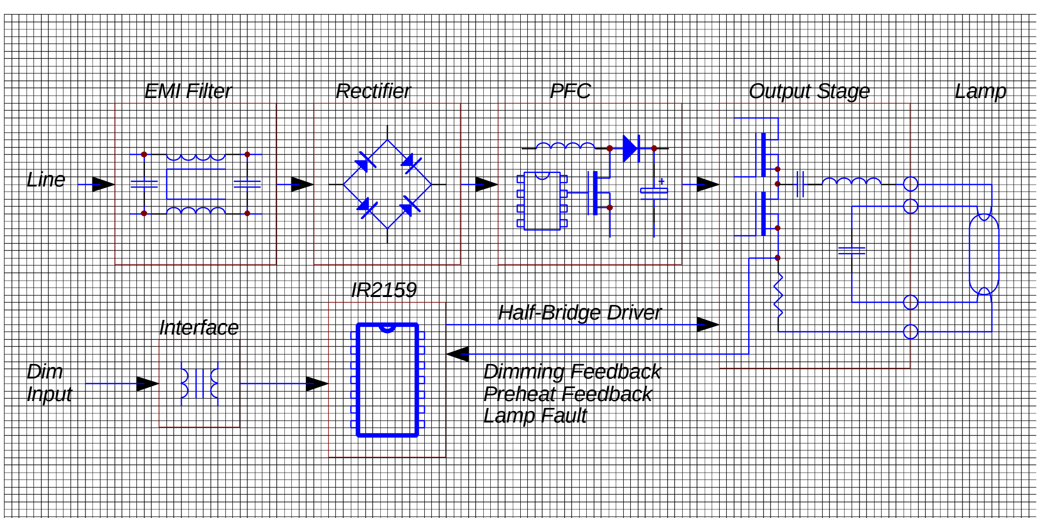
Features

- Drives: 1 x 32W T8 Lamp (IRPLDIM1U)
  1 x 36W T8 Lamp (IRPLDIM1)
- Input: 90-140VAC/60Hz (IRPLDIM1U)
  185-265VAC/50Hz (IRPLDIM1)
- High Power Factor/Low THD
- High Frequency Operation
- Lamp Filament Preheating
- Lamp Fault Protection with Auto-Restart
- Brownout Protection
- **IR2159** HVIC Ballast Controller

Description

The IRPLDIM1 is a high efficiency, high power factor, dimming electronic ballast designed for driving rapid start fluorescent lamp types. The design contains an EMI filter, active power factor correction and a ballast control circuit using the IR2159. This demo board is intended to ease the evaluation of the IR2159 Dimming Ballast Control IC, demonstrate PCB layout techniques and serve as an aid in the development of production ballast's using the International Rectifier IR2159.

Dimming Ballast Block Diagram



Demo Board Data Sheet intended for design information only.
Subject to change without prior notice.

Electrical Characteristics

Parameter	Units	Value (IRPLDIM1)	Value (IRPLDIM1U)
Lamp Type		36W T8	32W T8
Input Power (100%)	[W]	36	32
Input Current (100%)	[Arms]	0.16	0.27
Filament Preheat Current	[Arms]	0.6	0.6
Preheat Mode Lamp Voltage	[Vrms]	220	220
Preheat Time	[s]	1.0	1.0
Input AC Voltage Range	[VACrms]	185..255/50..60Hz	90..140/50..60Hz
Input DC Voltage Range	[VDC]	250..350	100..180
Power Factor		0.98	0.99
Total Harmonic Distortion	[%]	<15	<10
Maximum Output Voltage	[Vpk]	750	750

Note: Measurements performed with input AC line voltage = 120Vrms (IRPLDIM1U)
230Vrms (IRPLDIM1)

Fault Protection Characteristics

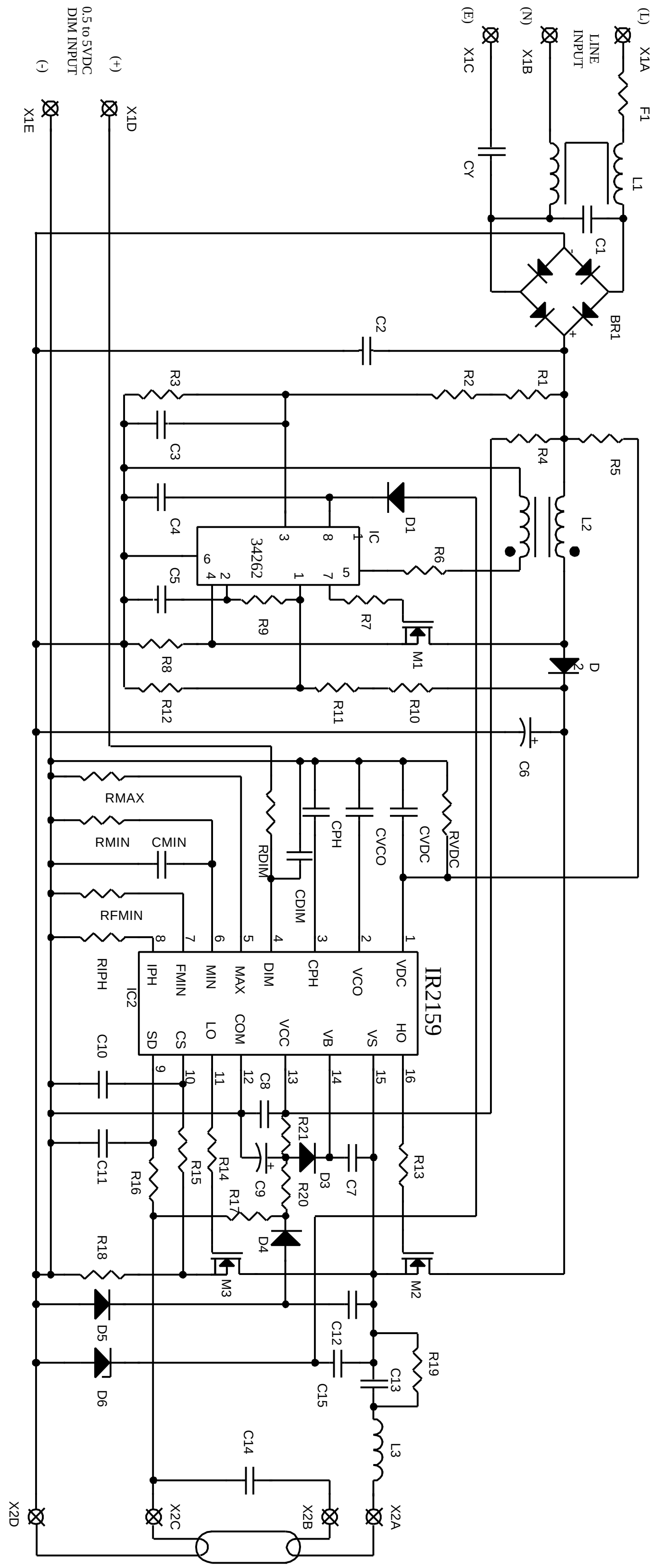
Fault	Ballast	Restart Operation
Line voltage low	Deactivates	Increase line voltage
Upper filament broken	Deactivates	Lamp exchange
Lower filament broken	Deactivates	Lamp exchange
Failure to ignite	Deactivates	Lamp exchange
Open circuit (no lamp)	Deactivates	Lamp exchange

Functional Description

Overview

The IRPLDIM1 Demo Board consists of an EMI filter, an active power factor correction front end, a ballast control section and a resonant lamp output stage. The active power factor correction section is a boost converter operating in critical mode conduction, free-running frequency mode. The ballast control section provides frequency modulation 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 closed-loop dimming, lamp fault detection, shutdown and auto-restart. All functional descriptions refer to the IRPLDIM1 schematic diagram.

IRPLDIM1/IRPLDIM1U Schematic Diagram



IRPLDIM1 Bill Of Materials

Lamp Type: T8/36W   Line Input Voltage: 185 to 265VAC/50/60Hz

Item	Qty	Reference	Description	Manufacturer	Part Number
1	1	BR1	Bridge Rectifier, 1A, 1000V	International Rectifier	DF10S
2	2	C4,C5	Capacitor, 0.47uF, SMT 1206	Panasonic	ECJ-3YB1E474K
3	3	CVCO,C3,CDIM	Capacitor, 0.01uF, SMT 1206	Panasonic	ECU-V1H103KBM
4	1	C1	Capacitor, 0.33uF, 275VAC	Roederstein	F1772433-2200
5	2	C2,C13	Capacitor, 0.1uF, 400VDC	Wima	MKP10
6	4	C7,C8,C11,CMIN	Capacitor, 0.1uF, SMT 1206	Panasonic	ECJ-3VB1E104K
7	2	CCPH,CVDC	Capacitor, 0.33uF, SMT 1206	Panasonic	ECJ-3VB1E334K
8	1	C6	Capacitor, 10uF, 450VDC,105C	Panasonic	EEU-EB2V100
9	1	C9	Capacitor, 4.7uF, 25VDC,105C	Panasonic	EEU-FC1H4R7
10	1	C10	Capacitor, 470pF, SMT 1206	Panasonic	ECU-V1H471KBM
11	2	C12,C15	Capacitor, 1nF,1KV, SMT 1812	Johanson	102S43W102KV4
12	1	C14	Capacitor, 10nF, 1600VDC	Panasonic	ECW-H16102JV
13	3	D1,D4,D5	Diode, 1N4148, SMT DL35	Diodes	LL4148
14	2	D2,D3	Diode, SMT SMB	International Rectifier	10DF60
15	1	D6	Zener Diode, 20V, SMT DL35	Motorola	MMSZ4707T1
16	1	IC1	IC, Power Factor Controller	Motorola	34262
17	1	IC2	IC, Dimming Ballast Controller	International Rectifier	IR2159
18	1	L1	EMI Inductor, 1x10mH, 0.7A	Panasonic	ELF-15N007A
19	1	L2	PFC Inductor, 2.0mH, 2.0Apk	RG Allen	RGA-EF25
20	1	L3	Inductor, 2.0mH, 2.0Apk	RG Allen	RGA-97408C
21	3	M1,M2,M3	Transistor, MOSFET	International Rectifier	IRF820
22	1	R15	Resistor, 1K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ1KV
23	1	RFMIN	Resistor, 33K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ33KV
24	1	RDIM	Resistor, 10K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ10KV
25	2	RIPH,RMAX	Resistor, 24K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ24KV
26	2	RVDC,RMIN	Resistor, 27K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ27KV
27	1	R12	Resistor, 10K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ10KV
28	2	R1,R2	Resistor, 680K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ680KV
29	1	R3	Resistor, 7.5K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ7.5KV
30	1	R4	Resistor, 470K Ohm	Yageo	470KQBK
31	1	R5	Resistor, 1M Ohm	Yageo	
32	1	R6	Resistor, 22K Ohm, SMT 1206	Panasonic	ERJ-8GEY22KV
33	3	R7,R13,R14	Resistor, 22 Ohm, SMT 1206	Panasonic	ERJ-8GEY22V
34	1	F1	Resistor, 0.5 Ohm, ½ Watt	Dale	CW-1/2
35	2	R9,R16	Resistor, 100K Ohm, SMT 1206	Panasonic	ERJ-8GEY100KV
36	2	R10,R11	Resistor, 820K Ohm, SMT 1206	Panasonic	ERJ-8GEY820KV
37	1	R17	Resistor, 1M Ohm, SMT 1206	Panasonic	ERJ-8GEY1MV
38	1	R8	Resistor, 1 Ohm, ¼ Watt	Yageo	1.0QBK
39	1	R18	Resistor, 0.8 Ohm, ¼ Watt	Yageo	1.0QBK
40	1	R19	Resistor, 100K Ohm, ¼ Watt	Yageo	
41	1	X1	Connector, 5 terminal	Wago	
42	1	X2	Connector, 4 terminal	Wago	236-404
43	1	J1	Jumper		
44	1	CY	Y-Capacitor		
45	1	RV1	Varistor		
46	2	R20, R21	Resistor, 10 Ohm, SMT 1206	Panasonic	ERJ-*GEY10V
Total	**68**				

IRPLDIM1U Bill Of Materials

Lamp Type: T8/32W   Line Input Voltage: 90 to 140VAC/50/60Hz

Item	Qty	Reference	Description	Manufacturer	Part Number
1	1	BR1	Bridge Rectifier, 1A, 1000V	International Rectifier	DF10S
2	2	C4,C5	Capacitor, 0.47uF, SMT 1206	Panasonic	ECJ-3YB1E474K
3	3	CVCO,C3,CDIM	Capacitor, 0.01uF, SMT 1206	Panasonic	ECU-V1H103KBM
4	1	C1	Capacitor, 0.33uF, 275VAC	Roederstein	F1772433-2200
5	2	C2,C13	Capacitor, 0.1uF, 400VDC	Wima	MKP10
6	4	C7,C8,C11,CMIN	Capacitor, 0.1uF, SMT 1206	Panasonic	ECJ-3VB1E104K
7	2	CCPH,CVDC	Capacitor, 0.33uF, SMT 1206	Panasonic	ECJ-3VB1E334K
8	1	C6	Capacitor, 10uF, 350VDC,105C	Panasonic	EEU-EB2V100
9	1	C9	Capacitor, 4.7uF, 25VDC,105C	Panasonic	EEU-FC1H4R7
10	1	C10	Capacitor, 470pF, SMT 1206	Panasonic	ECU-V1H471KBM
11	2	C12,C15	Capacitor, 1nF,1KV, SMT 1812	Johanson	102S43W102KV4
12	1	C14	Capacitor, 8.2nF, 1600VDC	Panasonic	ECW-H16822JV
13	3	D1,D4,D5	Diode, 1N4148, SMT DL35	Diodes	LL4148
14	2	D2,D3	Diode, SMT SMB	International Rectifier	10DF60
15	1	D6	Zener Diode, 20V, SMT DL35	Motorola	MMSZ4707T1
16	1	IC1	IC, Power Factor Controller	Motorola	34262
17	1	IC2	IC, Dimming Ballast Controller	International Rectifier	IR2159
18	1	L1	EMI Inductor, 1x10mH, 0.7A	Panasonic	ELF-15N007A
19	1	L2	PFC Inductor, 2.0mH, 2.0Apk	RG Allen	RGA-EF25
20	1	L3	Inductor, 2.0mH, 2.0Apk	RG Allen	RGA-97408C
21	2	M2,M3	Transistor, MOSFET	International Rectifier	IRF720
22	1	M1	Transistor, MOSFET	International Rectifier	IRF730
23	1	R15	Resistor, 1K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ1KV
24	1	RFMIN	Resistor, 36K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ36KV
25	1	RDIM	Resistor, 10K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ10KV
26	1	RMAX	Resistor, 24K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ24KV
27	1	RMIN	Resistor, 27K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ27KV
28	1	RVDC	Resistor, 47K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ47KV
29	1	RIPH	Resistor, 22K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ22KV
30	1	R12	Resistor, 13K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ13KV
31	2	R1,R2	Resistor, 680K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ680KV
32	1	R3	Resistor, 7.5K Ohm, SMT 1206	Panasonic	ERJ-8GEYJ7.5KV
33	1	R4	Resistor, 330K Ohm	Yageo	330KQBK
34	1	R5	Resistor, 1M Ohm	Yageo	
35	1	R6	Resistor, 22K Ohm, SMT 1206	Panasonic	ERJ-8GEY22KV
36	3	R7,R13,R14	Resistor, 22 Ohm, SMT 1206	Panasonic	ERJ-8GEY22V
37	1	F1	Resistor, 0.5 Ohm, ½ Watt	Dale	CW-1/2
38	2	R9,R16	Resistor, 100K Ohm, SMT 1206	Panasonic	ERJ-8GEY100KV
39	2	R10,R11	Resistor, 820K Ohm, SMT 1206	Panasonic	ERJ-8GEY820KV
40	1	R17	Resistor, 1M Ohm, SMT 1206	Panasonic	ERJ-8GEY1MV
41	1	R8	Resistor, 0.5 Ohm, ¼ Watt	Yageo	1.0QBK
42	1	R18	Resistor, 1.0 Ohm, ¼ Watt	Yageo	1.0QBK
43	1	R19	Resistor, 100K Ohm, ¼ Watt	Yageo	
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45	1	X2	Connector, 4 terminal	Wago	236-404
46	1	J1	Jumper		
47	1	CY	Y Capacitor		
48	1	RV1	Varistor		
49	2	R20, R21	Resistor, 10 Ohm, SMT 1206	Panasonic	ERJ-*GEY10V
Total	**68**				

The power factor correction section consists of the Motorola Semiconductor MC34262 Power Factor Controller IC (IC1), MOSFET M1, inductor L2, diode D2, capacitor C8 and additional biasing, sensing and compensation components (see schematic diagram). The IC was chosen for its minimal component count, low start-up supply current and robust error amplifier. This is a boost topology 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 (HPF). The design of the power factor correction section was taken from the Motorola Semiconductor MC34262 data sheet and information on the operation and design considerations for the MC34262 are contained therein.

Ballast Control

The ballast control section is built around the IR2159 Ballast Control IC, IC2 of the Demo board. The IR2159 contains an oscillator, a high voltage half-bridge gate driver, an analog dimming interface and lamp fault protection circuitry. A block diagram of the IR2159 IC is shown in figure 1 and a state diagram of the IR2159 is shown in figure 2.

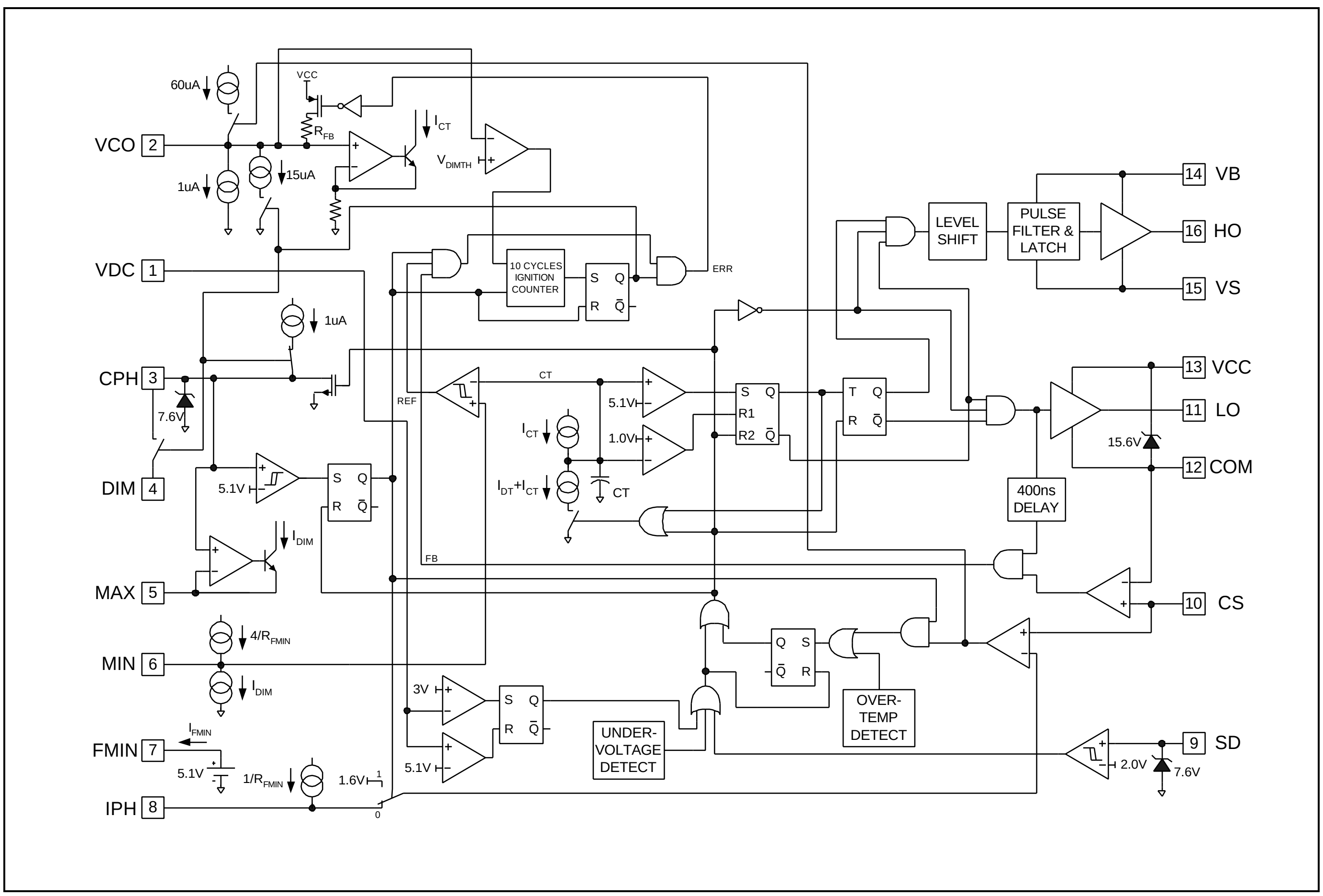

Figure 1: IR2159 Block Diagram

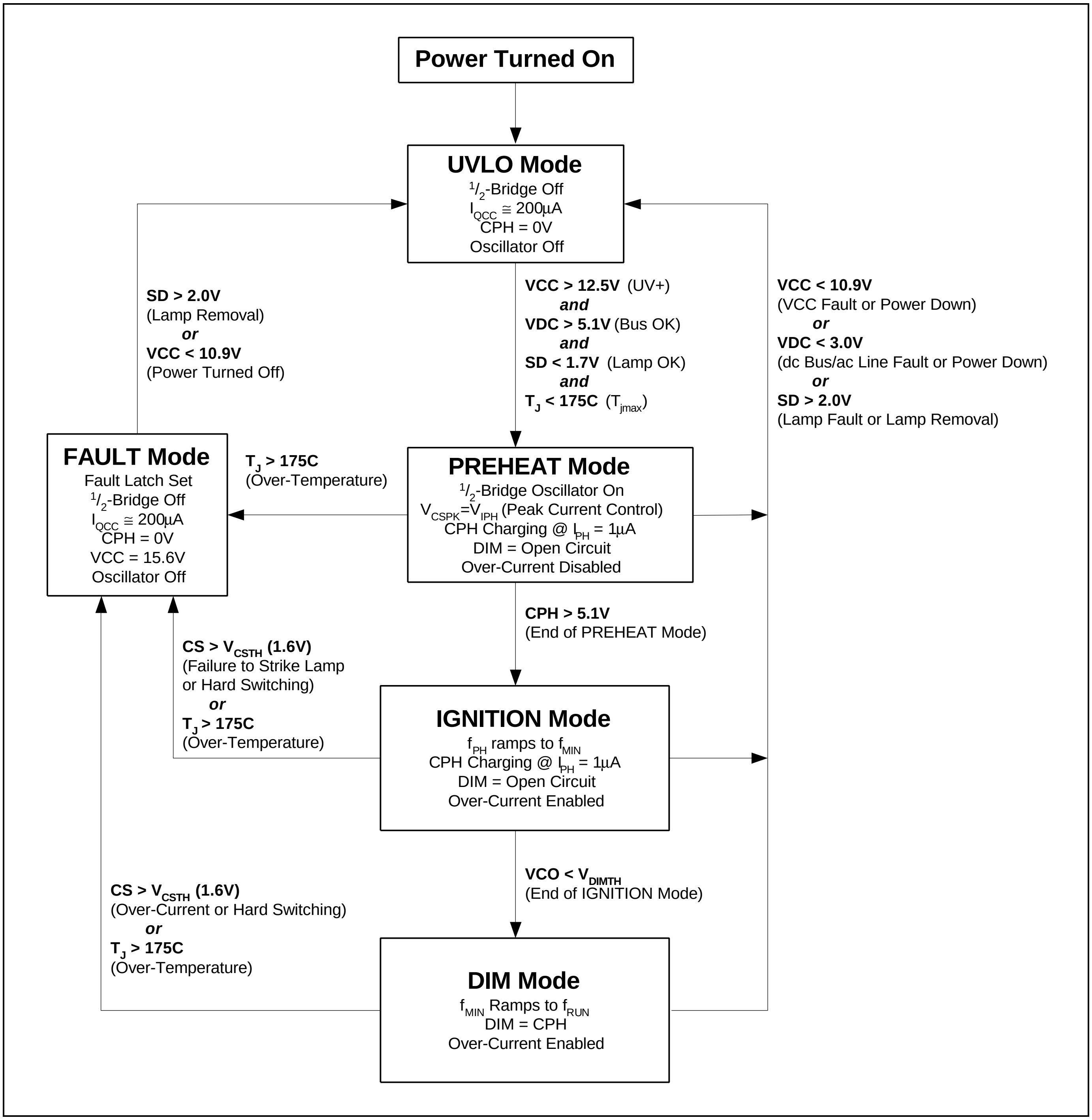

Figure 2: IR2159 State Diagram

Ballast Design

Lamp Requirements

Before selecting component values for the ballast output stage and the programmable inputs of the IR2159, the following lamp requirements must first be defined:

Variable	Description	Units
I_{ph}	Filament pre-heat current	Arms
t_{ph}	Filament pre-heat time	s
$V_{ph\max}$	Maximum lamp pre-heat voltage	Vpp
V_{ign}	Lamp ignition voltage	Vpp
$P_{100\%}$	Lamp power at 100% brightness	W
$V_{100\%}$	Lamp voltage at 100% brightness	Vpp
$P_{1\%}$	Lamp power at 1% brightness	W
$V_{1\%}$	Lamp voltage at 1% brightness	Vpp
$I_{Cath\min}$	Minimum cathode heating current	Arms

Table I, Typical lamp requirements

Ballast Output Stage

The components comprising the output stage are selected using a set of equations. Different ballast operating frequencies and their respective voltages and currents are calculated.

The inductor and capacitor values are obtained using equations (2) through (7). The results of these equations reveal the location of each operating frequency and the corresponding voltages and currents. For a given L, C, DC bus voltage, and pre-heat current, the resulting voltage over the lamp during pre-heat is given as:

$$V_{ph} = \sqrt{\left(\frac{V_{DC}}{p}\right)^2 + \frac{8L}{C} I_{ph}^2} - \frac{V_{DC}}{p} \quad \text{[Vpp]} \qquad \textbf{(2)}$$

The resulting operating frequency during pre-heat is given as:

$$f_{ph} = \frac{\sqrt{2} I_{ph}}{pC V_{ph}} \quad \text{[Hz]} \qquad \textbf{(3)}$$

The resulting operating frequency during ignition is given as:

$$f_{ign} = \frac{1}{2p}\sqrt{\frac{1+\frac{\frac{4}{p}V_{DC}}{V_{ign}}}{LC}} \quad \text{[Hz]} \qquad \textbf{(4)}$$

The total load current during ignition is given as:

$$I_{ign} = f_{ign} C V_{ign} 2p \quad \text{[App]} \qquad \textbf{(5)}$$

The operating frequency [Hz] at maximum lamp power is given as:

$$f_{100\%} = \frac{1}{2p}\sqrt{\frac{1}{LC} - \frac{32P_{100\%}^2}{C^2 V_{100\%}^4} + \sqrt{\left[\frac{1}{LC} - \frac{32P_{100\%}^2}{C^2 V_{100\%}^4}\right]^2 - 4\frac{1-\left(\frac{4V_{DC}}{V_{100\%}p}\right)^2}{L^2C^2}}} \qquad \textbf{(6)}$$

The cathode heating current at minimum lamp power is given as:

$$I_{Cath1\%} = \frac{V_{1\%} f_{1\%} pC}{\sqrt{2}} \qquad \textbf{(7)}$$

Design Constraints

The inductor and capacitor values should be iterated until the following design constraints have been fulfilled (Table II).

Design Constraint	Reason
$V_{ph} < V_{ph\max}$	Ignition during pre-heat
$f_{ph} - f_{ign} > 5kHz$	Production tolerances
$I_{ign} < I_{ign\max}$	Inductor saturation
$I_{Cath1\%} \geq I_{Cath\min}$	Lamp extinguishing during dimming

Table II, Ballast design constraints

IR2159 Programmable Inputs

In order to program the MIN and MAX settings of the dimming interface, the phase of the output stage current at minimum and maximum lamp power must be calculated. This is obtained using the following equations:

$$f_{\%} = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{32P_{\%}^2}{C^2V_{\%}^4} + \sqrt{\left[\frac{1}{LC} - \frac{32P_{\%}^2}{C^2V_{\%}^4}\right]^2 - 4\frac{1-\left(\frac{4V_{DC}}{V_{\%}\pi}\right)^2}{L^2C^2}}} \quad \textbf{(8)}$$

$$\varphi_{\%} = \frac{180}{\pi}\tan^{-1}\left[\left(\frac{V_{\%}^2}{2P_{\%}}C - \frac{2P_{\%}}{V_{\%}^2}L\right)2\pi f_{\%} - 4\frac{V_{\%}^2}{P_{\%}}LC^2\pi^3 f_{\%}^3\right] \quad \textbf{(9)}$$

With the lamp requirements defined, the L and C of the ballast output stage selected, and the minimum and maximum phase calculated, the component values for setting the programmable inputs of the IR2159 are obtained with the following equations:

$$R_{FMIN} = \frac{(25e-6) - (f_{MIN} - 10000)\cdot(1e-10)}{(f_{MIN} - 10000)\cdot(2e-14)} \quad \text{[Ohms]} \ \textbf{(10)}$$

$$R_{CS} = \frac{2\cdot(1.6)}{I_{ign}} \quad \text{[Ohms]} \ \textbf{(11)}$$

$$R_{IPH} = R_{FMIN}R_{CS}I_{ph}\sqrt{2} \quad \text{[Ohms]} \ \textbf{(12)}$$

$$C_{CPH} = (2E-7)(t_{PH}) \quad \text{[Farads]} \ \textbf{(13)}$$

$$R_{MIN} = \frac{R_{FMIN}}{4}\left(1 - \frac{\varphi_{1\%}}{45}\right) \quad \text{[Ohms]} \ \textbf{(14)}$$

$$R_{MAX} = \frac{R_{FMIN}\cdot R_{MIN}}{4\cdot R_{MIN} - R_{FMIN}\cdot\left(1 - \frac{\varphi_{100\%}}{45}\right)} \quad \text{[Ohms]} \ \textbf{(15)}$$

This ballast design procedure has been summarized into the following 4 steps:

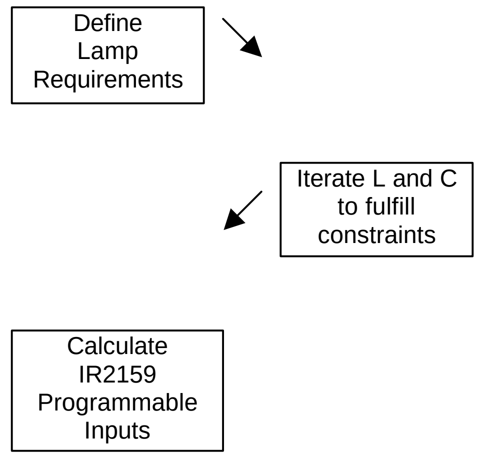

Figure 3, Simplified Ballast Design Procedure

IRPLDIM1U Design

Line Input Voltage: 90 to 140VAC/50/60Hz
Lamp Power/Type: 32W/T8

1) Lamp Requirements

Typical high-frequency (25kHz) lamp requirements for the 32W/T8 lamp type are given as:

Variable	Value	Units
I_{ph}	0.6	Arms
t_{ph}	1.0	s
$V_{ph_{max}}$	600	Vpp
V_{ign}	1300	Vpp
P_{max}	30	W
$V_{P_{max}}$	400	Vpp
P_{min}	1	W
$V_{P_{min}}$	330	Vpp
$I_{Cath_{min}}$	0.35	Arms

Table III, 32W/T8 lamp requirements

2) Iterate L and C to Fulfill Constraints

To select the ballast output stage inductor and capacitor, a range of values were input into equations (2) through (7), which have been summarized in the following table:

L [mH]	2.0	2.0	2.0
C [nF]	6.8	8.2	10
V_{ph} [Vpp]	748	668	592
f_{ph} [kHz]	53	49	46
f_{ign} [kHz]	49	45	40
I_{ign} [App]	1.4	1.5	1.7
$f_{P_{max}}$ [kHz]	49	46	43
$I_{Cath\,P_{min}}$ [Arms]	0.32	0.35	0.38

Table IV, Ballast parameters for different C values.

When compared against the lamp requirements, a capacitor value of 6.8nF gives a lamp voltage during pre-heat that exceeds the maximum allowable specified for this lamp type. This can ignite the lamp before the cathodes have reached their emission temperature, drastically reducing lamp life. The pre-heat current can be reduced to give a lower pre-heat voltage, but the pre-heat time must then be increased for proper heating. Also, $I_{Cath_{min}}$ is too low, which will cause the lamp to extinguish at low light levels where the arc current alone is too low to heat the cathodes. Increasing the capacitor value to 10nF fulfills the lamp requirements quite well, even allowing some room in the pre-heat voltage for the pre-heat current to be increased and the pre-heat time shortened. During dimming, however, the lamp voltage increases with decreasing lamp power due to lamp negative incremental impedance effects. A maximum is reached around 10% brightness, after which the lamp voltage decreases as the lamp is further dimmed. The maximum filament current occurs at the maximum lamp voltage, which for a capacitor value of 10nF, is too high and will over-heat the filaments. A capacitor value of 8.2nF was chosen which fulfills the lamp requirements without over-heating the cathodes.

3) IR2159 Programmable Inputs

With all of the lamp requirements fulfilled, the component values for setting the programmable inputs of the IR2159 are calculated as:

Equation No.	Variable	Value
(8)	$f_{100\%}$	46kHz
(8)	$f_{1\%}$	58kHz
(9)	$j_{100\%}$	-56.12deg
(9)	$j_{1\%}$	-89.27deg
(10)	R_{FMIN}	36kOhm
(11)	R_{CS}	1.0 Ohm
(12)	R_{IPH}	22kOhm
(13)	C_{TPH}	330nF
(14)	R_{MIN}	27kOhm
(15)	R_{MAX}	24kOhm

Table V, IR2159 Programmable Inputs for T8/32W lamp.

IRPLDIM1 Design

Line Input Voltage: 185 to 265VAC/50/60Hz
DC Bus Voltage: 400VDC
Lamp Power/Type: 36W/T8

1) Lamp Requirements

Typical high-frequency (25kHz) lamp requirements for the 36W/T8 lamp type are given as:

ble	Value	Units
I_{ph}	0.6	Arms
t_{ph}	1.0	s
$V_{ph\max}$	600	Vpp
V_{ign}	1500	Vpp
$P_{\max}$	32	W
$V_{P\max}$	282	Vpp
$P_{\min}$	1	W
$V_{P\min}$	330	Vpp
$I_{Cath\min}$	0.35	Arms

Table III, 36W/T8 lamp requirements

2) Iterate L and C to Fulfill Constraints

To select the ballast output stage inductor and capacitor, a range of values were input into equations (2) through (7), which have been summarized in the following table:

L [mH]	2.0	2.0	2.0
C [nF]	6.8	8.2	10
V_{ph} [Vpp]	700	622	546
f_{ph} [kHz]	57	53	49
f_{ign} [kHz]	51	46	42
I_{ign} [App]	1.4	1.6	1.8
$f_{P\max}$ [kHz]	42	42	41
$I_{Cath\,P\min}$ [Arms]	0.32	0.35	0.38

Table IV, Ballast parameters for different C values.

When compared against the lamp requirements, a capacitor value of 6.8nF gives a lamp voltage during pre-heat that exceeds the maximum allowable specified for this lamp type. This can ignite the lamp before the cathodes have reached their emission temperature, drastically reducing lamp life. The pre-heat current can be reduced to give a lower pre-heat voltage, but the pre-heat time must then be increased for proper heating. Also, $I_{Cath\min}$ is too low, which will cause the lamp to extinguish at low light levels where the arc current alone is too low to heat the cathodes. Increasing the capacitor value to 10nF fulfills the lamp requirements quite well, even allowing some room in the pre-heat voltage for the pre-heat current to be increased and the pre-heat time shortened. During dimming, however, the lamp voltage increases with decreasing lamp power due to lamp negative incremental impedance effects. A maximum is reached around 10% brightness, after which the lamp voltage decreases as the lamp is further dimmed. The maximum filament current occurs at the maximum lamp voltage, which for a capacitor value of 10nF, is too high and will over-heat the filaments. A capacitor value of 8.2nF was chosen which fulfills the lamp requirements without over-heating the cathodes.

3) IR2159 Programmable Inputs

With all of the lamp requirements fulfilled, the component values for setting the programmable inputs of the IR2159 are calculated as:

Equation No.	Variable	Value
(8)	$f_{100\%}$	46kHz
(8)	$f_{1\%}$	58kHz
(9)	$j_{100\%}$	-56.12deg
(9)	$j_{1\%}$	-89.27deg
(10)	R_{FMIN}	33kOhm
(11)	R_{CS}	0.8 Ohm
(12)	R_{IPH}	24kOhm
(13)	C_{TPH}	330nF
(14)	R_{MIN}	27kOhm
(15)	R_{MAX}	24kOhm

Table V, IR2159 Programmable Inputs for T8/32W lamp.

Important Note: These design kits are intended as a demonstration of the functionality and performance of the IR2159 Dimming Ballast Control IC only. Adequate EMI filtering, line transient protection, galvanic dim control input isolation, and ballast and lamp life testing are not considered in this design.

Waveforms

Figure 4 shows the voltage appearing across the lamp while Figure 5 shows the current flowing through the lamp during Startup, Preheat, Ignition and Dim modes.

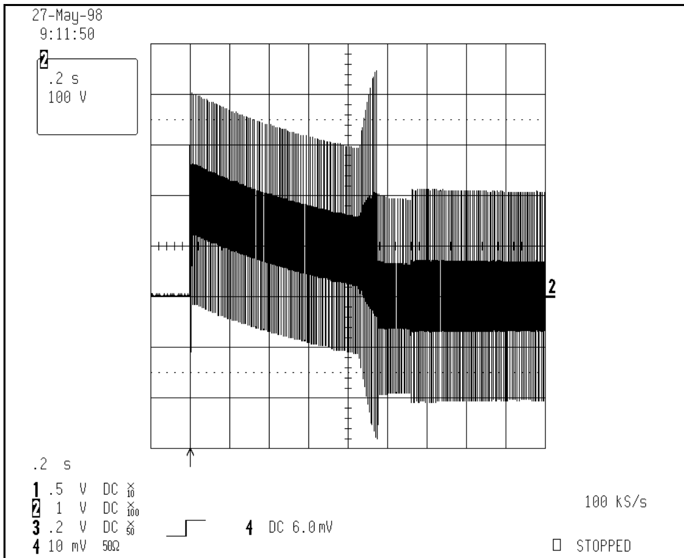

Figure 4: Lamp voltage during Startup, Preheat, Ignition and Dim (100%)

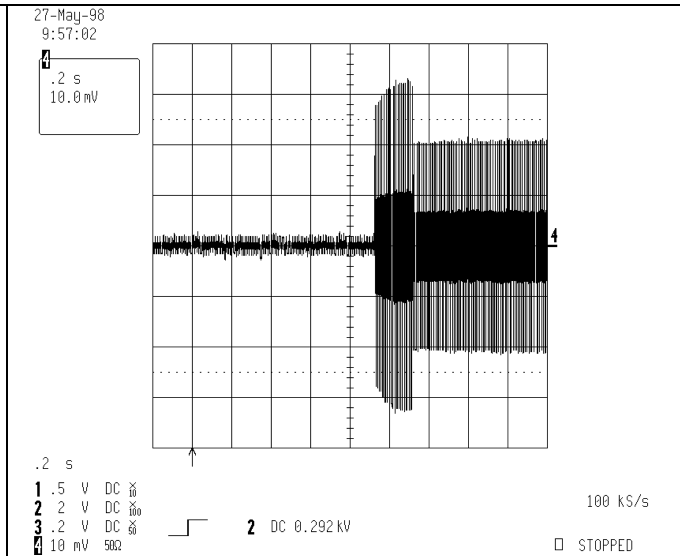

Figure 5: Lamp current during Startup, Preheat, Ignition and Dim (100%) (100 mA / div.)

Normal Powerdown

A Normal Powerdown occurs when the AC line voltage is disconnected from the ballast. When this occurs the voltage on the VDC pin of IC2 drops below the line fault threshold (3V) and IC2 shuts down in a controlled fashion. The oscillator is stopped, the half-bridge driver outputs (LO and HO) are turned off and capacitor CPH is discharged. IC2 also goes into its UVLO/micro-power mode and the bus voltage begins to collapse.

Fault Mode

Fault mode is when the ballast driver is shutdown due to the detection of a lamp fault. Note that when the ballast is in this Fault mode the power factor correction section of the ballast is also shutdown and the bus voltage will drop to the non-boosted/unregulated level. There are several lamp fault conditions which can put the ballast into the Fault mode. The lamp fault conditions detected include: near/below resonance (under-current) detection, hard-switching detection and over-current detection. Resistor RCS in the source lead of the low side MOSFET (M3) serves as the current sensing point for the half-bridge which is used to detect these lamp fault conditions. In operation when the half-bridge is oscillating, a voltage appears across RCS whenever the low side MOSFET, M3, is turned on or the high side MOSFET, M2, is turned off. The magnitude of this voltage directly relates to the current in the lamp resonant circuit. Figure 6 shows the voltage which appears across resistor RCS during normal Run mode conditions while Figure 14 shows the voltage appearing across the lamp during the end of Preheat mode, Ignition Ramp mode and the beginning of Run mode. Also shown in Figure 7 are the gate drive signals for the low side MOSFET (LO pin) and the high side MOSFET (HO-VS pin).

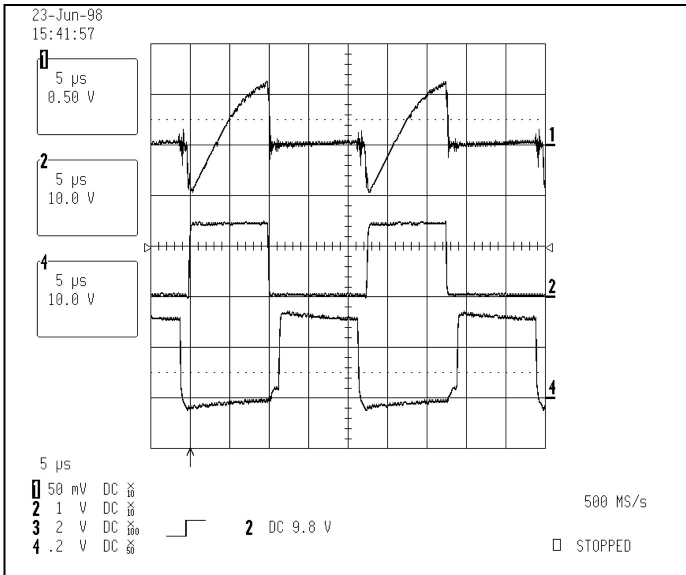

Figure 6: Normal Run mode; Upper trace: voltage across RCS, Middle trace: IC2 LO pin voltage, Lower trace: IC2 HO-VS pin voltage

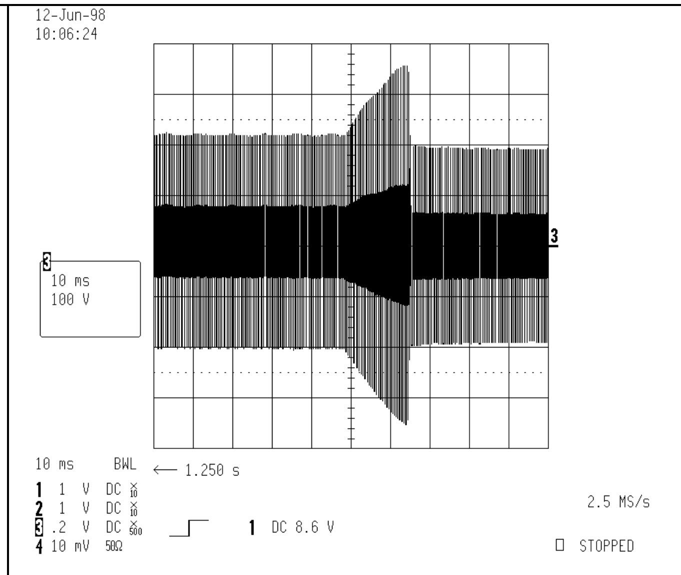

Figure 7: Normal lamp ignition: Lamp voltage during the end of Preheat mode, Ignition Ramp mode and the beginning of the Run mode

During the Preheat mode the over-current protection is disabled. However, at the end of Preheat mode (the beginning of the Ignition mode) the hard-switching and over-current detection are enabled. If at any time thereafter the voltage magnitude across resistor RCS rises above the over-current threshold (1.6V) of the CS pin of IC2, a lamp fault condition is signaled and the half-bridge output MOSFETs', (M2 and M3) are turned off and the ballast goes into Fault mode. This can happen if the lamp fails to ignite or if the upper filament is open. For failure to ignite the lamp, the current in the half-bridge increases and thus the voltage across resistor RCS increases above the over-current threshold signaling a fault. Figure 8 shows the voltage across resistor RCS and the voltage appearing across the lamp when the ballast detects a failure to ignite the lamp and goes into Fault mode. Figure 9 shows the voltage appearing across the lamp during the tail end of the Preheat mode and the Ignition mode for a failure of the lamp to ignite condition. If the upper filament is open, the half-bridge output hard-switches and each time the low side MOSFET (M3) is turned on a large current pulse occurs and thus a large voltage pulse occurs across resistor RCS signaling a fault, Figure 10 shows this hard-switching condition. Figure 11 shows the lamp voltage during the Preheat mode and beginning of Ignition Ramp mode for this hard-switching condition when the lamp fault condition is detected. The ballast will remain in Fault mode until either the line voltage is cycled or a lamp replacement is performed.

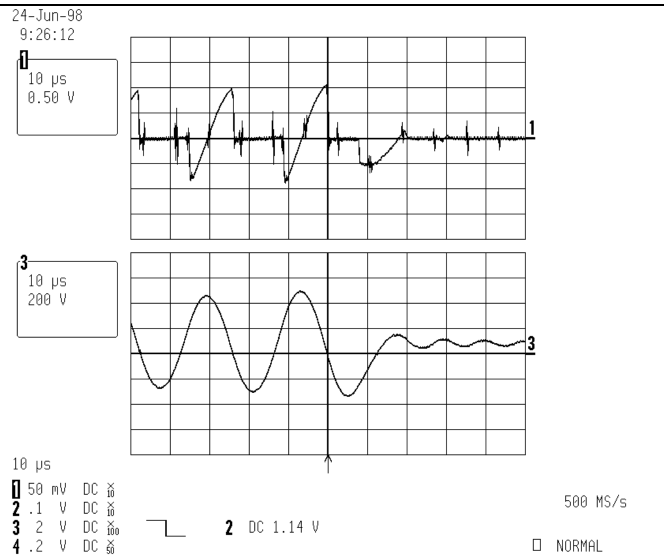

Figure 8: Failure of lamp to ignite condition (lamp filaments good): Upper trace: voltage across RCS, Lower trace: lamp voltage

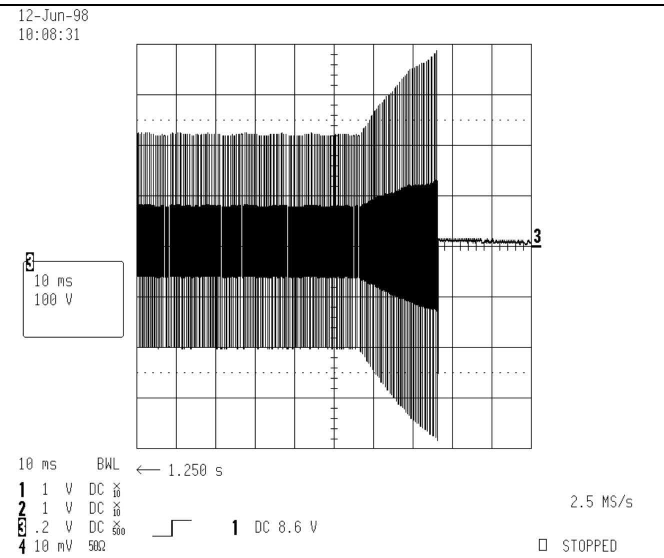

Figure 9: Failure of lamp to ignite condition (lamp filaments good): Lamp voltage during end of Preheat and Ignition Ramp modes

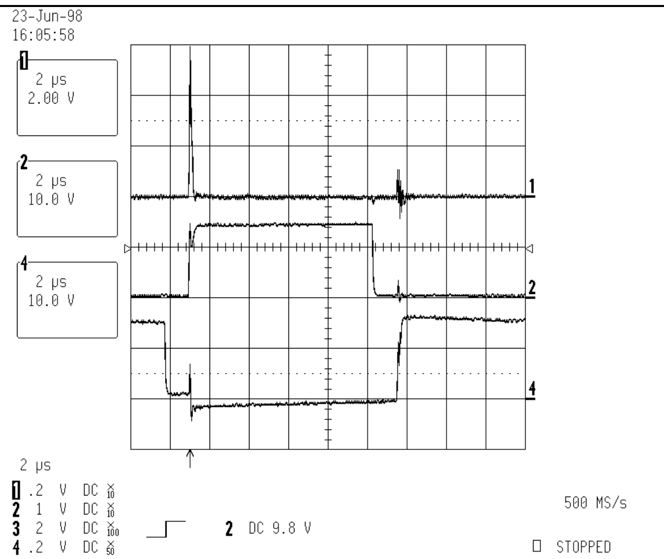

Figure 10: Hard-switching condition (upper filament open): Upper trace: voltage across RCS, Middle trace: IC2 LO pin voltage, Lower trace: IC2 HO-VS pin voltage

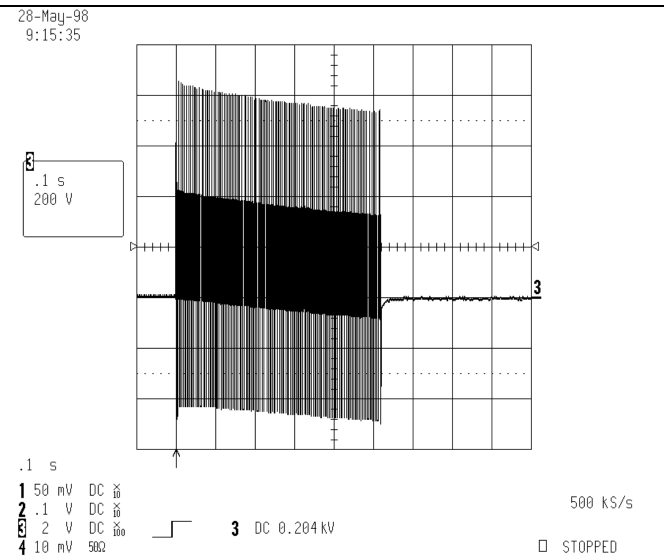

Figure 11: Hard-switching condition (upper filament open): Lamp voltage during Preheat mode and beginning of Ignition Ramp mode when lamp fault is detected