International Rectifier

IRPLLNR1

POWIRLIGHT™ REFERENCE DESIGN : LINEAR BALLAST

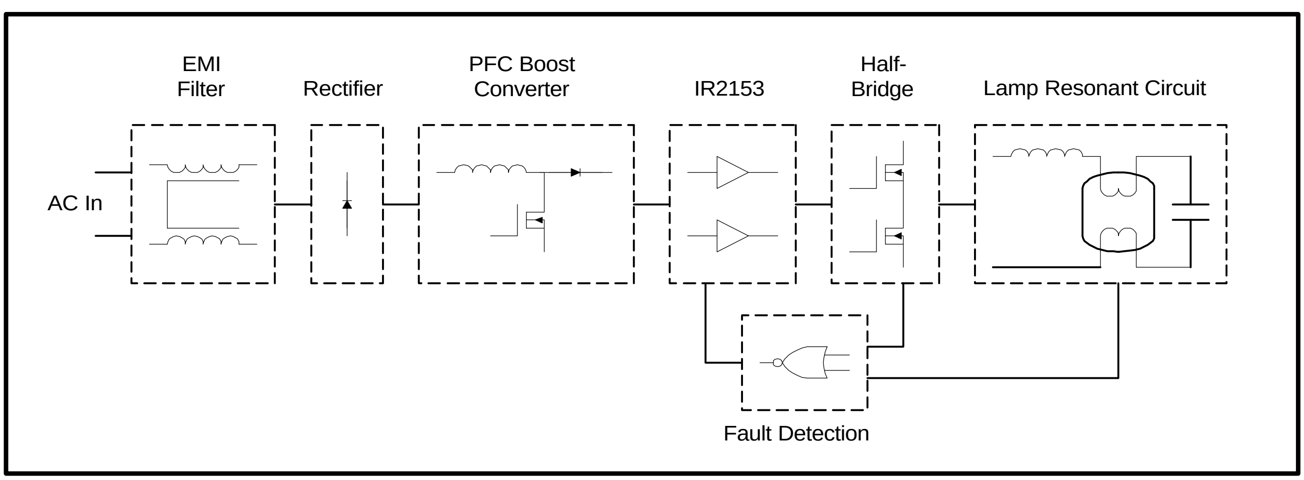
Features

- Drive 2X32WT8 or 2X40WT12
- Universal Input (90-275Vac)
- High Power Factor (0.99) & Low THD
- High-Frequency Operation (50kHz)
- Cathode Preheating (60kHz)
- Lamp Fault Protection with Auto-Restart
- Over Temperature Protection
- IR2153 HVIC Ballast Controller

Description

The IRPLLNR1 is a high efficiency, high power factor, non-dimmable electronic ballast designed for linear fluorescent lamp types. The design contains an active power factor correction circuit for universal voltage input as well as a ballast control circuit using the IR2153 for managing the lamp. Other features include EMI filtering, transient protection and lamp fault protection. The IRPLLNR1 is intended as a reference design to be used as development tool to speed up customers' time to market.

Block Diagram



Electrical Characteristics

Parameter	Units	Value	
Lamp Type		2/32T8	2/40T12
Input Power	[W]	65	80
Input Current (120VAC)	[A]	0.55	0.67
Pre-heat Output Frequency	[kHz]	60	45
Pre-heat Output Voltage	[Vp]	300	300
Pre-heat Time (TTL)	[s]	1.0	2.0
Running Output Frequency	[kHz]	50	35
Running Output Voltage	[V]	100	100
Input A.C. Voltage Range	[VAC]	90..275VAC/50/60Hz	
Input D.C. Voltage Range	[VDC]	100..350	
Temperature Range	[ºC]	0..70	
Power Factor		0.99	
Total Harmonic Distortion	[%]	<15%	
Maximum Output Voltage	[Vp]	650	

Note: Each lamp type requires a new ballast type with different component values as listed in the Bill of Materials.

Lamp Fault Protection Characteristics

Fault Conditions (one or both lamps)	Ballast	Restart Operation
Upper cathode out or broken	Lamp 2 continues running, or, deactivates if total load current not enough to commutate snubber (non zero-voltage switching)	Lamp exchange
Lower cathode out or broken	Deactivates	Lamp exchange
Broken tube (cathodes intact)	Deactivates	Lamp exchange
End-of-life	Deactivates	Lamp exchange
Short-Circuited	Deactivates	Lamp exchange

Functional Description

Overview

The IRPLLNR1 consists of a power factor front end, a ballast control section, a resonant lamp output stage and shutdown circuitry. The power factor controller is a boost converter operating in critically continuous, free-running frequency mode. The ballast control section provides frequency modulation control of a traditional RCL series-parallel lamp resonant output circuit and is easily adaptable to a wide variety of lamp types. The shutdown section consists of lamp circuit current detection and comparator logic for safe turn-off and smooth auto re-starting. All functional descriptions are referred to the IRPLLNR1 schematic.

Power Factor Control

The power factor controller section consists of the LinFinity LX1562 Power Factor Controller IC (IC1), MOSFET M1, inductor L3, diode D5, capacitor C8 and additional biasing, sensing and compensation components (see schematic). This 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 input current from the line (low THD) which is “in phase” with the AC input line voltage (HPF). The charging current of L3 is sensed in the source of M1 (R7) and the zero-crossing of the inductor current, as it charges the DC bus capacitor C8, is sensed by a secondary winding on L3. The result is critically continuous, free-running frequency operation where:

$$L3 = \frac{V_{in}^2 (V_{out} - \sqrt{2} V_{in}) \eta}{2 P_{out} V_{out} f_s \pi} \qquad [1]$$

$$I_{L_p} = \frac{P_{out} 2\sqrt{2}}{V_{in\,\min} \eta} \qquad [2]$$

where,

η = efficiency
V_{in} = nominal AC input voltage
V_{out} = DC bus voltage
P_{out} = lamp power
f_s = switching frequency

The value of the boost inductor (L3) can be calculated and the core should be dimensioned to handle the associated inductor peak currents (I_{L_p}) for the desired range of AC input voltage.

Ballast Control

The ballast control section consists of R18, R19, R20, C12, C13, C15, D10, M3 and the IR2153 ballast controller IC (IC3), and is responsible for driving the half-bridge output at different operating conditions: preheat, ignition and running. During preheat, the half-bridge is driven at a fixed frequency for a fixed duration of time so the lamp cathodes can be heated to their correct emission temperature. This maximizes the life of the filament coating and therefore the life of the lamp. Furthermore, lower ignition voltages and currents are needed to ignite the lamp, which reduce the maximum voltage and current ratings of the lamp resonant circuit (L4, L5, C21, C23), as well as the half-bridge power MOSFETs (M4, M5). After preheat, the frequency is then swept lower through the resonance frequency to the final running frequency where the lamp is driven to the manufacturer's recommended lamp power rating for the desired lamp type. As the frequency passes through resonance, the lamp ignites when the required ignition voltage is reached across the lamp. To achieve the various operating conditions, the corresponding frequencies are programmed with the RT and CT pins of the IR2153. C13 and C15 are first connected in series to define the preheat frequency where,

$$f_{ph} = \frac{C13 + C15}{1.4(R20)(C13)(C15)} \qquad [3]$$

When the voltage on C12 reaches the zener voltage of D10, M3 turns on and C15 is shorted. This gives a new operating frequency, the running frequency, defined as,

$$f_{run} = \frac{1}{1.4(R20)(C13)} \qquad [4]$$

The slow sweeping of the frequency from preheat to running (ignition ramp) occurs due to a combination of the limited transconductance of M3 and the slow rising voltage on the gate. The running frequency of the lamp resonant circuit for given component values is given as,

$$f_{run} = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - 2\left(\frac{P_{Lamp}}{CV_{Lamp}^2}\right)^2 + \sqrt{\left[\frac{1}{LC} - 2\left(\frac{P_{Lamp}}{CV_{Lamp}^2}\right)^2\right]^2 - \frac{1-n^2}{L^2C^2}}} \qquad [5]$$

where,

L	=	Lamp resonant circuit inductor	[H]
C	=	Lamp resonant circuit capacitor	[F]
P_{Lamp}	=	Manufacturers recommended lamp power	[W]
V_{Lamp}	=	Manufacturers recommended lamp voltage	[Vrms]
n	=	$\frac{2V_{DCbus}}{\sqrt{2}V_{Lamp}\pi}$	

Shutdown

The shutdown circuitry consists of a quad comparator IC (IC2), a lamp resonance current detection circuit* (R21, R22, R38, C16, D12) and a pull-up lamp removal circuit (R23, R24, R25, R26, D16, C22). The current detection rectifies and integrates a measurement of the lamp resonant current and is compared against a fixed threshold voltage. Should the current exceed the threshold in the event of over-current due to a non-strike condition of the lamp or non-zero voltage switching of the half-bridge due to one or more broken lamp cathodes, the CT pin of the IR2153 is latched below the internal shutdown threshold (1/6 Vcc) and the ballast turns off. The negative temperature coefficient of the rectifying diode of the current measuring circuit (D12) also causes the current measurement to increase with increasing ambient temperature, therefore latching the ballast off in the event of excessive ambient temperatures. In the event of a lamp exchange, the latch is reset with the pull-up network at the lamp, and the CT pin of the IR2153 is held below the internal shutdown threshold in an *unlatched* state. When a new lamp is reinserted, the ballast performs an auto restart without a recycling of the input line voltage. For a dual lamp ballast, a second pull-up network is added to the second lamp (R27, R28, R29, R30) and is 'OR-ed' together with the first lamp. If either lamp is removed during running, the ballast turns off. Should the *upper* cathode of either lamp break during normal operation, then the good lamp will continue running as long as the zero-voltage switching condition on the half-bridge is fulfilled. If the total lamp resonant circuit current for the one-lamp case is not high enough to commutate the snubber capacitor (C18) during the deadtime of the half-bridge, then the resulting current will exceed the threshold voltage of the current limit circuit and the half-bridge will latch off. This is a function of the DC bus voltage, the lamp type, the lamp resonant circuit (L4, L5, C21, C23), the running frequency (R20, C13), the snubber capacitor (C18), the current sensing resistor (R22) and the current limit threshold (R14, R15). All of these parameters must be correctly chosen for each new lamp type such that the lamp is driven to the manufacturers recommended lamp power while achieving complete lamp fault protection

Waveforms

The following waveforms (see Figures 1 and 2) are from a dual 40W/T12 ballast (see Bill of Materials). Figure 1 shows a typical waveform of the source current and drain-to-source voltage of the PFC MOSFET (M1) during full power (80W) at low line voltage. This is where the PFC has the highest peak currents. Figure 2 shows a typical waveform of the half-bridge output and lamp resonant circuit current (drain-to-source voltage and source current of MOSFET M5) during maximum lamp power.

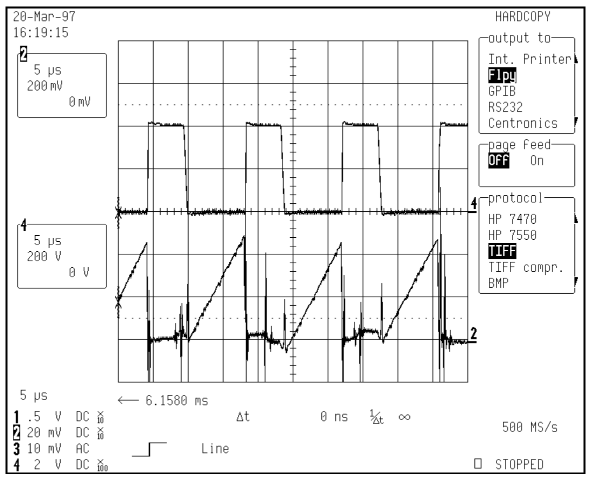


Figure 1 : Voltage (upper trace, 200V/div) and current (lower trace, 0.5A/div) waveforms of PFC MOSFET (M1) during full-load/low-line.

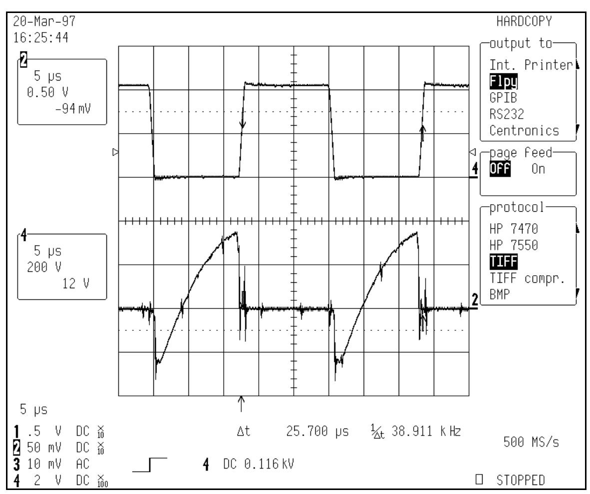
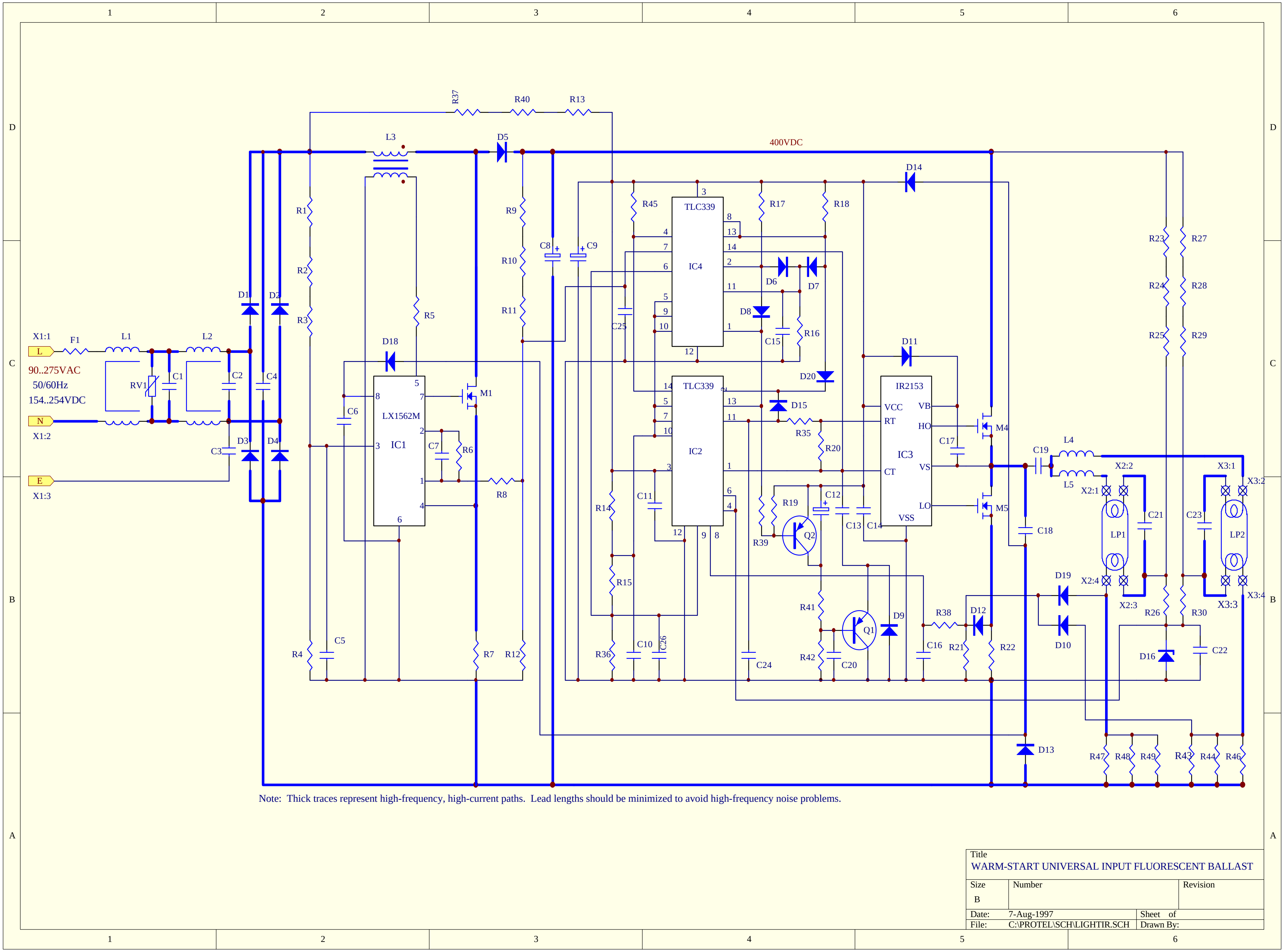


Figure 2 : Drain-to-source voltage (upper trace, 200V/div) and source current (lower trace, 0.7A/div) of MOSFET M5 during maximum lamp power.



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

Title
WARM-START UNIVERSAL INPUT FLUORESCENT BALLAST

Size	Number	Revision
B		

Date: 7-Aug-1997 Sheet of
File: C:\PROTEL\SCH\LIGHTIR.SCH Drawn By:

International Rectifier

WORLD HEADQUARTERS: 233 KANSAS ST., EL SEGUNDO, CA 90245 USA • (310)322-3331 • FAX (310)322-3332 • TELEX 472-0403
EUROPEAN HEADQUARTERS: HURST GREEN, OXTED, SURREY RH8 9BB, UK • (44)0883 713215 • FAX (944)0883 714234 • TELEX 95219

Sales Offices, Agents and Distributors in Major Cities Throughout the World. *Data and specifications subject to change without notice.*