APPLICATION NOTE

DISCRETE 1X18W HF-TL BALLAST

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Abstract

A description is given of a 1x18W HF-TL ballast and evaluation board (PR37692) which is able to drive a T8 TL-D lamp. The ballast, which is a Voltage Fed Half Bridge Inverter, has been designed for a nominal mains input voltage of 230Vrms±15%. The bipolar power switching transistor BUW85 is driven by a discrete driver circuit and a small driver transformer with a Multihole Binocular Core (MHB2). The free running frequency is approximately 45kHz. The system incorporates EMC filtering and a start-up and protection circuit.

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Summary

In the underlying report a description is given a of 1x18W HF-TL ballast and evaluation board. The ballast is a self-oscillating Voltage Fed Half Bridge Inverter, which has been developed to drive one 18W (T8) TL-D lamp. The circuit has been designed for a nominal input voltage of 230Vrms±15%, 50-60Hz and an input voltage range of 160-265Vrms. One of the key components is the BUW85 power switching transistor, but also the BUX85 can equally well be applied. The power switching transistor is driven by a discrete driver circuit, consisting of BYD33D diodes and a small driver transformer with a Multihole Binocular Core (MHB2). This transformer determines, together with the ballast coil and the ignition capacitor, the free running frequency of approximately 45kHz. The printed circuit board (PR37692) contains a mains filter to fulfil all EMC requirements but, since the power dissipated is less than 25W, a preconditioner is not incorporated.

CONTENTS

LIST OF FIGURES

1. INTRODUCTION.

In the underlying report a description is given of a 1x18W HF-TL ballast and evaluation board. A small and low cost ballast has been realised which is able to drive an 18W (T8) TL-D lamp. A Voltage Fed Half Bridge inverter has been chosen as lamp driver with a discrete driver circuit to drive the bipolar power transistor (BUW85). It is a self-oscillating system of which the switching frequency of 45kHz is determined by the saturation effect of the driver transformer, the storage time of the power switching transistor and the value of the ballast coil and ignition capacitor. The driver circuit consists of some BYD33D diodes and a small driver transformer with a Multihole Binocular Core (MHB2).

For a reliable operation of the lamp and HF-ballast, the fluorescent lamp is preheated first. This is achieved by a PTC which is put across the lamp. As the principle operation of the 18W ballast is equal to the principle which has been described in "Discrete 2x40W HF-TL ballast" [1], this report can be used as a reference. The main differences are that several new components have been used, like the PTC, two capacitors and the ballast coil. In this way the height of the PCB board could be reduced.

The inverter has been designed for a nominal input voltage of 230Vrms±15%, 50-60Hz and an operational input voltage range of 160-265Vrms. The system incorporates EMC filtering and a start-up circuit and a protection circuit for lamp replacement.

The printed circuit board (PR37692) is a double sided PCB which has a width of 27mm and a height less than 20mm.

2. CIRCUIT DESCRIPTION.

The HF ballast has been designed for a mains voltage of 230Vrms±15%, 50-60Hz. The circuit consists of two sections: the EMC filter + AC rectification section and the HF ballast section.
The AC mains voltage is rectified by bridge rectifying diodes and the DC voltage for the HF ballast is smoothed by a buffer capacitor. The resulting AC supply current contains harmonics of the mains frequency. As the total input power remains below 25W, no Power Factor Correction circuit is required to reduce the harmonic content. To meet the regulations, the common mode and differential mode disturbances into the mains are suppressed by the EMC filter.
The HF ballast is a Voltage Fed Half Bridge Inverter, which has been designed to drive one 18W TL-D (T8) fluorescent lamp. The Voltage Fed Half Bridge Inverter belongs to a group of high frequency resonant inverters which are very attractive to drive electronic ballasts. Not only the low voltage across the power switching transistors, but also the high efficiency that can be achieved make this inverter very popular.
One of the key components is the bipolar power transistor BUW85. This transistor is driven by a low cost discrete driver circuit, which derives its drive information from a current transformer in series with the ballast coil. This Voltage Fed Half Bridge Inverter is a self oscillating system of which the operating frequency is approximately 45kHz.
A detailed description of the basic operation of the ballast is given in report "Discrete 2x40W HF-TL ballast" [1]. As the basic operation of the 1x18W ballast and the 2x40W ballast is comparable, from now on only the differences between both systems are described.

3. SYSTEM DESCRIPTION.

The system description is subdivided into four sections namely the start-up, preheat, ignition and steady state phase. The system description starts with the steady state phase. The reason is that, as a long life time of the lamp is required, it is important that the lamp is driven in the current working point during the steady state phase.

3.1 Steady State phase.

The HF-TL ballast has been designed for a nominal mains voltage of 230Vrms. The half bridge switching circuit delivers a block voltage with an amplitude equal to half the rectified mains voltage to the lamp circuit. During the steady state phase it is important that the lamp is driven in the correct working point. For the 18W TL-D lamp holds that the lamp voltage should be 55V and the lamp current 0.29A. A switching frequency of 45kHz has been chosen as nominal switching frequency. It can be calculated that for a certain L,C combination the lamp is operating in the correct working point. However also other combinations are possible. Parameters like the preheat current, the available circuit power after ignition and component tolerances determine, which combination will be applied. The result is that a ballast coil (L2) of 1.5mH and a capacitor of 5n6F (= C4 + C5) will give the best performance. The ballast coil is a new product with a small core width (7mm) and a low coil former (17mm).

3.2 Preheat phase.

To obtain a good life time of the lamp it is important, that the electrodes are carefully preheated by a certain current and during a certain time. A PTC (R4), which is put in parallel to the lamp, ensures that the current is flowing via the electrodes. The complete circuit provides a more or less fixed current in the ballast coil and thus in the electrodes. During that period the voltage across the lamp has to remain sufficiently low to prevent that the lamp ignites too early. The frequency at which the circuit is operating is determined by L2, C4 and C5.
The current through the PTC together with the resistance (R25°C) of the cold PTC determine the power which is dissipated in the PTC during the preheat time. The size of the PTC together with the switch temperature (Tswitch) determine the desired preheat time. The result is a small PTC of the 661 series with a long life time which specially has been developed for lighting applications.

3.3 Ignition phase.

As soon as the switch temperature is reached, the impedance of the PTC rapidly increases. The series resonance of L1, C4, C5, and (Rel+Rptc) results in an increasing lamp voltage. This continues until the lamp voltage reaches its ignition value. Then the lamp ignites. As soon as the maximum ignition voltage is reached, also the current in the ballast coil is maximal. The absolute maximum value of this current determines, together with the value of L2, the size of the ballast coil.

The electrodes of the lamp stay warm because a part of the ballast current remains flowing via C5. The ratio between C4 and C5 is such that the PTC shunts the smallest capacitor. In this way the dissipation in the PTC remains during the steady state phase sufficiently high to keep the impedance of the PTC high. The applied PTC has for this application a suitable R25°C, Tswitch and size. Moreover its life time is high. For efficiency reasons new low loss capacitors have been applied for the positions C5 and C6.

The PTC can also be removed if cold ignition or a high efficiency of the total ballast is desired. In that case C4 should be replaced by a 5n6F capacitor, C5 can be omitted and replaced by a jumper, and moreover a resistor of 750k should be put in parallel to transistor TR1. This option however has not thoroughly been investigated.

3.4 Start-up phase.

The lamp circuit is not self starting. For this reason an additional start-up circuit has to be used. The input voltage is derived from the rectified mains voltage. After the HF ballast is powered up, the voltage across C8 starts to rise. This continues until the DIAC (D14) trigger voltage is exceeded. Then the base circuit of the lower transistor TR2 will be pulsed by the DIAC. After the initial turn-on of TR2, the oscillation sustains and a high frequency square wave excites the L-C resonant lamp circuit.

The DIAC starts together with C8 the half bridge circuit. In this way a relaxation oscillator is realised, consisting of C8, DIAC D14, D9, R7 and transistor TR2. In the steady state phase D9, R7 and TR2 take care of a repetitive discharge of C8, so that the DIAC does not conduct any more. Due to the positive feedback of the driver transformer (L3) the half bridge inverter will start to oscillate.

4. DRIVER CIRCUIT.

The principle of the drive operation and the design of the driver circuit do not differ from what has been described in [1] (Chapter 4). For this reason only the differences with respect to [1] are described below.

A discrete low cost driver circuit has been designed to drive the bipolar switching transistor BUW85 (SOT82).

In a half bridge concept the anti-parallel diode conducts ballast current first, before the transistor is conducting. In the application which has been described in [1] this diode was situated between base and common. As a result the ballast current is flowing via this diode and the base-collector diode. A problem however is that, due to the wide current gain (hfe) range of the BUW85, the base-collector current would influence switching behaviour of the transistor in a negative way. For this reason a diode (D5,D10) has been added to improve the drive of the transistor. If the range of the current gain samples is restricted to low and medium, these additional diodes can be omitted.

The BUX85 (TO220AB) can also be applied. The only difference is that the BUW85 has a higher thermal resistance (Rth). To reduce the temperature increase it is advised that the BUW85 should be clip-mounted to the housing.

The driver transformer consists of a MultiHole Binocular core (MHB2) and windings on the inner and outer legs. The primary (np=3) of the transformer has been wound on the centre leg and both secondary turns (ns=4) on the outer legs.

5. AC RECTIFICATION AND ELECTRO-MAGNETIC (EMC) FILTER.

The mains voltage is connected to a bridge rectifier circuit, which rectifies the AC supply to produce a DC voltage across the smoothing capacitor C2 (see chapter 10.1). As this occurs during a short period, the AC supply current will have a high amplitude during a short time. This will cause higher harmonics of the mains frequency. In some situations new regulations demand a reduction of the harmonic content. For this application however no additional measures are necessary because the input power remains below 25W.
In HF-ballasts Radio Frequency Interference (RFI) may be produced by direct radiation or by conduction of interfering currents through the input terminals. Direct radiation can be adequately suppressed by enclosing the HF-ballast in a metal box. It can be perforated to allow cooling by convection and careful attention has to be paid to the layout of the internal wiring (see chapter 10.2).
Common mode (a-symmetrical) RFI currents are generated by the midpoint voltage across the power switching transistors and the voltage across the lamp. For this reason the dV/dt of the midpoint voltage is limited by capacitor C7.
Differential mode (symmetrical) disturbance is mainly caused by the internal impedance of the electrolytic buffer capacitor C2 and the HF ballast current, which is partly flowing via this capacitor and the half bridge capacitor C6. Across C2 a voltage is generated which is the source of the differential mode RFI currents. To minimise this disturbance, an electrolytic buffer capacitor (C2) was chosen with a low ESR and ESL. As this capacitor is one of the key components which determines the life time of the ballast, a capacitor (042) with a high ripple current capability was chosen.
The common mode and differential mode currents must be prevented from flowing into the mains. The common mode filter consists of L1 (CU10d) and Y-capacitor C3 (MKP 336 6) and the differential mode filter consists of L1 and X-capacitor C1 (MKP 336 2).
The circuit was measured without a screened HF-ballast and without an armature. In the frequency range from 9kHz till 30MHz the disturbance is below the limits (see chapter 10.4).

6. Protections.

The protection principles are described in [1]. The only modification is that the protection circuit could be simplified by omitting two diodes.

7. PERFORMANCE.

Input:	Nominal input voltage: 230Vrms ± 15%
	Input voltage range: 160 - 265Vrms
Lamp:	18W TL-D
Efficiency:	85%
	98% with PTC disconnected
Switching frequency:	nominal switching frequency: 45kHz

8. REFERENCES.

[1] Discrete 2x40W HF-TL ballast
Author : H. Simons
Report nr. : AN96004

9. OSCILLOGRAMS.

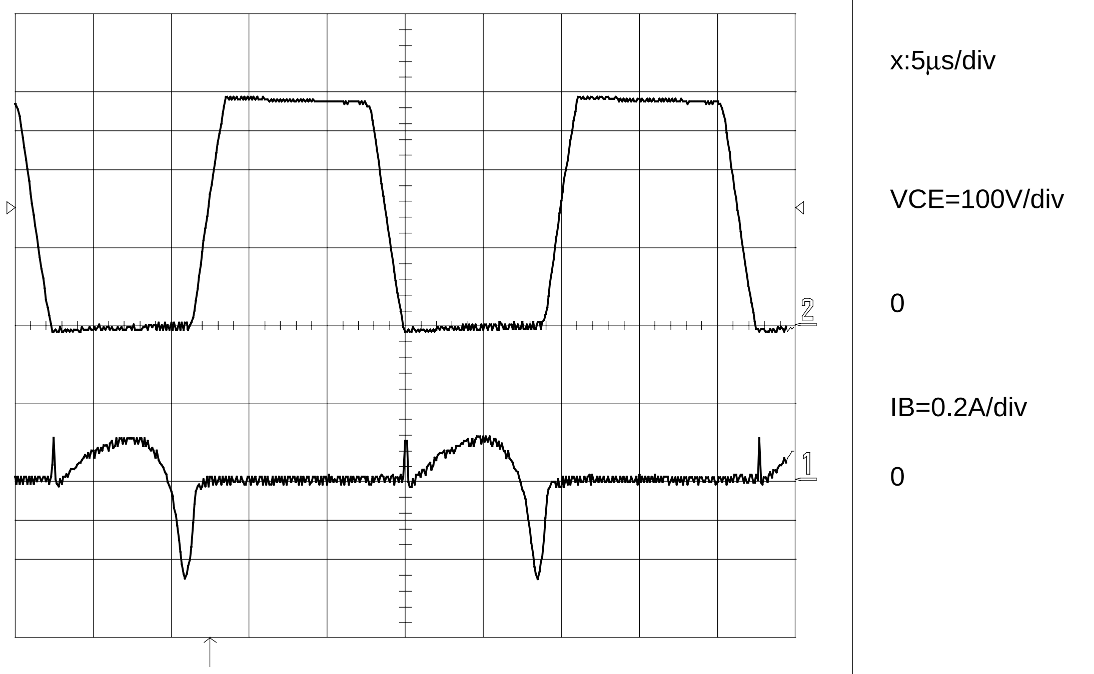


Fig.1 Base current and VCE of BUW85

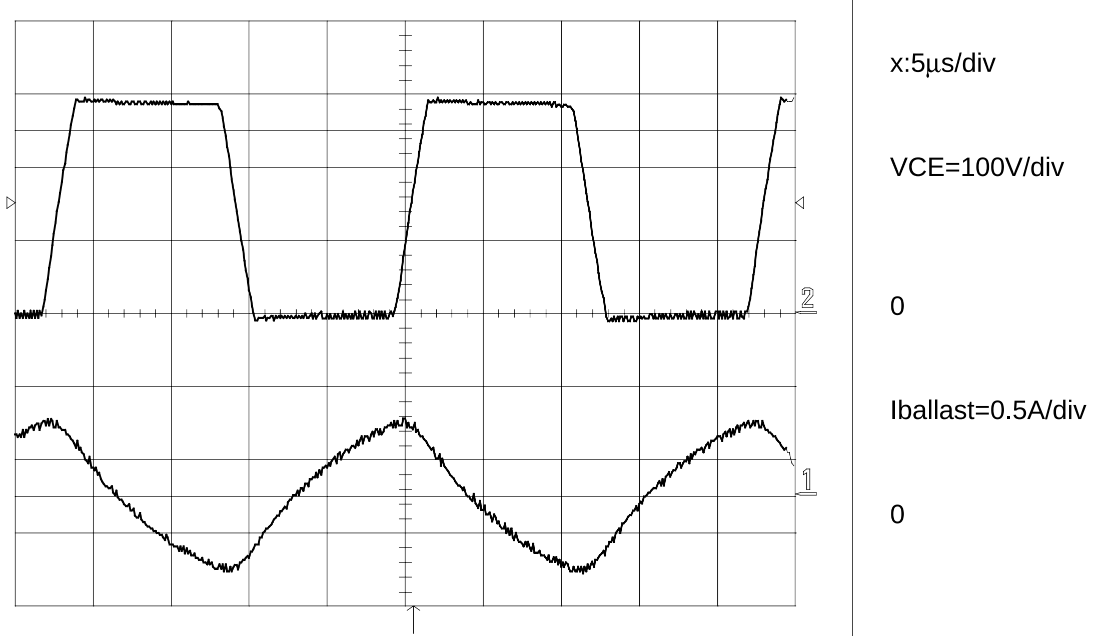


Fig.2 Ballast current and VCE of BUW85

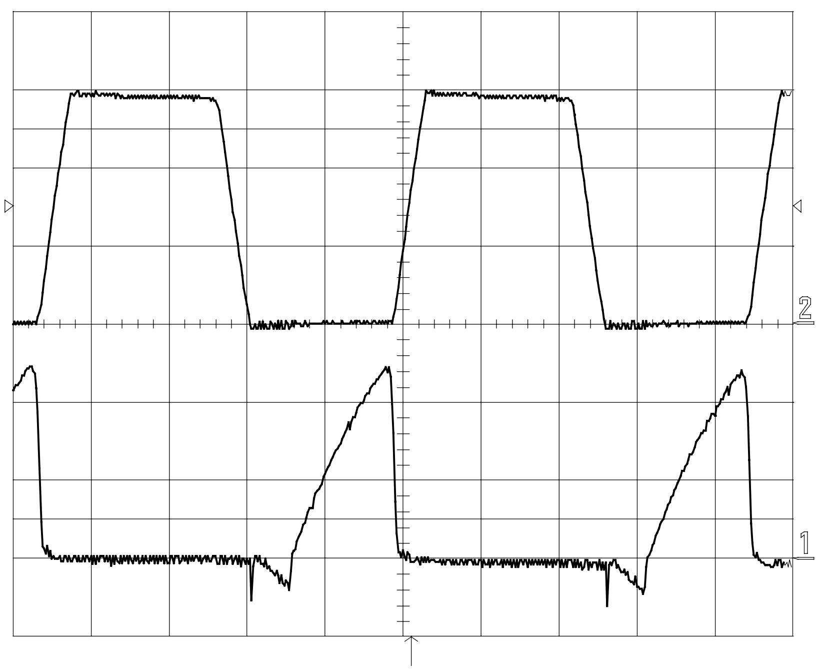


Fig.3 Collector current and VCE of BUW85

x:5µs/div

VCE=100V/div

0

IC=0.2A/div

0

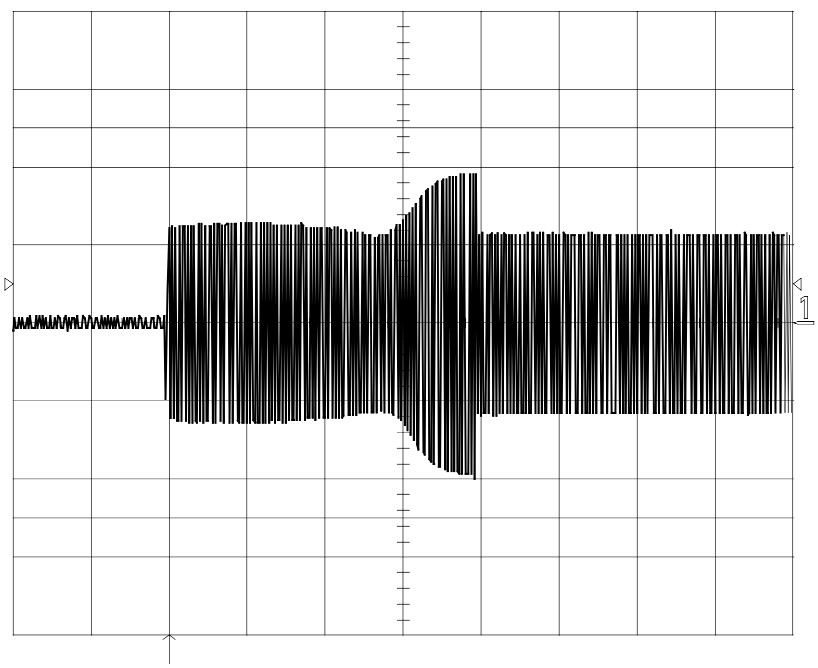


Fig.4 Current in the ballast coil.

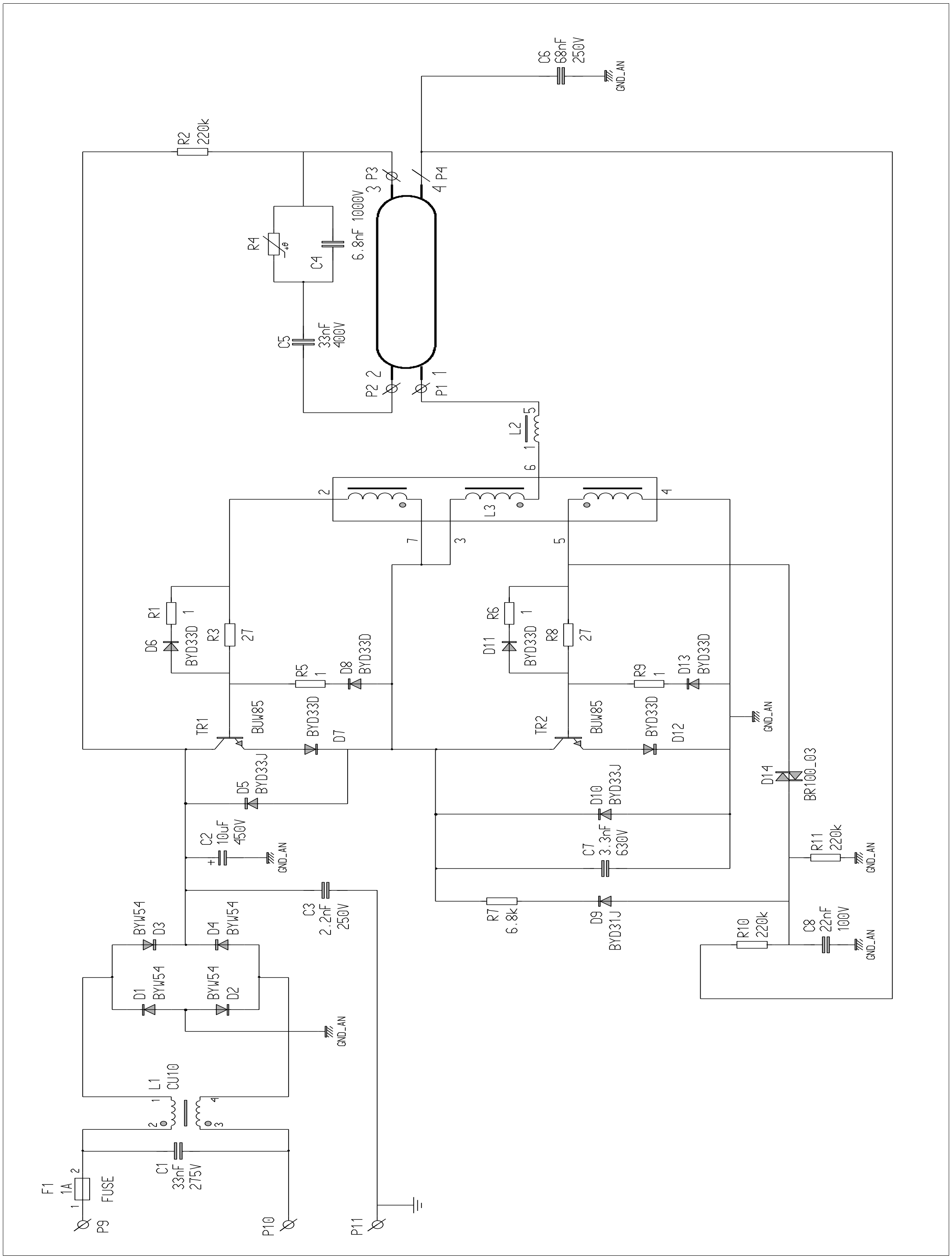
x:0.5s/div

Iballast=0.5A/div

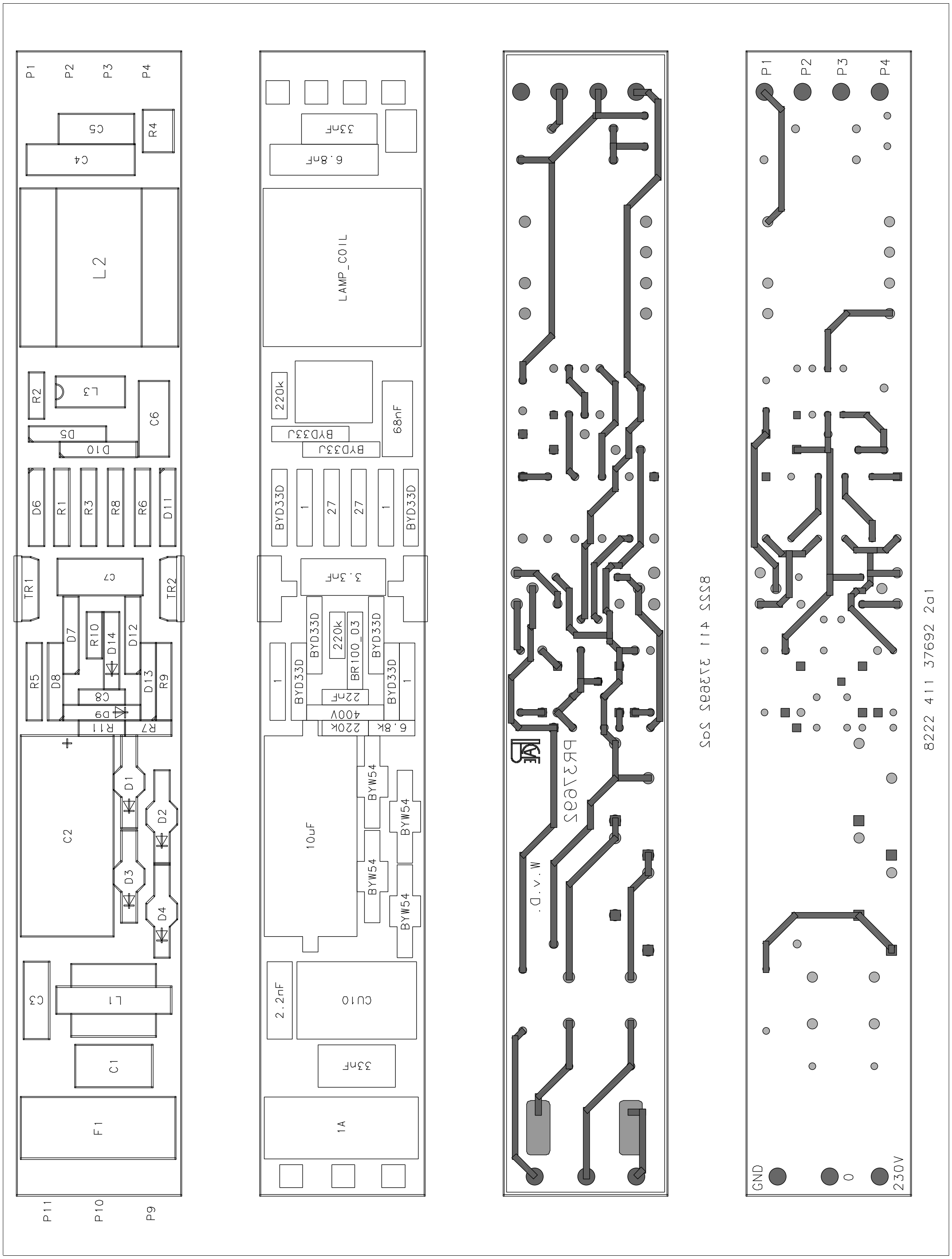
0

10. HF-TL BALLAST SCHEMATIC DIAGRAM, LAYOUT, PARTS LIST AND RFI MEASUREMENT.

10.1 HF-TL BALLAST SCHEMATIC DIAGRAM.



10.2 HF-TL BALLAST LAYOUT.



10.3 HF-TL BALLAST PARTS LIST.

Number of the Printed Circuit Board: PR37692

SEMICONDUCTORS:

D1,2,3,4	BYW54	4	9333 636 10153
D5,10	BYD33J	2	9337 234 20113
D6,7,8,11,12,13	BYD33D	6	9337 234 00113
D9	BYD31J	1	9339 235 60113
D14	BR100-03	1	9333 904 60113
TR1,2	BUW85	2	9334 398 10127
	BUX85	2	9332 965 90127

WIRE WOUND COMPONENTS:

L1	CU10d	1	3128 138 35121
L2	CE254d3	1	3128 138 35991
L3	MHB2-13/8/6-3C85 (core) (Hand made)	1	4313 020 40053

CAPACITORS:

C1	33nF/275V	1	2222 336 21333
C2	10µF/450V	1	2222 042 91109
C3	2n2F/250V	1	2222 336 60222
C4	6n8F/1000V	1	2222 378 74682
C5	33nF/400V	1	2222 479 54333
C6	68nF/250V	1	2222 479 44683
C7	3n3F/630V	1	2222 347 61332
C8	22nF/100V	1	2222 370 21223

RESISTORS:

R1,5,6,9	1R	4	2322 180 73108
R2,10,11	220K	3	2322 180 73224
R3,8	27R	2	2322 180 73279
R4	PTC	1	2322 661 93114
R7	6k8	1	2322 180 73682

10.4 RFI MEASUREMENT.