EVAL6520-1421

14 W / 21 W T5 miniature ballast driven by L6520 and STT13005D bipolar transistors

Data brief

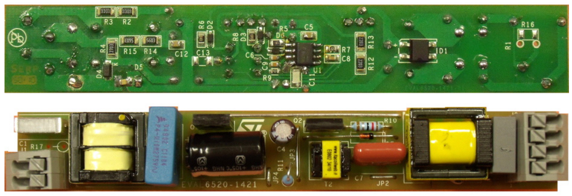
Features

- Drives either T5-14W-HE or T5-21W-HE lamps
- Standard form factor (19 mm x 120 mm)
- Compliance with IEC61347-2-3, IEC61000-2-3 and EN55022 Class-C

Description

The EVAL6520-1421 is a demonstration board able to drive either a 14 W or 21 W linear T5 fluorescent lamp with the L6520 low voltage ballast controller.

The half bridge consists of NPN high voltage power transistors driven by a suitable pulse transformer.



EVAL6520-1421

Contents

1 Introduction

The L6520 low voltage ballast controller is intended to drive extremely compact applications based on either MOSFETs or bipolar transistors.

The EVAL6520-1421 is capable of driving either a T5-14W-HE or T5-21W-HE lamp, with the same miniatured (16 mm wide) ballast.

The selection of both the resonant components and the bipolar transistors, together with the design of the suitable pulse transformer, and IC power supply is also described.

2 Board description

The board is supplied by any AC voltage in the European mains range and does not need any power factor correction having an input power of less than 25 W.

The half bridge voltage is obtained by filtering the rectified input voltage. This allows the use of a cheaper bulk capacitor and bipolar transistors.

The selection of a target condition is required by the range of the input voltage together with the necessity to drive two different kinds of lamps. In particular, the best driving condition and the best efficiency is obtained at 240 Vac with a 14 W lamp connected.

An EMI filter is placed at the board's input to meet IEC61000 standards.

The lamp's cathodes are current preheated to make the ballast choke more compact thanks to the absence of auxiliary windings.

The resonant network design starts from the selection of the resonant capacitor (C10) that corresponds to the desired ballast efficiency. The inductance (L1) can be obtained by the following equation:

Equation 1

$$\text{Lamp} = \left| \frac{\frac{1}{R_{Lamp}}}{\frac{1}{R_{Lamp}} + j\omega C_{RES}} \cdot \frac{V_{HB}}{j\omega L_{RES} + \frac{1}{\frac{1}{R_{Lamp}} + j\omega C_{RES}}} \right|$$

V_{HB} is the effective voltage obtained across the half bridge along one mains cycle. The lower voltage is obtained at 50 Hz and can be approximately computed as:

Equation 2

$$V_{HB} = \left(\frac{\sqrt{2}}{2} \cdot V_{IN} - V_F \right) + \sqrt{\left(\frac{\sqrt{2}}{2} \cdot V_{IN} - V_F \right)^2 - \frac{1.54 \cdot 10^5 \cdot P_{LAMP}}{f_{MAINS} \cdot C_{OUT}}}$$

where:

- V_F is the forward voltage drop of the rectifier bridge (1 V typ.)
- V_{IN} is the RMS value of the input voltage
- C_{OUT} is the value of the bulk capacitor in µF (In this case C3 = 4.7 µF has been selected)

A resonant capacitor equal to 3.9 nF has been selected and resonant inductor equal to 3 mH has been calculated.

It is now possible to estimate the ignition frequency, which must be higher than 46 kHz (minimum programmable value), and the minimum preheating frequency that guarantees a preheating voltage higher than 130 Vrms, as required by the lamp specifications.

Equation 3

$$V_{PH-IGN} = \left| \frac{\frac{V_{PFC} \cdot \sqrt{2}}{\pi} \cdot \frac{1}{j\omega C_{RES}}}{\frac{1}{j\omega C_{RES}} + j\omega L_{RES}} \right|$$

A preheating frequency equal to 70 kHz has been selected by connecting a 2.49 kΩ resistor (R5) between the FPRE pin and GND.

The half bridge is based on two STT13005D power bipolar transistors (Q1 and Q2). Both the high side and low side transistor are driven by a pulse transformer (T2).

To design this pulse transformer, the following parameters must be taken into account:

- Maximum available spacing on the PCB: this determines the core dimension.
- Maximum magnetizing current ($I_{mag,rms}$) on the primary side of the transformer: this current causes core losses to not be transferred as a useful signal on the secondary side of the transformer. To minimize it, a higher primary inductance should be adopted. Typical inductances are between 6 mH and 40 mH, depending on the core dimension and the core permeability.
- Primary to secondary transfer ratio (n): the output voltage of a step-down transformer is lower than the input voltage, whereas the output current is higher than the input current. This helps to obtain higher DC currents with lower IC power dissipation. The minimum Vbe(sat) must be guaranteed in any condition as well as the minimum IB that guarantees the saturation condition of the BJT.

The $I_{mag,rms(MAX)}$ is selected lower than 10 mA when Vcc is equal to 13 V and a typical storage time of 1.2 µs is considered, therefore the primary inductance must be:

Equation 4

$$Lpri \geq Vcc \cdot \frac{T_{on,max}}{\frac{I_{mag,rms}}{\sqrt{3}}} = \sqrt{3} \cdot Vcc \frac{\frac{1}{2 \cdot f_{run}} - T_{dt} - T_{sto} - 200ns}{I_{mag,rms}} = 1.732 \cdot Vcc \frac{9.42us - T_{sto}}{I_{mag,rms}} = 6.18mH$$

The Vbe of the bipolar transistor can be calculated as follows (see *Figure 2*):

Equation 5

$$Vbe = Vpri \cdot n - Ib \cdot Rb = \left[Vcc - \frac{Ib}{n} \cdot (Rds,on\_h + Rpri + Rds,on\_l) \right] \cdot n - Ib \cdot Rb$$

The Rds,on_h and the Rds,on_l are the ON resistances of the L6520 drivers and can be considered equal to 10 Ω each.

Ib is equal to Ic/hfe, and can be considered equal to Ic/6. Ib times Rb can be set between 0.7 V and 1 V, during run mode: in this design Rb (R6 and R8) can be selected between 10 Ω and 13 Ω.

With these constraints the following is obtained:

Equation 6

$$Vbe = \left[13 - \frac{0.46}{n} \cdot (20 + Rpri)\right] \cdot n - 0.76 = 13 \cdot n - 9.2 - 0.46 \cdot Rpri - 0.76 > 1.1 \rightarrow 13 \cdot n - 0.46 \cdot Rpri > 11.6$$

Selecting an Rpri (R7) equal to 47 Ω, the minimum transfer ratio should be equal to 2.55.

n = 5.6 has been selected.

The PWM_det pin network is composed of 3x220 kΩ resistors (R11 to R13) together with a 47 pF speed-up capacitor (C11). The value of the speed-up capacitor also avoids a misdetection of the hard switching.

During normal operation the IC absorbs the following currents from the Vcc:

1. Effective base currents of the BJTs divided by *n* (5.6). A 39 $mA_{(MAX)}$ is estimated.
2. Magnetizing current = 10 $mA_{(MAX)}$
3. L6520 power consumption: 8 $mA_{(MAX)}$

A maximum current of 57 mA_{rms} must be foreseen. For this reason, the IC power supply has been connected in series with the resonant network (D4 and D5). This connection does not interfere with the optimum preheating of the lamp's cathodes, but introduces a little offset (7.5 V typ.) into the lamp voltage.

This offset affects the EOL detection, but a different choice of values of the Zener diodes (D6 and D7) makes the detection symmetrical. The two values, together with the resistance values (R14 and R15), can be calculated through the following system of equations ($V_{Lamp,MAX}$ = 30 V and $V_{Lamp,min}$ = -16 V):

Equation 7

$$\begin{cases} V_{Lamp,MAX} = V_{EOL} + V_{Z,D7} + I_{BIAS} \cdot (R14 + R15) + V_{F,D6} \\ V_{Lamp,min} = V_{EOL} - V_{Z,D6} - I_{BIAS} \cdot (R14 + R15) - V_{F,D7} \end{cases}$$

Finally, a 4.7 µF is used as the Vcc bulk capacitor (C4) and two 100 nF ceramic capacitors (C5) are placed close to the Vcc pins of the two ICs.

By allowing the startup network (R2 to R4) to pass through the upper cathode of the lamp, the automatic re-lamp feature is easily obtained.

3 Board performance

Figure 1. EMI spectrum at nominal input voltage (230 Vac)

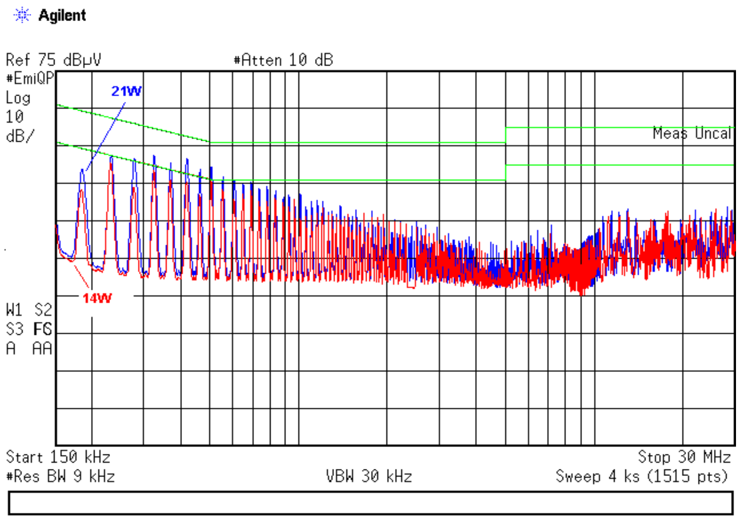


Figure 2. Lamp voltage and current (T5 14 W HE)

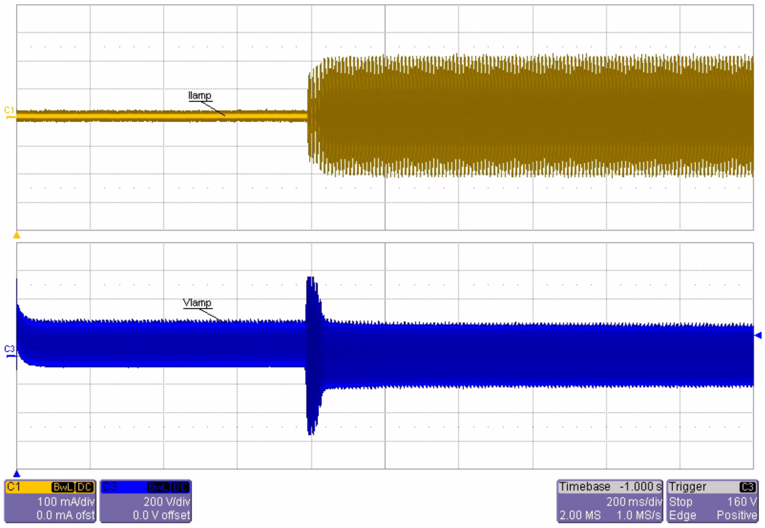
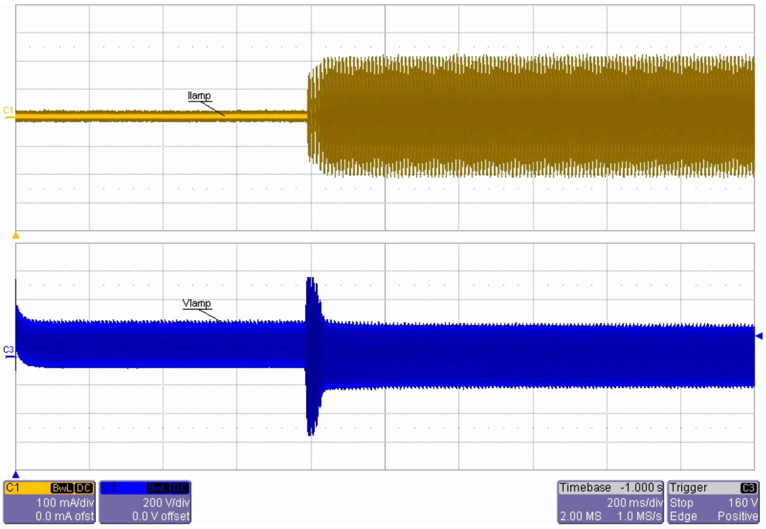


Figure 3. Lamp voltage and current (T5 21 W HE)



4 Application specifications

Table 1 and *2* show the application specifications for the input and lamp requirements.

Table 1. Input requirements

Parameter	Value	Unit
Input voltage	198 to 264	V_{rms}
Mains freq.	50 to 60	Hz
Input power	25	W max

Table 2. Lamp requirements

Parameter	T5 - 14 W	T5 - 21 W	Unit
Lamp current	170 ± 30%		mA_{rms}
Lamp voltage	82 ± 6%	123 ± 6%	V_{rms}
Max. ignition voltage	1000		V_{pk}
Max. preheating voltage	130		V_{rms}

5 Bill of material and board schematics

Table 3. Bill of material

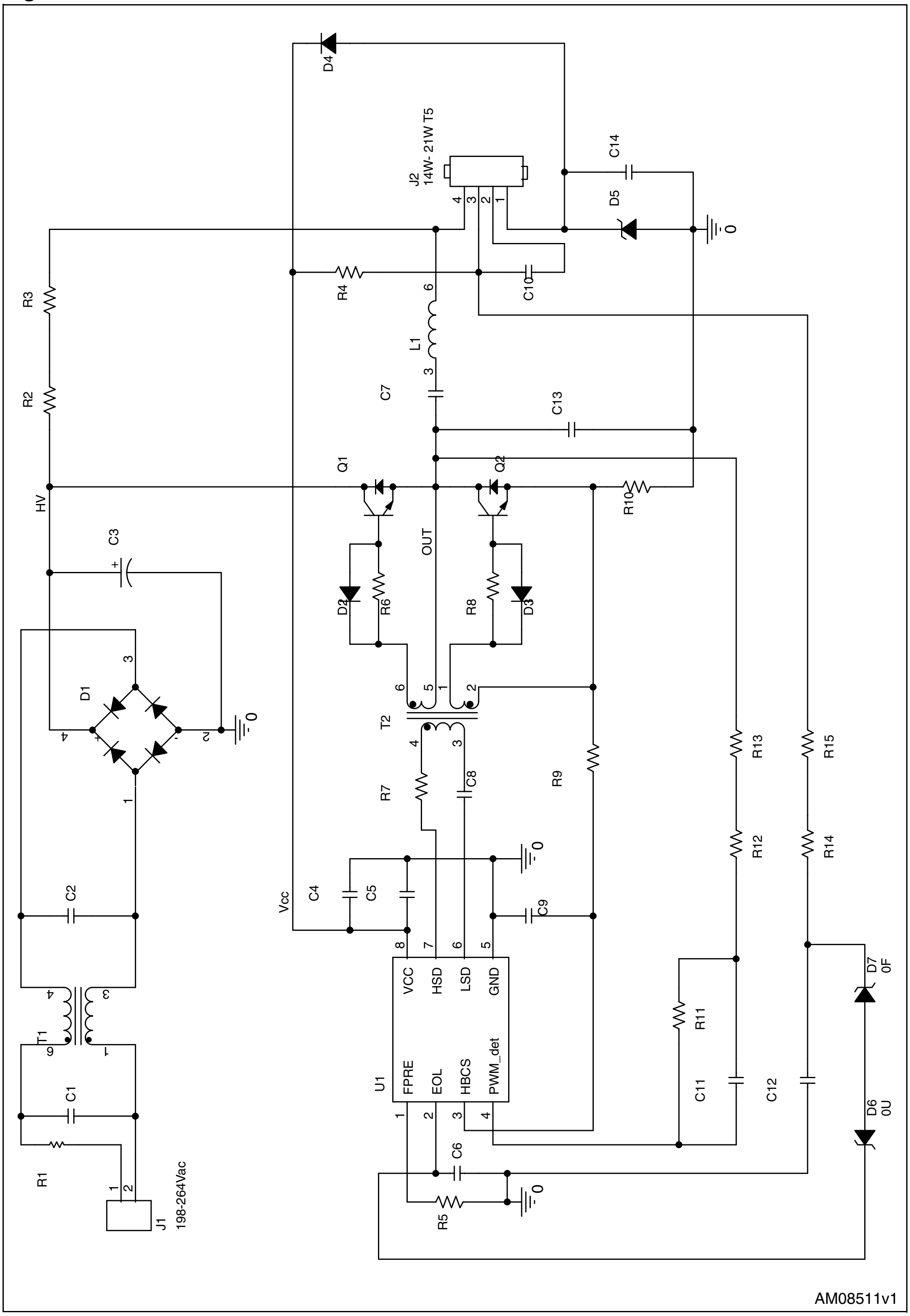
Reference	Value / part number	Rating	Notes
C1	100 nF	275 Vac	
C2	100 nF	275 Vac	
C3	4.7 µF	400 Vdc - 105 °C	
C4	4.7 µF	50 Vdc	
C5	100 nF	25 Vdc	
C6	1 nF	25 Vdc	
C7	100 nF	400 Vdc	
C8	100 nF	25 Vdc	
C9	1 nF	25 Vdc	
C10	3.9 nF	1000 Vdc	Panasonic ECQ P6392JU
C11	10 pF	500 Vdc	
C12	100 nF	25 Vdc	
C13	Not mounted		
C14	22 nF	50 Vdc	
R1	PCB fuse	6 A - 1 s	
R2	330 kΩ		
R3	330 kΩ		
R4	270 kΩ		
R5	2.94 kΩ	0.1%	
R6	10 Ω		
R7	47 Ω		
R8	10 Ω		
R9	470 Ω		
R10	1.2 Ω	1%	
R11	220 kΩ		
R12	220 kΩ		
R13	220 kΩ		
R14	560 kΩ		
R15	560 kΩ		
T1	2 x 33 mH CM-filter	440 mA / 250 Vac	SCLE16333-ITACOIL

Table 3. Bill of material (continued)

Reference	Value / part number	Rating	Notes
T2	5.6 : 1:1	12 mH	E0802-ITACOIL (*Figure 5*)
L1	3 mH	0.9 A	E16113-ITACOIL (*Figure 6*)
U1	L6520		
Q1	STT13005D		
Q2	STT13005D		
D1	B6S-E3/80		
D2	RB751V40T1		
D3	RB751V40T1		
D4	MMSD4148T1G		
D5	BZT03C15	3 W	
D6	MM3Z6V8ST1	6.8 V Zener	
D7	MM3Z6V8ST1	16 V Zener	
J1	V_{IN} connector	198-264 Vac	
J2	Lamp connector		

5.1 Board schematic

Figure 4. Board schematic



Appendix A Magnetic components data

Figure 5. Pulse transformer (T2) datasheet

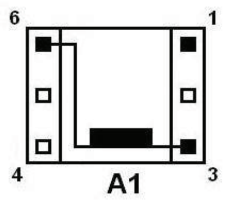
Figure 6. Ballast choke (L1) datasheet

PRODUCT DATASHEET

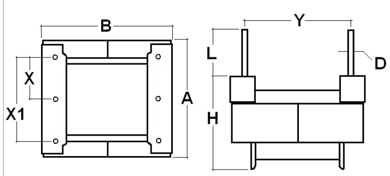
PRODUCT - REV	E16113	00
SAMPLING CODE	090710	

PRODUCT DESCRIPTION[1]		Inductor 3.0 mH	
Thermal class	B		
Inductance	3,0 mH +/-7%		
DCR	8,0 Ω max		
Rated current	0,192 A_{rms}		
Saturation current	> 0,65Apk		
Max peak current	0,85Apk		
Dielectric strenght	700Vac winding/core		

LAYOUT (BOTTOM VIEW)



DRAWING



DIMENSIONS (mm)

A	17,30	MAX
B	17,20	MAX
H	12,50	MAX
X	3,80	Typ
X1	7,60	Typ
Y	12,50	Typ
D	0,60	Typ Ø
L	5,50	Typ

COMPONENTS[2]	THERMAL CLASS	STANDARDS
Magnet wire	T.I. 155°C (F)	EN60172
Bobbin material	T.I. 130°C (B) - 20.000h	UL94/V-0 - IEC 60695
Insulation tape	T.I. 130°C (B)	IEC 60112
Varnish	T.I. 155°C (F)	

All the items, except those defined "safety transformers in compliance to the European standards EN61558-1 and EN61558-2-6" in our catalogue, are supplied as a semi-finished component for specific use into electronic equipments designed by the client. Type testing and any other valuation necessary to verify the compliance of the characteristics of the transformer with the technical, safety and any other requirement have to be done by the user, before using. Each requirement and test has to be requested in writing ; without written instructions the product will be tested according to our Quality System standards.

ST1 - ENG rev. 01 – 16/06/2010 — subject to change without notice

1 Some data can be changed following type tests
2 Only take into account materials actually present

AM07475v1

Revision history

Table 4. Revision history

Date	Revision	Changes
07-Mar-2011	1	Initial release.
28-Nov-2011	2	Updated *Section 2* and *Table 3*.