AN1897
Application note

VIPower™: low-cost universal input DVD supply with the VIPer22A-E

Introduction

In the past few years, many consumer products have been provided to the end user, such as DVD or VCD players. Generally, their power supply requires multiple outputs to supply a variety of control circuits: MCU, motor, amplifier, VFD.

Offline switch mode power supply regulators from ST's VIPer® family combine high voltage, avalanche rugged vertical power MOSFET with current mode control PWM circuitry. The result is the innovative AC-DC converter, simpler, quicker, with reduced component count and cheap.

The VIPer family complies with the "Blue Angel" and "Energy Star" norms, with very low total power consumption in standby mode, thanks to the burst operation. This document presents the application on DVD player power supply with the VIPer22A-E meeting the specifications in *Table 1*.

Figure 1. VIPer22A-E evaluation board

Table 1. Output specifications

Input	Output 1	Output 2	Output 3	Output 4	Output 5	Output 6
Universal line	5 V+/-5% (1)	+12 V+/-5% (1)	-12 V+/-5% (1)	-26 V+/-5% (1)	3.3 V+/-5% (1)	5 V_{stb}+/-5% (1)
Min. 85 V_{ac} Max. 265 V_{ac}	Imin. 20 mA Imax.1.5 A	Imax. 30 mA	Imax. 30 mA	Imax.50 mA	Imax. 150 mA	Imax.100 mA

1. The accuracy of +/-5% is reached for a range of load combination only. See *Section 3.2* for cross-regulation results.

Contents

1 Application description and design

1.1 Schematics

The overall schematic is shown in *Figure 3*.

1.1.1 Start-up phase

The VIPer22A-E has an integrated high voltage current source linked to the drain pin. At the start-up converter, it charges the V_{DD} capacitor until it reaches the start-up level (14.5 V), and the VIPer22A-E starts switching.

1.1.2 Auxiliary supply

The VIPer22A-E has a wide operating voltage range from 8 V to 42 V, respectively minimum and maximum values for undervoltage and overvoltage protections.

This function is very useful to achieve low standby total power consumption. The feedback loop is connected to 5 V output by D12 to regulate 5 V output. +5 V_{stb} output is blocked by Q3, so +5 V_{stb} regulation is neglected. When the standby signal is present, the Q3 V_{ce} cannot provide enough voltage to maintain D12 conducted, so the 5 V output is blocked, and the +5 V_{stb} output is connected to the feedback loop. In this condition the +5 V_{stb} is regulated. Thanks to the transformer structure, all the other secondary outputs and the auxiliary voltages are pulled down to a very low level, also pulling down the total power consumption. These features are below-indicated.

- In normal full load, the VDD voltage must be lower than the overvoltage protection.
- In short-circuit, the VDD voltage must be lower than the shutdown voltage. Actually, this condition leads to the well-known hiccup mode.
- In no-load condition, the VDD voltage must be higher than the shutdown voltage.

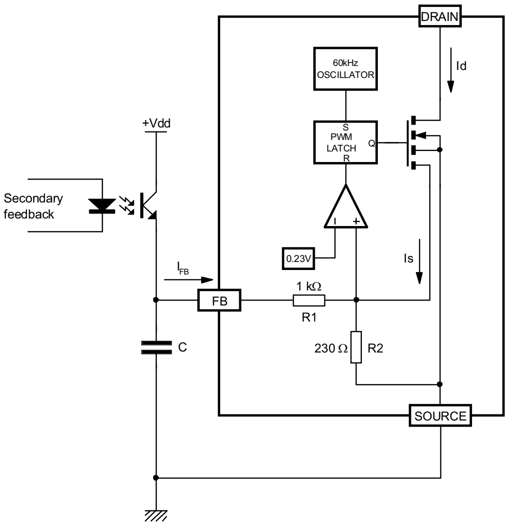
1.1.3 Burst mode

The Viper22A-E integrates a current mode PWM with a power MOSFET and includes the leading edge blanking function. The burst mode allows the VIPer22A-E to skip some switching cycles when the energy drained by the output load goes below $E = (T_b{*}V_{in})2 * f_{sw}/2L_p$ (T_b = blanking time, V_{in}= DC input voltage, f_{sw} = switching frequency, Lp = primary Inductance). The consequence is the reduction of the switching losses in case of low load condition by reducing the switching frequency.

1.1.4 Feedback loop

The 5 V output voltage is regulated by a TL-431 (U3) via an optocoupler (U2) to the feedback pin. If the output voltage is high, the TL-431 draws more current through its cathode to the anode and the current increases in the optocoupler diode. The current in optocoupler NPN increases accordingly and the current into the VIPer22A-E FB pin increases. When the FB current increases, the VIPer22A-E skips some cycles to decrease turn-on time and lower the output voltage to the proper level (see *Figure 1*). The 5 V output voltage is regulated thanks to the TL-431 reference voltage and the R8 and R9 resistive dividers.

Figure 2. VIPer22A-E FB pin internal structure



1.1.5 Primary driver

In a flyback power supply, the transformer is used as an energy tank during the on-time of the MOSFET. When the MOSFET turns off, its drain voltage rises from a low value to the input voltage while the secondary diode conducts, transferring to the secondary side the magnetic energy stored in the transformer. Since primary and secondary windings are not magnetically coupled, there is a serial leakage inductance that behaves like an open inductor charged at Ipk, causing the voltage spikes on the MOSFET drain. These voltage spikes must be clamped to keep the VIPer22A-E drain voltage below the BV_{dss} (730 V) rating. If the peak voltage is higher than this value, the device is destroyed. The RCD clamp (see *Figure 4*) is a very simple and cheap solution, but it impacts on the efficiency and on the power dissipation in standby condition. Besides, the clamping voltage varies according to the load current. RCD clamp circuits may allow the drain voltage to exceed the breakdown rating of the VIPer22A-E during the overload operation or during turn-on with high line AC input voltage. A Zener clamp is recommended (see *Figure 5*). However this solution gives higher power dissipation at full load, even if the clamp voltage is exactly defined.

1.2 Transformer consideration

On the electrical specifications of a multiple output transformer (cross-regulation, leakage inductance), the main efforts focused on the proper coupling between the windings. A lower leakage inductance transformer allows a lower power clamp to reduce the input power. It l leads to lower power dissipation on the primary side. Auxiliary and secondary windings are swapped in order to decrease the coupling to the primary one. The secondary windings act as a shielding layer to reduce the capacitive coupling. Fewer spikes are generated on the auxiliary windings, the primary and secondary windings have better coupling.

Designing transformers for low leakage inductance involves several considerations:

- Minimizing the number of turns
- Keeping ratio of winding height to width small
- Increasing width of windings
- Minimizing the insulation between windings
- Increasing coupling between windings

Figure 3. Application schematic

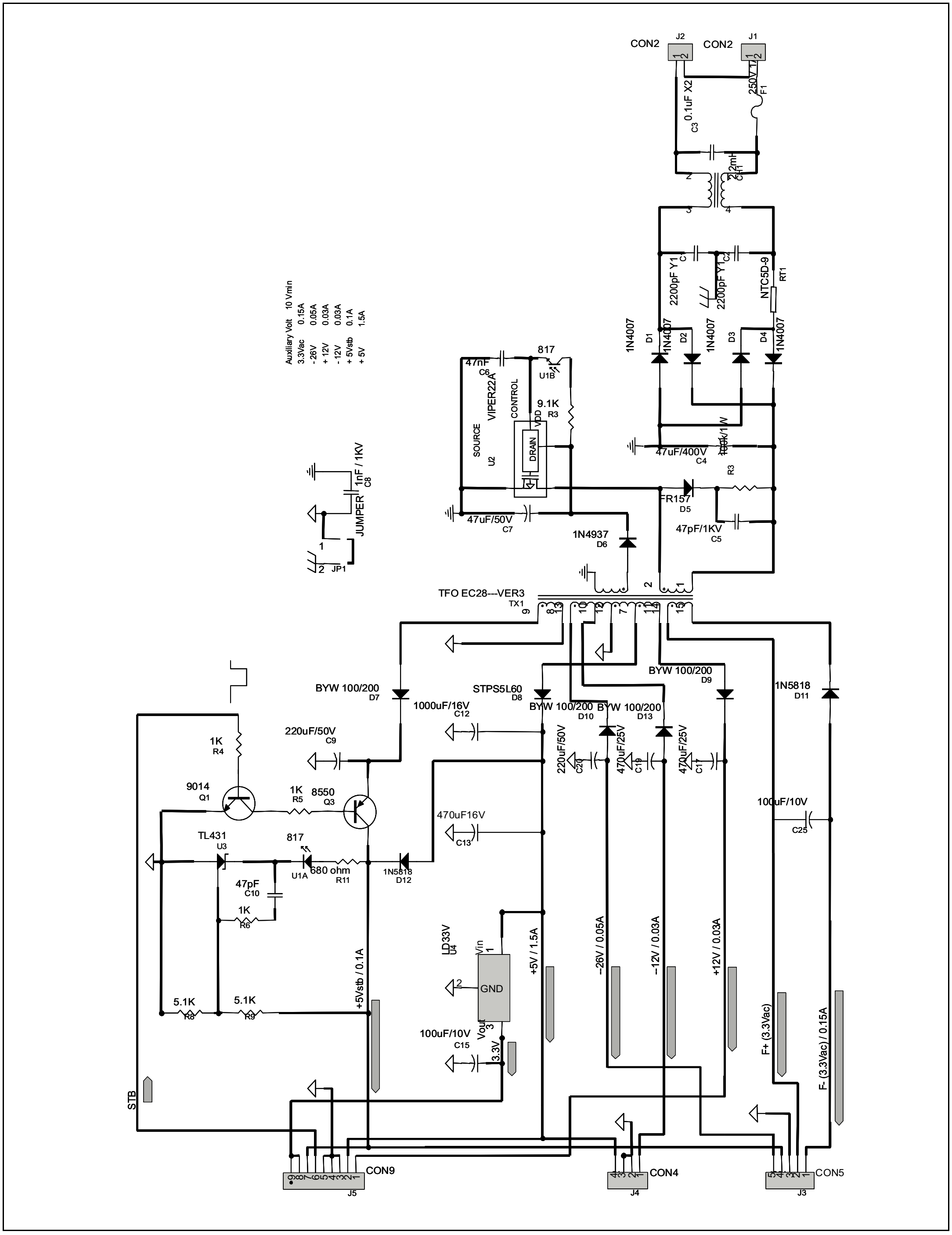


Figure 4. RCD clamp topology

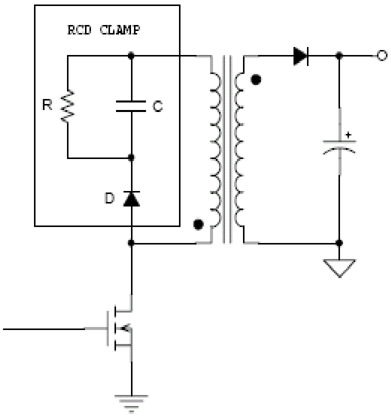
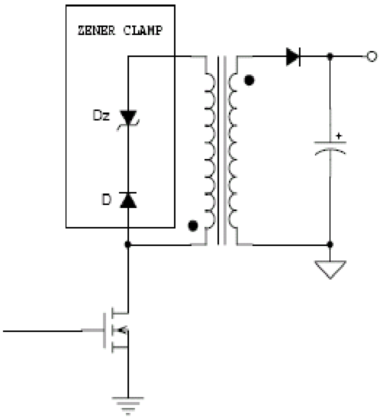
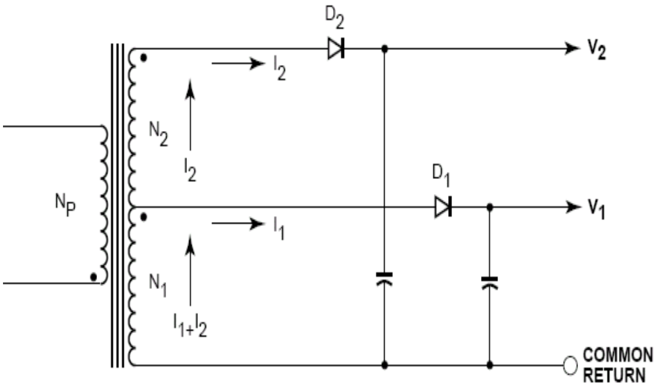


Figure 5. Zener clamp topology



For safety requirements, a leakage inductance value is 1 to 3% of the open circuit primary inductance. A high efficiency transformer should have low inter-winding capacitance to decrease the switching losses. Energy stored in the parasitic capacitance of the transformer is absorbed by the VIPer22A-E cycle-by-cycle during the turn-on transition. Excess capacitance also rings with stray inductance during switch transitions, causing noise problems. Capacitance effects are usually the most important in the primary winding, where the operating voltage (and consequent energy storage) is high. The primary winding should be the first winding on the transformer. This allows the primary winding to have a short length per turn, reducing the internal capacitance. The driven end of the primary winding (the end connected to the drain pin) should be the beginning of the winding rather than the end. This takes advantage of the shielding effect of the second half of the primary winding and reduces capacitive coupling to adjacent windings. A layer of insulation between adjacent primary windings can cut the internal capacitance of the primary winding by a four factor, with consequent reduction of losses. A common technique for winding multiple secondaries with the same polarity sharing a common return, is to stack the secondaries (see *Figure 6*). This arrangement improves the load regulation, and reduces the total number of secondary turns. Commonly a clamper based on an RCD network or a diode with a Zener to clamp the rise of the drain voltage is used.

Figure 6. Multiple output winding



2 Layout recommendation

Since EMI issues are strongly related to layout, a basic rule has to be taken into account in high current path routing, (the current loop area has to be minimized). If a heatsink is used it has to be connected to ground to reduce common mode emissions, since it is close to the floating drain tab. Besides, in order to avoid any noise interference on the VIPer22A-E logic pin, the control ground has to be separated from power ground.

3 Experimental results

3.1 Efficiency

Figure 7. Efficiency at 230 V_{ac} (load on 5 V)

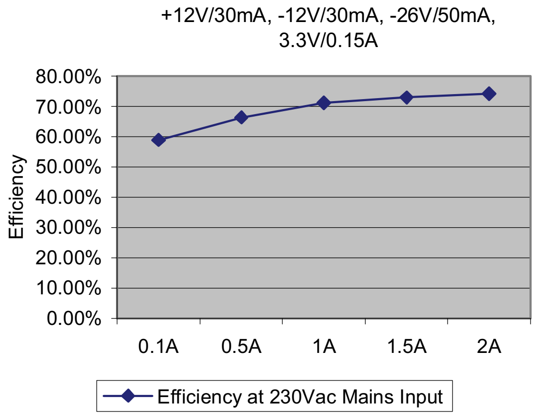


Figure 8. Efficiency at 260 V_{ac} (load on 5 V)

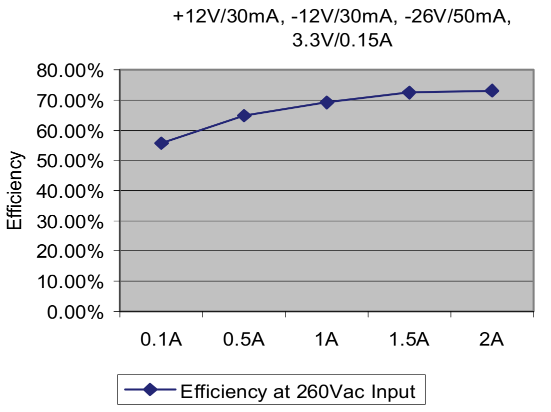


Figure 9. Efficiency at 85 V_{ac} (load on 5 V)

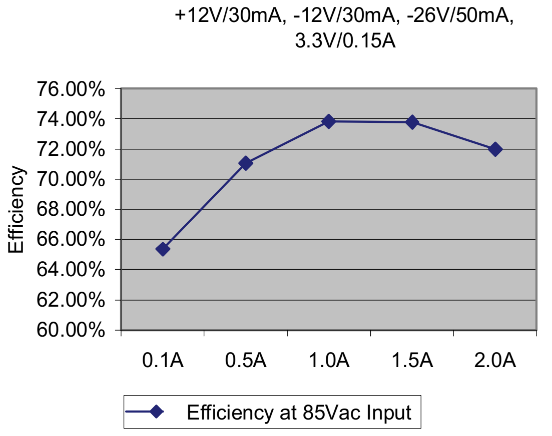
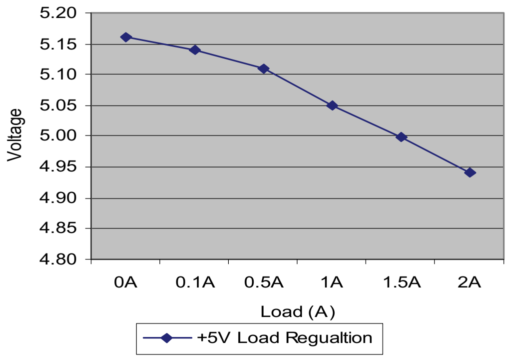


Figure 10. Load regulation (load on + 5 V)



3.2 Regulation

Table 2. Line regulation

Output	85 V_{ac}	85 V_{ac}	260 V_{ac}
5 V/ 0.1 A	5.15 V	5.15 V	5.15 V
5 V_{stb}/ 0 A	5.15 V 5	15.15 V	5.15 V
12 V/ 0 A	12.08 V	12.11 V	12.12 V
-12 V/ 0 A	-11.98 V	-11.99 V	-12.00 V
-26 V/ 0 A	-25.82 V	-25.85 V	-25.86 V
3.3 V/ 0 A	3.87 V	3.87 V	3.88 V

Figure 11. Cross-regulation

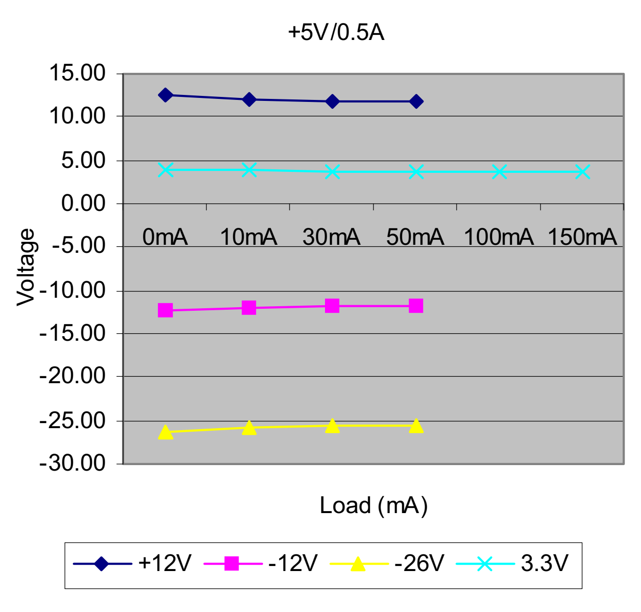


Table 3. Standby model

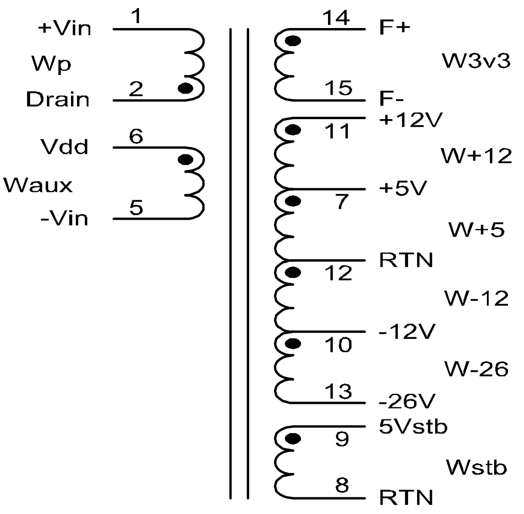
Output	85 V_{ac}	230 V_{ac}	260 V_{ac}
5 V	2.05 V	2.05 V	2.07 V
5 V_{stb} (100 mA)	5.08 V	5.11 V	5.14 V
12 V	4.00 V	3.99 V	3.98 V
-12 V	3.99 V	3.99 V	3.98 V
-26 V	9.12 V	9.10 V	9.08 V
3.3 V	1.70 V	1.50 V	1.51 V
PDIs	0.8 W	1 W	1.1 W

Table 4. Full load regulation

Output	85 V_{ac}	230 V_{ac}	260 V_{ac}
5 V/ 1.5 A	5.02 V	5.09 V	5.08 V
5 V_{stb}/ 0 A	5.02 V	5.09 V	5.08 V
12 V/30 mA	12.03 V	12.06 V	12.05 V
-12 V/30 mA	-12.01 V	-12.05 V	-12.05 V
-26 V/50 mA	-26.06 V	-26.16 V	-26.15 V
3.3 V/0.15 A	3.77 V	3.80 V	3.78 V
VIPer22A-E temp	53 °C	47 °C	45 °C

4 Transformer specification

Figure 12. Transformer structure

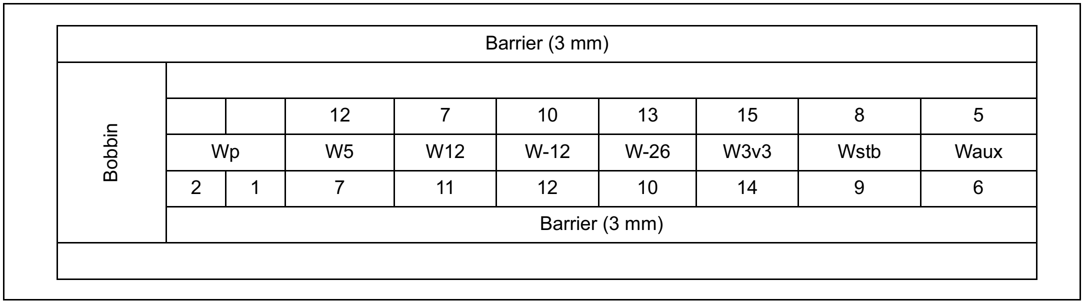


Primary inductance: Lp = 2.8 mH 1 kHz, 0.3V
Leakage inductance: Lk < 28 uH at secondary and auxiliary winding short (1 kHz, 0.3 V)
Core: EER28L
Bobbin: ER28 (6 + 9 pin)
Vendor: YuanDongDa electronics Co., Ltd

Table 5. Winding parameters

Layer description	Symbol	Start pin	End pin	Number of layers	Turns	Wire size (mm)
Primary	Wp	Pin 2	Pin 1	2	65	0.3
Out 1 (5 V/1.5 A)	W5	Pin 7	Pin 12	1	4	2*0.6
Out 2 (12 V/0.0 3 A)	W12	Pin 11	Pin 7	1	5	0.3
Out 3 (-12 V/0.0 3 A)	W-12	Pin 12	Pin 10	1	9	0.45
Out 4 (-26 V/0.05 A)	W-26	Pin1 0	Pin 13	1	10	0.3
Out 5 (5 V_{stb}/0. 1 A)	Wstb	Pin 9	Pin 8	1	12	0.3
Out 6 (3. 3V/0.15 A)	W3v3	Pin 14	Pin 15	1	3	0.3
Auxiliary	Waux	Pin 6	Pin 5	1	24	0.3

Figure 13. Winding construction diagram



Barrier (3 mm)									
Bobbin									
			12	7	10	13	15	8	5
	Wp		W5	W12	W-12	W-26	W3v3	Wstb	Waux
	2	1	7	11	12	10	14	9	6
	Barrier (3 mm)								

5 PCB layout

Figure 14. Bottom view of the evaluation board (not in scale)

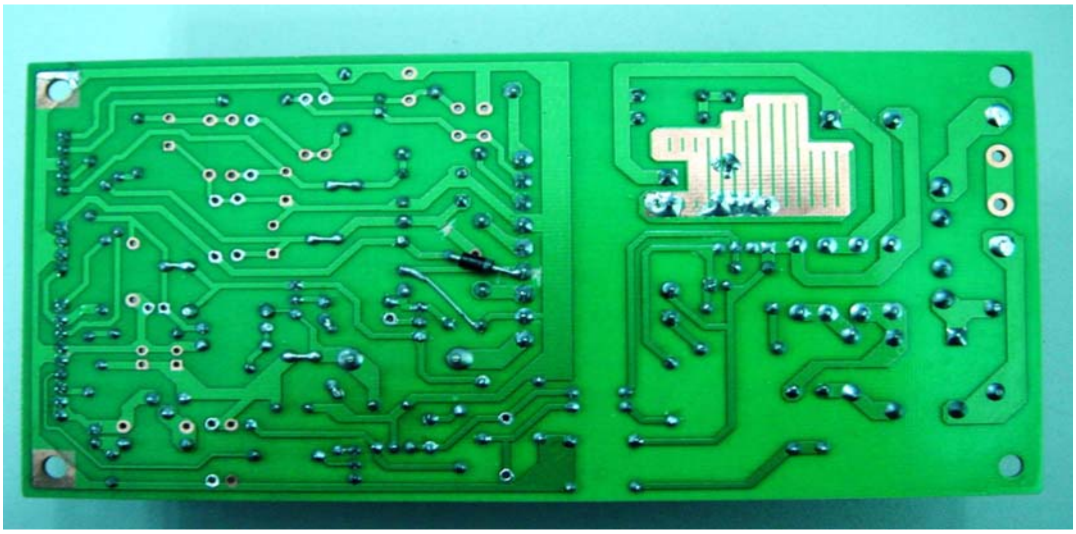


Figure 15. PCB art work (not in scale)

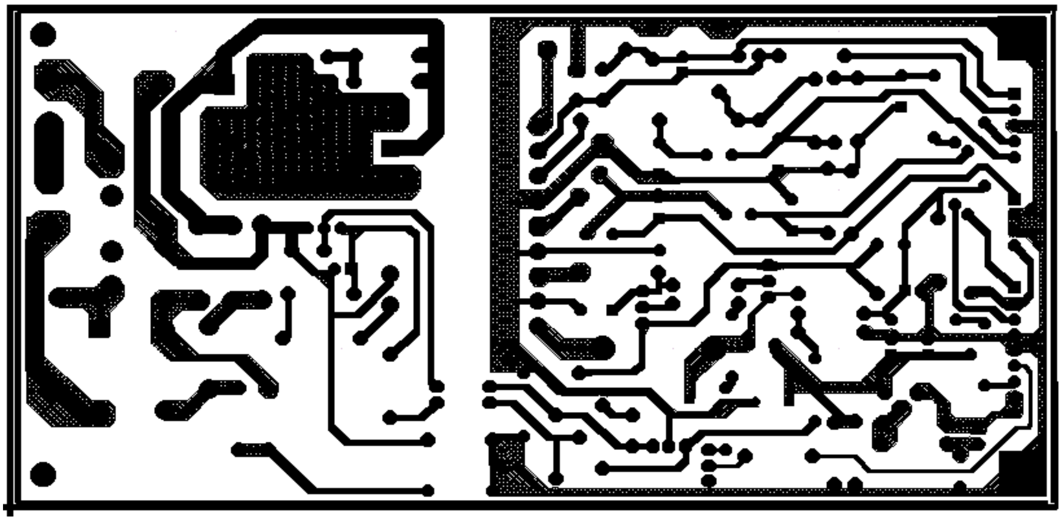


Table 6. Bill of materials

Reference	Description	Note
U1	Optocoupler PC817	Sharp
U2	VIPer22A-E DIP	ST
U3	TL431 ACZ	ST
U4	L4931 ABV33	ST
Q1	SS9014	
Q3	SS8550	
D1, D2, D3, D4	1N4007	
D5	FR157	
D6, D7, D9, D10, D13	STTH102	ST
D8	STPS5L60	ST
D11, D12	1N5818	ST
C1, C2	Y1 capacitor 2200 pF	
C3	X2 capacitor 0.1 uF	
C4	Electrolytic capacitor 100 uF/400 V	
C5, C8	1 nF/1 kV	
C6	Ceramic capacitor 47 nF/50 V	
C7	Electrolytic capacitor 47 uF/50 V	
C9	Electrolytic capacitor 220 uF/50 V	
C10	Ceramic capacitor 47 pF/50V	
C12	Electrolytic capacitor 1000 uF/16 V	
C13	Electrolytic capacitor 470 uF/16 V	
C15	Electrolytic capacitor 100 uF/10 V	
C17	Electrolytic capacitor 470 uF/25 V	
C19	Electrolytic capacitor 470 uF/25 V	
C20	Electrolytic capacitor 220 uF/50 V	
C25	Electrolytic capacitor 220 uF/16 V	
RT1	Not fit	
R2	9.1 K¼ W	
R3	100 K 1 W	
R4, R5, R6	1 K¼ W	
R8, R9	5.1 K¼ W	
R11	680 ¼ W	
CH1	2.2 mH common choke	
TX1	EER28 transformer	

Table 6. Bill of materials (continued)

Reference	Description	Note
F1	Fuse 1 A	
J1, J2	2-pin connector	
J3	5-pin connector	
J4	4-pin connector	
J5	9-pin connector	

6 Revision history

Table 7. Document revision history

Date	Revision	Changes
12-Nov-2014	2	Updated the title in cover page. Content reworked to improve readability, no technical changes.