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Stabilized Supply in Voltage 14.4 V and 300 A Current for Automotive Applications

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ABSTRACT:*The shortage of the automotive market in relation to options for sources of high power, led to the development of this work. Thus, we developed a stabilized voltage source and limited in current, with a 4320W effective power to act on voltage of 14.4V and a choice of two currents: 30A load option in battery banks and 300A in normal condition. The intended project can also be considered as a source of general use with analog control circuit based on discrete components. The power circuit assembly uses a methodology that allows for higher powers than the initially stipulated.*

Keywords:*Analog control circuit, phase-shifted full-bridge with current doubler converter, automotive source, SMPS.*

I. INTRODUCTION

The car audio industry has in recent years growth rates above the Brazilian economy as a whole, while the Gross Domestic Product (GDP) grew by about 5%, this sector has shown high growth rates driven by industry of new vehicles (30.21%) and motorcycles (22.6%). [1]

The maximum automotive sound power in the market is approximately 3000W. [2]

There are few options of switching power supplies with power near 3000W in the market; they operate exclusively with digital control circuit. [3], [4]

From the above, the proposed project is to obtain a high power Switched-Mode Power Supply (SMPS) with high efficiency and low noise (Radio Frequency Interference - RFI), targeted to the automotive sound market. It can also be used to power electronic devices because of the characteristic of stabilized output voltage and even to charge a bank of batteries, because the control is set to obtain two bands of constant output current. Another intended feature is to implement the project of power and control in a simple way, with discrete components easy to purchase in the domestic market.

The design of the control circuit aims to complete integration of the system with a inrush control, thermal protection triggering fans of heat sink from 35^{0}C and off the SMPS after 60^{0}C with stopping operation of the source, frequency synchronization possibility with another control system, generation of eight isolated pulses for driving the switches, feedback loop to control current and voltage outputs and indicative leds of operating conditions of the SMPS.

The search is for the versatility of the switching power supply using a phased-shifted full-bridge with current doubler converter [5], [6] in the system divided into steps allowing the use of several different stages of powers system with automatic dual voltage and a reduced size resulting in power above 3000W and high efficiency (above 92%).[7]

II. THE INPUT RECTIFIER

The AC input protection is accomplished through a thermal-electric breaker 63A.

We use an input rectifier of the smps as shown in Figure 1, in 220V, we have D_1, D_2, D_3 and D_4acting as a single phase full bridge rectifier $C_1$and C_2as output filter. With voltage of 127V we have in the positive half cycle,$D_1$and $D_4$is on and send energy to $C_1$and in the negative half cycle,D_2 and D_3 is on and charging C_2, acting as a voltage doubler because the voltages of $C_1$and C_2 adds up. [8], [9]

The inrush current control was done through series resistors in the power circuit and short circuited after charging capacitors. The control is performed by a pulse of 12V from the control circuit. We used three sets of transistors configured as a switch, to trigger the respective relays in parallel due to high current engaged as shown in Fig. 8 and 9. Three resistors are used in parallel 33Ωx5W (Fig. 8 and 9), after the control command, the relays are activated allowing the deployment of total power to the converter. [8].

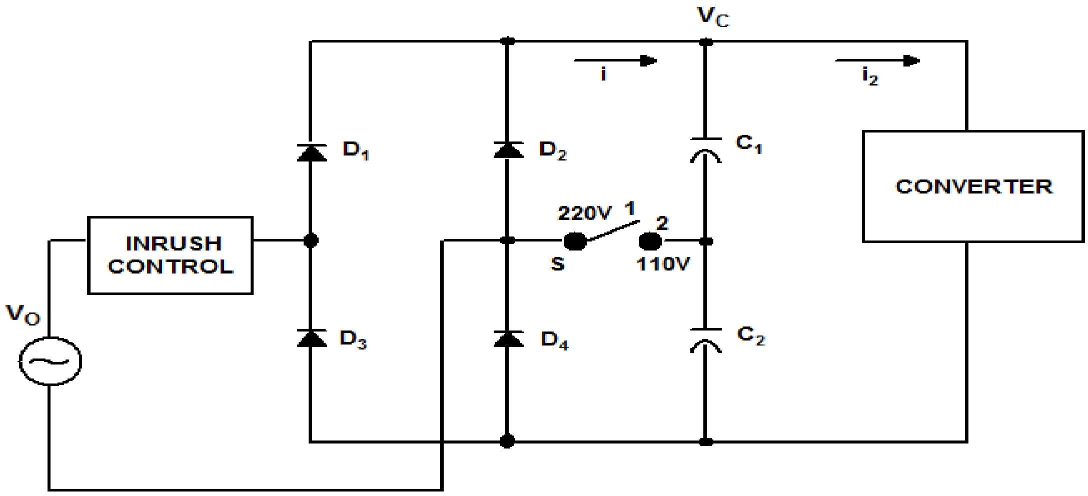

Figure 1.the input rectifier

The input rectifier has automatic selection for 127V and 220V (Vi) shown in Figure 2. These relays will switch to full-bridge rectifier (220V) or doubler (127V). Transistors Q1and Q2work as switch entering in cut-off or saturation according to the input voltage as shown in Table I and Table II, triggering the set of relays RL1, RL2 and RL3 (dividing the current through the contacts of the relays of about 34A). The division of current is ensured by the inclusion of equalization resistors (constantan alloy) in series with each relay. R1 comprises a set of three resistors of 15 kΩx0.25 W and three resistors of 3.3 kΩX0.25 W in parallel forming the 901.6 Ω resistor to achieve the minimum required voltage to drive the relays.

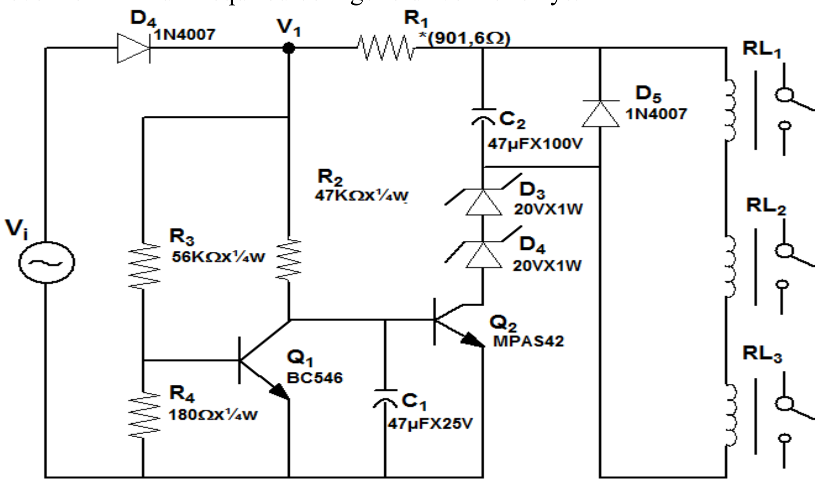

Figure 2.selector of input voltage

Table I
Voltages of the voltage detector

Voltage	127V	220V
V_{R4}	< 0.68 V	≈ 0.68 $V(V_{BE})$
V_{C1}	≈ 0,68V (V_{BE})	≈0
V_{RL1}+V_{RL2}+V_{RL3}	≈27 V	0

Table II
Summary of the status of components

Components	127V	220V
Q_1	Off	On
Q_2	On	Off
RL_1, RL_2 *and* RL_3	On	Off

The relay contacts are connected in the position shown by the switch of the input rectifier as Figure 1.

III. THE CONTROL CIRCUIT

The control block diagram of the smps is shown in Fig. 3.

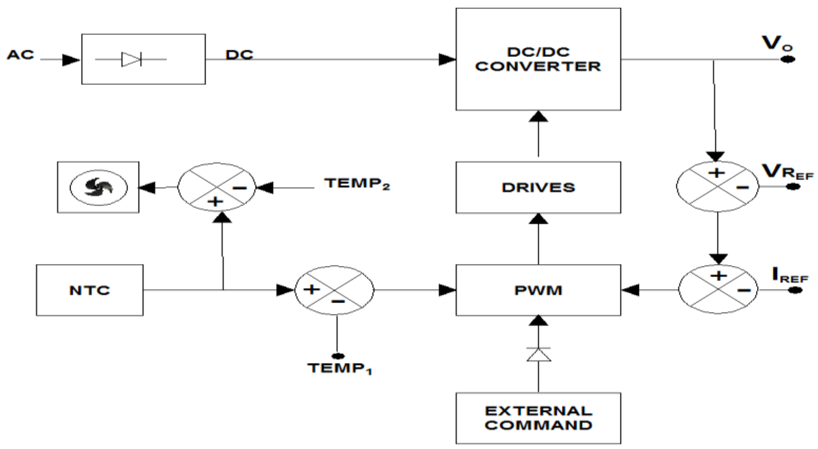

Figure 3.block diagram of the control circuit

The control system is based on the IC 3525 (Regulating Pulse Width Modulators), and operates in closed-loop from a reference voltage (V_{ref}) delivering 14.4V and has the option to work as a current source from a reference current adjustable allowing two levels of current carried through key. The choice of IC 3525 was his characteristics: internal soft-start, pulse-by-pulse shutdown, adjustabledeadtime control and oscillator Sync terminal. [10]

For control circuit feed was used a flyback converter with universal input (80-240V_{ac}) and stable output in 12V_{DC}. The thermal control is performed from NTC thermistor, set to trigger forced ventilation system from 35^{0}C ($TEMP_1$) and disabling the pulse control circuit from 60^{0}C ($TEMP_2$ - shutdown) as shown in Fig. 3.

The system has an emergency stop command where the control pulses can be turned off at any time. Inrush current control was performed by charging a capacitor, whose time constant RC provides the necessary time as Fig. 1 for charging the capacitors of the input rectifier ($C_1$and C_2), before triggering the relays as shown on Fig. 1.

It also has eight drives isolated to enable the use of any type converter, producing isolated pulses with voltage above 10V on the triggering of MOSFETs and negative voltage of -3.9V on the off, this isolation is provided by the using the pulse transformer drive circuit. [8]

SMD components were used to construct the control circuit searching for a miniaturization for use in general, allowing the size: 47mm height and 115mm in length as shown on Fig. 4.

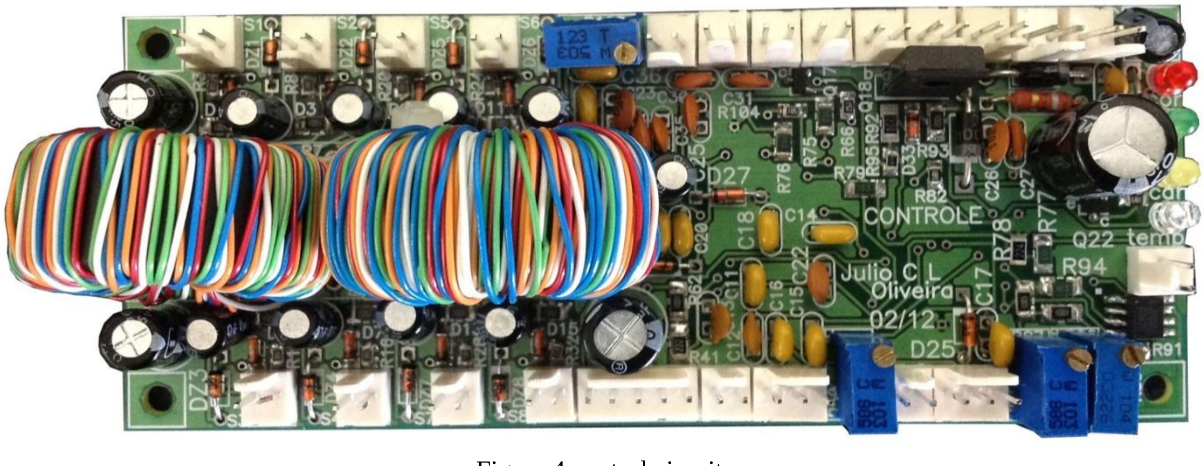

Figure 4.control circuit

IV. THE POWER CIRCUIT

The converter full-bridge was chosen to be suitable for power above 1000 W with current doubler because works with smaller inductors facilitating its construction as shown in fig. 5 [5], [6].

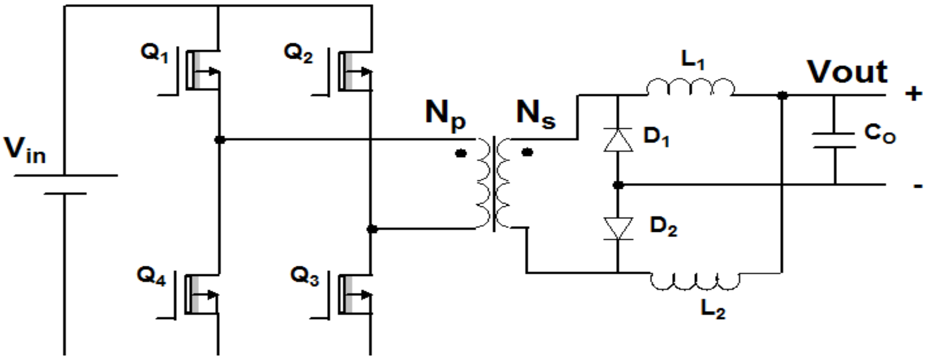

Fig 5.phase-shifted full-bridge with current doubler converter

Due to the limitation of the power of the switches, it was made a division of power involved and used two independent modules called CONVERTER MODULE coupled with two transformers with the primary in parallel and the secondary in series, to provide the voltage to the rectification module and filtering, as Fig. 6.

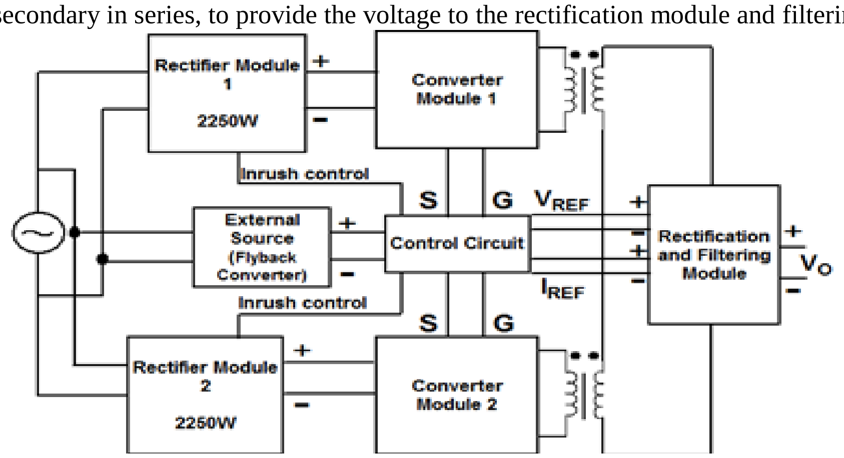

Fig 6. Complete block diagram of the converter

On the converter module, aiming the low cost, flexibility and ease of acquiring components, we used four IRF840 MOSFETs connected in parallel with the respective snubber for each MOSFET (Q_1, Q_2, Q_3 and Q_4) as Fig. 5.

The inductors L_1 and L_2 (Fig. 5) by being subjected to a current of 150 A each,were constructed by winding one copper tape (3.3x1.7)mm to obtain the inductance of 3.70 μH. [11], [12]

The rectification and filtering module comprises ten schottky diodes (MBR6045) and a bank of twenty capacitors with low impedance (2200μFx25V) connected in parallel [11], [13].

V. MOUNTING PROCEDURE

The smps must work with very high currents (300A) and power over 4320W so the procedure for use of modules as shown in Fig. 6 allows the flexibility and decrease the power required for each component.

The input rectifier 1 of Figure 7 was designed so that the connectors were in the opposite position in relation to the input rectifier 2 of Figure 8, facilitating and reducing the length of wire between the entrance of the rectifier and the thermo-electric breaker overcurrent protection entrance, the bridge rectifier being fixed in the heatsink as shown in Fig. 9.

Each converter module containing MOSFETs with their snubbers were assembled with the heatsink (lower box), above this in a aligned way was set the rectifier module to decrease the length of the bonds decreasing heat losses and space saving as Figure 9.

Converter's transformer was mounted on a core EE-65/33/26, and the secondary winding was calculated in one loop and due to the skin effect at 50 kHz had to be carried out with a copper tape with a width of 3.3mm and 3.3mm in height since the quantity of copper necessary to achieve the required current precluded their construction (418 AWG23 wire), were placed between the winding copper tape grounded to the negative of the rectifiers to eliminate interference, shielding the transformer through the Faraday shield. [11], [12], [14]

Figure 7. input rectifier 1

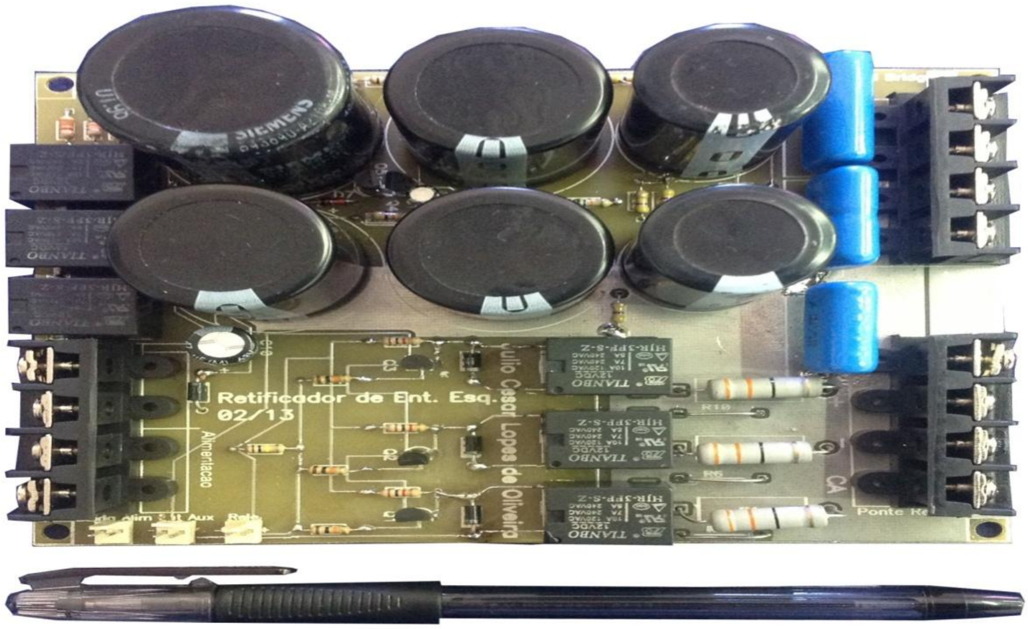

Fig 8.input rectifier 2

The inductors in the same way as the transformer due to the skin effect which occurs at 50 kHz should be constructed with 351 wires AWG25 so we used a copper tape of 3.3mm width and 1.7mm in height, winding up to reach the minimum required inductance of 3.70 μH. [11], [12]

The transformers and inductors were fixed orthogonally seeking noise reduction and decoupling of the magnetic components as shown in Fig. 9. [14]

The rectification and filtering module was divided into a rectifier module containing the schottky diodes and snubbers and a filter module which was superimposed containing the capacitor bank seeking to decrease the length of the links, the consequential losses due to the Joule effect and saving space as shown in Fig. 9.

VI. EXPERIMENTAL RESULTS

The experimental results for a 4.32 kW, 14.4 V/300 A rectifier with 127/220 VAC and 50 kHz switching frequency are show in Figures 10 and 11.

The waveform of a drive output control circuit of four isolated pulses at full load as show in Fig. 10, where duty cycle means 0.45.

The primary voltage waveform at full load as show in Fig. 11. The characteristic of phase-shifted full-bridge with current doubler converter is clear in this figure.

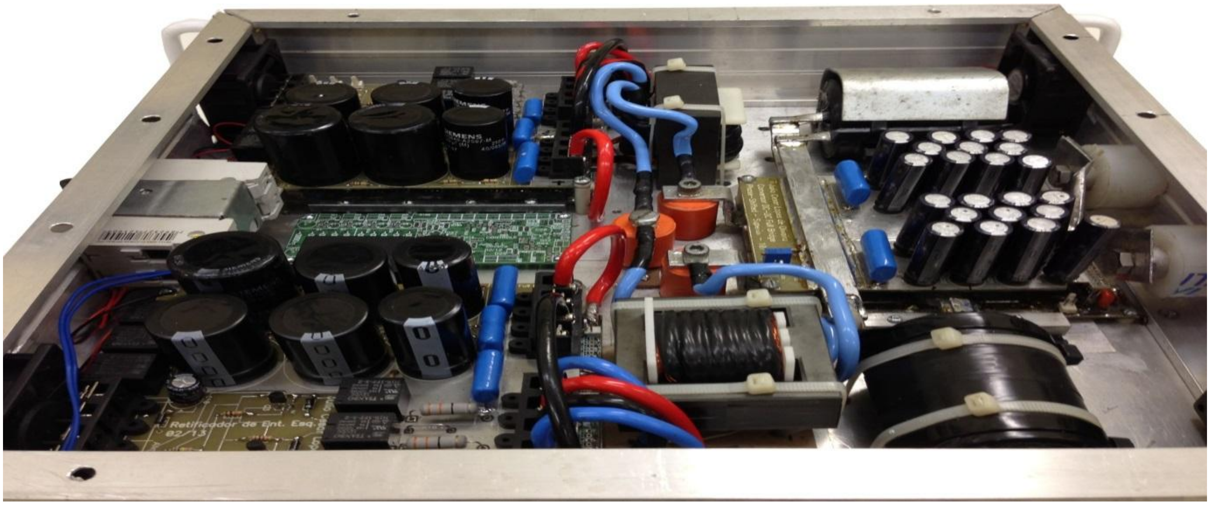

Fig 9.full source

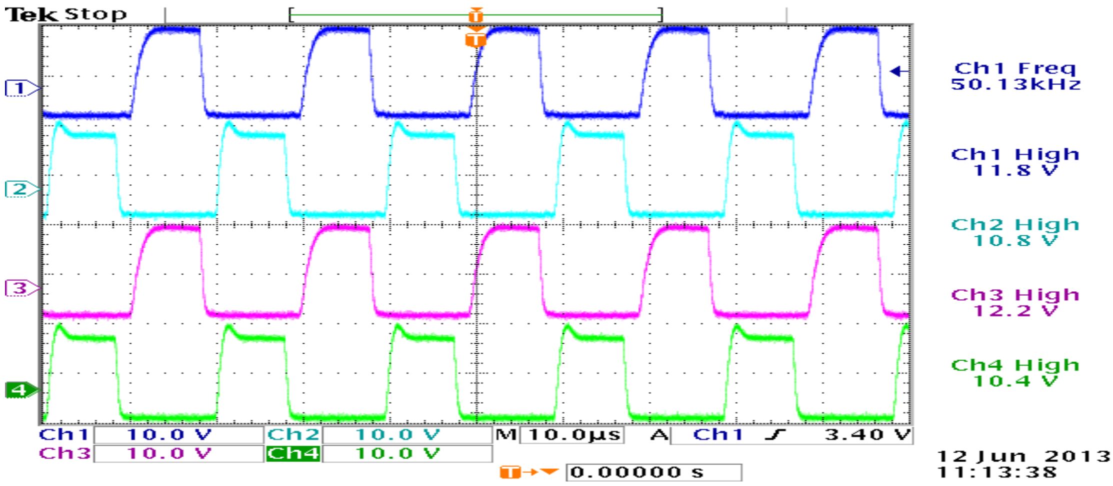

Figure 10.waveform of a drive output control circuit of four isolated pulses at full load

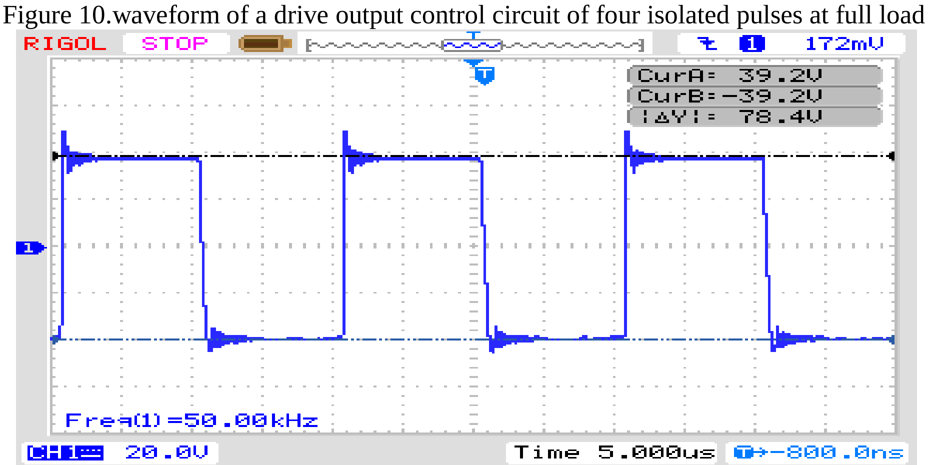

Figure11. Primary voltage waveform at full load

The measured converter efficiency under full load was 94% and regulation was 0.42%.

VII. CONCLUSION

Phase-shifted full-bridge with current doubler converter proved efficient for use in high power corresponding to the proposed power project of 4320W, the modular form used provided flexibility to the project allowing to obtain higher powers than the initially stipulated.

The implemented analog control circuit is quite compact due to the use of SMD components and may be used in any type of converter having several control features: thermal; inrush current; the output voltage (allowing closed loop work) having the possibility of working as a current source and the emergency stop feature. Included are the drives required for any type of converter allowing their widespread use.

Several precautions were taken to control RFI, such as Faraday shielding in transformers, minimization of current loops in the power circuit, reducing the length of connections with the consequent reduction of harmonics, the decoupling of the magnetic components seeking orthogonal alignment between them.

The aim of the present paper was achieved because the end result was a robust source with high power density, galvanically isolated and with great commercial feasibility.

As a suggestion to future work, adoption of more efficient switches, replacement switches for the diodes in Module Rectifier and Filtering, adoption of planar transformers and higher power output.

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