

DEVELOPMENT OF A HIGH-VOLTAGE HIGH-FREQUENCY POWER SUPPLY FOR OZONE GENERATION

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Abstract: *A high-voltage high-frequency power supply for ozone generation is presented in this paper. Ozone generation is intended to be used in air and in water disinfection. A power stage consisting of a single-phase Power Supply for regulating the output power, a current push-pull inverter (driver) and a control circuit are described and analyzed. This laboratory build power supply using a high voltage ferrite transformer and a PIC microcontroller was employed to energize a dielectric barrier discharge (DBD) ozone generator. The inverter working on the basis of control strategy is of simple structure and has a variation range of the working frequency in order to obtain the optimal frequency value. The experimental results concerning electrical characterization and water treatment using a homemade DBD ozone generator supplied by this power supply are given in the end.*

Key words: *Dielectric barrier discharge, ferrite transformer, high-frequency, high-voltage, inverter, ozone generation, power supply.*

1. INTRODUCTION

Ozone (O_3) is considered as an excellent powerful oxidizer and germicide. Its disinfection potential is significantly higher than chlorine and other disinfectants [1-4]. Nowadays, ozone is widely used for disinfecting and oxidizing in substitution of chlorine, due to the latter's byproducts such as smell, bad taste and carcinogenic agents resulting from it [5-7]. Indeed, ozone produces much less by-products and ozone itself is transformed into oxygen within a few hours [8-10]. Application of ozone technology are various and could be found

in disinfection, water and air purification, medicine... [11-15].

However, since ozone cannot be stored, it must be generated on site. Dielectric barrier discharge (DBD) method is considered as the most efficient way to produce ozone (fig.1). Oxygen is injected to pass through a small discharge gap between two high-voltage electrodes, one of them or both being covered by a dielectric layer in order to avoid sparks taking place [16-18]. These devices are usually supplied by a high-voltage, high-frequency power supply, since high frequencies decrease the necessary power to be used and increase the ozone production rate [19-21]. Thus, the power density applied to the discharge surface is increased as well as the ozone generation rate, for a given surface area, while the necessary voltage is decreased. The increase in the frequencies up to several kilohertz is now feasible using power electronic switching devices, such as MOSFETs [22-24]. The aim of the present work is the development of a simple high frequency high voltage power supply (HF-HVPS) for a DBD ozone generator, consisting in a power stage, a current push-pull inverter (driver) and a control circuit, where the output frequency could be easily regulated using PIC16F84A microcontroller [25-31]. A laboratory experimental bench of water treatment was carried out to study disinfection efficiency of a homemade ozone generator supplied by this power supply.

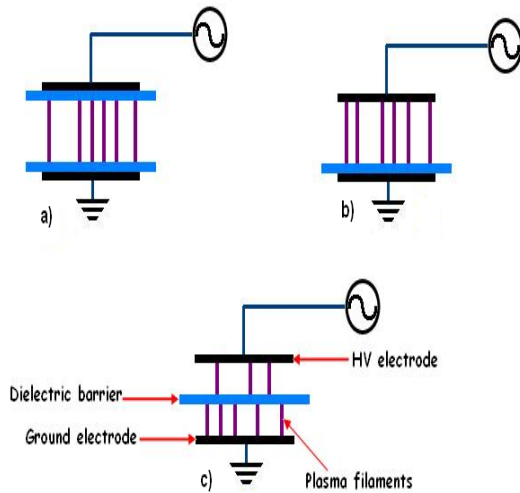


Fig1. Dielectric barrier discharge with a gas gap
a) The dielectric is located on each electrode;
b) The dielectric is located on one of the electrodes;
c) The dielectric is located between the two electrodes in the gas.

2. DESCRIPTION OF THE POWER SUPPLY

The power supply comprises a control circuit stage for generating a high frequency square signal and a power block composed of four MOSFETs controlled by the square signal (Fig.2). Input voltage is decreased to 6V using a step-down transformer 220/6 V, which is rectified and then fixed at a constant value of 5 V using a voltage regulator LM7805. This voltage (5V DC), used to power a microcontroller circuit, is transformed into a square signal of adjustable frequency. At the same time, a rectified and adjustable voltage (0-310 V), that feeds the primary of a step-up ferrite transformer of power 200 W, is transformed in a high frequency signal by the MOSFETs (IRF740) controlled by the square signal, thereby obtaining an adjustable high voltage output.

The main circuit of the ozone generation power supply is shown in figure 3. The switches used are MOSFETs, in parallel with diodes necessary to prevent MOSFET from conducting a reverse current.

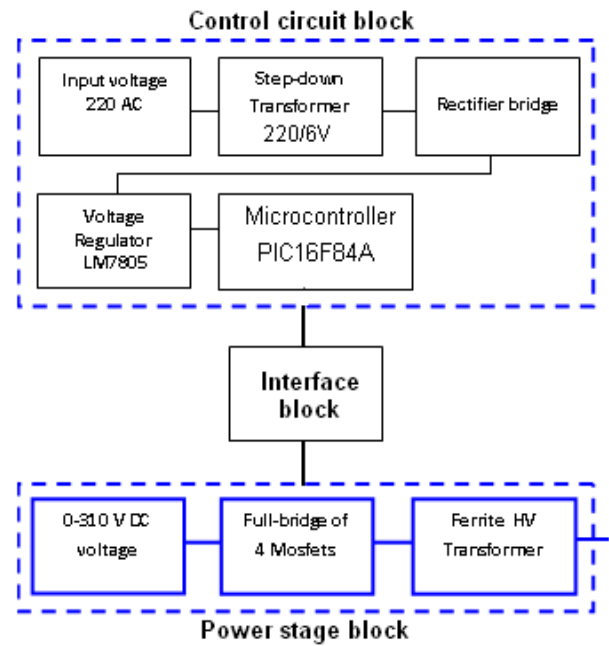


Fig 2. Block diagram of the high voltage supply

The main components of the inverter chain are: control, power interface and power stage blocks.

1. **Control block:** The generation of control signals is performed by a PIC16F84A microcontroller type circuit (fig.4). These signals are sent to the power switches through a galvanic isolation guaranteed by opto-couplers.

2. **Power interface block:** The interface must provide protection of the control circuit in case of problems on power circuit side. Galvanic isolation between control circuit (0V/5V) and power circuit (220V/1A) is then ensured.

3. **Power stage block (inverter):** The inverter uses IRF740 MOSFET package equipped with a freewheeling diode. It converts DC into AC voltages by means of the PIC microcontroller. Since the reliability of MOSFETs decreases with increasing temperature, the heating produced in the semiconductor junctions has to be evacuated using sinks.

The overall power supply, without the step-up transformer, is shown in figure 5.

3. EXPERIMENTAL SETUP

The home-made cylindrical DBD ozone generator used in this work consists of a stainless steel outer ground electrode of internal diameter 47 mm and a glass tube of external diameter 44 mm having a same length of 30 cm (figure 6). A discharge gap of 1.5 mm exists between the glass tube and the stainless steel electrode. An adhesive Aluminum tape, glued on the inside wall of the glass tube, was

used as the high voltage electrode. Two openings are operated on the generator to enable the air inlet and the ozone outlet.

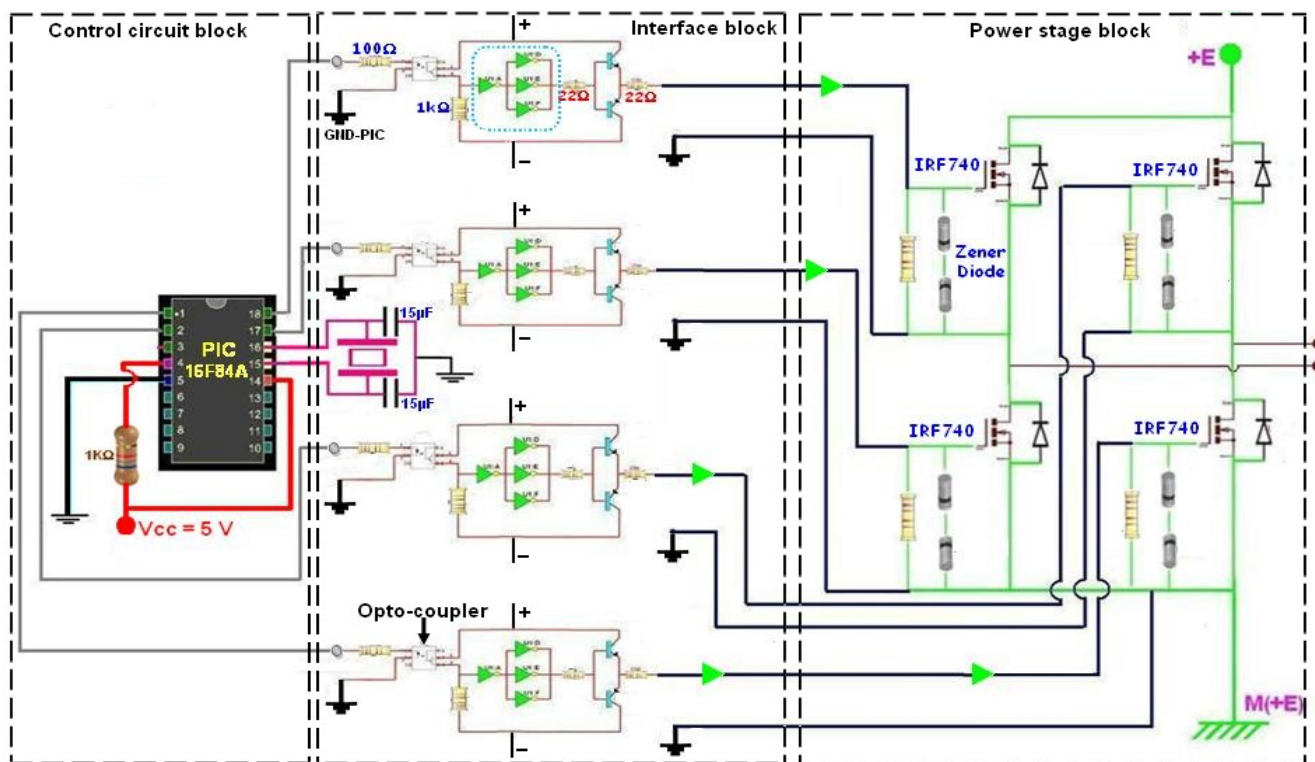


Figure 3. The proposed system of ozone generation power supply.

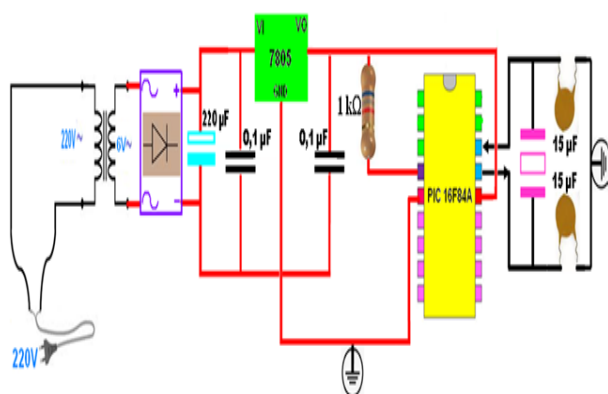


Fig 4. Circuit diagram of the control block.

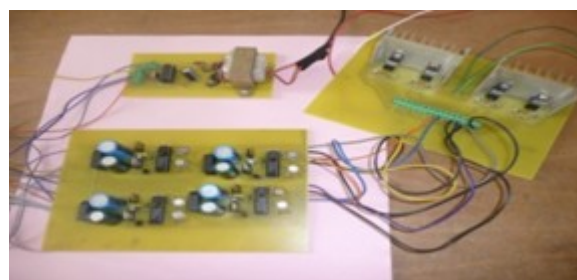


Fig 5. Overall power supply without HV transformer. a). Circuit control, b). Driver, c). Inverter.



Figure 6. Cylindrical DBD reactor

3.1. ELECTRICAL CHARACTERIZATION

The home-made power supply and ozone generator were thereafter tested for water treatment, using an experimental laboratory bench described in Figure 8. A first set of experiments was carried out with tap water to measure the ozone concentration dissolved in water using iodometric method. Once the water was set in circulation using a water pump, injection of ozone within the water loop is performed due to a venturi system, then mixed water with ozone is reintroduced into the tank. Water sample was taken at the output just before it falls in the tank. The experiments were carried out at constant values of ozone flow rate (5 l/min) and applied voltage (peak value 6 kV), according to the signal frequency.

A second set of experiments was conducted to treat contaminated waste water (fig.9) taken from the wastewater treatment plant of Sidi-Bel-Abbes city in Algeria.

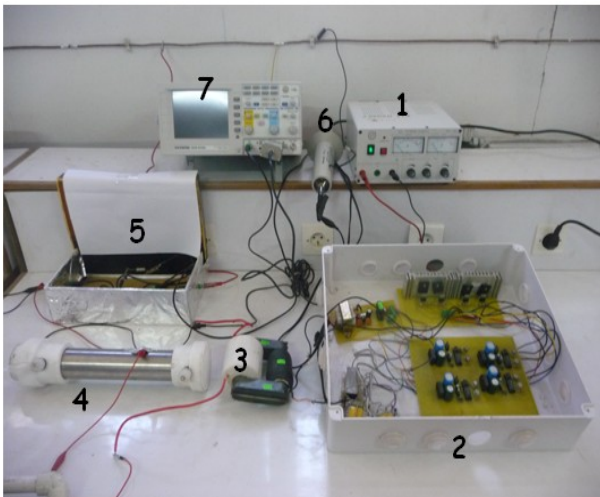


Fig 7. The experimental bench.

1. DC power supply for power block; 2. Inverter; 3. Ferrite-core HV transformer; 4. Ozone generator; 5. Measuring resistor; 6. HV probe; 7. Scope.

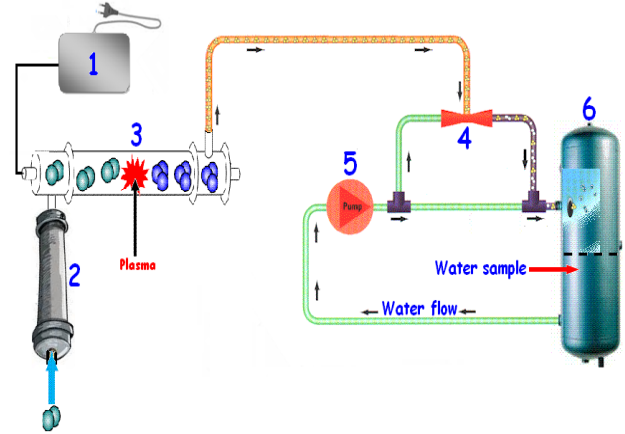


Fig 8. Descriptive representation of the water treatment process using ozone.

1. Home-made power supply; 2. Air dryer, 3. Ozone Generator; 4. Venturi injector; 5. Water pump, 6. Water to be treated.

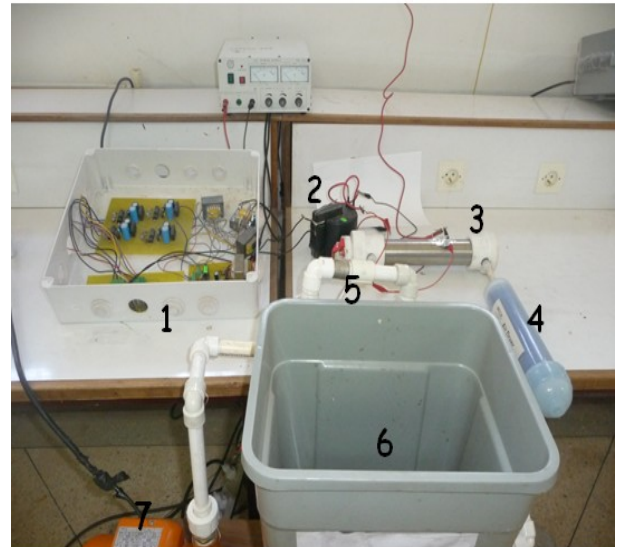


Fig 9. The experimental bench for ozone water treatment.

1. Home-made power supply; 2. HV transformer; 3. Ozone Generator; 4. Air dryer; 5. Venturi injector; 6. Water to be treated; 7. Water pump.

3.1. OBTAINED RESULTS AND DISCUSSION

The voltage developed by typical power supplies for DBD reactor reaches levels of several kilovolts, using a high voltage ferrite transformer. Fig. 10 illustrates the voltage waveforms at the input and the output of the high-voltage transformer. Voltage of sinusoidal shape with values up to 6 kV (peak value) was obtained with the HF-HVPS. Spikes can be seen during the process in the input DC voltage waveform. These spikes are mainly due to

the effect of transformer leakage inductance. Therefore, Zener diodes were used to maintain the voltage across switches below 400V, thus avoiding voltage breakdown in the MOSFETs. The maximum rating voltage of the IRF740 is 400V.

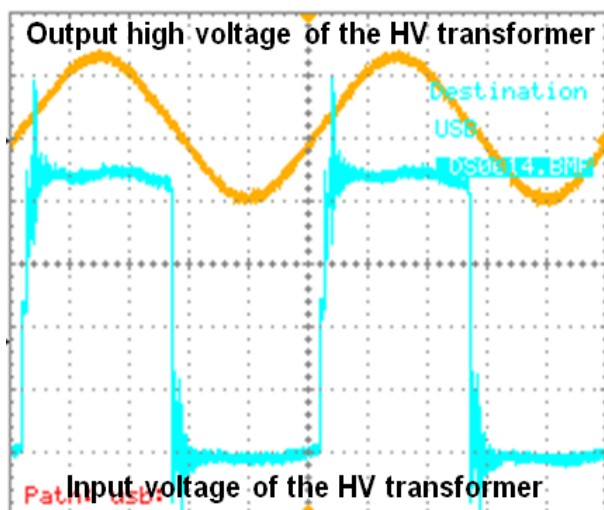


Fig. 10. Voltage waveforms obtained at primary side (Top, 5kV/div) and secondary side of the transformer (Bottom, 5 V/div). Horizontal scale: 10 μ s/div.

Figure 11 represents the variation of the high voltage obtained at the output of the ferrite transformer (Peak value), according to the input DC voltage of the MOSFETs bridge, for different values of the frequency. The natural resonance frequency was about 25 kHz when the load is in the normal discharging condition. It could be seen that the frequency is a significant factor to obtain higher values of voltage, because the transformer which is an inductive load creates resonance with the capacitance of the ozone generator.

Furthermore, results of ozone concentration in water as function of the flow rate are illustrated in figure 12 and results obtained after a physicochemical analysis both before and after treatment of the waste water sample are given in Table 1.

Obtained results demonstrate that production of ozone using DBD reactor is an effective way for the treatment of wastewater; the contaminant levels have decreased significantly.

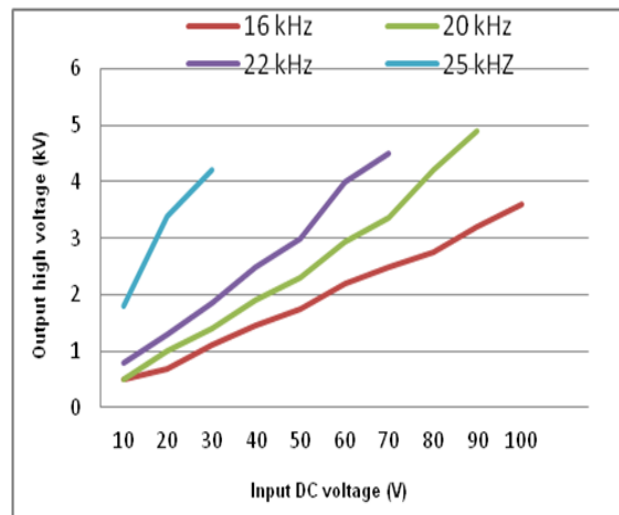


Fig. 11. Variation of the output high voltage according to DC input voltage of the inverter, for different values of the frequency.

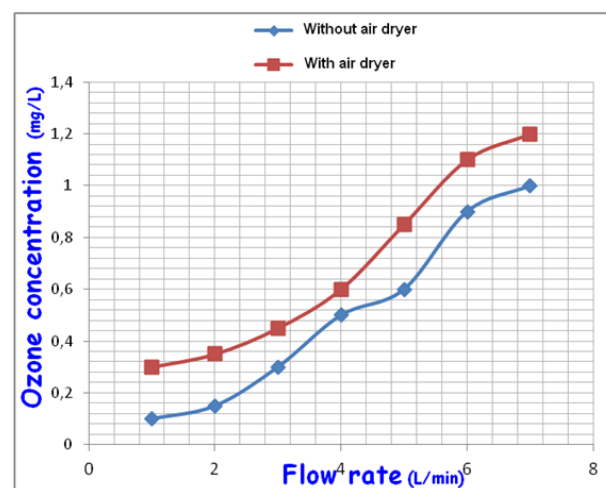


Fig. 12. Variation of the ozone concentration in water according to the flow rate.

TABLE 1. Obtained results after bacteriological and physicochemical analysis

Determination	Normes	Before treatment	After treatment
Germes aérobies à 37°C	20	60	35
Germes aérobies à 22°C	<10 ²	10	10
Coliformes			
Coliformes fécaux /100 ml	10	1100	28
Streptocoques D/50 ml	Abs	03	00
Clostridium sulfito-réducteurs à 46°C/ml	Abs	1100	1100
Clostridium sulfito-réducteurs à 46°C/20ml	Abs	Abs	Abs
	Abs	Abs	Abs

4. CONCLUSIONS

In this paper, a single-phase inverter employing 4 semiconductor switches has been proposed to supply a DBD ozone generator. The converter has been analyzed and output characteristics have been obtained. The design and implementation of the complete power supply have also been shown. The power supply was successfully employed to supply an ozone generator, shown by analyzing both the obtained ozone concentration and the bacterial analysis of a waste water sample.

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