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High voltage power supply for photocopier applications

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Abstract – This paper presents a high voltage power supply, which can be used in a large variety of applications like photocopier, air cleaners, laser printers etc. Some considerations of voltage multipliers, and design equations are presented. A simplified circuit with simulation and practical measurements is also included.

Keywords: voltage multiplier, self-oscillating converter, efficiency

I. INTRODUCTION

There are many applications where it is necessary a high voltage and low power supply. The main problem in this kind of supplies is the transformer, which must be very carefully designed and potted in special material. In many cases both the transformer and the voltage multiplier are potted together forming a high voltage unit. The high voltage supply also known as corona power supply, charges the photo conductor of a photocopier. A block diagram of photocopier high voltage unit is shown in figure 1. The photocurrent passing through the photo conductor must be regulated.

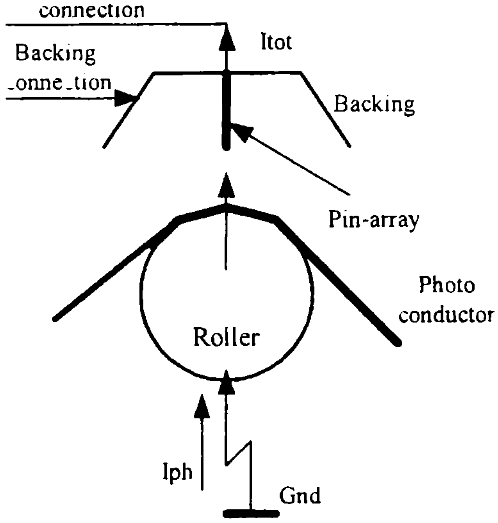

Fig 1 Block diagram of high voltage photocopier unit.

II. SOME REMARKS REGARDING THE VOLTAGE MULTIPLIERS

The classic multistage diode/capacitor voltage multiplier, popularized by Cockroft and Walton (CW) is probably the most popular means of generating high voltage at low currents at low cost.

The CW multiplier has a very poor voltage regulation that is the voltage drops rapidly as a function of the output current. In some applications, this is an advantage. The output V/I characteristic is roughly hyperbolic, so it serves well for charging capacitor banks to high voltages at roughly constant power. Furthermore, the ripple on the output, particularly at high load is quite high. It is quite popular for relatively low powered particle accelerators for injecting into another accelerator, particularly for heavy ions. The maximum output voltage of the corona supply in this application is V_{cor} =-13kV. A high level of the ripple is also useful, so $V_{cor\ pp}$ is about 1/5 from V_{cor} dc. The shape of the ripple is not critical. Given these requirements a 5 times voltage multiplier was chosen.

For a 5 times multiplier theoretical output voltage is:

$$V_{out} = 5 \cdot \sqrt{2} \cdot Vin_{rms} \quad (1)$$

In practice the output is significantly lower, particularly with a large number of stages.

The voltage drop under load can be calculated as:

$$V_{drop} = \frac{I_{load}}{f \cdot C} \cdot \left(\frac{2}{3} \cdot n^3 + \frac{n^2}{2} - \frac{n}{6} \right) \quad (2)$$

Where:

- I_{load} is the load current;
- C is the stage capacitance;
- f is the frequency;
- n is the number of stages.

The output ripple can be calculated using the equation:

$$V_{ripple} = \frac{I_{load}}{f \cdot C} \cdot n \cdot \frac{(n+1)}{2} \quad (3)$$

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The figure 2 shows schematics of a 5 times voltage multiplier and figure 3 the output and the input voltage. In this case the amplitude of the input voltage is 1000V. One can see the ripple (peak to peak) is about 2000V.

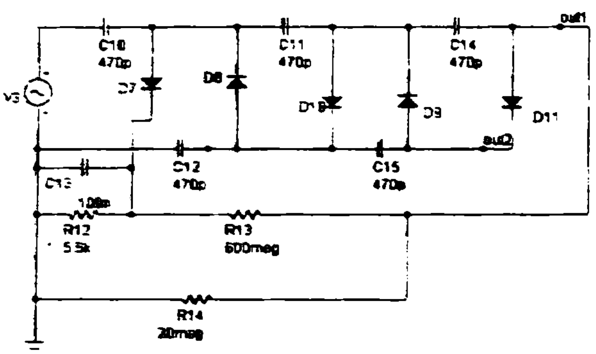

Fig. 2 The 5 times voltage multiplier.

Fig. 3 The output and the input voltage of 5 times voltage multiplier.

Figure 4 suggests a method to measure the output current. One can see in steady state regime the average value of the output current (through R14) is the same with value through R12.

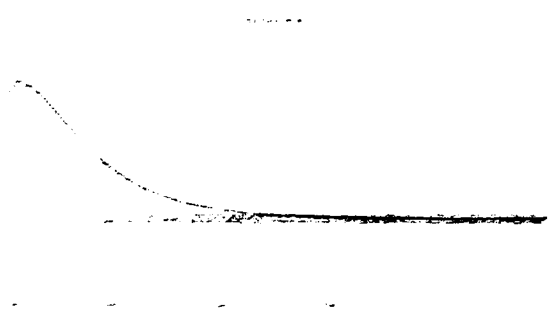

Fig. 4 The output current and measured current.

III THE CONVERTER AND THE OPERATION MODE.

Generally for this kind of application a flyback converter is generally used [1]. It can operate in discontinuous or continuous mode. Basically in discontinuous mode the circuit will be ringing after blocking of the rectifiers in the voltage multiplier. If the turn on of the transistor is random we will have a high peak current and high dissipation due to the discharge of the high voltage winding capacitance, unless "valley switching" is used. In continuous mode also the discharge of high winding capacitance occurs together with high di/dt of the high voltage diodes in [illegible] a critical situation because of high dissipation at blocking. Finally the critical conduction mode (border conduction) has not these drawbacks, and is therefore generally preferred in high voltage circuits, generally drive is derived from auxiliary winding of the transformer (self oscillating converter). Also in this kind of circuit bipolar transistor is preferred instead of MOSFET's [2],[3].

For high voltage power supply for low currents a good solution is to use a self-oscillating converter. A simplified version of the schematic proposed for this application is presented in figure 5. The high voltage connected to a pin-array, charges the photo conductor as in figure 1. The total output current Itot delivered by corona supply consists of two parts. One part is passing through the photo conductor Iph and one part to the backing of the corona unit. The amount of current flowing through the photo-conductor must be controlled. The reference of this current is set by the machine control by means of the PWM input. The schematic of PWM unit and also the protection circuit are not present in this simplified schematic.

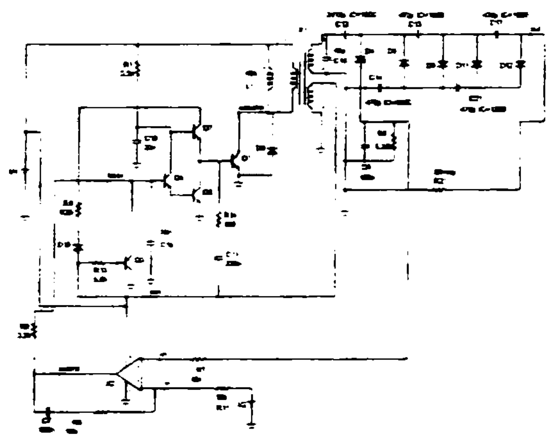

Fig. 5 The simplified schematic.

The simulated waveforms obtained using this circuit are shown in figure 6.

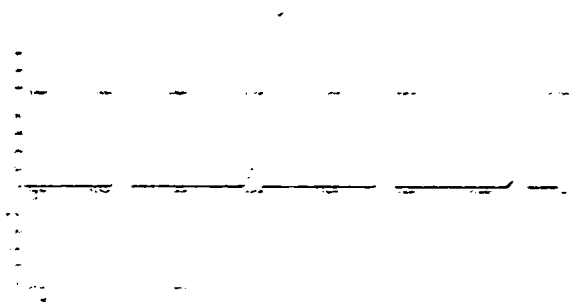

Fig. 6 Simulated waveforms

The real load of this power supply is very complex. For testing purpose a dummy load was built. The characteristic of this load is presented in figure 7, together with the real load for two temperatures.

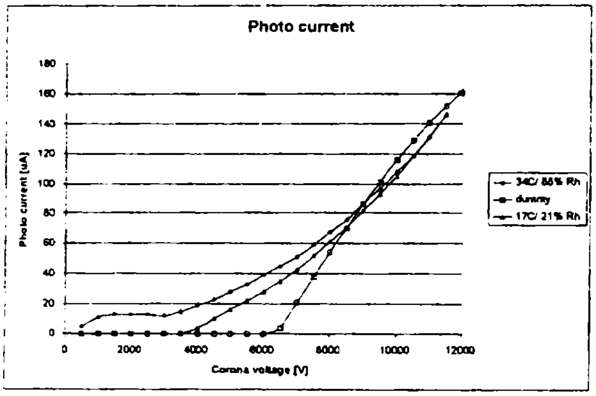

Fig. 7 Load characteristic.

The schematic was practical implemented and the real waveforms are shown in figure 8. If one compares the simulated results with practical results one can see they are similar. The laboratory model is shown in figure 9.

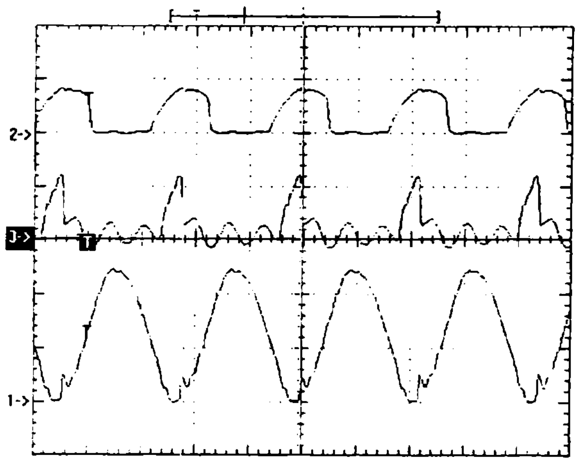

Fig. 8 Practical waveforms.

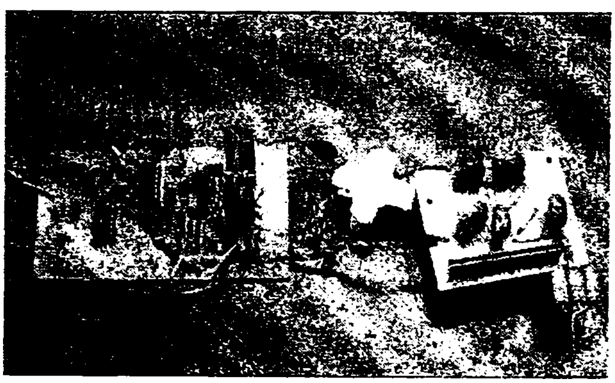

Fig 9 Laboratory model.

The experimental measurements are presented in table 1.

Table 1

V_{in}	I_{in}	P_{in}	V_{out}	I_{out}	P_{out}	Efficiency
24V	0.337A	8W	10.94kV	330µA	3.59W	44%
26V	0.347A	9W	11.2kV	339µA	3.79W	42%
24V	0.257A	6.2W	10.97kV	219µA	2.39W	39%
26V	0.270A	7W	11.24kV	225µA	2.5W	36%

CONCLUSION

The results presented in this paper are a part of a complex design. In simulation, a parasitic capacitance of the transformer was taken into account (C16). An estimated value is about 40pF. This capacitance influence the oscillating frequency of the converter and it is changing during the potting process. Another draw' ack 's effic'ency, wh'ch mus ' e increase o 60%.

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