

Feb. 22, 1966

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3,237,068

CORONA GENERATING CIRCUITS

Filed Aug. 9, 1962

3 Sheets-Sheet 1

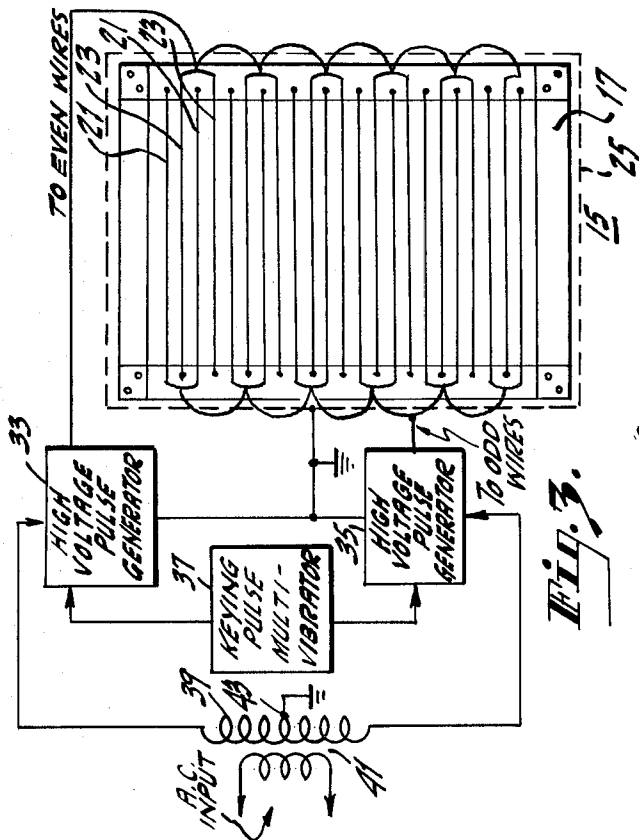


Fig. 3.

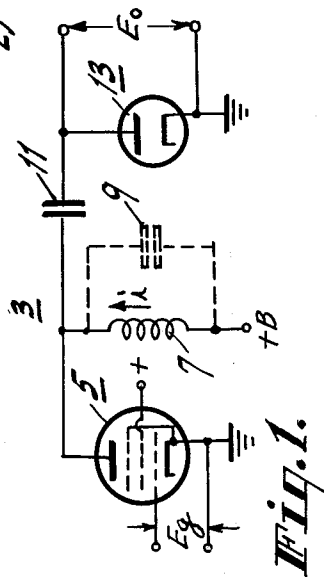


Fig. 1.

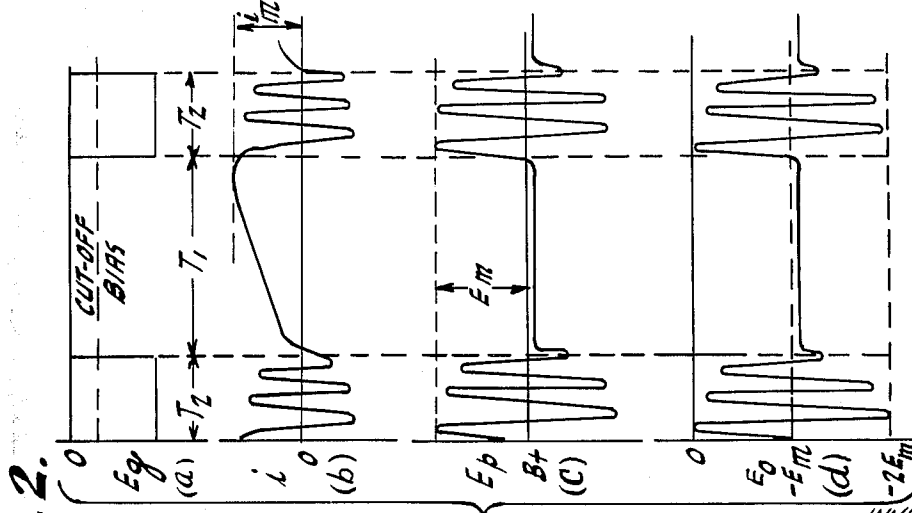


Fig. 2.

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3 Sheets-Sheet 2

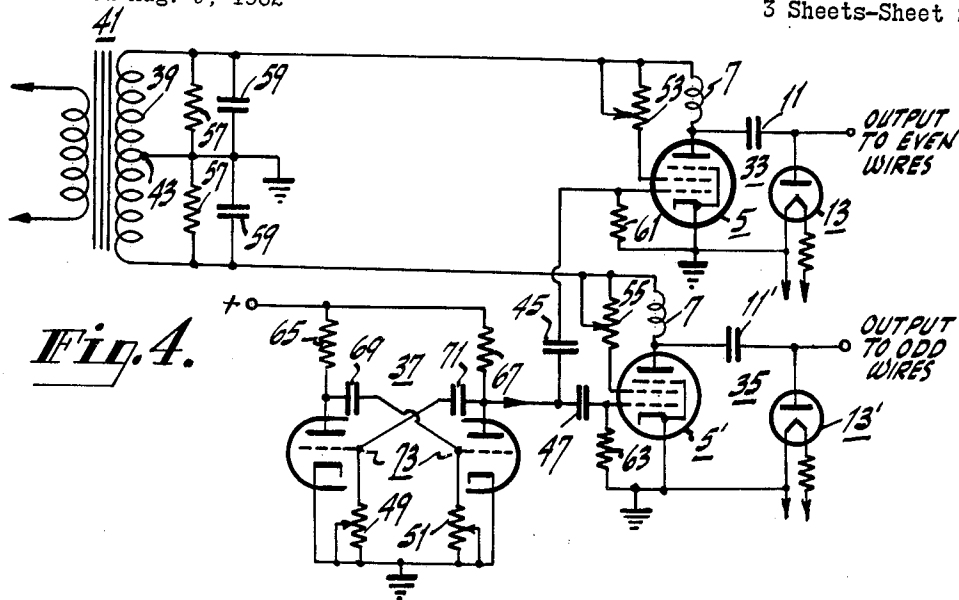


Fig. 4.

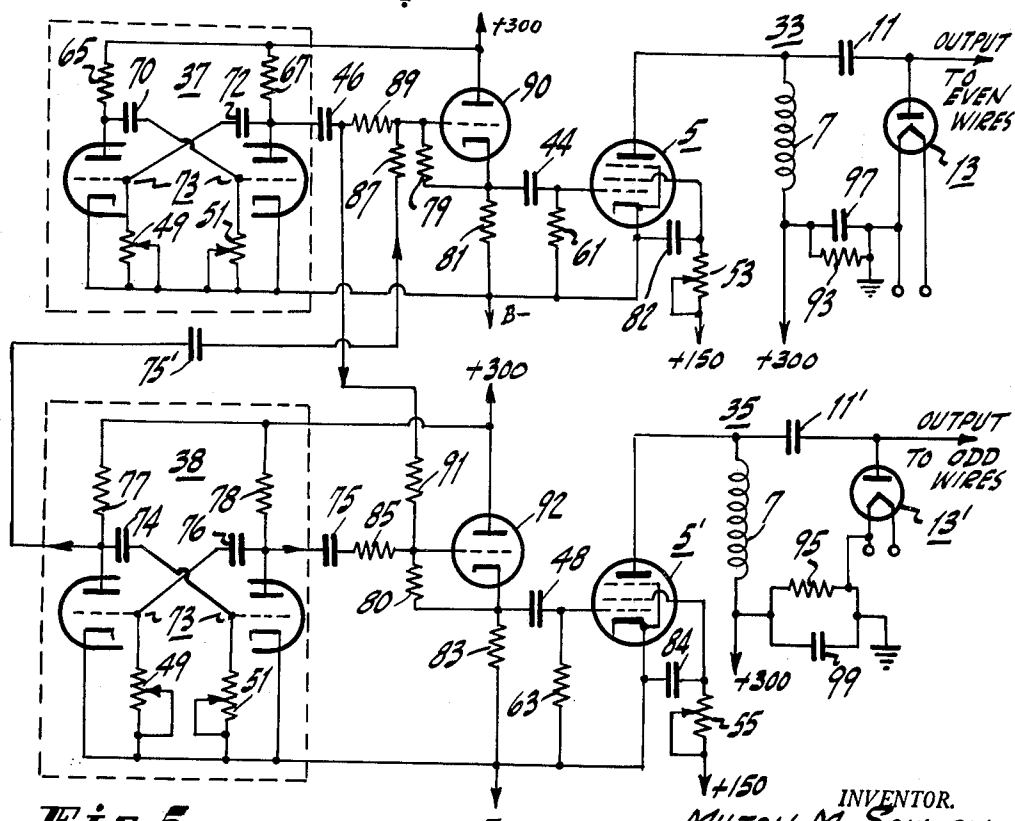


Fig. 5.

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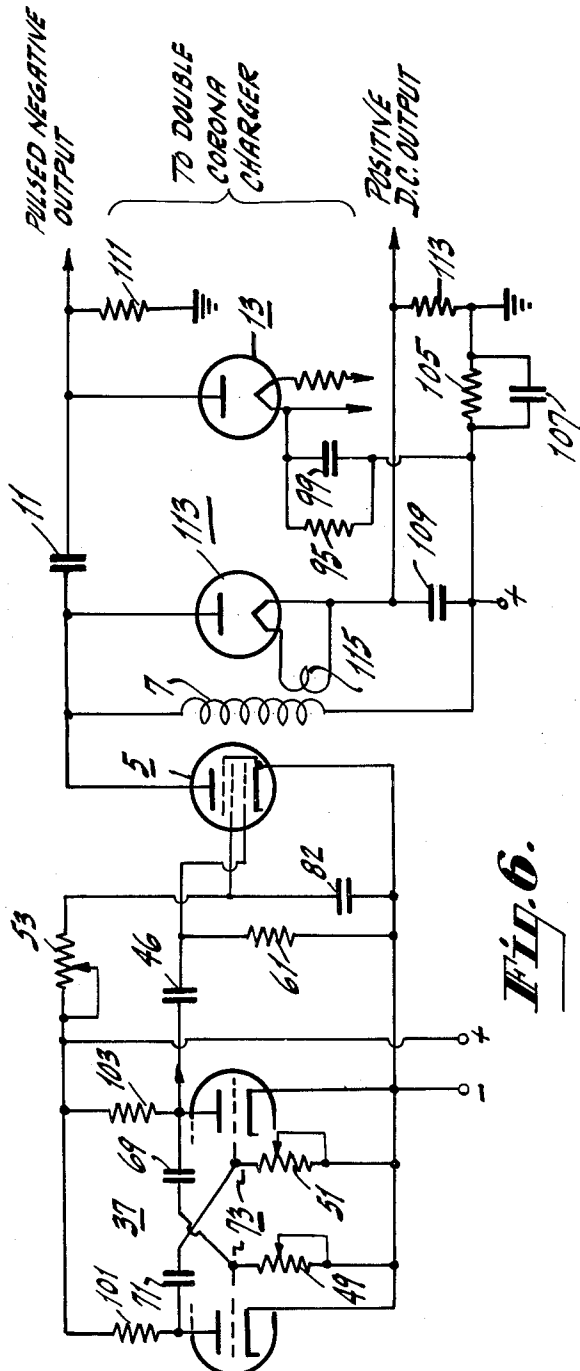
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3 Sheets-Sheet 3



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CORONA GENERATING CIRCUITS

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5 Claims. (Cl. 317-262)

This invention relates generally to improved methods of and means for generating charging voltages for corona generating elements employed in electrophotography and particularly to improved methods of and circuits for generating pulsed corona generating voltages which are selectively applied to different corona generating elements.

In electrophotography, it is common to apply a uniform electrostatic charge to the surface of a photoconductive layer. The charge in selected areas is then dissipated by exposing the surface to a light image. The resulting pattern of charges is then rendered visible by applying thereto finely-divided developer particles which adhere to the surface by triboelectric attraction. Permanent visible images can be obtained, for example, by using thermoplastic developer particles which can be heat-fused to the photoconductive layer.

Some photoconductive layers require negative charging for optimum results. One such layer comprises particles of photoconductive white zinc oxide dispersed in an insulating binder. Zinc oxide-binder layers are described in "Electrofax" Direct Electrophotographic Printing on Paper by C. J. Young and H. G. Greig, RCA Review, December 1954, vol. XV, No. 4. Charging is frequently and conveniently accomplished by exposing the surface of the photoconductive layer to a negative corona source. Such a source commonly consists of one or more fine wires in parallel array. When a voltage of the order of -3,000 volts to -10,000 volts is applied to the wire or wires, a negative corona is generated and negative ions are attracted to and deposited on the surface of the photoconductive layer to produce the negative charge thereon.

Production of negative corona with a fine wire or wires presents problems not encountered in the production of positive corona. The generation of positive corona appears as a continuous uniform visible sheath surrounding the wire, whereas the negative corona has a tendency to concentrate at discrete points along the wire appearing and disappearing at different sites. Ions, from the negative corona, deposit on a photoconductive layer in a non-uniform pattern resulting in non-uniform electrophotographic printing. Attempts to eliminate such "bright spots" in the corona discharge, by providing a highly polished continuous surface on the corona wire, have not been successful.

In electrophotography, superior recordings are obtainable only when very uniform electrostatic charges are established over the entire area of the electrophotographic recording medium. When there is relative movement between the corona generating elements and the electrophotographic recording medium, such non-uniformity in the electrostatic charge established on the recording medium is substantially reduced providing such relative motion is perpendicular to the axes of the corona generating elements. However, when the corona recording elements and the recording medium are substantially stationary, there is a tendency under some operating conditions to provide such non-uniformity of charge as to result in a "marbled density" recording. This effect has been somewhat decreased by applying alternating or pulsating potentials superimposed on fixed D.-C. voltages to the corona generating elements. However, even with such excitation there is a tendency to provide recordings having streaks parallel to the corona generating wires.

One of the objects of the invention is to provide improved methods of and means for establishing substantially

2

uniform electrostatic charges upon electrophotographic recording media.

Another object is to provide improved circuits for alternately energizing a plurality of alternate parallel-disposed corona generating elements for use in electrophotography, and the like.

A further object is to provide improved circuits for generating high frequency, high voltage corona generating pulses which are keyed at a substantially lower frequency.

Another object is to provide improved methods of and means for shock-exciting an inductive circuit for generating high voltage corona generating pulses.

A still further object is to provide an improved method of and means for shock exciting an inductive circuit for deriving, at a substantially lower frequency, corona generating pulses of a first polarity and corona generating voltages of the opposite polarity for application to an electrophotographic charging structure.

The foregoing objects are accomplished in accordance with the invention wherein an inductor in the output circuit of an electron discharge device is shock-excited by the application of cut-off pulses to the control element of the discharge device thereby providing high frequency output pulses keyed at the cut-off pulse frequency. The desired polarity of output pulses is selected by means of a clamping rectifier device, which can, if desired, provide voltage doubling of the generated pulses.

In a first embodiment of the invention a corona generating device comprises alternately interconnected corona charging wires disposed in a plane at a desired fixed distance from an electrophotographic recording element located upon a ground plane. A first high voltage, high frequency pulse generator is connected to the odd-numbered corona generating wires and a second high voltage high frequency pulse generator is connected to the even-numbered corona generating wires. Both generators may be excited by the same pulse source such as a multivibrator. The generators are alternately energized by application thereto of opposite phases of a low frequency A.-C. voltage.

A second and preferred embodiment of the invention employs a second bistable circuit such as a multivibrator for alternately keying on and off the two high voltage, high frequency pulse generators at a substantially lower switching frequency.

The first and second embodiments are especially advantageous in large area electrophotographic arrangements, such as the preparation of printing plates, wherein relative movement of the charger and printing plate would involve mechanical difficulties.

Another embodiment of the invention utilizes a single high voltage, high frequency pulse generator which is repetitively switched on and off by means of an astable circuit such as a multivibrator to provide pulsed high voltage corona generating potentials of one polarity and substantially constant D.-C. corona generating potentials of the opposite polarity. Such a voltage generating circuit is especially advantageous in the so-called "double corona" charging structures wherein in the constant voltage corona generating element is substituted for the ground plane normally used in single corona generating structures.

The invention will be disclosed in greater detail by reference to the accompanying drawings wherein:

FIG. 1 is a simplified schematic circuit diagram of the high voltage, high frequency pulse generator forming a part of the various embodiments of the instant invention;

FIG. 2 is a series of graphs illustrative of the operation of the circuit of FIG. 1;

FIG. 3 is a partial block schematic circuit diagram of the first embodiment of the invention;

FIG. 4 is a schematic circuit diagram of said first embodiment of the invention;

FIG. 5 is a schematic circuit diagram of the second embodiment of the invention; and

FIG. 6 is a schematic circuit diagram of said third embodiment of the invention.

Similar reference characters are applied to similar elements throughout the drawings.

Referring to FIG. 1, a typical high voltage, high frequency pulse generator 3 comprises an electron discharge device such as a tube 5 in which the anode current i is supplied through an inductor 7 which has a distributed capacitance 9. The grid-cathode circuit of the normally conducting tube 5 is switched with the negative pulse waveform E_g shown in graph (a) of FIG. 2 to sequentially cut off the anode current through the tube.

During the time T_1 (see FIG. 2b) the current i through the inductor 7 rises exponentially and reaches a peak value i_m at the end of the time T_1 whereupon the anode current of the tube 5 is cut off by the negative pulse E_g . The energy stored in the field of the inductor 7 resonates between its inductance L and its distributed capacitance C_D (shown at 9), (which also includes stray circuit capacitances) resulting in the damped sinusoid E_p of FIG. 2c during the cut-off period T_2 . The first positive peak E_m attained after cutoff, can be derived from Equation 1 which relates the kinetic energy of the inductor L at cutoff to the potential energy stored in C_D one-fourth cycle later.

$$\frac{1}{2}Li_m^2 = \frac{1}{2}C_DE_m^2 \quad (1)$$

This gives

$$E_m = i_m \sqrt{\frac{L}{C_D}} \quad (2)$$

In a typical example, if $L=0.5$ henry, $C_D=100 \mu\text{mf.}$, and $i_m=120$ ma., then $E_m=8.5$ kilovolts.

This example shows that sufficiently high voltages for corona generation can easily be generated across relatively small values of inductance with currents which can be handled by common vacuum tubes.

The high voltage, high frequency waveform E_p is applied to a clamp circuit comprising a series capacitor 11 and a shunt diode 13 which changes the waveform E_p of FIG. 2c to the waveform E_0 shown in FIG. 2d to provide a negative voltage waveform for corona generation.

A first embodiment of the invention shown in partially block schematic form in FIG. 3, the blocks of which are illustrated schematically in FIG. 4, includes a corona charger 15 comprising an insulating frame 17 supporting a plurality of alternately interconnected corona wires 21, 23 at a fixed distance from a conductive ground plane 25. The ground plane 25 may comprise a metal plate such as a printing plate coated with a photoconductive insulating layer of the general type described in the aforesaid Electrofax article. Alternatively, if desired, a piece of "Electrofax" paper, i.e., a paper suitably coated as described in said article, may be placed upon a metallic ground plate with the photoconductive surface facing the corona wires 21, 23. A pair of high voltage, high frequency pulse generators 33, 35, each like that of FIG. 1, are connected respectively to the even-numbered corona wires 23 and to the odd-numbered corona wires 21. A keying pulse source such as a multivibrator 37 provides the keying pulse E_g to both high voltage pulse generators.

In order to provide alternate application of the high frequency, high voltage waveform to the two sets of alternately interconnected corona wires, the anode circuits of the two pulse generators are energized by the alternate positive 370-volt phases of an alternating voltage. The A.-C. voltage can be derived from the secondary winding 39 of a transformer 41 which is energized from a 115 volt, 60 cycle A.-C. line, whereby the corona voltages are alternately applied to each group of alternate corona wires at a 60 cycle rate. The center tap 43 of the sec-

ondary winding 39 on the transformer 41 preferably is grounded, as are the cathode circuits of the multivibrator 37 and the high voltage generator tubes 5.

As shown in FIG. 4, the multivibrator 37 provides keying pulses through the capacitors 45, 47 to the control grids of the tubes 5 of the high voltage generators 33, 35. For the circuit parameters listed in the tables, the multivibrator frequency is about 4000 cycles.

Control of the time intervals T_1 and T_2 of the square waveform provided by the multivibrator is accomplished by adjustment of variable resistors 49, 51 in the grid-cathode circuits of the multivibrator tubes. Uniform charging can be obtained over a wide relative time range. However, the highest power output is derived from the circuit with the indicated parameters, for example, when $T_1 \approx 250 \mu\text{sec.}$ and $T_2 \approx 100 \mu\text{sec.}$

Individual control of the output voltage derived from each of the high voltage generators is provided by variable resistors 53, 55 connected between the anode voltage source and the screen grids of the tubes 5.

The circuit of FIG. 5 is similar to that of FIG. 4 with the exceptions that the high voltage, high frequency pulse generator tubes 5 and 5' are energized from a D.-C. source applied to the anodes through the inductors 7 instead of by the alternately phased A.-C. pulses derived from the transformer 41 of FIG. 4. The alternate switching of the output of the pulse generator tubes 5, 5' to the two sets of corona wires is accomplished by switching pulses derived from a second multivibrator 38 which are alternately applied through separate cathode followers 90, 92 to the control grid electrode of the corresponding pulse generator tubes 5, 5' respectively. The keying pulses derived from the first multivibrator 37 for actuating the pulse generator tubes 5, 5' are applied to the control grids of said pulse generators through the same cathode followers 90, 92, respectively.

In a typical embodiment of the circuit of FIG. 5, as indicated by the circuit parameters listed in the following chart, the keying frequency provided by the keying multivibrator 37 is about 4,000 cycles per second while the switching frequency provided by the second multivibrator 38 is about 40 cycles per second. However, wide variation in the pulse rates is permissible and considerable range of output pulse voltages and average corona current with varying numbers and areas of corona charging elements is achievable by variation of the adjustable resistors provided in the circuit and by proper selection of the amount of inductance introduced in the pulse generating circuit. The circuit has been found to provide very uniform charging of a photoconductive insulating layer on either paper or metallic printing plates without relative motion between the charger and photoconductive layer in time intervals of the order of one second.

The circuit of FIG. 6 utilizes some of the features of the foregoing circuits for generating both a pulsed negative high voltage output and a continuous positive D.-C. high voltage output for application to a "double corona" charger of the type wherein the photoconductive element is placed between the two corona elements and a ground plane is not required since it is effectively replaced by the positive corona.

In the circuit of FIG. 6, the keying multivibrator 37 drives the high voltage, high frequency pulse generator tube 5 in the same manner as described heretofore to provide oscillatory output voltages which are clamped by the diode 13 to provide the pulsed negative output for one element of the double corona charger. A second diode 113 having its anode coupled to the anode of pulse generator tube 5 has its cathode heated from a small winding 115 which is inductively coupled to the inductor 7. The cathode of the diode 113 is coupled to the remaining terminal of the inductor 7 through a smoothing capacitor 109 which smooths the positive half cycle pulses which pass through the rectifier 113. Thus a substantially constant D.-C. output is derived from the cathode of the

diode 113 to the positive corona charger element. The smoothing capacitor 109 thus insures that a positive corona field will be present during the occurrence of the pulsed negative corona. Without the smoothing action of the capacitor 109 the positive corona field would occur alternately with the negative corona field and would not provide as effective a ground plane therefor.

The following tables indicate circuit parameters for typical embodiments of the invention which have been found to provide very effective charging sources for corona charging in electrophotography:

Inductor 7:

0.5 henry—3000 turns No. 36 wire on ¼" I.D. form, single-pi universal winding ⅝" wide, on ferrite core 1½" long. Winding 115—4 turns No. 26 Tempreme wound on same form immediately adjacent to the universal winding. Entire coils and form dipped in glyptol.

Tubes:

5, 5—6BQ6GTB
13, 13'—1X2B
73, 90—92—12AU7A

Capacitors:

11, 11', 109—500 $\mu\text{mf.}$, 12.5 kv.
44, 48—.1 $\mu\text{f.}$
45, 47—1000 $\mu\text{mf.}$
46, 97, 99, 107—.005 $\mu\text{f.}$
59—.01 $\mu\text{f.}$
69—470 $\mu\text{f.}$
71—330 $\mu\text{mf.}$
70, 72—1000 $\mu\text{mf.}$
74, 76—.01 $\mu\text{f.}$
75, 75'—.06 $\mu\text{f.}$
82, 84—.1 $\mu\text{f.}$

Resistors:

49, 51—1 megohm
61, 63, 79, 80—1 megohm
53, 55—15,000 ohms
57—1 megohm
65, 67—22,000 ohms
77, 78—15,000 ohms
81, 83—1,000 ohms
85, 87—220,000 ohms
89, 91—330,000 ohms
93, 95, 105—470,000 ohms
101, 103—27,000 ohms
111, 113—220 megohms

It should be understood that circuit inductance and output voltages will be affected by the effective capacitance and shunt resistance of different types and sizes of corona charging elements. The circuit parameters listed heretofore have been found to provide excellent operation with alternately pulsed charging wires stretched on an insulating frame as large as 16" x 24" to charge a newspaper printing plate. The indicated parameters for the circuit of FIG. 6 have been operated successfully in a double corona charger in an office copier machine.

What is claimed is:

1. In an electrostatic charging system for electrophotography in which different corona generating elements are alternately energized, a pulse generating circuit comprising:

- (a) means for generating keying pulses of a first frequency,
- (b) an inductive shock-excitation circuit for generating high voltage pulses of a second frequency that is higher than said first frequency for corona generation,
- (c) means for applying said keying pulses to the last-mentioned circuit for generating high voltage pulses to shock-excite said high voltage pulses,
- (d) rectifier and capacitive means connected in series with each other and to said inductive shock-excitation circuit for clamping said high voltage pulses, and

(e) means connected between said rectifier and said capacitive means for applying said clamped high voltage pulses to selected ones of said corona generating elements.

2. In an electrostatic charging system for electrophotography in which different corona generating elements are alternately pulsed, a pulse generating circuit comprising:

- (a) means for generating switching voltages at a first frequency,
- (b) means for generating keying pulses at a second frequency substantially higher than said first frequency,
- (c) a pair of inductive shock-excitation circuits for generating high voltage pulses for corona generation of a third frequency that is higher than said second frequency,
- (d) means for applying said switching voltages to said shock-excitation circuits to alternately energize said circuits,
- (e) means for applying said keying pulses to said alternately-energized circuits to shock-excite said high voltage pulses, and
- (f) means coupled to said shock-excitation circuits for clamping and for applying said clamped high voltage pulses alternately and in the same polarity to different ones of said corona generating elements.

3. In an electrostatic charging system for electrophotography in which different corona generating elements are alternately pulsed, a pulse generating circuit comprising:

- (a) means for generating switching voltages at a first frequency,
- (b) multivibrator means for generating keying pulses at a second frequency substantially higher than said first frequency,
- (c) a pair of inductive shock-excitation circuits for generating high voltage pulses of a third frequency that is higher than said second frequency for corona generation,
- (d) means for applying said switching voltages to said shock-excitation circuits to alternately energize said shock-excitation circuits,
- (e) means for applying said keying pulses to said alternately-energized circuits to shock-excite said high voltage pulses,
- (f) rectifier and capacitive means connected in series with each other and to said shock-excitation circuits for separately clamping the high voltage pulses derived from said alternately-energized circuits, and
- (g) means connected between said rectifier and said capacitive means in each of said shock-excitation circuits for applying said clamped high voltage pulses alternately and in the same polarity to alternate ones of said corona generating elements.

4. The method of energizing a plurality of parallel disposed corona generating elements for applying a substantially uniform electrostatic charge to an electrophotographic recording medium comprising:

- (a) generating high voltage pulses of a first frequency,
- (b) clamping said high voltage pulses, and applying said clamped high voltage pulses in a selected polarity at a second frequency that is relatively lower than said first frequency to selected ones of said elements,
- (c) deriving voltages of opposite polarity from said generated pulses, and
- (d) filtering said last-mentioned derived voltages and applying said filtered derived voltages to other ones of said elements.

5. In an electrostatic charging system for electrophotography in which at least two different corona generating elements are selectively energized, a pulse generating circuit comprising:

- (a) means for generating keying pulses of a first frequency,

7

- (b) an inductive shock-excitation circuit for generating high voltage pulses, of a second frequency that is higher than said first frequency, for corona generation,
- (c) means for applying said keying pulses to the last-mentioned circuit for generating said high voltage pulses, 5
- (d) clamping means including a capacitor and a rectifier connected in series with each other and to said inductive shock-excitation circuit to clamp said high voltage pulses, 10
- (e) means connected between said rectifier and said capacitor for applying said clamped high voltage pulses in one polarity to one of said corona generating elements, and
- (f) means responsive to said high voltage pulses and 15

8

connected to said inductive shock-excitation circuit for applying a voltage in the opposite polarity to another of said corona generating elements.

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SAMUEL BERNSTEIN, *Primary Examiner*.