

Sept. 21, 1965

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3,208,076

ELECTROSTATIC PRINTER

Filed May 5, 1960

3 Sheets-Sheet 1

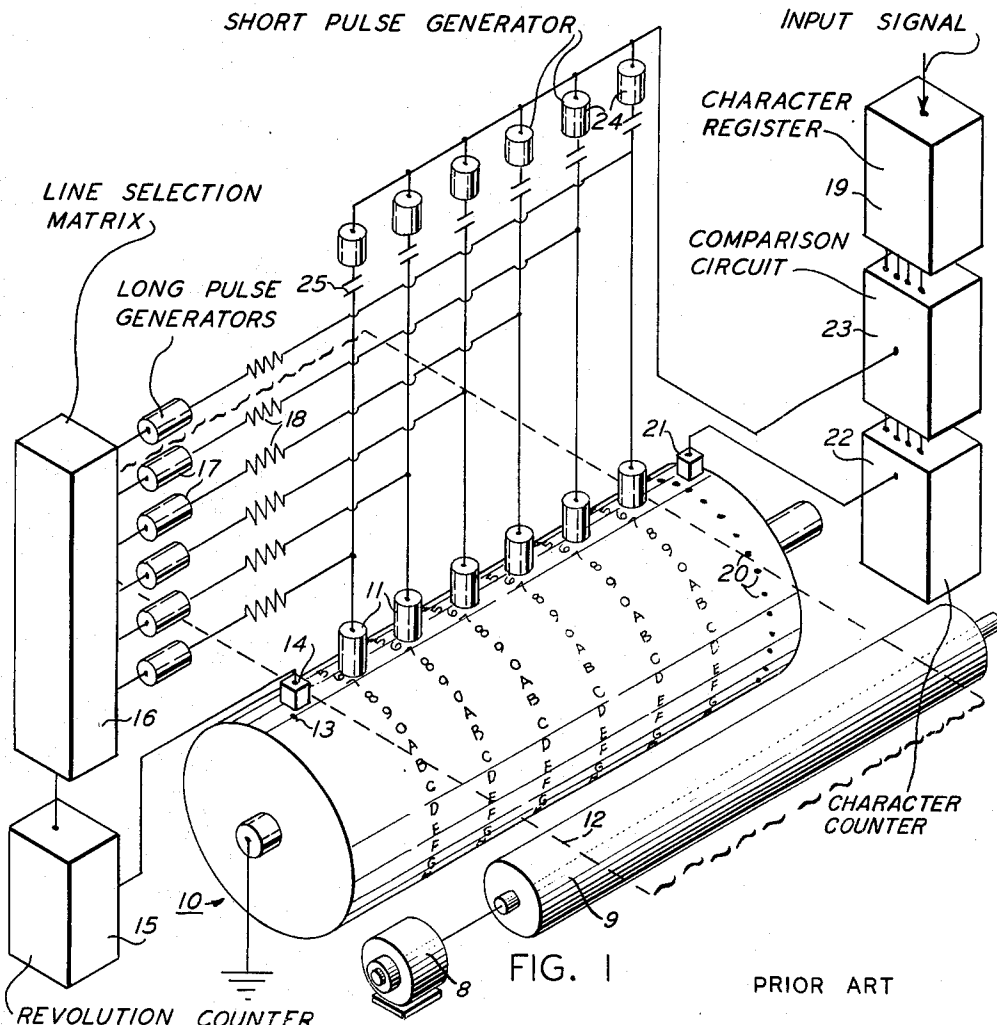


FIG. 1

PRIOR ART

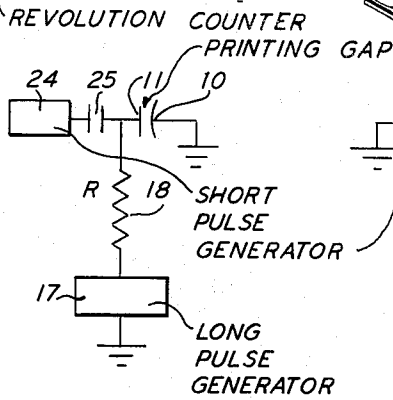


FIG. 2

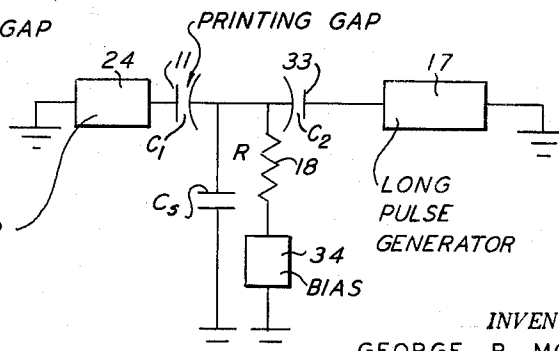


FIG. 4

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3 Sheets-Sheet 3

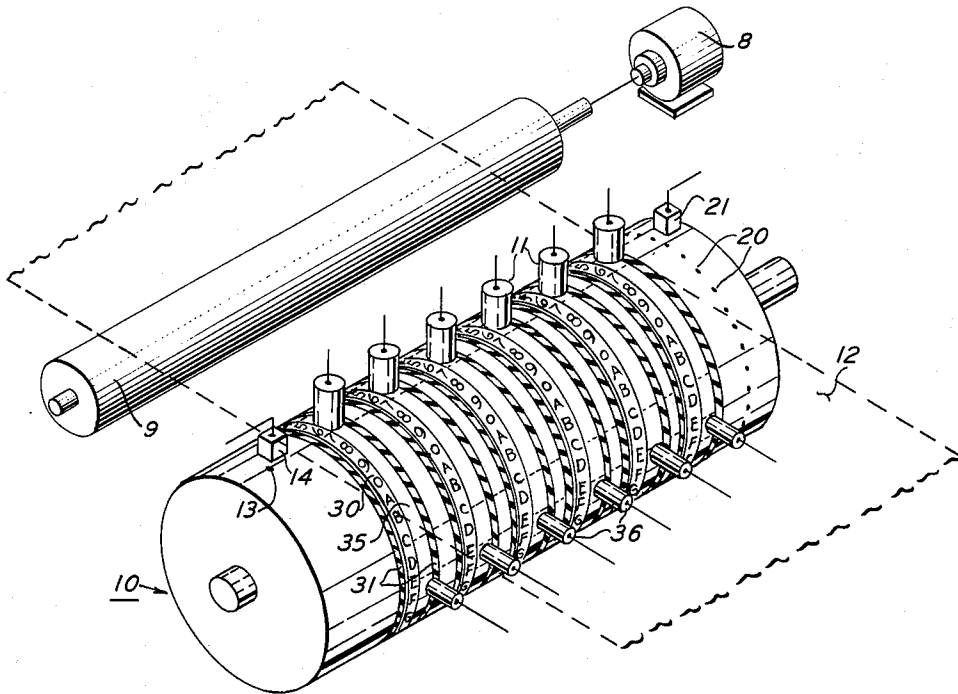


FIG. 6

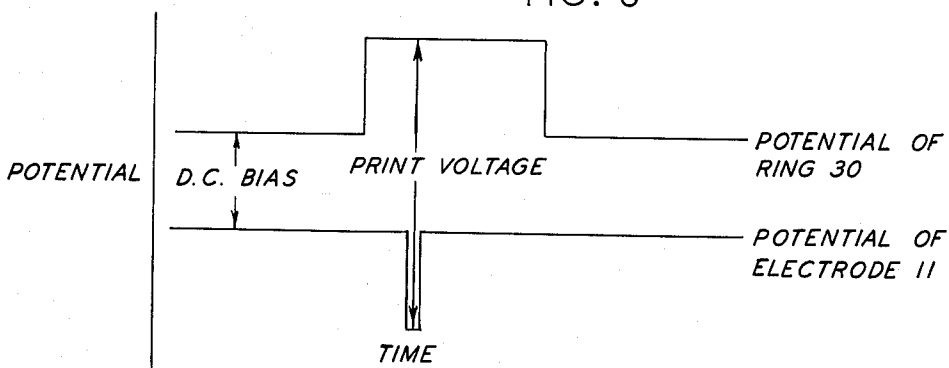


FIG. 5

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1

2

3,208,076

**ELECTROSTATIC PRINTER**

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 Filed May 5, 1960, Ser. No. 27,098  
 9 Claims. (Cl. 346-74)

This application relates to improved high speed multi-column electrostatic printers.

In accordance with the prior art involving electrostatic printing devices requiring intense electric fields for brief periods, difficulties have been encountered in applying pulses in order to bring about electrostatic recording. Now, in accordance with the present invention, there is disclosed novel means and techniques to apply electric pulses in electrostatic printers.

Further features and objects of the invention will become apparent from the specification and drawings, in which:

FIG. 1 is a partly isometric and partly schematic view of a high speed printer according to the prior art;

FIG. 2 is a circuit diagram corresponding to the apparatus of FIG. 1;

FIGS. 3A and 3B are perspective and sectional views, respectively, of a printing drum according to the present invention;

FIG. 4 is a circuit diagram corresponding to the apparatus of FIG. 3;

FIG. 5 is a graph showing voltage-time relationships in the apparatus of FIG. 3; and,

FIG. 6 is an isometric view of a modification of the apparatus of FIG. 3.

Referring now to FIG. 1, there is shown a type of high speed electrostatic printer generally known to the art. It includes as a key element an electrically conductive drum 10 which is rotatable at high speed about its axis by drive means, not shown. Drum 10 includes on its surface several sets of characters, generally conductive and generally in relief, arranged in parallel circumferential rings or bands as shown. A linear array of print electrodes 11 is positioned adjacent to drum 10, each electrode being aligned with a corresponding character band on drum 10. A web 12 of paper or other insulating material is fed between drum 10 and electrodes 11 by conventional moving means such as a motor 8 connected to a drive roller 9 as illustrated. A magnetic insert 13 positioned at one end of drum 10 operates in conjunction with magnetic detector 14 to provide an input pulse into revolution counter 15 for each revolution of drum 10. Revolution counter 15 cooperates with line selection matrix 16 to trigger a successive long pulse generator 17 for each revolution of drum 10. A separate generator 17 of electrical pulses of relatively long duration, hereinafter referred to as a long pulse generator is provided for each electrode 11 and each generator is connected to its corresponding electrode through a resistor 18. Each long pulse generator 17 when triggered produces an output pulse equal in length to the period of rotation of drum 10. Typical drum speeds in the range of 3,000 to 12,000 r.p.m. thus require pulse lengths ranging from 20 milliseconds ( $\frac{1}{50}$  second) to 5 milliseconds ( $\frac{1}{200}$  second). Pulse generators 17 will preferably also have a steady D.C. output voltage upon which the output pulse is superimposed, the sum of the steady and pulse voltages being less than that required to initiate an electrical discharge between an electrode 11 and drum 10.

The printer input signal, which may comprise an electronic computer output or the like, is applied to a character register 19. A series of magnetic inserts 20 in drum 10 cooperates with a magnetic detector 21 to provide a pulse input into character counter 22 each time a character or a line of characters on drum 10 passes an elec-

trode or electrodes 11. A comparison circuit 23 compares the states of character register 19 and character counter 22 and delivers an output pulse whenever a character on drum 10 desired to be printed is in alignment with an electrode 11. The output of comparison circuit 23 is fed in parallel to a set of generators 24 of electrical pulses of short duration, hereinafter referred to as short pulse generators 24 each of which when triggered produces a short output pulse having a duration of the order of a few microseconds. Each generator 24 delivers its output to a corresponding electrode 11 through a coupling capacitor 25. The sum of the bias and pulse voltages from pulse generator 17 and of the pulse voltage from generator 24 exceeds the threshold voltage for initiating an electrical discharge between drum 10 and an electrode 11, while lesser voltages fall below this threshold. Each such electrical discharge results in the deposition on web 12 of an electrostatic charge pattern corresponding in shape to that of the adjacent character on the surface of drum 10. There is thus formed on web 12 an overall pattern of electrostatic charge constituting a message or the like corresponding to the electrical input signal. The electrostatic charge pattern can be converted into a visible message by well-known image development techniques. Further information on electrostatic printers of this general character may be found in U.S. Patent 2,919,967, which issued June 5, 1960.

It is obvious that other electronic arrangements could be used in place of that shown in FIG. 1. In particular, it would be possible to employ only a single set of pulse generators each having a voltage output adequate in itself to initiate electrical discharge, and controlling the generators so that the output pulses appeared only at the proper electrodes and at the proper times to cause electrical discharge at desired characters. Such an arrangement is, however, less desirable than the one illustrated for several reasons. In the first place, the timing and distribution of pulses is much simpler in the illustrated arrangement. The long pulse generators are simply triggered in a uniform sequence which is independent of the information input, while the short pulse generators are all triggered in parallel independently of the long pulse generators. Furthermore, in the illustrated circuit no high level gates or switches are required in any of the pulse output circuits to direct pulses to particular electrodes. More important is the fact that the illustrated arrangement does not require very high voltage pulse generators. For typical drum-to-electrode spacings on the order of a few thousandths of an inch the threshold voltage for initiating electrical discharge is on the order of a thousand volts. As is well known, longer drum to electrode spacings require higher voltages to initiate electrical discharge; whereas, lesser spacings are difficult to achieve for mechanical reasons. As is also well known, the breakdown voltage of such a gap is also highly dependent on the nature and pressure of the gas or other medium in the gap. Generally, however, electrostatic printers of this character operate in ordinary air and at altitudes, and therefore pressures, suitable for human habitation. Accordingly the threshold voltage for initiating electrical discharge is generally on the order of a thousand volts, as previously stated. This is a higher voltage than can be conveniently obtained from a small economical pulse generator, since the output of a simple pulse generator is limited by the voltage rating of the vacuum tubes employed, and small vacuum tubes have maximum voltage ratings of about 250 volts. In the illustrated arrangement, however, pulse voltages of this order of magnitude are quite adequate.

FIG. 2 is a circuit diagram showing the connections to a single electrode 11 of FIG. 1. It has been found ex-

perimentally that the short pulse generator 24 requires capacitor 25 to be large, i.e., a long R-C time for efficient image formation. However, the long pulse generator 17, if it is a moderately high impedance generator, requires a small C, i.e., a short R-C time to avoid integration and secure a rapidly rising long pulse. These two requirements are clearly contradictory and not easily resolved by change of design for either generator.

FIGS. 3A and 3B show a modified form of printing drum adapted to overcome these shortcomings. In this modification the electrically conductive character elements are included in a set of separate character rings 30 which are insulated from each other and from drum 10 by insulating rings 31, rather than being electrically a part of drum 10 as in FIG. 1. The illustrated construction not only provides electrical insulation between successive rings 30 but also minimizes capacitive coupling between the rings. Each ring 30 is either connected through its associated high resistance resistor 32 to drum 10, as shown, or to a separate conductor which may be brought out through a hollow shaft employed for drum 10. In addition to print electrodes 11 described in connection with FIG. 1, drum 10 has associated therewith a set of capacitive induction electrodes 33, there being one electrode for each character ring 30. These electrodes 33 have as large an area adjacent to rings 30 as possible and are placed as close to rings 30 as is mechanically feasible so as to maximize the capacitance therebetween. The electrical circuitry is similar to that shown in FIG. 1 except that the short pulse generators are connected directly to electrodes 11 and the long pulse generators are connected directly to electrodes 33, there being no direct coupling between the two sets of pulse generators.

Fig. 4 is a circuit diagram showing the connections associated with a single character ring 30 of FIG. 3 more clearly than is shown in FIG. 3. Capacitor  $C_1$  represents the capacitance existing between character ring 30 and print electrode 11 while capacitor  $C_2$  represents the capacitance existing between character ring 30 and induction electrode 33 and  $C_s$  represents the shunt capacitance from character ring 30 to ground. In forming images with the apparatus of FIGS. 3 and 4, a bias voltage is chosen such that the sum of the bias voltage and either the long or the short pulse alone is insufficient to cause electrical discharge at  $C_1$ . This bias may be applied by a power supply 34 connected, as shown, by a D.C. potential furnished by the short pulse generator, or by a combination of the two. When a pulse is applied to induction electrode 33 by long pulse generator 17, a fraction of the pulse appears at  $C_1$  because of the capacitive voltage division caused by  $C_2$  and  $C_s$ . The output of pulse generator 17 is kept sufficiently low in this embodiment to avoid any electrical discharge at  $C_2$ . The total potential difference across the print gap  $C_1$  is now the D.C. bias plus the long pulse, since the time constant R-C<sub>2</sub> is chosen to be long compared to the time duration of the long pulse. A pulse applied by short pulse generator 24 to the print gap  $C_1$  raises the electrical field strength at  $C_1$  above the threshold for electrical discharge and causes the deposition of an electrostatic charge pattern in character configuration on a web 12 positioned between drum 10 and electrodes 11. When the long pulse terminates, the voltage at the print gap is reduced to substantially the bias level, and further image formation is prevented even though short pulses from generator 24 still appear at the print gap.

The various voltage relations described above may be more readily appreciated from a consideration of FIG. 5 which shows the voltages at print electrode 11 and character ring 30 as a function of time. No polarities are indicated because the system can be made to work with an electric field of either polarity applied to the print gap. The potential available for causing discharge is represented as the distance between the two lines in FIG. 5. Only when the outputs of both long and short pulse gen-

erators are simultaneously applied is sufficient potential available to cause discharge.

If the voltage pulses applied to electrodes 33 are raised to a sufficiently high level on the order of 1,000 volts, electrical discharge will take place between electrodes 33 and the character rings 30. Where pulse generators of this magnitude are available, the electrical discharge can be used to advantage to couple the pulse generator to the character rings. FIG. 6 is a view of a printing drum modified for more efficient operation according to this principle. The character rings 30 are provided with smooth conductive shoulder areas 35 and induction electrodes 33 are replaced by much smaller electrodes 36 since maximum capacitance between the electrodes and character rings is no longer necessary. Shoulder areas 35 provide a uniform conductive surface for operation with the small electrodes 36. Electrodes 36 should preferably be operated adjacent shoulder areas 35 rather than directly adjacent to the character bearing portions of character rings 30 since the spacing between the electrode and the ring is not constant, due to the presence of the characters, and therefore the breakdown voltage of the gap therebetween is non-uniform.

This invention has been described in terms of forming electrostatic images on an insulating web 12, but it is often preferred to form the images on a web which includes conductive, as well as insulating layers. Such a web may typically comprise a layer of metal foil laminated to or with a layer of paper or plastic material. When such a web is used, individual print electrodes 11 are completely ineffective in controlling electrical discharge at individual regions along the length of drum 10 since the insulating layer of the web is shielded from electrodes 11 by the conductive layer. When such a web is employed, it is necessary to control discharge and image formation by applying suitable voltages to individual mutually insulated character rings, such as character rings 30, on drum 10, although it is still possible to apply a uniform D.C. bias to the web through electrodes 11 or other means, such as a single long electrode. It is, of course, possible to apply voltages to these rings through slip rings or the like, but this has serious drawbacks. In the first place, slip ring action is uncertain at the high rotational speeds generally involved and is associated with the generation of considerable electrical noise together with rapid wear of the slip rings. In addition, considerable capacitive cross coupling of the character rings is virtually unavoidable unless the slip rings and their associated leads are shielded from each other, in which case the shunt capacitance associated with each character ring becomes excessively large. By using apparatus and methods of FIGS. 3 or 6, however, it is possible to apply appropriately timed printing pulses to individual character rings 30 without any of the drawbacks associated with prior systems including slip rings.

Although the invention has been described in terms of specific mechanical structures and specific electrical circuits it is apparent that its utility is not limited to the specific embodiments and there is accordingly no intention to limit the invention except by the scope of the appended claims. With reference to the claims, the phrase "mutually insulated" which appears therein is intended to define the relationship between character rings which are electrically connected, if at all, by resistances which are sufficiently great to allow separate rings to be operated at independent potentials.

What is claimed is:

1. In a high speed electrostatic printer the combination comprising a cylinder rotatable about its axis, means to rotate said cylinder about its axis at a constant angular velocity, a plurality of conductive rings positioned along said cylinder and coaxial therewith, electrical insulating means to mutually insulate said conductive rings, each said ring containing a set of symbols formed on its periphery, at least one print electrode spaced closely adjacent from

5

the circumference of said cylinder and defining a gap therewith, means to move a web of recording material between said cylinder and said print electrode, a plurality of coupling electrodes positioned close to but separate from said rings, there being at least one coupling electrode adjacent each ring, at least two pulse generators which produce opposite going pulses that differ significantly in length and connecting means establishing an electrical connection between one of said pulse generators and said print electrode and between at least one other of said pulse generators and said coupling electrodes.

2. A high speed printer according to claim 1 in which each coupling electrode extends in close proximity to a substantial fraction of the periphery of its associated conductive ring and in which the pulse generators which produce the longest pulses are connected to said coupling electrodes.

3. In a high speed electrostatic printer the combination comprising a cylinder rotatable about its axis, a plurality of conductive rings positioned along said cylinder and coaxial therewith, electrical insulating means to mutually insulate said conductive rings, each said ring containing a set of conductive symbols formed on its periphery, means to rotate said cylinder about its axis at a constant angular velocity, at least one print electrode spaced closely adjacent from the circumference of said cylinder and defining a gap therewith, means to move a web of recording material between said cylinder and said print electrode, a plurality of coupling electrodes positioned externally close to but separate from said rings, there being at least one coupling electrode adjacent each ring, at least one pulse generator which produces pulses in a first direction, which pulses have a duration as long as the time required for one of the conductive symbols on said conductive rings to pass said print electrode, connecting means forming an electrical connection between said pulse generator and said print electrode, at least one second pulse generator which produces pulses in a second direction having a duration substantially equal to the period of rotation of said cylinder and connecting means adapted to establish an electrical connection between each of said second pulse generators and a coupling electrode.

4. A high speed printer according to claim 3 in which each coupling electrode extends in close proximity to and coaxially with a substantial fraction of the periphery of its associated conducting ring.

5. A high speed electrostatic printer comprising a cylinder rotatable about its axis, a plurality of conductive rings positioned along said cylinder and coaxial therewith, electrical insulating means to mutually insulate said conductive rings, each said ring containing a set of symbols formed on its periphery together with a region free of characters and in the shape of a figure of revolution, means to rotate said cylinder at a constant angular velocity, at least one print electrode spaced closely adjacent from the circumference of said cylinder and defining a gap therewith, means to move a web of recording material between said cylinder and said print electrode, a plurality of coupling electrodes positioned close to but separate from the regions of said rings free of characters, there being at least one coupling electrode adjacent each ring at least one pulse generator which produces pulses in a first direction, which pulses have a duration as long as the time required for one of the conductive symbols on said conductive rings to pass said print electrode, connecting means forming an electrical connection between said pulse generator and said print electrode, at least one second pulse generator which produces pulses in a second

6

direction having a duration substantially equal to the period of rotation of said cylinder and connecting means forming an electrical connection between each of said second pulse generators and a coupling electrode.

6. An electrostatic printer according to claim 1 in which the pulse generating means connected to said coupling electrodes produces a pulse of a lesser magnitude than that required to initiate an ionizing on electrical field discharge between said coupling electrode and said cylinder, whereby said pulse generator is capacitively coupled to said cylinder across the air gap capacitor formed by said cylinder and said coupling electrode.

7. An electrostatic printer according to claim 1 further including means to apply a bias potential across the gap formed by said print electrode and said cylinder, said bias being of sufficient magnitude so that the concurrent application of opposite going pulses from said two pulse generators when added to said bias potential are sufficient to initiate an ionizing electrical field discharge across the gap formed by said cylinder and said print electrode.

8. The method of electrostatic printing comprising rotating a cylinder having a plurality of mutually insulated conductive rings positioned along said cylinder and coaxial therewith with a set of symbols formed on the periphery of each ring at a constant angular velocity spaced closely adjacent at least one print electrode which together define a printing gap, moving a web of recording material through said printing gap, applying a first pulse to said print electrode when a preselected symbol on said cylinder comes opposite said print electrode in the course of a cylinder rotation, said pulse being of a duration equivalent to the time during which said preselected symbol is opposite said print electrode and applying a second pulse which is opposite going to said first pulse to a selected one of said conductive rings by capacitively coupling said second pulse to said selected conductive ring across an air gap capacitor formed by said selected ring and a coupling electrode spaced closely adjacent said selected conductive ring, said second pulse being of a duration equal to the period of rotation of said cylinder and the sum of said two pulses being sufficient to raise the potential across said printing gap to that required to initiate an ionizing electrical field discharge across said gap.

9. In a high speed electrostatic printer in which printing is accomplished by the application of at least two pulses in coincidence to raise the potential across a printing gap formed by a rotating character cylinder and a print electrode above the potential required to initiate an ionizing electrical field discharge across said gap, the improvement comprising at least one coupling electrode electrically connected to one of said pulse generators closely adjacent but spaced from said character cylinder a distance greater than that which would cause an ionizing electrical field discharge between said coupling electrode and said cylinder upon the application of a pulse from said pulse generator capacitively coupling said pulse generator to said character cylinder.

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70