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H. EPSTEIN ET AL
PAGE PRINTING APPARATUS

2,919,171

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3 Sheets-Sheet 2

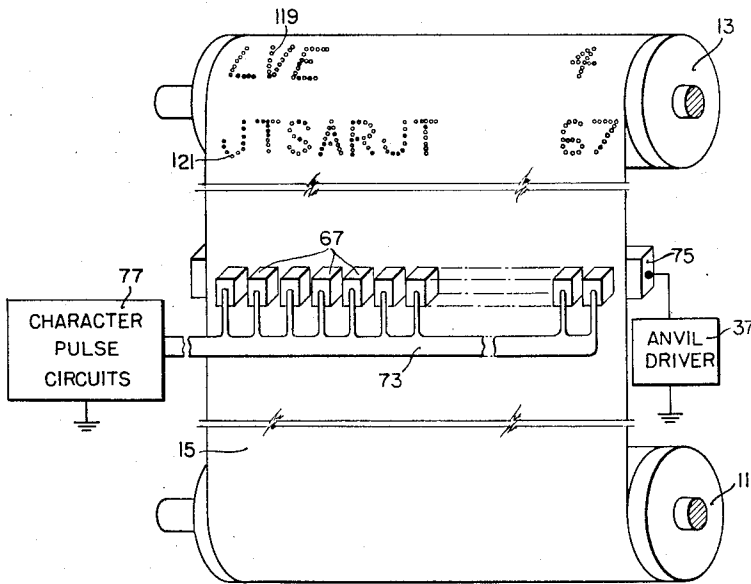


Fig. 7

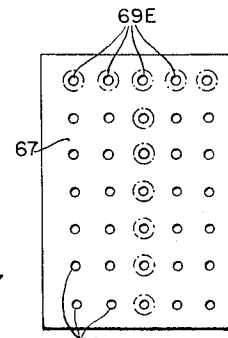


Fig. 9

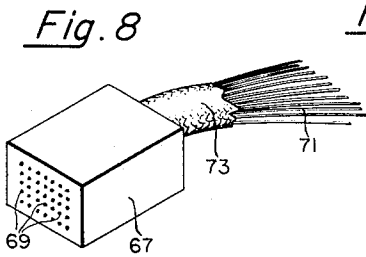


Fig. 8

Fig. 6

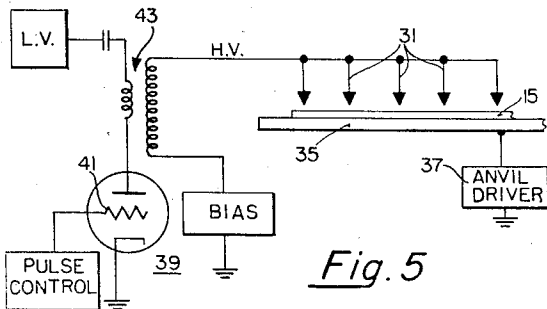
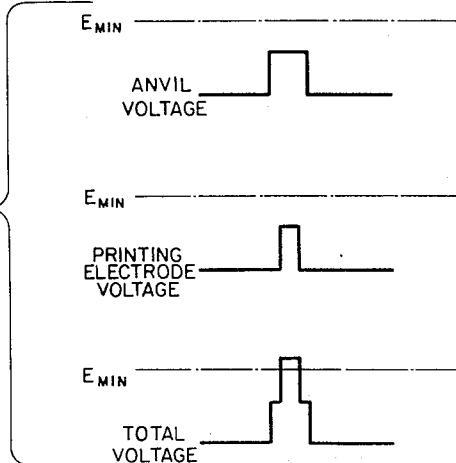


Fig. 5

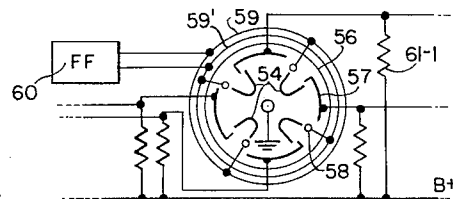


Fig. 13

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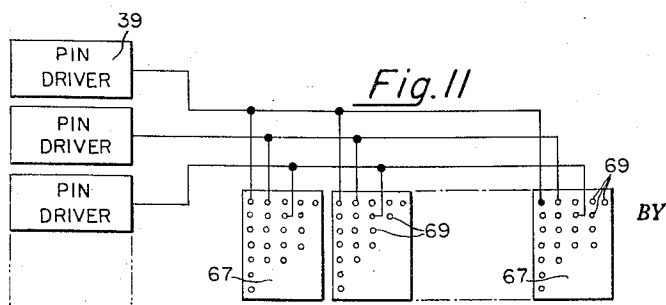
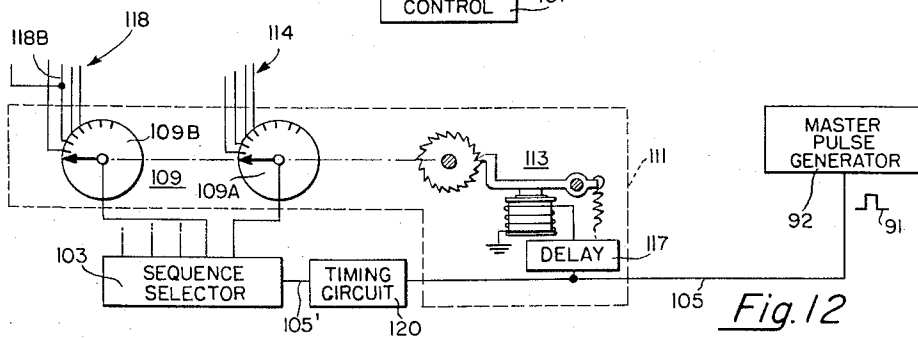
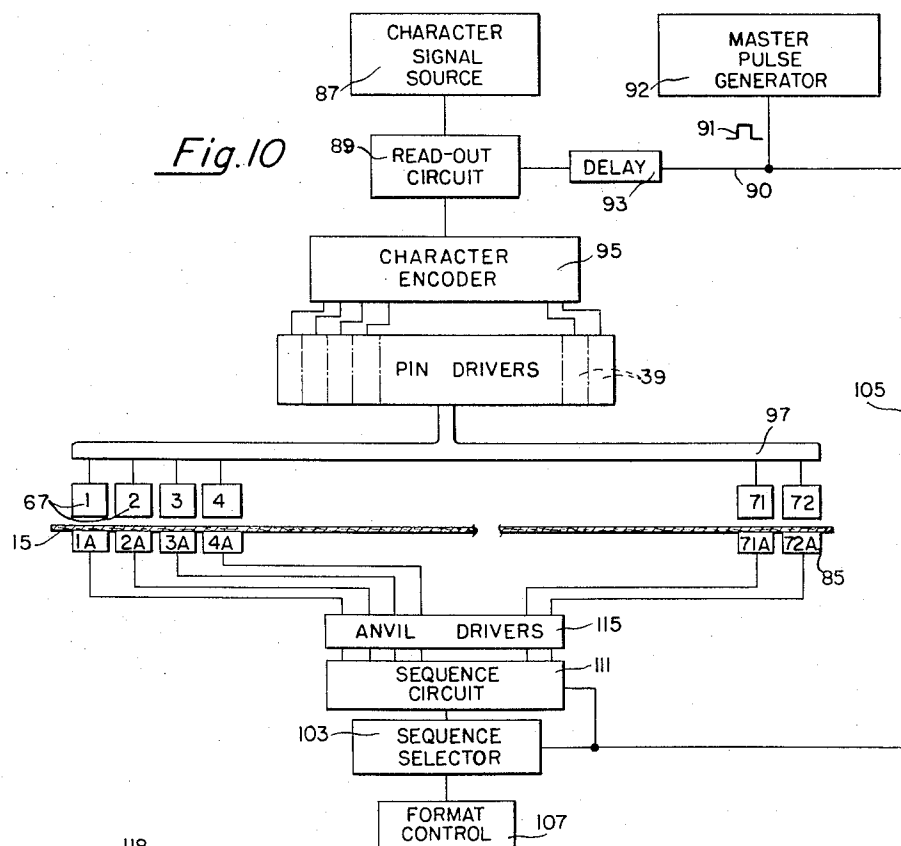
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3 Sheets-Sheet 3



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PAGE PRINTING APPARATUS

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Application February 27, 1957, Serial No. 642,872

21 Claims. (Cl. 346—74)

This invention relates to improvements in page printing apparatus, with particular reference to page printers of the so-called "electrographic" type.

In the electrographic printing process the indicia to be printed, such as letters, lines, dots, etc., are first formed as invisible electrostatically charged surface areas of a recording medium by means of silent electrical discharges from suitably shaped and suitably positioned electrodes. Subsequently these charged areas are rendered visible by the application of finely divided pigmented powder to the surface of the medium as a developing agent or "ink," the powder being held to the medium by electrostatic attraction substantially only over the charged areas. The powder image thus obtained is fixed in any of various available ways, to produce a permanent record. Further details of the electrographic process and of means for practicing it are disclosed in copending patent applications Serial No. 320,592, filed November 14, 1952, and Serial No. 443,646, filed July 15, 1954, both assigned to the assignee of the present invention; and, also, in a paper jointly authored by one of the present applicants, Herman Epstein, and an associate, published in Part IV of the Institute of Radio Engineers Convention Record of 1955.

The type of apparatus described in the above cited patent applications and publication is particularly suited to the high speed production of a printed record which does not vary greatly in format in different portions of the record. A strip printer which prints characters more or less continuously in a single column or relatively few columns extending in the direction of transport of the medium, is an example of this class of apparatus. (The term "character" is used broadly herein to refer to any printed marking employed, singly or as a component of a group of markings, to convey information. In a more specific sense it is used to refer to an alphanumeric character.) When page printing is required, including printing on continuous webs of considerable width, more complex problems usually are presented, such as the line-by-line printing of characters in positions selected from a large number of possible character printing positions in a line of text and in relationships which may vary from line to line. An output printer for an electronic digital computer is an example in point.

High operating speed, which is a generally desirable feature in printing apparatus, becomes of critical importance in apparatus for directly recording the output of electronic computers, telemetering receivers, and the like, because of the high rate at which data for printing are produced by such equipment. In prior art output printers wherein displacements of movable members or material masses occur in the printing operation, the mechanical inertia of such members or masses and the transit times involved in their required movements are factors inherently limiting operating speed. Printing by means of electrostatic charges, as carried out by the electrographic apparatus of the present invention, is free from these handicaps.

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The actual printing operation is not the only one which may involve delays or which may limit operating speed. Delays also may occur in connection with character selection and, in the case of page printers, the selection of character printing positions in a line of such positions across a page or web of page width. Certain earlier electrostatic printing devices although having the advantage of rapid character printing have the disadvantage that character selection involves the mechanical displacement of character printing members, this operation, therefore, being subject to the above cited limitations associated with such displacements. For example, in one such device an electrode wheel is employed bearing a plurality of raised type faces around the periphery thereof from which electrical discharges can be produced for printing purposes. The selection of a desired one of these type faces for printing in general involves a delay while the wheel is rotated through the necessary angle to bring the selected type face into printing position. In the presently disclosed apparatus, by way of contrast, the recording medium may be the only displaceable member. The operations of character selection, printing position selection and printing all can be carried out by electrically operating on stationary members. In the interest of simplifying the explanation of the principles of the invention, however, in some instances mechanical equivalents of certain adjunct electrical means, such as switches, are shown or referred to herein.

It is an object of the invention to provide page printing apparatus capable of operating at high speed and which inherently has a high degree of flexibility as to the format of the printed matter.

It is another object to provide high-speed page printing apparatus for line-by-line printing, wherein the characters or indicia to appear in a line of text may be rapidly selected and printed in any desired grouping and according to any desired sequence of characters or groups thereof.

It is another object to provide high speed page printing apparatus wherein the printing of a character is contingent upon the coincidental actuation of two co-operative and independently controllable stationary members, as by the application of a voltage pulse to each.

It is another object to provide electrographic page printing apparatus having stationary pin-type printing electrodes which may be selected singly or in groups for printing a variety of indicia in selected printing positions, together with independent printing control means therefor.

It is another object to provide electrographic page printing apparatus wherein the position in which a character is printed is selected from a group of printing positions each having stationary printing means variably operable to print different characters and all of which may be simultaneously conditioned to print the same character.

It is another object to provide electrographic printing apparatus for printing an array of characters on a displaceable medium in readily controlled selected relationship both transversely and longitudinally of the direction of displacement of the medium.

It is another object to provide electrographic printing apparatus wherein distinct and independently controllable stationary means are provided respectively to set up a condition for the printing of a character in a selected position and to cause the printing of said character in said position.

It is another object to provide electrographic page printing apparatus wherein aligned electrode matrix printing heads are provided for printing a line of text, each variably energizable for character selection and each

associated with an independently energizable means for printing position selection.

Other objects and advantages of the invention are brought out in the following specification, to be considered in connection with the appended drawings in which:

Fig. 1 is an end elevation of an electrographic printer, in simplified form, illustrating basic features of such apparatus;

Fig. 2 is a perspective view, with added electrical features, of an electrographic page printer in accordance with the principles of the invention and conforming, generally, to the arrangement of Fig. 1 but omitting certain portions thereof, wherein a single row of pin-type printing electrodes is employed;

Fig. 3 illustrates a modification of the printing circuit of Fig. 1, in schematic form;

Fig. 4 illustrates another modification of the printing circuit of Fig. 1, also in schematic form;

Fig. 5 is a schematic diagram of a pin electrode driver circuit;

Fig. 6 is a series of wave diagrams, for purposes of explanation;

Fig. 7 is a perspective view, with added electrical features, of a modification of the printer of Fig. 1, in which a row of matrix-type printing heads is employed;

Fig. 8 is a perspective view of one of the printing heads of Fig. 7;

Fig. 9 is an end view, to an enlarged scale, of the head of Fig. 8, with indications of energized electrodes therein;

Fig. 10 shows a portion of a circuit for an electrographic page printer, in block diagram form;

Fig. 11 shows a driver circuit for interconnected pin electrodes in a plurality of matrix printing heads;

Fig. 12 is a schematic diagram showing in detail certain features of the circuit of Fig. 10; and

Fig. 13 is a circuit diagram including an electron beam switching tube.

In the operation of all modifications of the invention disclosed by way of illustration herein, printing of a latent electrostatic image on a charge-retentive record medium occurs when a suitable difference of potential is produced between a pair of mutually insulated and spaced electrode means (individual electrodes or electrode assemblies) relatively positioned for charging the medium. In most instances printing results from the application of independently controlled voltage pulses, in coincidence, to these two electrode means. One means of the pair, however, may, under certain conditions, be held at a constant potential as the other is pulsed.

In one modification the paired electrode means above referred to may comprise on one side of a displaceable record sheet or continuous web either a single pin-shaped electrode selectable for energization from a line of such electrodes extending laterally across the sheet or a combination of such electrodes selectable for energization from the electrode matrix of a matrix-type printing head (which may itself be an element of a line of such heads) with the other electrode means of the pair constituted by a base electrode or "anvil" on the opposite side of the sheet and commonly opposed to all printing electrodes.

In another arrangement, instead of an anvil common to a complete line of pin electrodes or of matrix printing heads, either individual anvils for the several printing electrode means (whether individual pins or combinations of pins) or anvils common to groups of such means of less than printing line length are provided.

Both of the above electrode arrangements are operated according to the coincident voltage method of energization. In this method the anvil, instead of being held at a constant potential, as has previously been done, receives a voltage pulse which, added to a voltage pulse of less than printing value applied to the opposed printing electrode means makes up the necessary total printing voltage.

This pulsing of the anvils provides a second control, or second degree of freedom, permitting character printing position selection to be independent of the selection of the particular character printed, which is determined by the pulses applied to the printing electrodes. This makes possible a wide variety of arrangements for line-by-line printing of alphanumeric characters, of graphs, etc., certain of which are described below.

Referring, now, to the drawings, Fig. 1 shows in simplified form a system embodying basic features of the electrographic printing process. In this figure there is seen a supply roll 11 and a take-up roll 13 between which a recording medium or web 15 is transported (by means not shown in this figure) either continuously or in steps corresponding to a desired spacing of successive lines of the printed material. At station 17 any previously accumulated electrostatic charge on the record surface of the unprinted web is discharged, as by corona means 19, such means being commercially available. At printing station 21 this charge-free surface receives a patterned electrostatic charge constituting a latent image of the indicia later to be made visible. For this purpose there are provided at station 21 electrode assemblies which may be of various types, as illustrated in other figures and described in detail hereinafter. At inking station 23 web 15 passes through a receptacle containing finely divided pigmented inking powder 25, the powder adhering to the charged areas by electrostatic attraction. The inked image is rendered permanent upon the passage of web 15 past heating means 27, which partially softens either the inking powder or the record surface of web 15, or both, depending on which of these elements comprises material having thermoplastic properties. Passage between pressure rolls 29 ensures permanent adhesion of the ink particles to the medium, upon re-hardening of the softened material. After printing, web 15 which may be of page width, may be severed, if desired, to provide separate pages of printed material.

Fig. 2 shows an electrographic printer, according to the invention, for printing alphanumeric characters, plotting graphs, etc., including means, here illustrated as motor 30 for transporting continuous recording web 15. In particular, an arrangement of electrodes and associated apparatus is shown at printing station 21 in which a single row of spaced and mutually insulated pin-type printing electrodes 31 is provided, the electrodes having aligned discharge surfaces which are positioned closely adjacent the record surface of web 15. If this web has a paper base, the record surface may be constituted by a polyethylene coating, for example, which has both charge-retentive and thermoplastic properties. The mutual spacing of pins 31, laterally of the web, may be very small, of the order of 0.020 inch, to provide high resolution and an appearance of continuous lines, instead of recognition of the individual dots printed by the electrodes, in the visible image, here illustrated (with exaggerated spacing of the dots) at the left of web 15 as a graph and at the right as assemblies of dots forming the letter "T," in two reading positions. Instead of projecting beyond the surface of insulating support 33, as shown in Fig. 2 for clarity of illustration, the pin electrodes may be flush therewith. The spacing of the discharge surfaces of the pins from the record surface will usually range from less than a thousandth to a few thousandths of an inch. Actual contact with this surface, however, is not excluded.

On the opposite side of web 15 and having an electrode surface normally in contact with the non-record surface thereof there is positioned a base electrode or anvil 35 which, in the arrangement of Fig. 2 is common to all electrodes 31. Anvil 35 preferably is insulated from the frame of the apparatus for the application of a potential thereto differing from ground or reference potential. Printing occurs when a sufficient total difference of potential exists between anvil 35 and one or more electrodes

31, as a result of coincident voltage pulses applied to these opposed electrode means by suitable drivers 37 and 39, respectively, to produce a silent, non-arc ionizing discharge causing the record surface of web 15 to acquire an electrostatic charge over areas roughly corresponding to the discharge surfaces of the active printing electrodes. It has been found that, under given conditions, there is a minimum value for this difference in potential which must be equalled or exceeded to insure reliable printing, that is, to produce charges which are of sufficient strength to result in later satisfactory inking. This minimum value depends on the size and shape of the printing electrodes, the condition of the discharge surface, the atmosphere in which the discharge occurs, the record surface, and other factors. A representative value for discharges from pin electrodes of the above mentioned size and with the above mentioned spacing from the medium, may be around 1000 volts.

The relative voltage values involved in the coincident voltage method of printing are illustrated in Fig. 6 in each of the three wave diagrams of which the same assumed value of minimum printing voltage is represented by the position, above a base line, of a broken line designated E_{min} . In printing, a voltage pulse of lesser amplitude than E_{min} is applied to anvil 35, (top line of Fig. 6), as by driver circuit 37 (Fig. 2), and a voltage pulse, also of lesser amplitude than E_{min} is applied to one or more of printing electrodes 31 (middle line), as by individual driver circuits 39. These two pulses are polarized to be additive in producing a difference in potential between the active electrodes 31 and anvil 35 and their sum exceeds E_{min} , so that when they are coexistent for a sufficient interval, of the order of a microsecond or less, printing of the latent electrostatic image occurs. This is illustrated on the bottom line of the figure.

The diagrams of Fig. 6 are for the purpose of illustrating the addition of pulse amplitudes, only, without implying the directions of departure of the pulses from ground or other reference potential. It is sometimes desirable, for more precise control of the time of printing, to condition the apparatus for printing by the application of one of the necessary two pulses in advance of the other, actual printing then occurring with the advent of the second pulse. Prolongation of the first pulse beyond the occurrence of the trailing edge of the second pulse also may be desirable. These features are illustrated in the diagram on the bottom line of Fig. 6. Except for considerations applying to a particular design, it is immaterial which element, printing electrode or anvil, receives the first or the prolonged pulse.

In certain previously disclosed electrographic printing systems, for example as described in aforesaid patent application Serial No. 443,646, the anvil is maintained at a constant reference potential, usually so-called "ground" potential, and a constant bias relative thereto, less than the minimum printing voltage, is applied to the printing electrodes. An incremental voltage, to raise the total voltage above this minimum, is then applied to the printing electrodes for printing purposes. Since the bias in these systems is a steadily applied voltage and since both bias and the printing pulse are applied to the same electrode such a system is not as flexible in the matter of printing control as the two-pulse, two-electrode system of the present invention, which has other advantages over a bias system of operation later to be referred to herein.

When the apparatus of the invention is used for plotting the values of variable data, as a curve made up of discrete dots, seen in Fig. 2 at the left of web 15 (the individual dots in this case being the printed "characters"), data quantizing means will precede drivers 39 to select the leads 40 to be energized to supply energization to pin electrodes 31 in positions laterally of web 15 respectively corresponding to the data values to be plotted.

Fig. 5 shows one form of driver circuit 39 which may be used to supply a relatively high voltage pulse (say,

500 volts) to one or more pin electrodes in parallel. In this circuit low voltage control is exercised by way of the grid of triode 41, to vary the impedance of and hence the current passed by that device, while voltage step-up occurs by way of plate circuit transformer 43. Similar circuit means may be employed for anvil driver 37.

Two modifications of the electrode arrangement and associated circuitry of Fig. 2 are shown, schematically, in Figs. 3 and 4, respectively. In Fig. 3 individual anvils 45 cooperate with pin electrodes 31, respectively, each anvil having its own driver 37. In addition there are shown in this figure, in block form, pin selection circuits 47 and anvil selection circuits 49, the former circuit also being applicable to the arrangement of Fig. 2, preferably ahead of drivers 39. These are switching circuits which may take various known forms.

While the electrode arrangement of Fig. 2 provides two choices of printing procedure, (a) printing from a sequence of individual pins 31 by repeated excitation of common anvil 35 (series printing) or (b) printing from a plurality of pins 31 simultaneously, with a single pulse applied to anvil 35 (parallel printing), the arrangement of Fig. 3 provides further choices including, (c) simultaneous excitation of a plurality of one type of electrode means (pins or anvils) with control over the positions and the sequence in which printing occurs (selective printing) through control of the excitation of the other type of electrode means (anvils or pins). For instance, employing the timing of the pulses shown in Fig. 6, anvil voltage initially may be applied to any selected group of anvils 45 in consecutive or non-consecutive positions in the line of anvils. Control of the application of printing electrode voltage then affords control of the printed image both as to position laterally of web 15 and as to time of formation. The latter feature, in conjunction with transport of the web, continuous or line-by-line, affords control of the position of the image longitudinally of the web. It will be apparent, therefore, that through the appropriate operation of selector circuits 47 and 49 great flexibility in the printing of sequences and combinations of dots, and of the more complex characters formed thereby, can be attained.

The circuit of Fig. 4 represents an arrangement whereby a considerable decrease in the number of driver-circuits (with respect to the arrangement of Fig. 3) can be attained without undue sacrifice in flexibility of operation. In this case anvils 55 each are common to a group of printing electrodes 31, thereby effecting one portion of the saving in driver circuits. In addition, the printing electrodes in like-numbered positions in each group thereof are connected together for excitation from a common driver, thus effecting a second saving in driver circuits. Fig. 4 illustrates a circuit for printing a line of text having sixteen character positions making use of four groups of four pin electrodes each, with a single anvil for each group. Therefore, only four pin driver circuits, each exciting four pins, and four anvil driver circuits are required, a total of eight such circuits as compared to thirty-two in the case of apparatus of similar printing capacity employing the connections of Fig. 3. The saving in drivers becomes greater as the number of printing positions in a line increases. Assuming, for simplicity, that n , the number of printing positions in a line, is a perfect square and that the pin group served by a single anvil includes $\sqrt{n}$ pins; then the total number of drivers becomes $2\sqrt{n}$, as compared to $2n$ in the case of the individual drivers of Fig. 3. Since voltage pulses, only, are supplied, with relatively little power, the advantage of the saving in driver circuits more than offsets the disadvantage of the greater number of elements excited by each such circuit.

In Fig. 4 the pin and anvil selection means 56 and 56', respectively (corresponding in part to circuits 47 and 49 of Fig. 3), are shown as electron beam switching

tubes of the type disclosed in U.S. Patent No. 2,764,711, issued September 25, 1956, to Saul Kuchinsky, wherein a cathode-formed electron beam is switched between a plurality of target electrodes 57 under the control of switching electrodes 58, individual to the several beam positions. Switching times of the order of a fraction of a microsecond are attainable with these tubes. In the figure, for simplicity, the means supplying positive voltages to targets 57 and to beam forming electrodes 54 (so-called "spades" represented in Fig. 13) are omitted. A more detailed showing of such a tube having four beam positions, and of associated circuitry, is to be found in Fig. 13. A commercial form of beam switching tube suitable for use in the present circuit is manufactured by the Electronic Tube Division of Burroughs Corporation, Plainfield, N.J.

In the more detailed switching circuit of Fig. 13 beam switching electrodes 58 are shown connected in alternation to a pair of ring busses 59, 59' which may be pulsed in repeated sequence by the output of a flip-flop 60. As described in U.S. Patent No. 2,721,955, issued October 25, 1955, also relating to beam switching tubes of the type illustrated herein, this results in the electron beam of the tube being rotated intermittently to energize and complete the circuit of targets 57 in turn. Output pulses may be developed as the voltage drop across external target circuit impedances, such as impedance 61-1. When switching according to the positional sequence of the targets is not desired, the beam switching electrodes 58 may be selectively energized in random sequence, as suggested by independent anvil switching leads 62, two, only, of which are shown in Fig. 4, the switching beam being capable of jumping from one stable position to a non-adjacent position.

As previously described and as more particularly illustrated in Fig. 2, the elemental dots printed from a row of pin electrodes in the operation of any of the foregoing arrangements may be grouped to form more complex characters, including letters and numerals, as well as dotted lines such as graphs of data, by suitable excitation of the pins with respect to their positions and to time. An arrangement often requiring less circuitry, particularly for printing alphanumeric characters, is shown in Fig. 7 wherein instead of a row of single electrodes a row of printing heads 67 is provided each head comprising a matrix of pin-type electrodes. A perspective view of one type of printing head 67 is shown in Fig. 8. This particular type of head comprises a plastic encapsulated assembly of thirty-five pin-type printing electrodes 69 arranged in a 5 x 7 matrix, the individual electrodes of which may be simultaneously excited in combinations suitable to print desired complex characters. For instance, electrodes 69E are ringed in the enlarged end view of head 67 in Fig. 9 to indicate that these would be excited in this design of head, to print the letter "T." The pin spacing in one form of head extensively used is 0.017 inch in each direction, the pins being 0.003 inch in diameter. This permits the printing of alphanumeric characters of approximately upper case typewriter size. Further details of printing heads suitable for use in the present apparatus, and to methods of manufacture thereof, are to be found in co-pending patent applications of Cecil R. Joyce, Serial Nos. 609, 431, 631,194, and 631,211, filed September 12, 1956, September 28, 1956, and September 28, 1956, respectively, assigned to the same assignee as this patent application. Individual connecting wires 71 are provided for external interconnection of the pins, which may be grouped in a cable 73. Common anvil 75 of Fig. 7 has a dimension in the direction of the travel of web 15 commensurate with the corresponding dimension of heads 67 and is driven or pulsed, as in Fig. 2, by a driver circuit 37.

The energization or excitation of the electrodes of the matrix of a head 67 to print a letter, etc. includes a selection of the desired character or the generation of a

signal characteristic thereof, the encoding of this character or character signal as a group of pulses suitable for energizing the matrix electrodes and the application of these latter pulses to the appropriate electrodes of a selected printing head. In Fig. 7 the means for performing these several functions are grouped as character pulse circuits 77. Details of circuits suitable for selecting and encoding characters in connection with electrographic printing with pin electrode matrix heads are to be found in previously cited application Serial No. 443,646. In addition to single character printing, the simultaneous excitation of a plurality of heads according to the same or different characters and the printing of these characters upon the occurrence of a single anvil pulse, which may be termed "parallel matrix head printing," is feasible with the arrangement of Fig. 7 and is comparable to parallel printing with the single row of pins of Fig. 2.

Still greater flexibility and speed of operation, with simpler control over the format of the printed matter, is attained by the use of an individual anvil for, or associated with, each of the printing heads 67, instead of a single anvil common to all of the printing heads. Fig. 10 illustrates such an arrangement, employing individual anvils 85. This figure shows, in block diagram form, a character signal source 87, which may be a computer, a storage device, or other means for supplying data to be printed, the data being assumed for purposes of the following description to be printed as alpha-numeric characters. Read-out of a character signal from source 87 is accomplished by circuit 89. This circuit, which may comprise any of various known gating arrangements, is shown in the figure as being controlled by pulses derived from timing pulses 91 supplied by Master Pulse Generator 92, by way of delay circuit 93. Instead of control by a pulse from an independent master generator, read-out of a character signal or signals from circuit 87 may be under the control of a pulse generated at the termination of the printing of the previous character or combination of characters (by means not shown).

A character signal read from source 87 is suitably encoded for matrix head excitation by circuit 95 (reference again being made in this connection to application Serial No. 443,646) to supply pulses by way of driver circuits 39 to the conductors of cable 97 connecting, with the appropriate printing electrodes in the matrices of selected ones of heads 67. When the desired mode of operation calls for the simultaneous excitation of all printing heads 67 in a line of heads according to the same character, with independent selection of the position or positions in which this common character is printed, as will be considered at this point, the connections of Fig. 11 are suitable, wherein pins 69 in corresponding positions in all heads 67 are interconnected in parallel to a pulse driver 39 (three of the thirty-five such connections only, being shown). When the selected character excitation (in itself ineffective to cause printing) is impressed on all of heads 67 by voltage pulses which are applied to the pin electrodes necessary to print the selected character, the position or positions, transverse of web 15, in which the character is printed or established, and the sequence in which such printing occurs, where this is of significance, is determined, as before, by the anvil or anvils to which the anvil pulses are applied.

A pulse 91 from Master Pulse Generator 92, or its equivalent, in addition to initiating the read-out of a character signal from source 87 is supplied to a Sequence Selector 103 by way of lead 105. This selector is a switching device which is operated by Format Control 107 to select, at the start of printing a line of text, the positions and the sequence of positions, such as one after another, or serially, in which printing is to occur in that line. Different pre-set printing sequences are provided by multi-position switches 109 in Sequence Circuit 111,

of which switches 109A and 109B are seen in the detailed showing of that circuit in Fig. 12.

Format Control 107, in one mode of operation, senses (by means not shown) the beginning of a line of text as defined by the operation of an intermittent paper feed which advances web 15 in accordance with the spacing of the lines of the text, as mentioned hereinbefore. Such an intermittent web feed has been disclosed in copending patent application Serial No. 503,714, filed April 25, 1955. Master Pulse Generator 92 normally is synchronized (at a sub-multiple frequency) with the operation of such paper feeding means.

Format Control 107, according to a pre-set program thereof, sets up a path by way of the switching means comprised by Sequence Selector 103 whereby the versions of pulses 91 arriving at said selector over lead 105' during the printing of an entire line of text are applied to a particular switch 109, for example switch 109A, in Sequence Circuit 111. In the printing of such a line, operation of this switch, which has stationary contacts equal in number to the number of printing positions in the line, distributes the pulses to the anvils 85 connected to the respective contacts thereof.

Fig. 12 shows an arrangement for Sequence Circuit 111 which is suitable for line-by-line printing at moderate speeds. Switches 109 are commonly driven by stepping magnet 113 which is actuated, by way of a branch of lead 105, by versions of the same pulses 91 which control the printing and printing position selection operations. In this case the pulses are delayed by circuit 117, as referred to below. When the received pulses of themselves are ineffective to operate magnet 113 directly, amplification may be employed.

Tracing the functions of a master pulse 91 in controlling the operation of the apparatus, the leading edge of such a pulse first triggers timing circuit 120 (Fig. 12, employed, as explained, when it is desirable for the pin and anvil pulses to have slightly different but overlapping periods) to generate the leading edge of an anvil excitation pulse (Fig. 6); then by way of lead 90 a version of the pulse, delayed by circuit 93, initiates and terminates read-out, by circuit 89, of a character signal from circuit 87, thereby determining the leading and trailing edges of the encoded character pulses applied to the appropriate pin electrodes of a printing head or heads. It is assumed in this description that the signal available from source 87 is of suitable duration for the foregoing mode of operation.

Some time after the occurrence of the trailing edges of the character-encoded printing head pulses, timing circuit 120 terminates the anvil pulse (Fig. 6). Subsequently, the original pulse 91, delayed by circuit 117 (Fig. 12) causes the operation of stepping magnet 113. Operation of switches 109 to new positions by this magnet occurs later than the occurrence of the leading edge of the delayed, magnet-operating version of pulse 91, due to the inertia of the armature of magnet 113 and associated driven members. Stepping switches having operating rates suitable for many printing applications are commercially available. Magnet 113 having stepped the currently active switch 109 (switch 109A) to its next position, the apparatus is in condition to print the next character.

Operation of switch 109A causes the excitation of selected anvils 85, in turn, i.e., in sequence, according to one arrangement of characters in a line of printing, by way of leads 114 and individual anvil driver circuits 115, with which leads 114 connect, while switch 109B provides a means for exciting anvils 85 to print a different arrangement of characters in a line, by way of leads 118 and drivers 115. Consecutive contacts on switches 109, which determine the positions of successively printed characters in a line, need not correspond to anvils 85 in consecutive positions in the line. Thus, with a suitable number of suitably connected switches 109 to provide

selected arrangements of characters in a line of text and with the programming of these different arrangements by Format Control 107 (operating by way of Sequence Selector 103), any desired distribution of characters on a page or along a continuous web may be attained. The term "character" here may be taken in its broad sense, previously mentioned, to include a single dot. In place of mechanically operated switches 109, equivalent high speed electronic switching means are available, for example, the electron beam switching tubes previously described.

As illustrations of different arrangements of characters in a line of text which can be printed by the means of Fig. 10, two lines of characters, 119 and 121, are shown in Fig. 7. Line 119 may be considered, for example, to be printed with switch 109A controlling the anvil excitation, by way of leads 114, while leads 118 from switch 109B may provide the connections for printing line 121. It will be noted that the letter "T" occurs twice in line 121 and that lead 118B (Fig. 12) is shown branched to provide for the simultaneous excitation of the anvils in the two positions in which this letter is printed, all heads 67 at the instant of printing being excited to print a "T."

Throughout this specification mention has been made of the printing of dots from pin-shaped electrodes. While the production of a dot-shaped charged area on the recording medium might, at first sight, appear to follow automatically from the form of the discharge surface of such an electrode, in practice, under certain conditions, it has been found desirable, in order to secure good definition and to limit the spreading of the charged areas, to cause the printing discharge to occur in a specially prepared atmosphere, specifically one comprising an electronegative gas. This feature of electrographic printing is disclosed in co-pending application Serial No. 478,602, filed December 30, 1954, in the names of F. Innes, H. Epstein and R. Phelps, which is assigned to the assignee of the present application.

Mention has been made hereinbefore of systems in which a constant bias, supplemented by a print pulse for printing control, is applied to the printing electrodes, only, the anvil being held at ground or reference potential. This is in contrast to the division of the total printing voltage into two pulses which have so far been described herein as being separately applied to a printing electrode and anvil. In addition to greater flexibility, the independent pulsing of printing electrode and anvil has the advantage that the peak value of the switched pulses is lower with respect to ground than in the constant bias circuit and also that there is, under certain conditions, a reduction in complexity of the associated circuitry.

Certain of these advantages also may be realized in a system in which the total printing voltage is the resultant of two coincident pulses which are applied to the same instead of to different electrodes, for example pulses of similar polarity applied to the printing electrodes while the anvil is held at a constant potential. Control of the occurrence of either pulse can, in such a system, be employed to control printing.

While various embodiments and modifications of the invention have been described in the foregoing specification and illustrated in the drawings, the invention is not to be considered as limited thereto. The limits of the invention are defined solely in the appended claims.

What is claimed is:

1. In printing apparatus, a pair of stationary mutually insulated electrode means having closely spaced opposed surfaces defining a gap; an electrical charge retentive recording medium; means for mounting the recording medium in said gap; first means for applying separate pulses of predetermined amplitudes and polarities to said pair of electrode means, the amplitude of each of the separate pulses, when occurring alone, being insufficient to estab-

lish an electrically charged area on the recording medium in the gap; and second means for causing said first means to apply said pulses so that for a period of time they are in coincidence, the amplitude and the polarity of said pulses being such that when they occur in coincidence an electrically charged area is established on the recording medium.

2. In electrostatic printing apparatus the combination of an assembly of mutually insulated pin electrodes having end discharge surfaces in surface alignment, cooperative anvil electrode means insulated therefrom, respective portions of said anvil electrode means providing an electrode surface opposed to and similarly closely spaced from each of said pin electrode discharge surfaces, a printing medium capable of receiving and retaining electrostatic charge patterns, means for transporting said medium between said spaced pin electrodes and anvil electrode means, and means for producing silent non-arcing discharges between said pin electrodes and the portions of said anvil electrode means respectively opposed thereto, thereby to print electrostatic charge patterns on said medium, including means for applying voltage pulses each of less than printing value in independently controllable time relationship respectively to selected ones of said pin electrodes and to said anvil electrode means, coincidence of a pulse on a pin electrode and an opposed portion of said anvil electrode means producing a total voltage of printing value therebetween.

3. The combination defined in claim 2 wherein the portions of said anvil electrode means respectively opposed to said pin electrode discharge surfaces are electrically interconnected.

4. In printing apparatus, a pair of stationary mutually insulated electrode means having closely spaced opposed surfaces defining a gap; an electrical charge retentive recording medium; means for mounting the recording medium in the gap; first circuit means for applying a first type voltage pulse of predetermined amplitude and polarity to one of said pair of electrode means; second circuit means for applying a second voltage pulse of predetermined amplitude and of a polarity opposite to that of the first type voltage pulse to the other of said pair of electrode means; the amplitude of the first type voltage pulse and the amplitude of the second type voltage pulse alone being insufficient to establish an electrically charged area on the recording medium in the gap; and third circuit means connected to said first and second circuit means and operable to cause the same to produce first and second type voltage pulses in coincidence, the amplitudes of said first and second type pulses in coincidence being such as to establish an electrically charged area on the recording medium in the gap.

5. In electrographic printing apparatus: the combination of an assembly of a plurality of mutually insulated electrodes having end discharge surfaces in surface alignment; a cooperative anvil electrode common to said assembly of insulated electrodes and spaced therefrom to define a gap; a printing medium capable of receiving and retaining electrical charges; means for transporting the medium into the gap between the assembly of insulated electrodes and the anvil electrode; a plurality of electrode pulse drivers for producing electrode voltage pulses; circuit means connecting said plurality of electrode pulse drivers respectively to each of said mutually insulated electrodes of said assembly; an anvil pulse driver for producing anvil voltage pulses, circuit means connecting the anvil pulse driver to the anvil electrode; the amplitude of the anvil voltage pulses and of the electrode voltage pulses, when not occurring in time coincidence, being insufficient to establish electrically charged areas on the printing medium in the gap; and means for causing selected ones of said plurality of electrode pulse drivers to produce voltage pulses and for simultaneously causing said anvil pulse driver to produce an anvil pulse; the amplitudes and the polarities of the electrode voltage

pulses and the amplitude of the anvil voltage pulse together establishing electrical fields in the gap sufficient to electrically charge areas on the printing medium in the gap, the positions of said charged areas of the printing medium corresponding to the electrodes of the assembly to which electrode voltage pulses are applied.

6. In electrographic printing apparatus; the combination of an assembly of similar mutually insulated pin type electrodes having end discharge surfaces in surface alignment; a cooperative anvil electrode common to said assembly of pin type electrodes and spaced therefrom to define a gap; a printing medium capable of receiving and retaining electrical charges; means for transporting the printing medium into the gap between the assembly of pin type electrodes and the anvil electrode; electrical pulse driving means for producing voltage pulses for the pin type electrodes; electrical pulse driving means for producing voltage pulses for the anvil electrode; circuit means for connecting the anvil pulse driving means to the anvil electrode; circuit control means for selecting certain of said pin type electrodes and for applying electrode voltage pulses to such selected electrodes of the assembly; the amplitudes of the voltages produced by the anvil pulse driving means and the pin type electrode pulse driving means, when not occurring in coincidence, being insufficient to establish electrically charged areas on the printing medium in the gap; circuit means for causing the electrode pulse driving means and the anvil pulse driving means to produce their respective voltage pulses simultaneously; the amplitudes and polarities of the voltage pulses in coincidence establishing electrical fields in the gap sufficient to electrically charge areas of the printing medium in the gap, the positions of said charged areas on the printing medium corresponding to the electrodes of the assembly to which electrode pulses are applied.

7. In high speed electrostatic printing apparatus, the combination of, a plurality of similar stationary printing electrodes having the discharge areas thereof in surface alignment, said printing electrodes being arranged in a row with each electrode representing a printing position, anvil electrode means having portions thereof respectively opposed to said printing electrodes and similarly spaced from said discharge areas thereof to define a gap therebetween for the reception of a charge retentive recording medium, the operating relationship of each printing electrode and the anvil electrode means being such that when an electrical field is established therebetween by a difference in potential exceeding a critical value, an electrostatic charge is produced on the charge retentive medium interposed therebetween, means for generating two series of voltage pulses, the pulses of each series having an amplitude corresponding to a difference in potential less than said critical value, means controlling the relative occurrences of pulses respectively comprised by said two series to produce coincidence thereof, and connected to the pulse generating means for distributing such coinciding pulses in a given sequence to the electrodes of the printing position to thereby create a difference in potential between selected ones of said printing electrodes and the portions of said anvil electrode means respectively opposed thereto, said difference in potential exceeding said critical value thereof when due to coincident pulses of said two series and producing an electrostatic charged pattern on the charge retentive medium.

8. The combination defined in claim 7 wherein the portions of said anvil electrode means respectively opposed to said printing electrodes are electrically insulated one from another for selective excitation thereof by way of one of said individual pulse-utilizing circuit means.

9. In electrostatic printing apparatus the combination of a plurality of similar groups of mutually insulated pin-type printing electrodes, individual anvil electrode means for each of said groups commonly opposed to and spaced from the printing electrodes thereof, the spacing of all said electrode groups and respectively opposed anvil elec-

trode means providing a gap for the reception of a charge retentive record medium, means for creating a difference in potential exceeding a predetermined critical value between a selected combination of printing electrodes of a group and the opposed anvil electrode means, including means for generating and applying a pulse of less than said critical value simultaneously to a similar combination of printing electrodes in each of said groups, and means for applying a pulse likewise of less than said critical value to one of said anvil electrode means in coincidence with said first pulse.

10. In electrostatic printing apparatus the combination of a linear array of printing heads each comprising a matrix of pin-type printing electrodes; a similar array of anvil electrodes respectively cooperative with said heads for electrostatically printing characters on a charge-retentive medium positioned intermediate said heads and anvils; a source of character signals; means for encoding a character signal from said source in suitable form for energizing the electrodes of one of said heads according to a spatial pattern thereof adapted to the printing of said character, means for distributing signals thus encoded to selected ones of said heads, said encoded signals of themselves being ineffective to cause printing, a source of signals for energizing said anvils, of themselves ineffective to cause printing; and means for distributing said anvil signals to anvils respectively cooperative with said selected heads to produce coincident excitation of a head and an anvil cooperative therewith, said coincident excitation resulting in the printing of the character represented by said first signal as an assembly of spaced dot-shaped charged areas of said medium.

11. The combination defined in claim 10 wherein said means for distributing at least one of said coincident signals comprises pre-set means operable to determine the heads of said array from which characters are printed and the sequence in which they are printed.

12. The combination defined in claim 11 wherein said pre-set means comprises a plurality of electrode signal switching means together with programming means for selectively activating one of said switching means at a time.

13. In electrostatic page printing apparatus the combination of a displaceable medium in the form of a continuous web having a surface capable of receiving and retaining electrostatic charge patterns, means for displacing said medium, a row of spaced electrostatically operable printing heads extending transversely of the direction of said displacement each comprising a matrix of pin electrodes having aligned and discharge surfaces closely spaced and at like distance from said surface of the medium, other electrodes adjacent the opposite side of said medium respectively associated with said heads each providing a common opposed electrode surface in closely spaced relationship to the pin electrodes of the opposite head, means for applying first-type voltage pulses of like character to common selected pin electrodes of one of said printing heads in said row, means for simultaneously applying said pulses to corresponding electrodes of other of said heads in said row, means for applying second-type voltage pulses to selected ones of said other electrodes in selected combinations and in selected time sequences, and means timing the application of said first-type and second-type voltage pulses, coincidence of at least portions of a first-type and a second-type voltage pulse on a printing electrode and opposed other electrode being requisite to print an electrostatic image on the medium.

14. In electrostatic page printing apparatus the combination of a displaceable charge-retentive medium of substantially page width; a linear array of uniformly spaced stationary printing heads extending laterally of said medium and defining a plurality of printing positions in a line of text, each such head comprising a matrix of pin-type printing electrodes; a linear array of a like number of anvil electrodes respectively cooperative with said heads

for electrostatically printing characters on said medium; means for longitudinally advancing said medium between said heads and anvils in intermittent manner according to the spacing of the lines of text to be printed; means for energizing electrodes in a selected number of said heads to print the same character from each as an assembly of dot-shaped electrostatic charges on said medium; and independent means for energizing the anvils associated with a selected number of the thus energized heads, coincident energization of a head and associated anvil being required for the actual printing a character; and independent means actuated synchronously with said intermittent advancement of the medium for revising the selection of the energized heads and anvils.

15. In printing apparatus, the combination of a plurality of mutually insulated first type electrode means, said first type electrode means being arranged into separate and distinct groups; second type electrode means; first circuit means for producing first type electrical pulses; circuit means for applying first type pulses to selected ones of the first type electrodes in each of said groups, the first type electrodes energized in each group having corresponding locations within each of the groups; second circuit means for producing second type electrical pulses in coincidence with the said first type pulses; a recording medium adjacent to said first and second electrode means; circuit means for applying said second type pulses to increase the electrical potential of all the first type of electrodes of a selected one of said groups with respect to said second type electrode means, the coincidence of said second type pulses with the first type pulses on selected ones of said first electrodes establishing detectable areas on the recording medium, the location of said detectable areas corresponding to the location of the first type electrodes to which the first type pulses are applied in said selected one of said groups.

16. In printing apparatus, the combination of a plurality of mutually insulated first type electrode means, said first type electrode means being arranged into separate and distinct groups, a plurality of mutually insulated second type electrode means, one of said second type electrode means being associated with each of said groups, by being substantially uniformly spaced from the first type electrode of each of said groups, means for electrically energizing selected ones of the first type electrodes in each of said groups, the first type electrodes energized in each group being in corresponding locations within the groups, means for selectively energizing in coincidence with the energization of said first type electrode means selected ones of said second type electrodes; a recording medium adjacent to said first and second electrode means, the selective energization of the second electrode means associated with one or more of said groups simultaneously with the energization of selected ones of the first type electrode means of all the groups establishing detectable areas on the recording medium, the location of said detectable areas corresponding to the location of the energized first type electrodes in the groups whose associated second type electrodes are energized.

17. Printing apparatus comprising a plurality of matrix print heads, each print head being comprised of a plurality of first type electrode means arranged in an array, a plurality of first type pulse drivers which when energized produce first type pulses, one first type pulse driver being connected respectively in parallel to the first type electrode occupying corresponding positions in each matrix print head; a plurality of second type electrode means, one of said second type electrode means being associated with each of said matrix print heads, second type pulse drivers, which when energized produce second-type pulses; circuit means for applying a second type pulse sequentially and one at a time to the second electrode means associated with the print heads, a recording medium mounted adjacent to said print heads; circuit means for causing selected ones of said first type pulse

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drivers to be energized to enable each print head to print a given character, the amplitude of the first type pulse alone being insufficient to print said character on the recording medium; circuit means for causing the pulses produced by the selected first type pulse drivers and by the second type pulse drivers to be produced in coincidence, the amplitudes of said first and second type pulses in coincidence being sufficient to establish said character in the form of a detectable image on the recording medium adjacent to the print head to whose associated second type electrode a second type pulse is applied.

18. In recording apparatus the combination comprising a plurality of electrode recording means each including a matrix of mutually insulated pin-type electrodes; means for feeding a recording medium in proximity to the pin-type electrodes of said recording means; means for applying simultaneously to homologously situated pin-type electrodes of all said recording means a first pulse tending to energize same in accordance with a spatial pattern representative of a character to be recorded, the amplitude of said first pulse when occurring alone being insufficient to effect a recording by said pin-type electrodes on said recording medium; and means for applying to a selected recording means a second pulse in coincidence with said first pulse, the amplitude and polarity of said second pulse being such that when occurring in coincidence with said first pulse in the selected electrode recording means the latter produces recorded areas on said recording medium in accordance with the spatial pattern of the pin-type electrodes energized by said first pulse.

19. In recording apparatus the combination comprising a plurality of electrostatic recording means arranged in a spaced linear array, each of said recording means comprising a matrix of mutually insulated pin-type electrodes; means for feeding an electrical charge retentive recording medium in proximity to the pin-type electrodes of said recording means; means for applying simultaneously to homologously situated pin-type electrodes of all said recording means a first pulse tending to energize same in accordance with a spatial pattern representative of a character to be recorded, the amplitude of said first pulse when occurring alone being insufficient to establish electrically charged areas on the recording medium; and means for applying to a selected recording means a second pulse, said second pulse being applied simultaneously with the application of said first pulse and in coincidence with said first pulse, the amplitude and polarity of said second pulse being such that when occurring alone it is insufficient to establish an electrically charged area on the recording medium, but when occurring in coincidence with said first pulse in the selected electrostatic recording means the latter produces electrically charged areas on said recording medium in accordance with the spatial pattern of the pin-type electrodes energized by said first pulse.

20. In recording apparatus the combination of a plurality of electrode recording means each comprising a matrix

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of pin-type electrodes and another electrode cooperative therewith for recording characters on a recording medium positioned in proximity to said plurality of electrode recording means; a source of character signals; means for encoding a character signal from said source in suitable form for energizing the pin-type electrodes of one of said electrode recording means according to a spatial pattern representative of said character; means for distributing signals thus encoded to the pin-type electrodes of a plurality of said electrode recording means, said encoded signals of themselves being ineffective to cause recording on the recording medium; a source of signals for selectively energizing said other electrodes; and means for distributing said last-named signals to at least one of said other electrodes to produce excitation thereof coincident with the excitation of the pin-type electrodes by said encoded signals, said coincident excitation resulting in the recording, from each electrode recording means so excited, of the character represented by said encoded signal as an assembly of dot-shaped recorded areas on said recording medium.

21. In an alpha-numeric page printing apparatus the combination of a plurality of electrode recording means each comprising a matrix of pin-type electrodes and another electrode cooperative therewith for recording characters on a recording medium, said electrode recording means being arranged in a linear array corresponding of a line of printing; means for feeding a recording medium in proximity to said linear array of electrode recording means; a source of character signals; means for encoding each character signal from said source in suitable form for energizing the pin-type electrodes of one of said electrode recording means according to a spatial pattern representative of said character; means for distributing signals thus encoded to homologously situated pin-type electrodes of all of said electrode recording means, said encoded signals of themselves being ineffective to cause recording on the recording medium; and means for applying to said other electrodes of said recording means a further signal of itself ineffective to cause recording by its respective recording means, said further signal being applied to said other electrodes in consecutive sequence with each distribution of said encoded signals to produce excitation of each of said other electrodes consecutively and in coincidence with the excitation of the pin-type electrodes of its respective recording means, said consecutive coincident excitations resulting in the serial recording from the plurality of electrode means of the characters represented by said encoded signals as assemblies of dot-shaped recorded areas on said recording medium.

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