June 15, 1948. N. B. WALES, JR 2,443,407

GASEOUS DISCHARGE DEVICE

Filed June 18, 1947 2 Sheets-Sheet 1

Fig. 1.

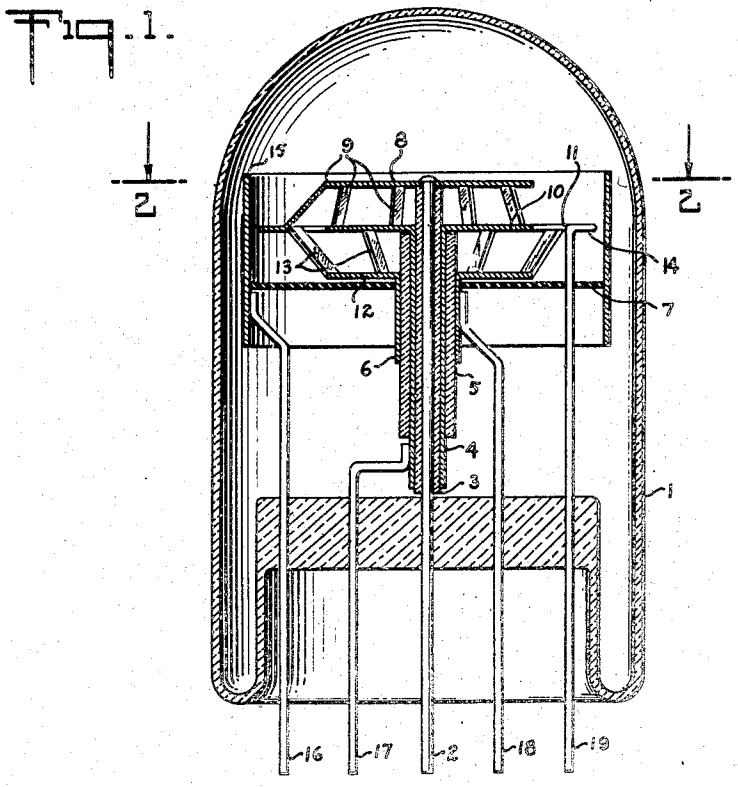
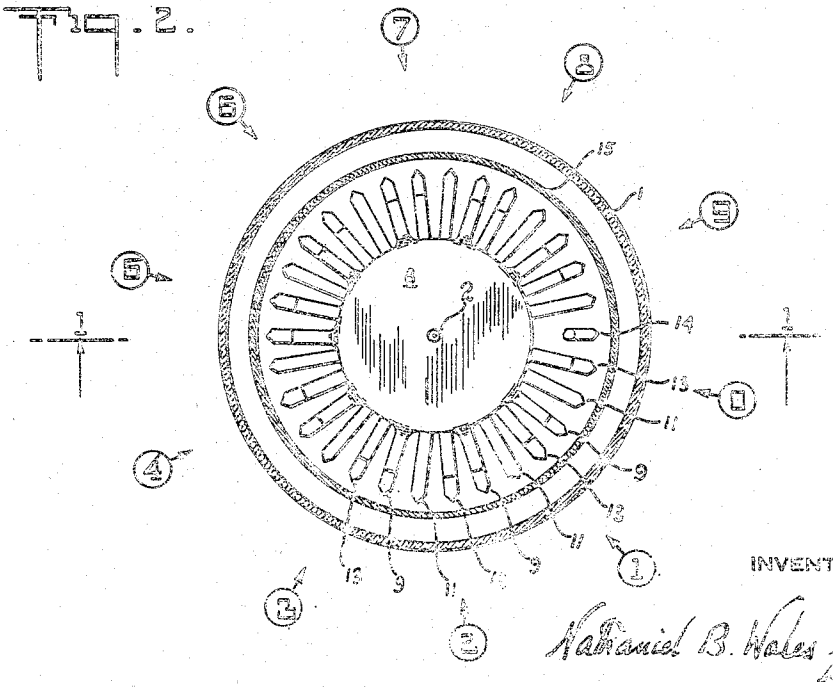


Fig. 2.



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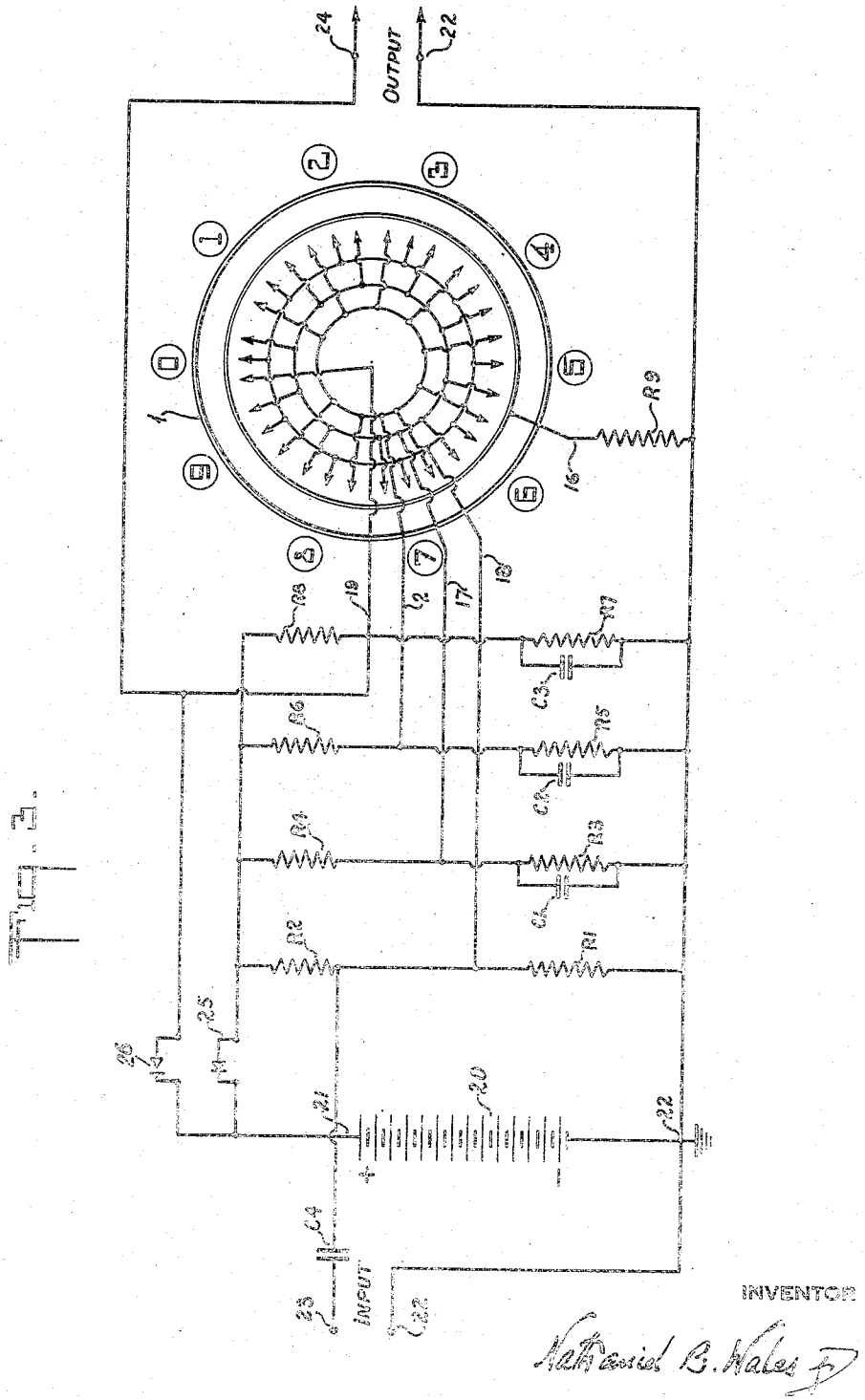


FIG. 2.

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2,443,407

UNITED STATES PATENT OFFICE

2,443,407

GASEOUS DISCHARGE DEVICE

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Application June 18, 1947, Serial No. 755,529

5 Claims. (Cl. 250—27.5)

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This invention relates to a gaseous electric discharge device in which a visible discharge is caused to move progressively between a series of adjacent electrodes in such a way as to comprise a counting or integrating device for electrical impulses impressed on the system.

In the preferred form of my invention I provide a system of three anodes each having a plurality of spaced discharge points so positioned as to form a path of sequentially alternate anodes with respect to a common cathode located parallel to this path, all of these electrodes being supported within a suitable preferably low pressure gaseous discharge atmosphere. Thus, in this form of my invention, when a potential in excess of the breakdown voltage is applied to any one of these anodes relative to the common cathode and through a cathode series load resistor, a visible discharge will take place at one only of the plurality of discharge points for that anode because of the fact that as soon as one discharge is established at a discharge point, its discharge current passing through the series load resistor causes a drop in the anode to cathode potential such that this lowered potential is inadequate to initiate a second discharge at any other point on this anode. It is this mutually exclusive discharge feature which is the basis of the mnemonic integrating characteristics of the system.

My invention provides for the transfer of discharge from one discharge point of the master anode to its next discharge point by causing an input pulse which is to be counted or integrated, first to de-energize the master anode, and then to energize sequentially the other two intervening discharge anodes before re-energizing the master anode, thereby physically transferring the discharge through a definite directed displacement representing one step on the multiple master anode. The reason why the discharge will transfer only to the adjacent discharge point instead of to some arbitrarily remote point of the same adjacent multiple anode, is that the presence of ions in the region surrounding the discharge and persisting even after the exciting voltage for the discharge has been removed, sets up preferential conditions for the re-establishment of a discharge in the neighborhood of the region in which a discharge has just terminated. Thus, if only two multiple alternate anodes were used there would be an ambiguity as to which of the adjacent points would capture the terminating discharge, whereas with three sequentially alternate anode systems there will be a positive directed preference for the discharge to

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move along the electrode path determined by the order of excitation of the anodes adjacent to the master anode.

It is to be noted that my invention will operate equally well using a common anode and three multiple cathodes, or indeed, the same electrode geometry will operate when excitation is supplied by alternating potentials. Further, the path of the alternate discharge points may be closed so as to comprise a cyclic or self-resetting counter, or the path may be linear or non-cyclic with special means provided for resetting. Also, within the principle of my invention, any number of sequentially alternate multiple electrodes above three may be used for special applications where it is desired to separate the possible points of discharge by a greater distance than is possible with three sets of discharge points.

The sequential transfer of excitation between the three multiple electrodes may be made by a switching device or commutator, or by electronic circuit means employing gate tubes for the intermediate electrodes and having resistance-capacitance delay circuits acting to trigger the gates in sequence, or the transfer may be accomplished by my preferred circuit shown in the accompanying drawings. In the latter the transfer is effected by supplying the intermediate electrodes with capacitance stored potentials of progressively lower values than that of the master electrode so that on the momentary removal, by an incoming pulse to be counted, of the master electrode potential the discharge is captured and maintained for a short time by the adjacent electrode until its capacitor is exhausted. This time the second sequential adjacent electrode takes over the discharge thereby bringing the region of discharge to a position adjacent to that master electrode point which is one removed and in the desired direction of displacement from the initial master electrode discharge. On re-excitation of the master electrode the discharge is thus established at this displaced position. In this case the preferential direction of discharge transfer is determined by the direction of descending potential applied to the intervening electrodes, since the higher of the two electrode potentials adjacent to a terminating discharge will capture it, providing, of course, a symmetrical surface condition and geometry obtains.

In the preferred form of my invention I disclose a cyclic closed discharge path provided with a special electrode for resetting the counter to a zero or index position. Means are shown for causing this device to yield an output impulse

each time the discharge passes this index position. Thus a group of such counting tubes connected in cascade so that the successive tubes in the series are caused to count in response to the index output impulses of the preceding stage will comprise a system capable of counting in any number system as determined by the number of discharge points provided on each of the master anodes. In the decimal system each such tube thus comprises a decade counter.

It is to be noted in the art of electronic counting that an electronic decade of either the Eccles-Jordan or thyratron ring type employs a minimum of four to ten tubes together with appreciable associated circuitry, in contradistinction to the single unit simplicity of the present invention in which the register is visibly indicated on a calibrated dial.

In addition, this invention has utility as a frequency divider, such as those used in television synchronization circuits, and as a predetermined limiting counter, such as those used in packaging machinery.

One object of this invention is to provide a simple and visible means for registering the count of rapid or random impulses in any number system.

A second object is to make possible a self resetting visible counter of compact and economical construction.

A third object is to provide an electrical device capable of yielding one output pulse in response to the accumulation of each predetermined number of input impulses.

Other objects are implict in the accompanying specification and claims.

Referring to the drawings:

Fig. 1 is a cross-section through the axis of a preferred form of my invention comprising a gas filled counting decade tube.

Fig. 2 is the section 2—2 of Fig. 1 comprising a plan view of the electrode structure.

Fig. 3 is the schematic wiring diagram of the potential gradient type of transfer circuit used in conjunction with the tube of Fig. 1.

Referring to Figs. 1 and 2, numeral 1 represents a conventional glass tube envelope which has been evacuated, degassed, and then filled with a suitable discharge gas, such as helium, hydrogen, neon or argon, or a combination thereof at a pressure of a few milimeters of mercury. The central electrode support wire 2 passes through and is supported by the press of the envelope 1. The electrode spider 8 comprises a group of nine radial fingers 9 at 36° intervals stamped from a single sheet of metal and doubly bent so that the pointed ends of the discharge fingers 9 lie in a plane displaced below but lying parallel to the central circular hub 8 of the electrode. Spider 8 is centrally secured to and supported by lead wire 2. It is to be noted that the tenth discharge finger of electrode 8 is missing, and that the place which it would occupy is taken by the resetting or index electrode 14.

The mid-electrode spider 10 comprises a flat stamped metal piece having ten radial equispaced pointed discharge fingers 11 which lie in the same plane as the ends of discharge fingers 9 of the upper electrode 8, but spaced therefrom by 12° displacement. Spider 10 is centrally secured to metal sleeve 4 which is supported on and insulated from central wire 2 by the glass sleeve 3. Lead wire 17 is secured to and affords external connection to sleeve 4 and its electrode 10.

The lower electrode spider 12 is similar to spider 8 but has its ten radial equispaced discharge fingers 13 bent upward and outward so that the discharge points lie in the same common plane as electrode points 9 and 11. The points of the electrodes 8, 10, and 12 thus lie on a common circle and, together with the radially bent electrode discharge point 14 of electrode 19 which is supported by the press of envelope 1, form a series of 30 equispaced sequentially alternate discharge electrodes. Electrode 12 is centrally secured to metal sleeve 6 which in turn is insulated from and supported by glass sleeve 5 concentric with and supported on sleeve 4. Lead wire 18 passing through the press of envelope 1 is secured to sleeve 6 and forms external connection to electrode 12.

The common electrode, preferably a cathode, comprises a cylinder of metal 15 supported on lead wire 16 and maintained concentric with the circle of discharge points by the mica insulating spacer disk 7.

The external connections to the tube are thus: master electrode 18, first transfer electrode 17, second transfer electrode 2, index electrode 19, and common electrode 16.

The circuit of Fig. 3 comprises a voltage supply shown as battery 20 leading to a network of resistors R_1 to R_8 which may be considered to be a series of four parallel voltage dividers or bleeders. The master electrode lead 18 is connected to the junction of resistors R_1 and R_2. The values of R_1 and R_2 are chosen such that the potential of the junction is well above the breakdown voltage of the master electrode 18, say 150 volts, anad such that enough current may flow through R_2 to sustain the discharge without dropping the potential of the junction to the extinction potential. In contradistinction to this discharge sustaining value of R_2, the values of the resistors R_4, R_6, and R_8 are such as to be unable to sustain a discharge from energy supplied by battery 20. The first transfer electrode lead 17 is connected to the junction between R_3 and R_4 and the values of these are chosen so as to maintain the potential of 17, relative to the ground lead 22, at a point lower than that of the master electrode. For 150 volts on the master electrode this potential might be 140 volts. The second transfer electrode lead 2 is in turn connected to the junction of resistors R_5 and R_6 and the values are chosen so that this potential is maintained lower again than first transfer electrode 17. On the same scale this value might be 130 volts.

The index electrode lead 19 is maintained at a potential substantially identical with that of second transfer electrode lead 2 by its own voltage divider R_7, R_8. Consequently, since electrode 14 geometrically occupies a position in the tube corresponding to the location of the discharge points 9 of electrode 8 it will perform identically, from a functional standpoint, with the behaviour of the points of electrode 8.

All discharge currents passing through the tube also pass through the common electrode load resistor R_9. It is the voltage drop across this resistor which causes the discharge within the tube to be mutually exclusive of the several alternative discharge points.

The capacitors C_1, C_2 and C_3 are so connected as to supply transient current to the transfer electrode leads 17, 2, and 19 respectively. The time constant of the values R_3C_1 is chosen so as to be small with respect to the length of input

pulse which is to be counted. The time constants R_5C_2 and R_7C_3 are chosen to be equal to or greater than the pulse duration in order to provide overlap.

The operation of my invention is as follows: Let it be assumed that it is desired to count electrical input impulses in the form of square waves applied to the terminals 23, 22. These input impulses after passing through the coupling condenser C_4 will produce voltage impulses appearing across resistor R_1. For the correct magnitude and polarity of these impulses these transient potentials will oppose the potential appearing across R_1 by virtue of the battery 20, and consequently the potential of the master anode 18 will drop with respect to the common electrode lead 16 until it is inadequate to sustain the discharge which has been maintained from one of the fingers 13 of master electrode 12. As before noted, since the values of R_4, R_6, and R_8 are sufficiently high that no discharge may be maintained through them by energy flowing from the battery, the steady state of the system necessarily requires that a continuous discharge be taking place at one of the master discharge points 13. As this discharge approaches extinction due to the opposing pulse voltage across R_1 the diminishing discharge current through common electrode resistor R_9 causes the potentials of all the remaining electrodes to rise with respect to the common electrode 15. However, since the first transfer electrode lead 17 is at the highest potential relative to the common electrode as determined by the voltage divider R_3R_4, and since one of its discharge fingers 11 is adjacent to the ionized region through which the discharge had been maintained, that finger of the first transfer electrode will capture the discharge in preference to the finger 9 of the second transfer anode which is on the other side of the master electrode finger which had maintained the discharge, because of the higher potential of 11. As soon as electrode 17 captures the discharge the current through R_9 again drops the potentials so that no other discharge is possible. However, the current of this captured discharge is being supplied by condenser C_1 and consequently in a short time this charge will be exhausted allowing the current through R_9 to drop again and the relative potentials to rise. At this point since the potentials on 18 and 17 are respectively disabled and exhausted the only remaining appreciable potential gradient adjacent to the last point of discharge is that between the second transfer electrode finger 9 and the common electrode 15.

For this reason, the discharge will now pass to the adjacent finger 9 of the second transfer electrode, and the discharge will remain there until the decaying potential across condenser C_2 becomes inadequate to sustain the discharge. By this time, however, the blocking pulse on resistor R_1 will have disappeared thereby allowing the discharge to pass to the master electrode 18 again. Thus in response to the pulse the discharge has progressively transferred itself from one finger of the master electrode to its next one thereby visibly registering the addition of the impulse. This process is repeated for successive impulses until the index position is reached. When the input impulse which will make the transit of electrode 19 occur, the discharge moves as above described from the number 9 finger of the master electrode to the adjacent finger of the first transfer electrode. Thence the discharge moves on to discharge point 14 because the electrical conditions on it are identical to those of the second transfer electrode. From point 14 the discharge moves as before back on to the "zero" finger of the master electrode 18, but in the process of discharging condenser C_3 of the index electrode a transient change of the potential of lead 19 has been generated. Since this transient occurs only once per revolution of the electrode cycle, it may be utilized as an output pulse appearing at the output terminals 24, 22. This output pulse may be coupled to the input connections of another such system as shown in Fig. 3 thereby comprising a two decade counter, and the process may obviously be extended to any number of cascade counter decades. Alternatively, since the output pulse frequency has an exact fractional relation to the input frequency, it may be utilized as a frequency divider. It is evident that any desired number of discharge points may be incorporated in the discharge cycle, either for the purpose of counting in other number systems than the decimal system, or for specific applications where particular frequency divisions or predetermined counting limits are desired.

It may be noted that there is an optimum duration and form of the input pulses which are to be counted, but in practice it is found that there are wide limits as to these specifications due to the long persistence of ions in the neighborhood of the last transfer electrode discharge. For this reason a minimum of input pulse shaping circuitry is necessary.

In the circuit of Fig. 3 means are provided for resetting the system to the zero position. These comprise the two switches 25 and 26. To reset the decade the normally closed switch 25 is opened thus causing all discharge in the tube to die out in a very short time by opening the lead to battery 20. Normally open switch 26 is thus closed thereby impressing the full battery voltage on the index electrode 19. This initiates a discharge at this point which will then transfer to the zero finger of the master anode on the reclosing of switch 25 and the subsequent opening of switch 26.

To those skilled in the art it will be evident that there are a great number of geometrical forms and circuit means for incorporating the principle of my invention, and for this reason it is not to be construed as a limitation of the scope of my concept that only one geometry and one circuit are shown in the drawings. For instance, it is possible to incorporate my invention in a tube having a central cylindrical common electrode and multiple electrode discharge points directed radially inward toward this common electrode. Or the electrode path may be comprised of intermeshing combs arranged in a linear array or in a torroidal envelope. Further, this device has been operated in the air without an envelope in the laboratory, so that no specialized atmosphere is required for its operation. In addition to the potential gradient type of transfer circuit shown in Fig. 3 it is within the scope of the invention to utilize any switching means whether mechanical or electronic which will set up preferential conditions for the discharge at physically adjacent points in sequence so as bodily to advance the location of the discharge.

What I claim and desire to secure by Letters Patent is:

1. A gaseous discharge device comprising, a gas-filled envelope, a master electrode formed with a plurality of discharge fingers, a first trans-

fer electrode formed with a plurality of discharge fingers adjacent to the fingers of the master electrode, a second transfer electrode formed with a plurality of discharge fingers adjacent to the fingers of the first transfer electrode, and a common electrode formed with a discharge surface spaced substantially equidistant from the discharge fingers.

2. A gaseous discharge device comprising, a gas-filled envelope, a master electrode formed with a plurality of discharge fingers, an index electrode having a single discharge finger, a first transfer electrode formed with a plurality of discharge fingers adjacent the fingers of the master and index electrodes, a second transfer electrode formed with a plurality of discharge fingers adjacent to the fingers of the first transfer electrode, and a common electrode formed with a discharge surface spaced substantially equidistant from all the discharge fingers.

3. A gaseous discharge device comprising, a gas-filled envelope, a master electrode formed with a plurality of discharge fingers, an index electrode having a single discharge finger, a first transfer electrode formed with a plurality of discharge fingers adjacent to the fingers of the master and index electrodes, a second transfer electrode formed with a plurality of discharge fingers adjacent to the fingers of the first transfer electrode, and a common electrode formed with a discharge surface spaced substantially equidistant from all the discharge fingers presenting a uniform interelectrode impedance between the fingers and the common electrode.

4. A gaseous discharge device comprising, a gas-filled envelope, a master electrode formed with ten discharge fingers, an index electrode

having a single discharge finger, a first transfer electrode formed with ten discharge fingers, a second transfer electrode formed with nine discharge fingers, and a common electrode formed with a discharge surface spaced substantially equidistant from all discharge fingers; the ten fingers of the second transfer electrode and the index electrode, the ten fingers of the first transfer electrode, and the ten fingers of the master electrode positioned in a complete circle.

5. A gaseous discharge device for recording and accumulating digital values comprising, a gas-filled envelope, a master electrode formed with a plurality of discharge fingers, the number of said fingers being equal to the radix of the accumulating system, a first transfer electrode formed with a plurality of discharge fingers adjacent to the fingers of the electrode, a second transfer electrode formed with a plurality of discharge fingers adjacent to the fingers of the master and first transfer electrodes, an index electrode with a single finger, a common electrode formed with a discharge surface spaced substantially equidistant from all discharge fingers, and conductive means for applying varying potentials to said electrodes.

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