United States Patent

Baasch

[15] **3,681,754**

[45] **Aug. 1, 1972**

[54] SELF LUMINOUS SHIFT REGISTER INFORMATION DISPLAY

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[21] Appl. No.: **845,414**

[52] **U.S. Cl.** .....**340/168 R,** 340/168 S, 340/166 R, 340/334

[51] **Int. Cl.** **H04q 9/00**

[58] **Field of Search** 340/166, 324, 168; 315/84.6, 315/169; 313/188, 203

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Primary Examiner—Donald J. Yusko

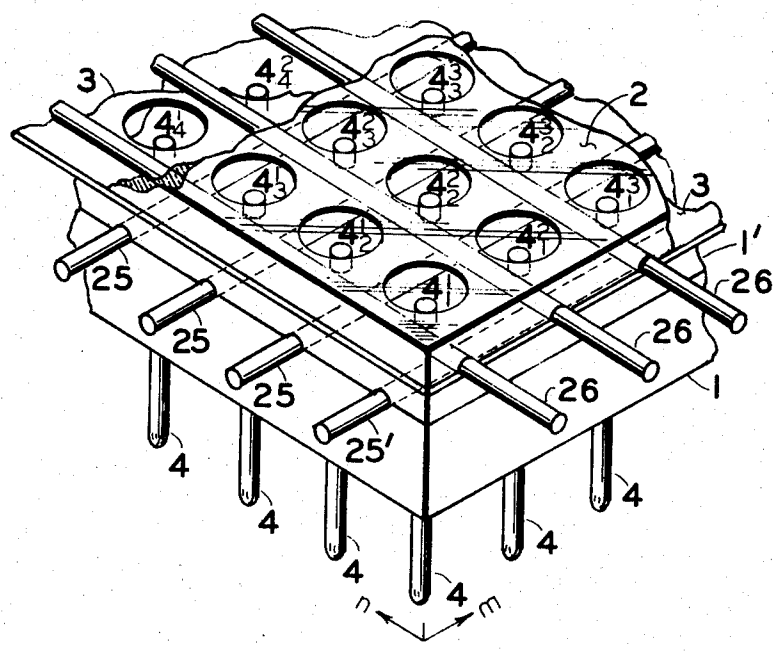
[57] **ABSTRACT**

A gas discharge device comprising an array of cold cathode glow discharge cells in cooperative relation and adapted to show luminosity of selectable cells in a programmable pattern of light bits. It is a self luminous information display and a shift register with visible store.

Prior art devices are glow discharge arrays having discrete element or x-y address mechanisms, glow discharge counting tubes which move a single glowing bit one step for each input pulse and shift registers which accept a sequence of data bits and by serial or parallel entry means store that sequence for subsequent retrieval, or, continuously move the data through with subsequent delayed output.

The prime element of invention is the combination of shifting means with a glow discharge matrix display. Shifting means employing one or more stepping cathodes with bidirectional stepping capability; shifting means employing one stepping cathode with preferential glow stepping cathodes and a magnetic propulsion shifting means can be adapted individually or in combination using common conductor means to accomplish the aim of the invention. Glow elements can be ignited and read out at any and all elements but preferentially at one or more peripheral cells of the array. Light address of the array is claimed.

20 Claims, 18 Drawing Figures



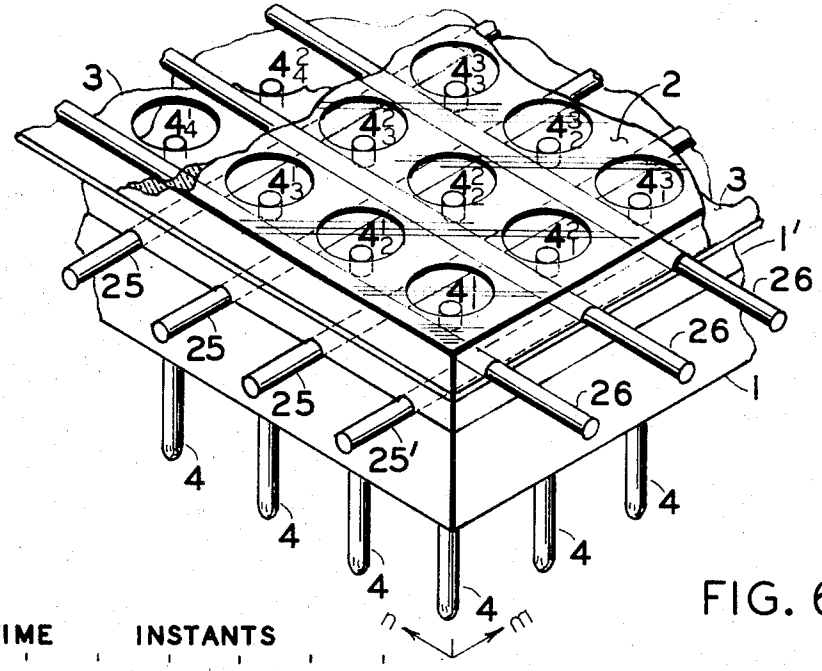


FIG. 6

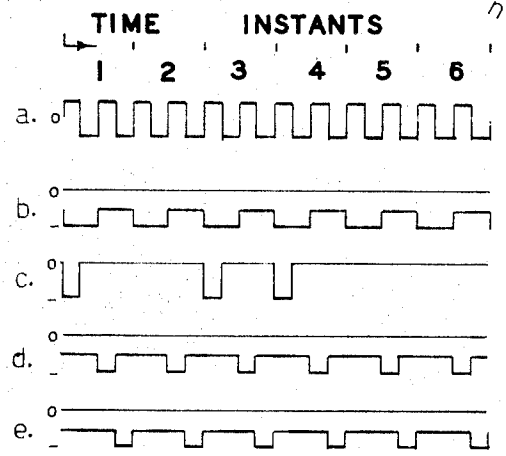


FIG. 2

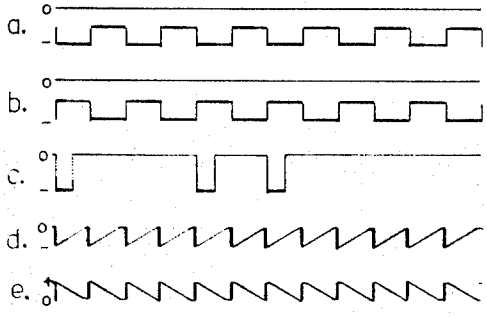


FIG. 5

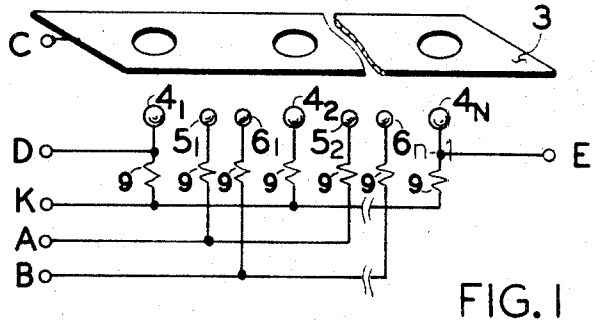


FIG. 1

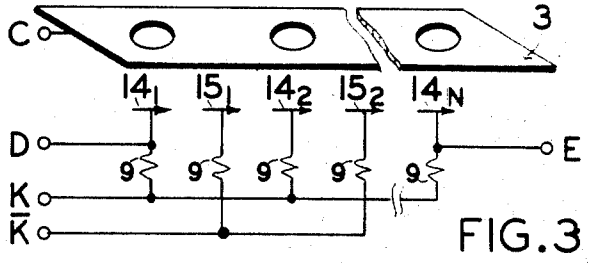


FIG. 3

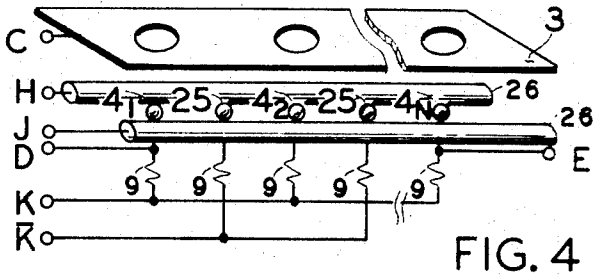


FIG. 4

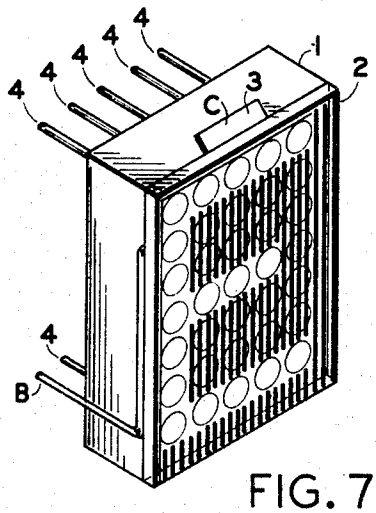


FIG. 7

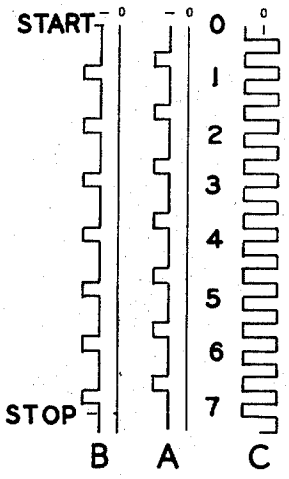
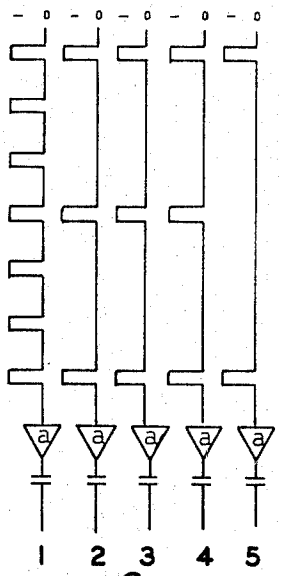


FIG. 9



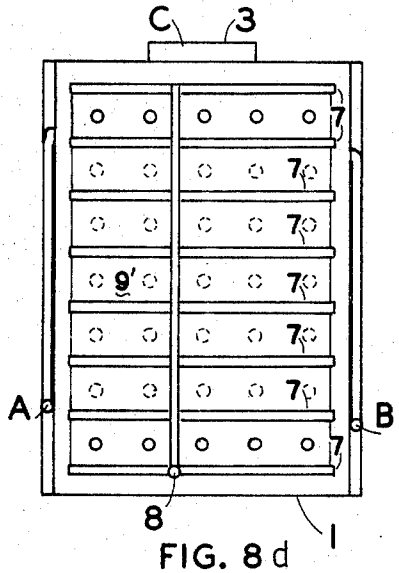


FIG. 8d

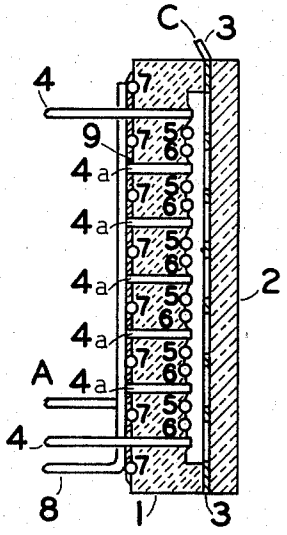


FIG. 8b

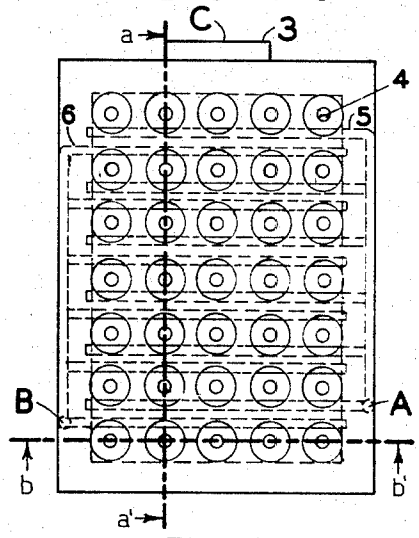


FIG. 8a

FIG. 8

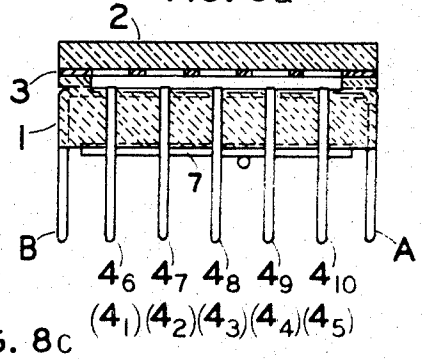


FIG. 8c

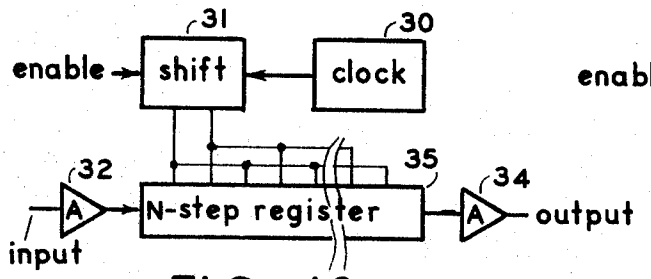


FIG. 10

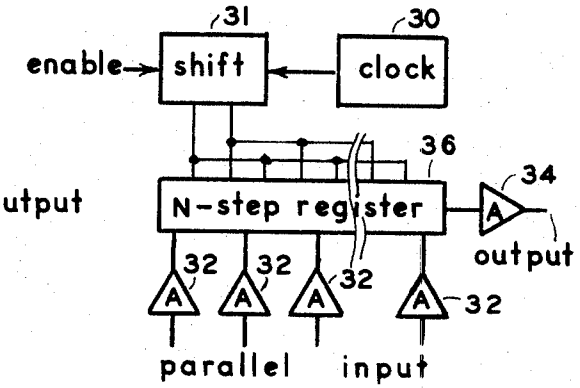


FIG. 11

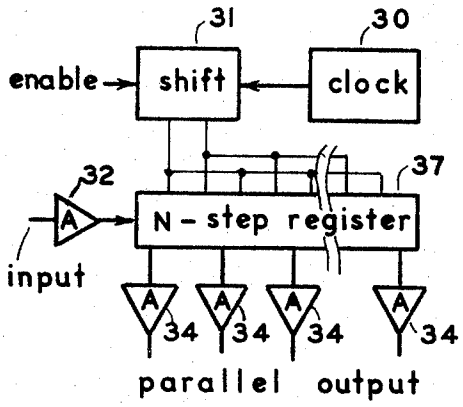


FIG. 12

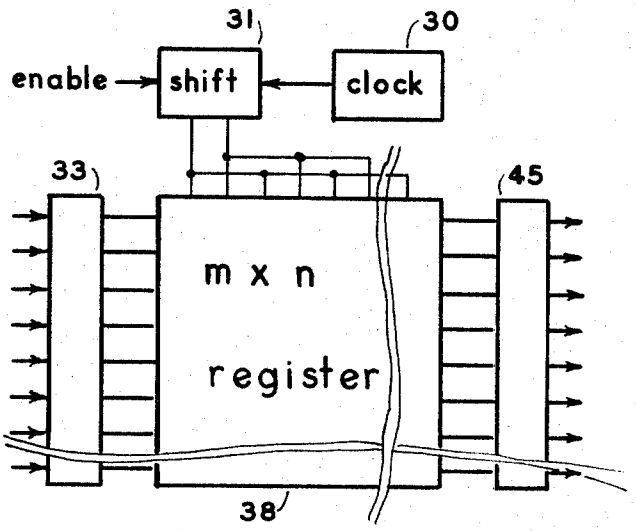


FIG. 13

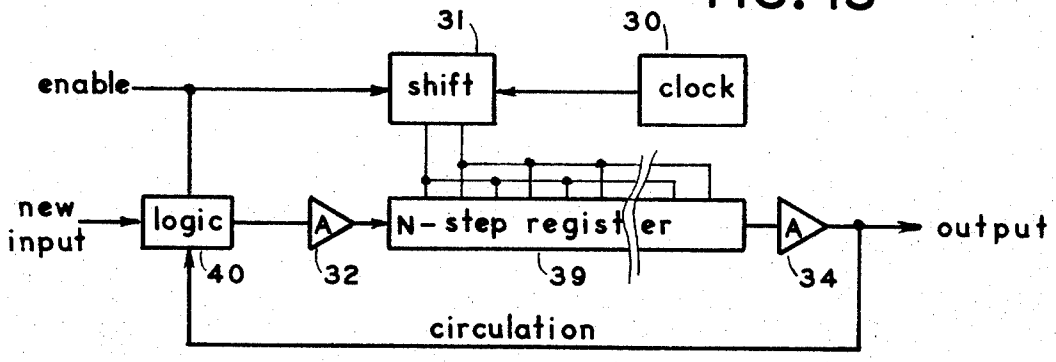


FIG. 14

SELF LUMINOUS SHIFT REGISTER INFORMATION DISPLAY

BACKGROUND OF THE INVENTION

This invention relates to Gas Discharge Tube Devices (Class 315). Registers (Class 235) and moving, step by step, and still visual displays (Class 340).

Prior art gas discharge devices revolve about the use of the elemental gas discharge cell or lamp. This cell comprises an anode and a cathode pair in cooperative relation, contained in an envelope filled with a suitable gaseous medium at suitable pressure for enabling a gas discharge to be established between the anode and the cathode. Call the anode a working anode and the cathode a working cathode. Means is provided in the envelope structure to make the glow within the cell visible from without.

The glow-discharge cell is a binary or two-state device. When it is not lit a relatively high voltage is necessary to ignite it, this is called ignition potential. Upon ignition of the cell there is a perceptible glow and the anode to cathode voltage falls to a lower value called the sustaining potential. Lamp current is limited by the resistive characteristic of the gas and cell structure and by auxiliary current limiting means. The difference between ignition potential and sustaining potential is called the potential margin and means may be employed to make this as much as one-half the striking potential. It is known that if the cathode of a glow discharge cell is illuminated, the ignition voltage is lowered in proportion to the photoemissive properties of the cathode. If a voltage midway between ignition potential and sustaining potential, which we shall call the working potential, is placed across a gas discharge cell, the cell may be ignited by shining a suitably powerful light upon it or by momentarily raising the working potential to or above the ignition potential by means of a boot-strapping pulse. These two methods of cell ignition are known respectively as light addressing and voltage addressing. The glow of a gas discharge cell, once initiated, continues to glow when a working potential is maintained across it and this is known as memory. The glow may be extinguished by lowering the anode-cathode voltage below the sustaining voltage. The time duration of ignition potential need only exceed the ionization time of the gas mixture and the time duration of the extinguishing potential need only exceed the deionization time of the gas mixture. The above description defines terms to be used in the disclosure and constitutes a unit-cell self-luminous display in which, in computer terms, no light constitutes a zero bit and light after ignition constitutes a one bit.

One known type of glow discharge display consists of a matrix of cold-cathode lamps separately excited. Information fed to the display moves across its surface from right to left. Such a display employes a tape programmed external switching means whereby the lamps are lighted in sequence.

A second known type of glow discharge display under production by Mullard, Ltd. of England is comprised of a 5 × 7 rectangular array of cells adapted to display alphanumeric characters by appropriate selective address to each of 35 cathodes. The tube is completed by adding an appropriately perforated anode grid and then sealed with a glass faceplate. Because of the individual address requirement to each

gas cell, these displays are limited by practical considerations to display of one or more numerals or characters.

Another known gas discharge display consists of a multitude of individual gas cells arranged in a two dimensional row/column matrix. The gas cell array is placed between two parallel glass plates separated by about one millimeter. One glass plate has a plurality of opaque conducting members running in a first direction parallel to the rows of cells and spaced so as to correspond to one end of the gas cells and serve as the cathode thereof. The other glass plate has transparent conducting members running in a second direction parallel to the columns of the gas cells and spaced so as to correspond to the other end of the gas cells and to serve as the anodes thereof. The array of gas cells is filled with a suitable gas mixture hermetically sealed between the glass plates. Excitation of individual gas cells is accomplished by applying dc voltage across row and column conductors corresponding to the selected cell. The display in the form of excited light bits, may be caused to move across the screen by sequentially commutating successive row or column conductors.

Still another display invented by Bitzer and Slottow is made similar to the one last described except that both conductor members are transparent and are coated with a glass insulation. This display having the same row by column electrode address (also referred to as an x-y address mechanism) is adapted for alternating current excitation. This potential is continually maintained across all cells at a peak potential below striking potential yet above sustaining potential. Suitably phased voltage pulses bootstrapped over the working voltage cause the ignition or extinguishing of selected cells when addressed to the corresponding x and y cordinates.

The above, last two described gas discharge displays, sometimes referred to as plasma displays, require driver electronics for each conducting member of the row and column conductors. This results in complicated switching problems when the display array becomes large or the number of resolved elements increases.

Still another class of glow discharge tube exists as glow discharge counter tube. Such devices comprise an anode and a plurality of cold cathodes in cooperative relation with the anode, the cathodes being mounted in one row which may be rectilinear, circular, or other geometrical form. These electrodes are positioned in an envelope containing a suitable gaseous medium at suitable pressure for enabling a gas discharge to be established between an anode and any one cathode. Tube design and operation is such that only one cathode is caused to glow at a time and the tube geometry is such that no preference is prevalent for any particular cathode. The cathodes are divided into working cathodes and stepping cathodes. The working cathodes are ones on which the glow rests when not stepping and these cathodes are excited by a constant dc potential maintained midway between the sustaining potential and the ignition potential. Symmetrically disposed between the working cathodes are two or more stepping cathodes which we shall letter consecutively A, B, C, etc. With this symmetrical type of tube one stepping cathode is insufficient and three or more

are superfluous. In any of these stepping tubes all of the A stepping cathodes are connected together. Similarly the B and the C cathodes. The purpose of the stepping cathodes is to capture the glow from a working cathode and transfer it in a particular direction to another working cathode. This is accomplished by momentarily increasing the potential to the A stepping cathode. However, using only one stepping cathode and due to the symmetry of tube structure, the glow has no preferential direction of motion. When two stepping cathodes are used the stepping voltage applied to A and B terminals is a two phase potential having a phase relationship which dictates direction of glow transfer. Similarly three phase potential or polyphase potential is used when three or more stepping cathodes are employed. This type of stepping tube is typical of the invention of N. B. Wales, Jr., U.S. Pat. 2,443,407 issued June 15, 1948.

M. A. Townsend in his U.S. Pat. No. 2,575,370 issued Nov. 20, 1951 showed that it was possible to eliminate stepping cathodes by suitably shaping or sensitizing the cathode structure so that a tube capable of stepping in a pre-determined direction could be made using only preferential glow transfer working cathodes. This tube is consequently stepped using a single phase stepping voltage.

Townsend's teachings are particularly important to the invention to be disclosed here because they permit the reduction of stepping cathodes required in the invention to one less than would be required with symmetrical electrodes and consequently permit the realization of a high density array of gas discharge cells as a register capable of being stepped with only one stepping cathode.

The stepping tube is not known to have been operated with one or more working cathodes ignited as an indicator of digital bits of information in time sequence. Such a tube would be known as a shift register.

Shift registers are well known computer components. They have many uses among which memory and time delay are important. They may be characterized as a cascaded system of binary elements which receive a sequence of data-bit signals at an input terminal and controlled by a shifting or stepping frequency signal, transfer that data-bit signal sequence in an orderly manner to an output terminal.

I recognized that the glow discharge matrix display, the stepping counter tube and the shift register are devices that can be combined to comprise a self-luminous Shift-Register-Memory-Display.

BRIEF SUMMARY OF INVENTION

The primary object of this invention is to provide a self-luminous information display with a simplified address mechanism for communicating numerical and alphabetical characters as discrete characters, words, sentences and complete literary works or data compilations within the physical capability of a particular display panel.

The invention consists of an improvement in glow discharge, sometimes called gas plasma, displays comprised of a multiplicity of gas discharge cells arranged in a two dimensional orderly manner. A typical arrangement of cells is a row by column matrix in a plane. All the cells of a display panel are contained in one enclosure having interconnecting passages between cells and filled by a suitable gas or mixture of gases at a pressure suitable to provide a localized glow discharge when appropriate operating potentials are applied between anode and cathode of each and any cell. When the anode is a common electrode containing holes corresponding to the matrix arrangement of cells and through which light emanates and upon which the light pattern conveying information is produced, then, the cooperating working cathodes are individual electrodes concentrically disposed with the anode holes. The inventive element consists of the addition of stepping means to a matrix display symmetrically placed with respect to the axis of concentricity of cathode anode hole alignment of each cell. These stepping means are ordinarily not visible from the observers viewing position of the display. They are suitably and selectively excited with a waveform derived from a clock stepping voltage of controllable frequency which is adjusted to shift (or step) the glow of any excited cell to the next succeeding cell. Similarly disposed stepping means for transfer of the glow in a particular direction may be connected in parallel and terminate at suitable common stepping terminals. Since a row by column matrix may have four directions of movement, then there can be as many as four sets of stepping means, one set for each stepping direction in this particular embodiment.

When all of the working cathodes are connected in parallel through suitable current limiting resistors, a suitable working voltage is applied at the common connection and access via suitable coupling means may be had to any working cathode for the purpose of applying an ignition voltage pulse or an erase voltage pulse to that particular cell.

When the display is operated to show alphanumeric information, and when each character is formed from a 5×7 dot-matrix font which will fill seven rows of the display; then under these address conditions only the seven peripheral cells at the right of the screen need by ignited as required, to write the message. Each column of the 5×7 font is ignited as required in unison with an appropriate row stepping voltage or current applied to the stepping terminals, which synchronously moves the message across the screen from right to left as it is written, like the movement of the famous moving sign atop the former New York Times Building in Times Square, New York.

After a complete line is written on the display panel, row shifting as terminated and this line may be moved up or down in toto by application of the stepping excitation to appropriate column stepping terminals. When the first information line has been moved up eight or more rows and the vertical shifting terminated, then resumption of the writing of a second line may begin.

Consequently, the objective of providing a self-luminous information display with a simple address mechanism has been achieved limited to only seven writing address terminals in the illustrated case plus no more than four shift terminals. The entire display within practical limits of size can be filled sequentially with information.

A third object of this invention is to provide means to read the information store out of the display in the

same sequence or in some other sequence by providing suitable data output electrical means. This objective is achieved by suitable coupling means to any working cathode and more specifically, for the case previously discussed, by stepping the message out of the display to the left at seven peripheral cells, line by line, and sensing by suitable coupling means the potential across the seven peripheral working cathodes where the moving line of information terminates. The data leaving the display is then the exact sequence as read into the display delayed by the storage time.

The information input to this panel being in the form of luminous cellular data bits may not only be coded to present alphanumeric characters, but may also be in the form of digital data bits or arranged to form line or arc segments. Under these conditions the display may be adapted to communicate graphic or pictorial information, or, the digital data store of a delay line or memory shift register.

By virtue of the shift register nature of this display it is a fourth object of this invention to provide a shift register having a self-luminous visually observable memory store.

A fifth object of this invention is to provide a shift register whose cost per bit is low compared to prior-art devices.

By virtue of the low cost per bit, the visibility of the register store and the feasibility of writing alphanumeric and symbolic symbols in similar registers, it is a sixth object to provide an electronic calculator of educational value when used in combination with suitable program logic encoders and decoders.

Another object of this invention is to provide a means for exciting to glow, by means of a concentrated beam of light applied to said cell, any arbitrary cell on the display panel not already lighted. This excitation to glow is brought about by providing a display with working cathodes having photoemissive properties and irradiating selected cathodes by typical means of a so called light addressing pen or a scanning laser beam.

Erasure of any information bit may be implemented by access to any working cathode by suitable coupling means and the promotion of that cell's extinction by reduction of the sustaining voltage to extinction value. Erasure of the whole display is accomplished by interruption of the working cathode voltage.

The aforementioned four sets of stepping means may each be comprised of one or more stepping cathodes. When one stepping cathode is used, the teachings of Townsend cited above are employed, and with respect to his FIG. 6 the working cathodes become his A cathodes and the stepping cathodes become his B cathodes wherein the stepping voltage varies above and below the working potential by the required amount to promote stepping. Under this condition one or both cathodes of a working-stepping pair must be formed to have a preferential direction of glow transfer as taught by Townsend.

When two stepping cathodes are employed as a pair they are excited with a suitable two phase voltage as explained under the detailed description to follow. The case for more than two stepping electrodes requires polyphase stepping voltage.

A third means for stepping a gas discharge register display is introduced in this invention. This means is magnetoplasmadynamic propulsion and is commonly known in aerospace terminology as rail propulsion. This propulsion means imparts directional characteristics upon non-directional cathode structures and greatly simplifies stepping circuitry.

BRIEF DESCRIPTION OF THE DRAWINGS

Any other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings, which disclose, by way of examples, the principle and species of the invention and the best modes which have been contemplated for reducing the invention to practical use.

FIGS. 1 to 5 are circuit schematics of three species and recommended idealized waveforms for driving the devices, which illustrate the principles of the disclosed invention.

FIG. 1 is a single row of a register using stepping cathode pairs.

FIG. 2 illustrates the waveforms of voltages used to drive the circuit of FIG. 1.

FIG. 3 is a single row of a register using directional cathodes and a single stepping cathode.

FIG. 4 is a single row of a register in which single stepping cathodes are used and where directional stepping characteristics are produced using magnetoplasmadynamic propulsion.

FIG. 5 illustrates idealized waveforms for use with FIGS. 3 and 4.

FIG. 6 is an isometric view of a self-luminous shift-register display-panel-section made in accordance with the principles and structure shown schematically in FIG. 4.

FIG. 7 is an isometric illustration of a 5 × 7 matrix unit-character self-luminous display and quinary shift register displaying an E in 5 × 7 dot matrix font.

FIG. 8, *a* to *d*, shows four views of the detailed drawing of the embodiment of FIG. 7 wherein the principle and species of structure of FIG. 1 is used.

FIG. 8*a* is a view of the face of the unit character display showing relative positions of anode holes, working cathodes and stepping electrodes. FIG. 8*b* is a side elevation cut through section *aa'* of FIG. 8*a*. This view shows the relative dimensions of the enclosure comprised of header assembly and faceplate coverglass which contains a suitable gas mixture in the space provided between faceplate and header. Also shown are the arrangement of the plurality of cathodes and the cooperative relation thereof with the anode. FIG. 8*c* is an end elevation cut through section *bb'* and shows the corresponding arrangement of cathodes, the addressable electrodes and the stepping terminals. FIG. 8*d* is a rear view showing the arrangement of conductors used to divide a deposited resistance coating on the back of the header to serve as suitable working cathode current limiting resistors.

FIG. 9 illustrates by timing diagram, recommended idealized signals for operation of the display of FIGS. 7 and 8 where a character "E" is to be produced.

DETAILED DESCRIPTION

Referring now to the drawings, the principle of operation and elements of invention over prior art are set forth in FIGS. 1, 3 and 4 which show three species of the invention. While only a single row of cooperating

unit-cells set is shown, this invention comprises a multiplicity of cooperating unit-cells set out in an array. Thus the characteristic row arrays of common-anode/cathode member pairs as set forth in the drawings, may be extended to comprise *n* row members and paralleled with like arrays to form *m* column members, where *n* and *m* are integers of practical value. Similarly any species shown may be rotated as an n member row about the terminal anode-cathode axis to form a polar array with n member rows radiating from a central point and spaced at 360/m degrees from each other. While these foregoing arrays are planar in nature, similar arrays may be set up on curved surfaces to suit specific requirements.

The distinct element of invention is the realization of a self-luminous, two dimensional gaseous discharge shift register capable of a continuously moving or static display of information and capable of being simply addressed, read out and stepped.

All of the unit displays to be described in this disclosure consist of a multiplicity of unit-cells in cooperative relationship contained in a hermetic enclosing vessel (not shown in FIGS. **1**, **3** and **4**) having therein a gaseous fill of one or more gases adapted to respond to previously defined electrode voltages as hereinbefore described for gaseous discharge phenomena.

FIG. **1** is a schematic of a first species of a register display having a single anode-electrode-member **3** adapted to be connected through a hermetic terminal at c to the anode supply. The anode has n holes in it corresponding to the information pattern to be displayed. The periphery of these anode holes may be considered the unit cell anodes all connected together. Concentric with each hole, equally spaced from the plane of each hole and cooperating with the anode electrode in the area of the hole periphery are working cathodes 4_i, where *i* denotes consecutive integers from *l* to *n* which have non-preferential glow transfer characteristics. Between each working cathode are two transfer cathodes 5_i, 6_i which cooperate with the anode member to transfer the glow between working cathodes by means of a suitable two phase stepping potential. The principles of operation involved are independent of the number of cathode sets (a set for this species consisting of a working cathode followed by two stepping cathodes) it being understood that a greater or lesser number of sets than shown in any particular device heretofore or hereafter described may be used. Each register row consists of a plurality of cathode sets in cooperative relationship terminated by a final working cathode 4_n.

In FIG. **1** the foregoing working cathodes 4_i are individually connected through suitable current limiting resistors **9** to a common terminal K. In constructing the register it is immaterial whether the individual cathodes penetrate the envelope in a multiplicity of hermetic terminals or whether the commoned cathodes penetrate the envelope in a common hermetic terminal. In the latter case the cathode resistors are internal to the envelope and properly shielded and/or insulated from the discharge while in the former case the cathode resistors are external to the envelope.

Similarly all the No. 5 stepping cathode terminals are fed through individual current limiting resistors **9** to a common terminal A. The No. 6 stepping cathodes are also similarly terminated in the terminal B. While this embodiment shows resistors of the same part number, it is understood that the resistance value could be different for different cathode types.

In FIG. **1** the first and last working cathodes are shown connected to ignition and/or read-out terminals D and E. It is understood that any cathode may be similarly connected to a terminal and adapted to receive or deliver a signal.

Operation of the display register shown in FIG. **1** is best understood by reference to FIG. **2** which shows by idealized square waveforms the recommended voltages to be applied to the display drive terminals. It is understood that any idealized waveforms are fully representative of low frequency waveshapes, practically portrayed, and that at higher repetition frequencies the rise and fall characteristics will be rounded off. With reference to FIGS. **1** and **2**, the waveshape at FIG. **2***a* is a clock timing frequency of variable repetition rate which can be stopped whenever working cathodes are at working potential.

All of the remaining voltage waveforms shown n FIG. **2** obtain their time duration by deriving suitable logic switching from the clock frequency. FIG. **2***b* shows suitable working cathode potential to be applied to terminal K of Flg. **1**. The potential varies between two levels, that of the working potential and that of suitable extinguishing potential.

FIG. **2***c* shows suitable glow striking potentials to be applied to the write terminal of the display as explained below. The waveforms shown provide for striking a glow at the first, third and fourth data instants and leaving zeros or no glow for the second, fifth and sixth data instants. FIGS. **2***d* and **2***e* show suitable two phase stepping cathode potentials which also vary between working potential and suitable extinguishing potential.

When information is passed from left to right in the register of FIG. **1**, the ignition potential, FIG. **2***c* is impressed upon terminal D; stepping phase, FIG. **2***d* is impressed upon the A terminal and stepping phase FIG. **2***e* is impressed upon terminal B.

Assume that in the first instant a discharge is obtained at the first working cathode 4_1 of FIG. **1**. During the third quarter of the first instant when the first working cathode potential drops to extinguishing potential, the first stepping cathode 5_1 assumes the working potential of FIG. **2***d* and the glow at 4_1 which lingers at 4_1 for an interval equal to its deionization time is transferred to cathode 5_1. During the fourth quarter of the first instant the cathode 5_1 drops to extinguishing potential at the same time that stepping cathode 6_1 assumes the potential of FIG. **2***e* and the glow is similarly transferred to cathode 6_1. Upon initiation of the second instant all working cathodes assume working potential again and the glow on the 6_1 stepping cathode is transferred to the second working cathode 4_2. As long as the clock operates, this distinct data bit is stepped from working cathode to working cathode until it reaches the 4n terminal where it is read out as a voltage pulse at terminal E.

In accordance with FIG. **2***c*, the second data bit is a zero, hence no glow is initiated at the 4_1 working cathode and no glow is propagated down the register for this data instant. During the third and fourth instants, data bits are present, hence a glow will be

propagated down the line corresponding to the third and fourth instants.

After six instants corresponding to the time interval of FIG. 2 stepping may be stopped by suitable logic and the visible register will show a six bit binary number 001101 as read from left to right. This constitutes a visible shift register store.

If the clock is again started for six instants, the stored number will come out of the terminal E working cathode in its original sequence. This constitutes a shift register memory.

If the clock continued to run after the sixth instant and the register is limited in length to, say, 10 working cathodes, then the sequence of data of FIG. 2*c* will emerge from the register delayed by 10 instants. This constitutes a 10 instant delay-line register.

When the self-luminous delay line register is as long as a sequence being fed in, it is possible to reshape the output by suitable amplification means and feed it back into the input. When this operation is properly synchronized we have a continually rejuvinated circulating memory register.

The sequence of data signals through the register may be reversed and consequently move from right to left. When the write signal of FIG. 2*c* is applied to the E terminal of FIG. 1 and the signals previously applied to stepping terminals A and B are interchanged, the glow will be stepped from right to left and the data fed in at terminal E will ultimately emerge at terminal D by the same stepping process previously described. The applications to register store, memory and delay line similarly apply.

An additional explanation of glow transfer using two or more stepping cathodes may be found in U.S. Pat. No. 2,433,407 issued June 15, 1948 to N. B. Wales, Jr. In Wales' device only one glow bit can be handled by the counter tube at one time therefore it is not a register device. Other pertinent differences between this invention and that of Wales, Jr. also exist.

FIG. 3 illustrates schematically a second species of self-luminous shift register display employing the preferential glow transfer cathodes as taught by M. A. Townsend in his U.S. Pat. No. 2,575,370 issued Nov. 20, 1951. Since the referenced patent adequately treats the details of this structure, the directional properties of the cathodes are represented by arrows here and are considered prior art. Use of the foregoing cathodes permits construction of a self-luminous display register with one less stepping cathode than was the case in FIG. 1. This simplification permits more compact structure and simplified drive potential as shown in FIG. 5 which will be explained below. Here again the invention of Townsend, cited above, is a counter tube not a register and other significant differences exist.

FIG. 3 is a self-luminous shift register display having a one member anode electrode 3 as heretofore described for FIG. 1. Location of the working cathodes and cooperative relations with the anode are also identical with those of FIG. 1 except that these working cathodes have a preferential glow transfer characteristic and are designated 14_i. The stepping cathodes 15_i shown in this schematic are similar to the working cathodes, having the same preferential glow transfer characteristic, but there is no hole provided in the anode structure to make their glow visible. This significant masking is explained below.

The operation of the register of FIG. 3 is explained by reference to the waveforms of FIGS. 5*a*, *b*, & *c*. When these waveforms are derived from the clock frequency of FIG. 2*a*, simple logic will give required waveforms.

FIG. 5*a* is a voltage which varies between working potential and extinguishing potential and is applied to the working cathodes at terminal K of FIG. 3. The waveform of FIG. 5*b* is the complement of FIG. 5*a* and likewise varies between working-potential and extinguishing potential. This is applied to the stepping cathode terminal $\overline{K}$ of FIG. 3.

The voltage of FIG. 5*c* is an ignition address potential to be applied at terminal D of FIG. 3. During the first half of the first instant the working cathodes are at working potential and a glow is ignited at the input terminal 14_1. At the commencement of the second half of the first instant, the working cathodes drop below sustaining voltage at the same time that the stepping cathodes are switched to working potential. Because of the deionization time of the gas and the preferential glow transfer characteristic of the working cathodes, the glow is transferred to the stepping anode 15_1. At the beginning of the second instant, the working cathodes again switch to working potential and the stepping cathodes switch to extinguishing potential. The lingering glow and the preference mechanism transfers the glow to the 14_2 working cathode. In like manner during the second instant the glow will be transferred to the 15_2 stepping cathode and ultimately to the 14_n working cathode where a readout pulse due to the glow will be available at readout terminal E.

It would be advantageous to provide a viewing hole above each stepping cathode of FIG. 3. However when this species is used as a register one cannot write at a working cathode when the stepping cathodes are at working potential, that is stepping, because the working cathodes are at extinction potential. When this hole is provided in the display, one can only write on alternate bits of the display.

FIG. 4 shows a third species of this invention. The anode and working cathode configuration is identical to FIG. 1. Here, however, only one stepping cathode 25 is disposed midway between the working cathodes and all cathodes have non-preferential glow transfer characteristics. Ambiguity of glow transfer explained in the prior art disclosure is eliminated by using a properly timed and directed magnetic field to propel the glow in the required direction during stepping.

When the register is constructed so that the localization of glow in the proximity of a hole exhibits strong bistable properties over glow at any other anode location, then the stepping cathode 25 may be provided with a display hole, the cathodes K and $\overline{K}$ may be tied together and proper electromagnetic pulses will serve to step the glow through the register. Tying K and $\overline{K}$ together is tantamount to supplying all cathodes with direct current at the working potential.

Magnetic propulsion is achieved in FIG. 4 by sending current pulses simultaneously in the same direction through the parallel conducting members 26 which are equally spaced and parallel to the working cathodes. The magnetic field set up by the current will exert a magnetoplasmadynamic effect on the glow discharge giving rise to propulsion in a direction orthogonal to both the glow discharge potential and the magnetic

field which is dependent upon the direction of current in conductors **26** of FIG. **4**.

It is also known that when and where the conducting members **26** make contact with the glow discharge and a voltage potential is placed across the pair shown in FIG. **4** at the terminals H and J, then the glow discharge is propelled down the line by another effect of magnetoplasmadynamic propulsion.

When magnetoplasmadynamic propulsion is used in this invention and direct current at working potential is applied to all working cathodes, it will be necessary, using properly derived logic, to interrupt the potential at terminal cathodes in order to extinguish terminating glow bits except when the propulsion effect is great enough to blow out the terminating glow bits.

FIG. **6** shows a preferred embodiment of the self-luminous shift register display made in accordance with the species of FIG. **4**. The device consists of a two dimensional array of working cathode terminals set hermetically in a vitreous medium such as a ceramic or glass header **1**.

When any of the species of FIGS. **1**, **3** and **4** comprise more than one row of register in a row by column array, then corresponding stepping cathodes are connected in parallel along the column and are implemented as a continuous conductor running parallel with and equally spaced from the columnar working cathodes and adjacent stepping cathodes.

FIG. **6** shows stepping cathode conductors **25** fused to the surface of the header **1** and spaced equidistant from the working cathodes and parallel to each other. An extra stepping cathode **25'** added outboard to the end working cathodes permits the voltage stepping cathodes **25** to be adapted as current stepping conductors when required, without impairing their use as a said voltage stepping cathode.

Structure **2** is a cover of transparent or translucent material, to the plane bottom of which is fused current stepping conductors **26** such that when the cover is mounted on the header they will be uniformly equidistant from the working cathodes, parallel to each other and orthogonal to the stepping cathodes **25**. Also disposed on the plane bottom is the anode electrode **3** having holes opposite corresponding working cathodes. In this embodiment the anode electrode is adapted to be grounded and the current stepping cathodes **26** make electrical contact with the anode electrode, however, the resistance of the anode coating is such that essentially all of the stepping current, applied as pulses, passes through the conductors **26**. The top surface of the cover **2** is of uniform thickness and either plane parallel and polished or lenticular in regions opposite the anode holes.

During final assembly, the cover **2** is fused to the header **1** by inserting a frame spacer **1'** between the two assemblies. The frame **1'** assures proper spacing of the anode and cathode and separates the stepping conductors **25** and **26**. Final electrode orientation is in accordance with aforementioned conditions.

FIG. **6** shows only one corner section of a total display which may be extended identically to some practical limit of working cathodes in both row and columnar extent. Each corner will look the same as FIG. **6** or its mirror image and thus the total array is defined. Although all working cathodes may be terminated in pins, for most applications only peripheral working cathodes need be accessible, as shown, and internal cathodes may be cut flush with the bottom of the header surface. When individual working cathode current limiting resistors are deposited on the bottom surface of the header reference may be made to FIG. **8** for applicable details.

Operation of the embodiment of FIG. **6** is as follows. For any row or column a glow may be obtained by timely ignition of a peripheral working cathode as heretofore established. Designate individual working cathodes as 4_n^m where m designates the column location and n designates the row location of an m by n matrix as previously defined.

Reference is made to the waveforms of FIG. **5**. The waveform of FIG. **5***a* is applied to all working cathodes 4_n^m through suitable individual cathode current limiting resistors **9** (shown in FIG. **4**). The waveform of FIG. **5***b* is applied to all stepping cathodes **25** and **25'** through suitable current limiting resistors. When the ignition address voltage FIG. **5***c* is supplied to all or any selected 4_1 cathodes, a glow will be initiated during the first half of the first instant at selected address points. During the second half of the first instant all working cathode potentials drop below sustaining potential and the stepping electrodes **25** and **25'** assume working potential. When the cathodes 4_n^m are preferential transfer cathodes directed down the line the glow is transferred to the stepping electrode **25**. When the cathodes 4_n^m are non-preferential, at the moment of voltage switching a current pulse is sent through conductors **26**. When the current pulses are directed down the line in the direction of ascending row cathodes, the glow discharge is propelled in that direction. The timing magnitude and duration of these current pulses is indicated in FIG. **5***d*. The successive stepping of glow bits down the line of paralleled register rows is by now apparent. FIG. **5***e* shows oppositely directed current pulses used to step the glow in the opposite direction.

When the localization of glow about anode-hole-working cathode pairs is strong in preference to a tendency to wander over the anode, the device has bistable properties as to location of glow. Then properly proportioned current pulses along conductors **26** will blow the glow bits from working cathode to working cathode. The stepping cathodes **25** are not required in this case but by sending a suitably proportioned current pulse down them the glow bits can be blown down the columns step by step. Thus both row by row and column by column stepping is feasible in the embodiment of FIG. **6** and by means of more than one species.

It is apparent that being able to shift registers in parallel along both rows and columns and being able to read in and out at peripheral electrodes, provides a means to serially write information into a register or group of registers and to be able to read out this information in parallel. Conversely information may be addressed in parallel and read out serially.

It is also apparent that information may be shifted up or down, right or left in ordered arrangement using this invention by simply reversing propulsion currents addressed to selected conductors or properly sequencing stepping voltages applied to the same conductors used as cathodes.

While in the particular embodiment of FIG. 6 the conductors 26 are at anode potential, these conductors can be insulated from the anode and so spaced therefrom to serve as stepping cathodes.

When directional cathodes are used, it is not necessary that both stepping cathodes and working cathodes be directional. Either one or both should have directional properties. When stepping by rows and columns is required the directional characteristic at each working cathode is set at 45° pointing partially in the direction to be stepped. It is obvious that when directional cathodes are employed the register stepping cannot be reversed from the preset conditions unless current stepping is used to overcome the preference mechanism.

FIGS. 7 and 8 show another preferred embodiment of this invention made in accordance with the species shown in FIG. 1. It is first a 5 × 7 matrix array of glow discharge cells suitable for the display of alphanumeric characters of the 5 × 7 dot matrix font. It is secondly a quinary shift register where five register rows of seven bits each are adapted to be shifted in parallel. It can be addressed at five terminals on either end of a row and it can be read out at the corresponding end. In FIG. 7 it is shown displaying the letter E in accordance with the coded sequence shown in FIG. 9.

The alphanumeric character display shown in FIGS. 7 and 8 is comprised of:

A hermetic header 1 which supports a 5 × 7 array of working cathodes 4, suitable stepping cathodes 5 and 6, current limiting resistors 9 for each cathode and terminals adapted to receive necessary control signals and voltage potentials;

A cover glass 2 with plane or lenticular faceplate and conductive anode coated backside having a configuration of holes through which the working cathodes are visible. A recess in the header in which the working cathode-ends terminate an in which the stepping cathodes are disposed is filled with suitable gas or gas mixture at suitable pressure to permit a glow discharge condition. The cavity is sealed and the enclosure completed by fusion of the cover glass 2 to the header assembly 1.

Structure of this embodiment is best learned by reference to FIG. 8 which shows several views of the device. FIG. 8*a* shows the orientation of the holes of the anode 3 with respect to each working cathode 4. Also shown is the relative positions of the stepping cathodes 5 and 6 and their respective separation and parallel connection of all 5 cathodes to electrode pin A and all 6 stepping cathodes to electrode pin B.

The side elevation FIG. 8*b* is taken through section *aa'* of FIG. 8*a*. The terminal pins 4 and 4*a* are set in the header by conventional multiform glass header manufacturing techniques as one example. The row terminating pins 4*i*, where *i*=1 to 5 and 6 to 10, are continuations of the terminal working cathodes and serve as address terminals or read terminals. The remaining working cathodes 4*a* terminate just beyond the rear of the header. The stepping cathodes 5 and 6 are spaced equidistant between the working cathode electrodes and are fused to the header surface. A shoulder cast as an integral part of the header 1 provides a mounting surface for the faceplate 2 and anode 3 which terminates in anode terminal C.

FIG. 8*d* shows the back of the header upon which is evaporated a resistance coating 9' comprising all the working cathode series resistors 9. The conductors 7 set in or on the back of the header serve to divide the resistance equally between cathodes. All of the conductors 7 are connected together and terminate in terminal 8. FIG. 8*c* is an end elevation section cut through section bb' of FIG. 8*a*.

In operation the anode terminal C is adapted to be grounded. All other terminals receive programmed voltages as explained below.

FIG. 9 shows general waveforms and timing sequence suitable for operating the character display when an E is to be displayed. At FIG. 9, C is a clock voltage used for timing. The waveform K is a programmed cathode voltage applied to terminal 8 and varies between working potential and extinguishing potential. At FIG. 9, A is the A stepping cathode potential applied to terminal A; B is the B stepping cathode potential applied to terminal B.

Shown in FIG. 9 aligned with terminal cathode pins 4_1 to 4_5 inclusive, of FIG. 8*c*, are the respective sequence of ignition voltages applied thereto. Drive amplifiers a couple the sequence of ignition pulses into the respective working cathodes in synchronism with the clock timing voltage. To enter the letter E the stepping starts one instant before the ignition encoder starts. This preliminary operation moves the letter last written out of row 1 and prepares it for the incoming ignition code. At the second instant with stepping voltages cooperating with activated discharge cells the lighted bits are stepped into place to display the letter E. Upon termination of the seventh instant, stepping stops and the letter E is displayed in the register. When stepping is enabled for another sequence of seven instants, the letter E code is moved out of the register to be discarded or for further processing. At the same time another letter or numeral or other symbol is encoded and written into the display.

This embodiment of the invention is designed for parallel address to a row, to be advanced sequentially along the column as opposed to the example given under brief description of the invention. This display as shown is suitable for digital meter-readings and other uses will be obvious to those familiar with the digital art.

Wherever in the above disclosure anode and cathode are used to denote specific electrodes, modification attempts may be made to interchange the function of these electrodes. Such modification will fall within the scope and spirit of this invention. For instance, when alternating current is used to provide working and stepping potentials, the electrodes will alternate their function.

The embodiments illustrated in FIGS. 10 to 14 inclusive illustrate the combination of the visible shift register as hereinbefore specified with known circuit means to accomplish well known shift register operational embodiments. The invention here being the visibility afforded by the register/display, which, with properly encoded data, may be character oriented rather than bit oriented. The 5 x 7 dot matrix font shown in FIG. 7 is an example of character oriented encoding. For the benefit of those skilled in the computer art, only a brief description of the blocks referenced by numerals should suffice.

LIGHT ADDRESS SYSTEM

A typical working cathode material would be, but not limited to **52** nickel alloy. Other metals may be used to plate or cap the working cathodes to suit specific requirements. When materials having high photoemission, such as the alkali metals (but not limited to them) are used to coat the cathodes of gas discharge cells, it is known that ignition can be achieved at lower than normal ignition voltage. Under suitable conditions of lighting obtained from a laser beam or a light address pen, a glow can be struck in any arbitrary cell when the ignition potential is depressed by photoionization, to the cell working potential. Such a means can be implemented in this invention to write on the display.

Although specific embodiments of this invention have been shown and described, it will be understood that they are but illustrative and that various modifications may be made and shifting may be accomplished by any of the three species shown, singly or in combination. Such modifications may be made without departing from the scope and spirit of this invention.

What is claimed is:

1. A self-luminous information display and visible store shift register, the combination of: a multiplicity of electrodes and an ionizable gas contained in an enclosure, said electrodes being in pairs comprised of anode and working cathode in cooperative relationship and arranged in an array, and having current limiting means in each of said working cathode leads; said electrode pairs having glow sustaining means and glow extinction means and said ionizable gas being readily ionized by ignition means between more than one of said electrode pairs simultaneously and thereby exhibiting more than one localized glow discharge throughout the array; at least one conductor adaptable as an electrode in said envelope adjacent to at least one of said electrode pairs and adapted to promote cooperation between influenced adjacent electrode pairs so as to transfer said glow discharges from pair to adjacent pair in response to electrical stepping means impressed upon said conductor(s).

2. The combination of claim **1** wherein the conductor(s) between adjacent electrode pairs are stepping electrodes having individual terminals, each of said terminals being excited with one different phase of a polyphase stepping potential, where the number of phases is equal to the number of conductors used between said electrode pairs.

3. The combination of claim **1** wherein the number of conductors between adjacent electrode pairs is limited to one stepping electrode and the working cathode of each electrode pair is a preferential glow transfer cathode, said stepping electrodes having means for receiving single phase stepping potential applied thereto and means for applying a complement of said stepping potential to said preferential glow transfer working cathodes.

4. The combination of claim **1** wherein said conductors adjacent to each electrode pair is limited to two effective conductors, one of said effective conductors being disposed on each side of a line of electrode pairs for each stepping direction, and having terminal means by which current pulses may be applied to said conductors to step by magnetohydrodynamic propulsion the glow discharge of each cell when glowing.

5. The combination of claim **1** wherein the said conductors adjacent to each electrode pair is limited to two, one of said conductors on each side of a line of electrode pairs for each stepping direction, said conductors being used alternately as conductor and as electrode such that: when the glow is being stepped in any direction the conductors encountered along said direction, with suitable stepping potential applied, are used as voltage stepping electrodes, and the conductors parallel to that direction, with suitable stepping current pulses applied, are used as current stepping electrodes and to impart preferential glow transfer characteristics to the working cathodes involved.

6. The combination of: a multiplicity of electrodes and an ionizable gas contained in an enclosure, said electrodes being in pairs comprised of anode and working-cathode in cooperative relationship having individual current limiting means and arranged in an array, said electrode pairs having glow sustaining means and glow extinction means, said ionizable gas being readily ionized by ignition means between more than one of said electrode pairs simultaneously and thereby exhibiting more than one localized glow discharge; in combination with electrical means to promote cooperation between adjacent electrode pairs of said array so as to transfer said glow discharges from cell to cell in an ordered manner in at least one direction.

7. The combinations of claim **6** wherein said electrical means comprises at least two conductors outside said enclosure running parallel to at least one line of electrode pairs and having one conductor on either side of said electrode pairs and terminal means on said conductors adapted to receive glow transfer current pulses, for the purpose of propelling said internal glow discharges from terminal pair to successive terminal pair in response to said current pulses.

8. A shift register having electrical input and electrical output means and optional visual means, comprising at least one row of bistable glow discharge cells all of said row(s) enclosed in one envelope containing an ionizable gas, first electrode means for entering a binary sequence into at least one of the said rows and second electrode means for moving out of each row, a binary sequence respectively stored in each row.

9. The shift register of claim **8** wherein said means for entering a sequence into a row is sequential and other sequences into other rows is also sequential bit by bit in synchronism with a means for stepping the condition of the first cell of the number of rows used to the second succeeding cell and through said row cells until all cells have been selectively set in accordance with the respective sequence.

10. The shift register of claim **8** wherein means for moving out a sequence is sequential bit by bit in synchronism with a resumption of the row sequential stepping means until all cells of a row have been emptied of the sequence previously stored.

11. The shift register of claim **8** wherein said means for entering a sequence into a row is in parallel and other words into other rows is by advancing said first written word in parallel, sequentially row by row along the columns by a stepping means which operates in synchronism with the said parallel writing means until all sequences have been entered.

12. The shift register of claim 8 wherein means for moving out a sequence is in parallel in synchronism with the resumption of the said stepping means for parallel transfer of sequences along the columns.

13. The shift register of claim 8 wherein binary sequences are entered sequentially and taken out of the register in parallel.

14. The shift register of claim 8 wherein binary sequences are entered in parallel and taken out of the register serially.

15. The combination of claim 1 wherein said working cathodes have photoemissive properties and said ignition means is through illumination of at least one cell using a laser beam.

16. The combination of claim 6 wherein said working cathodes have photoemissive properties and said ignition means is through illumination of at least one cell using a laser beam.

17. A gaseous discharge device comprising:

a gas filled envelope,

said gas filled envelope containing a multiplicity of cooperating electrodes having individual current limiting means to form a multiplicity of gas discharge cells, in combination with: means for the dc excitation of, more than one of said gas discharge cells and controlling said gas discharge cells into one of two states, that of non-conduction and that of conduction giving rise to a visible glow, means for promoting cooperative relationship between adjacent cells so that the glow at one cell can be transferred to any adjacent cell and such that no glow existing at a particular cell will result in no glow in said adjacent cell to which transfer action occurs, such means being adaptable to transfer an ordered pattern of glow bits in an ordered manner across the cell configuration in at least one direction.

18. In a visible store stepping register comprising: at least one row of bistable glow discharge cells having individual current limiting means, means for stepping the one or zero condition of the glow discharge of any cell to another adjacent cell in response to an electrical stepping signal,

means for entering a quantity into the first cell of the series by selectively controlling the cell to a one or zero condition as required by said entry, means for stepping at one speed the one or zero condition of said first cell to the next cell and through the row until all cells have been selectively set in accordance with a sequence of values equal to the number of cells in the row,

means for stepping the entered ones or zeros out of said row, at another speed of stepping.

19. The visible store stepping register of claim 18 whereby said output stepping means and said input stepping means are synchronous and means is provided for recirculation of the sequence of values continuously so as to form a recirculating stepping register.

20. The visible store stepping register of claim 18 whereby said output stepping means and said input stepping means are synchronous and said register constitutes a delay line register.

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