Conference on

DISPLAYS

7—10 September 1971

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Contents

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A DIRECT VIEW STORAGE TUBE WITH SELECTIVE ERASURE AS A DATA TERMINAL DISPLAY

A.B.E. Ellis.

Work has been carried out on a standard Direct View Storage Tube (D.V.S.T.) to selectively erase information written and stored on the storage target (mesh). Subsequently it was decided to evaluate the usefulness of this technique and a computer data terminal was chosen as the means by which this might be done.

Terminal Configuration The type of terminal was determined from the economic comparisons with existing commercial devices. In view of the extra cost of the D.V.S.T. over a normal C.R.T. it was decided to offset this by using no local storage apart from that on the display storage target. Its use in a simple alpha-numeric Video Data terminal was rejected owing to the low cost of commercial products and the simplicity of the storage requirement, and because the scope for evaluation of selective erasure would be limited. A graphics facility was included, as this increases the versatility and requires a larger storage capability in competitive devices. Operator interaction was deemed necessary to widen the scope further and to provide a useful demonstration of the selective erasure application. Since more exotic devices of this nature include large refresh stores and in some cases a satellite processor, the use of a D.V.S.T was confined to the simpler approach and the lower cost region of interactive graphics terminals. In order to cater for the kind of customer a low cost terminal would attract it was designed to operate over a G.P.O. link making use of the Datel 1A Modems in which the operator data is fed to the Central Processor (CP) via the slow channel (75 baud) while the CP supplied data over the fast channel (600/1200 baud). The circuits and timing were therefore tailored towards this slower operation and resulted in a reduction in hardware costs.

As the selective erase operation results in a loss of the displayed picture until the erasure is completed the display is continuously cycled between 'write' and 'erase' modes. This ensures continuity of visual display while the selective erasure is being carried out. The switching frequency is at about 800Hz in order to avoid electro-mechanical resonances of the storage target at lower frequencies (200-400Hz). This switching poses problems for the operation of the terminal which will be dealt with later.

A block diagram of the terminal is shown in figure 1 in which only the broad areas are shown for clarity. Only the less conventional aspects of the equipment will be dealt with.

The Display Unit The method used for operating the D.V.S.T. will now be discussed in conjunction with figure 2 which shows the components of the E712A 11 inch D.V.S.T.

Under normal operation i.e. in the 'write' mode the tube has the following potentials applied:

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Writing gun cathode	-5kV
Flood gun cathode	0V
Flood gun grid	+3-4V
Collector Mesh	+250V
Storage Mesh	+4-5V
Viewing Screen	+10kV

The collimating electrodes for the flood gun are provided with preset voltages in the range 20-250V and are set up for good collimation of the flood beam (even brightness over the tube face).

In operation the target is first cleared by an erase-prime procedure in which the backing electrode of the storage mesh (nearest the front of the tube) is raised to about +250V via a suitable resistance. This ensures that the target dielectric which is deposited on the rear of the backing electrode (i.e. the side facing the writing gun) collects flood electrons over the whole surface, filling in any previously written charge pattern. It is held there for several milliseconds. The potential is now reduced to between +8 and 10V for some tens of milliseconds enabling the target dielectric to accumulate a uniform charge of flood electrons over the surface. The dielectric charges down to about 0V, the flood gun cathode potential. The backing electrode potential is now reduced to its normal working value of 3-5V which results in a dielectric charge of about -5V over the whole target surface and cutting off of all flood gun electrons which are gathered by the collector mesh instead. The effect of this upon the display is a momentary flash on the screen followed by a darkened screen. The whole process takes about 100ms.

Writing and storage is now achieved by unblanking the write beam to produce electrons of sufficient energy to release secondary electrons from the storage dielectric. These electrons are gathered by the collector mesh which is itself too coarse to affect the writing beam directly. The regions in which 'writing' has taken place are thus positively charged to a maximum of 0V, and this allows the collimated flood beam to pass through these areas and to be accelerated to the viewing screen which is at 10kV. This results in a steady picture which persists after the write beam has been cut off.

The storage time is limited due to the gathering of positive ions by the target dielectric which raises its potential, the effect being that the viewing screen is slowly brightened as the flood beam is allowed to pass through the storage mesh. Positive pulses applied to the backing electrode provide cancellation of this effect by allowing some flood electrons to be gathered, cancelling the positive charge, but eventually the charge pattern becomes uneven and a full erase and prime procedure is required. In the terminal this is known as a 'page refresh' and is available as a manual demand or as an automatic request at 3-5 minute intervals.

The selective erasure is carried out by altering some of the electrode potentials in order to result in an accumulation of electrons at the appropriate point on the target dielectric when the write gun is unblanked. This is achieved by raising the storage mesh to about +350 volts, at the same time the collector mesh and the viewing screen are reduced to -50 volts to provide a retarding field to any electrons emitted by secondary emission from the dielectric surface. The flood gun is also cut-off to prevent its electrons reaching the now positive dielectric surface.

Some spread of electrons occurs in their return to the dielectric causing a loss of resolution on selective erase. This however eases the problem of registration accuracy of the deflected beam under the two different electron velocities. In fact a simple deflection sensitivity change is also made to maintain registration over the storage target.

The change of voltage at the viewing screen requires a 10kV electronic switch. The screen capacitance is several hundred picofarads which requires about 10mA constant current to complete the discharge in 200 μs.

Since the switching time is a total of 400 μs in one write/erase cycle of the terminal, about 400 μs is left for each of the two modes.

<u>The Graphics and Character Generators</u> The character generator is of the stroke-writing type which has been slowed to enable the deflection waveforms to be fed through the main deflection system (No high speed auxillary deflection is used). The characters are timedto start at the beginning of a write cycle to enable about three characters to be written in any mode.

The graphics generator employs two binary rate multipliers to provide digital outputs which are D-A converted before being used to deflect the writing gun beam. The writing time is deliberately slow (about 15ms total) and as it cannot complete a line within a write/erase half cycle (400 μs) the binary rate multipliers are gated to operate only in the appropriate active regions. Outside this gate they hold their information. Lines are thus drawn in short bursts. The graphics generator is very versatile and simple in its concept, it also has the advantage of 'infinite' storage time by holding the last deflection position while awaiting the next instruction from the operator or central processor.

<u>Graphics Input Devices</u> The use of a D.V.S.T. display introduces problems for interactive operation due to the method of display. For example a light pen cannot be used in its usual mode as the picture does not recycle, at least not more often than once in 3-5 minutes! If a rolling ball is used the spot or cross will leave a stored trail as it is moved around the screen. Several input devices were tried and will be briefly mentioned.

A transparent resistive film deposited on glass was used as a tablet which was fitted in front of the display screen. The tablet was energised with a d.c. signal, switched between the two axes. A probe was used to pick off the voltages which were converted to digital form and used as x-y position coordinates.

The resulting spot deflection on the screen could be seen through the tablet and adjusted if necessary. This method required direct contact between the probe and the resistive surface which caused wear and scratching. A similar tablet was used in which an insulating wear-resistant film covered the resistive film. The resistive film was energised with an alternating signal of about 1.2KHz frequency in such a way as to produce a linear phase shift across the energised axis. The probe signal picked up by capacitive coupling carried the position co-ordinate information in its phase with respect to one of the energising voltages. This method proved very insensitive to probe distance from the tablet and gave good results. In order to reduce the effect of coupling from the D.V.S.T. screen which was being switched through 10kV at 800Hz, a second transparent film was deposited on the rear side of the glass panel. This was earthed and provided an adequate screen.

A second device which was tried was a light pen. It is not possible to locate the position of the pen by comparison of the photocell response with the part of the refresh cycle reached when the response occurs. There are two reasons for this, there is a time lag when the terminal is refreshed from a remote central processor and the refresh only occurs at about 3-5 minute intervals. A different system was therefore tried in which, on demand the operator could initiate a raster covering the screen. This was written once and was sufficiently faint to leave no stored pattern. The writing current was controlled however to ensure a response from the photocell in the light pen. If this did not occur, up to three trials followed automatically. The cumulative use of the raster produced a progressive build-up of charge on the target until eventually it became visible. However a sufficient number of operations was possible between refreshes of the displayed data to provide a useful alternative input system.

During work on the transparent tablet the registration between the probe and the display position was not sufficient to enable a line to be joined to a specific point on a graphical picture and a 'cursor' mode was introduced which enabled a fine adjustment to be made. This was a local operation in that nothing is fed to the computer until the operator is satisfied with the spot position. Use is made of the write/erase cycle to prevent a stored 'trail' appearing on the screen. For each address produced from the probe the display operated for a complete cycle of write and erase, displaying the spot and then erasing it before a new address could be inserted. In this way the spot could be moved around the screen and adjusted to the operator's satisfaction. This suffered from the disadvantage that, as the spot was moved through an existing line a gap was left due to the erase cycle. This was not found to be troublesome and on refresh the correct picture was restored.

This 'cursor' mode led to reconsideration of the rolling ball as an economic input device and this was fitted using the cursor mode for its operation. A wrist bar or foot switch was introduced to cut off the writing beam when moving the spot across displayed data, thus reducing the gaps in a picture while moving the spot around.

<u>Terminal Operation</u> The method of operating the terminal was to keep a record of all data in a 'file' in the central processor. All characters and line addresses were sent to the central processor and returned to the terminal providing a check on the accuracy of the filed data. Lines were erased by over-writing in the erase mode but to reduce complexity all characters were erased by a small raster equal in size to the character.

The terminal was found to be a useful operational device and the interactive facilities, although limited, provided good control over the display for both graphics and alpha-numerics. Editing of alpha-numerics was easily accomplished and graphics modification very efficient. The equipment could be built as a competitive device despite the higher cost of the tube, its supplies and their switching. Some disadvantages were a poorer resolution compared to conventional CRT's, a rather small useful screen area and some non-uniformity of display brightness due to imperfect flood gun beam collimation. Work is however proceeding to improve these characteristics.

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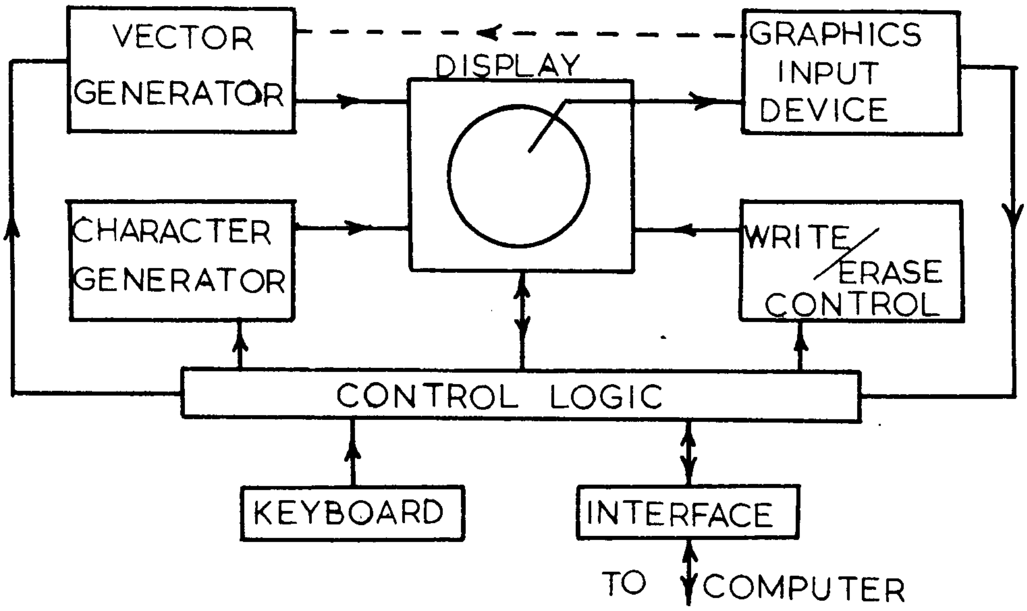

FIG.1 D.V.S.T. DATA TERMINAL

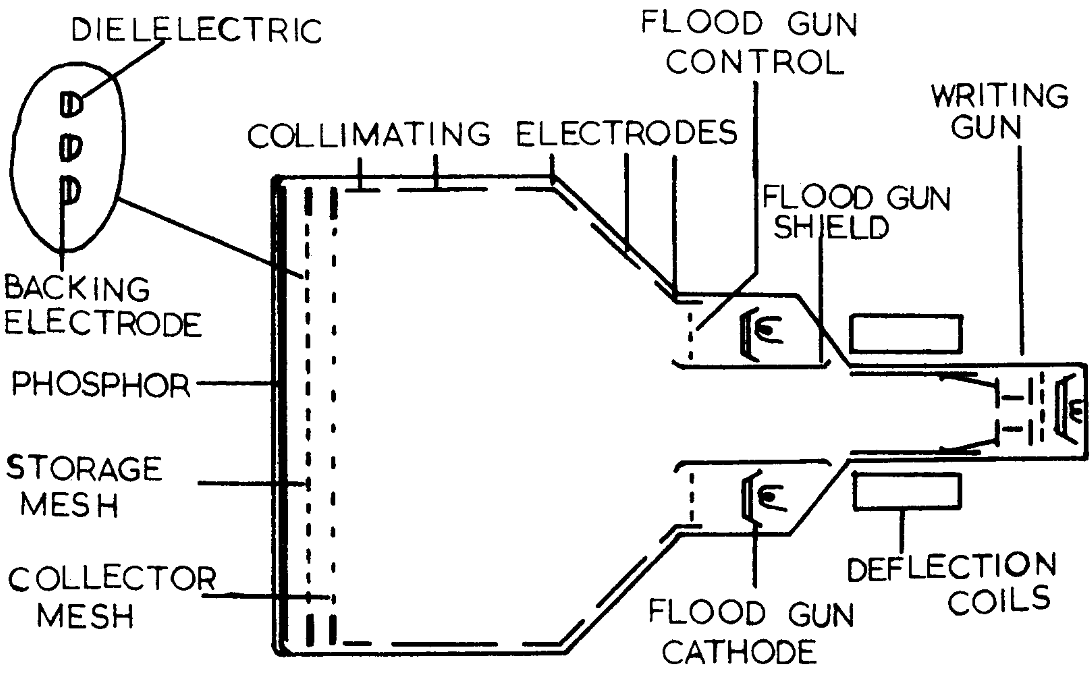

FIG.2 DIRECT VIEW STORAGE TUBE

DC GAS DISCHARGE MATRIX DISPLAYS

F. Walters

The DC gas discharge matrix display consists of a series of common anode lines at right angles to a series of common cathode lines. At each intersection a small gas cell and series resistor connects the anode line to the cathode line. When the appropriate voltages are applied the gas cells ionise forming a discrete light emitting area. The design of cells which have a higher striking voltage than running voltage allows the matrix to be driven such that selective writing, memory and selective erasing can be obtained.

A voltage level diagram Fig. 1. shows the necessary conditions for achieving this. Half voltage pulses Vp/2 are applied to the common anode and common cathode lines. When only one half voltage pulse increases the applied voltage to any cell it must not strike but when the anode and cathode pulse reinforce one another any cell must strike. By reversing the pulses similar conditions apply for selective erasure. In order to have selective writing and selective erasing on a panel then either the spread in extinction or striking voltage, whichever is greater, must be less than half the voltage gap between striking and extinction. If this condition is not satisfied the matrix can still be operated as either a selective write only device with line or panel erase or selective erase only. With this mode the panel or line is written up completely and the appropriate elements erased.

The final choice for addressing and the method of driving will depend on the specific applications and the cost of achieving the desired performance.

Cell Characteristics Fig. 2. shows some of the factors affecting the cell DC striking voltage and DC running voltage. By a combination of type of gas, spacing and pressure a wide variation in nominal striking and running characteristics can be achieved. On a panel with integral resistors the equations governing the maintaining condition are: $V_m = V_r + I_r R$, where V_m = maintaining voltage, V_r = Running voltage, I_r = Cell running current R = Cell series resistor.

For extinction the condition is:- $V_{ex} = V_r + I_e R$ where I_e = extinction current and depends on the value of R and the cell diameter. For cells 0.5mm diameter and R = 4.0 Megohms, I_e = 10 Microamps.

Typical designs aim at having the lowest striking voltage, lowest pulse amplitude for addressing and lowest dissipation, consistent with achieving the necessary cell density, luminance and low spreads on the striking and erasing voltages. With V_m = 260 volts; R = 4 Megohms; I_r = 20 microamps a luminance of 4,000 Nits can be achieved in the centre of the light emitting area.

The viability of any design for selective writing and erasing depends on the spread in the nominal value of the striking voltage and erase voltage over the complete panel.

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Striking Voltage Spread The factors affecting this spread are:-

(a) Availability of free electrons for initiating a discharge.
(b) Physical size variations in the cell.
(c) Choice of gas.
(d) Design of panel to minimise crosstalk.
(e) Pulse width and number of pulses used for writing.
(f) Driving circuitry design.

All these factors tend to be inter-related and the definition and measurement of striking voltage spread needs to be directly related to a specific application. The initial research in DC panels was with a 16 x 16 matrix with a cell density of 64 cells/cm^2 and all subsequent results refer to assessing this type of panel for random access addressing.

Some form of priming is essential in order to restrict the overvoltage needed for reliable breakdown. With efficient priming cells can strike in 30 microseconds, but require a certain overvoltage (above the DC striking voltage) in order to ensure reliable operation with single pulse addressing. Using a train of pulses will reduce the overvoltage but complicates the driving circuitry.

Devices have been made using tritium gas as a priming agent which require overvoltages of 1% with 500 microseconds pulse 4.0% with 200 microsecond pulse and 6.5% with 100 microsecond pulse. These figures apply under the worse case conditions i.e. with no other adjacent cells on and one pulse operation. The maximum striking voltage level on a panel must be determined under these worst case conditions.

The minimum striking voltage should be determined with adjacent cells on so any crosstalk effects are included. Devices have been made in which the minimum striking voltage varies by less than 1% with variation of pulse width or the number of adjacent cells on.

When a line of information is to be written instantaneously the drive circuitry must have a low enough impedance to prevent regulation effects increasing the spread.

The manufacturing techniques which affect items (b), (c) and (d) have not been optimised and the spread due to these factors can still be excessive. The lowest spread in striking voltage using DC voltages has been 20 volts over a 4 character area. Allowances for pulse overvoltage and other margins indicate a minimum half pulse voltage of 50 volts can be obtained. At this stage of development it is difficult to state what efficiency would be obtained in achieving a particular spread over a specified area.

Erase Voltage Spread. The erase condition has one advantage over the striking conditions, namely that priming is not involved and the statistical lag is zero. With a 100 microsecond pulse only 2.5% overvoltage is needed for erasure.

The control of the erase spread is again not yet optimised and the lowest spread obtained is 30 volts, allowing 40 volt half pulses to be used. Selective erase mode of operation is a more reliable mode than selective write.

Typical Device Characteristics. No device has yet been made which allowed selective write and selectkive erase at the same maintaining voltage.

The type of results being obtained are as follows. The results are pulse measurements and the devices do work under the specified conditions.

Device 1. V_S max = 435 V_S min = 370
V_E max = 275 V_E min = 230

With 280v maintaining and half voltage pulses of 80 volts 100 microsecond duration, random access selective write is possible. With 340v maintaining and half voltage pulses of 60 volts 100 microseconds duration, random access selective erase is possible.

Attempts to improve devices by increasing the pressure to give a greater differential between strike and erase usually leads to other defects such as a deficiency in priming which in turn means a higher spread and no benefit is obtained.

Device 2. V_S max = 365 V_S min = 315
V_E max = 240 V_E min = 195

With 250 volts maintaining and 60v half pulses of 100 microseconds duration, random access, selective write is obtained. Alternatively with 310 volts maintaining and 60v half pulses random access, selective erasure is obtained.

These devices operate with about 20 microamps running current and have a luminance of 4,000 Nits.

Contruction. The major problem initially with the DC gas discharge panel was producing the necessary number and value of resistors plus connections in the available space. As the ultimate application is for displays with thousands of cells the use of discrete individual resistors was not considered. The various techniques considered for producing a compact resistor plate i.e. thin film, conducting glass, sputtered films and thick film, suffered from various defects, the major ones being the fabrication of sufficiently small resistors with a high resistance value. The advent of high resistivity thick film inks has enabled many of the problems to be overcome.

The present design of device is shown in Fig. 3., and it comprises three plates. The anode plate is a transparent glass window with thick film conductors fired onto it. The spacer plate is a photosensitive glass which allows accurate and precise etching of the series of holes which form individual gas cells. The resistor plate comprises L shaped resistors, printed and fired onto the substrate. One end of the resistors is common to a thick film conductor. Over all this is printed a cover glaze except at the free end of the resistor, which is left bare.

On the bare end of the resistor is deposited the nickel cathode which lines up with each hole in the spacer plate. The three plates are held together and sealed with pyroceram around the edges. The devices are then evacuated and filled with a suitable gas to give the desired characteristics. The finished thickness of the device can be as low as 4.0mms but a reservoir volume is usually added increasing the size to 6.25mms.

The production processes used are capable of high accuracy and uniformity and should eventually produce devices with controlled nominal values and low spreads in these values.

Life. The three main effects which change the device characteristics with time are:- (a) Gas Clean Up. (b) Variation of Cathode Surface. (c) Change in resistor value.

The use of a nickel cathode greatly improves the device life and devices with uniform nickel cathodes, reservoir volume and external resistors have given a life of over a 1000 hours with approximately only 10 - 20 volts change in characteristics. This is expected to improve when the factors influencing the spread in characteristics of manufacture are better controlled.

The manufacture of the correct value resistor and maintaining its value with time has not been optimised. The typical spread in resistor values after all production processes is ± 30%. The resistors are then trimmed to give a spread of ± 5% and the variation in spread with life should not be more than ± 10%. After 1000 hours running the resistor spread is typically ± 25%. Better control of the method of manufacture together with optimisation of resistor material and pre-ageing techniques should allow the necessary control to be achieved.

Circuitry. A typical drive circuit for experimental panels is shown in Fig. 4. The panel is diode coupled to the maintaining supply and the pulses are capacitively coupled to the common anode and cathode lines.

Conclusion. The DC gas discharge display matrix has a number of potential advantages over other forms of storage displays and other forms of matrix storage displays. These are:-

(a) Luminance - 4,000 Nits.
(b) High Conversion Efficiency - only 5mw per cell is dissipated at 4,000 Nits output resulting in low operating temperatures.
(c) Long Life - Because of the very low DC currents used to achieve a high light output sputtering is minimised.
(d) High Stability of Characteristics - Because of the device design crosstalk and memory effects are minimised.
(e) Cheap Display The thick film techniques used in manufacture allow cheap and reliable manufacture of the basic parts and with suitable control should result in a cheap display device.

For the present devices to be viable commercially improvements are needed in controlling the spread of characteristics with particular emphasis on control of the series resistors. Forty character displays are currently being developed and the manufacturing techniques have been extended to give cell densities of 256 cell/cm^2.

Acknowledgements. I would like to thank Ferranti Ltd. for permission to publish this paper. I acknowledge the encouragement of Mr. G. Watkins R.R.E., Mr. D.E. Bundy R.A.E., the many suggestions of colleagues and the invaluable assistance of the staff at Ferranti Ltd.,

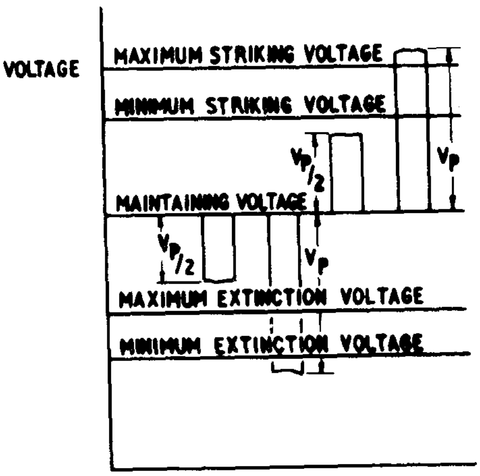

FIG. 1. VOLTAGE LEVEL DIAGRAM

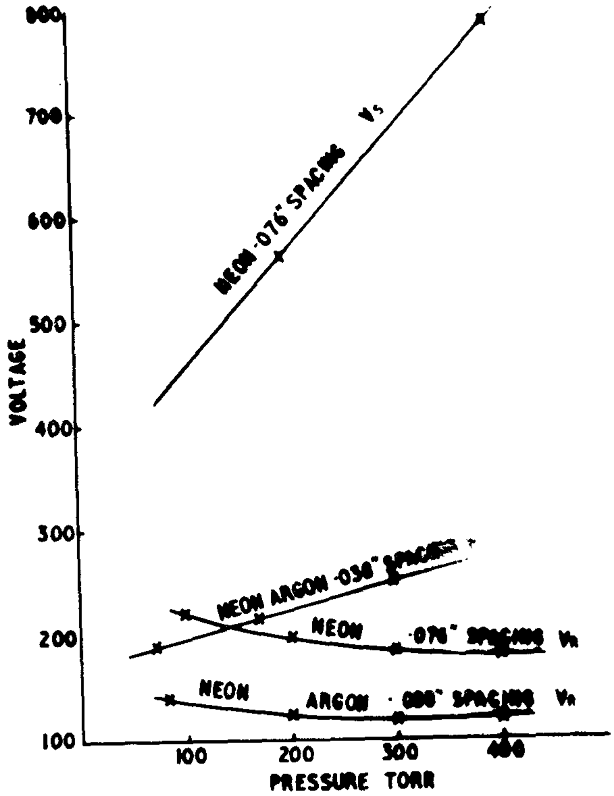

FIG. 2. FACTORS AFFECTING STRIKING VOLTAGE AND RUNNING VOLTAGE

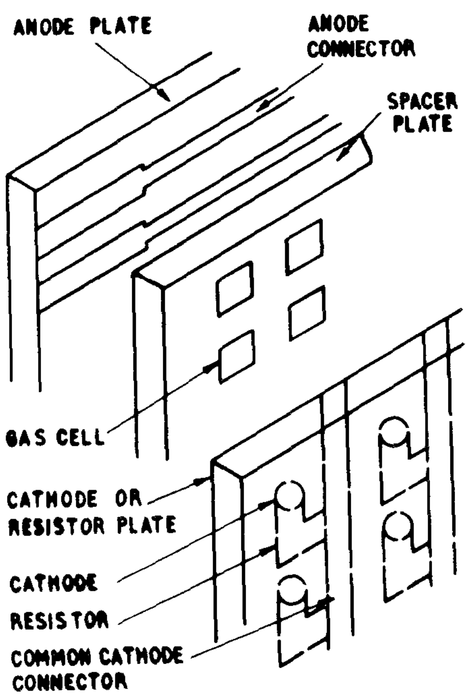

FIG. 3 EXPLODED VIEW OF DEVICE

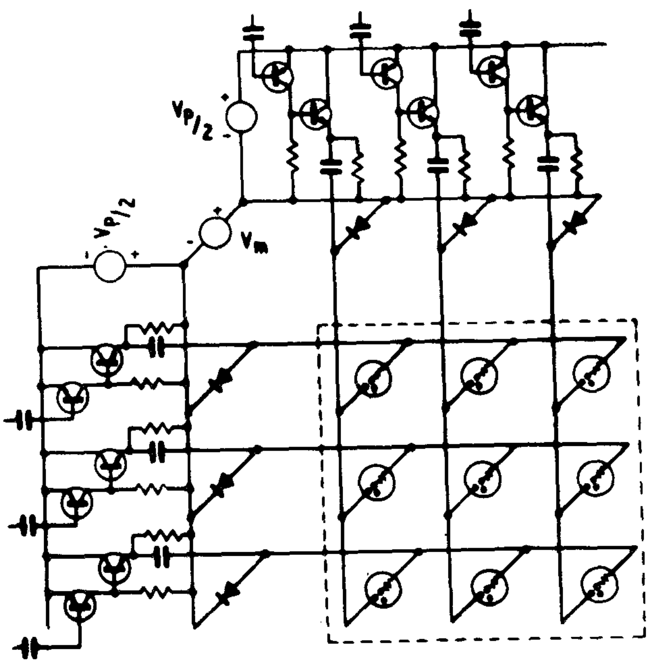

FIG. 4. DRIVE CIRCUIT FOR LARGE ARRAYS