Running text display as seen against a background of fairly low light level.

Running text display panel and control unit as seen in a normally lighted environment; the panel is a demonstration model containing 700 trigger tubes. The cabinet shown below the panel houses the power supplies as well as the control circuitry for entering information in the display.
Running Text Display with Cold-Cathode Trigger Tubes

J. G. M. Thaens* and P. H. G. van Vlodrop*

In the described display cold-cathode trigger tubes operate as memory elements for storing textual information, as switches for transporting it and, at the same time, as lights for spelling it out. Text can be written in with the aid of simple equipment which, since it neither makes use of hazardous materials nor gives rise to radio interference, can be located according to the user’s convenience. The long life of the trigger tubes and modular construction of the display panel combine to keep maintenance problems to a minimum.

Introduction

Means for putting up a running text in lights have been known for more than half a century. Though they can lay no claim to novelty, winking lights that catch the eye and make words move are still one of the most arresting of all forms of visual display. Why then are they not more widely used? There are several reasons, all of them cogent.

At least until very recently no way had been found to shrink the size and cost of the needed equipment to a scale that would-be users could afford. Complexity and maintenance expense were other deterrents. Another that was still more formidable was the mercury bath on which the commonly used switching principle depended; the health hazard it presented was one that could not be overlooked. In the face of such difficulties efforts were of course made to copy the desired effect by optical instead of electrical means, but without notable success. Now, however, it is possible to bypass the former obstacles and build small, inexpensive running text displays that have none of the complexity or maintenance problems of their predecessors. The new approach takes advantage of the unique properties of the cold-cathode trigger tube: a switching element that can also do duty as an eye-catching light source.

In the running text display to be described, the trigger tube used is the ZC1050, a neon-filled tube with a pure molybdenum cathode and a very high light output. Because of its high speed as a switch and complete lack of afterglow as a light source it lends itself to much faster operation than would be possible with most incandescent lamps. Moreover, its guaranteed minimum life of 10,000 h far exceeds that of incandescent lamps and its performance is improved rather than degraded by repetitive switching.

Only the circuit details essential to the operation of the display are described; except for a control circuit for generating suitable switching pulses, the ancillary equipment is not. Of several practical means for entering and transporting text, paper tape is probably the most convenient, but the equipment to go with it will differ considerably according to whether the tape is perforated in letter patterns or a digital code and whether it is read mechanically or optically.

* Philips Elcoma Division, Central Application Laboratory, Eindhoven.
and the same potential also appears at the cathode of $D_3$ (Fig. 3b). All other tubes are extinguished; their anodes are only fractionally below the supply voltage $V_s$ (owing to the small flow of primer current) and their trigger electrodes are all biased to 110 V.

To extinguish $V_1$ the potential of the extinction pulse line is dropped from 220 V to 0 V; the resulting negative-going transient (reduced in amplitude by the voltage dividing action of $R_1$ and $R_2$) drives the anode potential below the maintaining voltage and the tube stops conducting. (To allow for complete decay of residual ionisation and prevent accidental reignition, the extinction pulse line is held at 0 V for 880 µs; the shape of the extinction pulse is shown in Fig. 3c. It is to be noted that, as shown in Fig. 3d, the pulse also momentarily lowers the anode potential of all other tubes besides $V_1$, but for those that are already extinguished this is of no consequence.)

After its initial fall the anode potential of $V_1$ rises again towards $V_s$ at a rate determined mainly by $R_1$, $R_2$ and $C_2$; as it does so, the cathode potential of $D_2$ also begins to rise, though more slowly because of the much longer time constant of the network $R_3 R_4 C_3$. At the end of the 880 µs of the extinction pulse an ignition pulse (Fig. 3d), rising to 320 V from a base of about 120 V, is applied to the common line connecting the anodes of $D_1$ to $D_n$ and is passed almost completely by $D_2$, the cathode of which is still at a comparatively low potential. (In response to the ignition pulse the cathodes of all other diodes drop slightly below 320 V so that a pulse is also passed to the trigger electrodes of the other tubes, but it is much too small to ignite them.)

The requirements for ignition — a bias voltage supplemented by a pulse of sufficient amplitude to exceed the triggering threshold — are therefore fulfilled only at the trigger electrode of $V_1$. Accordingly that tube ignites and its anode potential immediately drops to the maintaining voltage. The capacitor $C_3$ then discharges by way of $R_1$, bringing the cathode potential of $D_n$ down to the same level and establishing the prerequisite condition for subsequent ignition of tube $V_n$.

In this way each extinction pulse extinguishes the conducting tube and each ignition pulse ignites the next tube to the right; conduction is therefore stepped from tube to tube along the register.

If the circuit is connected as a ring, when $V_n$ is extinguished, the next tube to ignite will be $V_1$, and the entire cycle will continue to repeat itself. If it is not connected as a ring, the condition at the trigger electrode of $V_1$ must be changed by external means (i.e. via the information input) to start a new cycle.

For the sake of simplicity the foregoing description of the operating cycle was based on the assumption that only one tube at a time was conducting; however, inspection of the circuit will show that this limitation is by no means a necessary one. In fact, any number of tubes up to $n$, in any arbitrary sequence, may be conducting simultaneously. Each conducting tube establishes the prerequisite condi-
tion for igniting the next tube to its right; so the
effect of each extinction pulse will be to extinguish
any conducting tube that does not have another con-
ducting tube immediately to its left, and of each
ignition pulse to ignite any non-conducting tube
that does have a conducting tube on its left. An
arbitrary pattern of information stored in a nine-
place register connected as a ring would change as
indicated below over three shift sequences (1s being
used to indicate a conducting and 0s a non-conduct-
ing tube):

after \( n \) shifts \[1\ 0\ 1\ 1\ 1\ 0\ 1\ 0\ 1\]
after \( n + 1 \) shifts \[1\ 1\ 0\ 1\ 1\ 1\ 0\ 1\ 0\]
after \( n + 2 \) shifts \[0\ 1\ 1\ 0\ 1\ 1\ 1\ 1\ 0\ 1\]

Information is admitted to the shift register by
way of the switch \( S \), which communicates with a
two-valued voltage source. When the source voltage
is 140 V (\( \approx V_E \)) the tube \( V_1 \) will be ignited and a
1 entered in the register as soon as an \textit{ignition} pulse
is applied; and when the source voltage is 320 V
(\( \approx V_S \)), the tube \( V_1 \) will be extinguished and a
0 entered in the register as soon as an \textit{extinction}
pulse is applied. Information once entered can be
stored for continuous recycling by moving the
switch \( S \) to the "ring" position.

To minimise ignition delay a small primer current
is drawn continuously by way of diode \( D_{14} \), the
cathode of which is returned to 0 V; and to prevent
the primer discharge from being extinguished during
the shift sequence, the anode-to-primer voltage is
augmented by capacitor \( C_7 \), which passes the
negative-going extinction pulse to the primer electrodes
of all tubes.

The calculated operating tolerances of the shift
register are tabulated below:

<table>
<thead>
<tr>
<th>Description</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extinction time, ( \tau_{ex} )</td>
<td>880 ± 50 ( \mu s )</td>
</tr>
<tr>
<td>Ignition time, ( \tau_{ig} )</td>
<td>60 ± 10 ( \mu s )</td>
</tr>
<tr>
<td>Supply voltage, ( V_S )</td>
<td>320 V ± 10%</td>
</tr>
<tr>
<td>Bias voltage, ( V_b )</td>
<td>110 V ± 5%</td>
</tr>
<tr>
<td>Extinction pulse (p-p), ( V_{ex} )</td>
<td>220 V ± 15%</td>
</tr>
<tr>
<td>D.c. level of ignition pulse line, ( V_i )</td>
<td>120 V ± 15%</td>
</tr>
</tbody>
</table>

Measurements have shown that when \( V_S \) is derived
by way of a voltage reference tube from \( V_S \), variations
of \( \pm 15\% \) and \( \pm 20\% \) in the latter are tolerable.

**Control Circuit**

The shift register can be driven by any source
able of supplying the required sequence of pulses.
A circuit which has proved satisfactory in practice
and has little sensitivity to either r.f. interference or
supply voltage fluctuations is diagrammed in Fig. 4;
it can be operated either as a free-running pulse
operator of variable frequency or as an externally
triggered one.

Transistors \( TR_1 \) and \( TR_2 \) are connected as a
Schmitt trigger. When switch \( S_{1a} \) is closed (\( S_{1b} \)
open), one positive-going pulse is produced at the
collector of \( TR_2 \) in response to each operation of the
push-button switch \( S \). When switch \( S_{2a} \) is closed
(\( S_{2b} \) open), the output pulse of \( TR_2 \), amplified
and inverted by \( TR_3 \), is fed back to the base of \( TR_1 \),
making the circuit astable. In this mode of oper-
ation, the pulse repetition frequency can be varied
between 8 Hz and 90 Hz by means of the adjustable
resistor \( R_e \). The operating cycle can be understood
by reference to the waveforms \( a \) to \( d \) pictured in
Fig. 5.

The pulse output of \( TR_3 \) is amplified by \( TR_4 \) and
after being differentiated mainly by the network
\( C_9 R_{21} R_{22} \), applied to the base of \( TR_5 \) (see Fig. 5e;
for the collector voltage of \( TR_5 \) see Fig. 5f). With
the aid of resistor \( R_{32} \), the width of the nega-
tive-going spike can be adjusted so as to drive the trans-
istor into cut-off for 880 \( \mu s \), the time required to
extinguish the tubes of the shift register. To obtain
the requisite amplitude and power, the extinction
pulse is further amplified by \( TR_6 \), \( TR_7 \) and \( TR_8 \).

As indicated in Fig. 5g, as soon as \( TR_6 \) is cut off,
the extinction line rises suddenly by an amount \( V_p \)
which depends on the number of tubes in the display.
To prevent this from causing spurious ignition, the
values of \( R_{30} \) and \( R_{31} \) in the circuit of Fig. 4 should
be inversely proportional to the number of tubes
used; the values annexed to the drawing are adapted
for a display having about 700 tubes.

As mentioned on p. 95, the ignition pulse must
immediately follow the extinction pulse, while the
triggering diodes of the shift register are still properly
biased. The circuit of Fig. 4 ensures this sequence by
making use of the differentiated trailing edge of the
signal taken from \( TR_6 \) (Fig. 5h) to drive the ignition
pulse amplifier. As a result of the positive-going
spike, \( TR_{12} \) is bottomed and its emitter potential
rises from a quiescent level of 120 V to the full value.
Fig. 4. Control circuit for originating extinction and ignition pulses suitable for driving the shift register of Fig. 2.

All resistors: ± 5% all capacitors except electrolytics: ± 10%; electrolytic capacitors: ± 20%.
Transformer T: H20 core; secondary: 25 turns 0.35 mm diameter enameled copper wire; primary: 100 turns 0.28 mm diameter enameled copper wire wound on top of and insulated from the secondary.
of £₅ (Fig. 5J); the duration of the pulse can be adjusted by means of the resistor $R_{33}$ in the differentiating network at the base of $TR_9$.

Either in the externally triggered or the astable mode of operation, each complete cycle of the control circuit advances the contents of the shift register one place.

Fig. 5. Representative waveforms in the circuit of Fig. 4.

a - Base voltage of $TR_1$

b - Collector voltage of $TR_1$

c - Collector voltage of $TR_2$

d - Collector voltage of $TR_3$

e - Base voltage of $TR_5$

f - Collector voltage of $TR_5$

g - Collector voltage of $TR_9$ (extinction pulse)

h - Differentiated collector voltage of $TR_5$ as applied to the base of $TR_9$

i - Collector voltage of $TR_{11}$

j - Emitter voltage of $TR_{12}$ (ignition pulse)

Procedure for Entering Text in the Display

Any of a number of input devices, such as punched tape readers or Telex decoders, can be used for entering the desired text in the display. Details of these devices being too various for discussion here, the general principle of entering the text will be discussed with reference to a writing-in circuit in which a simple on-off switch furnishes the input information.

Fig. 6 shows a writing-in circuit for one shift register. As many such circuits are needed as there are horizontal lines of lights (shift registers) on the display panel; however, all writing-in circuits can make common use of those components shown outside the rectangle drawn in broken line.

To light one tube of the shift register, push-button switch $S_1$ is momentarily closed, igniting the trigger tube of the writing-in circuit and thereby causing its anode potential to drop to the maintaining voltage (140 V) and remain at that level until the tube is extinguished by the next extinction pulse. Since the anode is connected to the information input terminal of the shift register, this establishes the required bias at the cathode of $D_1$ (see Fig. 2) so that the first tube of the register will be ignited by the following ignition pulse.

If a mistake is made while entering information, the tube of the writing-in circuit can be extinguished by opening switch $S_2$, thus disconnecting the anode
from the supply rail. This prevents the mistaken entry from being written in, but has no effect on information already stored in the shift register.

It is to be noted that the complete writing-in sequence for one place in the shift registers comprises two independent actions. First, the instruction either to light or not to light the first tube of the register is entered by closing switch \( S_1 \) of Fig. 6 or leaving it open. And second, the instruction is executed and the shift register advanced one place by closing switch \( S_1 \) of Fig. 4.

If only a short text is to be endlessly repeated, the required pattern of lighted and unlighted tubes can be entered by hand in all the shift registers, after which the switches \( S \) of the registers (Fig. 2) should be set to the “ring” position and the switch \( S_2 \) of Fig. 4 to the “free-running” position with contacts \( a \) open and \( b \) closed.

If a long text, exceeding the storage capacity of the shift register, is to be repeated, it is best to reduce it to a pattern of perforations in paper tape that can be spliced together as a loop and run endlessly through a reader. For this mode of operation, the circuitry associated with the tape reader must be able to supply, alternately, the functions of switches \( S_1 \) in Figs 4 and 6. Switch \( S \) of Fig. 2 should not, of course, be in the “ring” position but should make contact with the “information input” terminal.

Similarly, if a continuously changing text, such as news or market reports, is to be displayed, the information source and such decoding circuits as may be associated with it should be able to supply the functions of switches \( S_1 \) in Figs 4 and 6.

**Power Supplies**

As mentioned previously, the anode and bias voltage of the shift register should be constant within limits of \( \pm 10\% \) and \( \pm 5\% \), respectively. A satisfactory circuit for supplying the anode voltage is shown in Fig. 7. At a mains voltage with an r.m.s. value of 220 V the voltage delivered by this circuit will, as a matter of fact, be slightly lower than 320 V, but nevertheless well within the specified tolerance. The 110 V bias voltage can be obtained from the 320 V supply rail with the aid of a voltage reference tube circuited as shown in Fig. 8.

For the circuit of Fig. 4 supply voltages of \( +320 \text{ V}, +12 \text{ V} \) and \( -6 \text{ V} \) are required. The \( +12 \text{ V} \) supply in particular must be substantially independent of normal mains voltage fluctuations, variations in ambient temperature, and the rather large momentary changes in load due to the pulsed mode of operation of the control circuit.

In general, it should be capable of meeting the following specifications:


Fig. 8. Voltage reference tube circuit for obtaining 110 V bias voltage from 320 V anode supply rail.
($R = 10 \ \text{k}\Omega, 5.5 \ \text{W}, V = \text{OB2}$)

- output voltage: $+12 \ \text{V}$
- output current: 0 to 500 mA
- ripple (p-p): $< 2 \ \text{mV}$
- internal resistance
  - for slow variations: $< 50 \ \text{m}\Omega$
  - for 100 kHz: $< 500 \ \text{m}\Omega$
- stability against 10% mains
- voltage variation
  - short term: $< 0.1\%$
  - long term: $< 0.2\%$

**Construction**

In this article a running text display making use of ZC1050 trigger tubes has been described and illustrated in terms of essential functions and elements, no account being taken of size. In general, a single display panel can be of almost any required length and height; shift registers comprising several hundred places (trigger tubes) are entirely practical and as many of them can be placed side by side as may be needed to delineate characters of the desired height.

A practical minimum height for a panel is probably seven units, allowing any single letter to be delineated by a five-by-seven matrix of tubes; the maximum usable height is limited only by budgetary and space considerations. A worthwhile advantage of using a matrix larger than five-by-seven is that it confers more freedom in the design and spacing of individual characters.

A convenient construction for the display is shown in the photograph of Fig. 10. The panel is divided into segments, each consisting of a catadioptric housing for one vertical column of trigger tubes and a plug-in circuit board on which the components of one stage of each of the seven shift registers are mounted. Interstage connections are made at the back, by way of sockets which engage the rear edges of the circuit boards. Besides the structural simplicity that it gives, an advantage of mounting corresponding stages of the separate shift registers on common circuit boards in this way is that it facilitates servicing. In case of a fault in one shift register, the comparatively small circuit board containing the defective element can be quickly and easily replaced.

A typical segment is shown disassembled in Fig. 11. The tube housing is a block of acrylic resin drilled through on equal centres to receive the seven trigger tubes that project from the forward edge of the circuit board. Aluminised parabolic counterbores augment the brightness of the lighted tubes and a primitively embossed fascia enlarges their angle of visibility. The circuit board, which is attached to the tube housing by two screws, slides into the mounting rack of the display panel on plastic rails that frictionally engage its upper and lower edges. The complete segment is secured to the frame rails of the mounting rack by two captive screws in the tube housing that can also be used to facilitate its removal.

Only the shift registers need necessarily be housed behind the face of the display panel; the control
circuit and writing-in circuit can be mounted elsewhere, though preferably close by to prevent degradation of the control pulses and minimise the risk of interference on the lines. The input equipment, however, including such tape reading and decoding apparatus as may be used, can within reasonable limits be as remote from the display panel as may be convenient. In general, the number of wires to be cabled from the input equipment to the control and writing-in circuits will be only two more than the number of shift registers that make up the height of the panel.

Merely to give an idea of the relative size of the equipment, the lower photograph on p. 92 shows a control unit in which the power supplies, control circuit, and writing-in circuits for a seven shift register display panel are all housed in a single 19 inch cabinet.
For the benefit of those who may wish to explore more thoroughly the display possibilities offered by trigger tube shift registers, some of the essential properties and characteristics of the ZC1050 are tabulated below; for more detailed particulars reference should of course be had to the manufacturer’s data sheets.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anode-to-cathode supply voltage</td>
<td>300 V</td>
</tr>
<tr>
<td>Anode-to-cathode maintaining voltage</td>
<td>136 V</td>
</tr>
<tr>
<td>Anode-to-primer supply voltage</td>
<td>265 V</td>
</tr>
<tr>
<td>Trigger-to-cathode ignition voltage</td>
<td>180 V</td>
</tr>
<tr>
<td>Cathode current</td>
<td>2 mA</td>
</tr>
<tr>
<td>Primer current</td>
<td>30 µA</td>
</tr>
<tr>
<td>Luminous flux</td>
<td>0.5 lm</td>
</tr>
</tbody>
</table>