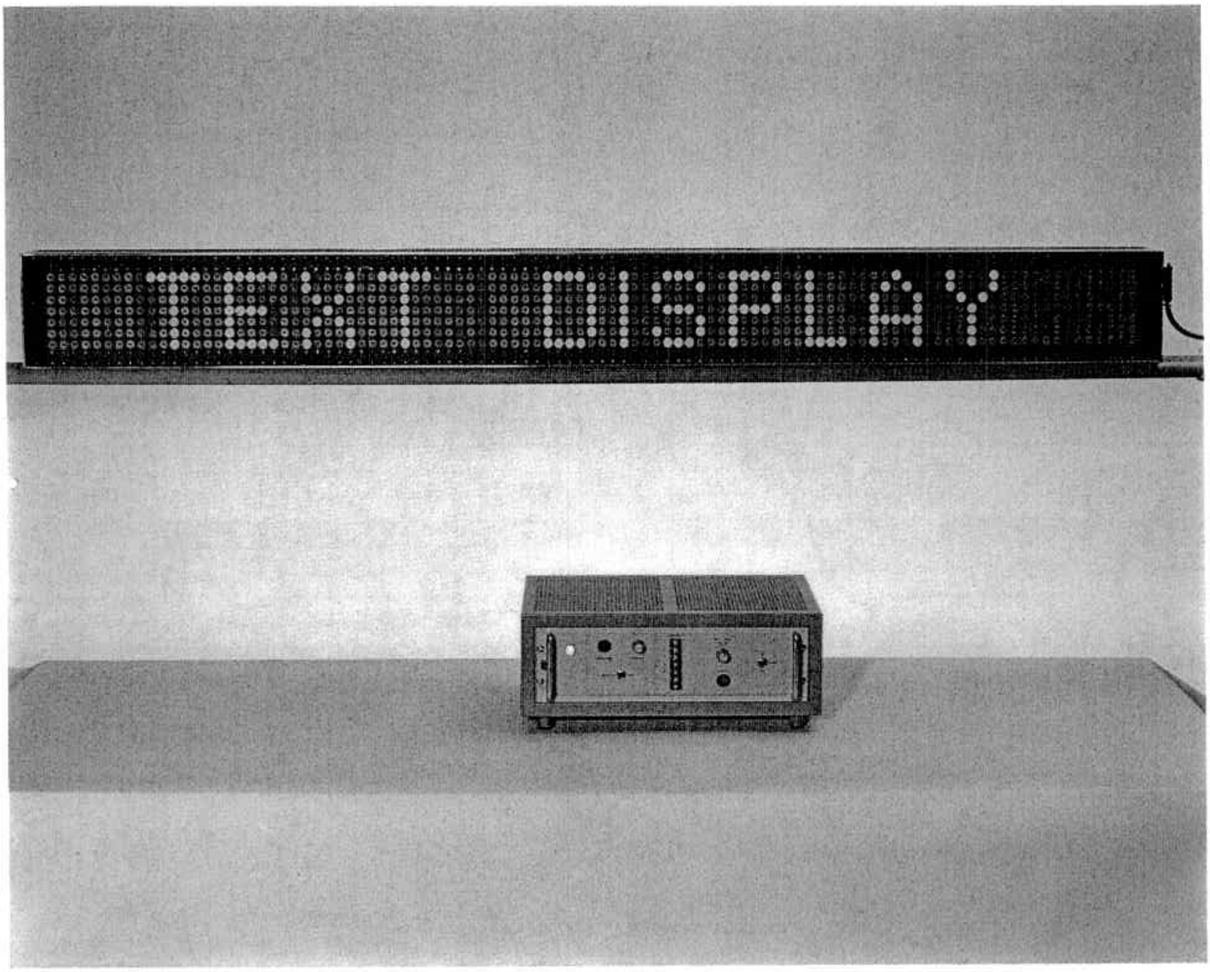
Running text display as seen against a background of fairly low light level.



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.

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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.

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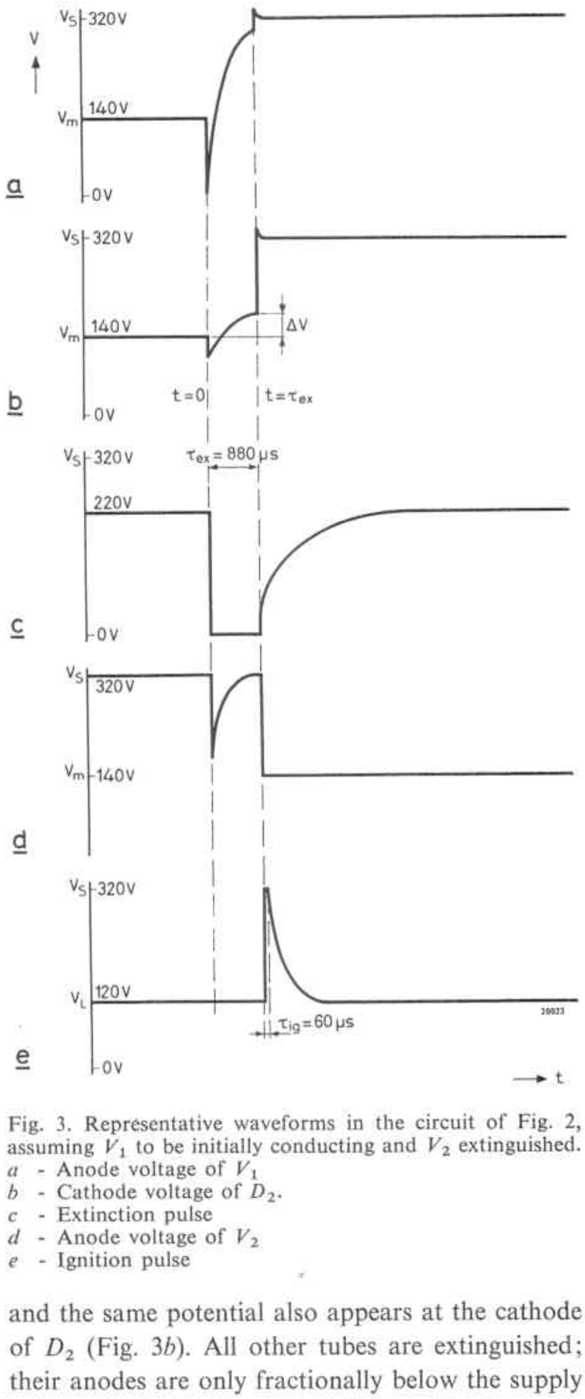

Fig. 3. Representative waveforms in the circuit of Fig. 2, assuming V_1 to be initially conducting and V_2 extinguished.
a - Anode voltage of V_1
b - Cathode voltage of D_2.
c - Extinction pulse
d - Anode voltage of V_2
e - Ignition pulse

and the same potential also appears at the cathode of D_2 (Fig. 3*b*). 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. 3*c*. It is to be noted that, as shown in Fig. 3*d*, 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 $R_3R_4C_3$. At the end of the 880 μs of the extinction pulse an ignition pulse (Fig. 3*d*), 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_2. Accordingly that tube ignites and its anode potential immediately drops to the maintaining voltage. The capacitor C_5 then discharges by way of R_{10}, 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 condition 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 conducting 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-conducting 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	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 ($\simeq V_m$) the tube V_1 will be ignited and a 1 entered in the register as soon as an *ignition* pulse is applied; and when the source voltage is 320 V ($= V_S$), the tube V_1 will be extinguished and a 0 entered in the register as soon as an *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_{n+1}, 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:

extinction time, τ_{ex}	880 ± 50 μs
ignition time, τ_{iq}	60 ± 10 μs
supply voltage, V_S	320 V ± 10%
bias voltage, V_b	110 V ± 5%
extinction pulse (p-p) V_{ex}	220 V ± 15%
d.c. level of ignition pulse line, V_i	120 V ± 15%

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

Control Circuit

The shift register can be driven by any source capable 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 generator of variable frequency or as an externally triggered one.

Transistors TR_1 and TR_2 are connected as a Schmitt trigger. When switch S_{2a} is closed (S_{2b} open), one positive-going pulse is produced at the collector of TR_2 in response to each operation of the push-button switch S_1. When switch S_{2b} is closed (S_{2a} 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 operation, the pulse repetition frequency can be varied between 8 Hz and 90 Hz by means of the adjustable resistor R_6. The operating cycle can be undertood 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 $C_9R_{21}R_{22}$, 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_{22} the width of the negative-going spike can be adjusted so as to drive the transistor into cut-off for 880 μs, 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_8 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

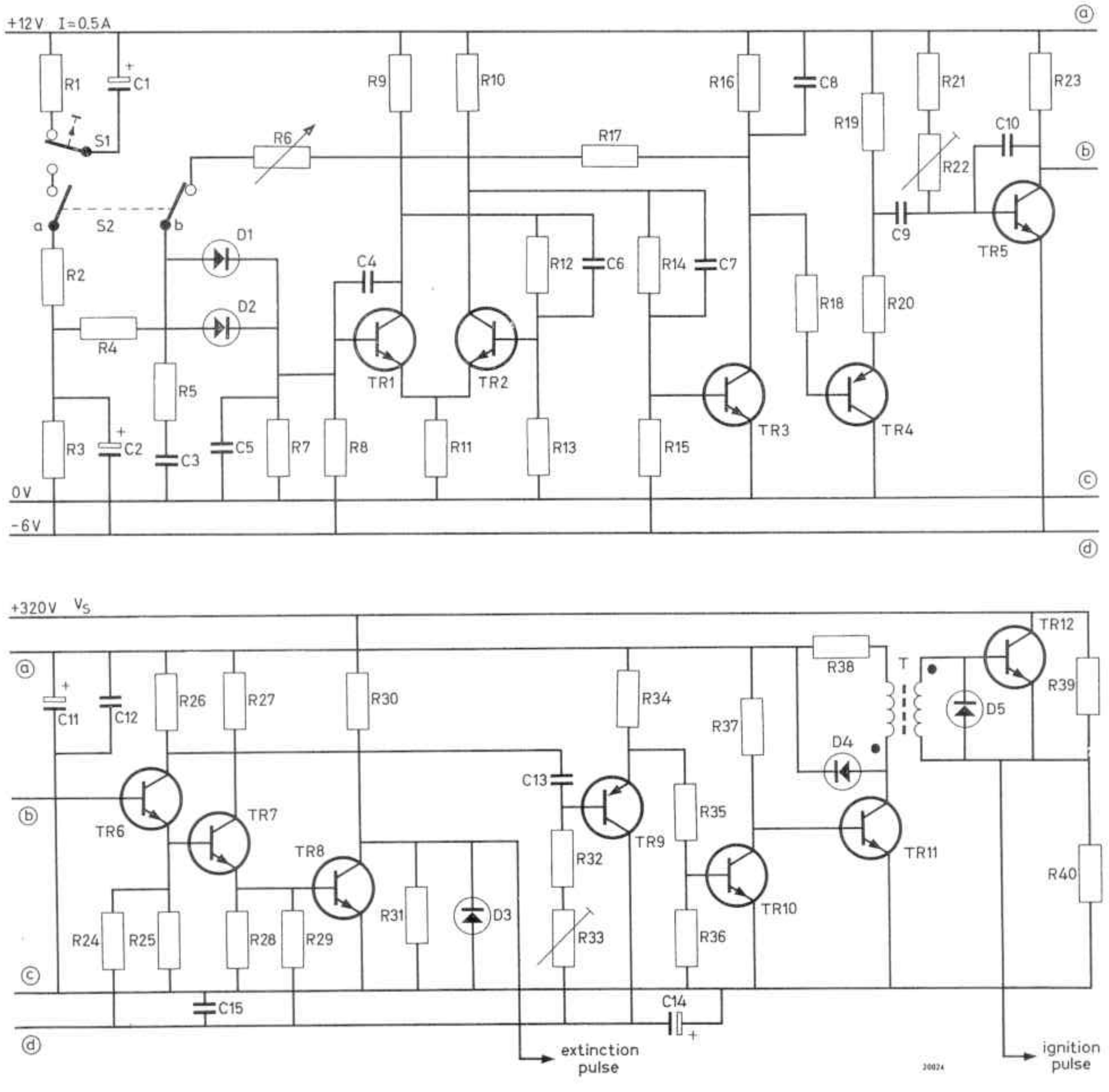

Fig. 4. Control circuit for originating extinction and ignition pulses suitable for driving the shift register of Fig. 2.

R_1	5.6 kΩ, 1/8 W	R_{15}	22 kΩ, 1/8 W	R_{29}	1 kΩ, 1/4 W	C_1	2.5 µF electrolytic
R_2	27 Ω, 1/4 W	R_{16}	2.2 kΩ, 1/4 W	R_{30}	3.9 kΩ. 16 W	C_2	1 µF electrolytic
R_3	10 kΩ, 1/8 W	R_{17}	12 kΩ, 1/8 W	R_{31}	10 kΩ, 16 W	C_3	4.4 µF polyester
R_4	10 kΩ, 1/8 W	R_{18}	10 kΩ, 1/8 W	R_{32}	10 kΩ, 1/8 W	C_4	2.2 nF
R_5	470 Ω, 1/8 W	R_{19}	470 Ω, 1/4 W	R_{33}	5 kΩ, 1/4 W pot.	C_5	12 nF
R_6	100 kΩ, 1/4 W pot.	R_{20}	560 Ω, 1/8 W	R_{34}	1.5 kΩ, 1/4 W	C_6	220 pF
R_7	470 kΩ, 1/8 W	R_{21}	10 kΩ, 1/8 W	R_{35}	3.3 kΩ, 1/8 W	C_7	330 pF
R_8	270 kΩ, 1/8 W	R_{22}	10 kΩ, 1/4 W pot.	R_{36}	1.5 kΩ, 1/8 W	C_8	8.2 nF
R_9	1.5 kΩ, 1/4 W	R_{23}	1 kΩ, 1/4 W	R_{37}	330 Ω, 1/2 W	C_9	220 nF
R_{10}	1.5 kΩ, 1/4 W	R_{24}	6.8 kΩ, 1/8 W	R_{38}	33 Ω, 8 W	C_{10}	3.3 NF
R_{11}	220 Ω, 1/8 W	R_{25}	4.7 kΩ, 1/8 W	R_{39}	{ 39 kΩ, 5.5 W in parallel with 68 kΩ, 1 W	C_{11}	1000 µF electrolytic
R_{12}	15 kΩ, 1/8 W	R_{26}	560 Ω, 1/2 W			C_{12}	3.3 nF
R_{13}	22 kΩ, 1/8 W	R_{27}	27 Ω, 2 W			C_{13}	8.2 nF polyester
R_{14}	15 kΩ, 1/8 W	R_{28}	1 kΩ, 1/4 W	R_{40}	15 kΩ, 5.5 W	C_{14}	40 µF electrolytic
						C_{15}	3.3 nF

All resistors: ± 5% all capacitors except electrolytics: ± 10%; electrolytic capacitors: ± 20%. Transformer *T*: H20 core; secondary: 25 turns 0.35 mm diameter enamelled copper wire; primary: 100 turns 0.28 mm diameter enamelled copper wire wound on top of and insulated from the secondary.

of V_S (Fig. 5*j*); 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.

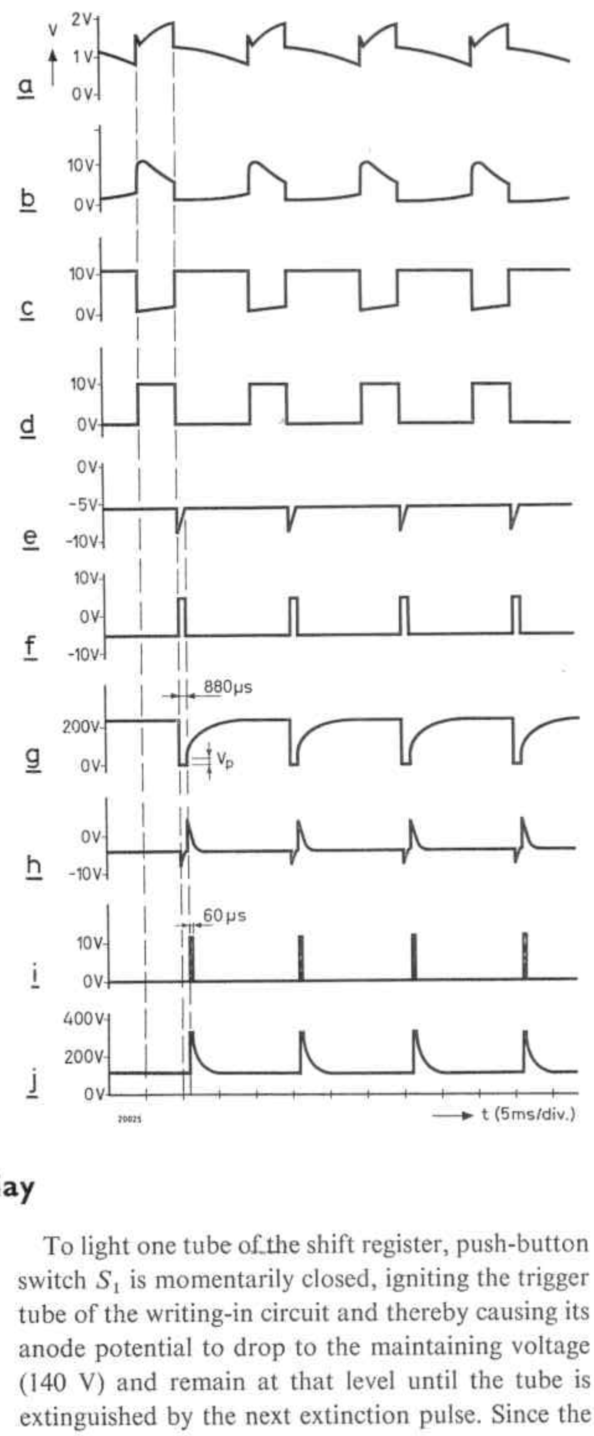

Fig. 5. Representative waveforms in the circuit of Fig. 4.
a - Base voltage of TR_1
b - Collector voltage of TR_1
c - Collector voltage of TR_2
d - Collector voltage of TR_3
e - Base voltage of TR_5
f - Collector voltage of TR_5
g - Collector voltage of TR_8 (extinction pulse)
h - Differentiated collector voltage of TR_6 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.

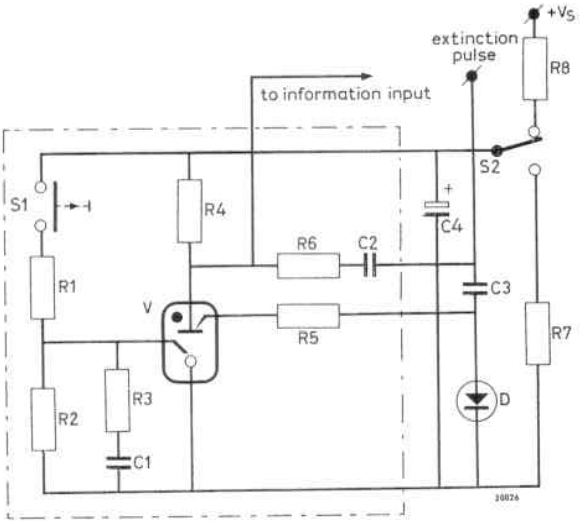

Fig. 6. Trigger tube circuit for writing information into the shift register of Fig. 2. The function of the switch S_1 is normally performed by a mechanical or electronic information source such as a tape reader or decoder.

R_1	100 kΩ, ¼ W ± 5%	R_8	4.7 kΩ, 1 W ± 5%
R_2	2.2 MΩ, ¼ W ± 10%	C_1	2.2 nF ± 10%
R_3	10 kΩ, ⅛ W ± 5%	C_2	2.2 nF ± 10%
R_4	82 kΩ, ½ W ± 5%	C_3	220 nF ± 10%
R_5	10 MΩ, ⅛ W ± 10%	C_4	64 μF ± 20%
R_6	22 kΩ, ⅛ W ± 5%	D	BYX10
R_7	3.3 kΩ, 1 W ± 5%	V	ZC1050

Power Supplies

As mentioned previously, the anode and bias voltage of the shift register should be constant within limits of ± 10% and ± 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 V, +12 V and −6 V are required. The +12 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:

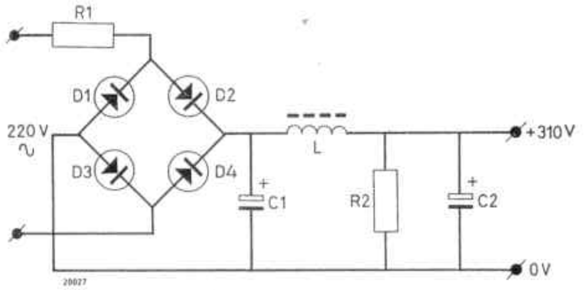

Fig. 7. Supply circuit for deriving 320 V anode voltage from 220 V mains.

R_1	4 Ω, 100 W	C_2	400 μF
R_2	100 kΩ, 1 W	L	170 mH, 2.2 Ω, 2 A
C_1	400 μF	D_1 to D_4	BZY10

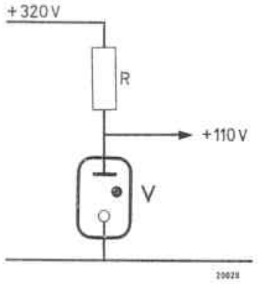

Fig. 8. Voltage reference tube circuit for obtaining 110 V bias voltage from 320 V anode supply rail.
(R = 10 kΩ, 5.5 W, V = OB2)

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

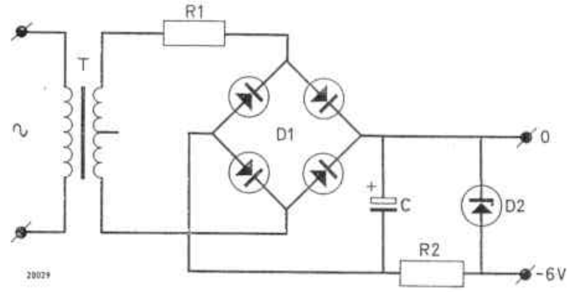

Fig. 9. Supply for −6 V bias voltage required in the circuit of Fig. 4.

R_1	10 Ω,	½ W	D_1	BY122
R_2	100 Ω,	2 W	D_2	BZY96-C6V2
C	100 μF		T	sec. 2×6.3 V, 1 A

The demands on the −6 V supply are not nearly so severe; a simple but satisfactory circuit is shown in Fig. 9. Large smoothing capacitors for both supplies are incorporated in the control circuit (C_{11} and C_{14} in Fig. 4) and are shunted by 3.3 nF ceramic capacitors to bypass r.f. interference. The +320 V supply can of course be taken from the same rail as is used for the shift register.

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 prismatically 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 ways 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

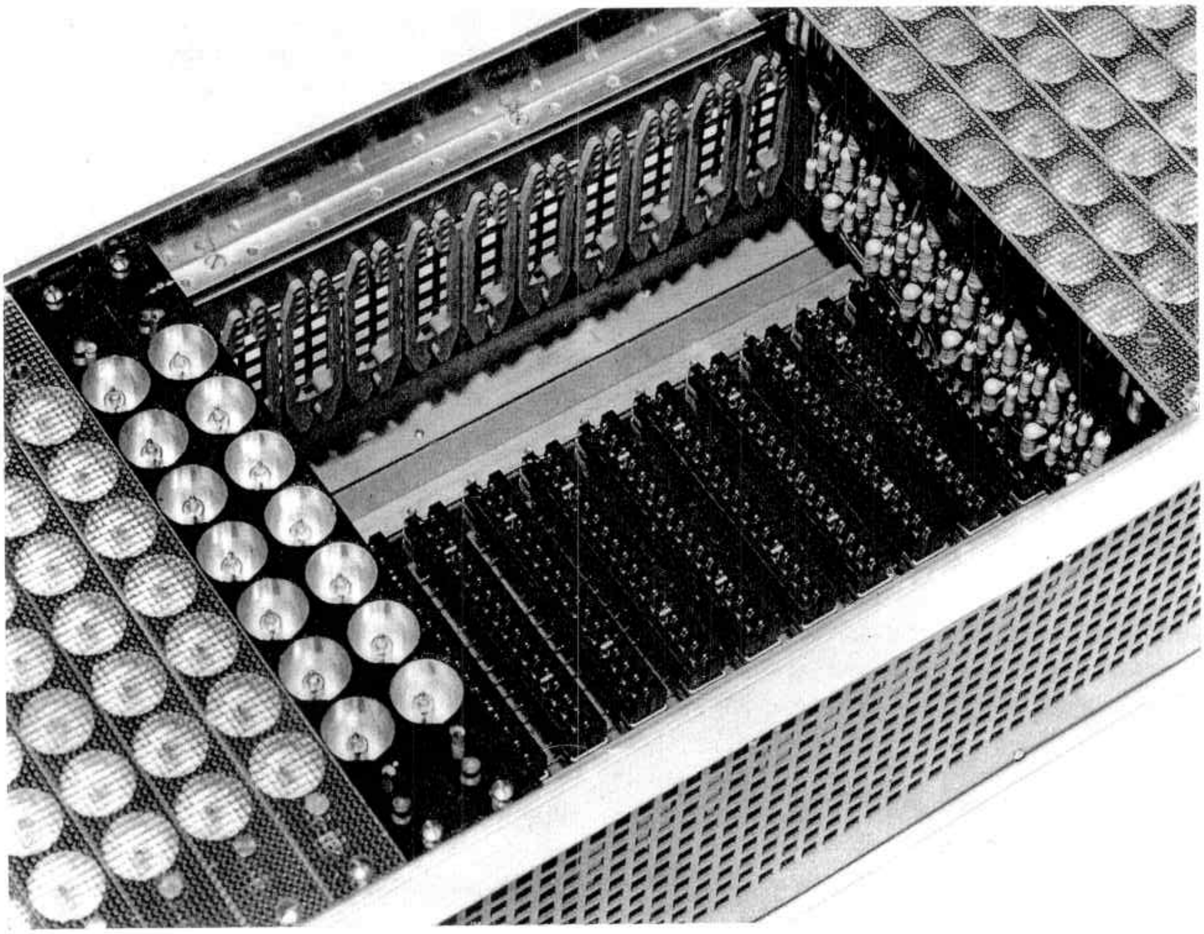

Fig. 10. Display panel with ten segments removed, showing interior arrangement of shift register circuits boards and connecting sockets. The embossed fascia has been removed from two of the segments to show the trigger tubes in their aluminised reflectors.

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.

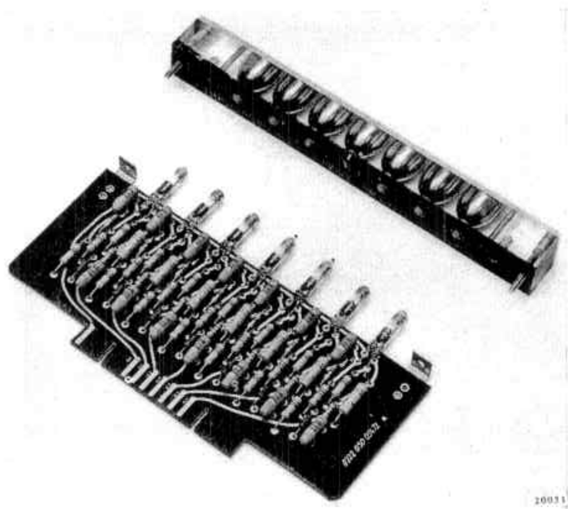

Fig. 11. One segment of the display panel disassembled, showing printed circuit board, trigger tubes, and catadioptric tube housing.

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.

Anode-to-cathode supply voltage	300 V
Anode-to-cathode maintaining voltage	136 V
Anode-to-primer supply voltage	265 V
Trigger-to-cathode ignition voltage	180 V
Cathode current	2 mA
Primer current	30 μA
Luminous flux	0.5 lm