An experimental two-cathode glow tube, with low voltage transition of glow between the two cathodes has been developed. The tube is used to indicate the state of a transistorized binary circuit, for which the conventional two-electrode glow tube cannot be used.

Three-electrode cold cathode tube for the indication of the state of a transistorized binary circuit

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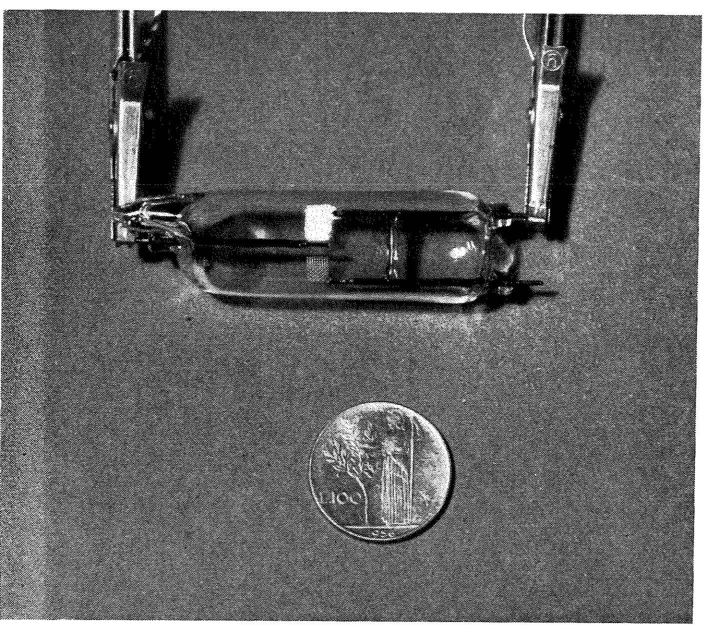

INTRODUCTION

It is known that a two element glow tube is generally used to indicate in which of the two possible states is an electron tube binary counter (Eccles-Jordan).

This simple solution is possible because the voltage excursion available at the anode of one of the two vacuum tubes exceeds generally the difference between the breakdown voltage and the maintaining one for normally used glow tubes.

In the case of a transistorized binary circuit the voltage excursion available at the collector of the binary has a low value which is, as a limit, the supply voltage of the binary. This must be conservatively lower than the breakdown voltage of the used transistors. As known, breakdown voltage is lower for high frequency transistors. Normally a high working voltage auxiliary transistor is used to overcome the difficulty **. The glow tube described in this paper *** allows direct indication of binary state in spite of low available voltage excursion: instead of using the voltage excursion available to strike the discharge, in order to have a luminous indication (cathode glow), this excursion is used to change the space position of the glow between two cathodes connected with the collectors of the two transistors. A voltage of 3 volts is sufficient to cause a transition: moreover, a source of constant voltage

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(**) For instance the 2N398-RCA.
(***) Patent pending.

(of about 200 volts) is required, in order to maintain the discharge.

OPERATING PRINCIPLE AND EXPERIMENTAL RESULTS

The tube has one anode and two cathodes; these ones are symmetrically disposed in respect to the anode, as it can be seen in fig. 1, and we shall name them « electrode No. 1 » and « electrode No. 2 ». The characteristic V-I of the glow discharge between the anode and the electrode No. 1 (cathode) is given in fig. 2.

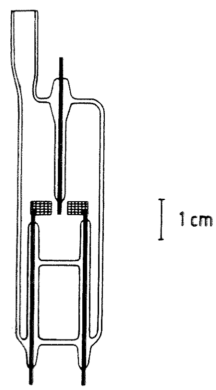

Fig. 1. Three-electrodes tube.

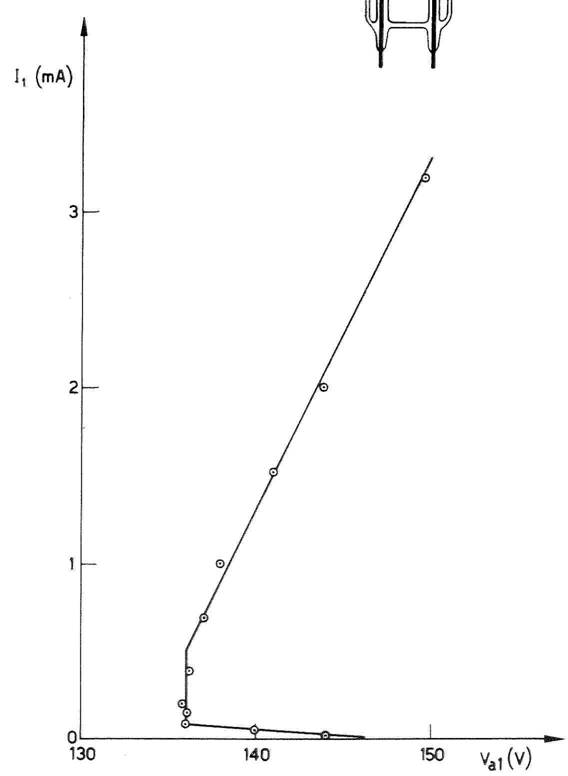

Fig. 2. V-I characteristic of the glow discharge between the anode and one of the cathodes.

It has been measured by clamping electrode No. 2 with a low resistance to a convenient voltage (110 volts below the potential of the anode) in order to avoid that the electrode No. 2, if floating, changes the electrical characteristics of the discharge [1].

The working point is set, to get the wanted behaviour by a proper anode resistance in order to bring the current I to the value correspondent to the beginning of the abnormal glow discharge region: for such value I, the cathode glow covers the whole cathode No. 1 [2]. Electrode No. 2 is inserted into the plasma of the positive column of the discharge and, therefore, acts like a probe [3].

The characteristics of this probe is given in fig. 3. When electrode No. 2 is sufficiently negative in respect to the plasma, so that the ions collected on it have sufficient energy, it will contribute to maintain the plasma by the Townsend γ process on it [4]. When it assumes a potential about equal to that of electrode 1, it is able to maintain the plasma and becomes an auxiliary cathode: if, then, its voltage is furtherly lowered by two or three volts, it will collect the total current: the cathode glow is entirely on electrode No. 2, while electrode No. 1 behaves in turn as a probe.

The complete V-I characteristics of electrode 2 is given in fig. 4 for a definite anode load resistance and voltage supply V_b and, as can be seen, it is the same of that of fig. 2 except for the low currents. The voltage drop corresponding to the negative slope section has been strongly reduced owing to the presence of the discharge between anode and electrode 1.

For analyzing the behaviour of the device, the V-I characteristic of fig. 4 has been idealized with the two linear segments shown with dotted lines in the same fig. 4. The small negative slope region has been substituted with a zero resistance region and therefore our analysis will not account for small loops of hysteresi actually observed in operation but negligible as far as practical application of the device is concerned. The characteristic for the two parallel glow discharges, when a voltage V_{21} is in-

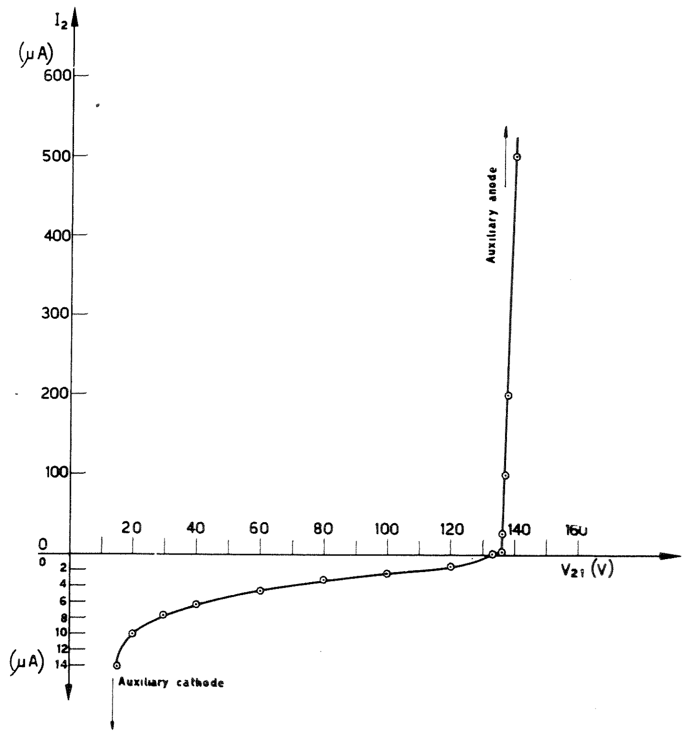

Fig. 3. Characteristic of electrode 2 as a probe in the plasma of the discharge between the other two electrodes.

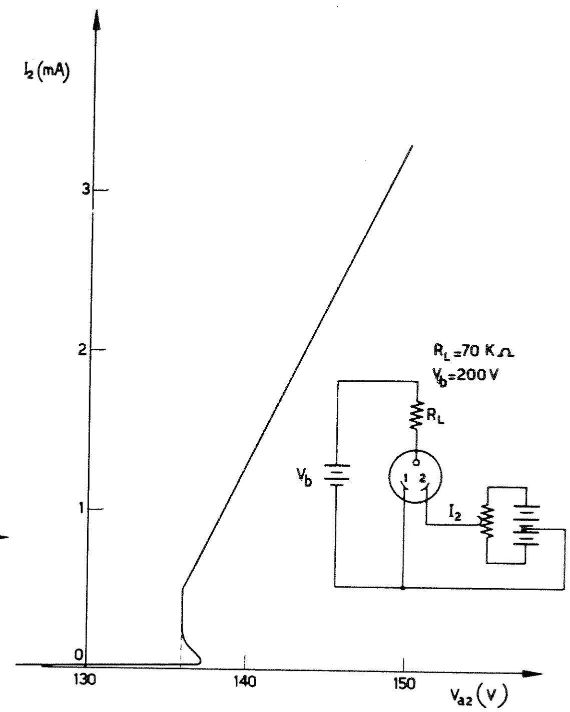

Fig. 4. Characteristic of electrode 2 for load resistance and VI supply as in figure.

serted between the two cathodes, is given by the sum of two characteristics as that of fig. 4 translated each other by V_{21}.

A family of these characteristic curves is drawn with V_{21} as parameter in fig. 5. The locus of points on which the ratio I_2 to total current I_t has the value 0,5 is obtained when $V_{21} = 0$.

Ratios $I_2/I_t > 0{,}5$ are obtained when $V_{21} < 0$; ratios $I_2/I_t < 0{,}5$ reciprocally when $V_{21} > 0$.

The percentage of the current carried by the electrode No. 2 for each value V_{21} is read on the intersection of the corresponding characteristic with the load line (anode resistance).

For the load lines of the fig. 5 the dependence of I_2 versus V_{21} is given in fig. 6.

The plots are similar to those visually observed on the oscillograph, except for the small hysteresis loops which are drawn with dotted lines on the same fig. 6. The hysteresis loops are due to the negative resistance which has been ignored in the plots.

The reliability of the described discharge tube rests on the stability of the two normal glow voltages between anode and electrodes No. 1 and No. 2 respectively. The stability of these voltages is mainly connected with the cathode materials and cathode processing as by contamination of filling gas by degassing products.

The feasibility of a practical glow tube such as the one described has been suggested by the excellent stability of some glow discharge tubes used as a voltage standards.

After an initial drift, voltage is constant, within some tenth of a volt, for more than 3 000 hours [5]. It could be objected that probably the normal glow discharge of the two cathodes will differ by many volts after a long permanence of the glow discharge

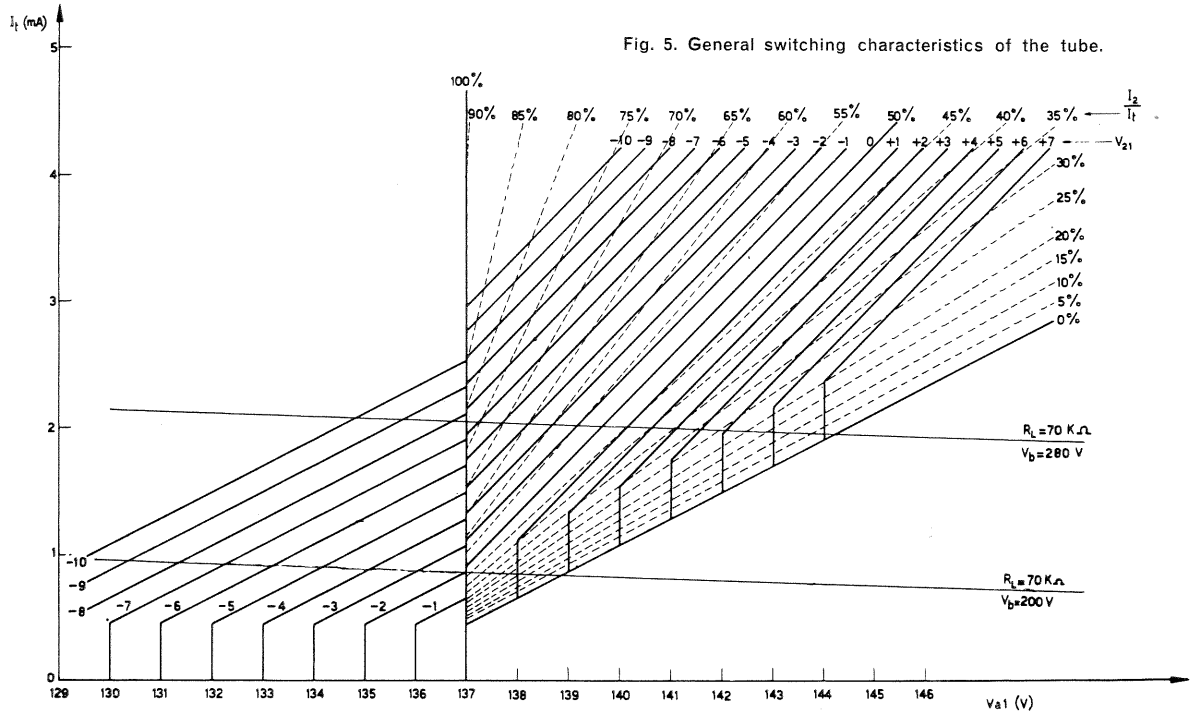

Fig. 5. General switching characteristics of the tube.

on one of them because of cathode sputtering. This actually has been a serious difficulty in the development of dekatrons. In our case, however, when, for instance, the discharge is on the electrode No. 1, the electrode No. 2 is in the positive column and has nearly the same potential of electrode 1 so that it is struck by ions with the same energy, obviously at a very different rate. This bombardment should be sufficient to mantain the second electrode in the same conditions as the first.

Our experimental tube has been successfully tested only for some tens of hours and technological data are given below without pretending to achieve the stability results of standard voltage reference tubes of [5]. Research is in progress now in this direction.

TECHNOLOGICAL DATA OF THE DESCRIBED TUBE

We have chosen for the components of the tube, the following materials:

anode: Mo bar - diameter 1 mm - length 30 mm
cathodes: Fe wire gauze - sizes 3 × 5 mm (with wires ⌀ 0,2 mm spaced 0,5 mm) inserted on Mo bars ⌀ 1 mm - length 28 mm
envelope: siglass 46.

CONSTRUCTION DESCRIPTION

1. The Mo bars, after shaped and cleaned, are covered with a thin sheat of siglass 46, in order to form the glass-to-metal joint.

It is important that the bar is covered with glass as much as possible, to avoid both the Mo sublimation and the interaction of the unsheated Mo, on the electrical characteristics of the discharge.

The fig. 7 shows how bars must be sheated. Glass-to-Mo seals to assure a perfect adhesion between glass and metal must have a light brown colour, corresponding to the film of Mo O_2 fused in glass.

2. The Fe wire gauzes (cathodes) are jointed to the respective ends of the bars. This operation is made by welding in a reducing atmosphere. This is to avoid the formation of oxides which would remar-

kably lower the mechanical resistance of the Fe-to-Mo seals.

3. The Mo terminals are conveniently separated sealing a thin strip of glass between them (fig. 8).

4. The glass bulb is prepared, as in fig. 1; the tube is filled with phosphoric acid at 50° Bé, the three electrodes are connected together and are subjected to a potential difference applied between them and a stainless-steel wire, inserted in the solution, acting as a cathode; the connection of the tube to the vacuum must be large enough to permit an easy filling with the solution.

The current density is fixed at 1 A/cm² for some seconds of the treatment and is, then, reduced at about 0,2 A/cm².

When Mo has a shining metallic colour, the solution is evacuated, and the glass bulb is cleaned.

The Fe wire gauzes are not altered by this operation but, however, they remain slightly oxided (oxidation due to operation No. 2).

Fe is treated with a process of ionic bombardment cleaning for which we act in the following way: high vacuum is done in the tube (about 10^{-6} mm Hg), we fill it with about 10 mm Hg Argon and between the cathodes an a.c. voltage is applied, in order to have a current density of about 20 mA/cm².

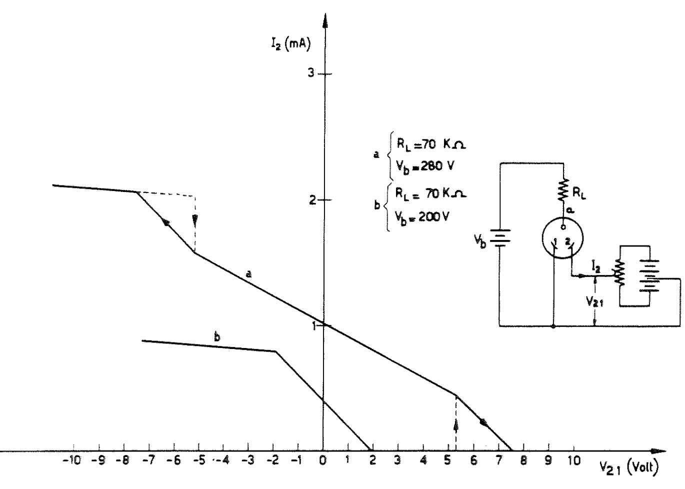

Fig. 6. Switching characteristic for load resistance and VI supply as in figure.

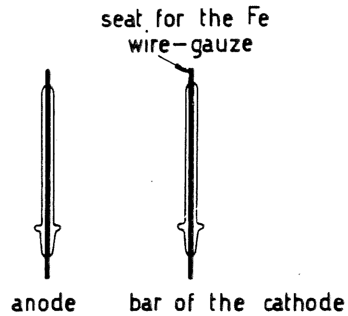

Fig. 7. Construction details.

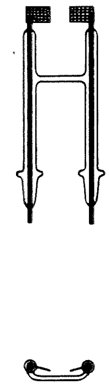

Fig. 8. Construction details.

The Fe wire gauzes become red-hot because of the ionic bombardment [6].

6. The gauge is, then, evacuated and outgassed, then filled. For the filling we have used a Penning mixture [7].

The filling is: Neon 53 mm Hg + 0,06% Argon. The pression is chosen so that the tickness of the cathode fall is sufficiently small in order to have a glow sufficiently restricted on the interested cathode [8]. ■

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sommario

TUBO CATODICO A TRE ELETTRODI PER LA INDICAZIONE DELLO STATO DI UN CIRCUITO BINARIO A TRANSISTOR

Si è studiato e costruito un tubo sperimentale a scarica a bagliore a doppio catodo, con transizione della luminosità da un catodo all'altro a bassa tensione, per segnalare lo stato elettrico di un circuito binario a transistor per il quale non è possibile usare come spia una comune lampada al neon a due elettrodi.