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NUMERICAL INDICATOR TUBES
application note

NUMERICAL INDICATOR TUBES

PRINCIPLES OF OPERATION AND METHODS OF USE

In this application note, the first of a series, the principle of the glow discharge is considered, and the way in which it can be applied to a numerical indicator tube. The various ways in which indicator tubes can be used in display systems are discussed, and the advantages and disadvantages of the systems considered.

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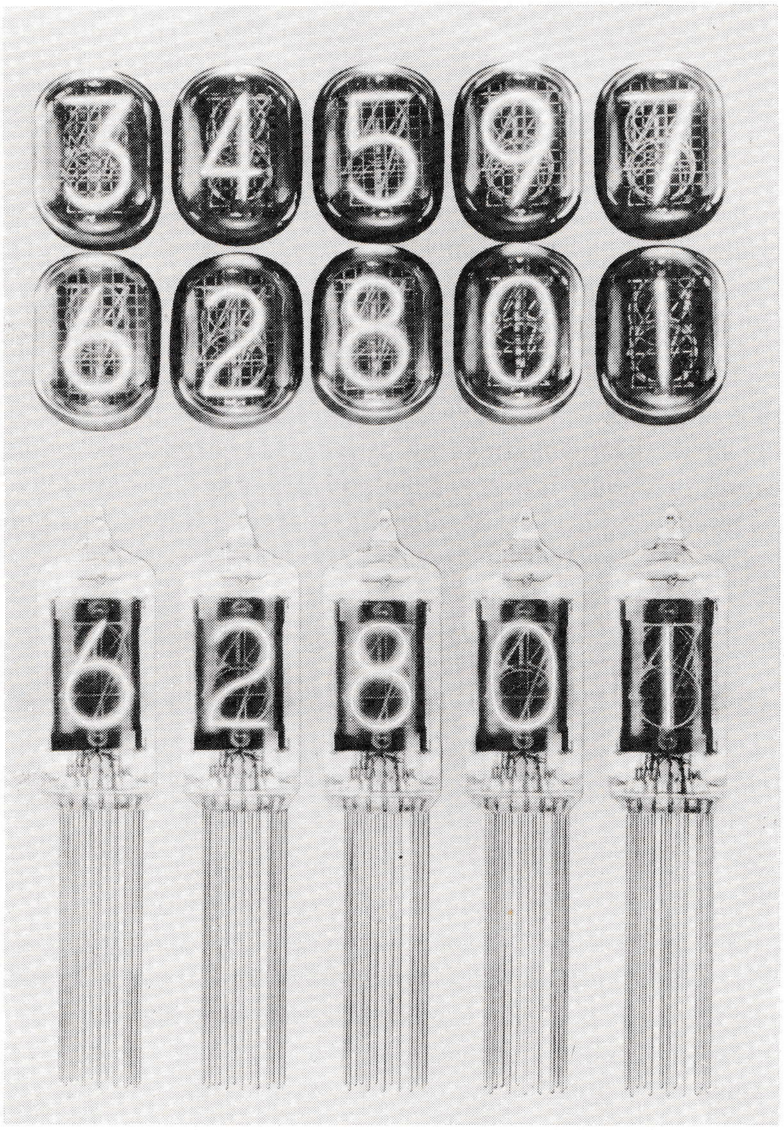

End-viewing and side-viewing numerical indicator tubes ZM1162 and ZM1172 with rectangular envelopes for close spacing

NUMERICAL INDICATOR TUBES

PRINCIPLES OF OPERATION AND METHODS OF USE

Numerical indicator tubes are cold-cathode gasfilled devices which allow numbers or symbols to be clearly displayed. They offer several advantages over other types of display devices — in particular high reliability, long life, and simplicity of driving circuits.

Most numerical indicator tubes display the numerals 0 to 9, although the principle applies equally to characters and symbols. The indicator therefore consists basically of the characters to be displayed stacked one behind the other to give the minimum of visual interference and forming the cathodes of the tube. A single anode is used, and a glow discharge is struck between the anode and the cathode representing the particular character to be displayed.

PRINCIPLE OF GLOW DISCHARGE

In any gasfilled device, there are free electrons and ions produced by the effects of natural radiation. If a voltage is applied between the anode and cathode of the device, electrons are attracted to the anode and positive ions to the cathode. As the voltage is increased, so the ionisation is increased until it is self-sustaining. The value of anode voltage at which this condition occurs is called the "ignition" or "striking" voltage.

After ignition, the voltage between the anode and cathode falls towards the "maintaining" value because slow-moving positive ions form a space charge or virtual anode near the cathode. Electrons removed from the cathode by bombardment of the positive ions enter a strong electric field and are given sufficient energy to cause ionisation despite the fall in voltage across the device. The device is operating in the "glow discharge region" with the discharge covering a small part of the cathode. If the cathode current is increased, the glow covers more and more of the cathode although there is little effect on the maintaining voltage.

When the glow covers all of the cathode, a further increase in current drives the device into the "abnormal discharge region" where both the anode voltage and dissipation increase. Numerical indicator tubes are operated in the abnormal discharge region to ensure that the glow covers the whole of the cathode.

The voltage distribution between the anode and cathode in relation to the glow discharge is shown in Fig. 1. The discharge consists of a number of regions, the "negative glow" forming a sheath that surrounds the cathode, and this is used to display the required character. The "positive column" is eliminated in numerical indicator tubes by suitable design of the electrodes.

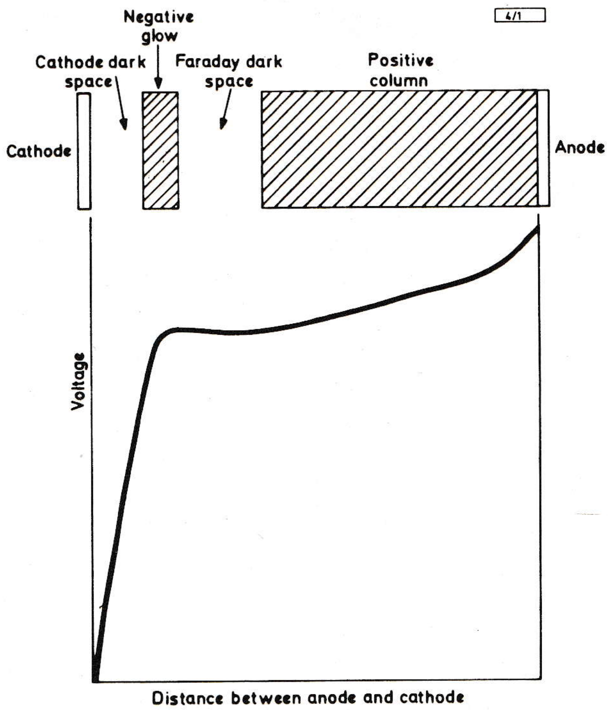

Fig. 1 — Voltage distribution between anode and cathode of a gasfilled diode showing relation to the glow discharge

CONSTRUCTION OF NUMERICAL INDICATOR TUBES

In a typical numerical indicator tube, thin metal cathodes in the form of the numerals 0 to 9 are mounted on supporting rods and separated by small insulating beads. The stack is surrounded by a cylindrical anode with a solid base and a mesh top through which the characters are viewed. Electrical connections are made to each cathode from the base pins, and the whole assembly contained in a glass envelope. Because the cathodes are made from metal with a small cross-section, and the glow around the cathode has a much larger diameter than the cathode itself, the glowing character can be easily seen.

Tubes can be designed for end-on viewing or side viewing, and rectangular envelopes can be used to allow closer mounting of tubes.

The colour of the glow depends on the gas inside the tube. Most indicator tubes have a bright orange-red glow, produced by neon with small quantities of argon and mercury added.

OPERATION OF NUMERICAL INDICATOR TUBE

From the preceding sections it can be seen that to operate an indicator tube requires:

1. a voltage between the anode and display cathode initially greater than the ignition voltage for the tube;
2. a voltage after ignition greater than the maintaining voltage of the tube;

3. a current large enough to ensure that the glow covers the whole cathode but not too large so that the glow spreads to the cathode connections.

The individual cathodes must be switched so that the igniting voltage is established between the anode and the required cathode.

These requirements lead to the basic display circuit shown in Fig. 2. The cathode switches are shown as mechanical switches, the switch corresponding to the required cathode being closed to display the numeral. A discharge is struck between this cathode and the anode, and current flows through the tube. The resistor R_a is chosen to limit the current to the required value at the anode maintaining voltage.

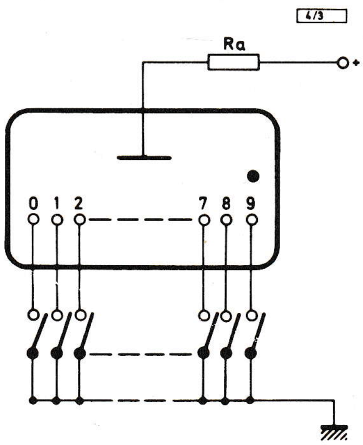

Fig. 2 — Basic display system for numerical indicator tube

This simple treatment has neglected the effect of the other cathodes on the discharge between the anode and the "on" cathode. The "off" cathodes act as probes, taking part of the tube current. If the cathodes are isolated, as in Fig. 2 where mechanical switches are used, they will assume a floating potential slightly lower than that of the anode. If however a leakage current can flow, the cathode potential will decrease and a greater proportion of the tube current will flow through the "off" cathodes. This results in a background haze which decreases the readability of the displayed numeral. If the cathode potential is increased above the floating potential, the "off" cathodes can function as anodes and supply current to the "on" cathode.

It is therefore necessary in cases where cathode leakage current can flow to maintain the potential of the "off" cathodes between two limits. The potential should be high enough to ensure clear readability of the displayed numeral, but not too high so that subsidiary discharges are formed. This cathode bias can be provided by a separate voltage supply or by a cathode resistor whose value is chosen to give the required cathode potential when the leakage current flows. Cathode bias will be considered for various drive systems in later application notes. For the present, it is assumed that mechanical switches are used in the discussion of the display systems.

So far, it has been assumed that d.c. voltages are applied to the numerical indicator tube. The tubes can be operated with the positive half-cycle of an a.c. waveform or with pulses. The light output from the display is proportional to the mean value of the current, but with pulse operation the peak current level is higher than that with d.c. operation, and so the numeral will therefore appear brighter. The lowest operating frequency is determined by flicker, while tubes have been operated at frequencies as high as 100kHz.

PRINCIPLES OF DISPLAY SYSTEMS

Static and Dynamic Displays

In a practical display system, several numerical indicator tubes are used. There are two methods of driving the tubes. In one, the static system, each cathode is switched individually. In the other, the dynamic system, all the cathodes representing the required numeral are switched and the particular numeral selected by switching the anode of the corresponding tube.

The basic circuit of a static display system is shown in Fig. 3. This circuit is merely an extension of the single-tube system shown in Fig. 2. Each tube has ten switches, one for each cathode. If there are n tubes in the display system, then 10n switches are required.

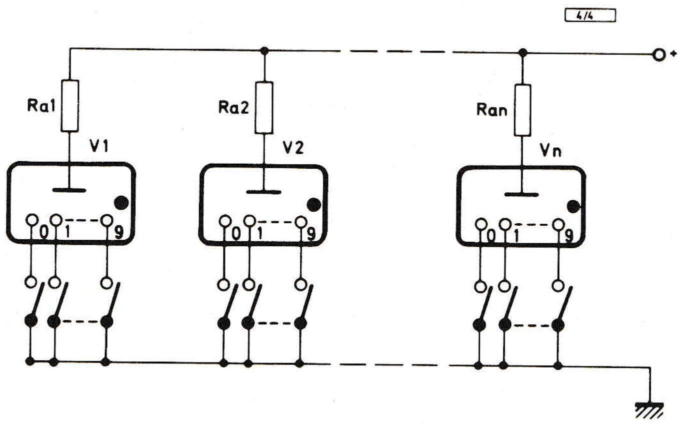

Fig. 3 — Basic circuit of static display system

The number of switches can be considerably reduced by using the dynamic system shown in Fig. 4. In this, only ten cathode switches are used but a switch is incorporated in the anode circuit of each tube. To display a numeral, say 7 on V_2, switches S_{c7} and V_{a2} must both be closed. Thus the reduction in the number of cathode switches is accompanied by the complication of closing the required anode switch. The total number of switches required for a display of n tubes is (10 + n) switches.

Dynamic display can be achieved in two ways: cathode scanning and anode scanning. In cathode scanning, the cathodes of the numerical indicator tubes are selected sequentially in a continuous cycle and the anode switches are closed at the appropriate time to display the required numerals. In anode scanning, the anodes

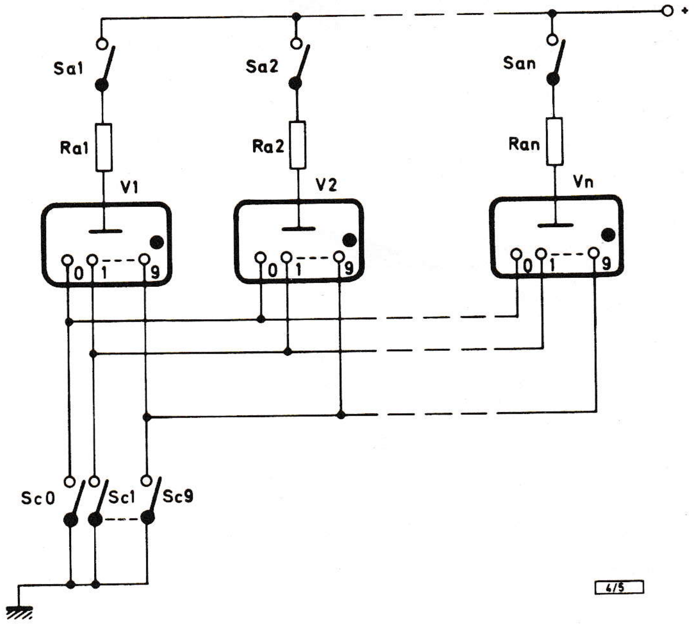

Fig. 4 — Basic circuit of dynamic display system

are selected in a continuous cycle, and it is the cathode switches that are closed to display the required numerals. The rate at which the anodes and cathodes are selected is sufficiently high for the selected numeral to appear to be displayed continuously.

Cathode Scanning

The schematic circuit of a cathode-scanning dynamic display system is shown in Fig. 5. The information to be displayed is the read-out of the decimal counters C_1 to C_n. (The circuits supplying this information to the counters are not shown for simplicity.) Each counter is associated with a numerical indicator tube. The cathodes of the tubes are supplied sequentially with pulses from the pulse generator, in this case starting with cathode 9. At the same time, pulses are supplied to the counters. The counters close the anode switch of their associated indicator tube when the pulse from the generator coincides with the read-out pulse and a carry pulse is produced. If, for example, counter C_1 is given the numeral 7 to be displayed, then the third pulse from the generator in the pulse diagram of Fig. 6 coincides with the read-out pulse, the anode switch S_{a1} is closed, cathode switch S_{c7} is also closed at the same time, and so the numeral 7 will be displayed by V_1. If counter C_2 is to display the numeral 5, two pulses later cathode switch S_{c5} will be closed, a carry pulse will be produced by counter 2 to close the anode switch S_{a2}, and V_2 will display the numeral 5.

There are two main disadvantages to the cathode-scanning system. The first is that the cathode switches must be rated to carry the total current of all the indicator tubes. If the same numeral is displayed by all the tubes (the zero reading is a likely occurrence), the peak anode current of all the tubes can flow through the one cathode switch. The second disadvantage is that the system cannot be used to display the output of passive registers such as a magnetic-core memory system or

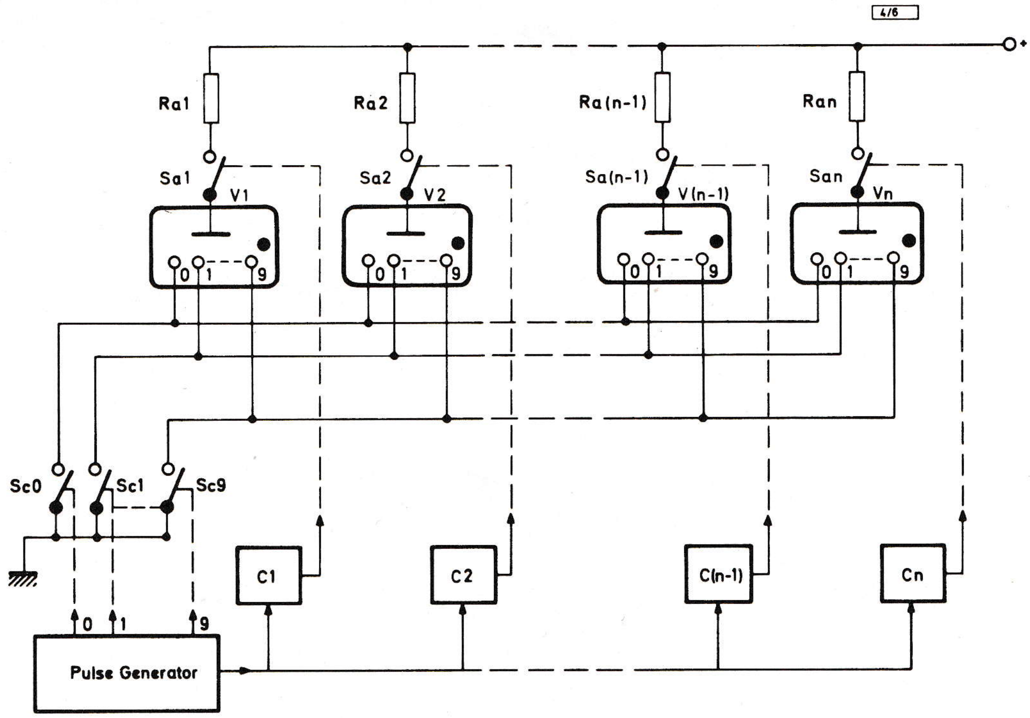

Fig. 5 — Schematic diagram of cathode-scanning display system

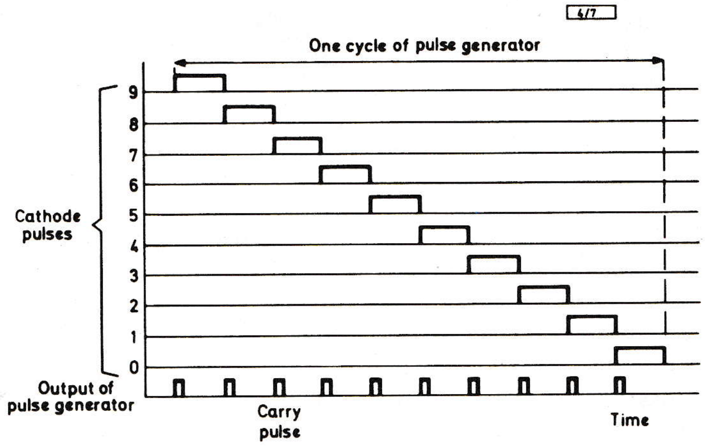

Fig. 6 — Pulse diagram for cathode-scanning system

a shift register. For these systems, an anode-scanning display system must be used.

Anode Scanning

The schematic diagram of an anode-scanning display system is shown in Fig. 7. This system displays the read-out of a memory or shift register. The memory is interrogated by the control unit, and the first numeral to be displayed is passed to the cathode selector. This unit consists of a decoder which translates the signal

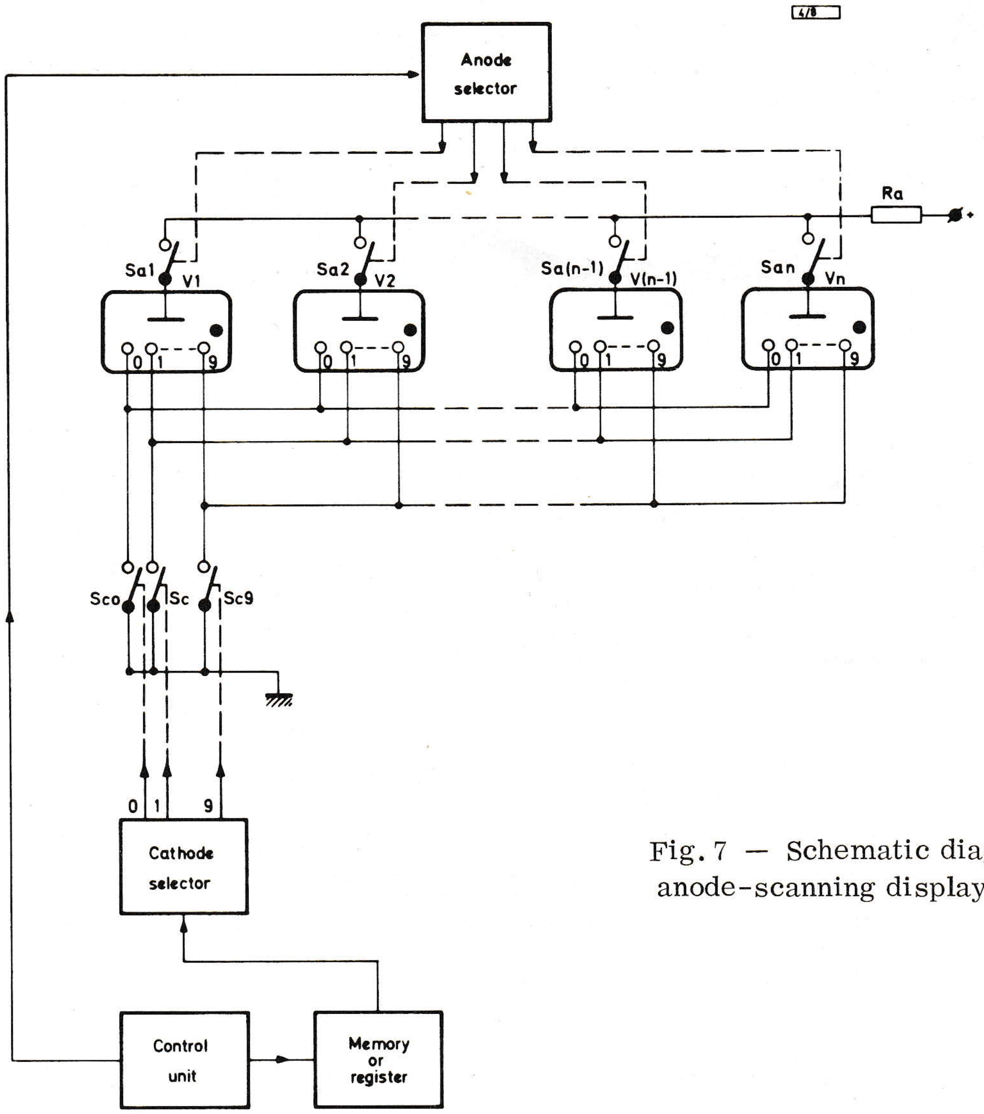

Fig. 7 — Schematic diagram of anode-scanning display system

from the memory into decimal form, and then closes the switch corresponding to the numeral. At the same time, the control unit sends a pulse to the anode selector which closes the anode switch of V_1, S_{a1}. Indicator tube V_1 therefore displays the first numeral from the memory. The control unit then interrogates the memory a second time, and the second numeral is passed to the cathode selector. The corresponding cathode switch is closed, and the pulse from the control unit to the anode selector causes the anode switch S_{a2} to close. Indicator tube V_2 therefore displays the second numeral from the memory. Successive pulses from the control unit cause the anode switches of all the indicator tubes to be closed in sequence, and so the numerals from the memory are displayed in turn.

The anode-scanning system overcomes the disadvantages of the cathode-scanning system about the rating of the cathode switches. As only one indicator tube is lit at a time, even if the same numerals are to be displayed by all the tubes, only the peak anode current of one tube will flow through the cathode switch.

CHOICE OF DISPLAY SYSTEMS

It can be seen from the descriptions of the various display systems that the type of system used in a particular application may be determined by the application itself. For example, a dynamic anode-scanning system must be used to display the read-out of passive registers. Where a choice of system exists, economic considerations may well determine the choice. A static system requires a large number of cathode switches. The number of switches is reduced in a dynamic system but more complex circuits such as counters are required. Thus it is necessary to take into account the cost of components, and such factors as reliability and replacement when choosing the type of display system.

DRIVING METHODS FOR NUMERICAL INDICATOR TUBES

Various circuits can be used for anode and cathode switches in the display systems described. Circuit elements such as transistors, integrated circuits, or silicon controlled switches can be used as the active elements. The choice will depend on many factors which will probably by resolved by the application itself. The design of circuits using these elements will be the subject of later application notes in this series.