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A RADIO CORPORATION OF AMERICA SUBSIDIARY

Harrison, New Jersey

RCA RADIOTRON DIVISION

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APPLICATIONS NOTES

APPLICATION NOTE ON OPERATION OF THE GAS-TRIODE OA4-G

The OA4-G is a cold-cathode, glow-discharge tube of the starter-anode type designed for use primarily as a relay tube in carrier-actuated equipment. The OA4-G consists of a cathode (K), starter-anode (P_1), and anode (P_2) arranged as shown in the photograph of Fig.1; socket connections and symbolic representation of the tube are shown in Fig.2.

In normal operation of the OA4-G, a relatively small amount of energy initiates a glow-discharge between cathode and starter-anode. This discharge produces free ions which assist in initiating the main discharge between cathode and anode. The anode current (I_{b2}), which flows during the cathode-anode discharge, actuates a relay or other device connected in the anode circuit. It is the purpose of this Note to describe the characteristics of the OA4-G and to show its mode of operation in a typical carrier-actuated system.

Breakdown Characteristics

Any one of six different discharges may occur in a gas-triode, depending on the relative potential differences and relative distances between electrodes. The closed curve which describes the voltage conditions necessary for breakdown between any two electrodes in a tube of given geometry is called the breakdown characteristics of the tube.

Consider the test circuit of Fig.3. A voltage E_{bb1} is applied to P_1 through a high resistance R_{b1}; a voltage E_{bb2} is applied to P_2 through a load impedance R_{b2}. From the curve of a typical tube shown in Fig.4, it will be noted that for values of E_{b2} less than approximately +285 volts, no discharge is initiated until E_{b1} is approximately +85 volts. When this value is reached, a discharge between K and P_1 is initiated. This condition is depicted by section A (above zero ordinate) of the breakdown characteristics shown in Fig.4.

When the anode voltage is increased to +285 volts, a breakdown occurs between cathode and anode. The value of anode voltage required for breakdown between K and P_2 is substantially independent of starter-anode voltage for values of E_{b1} greater than approximately +18 volts, and less than +85 volts as shown by section B of Fig.4. Section B, therefore, shows the relation between E_{b2} and E_{b1} that is necessary for a cathode-anode discharge when there are no ions to assist the initiation of the breakdown.

Section C of Fig.4 shows the relation between E_{b2} and E_{b1} that is required for a discharge between starter-anode and anode when there are no ions to assist the initiation of this discharge. In this discharge, the starter-anode acts as a cathode, so that the slope of section C would be approximately 45 degrees were there no third electrode in the tube. This discharge can occur with positive values of E_{b1}, because the distance between P_2 and P_1 is less than that between P_2 and K.

Section D shows the relation between E_{b2} and E_{b1} that is required for a discharge between starter-anode and cathode when there are no ions to assist the initiation of this discharge. It should be noted that this discharge takes place between the same two electrodes as in section A. However, under the conditions of section D, P_1 acts as cathode, because it is negative with respect to K.

Sections E and F show the relations between E_{b2} and E_{b1} that are required to initiate a discharge between anode and cathode and between anode and starter-anode, respectively, when there are no ions to assist the initiation of these discharges. In these cases, as in the previous ones, the first word of the term describing the discharge denotes the electrode acting as cathode.

The breakdown characteristics of Fig.4 indicate the voltage conditions necessary for breakdown between any two electrodes when there is no assisting discharge current. For example, a discharge between anode and cathode is initiated when E_{b2} = +285 volts and I_{b1} = 0. When the voltage applied to P_1 is increased so that starter-anode current flows, the discharge between cathode and anode can be initiated at values of E_{b2} less than 285 volts. A relation between the assisting- or initiating-discharge current between two electrodes and the voltage on the third electrode necessary to initiate a discharge to the third electrode is called a transition characteristic.

Transition and Anode Characteristics

The OA4-G is designed for operation only in that part of the breakdown characteristics designated by section A (positive anode) of Fig.4. Although the tube functions in other regions, as previously described, its operation in these regions is unstable because of design characteristics. In normal operation, a discharge between cathode and starter-anode assists in initiating a main discharge between cathode and anode.

The relation between starter-anode current and starter-anode voltage is shown in Fig. 5. This curve is obtained by applying various values of E_{bb1} to P_1 through a high resistance (R_{b1} in Fig.3) and recording I_{b1}; the starter-anode voltage is then $E_{bb1} - I_{b1}R_{b1}$. The load line R_{b1} intersects the abscissa at values of E_{bb1} of interest. As E_{bb1} is increased above the value at which the K - P_1 discharge occurs, I_{b1} increases proportionately and the starter-anode voltage (E_{b1}) remains substantially constant at approximately 60 volts.

Now, for each value of I_{b1}, there is a corresponding value of E_{b2} necessary to initiate the main discharge between cathode and anode. This relation between I_{b1} and E_{b2}, the transition characteristic, is shown in Fig.6. It shows the anode voltage necessary to initiate a discharge between cathode and anode when there is an assisting discharge current (I_{b1}) flowing. For practical purposes, it is convenient to think of the discharge to starter-anode as transferred to the anode when sufficient anode voltage is applied; hence, the name transition characteristic is used to define the relation shown in Fig.6.

The transition characteristic approaches the line E_{b2} = 70 volts, the voltage drop across the tube. When the value of E_{b2} is less than the voltage drop across the tube, the transfer of the main discharge cannot take place.

The anode characteristic of the tube (Fig.7) shows the relation between anode current and anode voltage. This relation is obtained by varying E_{bb2} and recording I_{b2}. The anode voltage is then $E_{bb2} - I_{b2}R_{b2}$. Fig.7 shows that over the useful operating range the anode-cathode voltage drop remains substantially constant at 70 volts. Operation at anode currents less than 5 milliamperes or greater than 25 milliamperes is not recommended.

The OA4-G in a Carrier-Actuated System

An important application of the OA4-G is its use as a relay tube in carrier-actuated systems. The circuit of a typical receiver system is shown in Fig.8. Low-frequency voltage is applied between anode and cathode through relay S and r-f coil L. A portion of this voltage is also applied between starter-anode and cathode through coil L by means of the voltage divider R_1 and R_2. Under the conditions shown in Fig.8, 65 volts peak is applied to P_1 and is in phase with the anode voltage. In addition to this low-frequency voltage, the line carries radio-frequency voltage that is furnished by a remote transmitter. When the resonant frequency of L and C is the same as the frequency of the r-f voltage on the line, a comparatively high r-f voltage is generated across L. The r-f voltage across L is applied to P_1 and P_2 in series with their respective low-frequency voltages.

The radio-frequency voltage is modulated 100 per cent at 60 cycles when the transmitter is a-c operated. Under these conditions, the wave form of the voltage impressed on P_1 is shown in Fig.9. With the proper adjustments, the value of starter-anode voltage is greater than that required to initiate a discharge between K and P_1 for only a part of the interval t. During the small interval ab, the gas (argon) ionizes at an increasing rate; during the interval bc, the rate of ionization decreases;

and during the interval cd, the gas de-ionizes at a comparatively slow rate. The process is repeated during successive r-f cycles and the discharge to starter-anode is completed only when the number and amplitude of the peaks are sufficiently great. Thus, to initiate a discharge under a-c conditions, it is not sufficient that the peaks exceed the value required for d-c excitation; the rates of ionization and de-ionization, the amplitude of each r-f cycle above the value required with d.c. applied, and the frequency should be considered. For power-line frequencies of the order of 60 cycles and radio frequencies of the order of 100 kilocycles, it is suggested that $E_{R2} + E_L$ be greater than 110 volts peak.

It should be noted that the low-frequency starter-anode and anode voltages are in phase and that the r-f voltage may be applied during one-half or throughout the entire low-frequency cycle. When the r.f. is generated during one-half of the low-frequency cycle, it is possible for the r-f voltage to be applied to the OA4-G during the half-cycle when its anode is negative. Under these conditions, it is merely necessary to reverse the line plug to either the transmitter or the receiver to obtain proper operation. It should also be noted that during the half-cycle that anode and starter-anode are negative, the OA4-G may be operating in a region corresponding to section D (negative anode) of Fig.4. On alternate half-cycles, therefore, a discharge between starter-anode and cathode may take place.

From this description, it is seen that the r-f signal need not supply all the power required to initiate the K - P_1 discharge. In actual practice, R_2 is adjusted for a value of E_{R2} that is somewhat less than the breakdown value. Then, the r-f voltage need only be enough to supply the difference between the breakdown voltage and the applied low-frequency voltage. In addition, the r-f signal should have sufficient amplitude to compensate for low line voltage. It is recommended, therefore, that provision be made to supply an r-f starter-anode voltage (E_L) of at least 55 volts peak.

Fig.10 shows the circuit of a typical transmitter. The power line over which the r-f is transmitted also furnishes plate voltage (a.c.) for the tube. The distributed constants of the line may have some effect on the amplitude or frequency of the r-f signal. However, these effects can be reduced by inserting a coupling tube between oscillator and power line.

CHARACTERISTICS

Peak Anode Breakdown Voltage (Starter-Anode connected to Cathode)	225 min.	volts
Peak Positive Starter-Anode Breakdown Voltage	70 min.	volts
	90 max.	volts
Starter-Anode Current (For transition of discharge to anode at 140 volts peak)	100 max.	microamperes
Starter-Anode Voltage Drop	60 approx.	volts
Anode Voltage Drop	70 approx.	volts

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS FOR RELAY SERVICE

Peak Cathode Current	100 max.	milliamperes
D-C Cathode Current	25 max.	milliamperes
Typical Operation with A-C Supply:		
Anode-Supply Voltage (RMS)	105-130	volts
A-C Starter-Anode Voltage (Peak)	70 max.	volts
R-F Starter-Anode Voltage (Peak)	55 min.	volts
Sum of A-C and R-F Starter-Anode Voltages (Peak)	110 min.	volts

REFERENCE

Kimball, Charles N., "A New System of Remote Control", RCA Review, January, 1938 (p.303).

FIG. 1

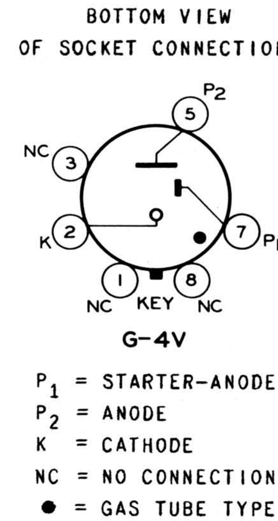


FIG. 2

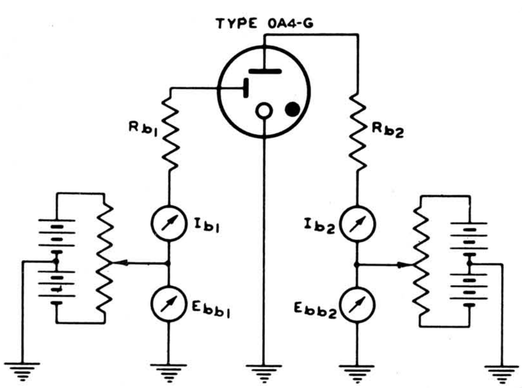


FIG. 3

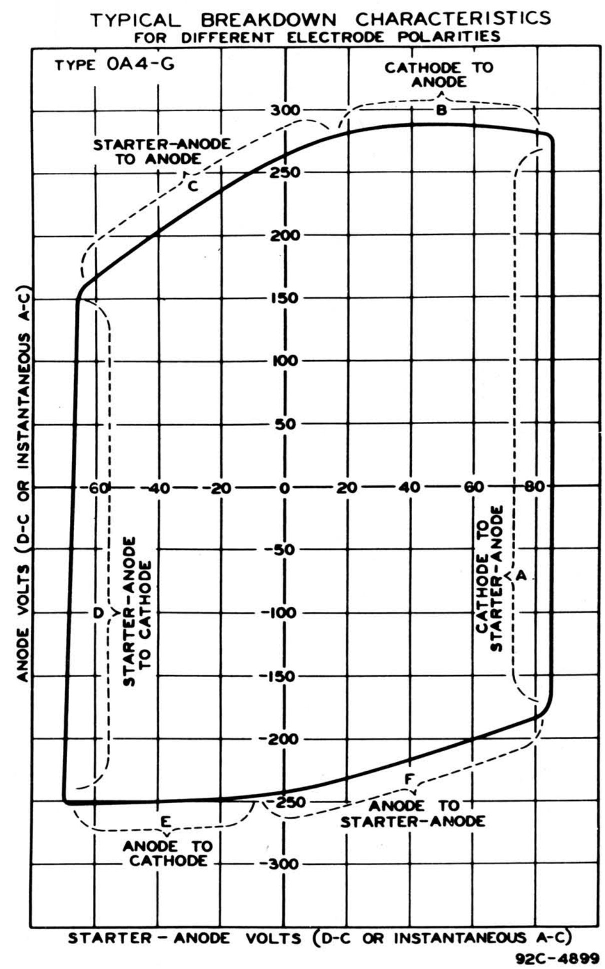


FIG. 4

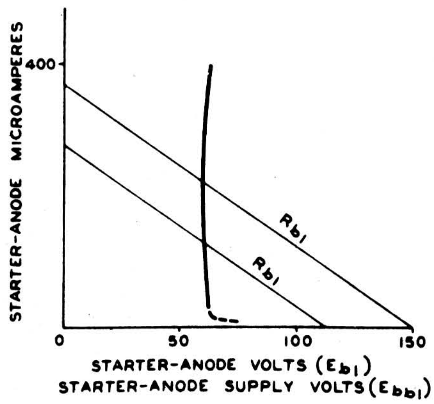


FIG. 5

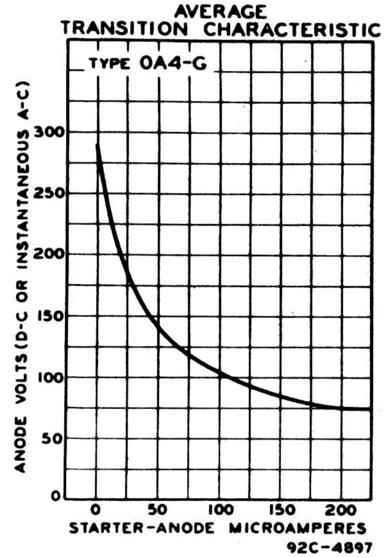


FIG. 6

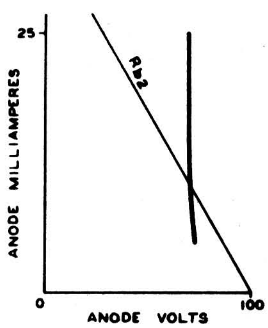
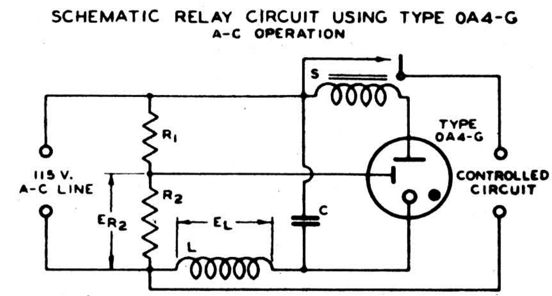


FIG. 7



C } = HIGH-Q TUNED CIRCUIT FOR R-F SIGNAL
L }
R_1 = 15000 OHMS (½ WATT)
R_2 = 10000 OHMS (½ WATT)
S = RELAY—CHOSEN FOR DESIGN REQUIREMENTS

FIG. 8

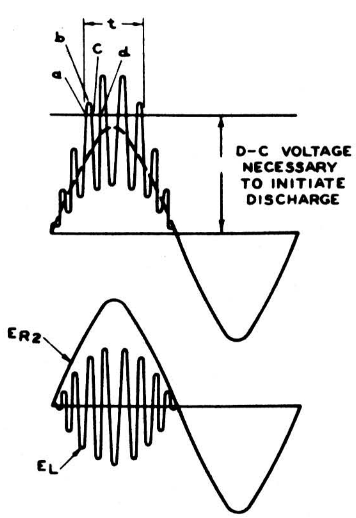


FIG. 9

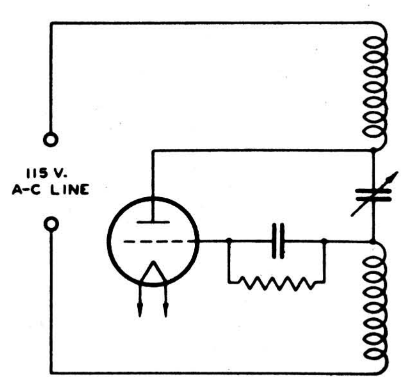


FIG. 10