A thermionic trigger

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equal to the peak voltage of the supply. If, however, it is shunted by a resistance, this will lower the maximum potential attained, and also introduce a ripple of somewhat complicated wave-form owing to the partial discharge of the condenser while the rectifier is not conducting. In the present experiment, a 16 μF. condenser was connected through a small Westinghouse rectifier to a transformer giving about 20 V. peak, and was shunted by various resistances. The maximum and minimum voltages across the condenser were measured with the thyratron potentiometer, and are shown in Fig. 2, plotted against the reciprocal of the shunting resistance. From this the effect of load, both in diminishing the maximum potential and increasing the ripple, can be seen. These results were substantially confirmed by examination with the cathode-ray oscillograph; this method is, however, less suitable than the thyratron potentiometer for the accurate quantitative investigation of such problems.

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A THERMIONIC TRIGGER

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ABSTRACT. A simple hard valve circuit is described which provides positive off-on control with any desired differential from 0·1 V. to 20 V. Less than 10^{-6} amp. is required at the input, but up to 20 ma. at 200 V. is available in the output. Either positive or negative control is possible. The operation cycle occupies about 10 μ sec. Applications to cathode ray oscillography, to "thermostating" and to lighting control are illustrated.

THERE are numerous electrical systems in which it is desired that a slowly varying potential from some control device shall actuate another circuit in a positive, "on-off" manner. Usually either a gaseous valve or a mechanical relay is employed, with or without amplification.

While these methods are quite satisfactory for many purposes, they do not give the quickness of action and flexibility of control which modern design demands. The thyratron operates quickly enough but requires some special means of de-ionization, has no inherent differential characteristic, and is notoriously subject to variation of characteristic with time and temperature. Besides, it consumes much cathode heating power and requires a "warm-up" period before anode potential may be applied. The relay, while it is dependable, is necessarily sluggish and insensitive, and has a limited range of differential with any given design.

The method here suggested, which is similar to certain trip relay circuits,* is to use a hard valve circuit into which has been incorporated an adjustable differential trigger action. The anode current starts suddenly (within 1–10 μ sec.) after an inferior critical input potential level has been reached, and remains at full strength until a superior critical potential is reached, whereupon the system reverts to its former condition equally quickly.

As will be noted on reference to the graph (Fig. 2), the inferior or "on" critical potential is substantially constant, while the superior or "off" potential is readily and linearly adjustable by means of the rheostat *R*. Thus the differential between "on" and "off" may be varied smoothly from zero to more than 20 V. without affecting instantaneous positive action.

The circuit (Fig. 1) is substantially that of a two stage direct-coupled amplifier of simple design with the addition of a rheostat *R* in the common cathode circuit. The action can be seen roughly by considering the circuit as two separate amplifiers directly coupled. A positive increment of potential to the input grid causes a large negative increment to the second grid's potential and, it is true, a slight increment in its own grid bias which tends to minimize the increase in first anode current. The second valve however experiences a very large decrement in current and consequently causes a large decrement in first tube bias, thus

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* *e.g. E.T.Z.* **53** 1932 (669).

rendering it unstable and tripping the "trigger". The inverse operation occurs when, with a sufficiently negative input voltage, the positive potential returned from the second valve is finally overpowered.

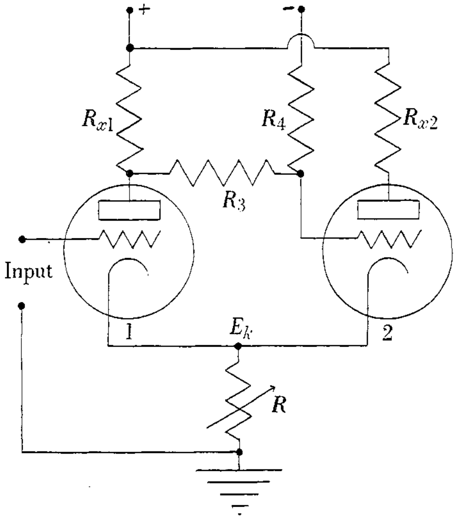

Fig. 1. Thermionic trigger circuit

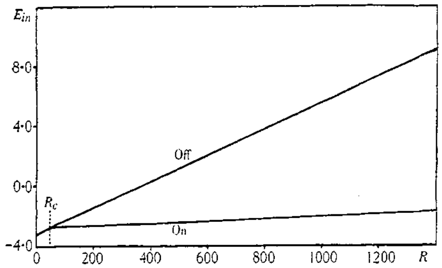

Fig. 2. Differential trigger characteristic

More quantitatively, an applied input voltage E_{in} causes a change of cathode voltage E_k of

$$E_k = E_{in} - E_{g1},$$

but

$$E_k = M_1 E_{g1} R - A M_2 E_{g1} R,$$

where M_1 is the overall mutual conductance of the first triode, given approximately by the expression

$$M_1 = M_{g1}\, R_{a1}/(R_{x1} + R_{a1});$$

M_2 is a similar expression for the second triode; A is the net amplification of the first valve given approximately by

$$A = \mu_1 \frac{R_{x1}}{R_{x1} + R_{a1}} \frac{R_4}{R_3 + R_4},$$

E_{g1} is the change of potential at the first grid, R_{a1} and R_{a2} are the anode resistances, R_{x1} and R_{x2} the load resistances, and M_{g1} and M_{g2} are the mutual conductances respectively of the first and second valves. μ_1 is the amplification factor of the first valve.

Equating the two expressions for E_k we find

$$E_{g1} = E_{in} \frac{1}{1 + M_1 R - A M_2 R}.$$

Now usually $M_1 < M_2$ and $A \geqslant 1$, so the second term in the denominator may be neglected. It is then obvious that the system passes out of equilibrium when $A M_2 R \geqslant 1$. Negative values indicate that equilibrium is not yet established, so the system will shift to new loci along the A, M_1, M_2 characteristics until the system just balances, hence the differential.

In a circuit now in use, the following set of constants is employed:

$\mu_1 = \mu_2 = 36$, $M_{g1} = M_{g2} = 1{\cdot}5$ millimhos, $R_{a1} = R_{a2} = 20{,}000\ \Omega.$, $R_{x1} = 10^5\ \Omega.$, $R_{x2} = 10^4\ \Omega.$, $R_3 = 5 \times 10^5\ \Omega.$, $R_4 = 2 \times 10^6\ \Omega.$ and negative bias $= 200$ v.

(This is for the type 6A6 valve; almost any triodes or pentodes may be used.) From this data $M_1 = 0{\cdot}25$ millimho, $M_2 = 1$ millimho, and $A = 24$; hence the critical value of R, namely R_c, is given by

$$R_c = \frac{1}{AM_2 - M_1} = \frac{1}{24 \times 10^{-3} - 2{\cdot}5 \times 10^{-4}} = 42\ \Omega.$$

Experimentally this value is verified, well within the limit of error, as 45 Ω.

Uses for the circuit are at once obvious. It may be used to control thermostats, refrigeration, lighting, chemical reactions; all using the adjustable differential trigger in conjunction with some source of potential which varies continuously with the phenomenon to be controlled. It gives convenient accept-reject indication for mass production checking and provides convenient photoelectric selection and counting.

In other cases its fast action is the specially attractive feature. In cathode-ray oscillography it provides convenient sweep circuit synchronization, while in the laboratory it provides an easy method for producing rectangular A.C. waves of any desired frequency and phase and, in another application, acts as a frequency meter more linear than one of the thyratron type, and one immune to locking.

Since output may be taken from either triode, and one is on while the other is off, obviously either positive or negative control may be had, although somewhat less power may be taken in the first case. In the normal connection, using small receiving triodes, up to 20 ma. at 200 V. may be taken, but much larger amounts may be had if large valves are used or several are paralleled; in any case, the input power need not be more than 0·2 V. at less than a microampere. Voltage operated loads may be connected to either anode or between cathode and earth; current operated devices should be inserted in series with either the cathode or an anode circuit.

Operation is gratifyingly stable and is quite insensitive to supply line variations provided reasonable constants for the various circuits are chosen. Under typical conditions, both critical potential and differential may be depended upon to stay within 100 mv. under all ordinary conditions.

LABORATORY AND WORKSHOP NOTES

THE ZERO SHIFT IN SENSITIVE MOVING-COIL GALVANOMETERS. By V. VOSS, M.A., Ph.D. and M. N. S. IMMELMAN, M.Sc.,

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THE shift of zero in galvanometers is a bugbear in every physical laboratory. When, for instance, the coil of a certain ballistic galvanometer in this laboratory was given a "kick" of 23 cm. on the scale, to the right, then immediately short-circuited and the position of rest of the reflected beam noted, and then this was repeated with the "kick" to the left, the two positions of rest differed by nearly 2 cm. If, however, instead of short-circuiting the coil after a "kick", the galvanometer circuit was closed through a resistance of about 1000 Ω., the coil would swing to and fro several times and the spot of light would always come to rest at the same point. That the shift of zero on short-circuiting the coil was not due to the temper of the suspension-strip having been affected by the heat of the soldering-iron was shown by replacing the soldered joints by tiny screw-clip joints. The shift of zero was then as evident as before.

It was suggested by Prof. R. W. Varder and Prof. W. H. Logeman, with whom the