AN ELECTRONIC RECEIVING RELAY FOR VOICE FREQUENCY CARRIER TELEGRAPH WORKING

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ABSTRACT

An electronic relay circuit has been designed using two thyratron tubes connected " inverse-parallel " to replace the usual electromechanical receiving relay in the voice frequency carrier telegraph terminal equipment. The electronic relay has several advantages over the existing type and has possibilities of further development.

INTRODUCTION

The function of the receiving relay in the voice frequency carrier telegraph equipment is to operate the local circuit, which includes the receiving apparatus, in accordance with the signal received from the distant station (Fig. 1).

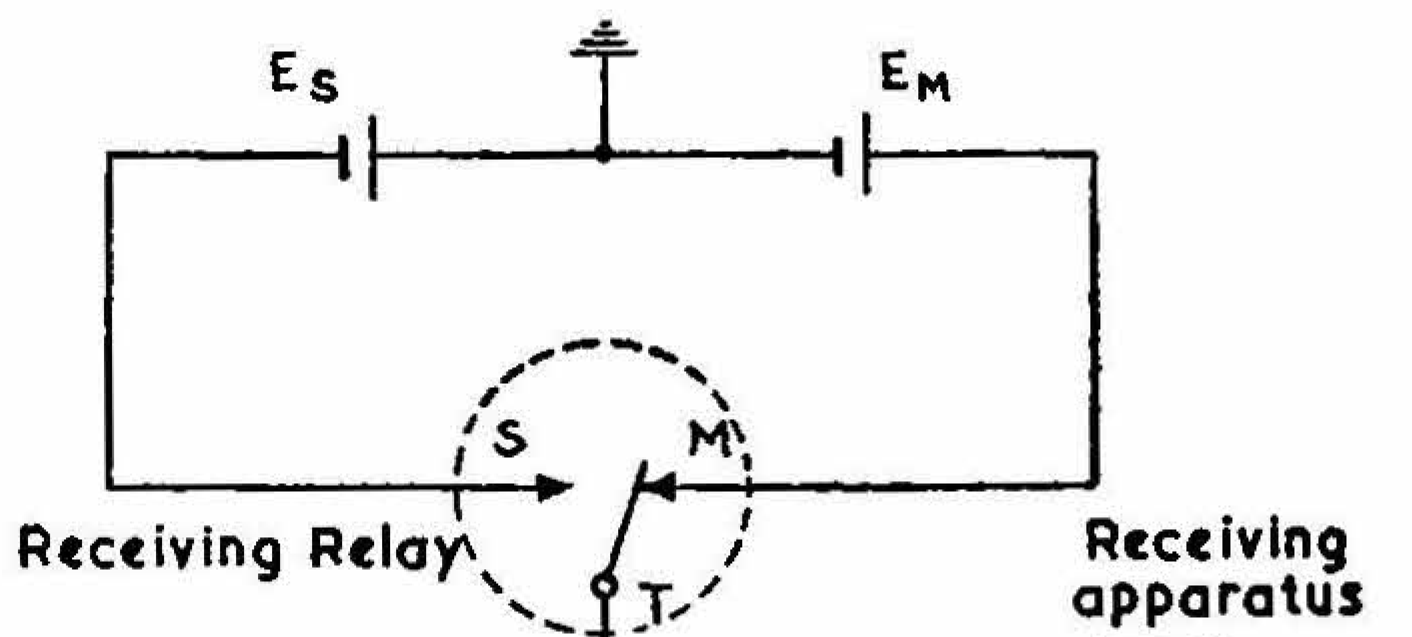

FIG. 1. Operations performed by the receiving relay.

(*a*) In the absence of a signal the receiving relay connects a battery with one polarity to the d.c. extension; and (*b*) on the arrival of a signal, it cuts off the first battery and connects a battery with the opposite polarity to the d.c. extension.

In present-day practice, these operations are performed by an electromechanical receiving relay. This paper describes an electronic type of receiving relay which can perform these operations and can advantageously replace the existing type. The inverse-parallel type of connection of the two thyratron tubes is used (Fig. 2), and their operation is so controlled that the tube T_s alone conducts during spacing intervals, thereby connecting the spacing battery to the d.c. extension; and the

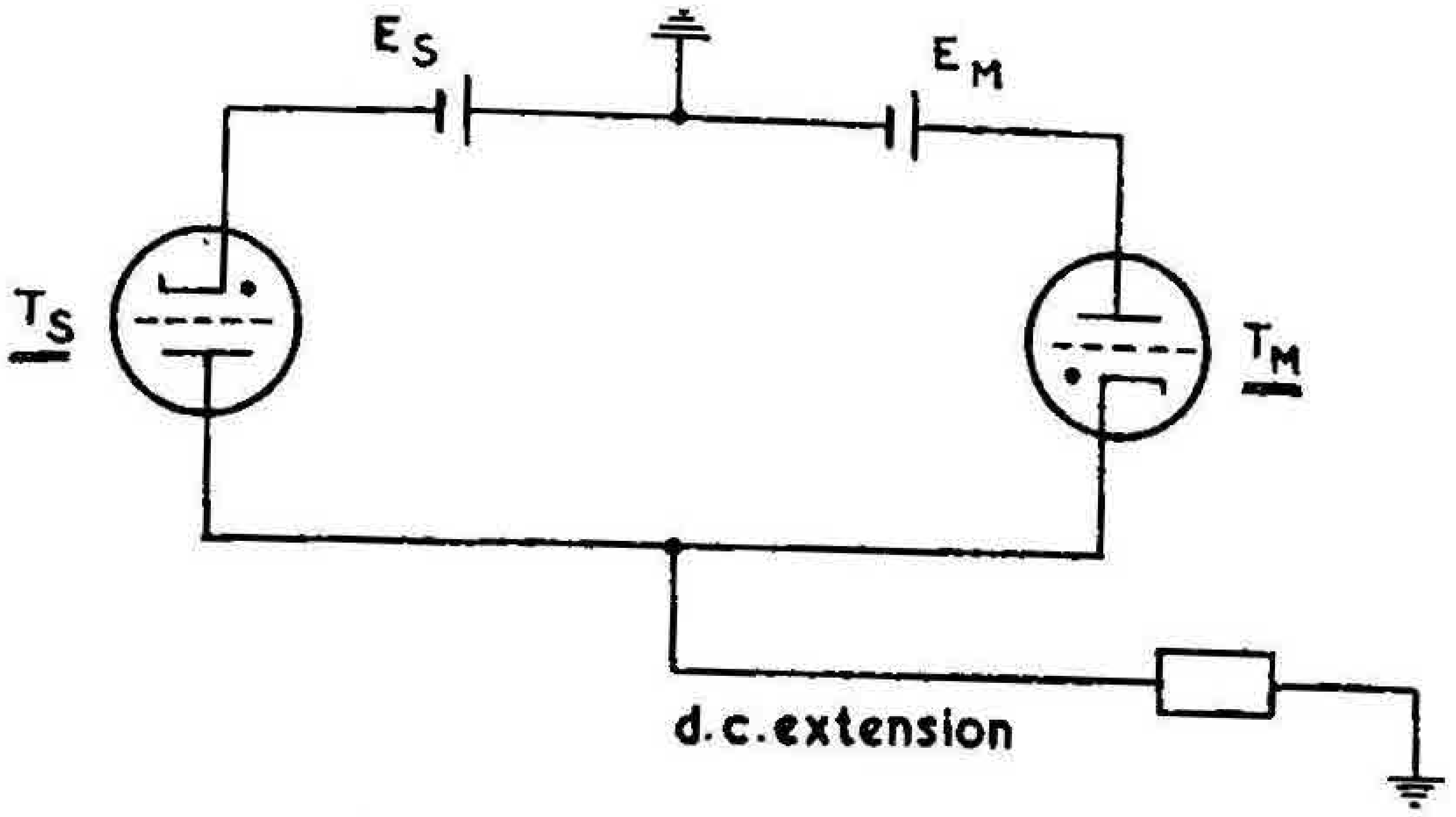

FIG. 2. Two thyratron tubes performing the same operations.

tube T_m alone conducts during marking intervals, thereby connecting the marking battery to the d.c. extension.

PRINCIPLE OF OPERATION

The operation of the relay is on a principle similar to that of the "scale of two" automatic counter.[1] Use is made of the fact that when a negatively biased gaseous tube is conducting in a d.c. circuit, the direct current may be interrupted by making the anode of the conducting gaseous tube negative with respect to its cathode for a time-interval greater than the deionization time of the gas in the tube.

Let initially the grids of both the tubes be sufficiently negative to prevent the striking of the tubes (Fig. 3). Now let the tube T_s, for instance, strike due to the

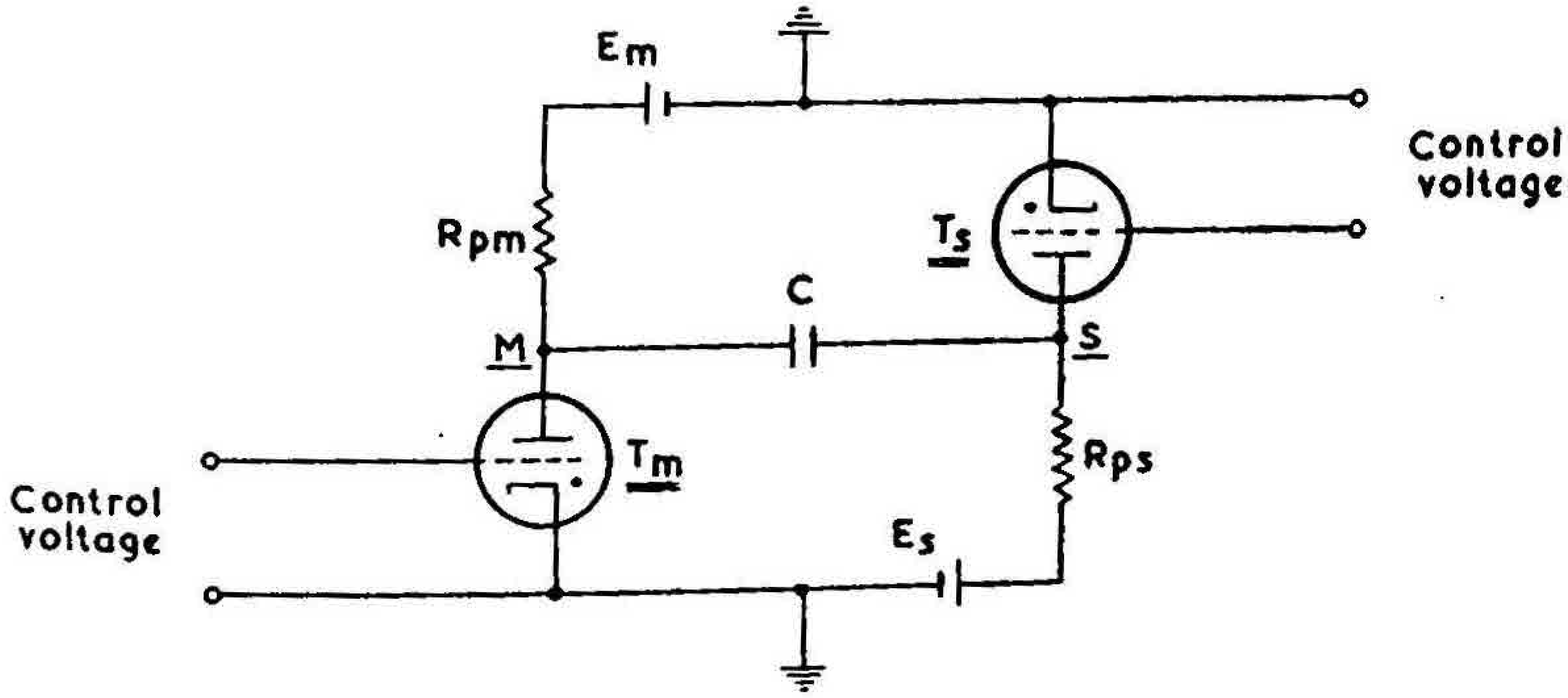

FIG. 3. Principle of operation.

reduction of its negative grid bias which is then restored to its previous value. The capacitor C will charge to $(E_m - E_{ts})$ volts with the point S negative and M positive, E_{ts} being the voltage drop across the tube T_s when it is conducting. If now the tube T_m is permitted to strike, M will come down to a level of E_{tm} volts equal to the drop across T_m when it is conducting, which in turn will temporarily make S negative with respect to the cathode of the tube T_s by $(E_m - E_{ts} - E_{tm})$ volts. In the case of the tube T_s, this corresponds to having a negative anode voltage. The tube T_s gets extinguished; and if this state persists for a time-interval greater than the deionization time of the gas in the tube, it will not reignite; and the potential of the point S will, therefore, sweep up to a value of E_s volts. The time required for this change in the potential of the point S will depend on the time constant of the CR_{ps} combination. The capacitor will now be charged to $(E_s - E_{tm})$ volts but with the point S positive and M negative. If now the grid of T_m is made negative again and T_s is permitted to strike, the same chain of events is repeated, the two tubes interchanging their roles.

The capacitor, C, may be called a commutating capacitor because it is through the commutating action of C that the striking of one tube extinguishes the other.

Circuit Performance

The actual circuit that has been developed is shown in Fig. 4.

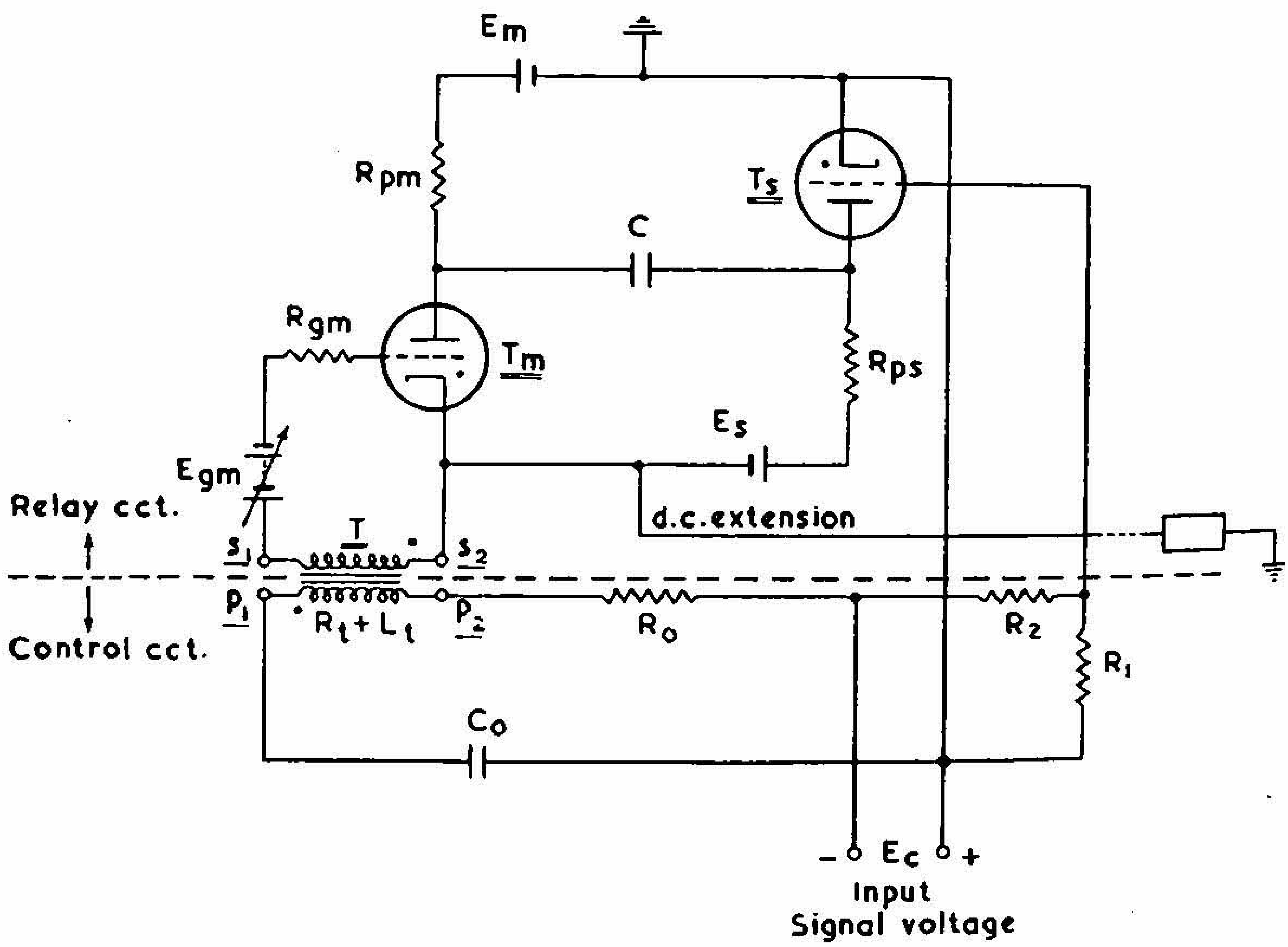

FIG. 4. Actual circuit developed.

In the absence of the signal the grid of the tube T_m is negative with respect to its cathode by E_{gm} volts, which is well beyond the critical value needed to prevent it from striking with the applied anode voltage of E_m volts. The tube T_s is, however, conducting as its grid and cathode are at the same potential; and a negative battery is connected to the d.c. extension. On the arrival of the signal, current flows in the primary of the transformer T in the direction P_1 to P_2 till the condenser C_0 in the control circuit is fully charged. This induces a current in the secondary of the transformer in the direction S_2 to S_1 which reduces temporarily (for a time interval greater than the ionization time of the gas in the tube) the negative grid bias of T_m and thus causes it to strike. T_s is extinguished due to the commutating action of the condenser C and the positive battery is now connected to the d.c. extension. At the same time the grid of T_s becomes negative with respect to its cathode by $E_{gs} = E_c \cdot R_1/(R_1 + R_2)$ volts. With a suitable value of E_c (and with some fixed bias on the grid of T_s, if necessary) the total negative grid bias of T_s can be arranged to be well beyond the critical value needed to prevent it from striking with the applied anode voltage of E_s volts. T_s is thus prevented from striking again as long as the signal exists. The grid bias of T_m assumes the original value a short while after the arrival of the signal; but now it has no control over T_m, which, therefore, remains conducting.

The removal of the signal voltage E_c also removes the negative bias on the grid of T_s and causes it to strike. T_m is extinguished due to the commutating action of C and does not strike again as its grid is negatively biased beyond the cut-off value. The current induced in the secondary of the transformer, due to the discharge of C_0 through its primary adds to E_{gm} so that there is no possibility of T_m striking unless the signal is received again. The negative battery is now connected to the d.c. extension as before.

In standard voice frequency carrier telegraph working, the spacing and marking intervals mean the absence and presence of the carrier current over the particular channel; and only when the carrier current exists is the signal voltage E_c available at the input terminals of the receiving relay (Fig. 4). Thus T_s and T_m are made to conduct alternately during the spacing and marking intervals respectively.

CIRCUIT ELEMENTS AND THE CIRCUIT CONSTANTS

(i) The cathodes of the two tubes are not at the same potential. Tubes with indirectly heated cathodes must, therefore, be used if the filament supply is to be common to both. Alternatively a filament transformer must be used with two separate secondary windings insulated from each other for a potential difference of $(E_m + E_s)$ volts.

(ii) The grid circuits of the two tubes and also the control voltages applied to the two grids must be isolated from each other for direct current. In the circuit that has been developed, this is secured by using the transformer secondary in the grid circuit of T_m.

(iii) The thyratrons are used as switches operating by changes of control voltages applied to their grids. Evidently their usefulness will increase with higher grid resistors, *i.e.*, with lower power consumption in the grid circuit before the corresponding tube becomes conducting. However, as pointed out by Richter,[2] preconduction grid currents can be expected to be fairly large in the case of gas-filled tubes and these lead to trouble if very high resistors are included in the grid circuits. Suitable values of grid resistors must therefore be chosen.

(iv) Even for single current working it is desirable, for rapid recovery and reliable commutating action of C, to have E_m and R_{pm} to be equal to E_s and R_{ps} respectively.

(v) The value of the commutating condenser C depends on the line current required and should be kept as small as possible to secure rapid recovery. For the same reason, R_{pm} and R_{ps} should also be kept as small as possbile. However, the time constants of the combinations CR_{pm} and CR_{ps} must be sufficiently large so that the extinguished tube will remain non-conducting for a time-interval greater than the deionization time of the gas in the tube.

(vi) The time lag between the arrival of the signal and the striking of T_m depends on how quickly the current induced in the secondary of the transformer reduces its negative grid bias, *i.e.*, on how quickly the current is established in the primary of the transformer. The charging path of the condenser C_0 in the control circuit consists of R_0, R_t and L_t (the primary winding of the transformer) and C_0. Therefore, it is desirable to have

$$\left[\frac{(R_0 + R_t)^2}{4\,L_t^2}\right] \rightarrow \left[\frac{1}{L_t\,C_0}\right].$$

The condenser C_0 discharges on the removal of the signal and the discharging path includes R_1 and R_2 in addition. It is essential that throughout the discharge P_2 must remain positive with respect to P_1; in other words, the discharge must not be of an oscillatory nature in which case T_m also may strike during the spacing intervals. The following condition must then be satisfied, *viz.*

$$\left[\frac{(R_1 + R_2 + R_0 + R_t)^2}{4\,L_t^2}\right] > \left[\frac{1}{L_t\,C_c}\right].$$

Again, for rapid recovery it is desirable, as before, that these two quantities should be nearly equal. So, R_1 and R_2 should be as small as possible. But for values of R_1 and R_2 which are very small, too much power will be consumed during marking intervals.

The values of R_1, R_2, R_0 and C_0 must, therefore, be suitably chosen. R_t and L_t are fixed by the choice of the transformer.

(vii) The choice of the transformer depends on (*a*) the ratio of the input signal voltage available and the induced voltage required in the secondary of the transformer, and (*b*) the optimum value of the d.c. resistance in the grid circuit of T_m.

Modifications Necessary in the Voice Frequency Carrier Telegraph Terminal Equipment

In the voice frequency carrier telegraph receiving circuit, the incoming signal after passing through the receive filter, is amplified and detected before being applied to the receiving relay. Usually the operate coil of the receiving relay is included in the anode circuit of the detector. During marking intervals the anode current becomes equal to or greater than the operate requirement of the relay, the relay tongue changes over to the marking stop and remains there till the termination of the marking signal. Thus, the operation of the receiving relay depends usually on the magnitude of the anode current of the detector. But in the case of the electronic receiving relay, the volatge E_o applied across the input terminals (Fig. 4) is the important consideration. The desired result can be achieved by including a suitable resistor in the anode circuit of the detector, the voltage developed across it being applied to the input terminals of the electronic receiving relay.

Advantages of the Electronic Receiving Relay

(i) The electronic receiving relay is more sensitive.

(ii) As it does not have any mechanical moving parts, the lag due to the mechanical inertia in the usual electromechanical relay is eliminated. The operating or the recovery time of an electronic relay is very much smaller (of the order of only a few microseconds) compared to the transit time of the electromechanical relay. It is, therefore, capable of working at higher speeds.

(iii) Difficulties, like the chattering of contact springs and the contacts getting worn out, leading to distortion are eliminated.

(iv) The electronic relay circuit is quite simple and free from frequent critical adjustments. It is expected to retain a constant standard of performance over a long period.

Further Scope of Work

It should be possible to eliminate the voltage source E_{gm} and provide the grid bias for T_m either from the detector output or from the output of the conducting tube.

Also, with a few modifications it should be possible to use this electronic receiving relay for " two tone working "—only one relay being used as the receiving relay of the two channels over which the mark and space signals are sent.

It is hoped that this electronic relay may find applications in other fields as well.

References

1. Wynn Williams, C. F. .. "A Thyratron 'scale of two' Automatic Counter," *Proc. Roy. Soc.*, A, 1932, 136, 314-15.

2. Walter Richter .. *Fundamentals of Industrial Electronic Circuits* (McGraw-Hill), 1947, 424-26.