

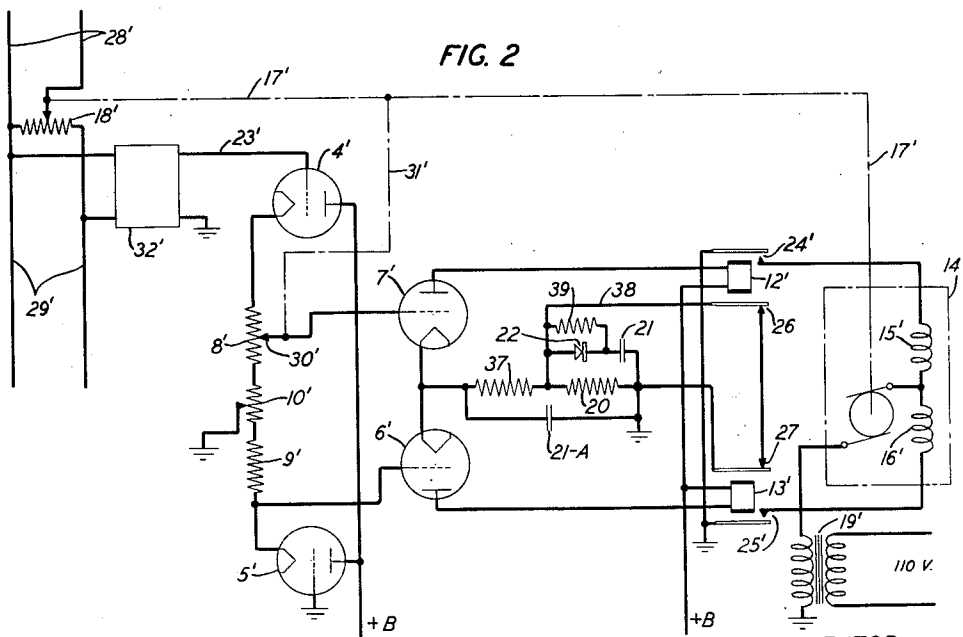
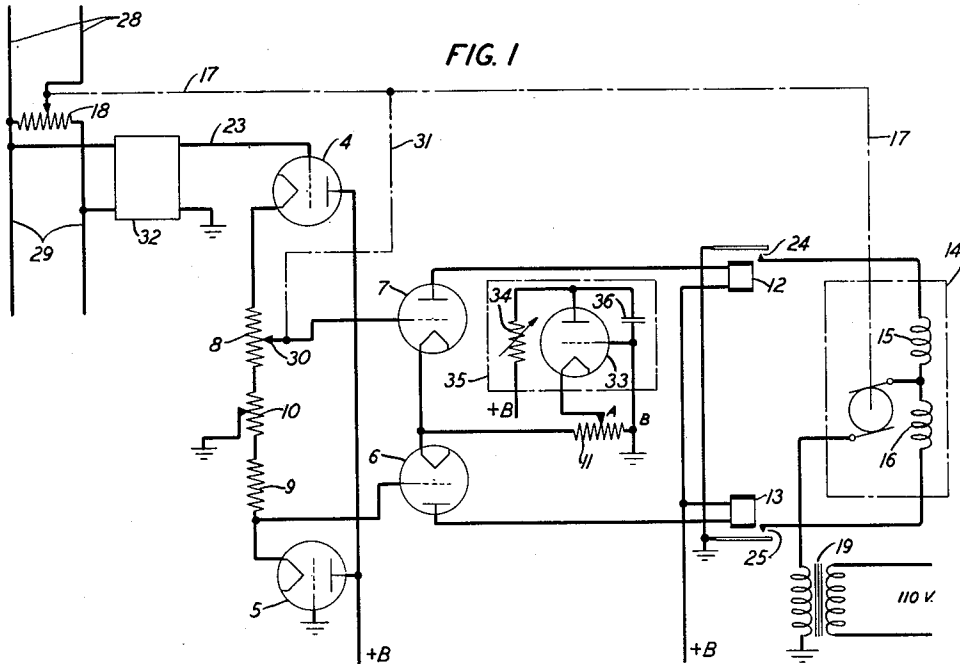
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RELAY CIRCUIT

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RELAY CIRCUIT

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1

This invention relates generally to relay circuits and more specifically it relates to relays in vacuum tube plate circuits.

An object of the invention is to provide a more reliable relay operation than has been available before.

Another object of the invention is a relay circuit in which the release of the relay contacts are effected in a consistently reproducible manner.

A further object of the invention is the improvement generally of relay operation.

A third object is a relay circuit whereby the deenergization of a relay is effected by a signal voltage substantially equal to the signal voltage required to energize the relay.

It is well known in the prior art that the value of current at which a relay will operate is considerably greater than the value of current at which a relay will release. Furthermore, the releasing value of current is not a consistent value.

The invention, in carrying out the objectives enumerated herein, overcomes these difficulties. The circuit comprises an amplifier having the rectified and filtered part of a first signal voltage fed into its input, two vacuum tubes having their cathodes electrically connected together and also connected to a common pulsating voltage. A second signal voltage comprising a variable portion of the output of the amplifier is impressed upon the input of one of said vacuum tubes. A relay is placed in the output circuit of each of said vacuum tubes. Under balanced conditions, when said second signal voltage is impressed on the input of one of said vacuum tubes, neither relay operates. When said second signal voltage increases beyond a desired value, the relay in that tube circuit operates, remains operated during the steady state portion of the pulsating voltage cycle, and is released during the pulse interval of this cycle, the operation being repeated during successive pulsating voltage cycles until said second signal voltage no longer exceeds the desired value. A motor is step driven by the operation of said relay, correcting the strength of said second signal so that the circuit will become balanced and the relays will not operate. This step driven motor at the same time corrects a third signal so that said third signal will always remain at a substantially constant value. This "third signal" may comprise a whole separate signal group in other pairs of a common cable such as in a pilot wire control system, a separate group of channels on the same pair as in a carrier pilot channel control system, or may be derived directly from said first signal itself by an electrical coupling with said first signal as in an audio fre-

2

quency automatic volume control system. If the said second signal voltage strength should become decreased, the tube, the input of which receives the said second signal voltage, will draw less plate current than under balanced conditions, and the common cathode potential drop will accordingly decrease, thus allowing the plate current in the other tube to increase which results in a similar operation of the associated relay and subsequent correction of the second and third signal voltages by the motor.

The invention, its nature and objects, will be more fully understood from the drawings and the following detailed description.

Fig. 1 shows a circuit employing intermittent relay operation with a relaxation oscillator signal voltage source applied across A, B. The values of the circuit elements for a preferred embodiment of the invention are as follows: resistance 8 is 3500 ohms, resistance 9 is 3500 ohms, resistance 10 is 1000 ohms, resistance 11 is 4130 ohms, and the resistances of relays 12 and 13 are 5500 ohms each.

Fig. 2 illustrates a similar circuit with a resistance capacitance circuit common to the cathode of the two tubes which causes intermittent operation of one or the other of two relays when circuit conditions so require. The values of the circuit elements for a preferred embodiment of the invention as shown in Fig. 2 are as follows: circuit elements 8', 9', 10', 12', and 13' have the same value as in Fig. 1, resistance 20 is 5000 ohms, resistance 26 is 4130 ohms, condensers 21 and 21-A are each 250 microfarads, bleeder resistance 39 is 250 ohms and is provided to protect relay contacts 26 and 27. Asymmetrical device 22 bypasses resistance 39 to provide low surge impedance across resistance 20 at the instant either contact 26 or 27 opens.

In Fig. 1, amplifier-rectifier 32 converts to a proportional direct current voltage, if the first signal on leads 29 is alternate current, for application to the grid of vacuum tube 4. If the first signal on leads 29 is direct current, rectification is obviously not required. Vacuum tube 4 is shown as a triode but any vacuum tube amplifier may be used here. Vacuum tube 5 is of a type identical to that chosen for tube 4. Vacuum tube 5 establishes a set potential for vacuum tube 6. This reference potential is not necessarily a fixed voltage. It varies with plate voltage variation in such a manner as to maintain current balance in vacuum tubes 6 and 7 when the first signal remains unchanged and moreover tends to keep the absolute value of their plate currents constant, thereby maintaining circuit sensitivity at a con-

3

stant value despite poor voltage regulation. Thus the chief function of vacuum tube 5 is to provide circuit stability. Vacuum tubes 6 and 7 are also triodes, although other types of tubes, or any device capable of responding to a variable signal to produce a variable output, such as a transistor, can be utilized. Resistances 8 and 9 constitute the load on tubes 4 and 5 respectively and resistance 8, in addition, establishes a grid potential on tube 7. Resistance 10 is for the purpose of adjusting and balancing the loads of vacuum tubes 4 and 5. A relaxation oscillator signal voltage is arranged across leads A, B and the signal is impressed on resistance 11 which is common to the cathode of tubes 6 and 7. Relays 12 and 13 are in the plate circuit of tubes 7 and 6 respectively. Motor 14 is capable of rotating in either direction according to the excitation of field 15 or field 16. Shaft 17 acts on potentiometer 18 to exercise control over the signal voltage outgoing on leads 28 and maintain said outgoing signal voltage at a constant value. Power supply 19 provides armature current for motor 14.

In Fig. 2, circuit elements 4', 5', 6', 7', 8', 9', 10', 12', 13', 14', 15', 16', 17', 18', 19', 28', 29', 30', 31', and 32', can be described in the same way the corresponding elements were described in Fig. 1. Resistance 20 is common to the cathodes of tubes 6' and 7'. Shunting a portion of resistance 20 are condenser 21 and rectifier 22. Shunting this network, including resistance 37, is condenser 21—A.

The operation of the circuit shown in Fig. 1 will now be described in detail.

It is desired to control the strength of a signal voltage on leads 28 and to avoid "hunting" in so doing. Assume the incoming signal voltage on leads 29 becomes stronger so that the portion transmitted beyond 28 in its present setting is stronger than desired. The grid on tube 4 becomes less negative with respect to its cathode and the plate current of tube 4 is increased. The potential drop across resistance 8 becomes greater with the consequence that the grid of tube 7 becomes more positive with respect to ground (less negative with respect to its cathode) which in turn causes a larger plate current to flow in tube 7. This increased plate current is sufficient to operate relay 12 and close contact 24. However, all this time a relaxation oscillator, shown in dotted box 35, has been producing voltage pulses in resistance 11 by forcing periodic current pulses through its terminals A and B which will correspondingly vary the cathode potentials of tubes 6 and 7 during the pulse occurrence, and consequently vary also the plate currents thereof. During the steady state interval between pulses normal plate currents flow, the effect of the pulses being to cause a momentary reduction in both plate currents during actual pulse occurrence. Instead of the usual form of relaxation oscillator shown a conventional sine wave oscillator feeding a class C amplifier and rectifier may be employed to furnish the desired single sided pulses on a cyclic basis. Relay 12 will release due to the drop in plate current initiated by said pulse. Thereafter, relay 12 will be operated and released once during each relaxation oscillator cycle until the "steady state" grid potential on tube 7 with respect to its cathode has been increased sufficiently, and the resulting plate current in tube 7 decreased sufficiently, so that it is insufficient to operate relay 12. When this event occurs, it will of course mean that the signal voltage on the grid of tube 7 with respect to its cathode is just less than the signal voltage

4

thereon at the time the relay 12 first began its operation. The potential on the grid of tube 7 with respect to its cathode is caused to become more negative by the operation of motor 14 moving the sliding arm 30 to a new position (downward on Fig. 1).

The relaxation oscillator shown in box 35 of Fig. 1 may comprise a gas triode, or thyratron, such as a type 884, for vacuum tube 33, a condenser 36 and an adjustable resistance 34. Operating from the same +B supply, and using a capacity of about 35 microfarads and charging resistances between $\frac{1}{4}$ megohm and 1 megohm the period of one cycle was readily varied from 1 second to 6 seconds. Different B-supply voltages will affect the choice of suitable constants to get desired timing. The total resistance in the discharge path should be sufficiently large that the tube rating is not exceeded.

Step-by-step rotation of motor 14 is caused by the cyclically recurring operation of relay 12 which operates and releases intermittently and consequently intermittently closes and opens the motor circuit of motor 14 through one of its field windings 15. Shafts 17 and 31 turn, moving sliding arm 30 downward to decrease the signal voltage input on tube 7 until the relay 12 no longer reoperates. It is to be noted that the effect of this circuit arrangement is the same as if the relay 12 had the same operate and release values of winding current.

The potential of the cathode of tube 6 with respect to ground is also varied by the unilateral pulsations fed into terminals A, B but its cathode potential is normally, i. e., at balanced conditions, not low enough to produce a plate current sufficient to operate relay 13 during any portion of the steady state portion of the relaxation cycle, and when the plate current in tube 7 is greater than normal, the steady state cathode potential of the cathode of tube 6 is more positive than under balanced conditions so that relay 13 will, of course, not be able to operate.

Should a large enough drop in signal voltage on lead 29 occur, for a given position of slider 30, tube 7 would draw less steady state plate current than under balanced conditions and consequently the cathode potential of tube 6 with respect to ground would be correspondingly lowered which in turn would sufficiently increase the plate current of tube 6 so that relay 13 would operate during each steady state interval between relaxation oscillator pulses. The contact 25 will close completing the circuit for motor 14 through field winding 16 causing the motor to operate in a step-by-step manner in a direction of rotation opposite to that when relay 12 operated. The shaft 17 will adjust resistance 18 to increase the strength of the outgoing signal voltage on leads 28. By the time signal voltage on lead 28 has reached its proper value motor 14 will have acted through shaft 31 to increase the potential on the grid of tube 7 in a positive direction with respect to ground sufficiently so that tube 7 will be drawing enough current to cause cessation of the operation of relay 13 by virtue of the fact that increased plate current in tube 7 will cause an increase in positive potential of the cathode of tube 6 with respect to ground and motor 14 will cease rotation.

It is to be noted that for any constant value of plate supply voltage the only purpose of tube 5 is to maintain a suitable constant reference voltage on the grid of tube 6. Since the grid and the plate of tube 5 are at a constant potential, the cathode must also remain at a constant po-

5

tential. As the cathode of tube 5 is connected to the grid of tube 6, the grid of tube 6 must also remain at a constant potential, all with respect to ground. If plate supply voltage fails to remain constant, plate currents in tubes 4 and 5 will change in like manner so that increment or decrement in grid potential of tubes 7 and 6 with respect to ground due to this cause will undergo substantially identical change. In this manner a balance of plate currents in tubes 7 and 6 is maintained even though plate supply voltage is not perfectly constant. Moreover, circuit constants can be so adjusted that the effective shift in grid bias due to plate voltage change is just adequate to maintain constant plate current at the changed plate voltage value.

The circuit shown in Fig. 2 operates essentially the same as the circuit shown in Fig. 1 and performs the same function. However, instead of utilizing a relaxation oscillator applied across the terminals A, B in Fig. 1 for the purpose of providing a pulsating voltage, Fig. 2 has a resistance-capacitance combination which charges and discharges and causes an intermittent operation of the relay in the plate circuit of the tube being utilized.

The operation of the circuit disclosed in Fig. 2 will now be discussed in detail. Assume as in the case of Fig. 1 a properly poled direct current signal voltage is introduced on lead 23. If this signal is larger than is desired, for the existing slider position, tube 4' will amplify the signal voltage and the grid of tube 7' will become more positive with respect to ground because the plate circuit current in tube 4' will have increased and consequently the voltage drop across resistance 8' will have increased as in the case of Fig. 1. Since the grid of tube 7' has become less negative with respect to its cathode, tube 7' will therefore draw more plate current which, under the conditions assumed, will be sufficient to operate relay 12'. Up until the point in time at which relay 12' operates, the operating path for said relay 12' will be from tube 7' through resistor 37, through lead 38, contact 26, contact 27 to ground, through +B battery to relay 12' and back to tube 7'. Immediately upon operating, relay 12' will open contact 26. The direct current path for the plate current will under this condition traverse both resistances 37 and 20, yielding a larger cathode potential drop than existed prior to the operation of relay 12'. Transient effects occur, however, immediately upon the opening of contact 26. Condensers 21 and 21—A will oppose the transition to the new direct current equilibrium conditions. The initial rush of plate current into the parallel combination of resistance 20, capacitor 21 and asymmetric device 22 bridged by resistor 39 will serve to charge up condenser 21. The asymmetric device is poled so as to be conducting during this charging interval. During the initial stages of the time interval required for capacitor 21 to charge, the voltage drop across the said parallel combination will be relatively small. Thus the said parallel network provides a time delay during which departure from the preceding steady state cathode potentials is resisted. Condenser 21—A similarly requires charging time to reach the new conditions and therefore contributes additionally to this time delay. However, as capacitors 21 and 21—A begin to charge, the potential of the cathode of tube 7' will become more positive with respect to ground, thus decreasing the plate current in tube 7'. A point will be

6

reached where the plate current becomes sufficiently small so that the relay 12' will be deenergized and contact 26 will close and contact 24 will open. When this occurs the plate circuit of tube 7' will again lead to resistance 37, lead 38, contacts 26 and 27 to ground. Also, capacitor 21, since it no longer has voltage supply across it, will discharge through lead 38, contacts 26 and 27, and resistance 39, asymmetric device 22 being poled to be non-conducting for this direction of current flow. Resistance 39 is chosen to limit current flow through contacts 26 and 27 at time of switching to prevent pitting of the contacts. Capacitor 21—A, being charged to a higher voltage than the new stable conditions call for, will proceed to discharge through resistance 37. This discharge will continue until the potential of the cathode of tube 7' has been lowered to a point where the plate current of tube 7' has increased sufficiently to reoperate relay 12' which starts the cycle all over again.

It is to be noted that asymmetrical device 22 will allow the condenser branch circuit paralleling resistor 20 to assume a considerably lower transient impedance than contact protecting resistor 39 would otherwise permit during the charging period of condenser 21. On the other hand, during the discharging period of condenser 21 the initial rush of current surging through the perhaps chattering contacts of the just released relay 12' or 13' is limited by resistor 39 to a safe value since asymmetric device 22 in this current direction presents a shunting resistance which is now high compared to that of resistance 39. Except for the protection offered by this resistance 39, upon deenergization of relay 12' or relay 13', contacts 26 or 27, respectively, are suddenly thrown directly across condenser 21 which is in a charged condition. Thus the apparently contradictory functions of providing a sufficiently high and yet negligibly low resistance are accomplished by selective means based on direction of current flow through asymmetric device 22.

As in the case of Fig. 1, with each intermittent operation of relay 12' contact 24 will correspondingly close and open, thus intermittently completing the circuit for the coils of motor 14'. Consequently motor 14' will rotate in an intermittent fashion, that is, in a step-by-step manner. The motor 14', through shaft 31', moves sliding arm 30' to a new position whereby the signal voltage on the grid of tube 7' is of such a value that neither relay 12' nor 13' will operate. Corrections of the signal voltage outgoing on leads 28' are made at resistance 18' by means of shaft 17'. When the signal on the grid of tube 7' has been decreased to its desired value, the plate current in tube 7' will no longer be sufficient to reoperate relay 12'. Thus motor 14' will cease step-by-step operation until further correction is necessary in the incoming signal to the grid of tube 4'. Should the signal voltage on leads 29' become weaker so that the portion transmitted beyond 28' in its present setting is weaker than desired, the direct current signal voltage appearing on lead 23' will be less than required by the present position of slider 30' of potentiometer 8'. Consequently the plate current in tube 7' will become less. This will result in a smaller potential drop across resistor 37 which thereby will decrease the effective negative potential on the grid of tube 6' with respect to its cathode, to increase the current in the plate circuit of tube 6'. The increase in plate current will be sufficient to operate relay

13' thus opening contact 27 and closing contact 25. Upon the opening of contact 27, condenser 21 will begin to charge.

As condenser 21 proceeds to charge, voltage across it begins building up, tending to increase the voltage between cathodes of tubes 6' and 7' and ground. The action is somewhat retarded by the necessity of condenser 21—A to acquire a greater charge in order to sustain the higher terminal voltage. Concurrently with the rise in voltage across 21—A the corresponding increase in effective negative grid potentials of tubes 6' and 7' with respect to their cathodes will reduce the plate currents drawn by said tubes. The process of charging on condensers 21 and 21—A will continue until the plate circuit current through the energized relay will have been reduced to a point where it is insufficient to sustain the energization of the coil winding of relay 13'. Relay 13' as a result becomes deenergized, opening the contact 25 and closing contact 27. Upon closure of contact 27, condenser 21 will be discharged through lead 37, contacts 26 and 27, resistance 39 (shunting the now non-conducting asymmetrical device 22) to condenser 21. While condenser 21 is discharging as described, condenser 21—A is also discharging. In order to acquire the lower terminal voltage required by the released positions of relays 12' and 13', it must give up its charge to a corresponding extent. This excess charge will dissipate itself in resistance 37. Thus the transition from a large cathode potential drop to a normal one is likewise a delayed action. When the potential of condenser 21—A has decreased in the described manner to a certain point, the effective negative grid potential of tube 6' with respect to its cathode will have correspondingly reached a sufficiently low value and the resulting plate current will have increased to a point where it is again large enough to operate relay 13' thus completing the cycle. With each of these cycles, contacts 25 will, of course, open and close. During each portion of the cycle wherein contact 25 is closed, the motor circuit including one field coil 16' of motor 14' will be energized and the motor 14' will rotate. This step-by-step operation of motor 14' will be mechanically transmitted through shaft 17' back to potentiometer 18' in the outgoing line 28' and also to slider arm 30' where the necessary correction of the incoming signal voltages on the grid of tube 7' is effected. When the signal voltage on the grid of tube 7' has been increased in strength to the desired value the plate current of tube 7' will be large enough so that the plate current of tube 6' cannot be great enough to operate relay 13'.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In a control circuit, two vacuum tubes, means for operating said tubes, a relay in the output circuit of each of said tubes, a pulsating voltage source common to the cathodes of both of said vacuum tubes, one of said tubes having a signal impressed on its input circuit, said pulsating voltage source causing intermittent operation of one of said relays upon deviation of said signal from a desired value, a power means comprising a motor responsive to said relay operation to correct said signal to said desired value.

2. In a control circuit, two vacuum tubes, means for operating said tubes, a relay in the output circuit of each of said tubes, a pulsating voltage source common to the cathodes of said vacuum tubes, a resistance in common with said cathodes of said two vacuum tubes one of said vacuum tubes having a signal voltage impressed upon its input circuit, said pulsating voltage source causing intermittent operation of one of said relays upon deviation of said signal voltage from a desired value, a stronger than desired signal causing the relay associated with the vacuum tube upon whose grid said signal voltage is impressed to operate, and precluding said other relay from operating a weaker than desired signal causing the other of said relays to operate and precluding operation of the relay associated with the vacuum tube upon whose input circuit the aforementioned signal voltage is impressed and motor means responsive to said relay operation to correct said signal voltage to a desired value.

3. An electrical control circuit comprising a first vacuum tube having a first signal voltage impressed upon the grid thereof, a second vacuum tube, the grid of which has impressed thereon a portion of the voltage output of said first vacuum tube, a first relay associated with said second vacuum tube, a third vacuum tube, the cathode of which is electrically connected to the cathode of said second vacuum tube, a second relay associated with said third vacuum tube, a pulsating voltage source common to said cathodes to cause intermittent operation of one of said relays, the relay operated being determined by the strength of said signal voltage impressed on the grid of said first vacuum tube, motor means responsive to the operation of said relay to change the portion of said voltage output of said first tube to be impressed on the grid of said second tube to a desired value, and said motor means to also alter a second signal voltage to a desired value, said second signal voltage being electrically connected to said first signal voltage by coupling means.

4. An electrical control circuit comprising an amplifier to amplify a rectified signal voltage derived directly or indirectly from a main conducting circuit to be controlled, a first vacuum tube, a second vacuum tube, a relay associated with each of said first and second vacuum tubes, the grid of said first vacuum tube to have impressed thereon a portion of the output of said amplifier, said first and second vacuum tubes being interrelated in such a manner that but one vacuum tube can produce enough plate current to operate its associated relay at any one time, a resistance common to the cathodes of said first and second vacuum tubes, a relaxation oscillator output impressed upon said resistance to cause intermittent operation of either of said relays being operated, a circuit output means connected to said main conducting circuit by potentiometer means, motor means responsive to the operation of said relays to operate said potentiometer so as to correct the outgoing signal to a desired value, and said motor means to also correct said portion of the output of said amplifier to a desired value.

5. In a control circuit two vacuum tubes, means for operating said tubes, a relay in the plate circuit of each of said tubes, a resistance common to the cathodes of said vacuum tubes, a relaxation oscillator to provide a pulsating voltage source across a portion of said resistance common to the cathodes of said vacuum tubes, one of said

vacuum tubes having a signal voltage impressed upon its grid, said relaxation oscillator pulsating voltage source causing intermittent operation of one of said relays upon deviation of said signal voltage from a desired value, a stronger than desired signal causing the relay associated with the vacuum tube upon whose grid said signal voltage is impressed to operate, and precluding said other relay from operating, a weaker than desired signal causing the other of said relays to operate and precluding operation of the relay associated with the vacuum tube upon whose grid the aforementioned signal voltage is impressed, and motor means responsive to said relay operation to correct said signal voltage to a desired value.

6. In a control circuit, two vacuum tubes, means for operating said tubes, a relay in the plate circuit of each of said vacuum tubes, a resistance common to the cathodes of said vacuum tubes, a capacitance in series with a shunted asymmetrical device in parallel with a portion of said resistance, a second capacitance in parallel with the whole of said resistance, a shunting circuit around said capacitance and asymmetrical device, said shunt comprising a plurality of contacts operable by said relays, one of said vacuum tubes having a signal voltage impressed upon the grid thereof, said capacitances acting in cooperation with said vacuum tubes and said relays to charge and discharge to produce a pulsating voltage upon the cathodes of said vacuum tubes which causes intermittent operation of one of said relays, motor means responsive to said relay operation to correct said signal voltage to a desired value.

7. An electrical control circuit comprising an amplifier to amplify a first signal voltage to be controlled, a first vacuum tube, a second vacuum tube, each of said tubes having a relay associated therewith, the input of said first tube to have impressed thereon a portion of the output of said amplifier, said first and second vacuum tubes being interrelated in such a manner that but one vacuum tube can pass enough plate current to

operate its associated relay at any one time, a capacitance in series with an asymmetrical device in parallel with a portion of said resistance, a shunting circuit around said capacitance and asymmetrical device, said shunt comprising a plurality of contacts operable by said relays, a second capacitance in parallel with the whole of said resistance, said capacitances acting in cooperation with said vacuum tubes and said relays to produce a pulsating voltage when the said first signal voltage impressed upon said input of said amplifier deviates from a desired range of values, said pulsating voltage to cause intermittent operation of one of said relays and motor means responsive to said relay operation to correct a second signal voltage to a desired value, said second signal being derived from said first signal voltage by electrical coupling means.

8. In a control circuit, two vacuum tubes, one of said tubes having a signal voltage impressed upon the control element thereof, means for operating said tubes, a relay in the output circuit of each of said tubes, a parallel combination of resistance and capacitance common to the cathodes of both tubes, a shunting circuit around said resistance and capacitance in a parallel network comprising contact springs of said relays, said signal voltage allowing sufficient current to flow in the output circuit of one of said tubes to operate the associated relay should said signal voltage deviate from a desired range of values, said resistance and capacitance combination cooperating with said tubes and said operating relay to produce an intermittent charge and discharge of said capacitance resulting in corresponding decrease and increase of output current of said tube associated with the operating relay which creates an intermittent operation of said relay and means responsive to said relay operation to correct said signal voltage to a desired value.

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No references cited.

Disclaimer

2,508,029.—*Walter F. Kannenberg*, Gillette, N. J. RELAY CIRCUIT. Patent dated May 16, 1950. Disclaimer filed Apr. 10, 1952, by the assignee, *Bell Telephone Laboratories, Incorporated*.

Hereby enters this disclaimer to the subject-matter in claim 1 of said patent.

[*Official Gazette May 6, 1952.*]